NANYANG TECHNOLOGICAL UNIVERSITY SINGAPORE

NTU Carbon Footprint Framework for Universities

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Prepared By
NTU Institute of Science and Technology for Humanity (NISTH)
NTU Sustainability Office

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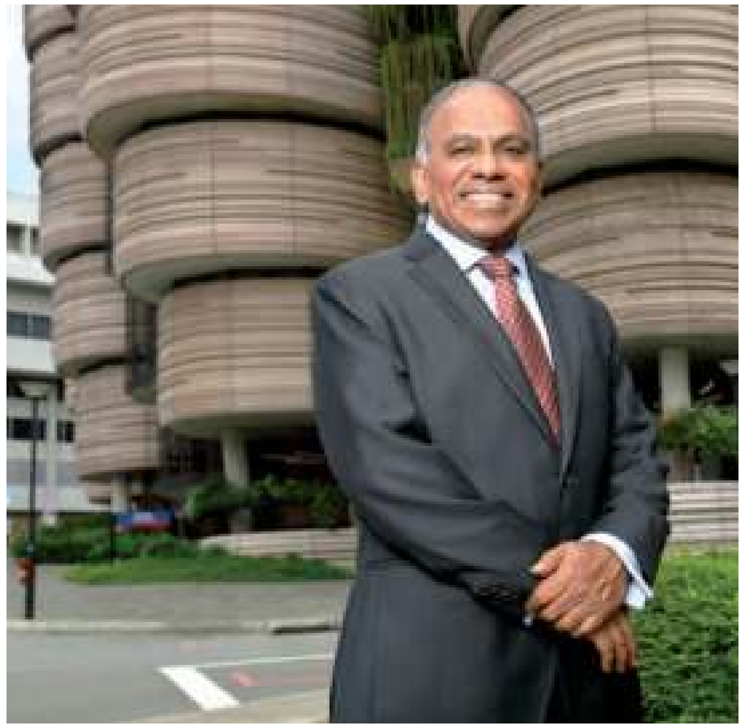
Message From the President



Climate change and its consequences pose significant challenges for the future of humanity. They require integrated solutions across the intellectual domains dealing with Social Sciences, Humanities and Arts for People and the Economy (SHAPE), and Science, Technology, Engineering and Mathematics (STEM). Science is needed to elucidate, map, and guide our efforts to counter climate change or mitigate its effects. We look for innovative solutions from the fields of engineering, physical and life sciences, medicine, as well as from disciplines at the intersections of technology, human psychology, and human behaviour. Any potentially effective interventions will require strong governance grounded in ethics, and sound policy making. Changing the way people live and industries work necessitates the inculcation of behavioural changes, a reassessment of value propositions, and life-long learning through revisiting our deep-seeded norms and values.

NTU is committed to building a responsible future for the betterment of humanity. We have therefore taken important steps to integrate our research and education programs across our entire spectrum of activities. The Interdisciplinary Core Curriculum, introduced in 2021 as part of our NTU 2025 Strategic Plan, established educational modules shared by all our undergraduate students to develop skills and knowledge in ethics and climate science, in addition to nurturing creativity, teamwork, and collaborations to design solutions across disciplinary and cultural boundaries. The Sustainability Office, also established in 2021, coordinates our firm commitment and actions in response to the challenges posed by climate change, by harnessing the collective efforts of the entire NTU community of members and stakeholders, across all sectors. We also strive to Walk-the-Talk by realising a Green Campus through optimising building design, nurturing a culture of achievable and sustainable behaviours, and harnessing renewable energy.

We have developed a unique Carbon Footprint estimation tool, specifically for universities. This report is a first instalment providing insights into the best practices, exploring the limitations of current approaches, and novel pathways to guide the transparent reporting and measurement of the carbon footprints of universities. We share this report with you in the hope that the NTU Carbon Footprint Framework for Universities will be a valuable resource for universities worldwide as we work together to improve its effectiveness and impact and continue to develop associated toolkits.

Prof Subra Suresh
President and Distinguished University Professor
Nanyang Technological University,
Singapore

Abstract

This report offers insight into current approaches and frameworks that are developed and adopted by universities worldwide to measure their carbon footprint (CFP). Available CFP measuring tools are assessed and an analysis of contributing emission sources that are specific to institutes of higher education (IHE) is presented. The report also evaluates (1) university rankings and their underlying parameters, (2) the homogeneity of CFP information reported by universities, (3) the contribution of emission sources to total CFP, (4) a study of specific approaches implemented by universities to reduce carbon emissions, and (5) an evaluation of the key factors that influence the overall CFP of a university. A possible framework for measuring CFP that is specific for NTU and generally applicable to universities worldwide is provided. Finally, the report identifies strategies for behavioural change and helps overcome the current gaps in collecting CFP-relevant information for universities.

Executive Summary

Universities, as cradles of knowledge and research aiming for societal impact, have been engaged in research on climate change, modelling and predicting as well as identifying ways to mitigate the consequences of climate change. As large organisations with correspondingly high amounts of students, staff and infrastructure, universities have also become significant producers of greenhouse gas (GHG) emissions. This calls for the need to standardise and operationalise the approach toward measuring and reducing CFP across all universities worldwide. The uniqueness of every university complicates the operationalisation and standardisation of measuring carbon emissions. University campuses consist of buildings and infrastructure with a variety of functions that support different specialities of research and education. For instance,

- Research-intensive universities require more energy to support their laboratory facilities. They may also produce more toxic and hazardous waste or consume substantially greater amounts of water.
- Universities that provide on-campus housing for students and staff may record lower emissions related to transport and travel, but an increased consumption of energy and water for residential buildings.
- Universities that provide comfortable dining and studying places may manage to cut energy expenses for lighting and air-conditioning by grouping students and staff in dedicated locations.
- Greenhouses and fertiliser use can increase the CFP of agriculture-focused universities.
- Bigger universities that possess sports complexes, swimming pools or hospitals produce more carbon emissions due to the power and maintenance needs of complex infrastructure.
- If owned by a university, the university's CFP is also significantly affected by its transport vehicles.
- Universities worldwide also vary in their approaches toward energy generation. For example, a university can generate electricity from alternative sources of energy on its premises, sell the energy surplus as carbon credits, or purchase its energy from vendors.
- The landscape and geographical latitude of a university also impact a university's CFP. For example, location of a university in a large and flat terrain enables effective production of wind and solar energy, while heavy rains, characteristic for tropical latitude, encourage wastewater collection and treatment.
- The landscape may also support the implementation of carbon sequestration methods. For example, universities located in the areas with lush vegetation can compensate carbon emissions by storing CO_2 in grasslands, forests, soils and oceans. Availability of porous rocks formations in geological basins close to university campuses enables storage of captured pressurised liquid CO_2.

Currently, the development of CFP measurement framework specifically for universities to aid them in measuring and reporting their GHG emissions is still at the very nascent stage. This document explores the applicability of currently available CFP analysis methods and frameworks for universities, identifies best practices adopted by universities in measuring CFP, and proposes a CFP Framework for universities. It also suggests the measurement of a CFP score, weighed against university's total CFP, number of students and employees and transparency in reporting emission data. The report describes the history of sustainability at NTU and draws upon the milestones in research, education, technological and behavioural change to achieve the future vision of a sustainable university.

An Overview of Carbon Footprint Measurement for Universities

Existing CFP frameworks focus on corporate or industrial organisations

There are two main CFP measurement and reporting frameworks used globally: the GHG protocol[1] and the Intergovernmental Panel on Climate Change (IPCC) GHG inventories[2]. These frameworks provide the basic elements needed for CFP measurement and have formed the basis for other available sustainability frameworks.

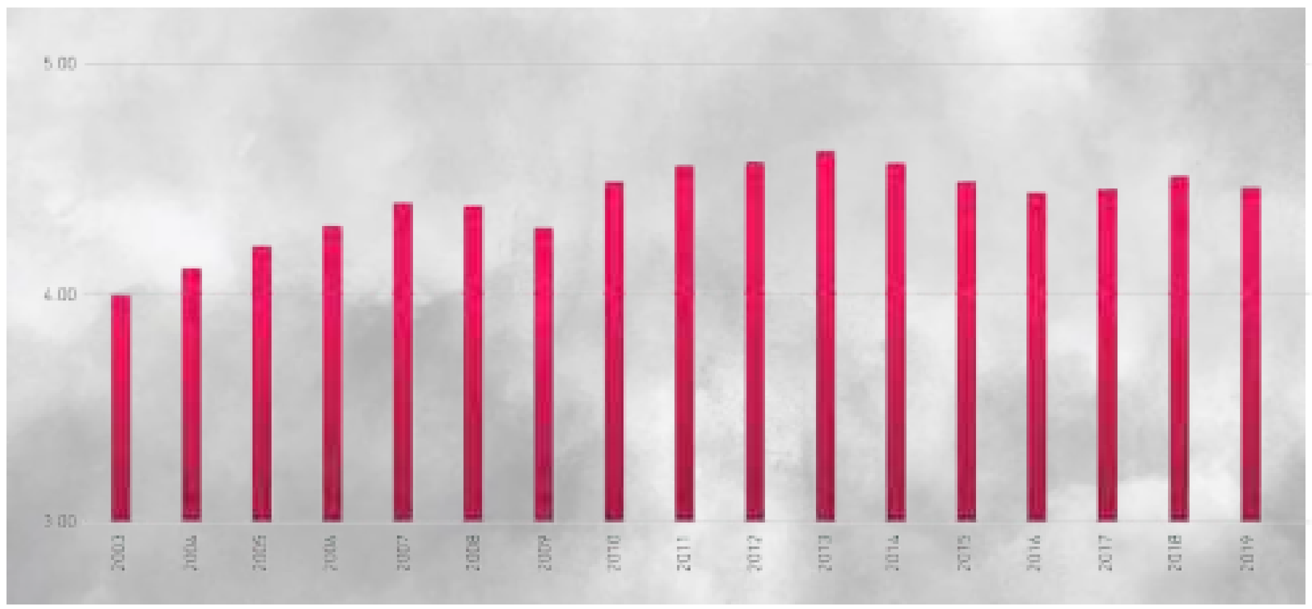
The GHG Protocol Corporate Standard classifies company's GHG emissions into three scopes[3]. Scope 1 emissions are direct emissions from owned or controlled energy sources. Scope 2 emissions are indirect emissions from the generation of purchased energy. Scope 3 emissions are all indirect emissions that occur in the value chain of the organisation, including both upstream (produced by suppliers) and downstream (produced by customers) emissions. Accounting for all emission scopes during CFP measurement will allow corporations or institutes to achieve goals including:

- Managing GHG risks and identifying reduction opportunities.
- Public reporting and participation in voluntary GHG reporting programs.
- Participating in mandatory GHG reporting programs.
- Purchasing carbon credits,
- Receive recognition for voluntary early action to reduce carbon emissions in the form of carbon credits.

The IPCC GHG inventories at the national level provide methods for estimating national inventories of anthropogenic emissions by sources (namely energy, waste, industrial processes and product use, agriculture, forestry, and other land use)[4]. The guidelines were developed in response to the United Nations Framework Convention on Climate Change, whose main objective was to assess scientific, technical, and socio-economic information relevant to the understanding of anthropogenic climate change, potential impacts of climate change and options for its mitigation and adaptation. The IPCC GHG inventories list, by source, the amounts of pollutants emitted to the atmosphere during a given time period, using the methodology guidelines developed for documenting.

The CFP measurement and reporting frameworks mentioned above are widely used. The frameworks build awareness about CFP emissions for businesses but may fall short of the national specificity of GHG emissions, solidified calculation tools, or the applicability of certain emission factors for non-corporate or non-industrial organisations. These two frameworks, however, lay the foundation for other sustainability frameworks and measurement methods that are described in the following chapters.

WORLD CO_2 EMISSION, TONNES/CAPITA



Climate Watch. 2020. GHG Emissions. Washington, DC: World Resources Institute.

GHG and IPCC frameworks form the basis for other sustainability frameworks

The CFP measurement and reporting frameworks in the previous section have led to the development and implementation of other sustainability frameworks that can be adopted in various sectors. Mentioned frameworks (GHG Protocol Corporate Standard and the IPCC GHG inventories) are based on the premise of reducing carbon emissions by improving energy efficiency and cutting down general and water waste.

Out of all available sustainability frameworks, we selected four related to the construction, operation, and management of buildings, as, according to Helmers et al.[5], the university's buildings contribute the most to its CFP. Furthermore, this report aims to determine a CFP measuring framework for NTU in the local context. Therefore, it is important to evaluate the Singapore national standards.

An example includes ISO 14001, which is a standard applied in environmental management systems (EMS)[6]. It includes an overview of the requirements for an EMS, provides guidance on their implementation, and recommends controls for processes that have environmental impact. Some of the environmental impacts that ISO 14001 requests organisations to consider are (1) air pollution, (2) water and sewage issues, (3) waste management, (4) soil contamination, (5) climate change mitigation and adaptation, and (6) resource use and efficiency.

LEED (Leadership in Energy and Environmental Design)[7] is the most widely-used green building rating system in the world. It provides a framework for constructing and maintaining low-carbon and energy-efficient buildings. A building is certified by Green Business Certification Inc. upon adherence to requirements in energy, water, waste, transportation, materials, health, and indoor environmental quality.

The Sustainability Tracking, Assessment & Rating System™ (STARS) is a framework for colleges and universities to measure their sustainability performance via a self-reporting online tool[8]. It provides a framework for understanding sustainability in all sectors of higher education and enables comparisons over time and across institutions by assigning ranks to participating universities worldwide. It records long-term sustainability goals for already high-achieving institutions while aiding universities in taking their first steps towards sustainability. However, it does not provide the regulations for standardised reporting of CFP emissions.

To qualify for a STARS ranking, a university requires subscription, a cover letter from a high-ranking executive and a scored report prepared according to the STARS criteria. A subscription scheme may hinder participation of less resourced universities, especially from the Global South. STARS will be discussed further in the section "State of the Art Sustainability Rankings and Metrics".

1. Greenhouse Gas Protocol (2001). https://ghgprotocol.org/
2. IPCC Guidelines for National Greenhouse Gas Inventories (1995). https://www.ipcc-nggip.iges.or.jp/public/index.html
3. Greenhouse Gas Protocol FAQ. https://ghgprotocol.org/sites/default/files/standards_supporting/FAQ.pdf
4. IPCC Guidelines for National Greenhouse Gas Inventories (2006). https://www.ipcc-nggip.iges.or.jp/public/2006gl/
5. Helmers, E., Chang, C.C., et al. (2021) Carbon footprinting of universities worldwide: Part I—objective comparison by standardized metrics. Environ Sci Eur 33, 30.
6. ISO 14004:2016 Environmental Management Systems: General guidelines on implementation (2016). https://www.iso.org/iso-14001-environmental-management.html
7. LEED rating system. https://www.usgbc.org/leed
8. The Sustainability Tracking, Assessment & Rating System (2010). https://stars.aashe.org/about-stars/

Tahir Foundation Connexion at SMU Campus, Singapore, a Green Mark building. Image from https://news.smu.edu.sg

The sustainability frameworks discussed above are linked to the construction, operations, and management of green buildings as well as for tracking the sustainability efforts of universities. The Green Mark certification provides an overview of the local practice, signalling the importance of including local climate and landscape parameters that impact sustainability policies. The Green Mark certification scheme was launched in Singapore in January 2005[9]. It is a green building rating system designed to evaluate a building's environmental impact and performance. It provides a framework for assessing the overall environmental performance of new and existing buildings to promote sustainable design, and best practices in construction and operations in buildings.

These frameworks often do not account for all emission sources, but they target reduction of carbon emissions mainly through improving energy efficiency and cutting down waste. The frameworks are not exhaustive and will likely continue to expand in proportion to the growth in effort to mitigate climate change. Comparing these frameworks allows us to identify the best practices and gaps for the development of a new framework for NTU.

Agreeing on standard units of measurement

The methods and approaches of many countries and regions toward monitoring, certifying, and reporting sustainable practices, projects, and buildings hardly differ. Most of the certification and reporting methods examine general sustainability metrics (such as emissions, energy, water, and waste management). These are good for identifying and reducing emissions, energy use, water waste, and general waste directly.

However, sustainability baselines and targets differ across universities, which makes using these general sustainability metrics difficult for benchmarking. Some universities may generate renewable energy while other universities target general waste reduction. A single unit to summarise the different sustainable efforts would provide insight for universities should they choose to benchmark themselves against other universities or organisations.

Breaking down the total emissions to their core factors (energy, water, waste etc) appears to be advantageous, as it provides a more comprehensive and detailed overview of an entity's CFP.

It is important to note, however, that calculating the overall CFP of an entity would not be considered complete without accounting for CO_2 emissions related to materials and construction processes throughout the whole lifecycle of a building or element of infrastructure (so called embodied carbon[10]). Embodied carbon includes emissions from the extraction, production, processing, transportation, and usage of materials in a building. However, the term 'embodied carbon' is used only in relation to the built environment. According to Marchi et al.[11], embodied carbon contributes around 60-70% to a household's CFP and is closely connected to supply chains and products.

Life cycle CO_2 ($LCCO_2$), sometimes referred to as the fuel cycle, is another important contributor to overall CFP that assesses GHG impacts of a fuel, including each stage of its production and use (feedstock production and transportation, fuel production and distribution, and use of the finished fuel)[12]. $LCCO_2$ allows for keeping track of, or understanding, the carbon emissions caused by fuel usage during implementation of any organisation's process or activity. $LCCO_2$ excludes emissions associated with physical

9. Green Mark Certification Scheme (2005). https://www1.bca.gov.sg/buildsg/sustainability/green-mark-certification-scheme
10. Carbon Cure (2020). What is Embodied Carbon? https://www.carboncure.com/concrete-corner/what-is-embodied-carbon/
11. Marchi, L., Vodola, V., et al. (2021) Contribution of individual behavioural change on household carbon footprint. E3S Web Conf., 263, 05024.
12. United States Environment Protection Agency. Lifecycle Analysis of Greenhouse Gas Emissions under the Renewable Fuel Standard. https://www.epa.gov/renewable-fuel-standard-program/lifecycle-analysis-greenhouse-gas-emissions-under-renewable-fuel

and organisational infrastructure (e.g., facility construction, employees commuting to the facility). For example, the $LCCO_2$ model for water use in a university includes the emissions from active transportation of water (pumps and trucks), collection of wastewaters (pre-filtration) and post-processing (such as filtration and membrane treatment).

While adopting models like embodied carbon and $LCCO_2$ allows the collection of useful information for CFP measuring, how the concepts may be applied to universities is not well defined and quantified yet. For a start, all products and processes of a university will need to be consolidated with the help of downstream and upstream suppliers, which may require regular updates due to technical changes, innovations, and introduction of new products to the market.

Moreover, it is also important to consider the year at which a university started recording its CFP and documenting the measures to reduce it. Visibility of the time range within which a university committed to introduce energy efficient practices to achieve established goals would also be useful.

Having a single unit of measurement across the different sustainability categories (Emissions, Energy, Water & Waste) may allow for a good rating or scoring system for universities. It would also allow them to compare each sustainability category for better insight, management, and target setting. The availability of a single measure may facilitate comparison and quantification of the efforts and improvements in the CFP reduction.

Given the non-unified units for measuring emissions arising from different emission sources worldwide (kWh for energy, L or gallon for water, and tonne for waste[13]), the amount of CO_2 may provide a better baseline and scoring system for universities or across the sustainability categories (Emissions, Energy, Water & Waste).

It is also important to remember that while energy conversion factors – factors which convert amount of used fuel in units of kilograms carbon dioxide equivalent ($kgCO_2e$) – are publicly available, they can have specific features related to national standards. For example, carbon emissions caused by the energy production (kWh) in different parts of the world fluctuate, hinging on the mixture of energy sources and efficiency of conversion that are defined by technology type, plant size, and outdoor temperature[14]. It complicates the usage of commercially available tools for CFP measuring in countries across the world and calls for careful investigation of national standards of energy conversion factors.

The Asian Development Bank collated the Grid Emission Factors for ASEAN member states to inform CFP calculation[15]. Careful assessment of emission factors that are included in CFP measurement might facilitate the comparison of CFPs internationally.

The next step is to investigate the efforts of universities in their approaches toward CFP measuring, including sustainability and CFP frameworks as well as the available tools and emission factors that universities select in CFP measuring. The analysis of existing frameworks for CFP measuring used by the universities may provide an understanding of the most widely used tools, their benefits, and weak points, as well as identify the weightiest contributing factors to total university's CFP emission sources. Collected information may aid in more accurate design of a tool to measure universities' CFP and NTU's CFP in particular. This is discussed in the following chapter.

13. Carbon Trust (2020) https://www.carbontrust.com/resources/conversion-factors-energy-and-carbon-conversion-guide
14. Noussan, M., Neirotti, F. (2020) Cross-Country Comparison of Hourly Electricity Mixes for EV Charging Profiles. Energies, 13 (10).
15. Asian Development Bank (2017) Guidelines for estimating Greenhouse Gas Emissions of Asian Development Bank projects. https://www.adb.org/sites/default/files/institutional-document/296466/guidelines-estimating-ghg.pdf

Carbon Footprint Measurement: A Worldwide Comparison of Universities

This chapter will provide an overview of existing CFP frameworks that are currently used by universities to measure their CFP. It will critically assess the emission sources that are included and will explore the parameters that may have an impact on the university's total CFP, such as geographical location, terrain, campus size, research intensity and others. This chapter will also list the best practices used by universities worldwide to reduce their CFP as well as existing sustainability rankings that collate reports about sustainability practices from participating universities. It will also analyse the importance of combining technological improvements with behavioural change to decrease carbon emissions.

Universities generally adopt existing CFP frameworks

To date, there is not an internationally adopted and standardised tool for calculating the CFP of universities[16]. In order to gain an understanding of how universities measure their CFP, a consensus on the tools to use, frameworks to apply and the included emission sources need to be established. It is needed to help compare the effectiveness of universities worldwide in CFP reduction and to identify similar actions leading to more sustainable universities. To understand how universities record and calculate their emissions, we need to first evaluate the frameworks and tools for CFP measurements.

Valls-Val et al.[17] conducted a study among universities to evaluate tools and frameworks that were being used to measure CFP. Among universities analysed in 25 studies, 54% of universities used GHG Protocol[18], 20% - IPCC Guidelines[19], 11% - ISO 14064–1[20], while Budihardjo et al.[21] and Thurston and Eckelman[22] applied PAS 2050[23], indicating that the most widely utilised framework is the GHG Protocol.

While most universities that report their CFP perform calculations in spreadsheets, some utilised commercially available tools. For instance, the Clean Air - Cool Planet Carbon Calculator[24] was used by universities from Texas[25], University of Illinois[26] and Louisiana State University[27]; the Economic Input–Output Life Cycle Assessment online tool[28] was applied by Yale University[29] and Clemson University[32]; the IELab[31] was deployed by University of Melbourne[21]; the Umberto Software[33] was the tool used by the Birla Institute of Technology and Science Pilani (India)[34]; and SimaPro[35] was employed by the University of Haripur (Pakistan)[36].

16. Robinson, O.J., Tewkesbury, A., et al. (2018) Towards a universal carbon footprint standard: A case study of carbon management at universities. J Clean Prod 172, 4435–4455
17. Valls-Val, K., Bovea, M.D. (2021) Carbon footprint in Higher Education Institutions: a literature review and prospects for future research. Clean Techn Environ Policy 23, 2523–2542.
18. Greenhouse Gas Protocol, 2001. https://ghgprotocol.org/
19. IPCC Guidelines for National Greenhouse Gas Inventories, 2006. https://www.ipcc-nggip.iges.or.jp/public/2006gl/
20. ISO 14064–1: Greenhouse gases—specification with guidance at the organizational level for quantification and reporting of greenhouse gas emissions and removals, 2006. https://www.iso.org/standard/38381.html
21. Budihardjo, M.A., Syafrudin S., et al (2020) Quantifying carbon footprint of Diponegoro University: non-academic sector. IOP Conf Ser Earth Environ Sci 448, 012012.
22. Thurston, M., Eckelman, M.J. (2011) Assessing greenhouse gas emissions from university purchases. Int J Sustain High Educ 12, 225–235.
23. PAS 2050: Specification for the assessment of the life cycle greenhouse gas emissions of goods and services, 2011.
24. CA-CP: Clean air cool planet carbon calculator, 2020
25. Bailey, G,, LaPoint, T. (2016) Comparing greenhouse gas emissions across Texas universities. Sustain 8, 1–24.
26. Klein-Banai, C., Theis, TL., et al. (2010) A Greenhouse gas inventory as a measure of sustainability for an urban public research university. Environ Pract 12, 35–47.
27. Moerschbaecher, M., Day, J. W. (2010) The greenhouse gas inventory of Louisiana State University: a case study of the energy requirements of public higher education in the United States. Sustainability 2, 2117–2134.

Most of the applied tools for universities' CFP calculation are intended for industry and do not allow the inclusion of emission factors that are only relevant to universities. The Campus Carbon Calculator that was developed by the University of New Hampshire in collaboration with Clean Air - Cool Planet and later replaced by the subscription-only SIMAP is currently the only commercially available tool for calculating CFP of universities that includes Scope 3. Another tool, CO2UV, that is suitable for measuring the CFP of universities was developed by the Universitat Jaume I (Spain) but is currently not publicly available. Both tools offer the fullest inventory of carbon and nitrogen emission sources relevant to universities as they include sources such as disposal of laboratory and hazardous waste, student and staff commuting and business travels. They also provide a platform to publicly self-report a university's CFP.

The difference in CFP measurement tools and the variation in the included carbon emissions can be partially explained by the lack of international standards that universities need to adhere to and by the absence of a recognised certification process that could validate university's efforts in CFP reporting.

The Central Building of Leuphana University Lüneburg. Image from www.leuphana.de

Universities differ in their efforts to track and report their CFP

Another reason for the absence of a certified tool for measuring university's CFP can lie in the difference in national policies that prioritise and facilitate measurement of certain emission factors. Although desirable, the practice of empowering universities to calculate their CFP is not widespread. The UK encourages universities to report their CFP[38] but does not have a standardised tool or method for that purpose. In Germany, some of the universities record their CO_2 emissions in detail like the University of Potsdam[39] and the Leuphana University in Lüneburg[40]. The latter also describes itself as the "first climate-neutral university worldwide without purchasing certificates"[41]. It has a unique approach of achieving zero carbon through the production of surplus renewable energy that is sold in a type of carbon credits. Universities in Asia, Africa and South America are still lagging without a consolidated approach to CFP recording.

28. EIO-LCA: Economic input-output life cycle assessment, 2020.
29. Thurston, M., Eckelman, M.J. (2011) Assessing greenhouse gas emissions from university purchases. Int J Sustain High Educ 12, 225–235.
30. Clabeaux, R., Carbajales-Dale, et al. (2020) Assessing the carbon footprint of a university campus using a life cycle assessment approach. J Clean Prod 273, 122600.
31. IELab. Australian ecology laboratory. 2020. https://ielab.info/
32. Stephan, A., Muñoz, S., Healey, G., Alcorn, J. (2020) Analysing material and embodied environmental flows of an Australian university—towards a more circular economy. Resour Conserv Recycl 155, 104632.
33. Umberto LCA software (2020). https://www.ifu.com/umberto/lca-software/
34. Sangwan, K.S., Bhakar, V., et al. (2018) Measuring carbon footprint of an Indian university using life cycle assessment. Procedia CIRP, 69, 475–480.
35. SimaPro software (2020). https://simapro.com/
36. Ullah, I., Islam-Ud-Din, H.U. et al (2020) Carbon footprint as an environmental sustainability indicator for a higher education institution. Int J Glob Warm 20, 277–298.
37. SIMAP. Sustainable Indicator management & analysis platform tool (2020). https://secondnature.org/signatory-handbook/simap/.
38. Gov.Uk (2020) Guidance: Streamlined energy and carbon reporting for college corporations. https://www.gov.uk/government/publications/college-corporation-financial-management-good-practice-guides/streamlined-energy-and-carbon-reporting-for-college-corporations
39. University of Potsdam (2019) Klimaschutzkonzept der Universität Potsdam. Report, pp 99. https://www.uni-potsdam.de/fileadmin/projects/umweltportal/pdf/191209_ARC_U_Klimaschutzkonzept_der_Universtitat_final.pdf
40. Opel, O,, Strodel, N,, et al. (2017) Climate-neutral and sustainable campus Leuphana University of Lueneburg. Energy 141, 2628–2639.
41. Leuphana (2020). Klimaneutrale Universität. https://www.leuphana.de/universitaet/entwicklung/nachhaltigkeit/klimaneutrale-universitaet.html.

As mentioned in the previous section (p.10), 54% of universities were found to adhere to the "GHG Protocol Corporate Accounting and Reporting Standard"[42], which defines the CFP as the total amount of GHG emissions generated directly or indirectly by activities carried out by the organisation, usually expressed in the carbon dioxide equivalent (CO_2e). It breaks the emissions into 3 categories:

1. **Scope 1.** All direct, on-site emissions that result from facilities operation, or emissions caused by internal infrastructure. It includes emissions from burning fossil fuels to provide electricity for the buildings, running a power plant, fuelling fleet vehicles, applying fertilisers, using refrigerants, cultivating livestock and leakage of refrigerants.
2. **Scope 2.** Off-site emissions from the generation of electricity, steam or chilled water that are used to cover the energy needs of a university. It includes both the purchased electricity and on-site production of energy, for instance through university-owned solar or photovoltaic panels, nuclear plants etc.
3. **Scope 3.** Purchased goods and services that include consumption of materials (paper, water, food, laboratory chemicals, electronic equipment, fertilisers) and their recycling, waste (wastewater, construction waste etc), and utility transmission losses (around 5% of electricity in the US is getting lost due to transmission of electricity[43]), as well as fuel used for commuting by public and private transport and university related air travel.

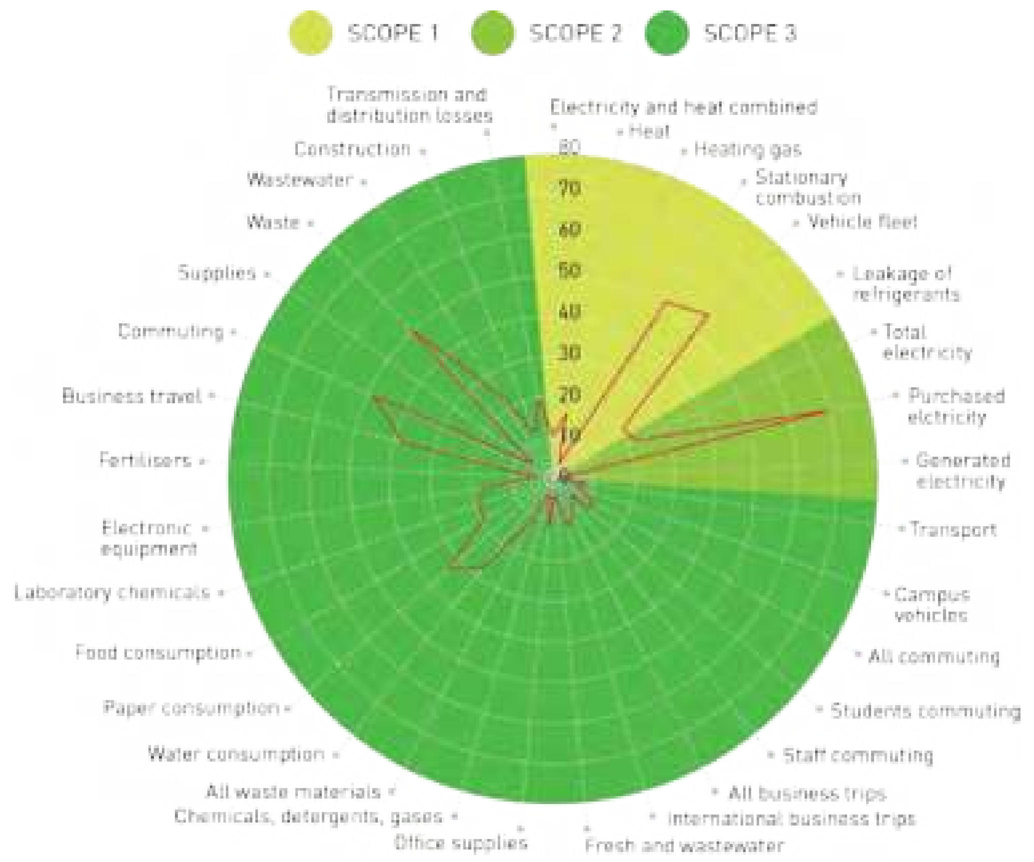
An institution's Scope 2 and 3 emissions will always be another organisation's Scope 1 emissions (e.g., air travel or energy purchase). Usually, for an organisation's inventory of emission sources to be considered complete, only Scopes 1 and 2 emissions are included. For example, among 566 universities that participated in the Times Higher Education (THE) survey (where more than half of participants were committed to a net zero target[44]), only half accounted for the universities' indirect emissions under Scope 3.

This means that a university's fuel and energy choices are not reported from a life-cycle perspective (and, therefore, do not include emissions generated by production and transport of downstream and upstream products and services) and do not account for embodied carbon in already-existing buildings. As a result, any environmental impact connected with the use of the goods and services is ignored. Currently, it is challenging to collate all products and services and emissions related to their production and transport due to the need to involve many offices to collect the necessary information. Besides, the choice of products and services constantly varies, calling for frequent updates in inventory of emission sources.

Some of the universities, as Yale University (US), run their own power plants (electricity, steam heating, and chilled water plants) which shifts energy production to Scope 1. Others, such as NTU and the Leuphana University Lüneburg, possess photovoltaic systems that convert thermal energy into electricity. Managing a university's own fleet of vehicles also contributes to Scope 1, while renting the fleet from outside or using transport for business travel has an impact on Scope 3 emissions. Carbon dioxide emissions from combusting certain fuels that have traditionally been considered carbon neutral (synthetic and biofuels) are excluded from Scope 1.

42. WRI (2011) Corporate Value Chain (Scope 3) Accounting and Reporting Standard - Supplement to the GHG Protocol Corporate Accounting and Reporting Standard. Report, world resources institute. https://ghgprotocol.org/sites/default/files/standards/Corporate-Value-Chain-Accounting-Reporing-Standard_041613_2.pdf
43. Lost In Transmission: How Much Electricity Disappears Between A Power Plant And Your Plug? (2015) http://insideenergy.org/2015/11/06/lost-in-transmission-how-much-electricity-disappears-between-a-power-plant-and-your-plug/
44. Impact Rankings 2021: climate action. Times Higher Education (2021) https://www.timeshighereducation.com/rankings/impact/2021/climate-action#!/page/0/length/25/sort_by/rank/sort_order/asc/cols/undefined

PERCENTAGE OF UNIVERSITIES THAT REPORT CERTAIN EMISSION FACTORS



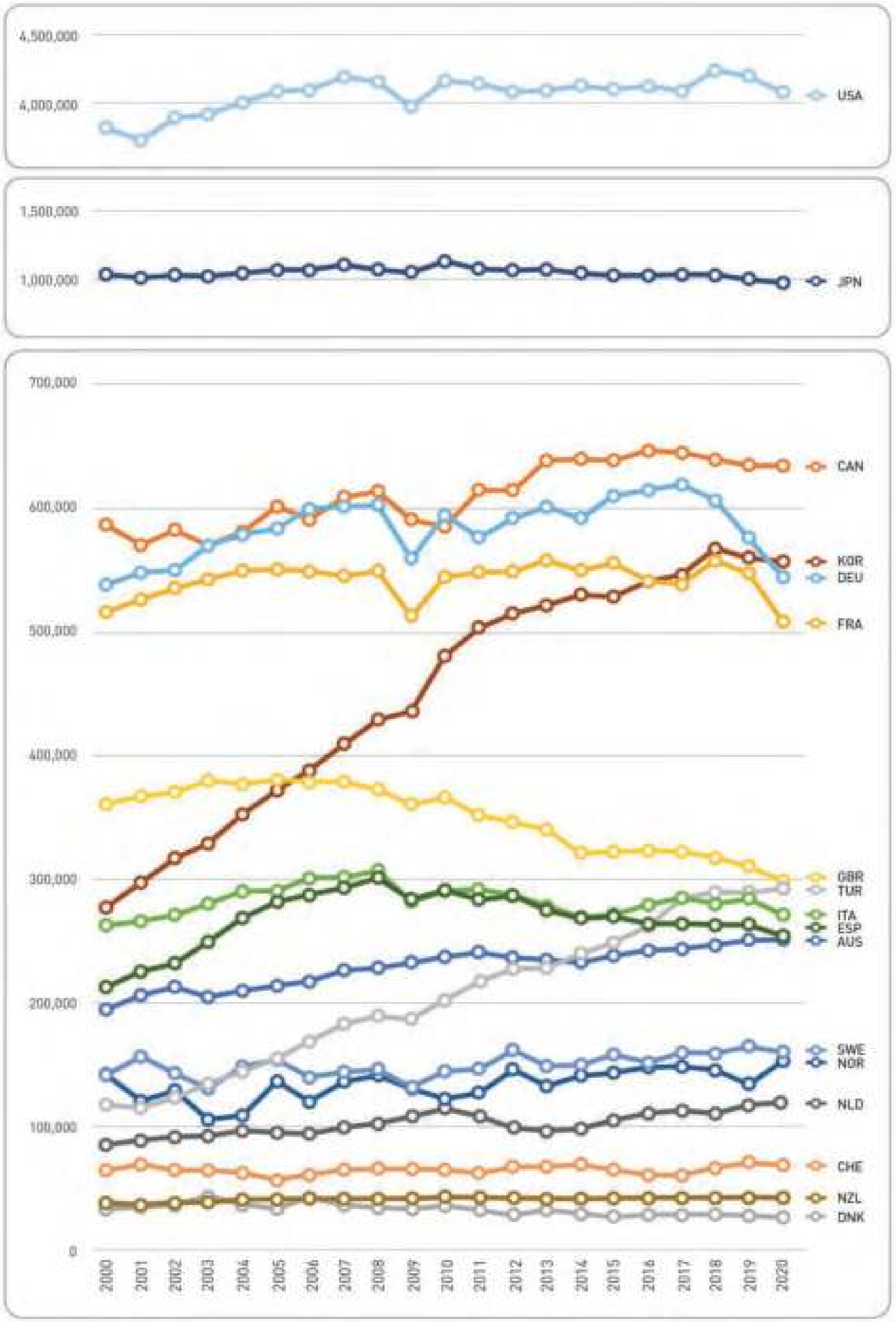
A few carbon emissions categories strongly determine the CFP of a university

Based on an analysis of universities that record their emissions performed by Helmers et al.[45] and Valls-Val et al.[46], the major contributor to a university's CFP is energy consumption in buildings (Scope 2), followed by mobility and commuting (Scope 3). Similar findings can be observed in the works by Bailey et al.[47] for universities in the US, by Butt[48] in New Zealand, by Güereca et al.[49] in México and by Jung et al.[50] in Korea. The range of the contribution of students' and staff's mobility varies from 22.2% at the University of Melbourne to 90.8% at the Umwelt-Campus Birkenfeld (Germany). 45.3% of universities report emissions numbers from mobility that are similar to those of energy consumption. The COP26 Universities Network reported in 2019 that in the UK, student flights account for 18% of university emissions, with 4% more added by the mobility of the faculty[51]. There is an unproven assumption that universities with fewer international students and staff might contribute less to the overall CFP, although this assumption should be substantiated with studies on the matter.

There is also a difference in how the total emissions are tallied by universities, as some of them report the total of transport activities (as KU Leuven)[52] while others categorise various sources of emissions resulting from mobility[53]. There was an attempt by Tongji University (China) to quantify students' travel during their private time, but it could not be recorded properly due to personal

45. Helmers, E., Chang, C.C., et al. (2021) Carbon footprinting of universities worldwide: Part I—objective comparison by standardized metrics. Environ Sci Eur 33, 30.
46. Valls-Val, K., Bovea, M.D. (2021) Carbon footprint in Higher Education Institutions: a literature review and prospects for future research. Clean Techn Environ Policy 23, 2523–2542
47. Bailey, G., LaPoint, T. (2016) Comparing greenhouse gas emissions across Texas universities. Sustain 8, 1–24.
48. Butt, Z. H. (2012) Greenhouse gas inventory at an institution level: a case study of Massey University, New Zealand. Greenh Gas Meas Manag 2, 178–185.
49. Güereca, L.P., Torres, N., et al. (2013) Carbon Footprint as a basis for a cleaner research institute in Mexico. J Clean Prod 47, 396–403.
50. Jung, J., Ha, G., et al. (2016) Analysis of the factors affecting carbon emissions and absorption on a university campus—focusing on Pusan National University in Korea. Carbon Manag 7, 55–65.
51. How can carbon offsetting help UK Further and Higher Education Institutions achieve net zero emissions? COP26 Universities Network Briefing (2021) https://www.gla.ac.uk/media/Media_770459_smxx.pdf
52. Sustainability at KU Leuven 2014-2017. https://www.kuleuven.be/duurzaamheid/sustainability/doc/sustainability-at-ku-leuven-2014-2017.pdf
53. Helmers, E., Chang, C.C. et al. (2021). Carbon footprinting of universities worldwide: Part I—objective comparison by standardized metrics. Environ Sci Eur 33, 30

ANNUAL ELECTRICITY GENERATED BY SELECTED COUNTRIES (GIGAWATTS PER HOUR)



OECD (2022), Electricity generation (indicator). doi: 10.1787/c6e6caa2-en

data protection regulations[54]. The emissions resulting from mobility and transport activities largely depend on the size of a university's community, its remote location, the availability of on-campus housing and available modes of commuting. For example, compared to the examples provided earlier, University of Twente' mobility's share of the CO_2 footprint is only 15%, of which 12% is commuting, due to wide use of bicycles[55]. At the same time, many universities do not include commuting in their CFP calculations as it is conducted by external partners.

Compared to the emissions produced by mobility, freshwater and wastewater consumption, use of office supplies, chemicals, gases, detergent, and waste disposal contribute only marginally to the overall emissions (0.14–14.9% with average 2.6%)[56]. However, it is necessary to consider the research intensity of a particular university, as STEM-oriented universities may require more complex infrastructure and would use more energy (for instance, for refrigerators, computing power and toxic waste disposal).

Contextual factors influence the CFP of each university

In his analysis of universities' CFPs, Helmers et al.[57] highlighted that the level of carbon emissions per capita at a university strongly correlates with national CFP per capita. This observation is supported by the big differences in CFP among US and Australian universities as compared to the rest of the world. This correlation can be explained by higher standards of living, a more developed economy, higher consumption rates, vast territories and big cities that require long-range and intensive transport connectivity.

It is important to note that while the majority of universities calculate CFP per capita (including students and staff), some universities refer only to students, excluding staff[58,59]. However, if the university is research-intensive, carbon emissions should also account for the amount of research done, and technical and support staff. Helmers et al.,[60] demonstrated that the ratio of students per staff is not indicative of CO_2 emissions. He also suggests considering different emission factors (such as used energy, number of fleet vehicles or consumed water) with relation to capita. The obtained values of emission source per capita may allow for a better comparison of universities' CFP.

There is an assumption that geographical latitude has an impact on the CFP of universities, as those in northern locations would require more heating while those in southern areas require more air-conditioning. However, the universities in tropical locations as Johor Bahru, Singapore, and Mexico City have relatively low CFP. At the same time, Leuven University has almost 3 times higher carbon emissions (in $MtCO_2e$ per capita) than ETH Zurich, despite being located near each other. It indicates that geographical latitude is not an exhaustive parameter to compare the CFPs of universities, as there is a variety of other factors that can turn the scale.

The size of a university, including multiple campuses and additional infrastructure, as well as their research intensity can potentially impact the total CFP. Big universities with in-house hospitals and sports complexes (including swimming pools) have a higher density of on-campus populations or a commuting rate that requires greater energy expenditure. Research-oriented universities produce more emissions due to the need for more resources and employees to perform research work. But the analysis of the CFP of the research-intensive university of Lüneburg in comparison to the less research-oriented Umwelt-Campus Birkenfeld demonstrates that while having relatively small campus, Umwelt-Campus Birkenfeld has a higher footprint. The comparison among big universities reveals similar results[61]: King's College London has a CFP that is almost 5 times higher than ETH Zurich, despite both universities being research intensive

54. Li, X., Tan, H., et al. (2015) Carbon footprint analysis of student behavior for a sustainable university campus in China. J Clean Prod 106, 97–108.
55. University of Twente Carbon Footprint Report (2020).
56. Helmers, E., Chang, C.C. et al. (2021). Carbon footprinting of universities worldwide: Part I—objective comparison by standardized metrics. Environ Sci Eur 33, 30
57. Helmers, E., Chang, C.C., et al. (2021) Carbon footprinting of universities worldwide: Part I—objective comparison by standardized metrics. Environ Sci Eur 33, 30.
58. Li, X., Tan, H., et al. (2015) Carbon footprint analysis of student behavior for a sustainable university campus in China. J Clean Prod 106, 97–108.
59. Letete, T.C.M., Mungwe, N.W., et al. (2011) Carbon footprint of the University of Cape Town. J Energy Southern Africa 22(2), 2–12
60. Helmers, E., Chang, C.C., et al. (2021) Carbon footprinting of universities worldwide: Part I—objective comparison by standardized metrics. Environ Sci Eur 33, 30.
61. Helmers, E., Chang, C.C., et al. (2021) Carbon footprinting of universities worldwide: Part I—objective comparison by standardized metrics. Environ Sci Eur 33, 30.

and including resource-consuming medical departments. However, widespread exploration of renewable energy sources and adopting green energy on campus mitigates a university's total CFP. For example, ETH Zurich is powered by 100% renewable energy that makes its CFP (expressed in kgCO_2/m^2) relatively small.

It is necessary to emphasise that embodied carbon contributes to around 60-70% of a household's CFP[62]. According to Helmers et al.[63], the total CFP of Umwelt Campus Birkenfeld and NTU (Singapore) comprises of 59.2% and 29.8% of the total building CFP respectively. Moreover, transition to renewable energy on-campus shifts the focus from energy emissions towards emissions caused by embodied carbon, since its contribution to a university's CFP may outpace energy-related emissions. In Singapore, the need to account for embodied carbon is even more important due to a high rate of construction and renovation that has a drastic impact on GHG emissions. While operational carbon output can be improved during the lifespan of a building through renovations and deploying innovative technological solutions, embodied carbon, when not considered during the design stage, remains stable over years. It is explained by the fact that the carbon emissions produced during construction of a building cannot be changed. Given the high intensity of urban renewal in Singapore, NTU and other Singaporean universities should prioritise renovating already existing buildings over demolishing and constructing new ones, and also give importance to enhancing the quality and functions of materials.

It is clear that every university operates in a unique context which impacts its total CFP in one way or another. Currently, a comparison across all universities would be complicated to execute due to the different emission parameters that are selected by universities from the GHG inventory list. For example, data under Scope 3 emissions can be difficult to collect and homogenise. Naturally, it is expected that research intensive universities with a large campus size, located further from a central infrastructure, with limited on-campus housing and located in areas with high or low temperature would generate the most carbon emissions as a result of needing intensive use of energy. However, access to renewable energy mitigates the mentioned factors and greatly reduces the CFP of energy-demanding universities. While no correlation was found between mentioned university parameters and CFP[64], a university's CFP seems to be related most to the national carbon emission per capita, meaning that countries with more developed economies will consequently have more emission-intensive universities.

Best practices from a worldwide comparison of universities

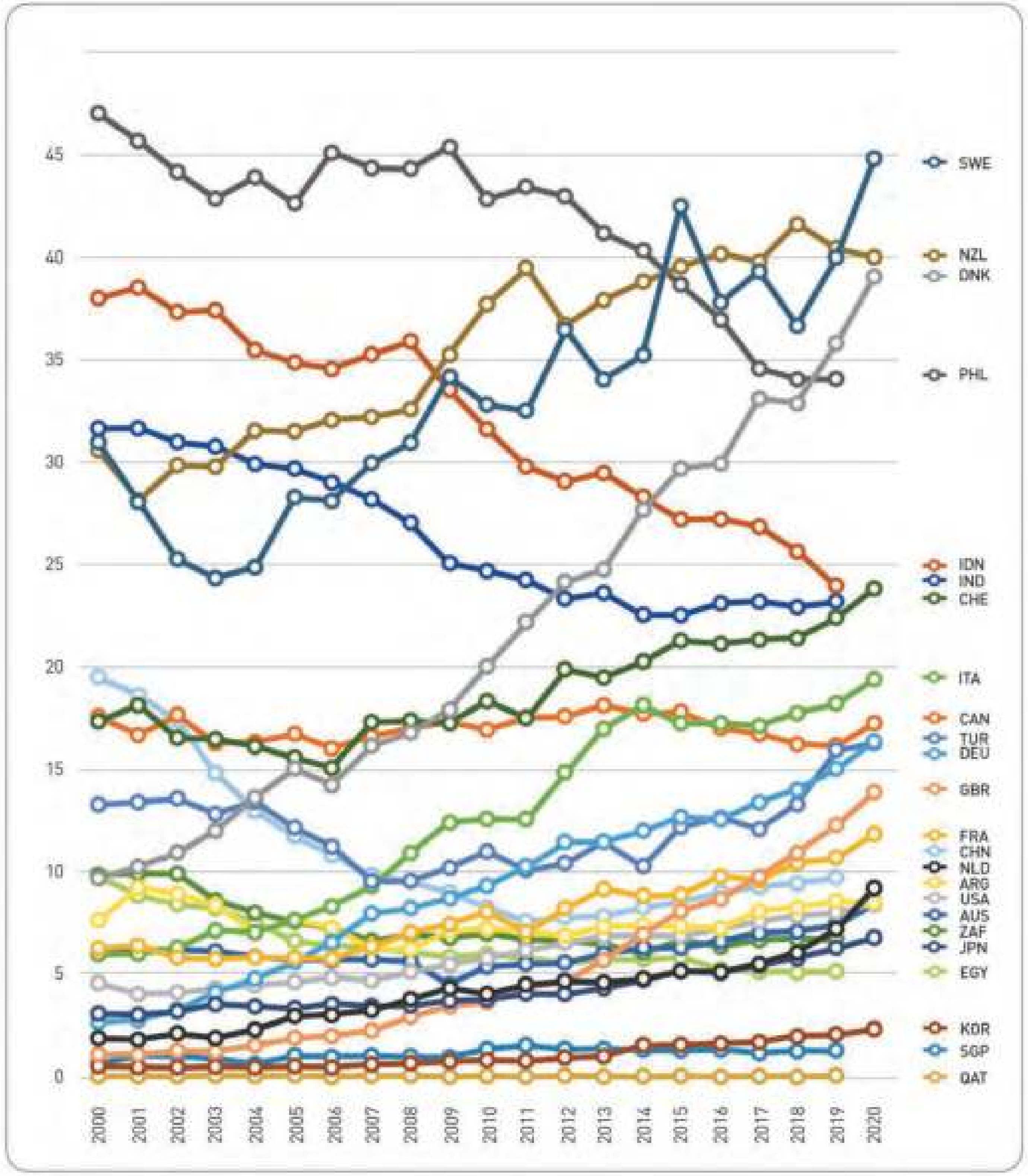
Being academic frontrunners in sustainability, many universities committed to becoming carbon neutral. Naturally, there are some commonalities for universities in a certain geographical region or climate zone.

For example, European and North American universities subjected to mild winters and moderate summers require established heating systems that can differ by fuel type used and carbon emissions. These universities have access to a variety of sources of renewable energy, originating from landscape diversity. For instance, vast terrains in the US facilitate adoption of wind and solar energy, while mountainous areas rich in rivers enable development of hydropower. Europe hosts the majority of old universities in brick buildings – natural heat retainers – which additionally mitigates the amount of carbon emissions produced by heating systems. Europe is well covered by a train network that allows for low-carbon everyday commuting and local business travels, while the USA, due to its large territory and limited rail network, remains mostly dependent on air travel.

The analysis of best practices of universities in reducing their CFP indicates that the available information about sustainability practices is predominant mostly for American, European and Australian Universities, while universities in the Southern Hemisphere are significantly less represented. It is anticipated that South Asian, African, and South American universities located

62. Marchi, L., Vodola, V., et al. (2021) Contribution of individual behavioural change on household carbon footprint. E3S Web Conf., 263, 05024.
63. Helmers, E., Chang, C.C., Dauwels, J. (2022) Carbon Footprinting of Universities Worldwide Part II: First Quantification of Complete Embodied Impacts of Two Campuses in Germany and Singapore. Sustainability 14(7), 3865.
64. Helmers, E., Chang, C.C., et al. (2021) Carbon footprinting of universities worldwide: Part I—objective comparison by standardized metrics. Environ Sci Eur 33, 30.

THE USE OF RENEWABLE ENERGY IN SELECTED COUNTRIES AS % OF PRIMARY ENERGY SUPPLY



OECD (2022), Renewable energy (indicator). doi: 10.1787/aac7c3f1-en in the tropics require constant air-conditioning. High humidity and frequent rainfall prompt efficient water reclamation. However, strong dependence on fossil fuels and nascent renewable energy networks complicate fast adoption of green energy on their campuses.

At the same time, the commitment to reducing GHG in Asia is increasing. In October 2020, more than 200 of the world's leading companies (including Sinopec, PetroChina, and Asia Pacific Resources International Limited) announced plans for net zero carbon emissions by 2050[65]. At 16 universities in Asia (with the majority from Malaysia and Indonesia), more than 85% of students and staff reported the presence of developed sustainability campus programmes that included the preparation of sustainability reports and establishment of sustainability offices[66]. However, a quick reduction of carbon emissions in Asian countries is often hindered by policies that subsidise the cost of petroleum products and electricity for the benefit of the poorest sections of society[67]. This also slows down the development and adoption of renewable energy. Other barriers include limited financing and cooperation between the public and private sectors on more sustainable practices, lack of vision in long-term planning, poor regulatory frameworks related to emission reduction targets and the ability to monitor and verify emissions effectively[68].

The University of San Francisco, USA, became carbon neutral in 2019 by improving water conservation, switching to green cleaning supplies, installing micro turbines to yield power and heat on campus, and purchasing carbon offsets[69]. The Leuphana University of Lüneburg (Germany) achieved carbon neutrality in 2014 by avoiding or offsetting emissions from business trips and vehicles, electricity, heating, water, and paper consumption[70]. Charles Sturt University, located in New South Wales, Australian Capital Territory, and Victoria became the first Australian carbon neutral university[71] by switching to renewable energy sources including roof-top solar and cogeneration (simultaneous production of multiple forms of energy from a single fuel source), energy efficiency upgrades across existing buildings, and adopting sustainable building principles and behavioural change programs. Monash University (Australia) has committed to achieve zero carbon emissions by 2030 through the implementation of zero energy buildings, construction of renewable energy plants and decreasing energy consumption through technological and behavioural changes[72]. NTU (Singapore) pledged to achieve net zero water consumption, close to net zero waste and emissions by 2030[73]. And these are just few examples among a pool of universities committing to net zero carbon emissions.

Undoubtedly, one of the most effective ways to reduce CFP is to utilise green energy from available external sources (renewable power plants) or to develop green resources on the university premises. While many European universities utilise solar and wind energy to power universities, the University of New Hampshire (US) utilises hydrothermal power[74]. Photovoltaics is extensively adopted by NTU. The University of New Hampshire (US) has had the same use of energy on campus since 2010, but GHG emissions dropped

The University of New Hampshire (US).

65. Hicks, R. (2020) 200 of world's largest corporations commit to net zero emissions by 2050, reverse biodiversity loss and fight inequality. Eco-business. Retrieved from https://www.eco-business.com/news/200-of-worlds-largest-corporations-commit-to-net-zero-emissions-by-2050-reverse-biodiversity-loss-and-fight-inequality/
66. Filho, L.W., Dinis, M.A.P., Sivapalan, S., et al. (2021) Sustainability practices at higher education institutions in Asia. Int J Sustain High Ed.
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68. Raitzer, D.A., Bosello, F., Tavoni, M., et al. (2015) Southeast Asia and the economics of global climate stabilization. Asian Development Bank. https://www.adb.org/sites/default/files/publication/178615/sea-economics-global-climate-stabilization.pdf
69. USF (2019). University of San Francisco Achieves Carbon Neutrality More Than 30 Years Ahead of Goal. University of San Francisco. https://www.usfca.edu/newsroom/media-relations/news-releases/carbon-neutrality
70. Opel, O., Strodel, N., et al. (2017) Climate-neutral and sustainable campus Leuphana University of Lueneburg. Energy 126, 2628–2639.
71. Charles Sturt University = Carbon Neutral (2016). https://www.csu.edu.au/sustainability/about-us/carbon-neutral-university
72. Monash net zero initiative. Brochure (2020). https://www.monash.edu/__data/assets/pdf_file/0010/2042668/Monash-Net-Zero-Brochure.pdf.
73. NTU Sustainability Report (2017) Retrieved from https://ebook.ntu.edu.sg/2017-ntu-sustainability-report.html
74. The University of New Hampshire's Climate Action Plan (2021). https://unh.app.box.com/s/h1ax4wcagbn1otsbez1f8lima986vboc

fivefold. It occurred as a result of adopting 100% renewable electricity produced by a combined heat and power plant, supported by the landfill gas and micro-hydropower facilities from facilities nearby. In order to decrease the CO_2 emissions caused by its fleet use, the University of New Hampshire maintained a fleet of university-owned vehicles primarily to support service and operations, reinforced by a range of measures including green purchasing practices, a departmental bike program, and enhanced vehicle maintenance. The excessive production of green energy can be used to offset CO_2 emissions, as is practiced by Leuphana University Lüneburg in Germany, the heating network of which is based on biomethane-powered combined-heat-and-power supported with photovoltaics[75].

Besides the approaches mentioned above, other ways to reduce carbon emissions at universities include using low energy technologies to construct new buildings and to renovate existing buildings[76], actively developing available sources of renewable energy and exploring ways for water recycling and optimising the management of energy consumption; installing thermal blankets in the indoor swimming pool to reduce heat loss[77]; maximising planting of trees on campus and increasing biodiversity via reconstructing natural systems[78]. For example, the majority of NTU's buildings were equipped with efficient water-cooled air-conditioning systems and intelligent energy management systems to manage the building's energy consumption, smart Air-Conditioning and Mechanical Ventilation (ACMV) optimisation. This was enhanced by solar photovoltaic panels that offset 100% of the buildings' total energy consumption and a Passive Displacement Cooling system that uses a chilled-water cooling coil to create the air circulation through natural convection process. NTU's sports complex was constructed using an Engineered Wood System for the whole building to minimise heat gain, a Passive Displacement Cooling System (Induction Air Distribution System), an Energy Efficient Chiller Plant System, an operable façade design

The Hive at the Nanyang Technological University, Singapore.

for maximum natural ventilation and sunlight effect that reduced carbon emissions originated from energy use, and waste heat recovery for the hot water showers that enabled reduction of water usage. Accompanied by motion sensors for lighting and LED lights, these buildings achieved either a Super Low Energy or Zero Energy ranking by BCA Awards in 2019. The adoption of these measures allowed NTU to decrease 37% of its GHG in 2017 as compared to 2011[79].

To reduce emissions connected to mobility and commuting, on-campus housing could be expanded, and rail service and bicycle/pedestrian infrastructure could be also improved. For example, NTU presented a free electric bicycle-sharing service and is testing a fully automated Group Rapid Transit autonomous vehicle – a driverless bus shuttle service[80].

Other less demanding actions could be the closure of buildings during holidays or grouping university activities during the daytime (e.g., finishing the classes before dark reduces use of energy for lighting). Mexico University analysed four scenarios of reducing campus CFP that included: (1) half of the students and staff attend University 3 days per week; (2) reducing the use of cars and increasing the use of public transport; (3) introducing carpooling; and (4) combining remote work arrangements with a carpooling system[81]. The last alternative ensured the greatest reduction in GHG emissions.

75. Opel, O., Strodel, N., et al. (2017) Climate-neutral and sustainable campus Leuphana University of Lueneburg, Energy, 141, 2628-2639.
76. BCA Awards 2019 (2019). https://www.bca.gov.sg/greenmark/others/gm2019.pdf
77. Valls-Val, K., Bovea, M.D. (2022) Carbon footprint assessment tool for universities: CO2UNV. Sustainable Production and Consumption, 29, 791-804, https://doi.org/10.1016/j.spc.2021.11.020.
78. The rejuvenated Yunnan Garden, a sprawling open space of greenery, waterscapes and heritage landmarks, officially opened its doors on 13 February 2020 (2020) https://www.ntu.edu.sg/news/detail/the-rejuvenated-yunnan-garden-a-sprawling-open-space-of-greenery-waterscapes-and-heritage-landmarks-officially-opened-its-doors-on-13-february-2020
79. NTU Sustainability Report (2017) Retrieved from https://ebook.ntu.edu.sg/2017-ntu-sustainability-report.html
80. NTU Sustainability Report (2017) https://ebook.ntu.edu.sg/2017-ntu-sustainability-report.html
81. Güereca, L.P., Torres, N., et al. (2013) Carbon Footprint as a basis for a cleaner research institute in Mexico. J Clean Prod 47, 396–403.

Lifelong education in sustainability practices

Aspiring towards a low-carbon future by implementing energy-efficient solutions alone is unlikely to be sufficient to significantly reduce GHG emissions. Only when combined with changes in people's behaviour (also considered a cheap and speedy method) is there potential to significantly affect energy consumption[82,83]. Van De Ven et al. demonstrated that adoption of behavioural policies can mitigate the CFP emissions per capita by 6 to 16%[84]. Accommodating changes in behaviour can help save 10 to 20% of energy at minimal cost and without upgrading facilities[85], including a 30% reduction in heating energy consumption and around 50% in cooling energy consumption[86].

People might experience various individual, societal, institutional, and governmental barriers in changing behavioural patterns, among which are a lack of awareness about the impact of GHG emissions and social competition to facilitate adoption of new habits, resistance to change, demographic factors, economic and technical barriers, low stimulus, and lack of social culture[87,88].

Recently, the importance of non-expensive, non-regulatory, and non-monetary policy interventions, in particular nudging (positive reinforcement and indirect suggestion on how to change the behaviour) and boosting (enablers of specific behaviours to foster people's decision-making competences) has been highlighted[89]. Individual CFP could be mitigated via nudges, among which eco-defaults (pre-selected options that allow people to easily adopt sustainability practices; e.g., mandatory subscription for renewable energy instead of fossil fuels), context re-framing (e.g., focusing on social gains rather

than individual inconvenience); communicating societal expectations (e.g., comparing energy use with that of neighbours) and use of eco-labels for environmentally preferred products that meet eco-standards are considered the most efficient[90]. It was also observed that communicating the benefits of changes in behaviour towards reducing CFP through the prism of personal health gains motivates people to become more climate-friendly[91,92,93].

The majority of studies on climate-related behaviour are focused on societies as a whole, households, or countries, which indicates the necessity to examine the barriers that university students and staff experience in adopting more climate-friendly behaviours[94]. Every university will have its own approach toward adopting climate-friendly policies. For instance, Li et al.[95] conducted surveys among Tongji University students to identify the biggest contributors to their CFP. 65% of carbon emissions were attributed to daily life (dining (34%), showering (18%), and dorm electricity (14%) among them), 20% to transportation, and 15% to academic activities. The authors also found that men, graduate students, and students from metropolitan areas

82. Pollitt, M.G., Shaorshadze, I., et al. (2013) The role of behavioural economics in energy and climate policy. In Handbook on Energy and Climate Change; Edward Elgar Publishing: Cheltenham, UK, 2013; pp. 523–546.
83. Van Sluisveld, M.A., Martínez, S.H., et al. (2016) Exploring the implications of lifestyle change in 2 ĐC mitigation scenarios using the IMAGE integrated assessment model. Technol Soc Chang 102, 309–319.
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94. Nauges, C., Wheeler, S. (2017) The Complex Relationship Between Households' Climate Change Concerns and Their Water and Energy Mitigation Behaviour Ecol Econ 141, 87–94.
95. Li, X., Tan, H., et al. (2015) Carbon footprint analysis of student behavior for a sustainable university campus in China. J Clean Prod 106, 97–108.

produced more GHG emissions than women, undergraduates, and students from rural areas and small towns. Interestingly, communal activities like eating in the canteens, showering in communal showers, and studying in the library had a lower impact on CFP. Behavioural differences between genders should also be considered by universities. For example, the study demonstrated that women preferred dining (67%) and studying (80%) in communal facilities rather than alone or in dorm rooms, as compared to men (45% and 40% respectively).

As living standards and behaviours change, it is important to consider that students may develop preferences for private facilities and more thermal comfort, which emphasises the necessity of long-term planning of facilities aiming to meet changing preferences, behaviours and personalised needs in a sustainable way.

While many universities target zero carbon emissions, there is not a single IPCC concept achieving it[96]. Based on the available literature and best practices, this goal can be achieved only through excessive production of renewable energy or with a powerful approach toward carbon sequestration.

To reduce the CFP further, carbon offsets that fall into two broad groups – emission reductions and carbon removals[97] – need to be utilised by universities[98]. Examples of emission reduction offsets include reducing or capturing emissions

of long-lived pollutants and avoiding deforestation. Carbon removal offsets include nature-based solutions such as the restoration of peatlands, coastal habitats and native forests, and technology-based solutions such as direct carbon capture or mineralising CO_2 into building materials. Nature-based carbon removal is deployable at scale today and can support ecosystem restoration, biodiversity and livelihoods while remaining relatively cheap. It is necessary to note that carbon offsets will be useful for achieving net zero, but they do not substitute for a university's reduction of emissions.

In 2019, the International Institute for Geo-Information Science and Earth Observation of University of Twente started compensating their GHG emissions from flying by KLM, Air France, and Delta Air by reforestation, and for emissions from other airlines by leading two sustainable projects in Rwanda[99]. The University of New Hampshire (US), besides compensating carbon emissions, also invests in the development of renewable energy sources by purchasing Renewable Energy Credits produced and sold from wind farms in Texas and the Great Plains, which helps drive costs down for clean energy projects and allows the industries to scale[100].

It is important to remember that, before any intervention to reduce the CFP, it is necessary to conduct the assessment of present technical characteristics (such as infrastructure or used materials), economic indicators (investment, annual cost, saved cost, and pay-back) and environmental impact (CFP improvement potential) for each individual improvement action (such as use of more sustainable materials, implementation of renewable energy powerplants etc). It allows for an eco-efficiency analysis. For example, construction of a new house emits 50 tonnes CO_2, while its renovation only 15 tonnes[101]. However, the renovation should be planned in a way to prolong the operation of a building with the maximum use of eco-efficient materials to reduce the CFP.

As can be seen, while there is no homogeneity among universities with regards to their approaches

96. Schaeffer R. J., Meinshausen M., et al. (2015) Zero emission targets as long-term global goals for climate protection. Environ Res Lett 10, 105007.
97. How can carbon offsetting help UK Further and Higher Education Institutions achieve net zero emissions? COP26 Universities Network Briefing (2021) https://www.gla.ac.uk/media/Media_770459_smxx.pdf
98. What is a Carbon Offset? Carbon Offset Guide. https://www.offsetguide.org/understanding-carbon-offsets/what-is-a-carbon-offset/
99. ITC compensates flights by neutralizing CO2 footprint (2020) https://www.itc.nl/news/2020/2/125466/itc-compensates-flights-by-neutralizing-co2-footprint
100. The University of New Hampshire's Climate Action Plan (2021). https://unh.app.box.com/s/h1ax4wcagbn1otsbez1f8lima986vboc
101. Pedersen, H. (2020) Renovation is both greener and cheaper than new-build. https://ramboll.com/ingenuity/renovation-and-new-build

to reduce CFP, incorporating renewable energy into the university energy system remains the most widely utilised intervention.

The type and amount of renewable energy differ across countries and is largely conditioned by the available infrastructure and landscape. Successful integration of green energy grids into the university system helps reduce CFP and eventually even offset it. The investment in eco-friendly on-campus transportation (introduction of bicycles, electric vehicles etc) and compensating GHG emissions caused by air-travel are viable approaches to reduce the university's total CFP. The availability of the necessary transport infrastructure, central location, and compact size of a university campus can potentially contribute to reducing the CFP[102].

When the reduction of CFP is not possible, the use of carbon offsets is encouraged. It is important to remember, however, that carbon offsets should be used only as a last resort as they do not stop carbon emissions. Efforts should be mostly directed toward the decrease of GHG emissions.

State of the art sustainability rankings and metrics

Universities worldwide acknowledge the importance of implementing sustainability practices along with the CFP measurements. In order to understand how the universities are currently evaluated and ranked and to explore the metrics that are applied to quantitively assess the universities' commitment to sustainability practices, we looked into the most recognised rankings (STARS, THE Impact ranking and Green Metric).

The Association for the Advancement of Sustainability in Higher Education (AASHE) consolidated the sustainability reports from the universities worldwide and built a platform for the exchange of the best sustainability practices by developing the Sustainable Campus Index[103]. This ranking aims to assess top-performing colleges and universities as measured by the Sustainability Tracking, Assessment & Rating System (STARS)[104]. The usage of the STARS Reporting Tool promotes the collection of standardised, transparent, and internationally comparable data by reporting the basic CO_2 emissions of a university by sector, number of students and staff, the energy intensiveness space of a campus, environmentally friendly activities, academic curriculum, and whether it includes modules on environmental sustainability etc.

The contributing parameters are:

- Air & Climate
- Buildings
- Campus Engagement
- Coordination & Planning
- Curriculum
- Diversity & Affordability
- Energy
- Food & Dining
- Grounds
- Investment & Finance
- Public Engagement
- Purchasing
- Research
- Transportation
- Waste
- Water
- Wellbeing & Work

All the universities included in the ranking undertake different approaches toward achieving carbon neutrality.

However, the STARS tool does not provide any critical assessment and verification of self-reported data, despite publishing data about selected emission sources. STARS also does not require universities to report their CFP. Nevertheless, the collection of reports with sustainability actions sheds light on environmentally friendly practices adopted worldwide.

For example, the American University in Washington (US) ditched desktop printers in favour of shared ones that led to a reduced use of electricity and paper[105]. California State University, Dominguez Hills (US) installed one of the largest behind-the-meter battery storage systems (on-site options that allow energy customers to store capacity for use as needed) in Southern California[106]. The University of Central Michigan promoted a circular economy by developing a closed loop composting system for food scraps[107]. Dickinson College (US) developed a 3 MW solar field, transitioned to nearly 100% LED lighting, improved the efficiency of their central energy plant and energy intensive buildings, replaced older equipment with high efficiency alternatives, incorporated energy efficient design when renovating existing buildings and constructing new buildings, and sourced electricity from renewable energy[108]. The Kendeda Building for Innovative Sustainable Design at Georgia Institute of Technology (US) is considered regenerative: over the course of a year, it collects 15 times the amount of water needed for operations. It is supported by a photovoltaic system that supplies over 200% of the building's energy needs, with the excess being exported to adjacent buildings[109]. A central steam plant at Keene State College (US) transitioned from using No. 6 heating oil to LR-100, a biofuel made from used cooking oil that is certified carbon neutral and can generate thermal renewable energy credits[110]. At the same time, the University of Utah (US) diverted to geothermal energy, resulting in a 23% reduction in the university's GHG emissions[111]. Some universities reconsidered their investments. For example, the University of Guelph (Canada) reported the reduction of carbon intensity of the endowment by 17.5% in 2019, achieved through consultations with fund managers and divestment of holdings with fossil fuel reserves[112].

The STARS ranking covers the sustainability efforts of mainly American and European universities, which does not allow for comparison of best practices across the globe. Moreover, participation in the STARS ranking requires paid membership which limits participation and suggests that payment is needed to be ranked. At the same time, the STARS ranking offers an understanding of the best practices employed by the universities that aim for CFP reduction. This greatly reduces the usability of the STARS tool in present goals to better homogenise CFP calculations between universities.

University sustainability effort by sustainable development goals (SDG)

Another Impact ranking to estimate sustainability efforts of participating universities was produced by the Times Higher Education Impact Ranking 2021 and was based on the commitment to SDGs[113]. The ranking methodology for climate action (SDG 13) is based on an assessment of the quantity of university research into climate change (weight 27%), its use of low-carbon energy (27%), its preparations

102. Helmers, E., Chang, C.C., et al. (2021) Carbon footprinting of universities worldwide: Part I—objective comparison by standardized metrics. Environ Sci Eur 33, 30.
103. 2021 Sustainable Campus Index (2021). https://www.aashe.org/wp-content/uploads/2021/11/SCI-Nov-2021.pdf
104. Stars (2020) The sustainability tracking, assessment & rating system. Stars Participants & Reports. https://reports.aashe.org/institutions/participants-and-reports/?sort=rating.
105. American University. Managed Print Program (2021) https://reports.aashe.org/institutions/american-university-dc/report/2021-03-05/IN/innovation-leadership/IN-47/
106. CSUDH Co-Partners with So Cal Edison on $20 Million Clean Energy Pilot (2019) https://news.csudh.edu/clean-energy-pilot/
107. Central Michigan University Composting Program: Full Circle Effect (2020) https://reports.aashe.org/institutions/central-michigan-university-mi/report/2020-10-15/IN/innovation-leadership/IN-47/
108. Dickinson College. Carbon Neutral 2020 (2021) https://reports.aashe.org/institutions/dickinson-college-pa/report/2021-03-05/PRE/introduction/PRE-2/
109. Georgia Institute of Technology. The Kendeda Building for Innovative Sustainable Design (2021) https://reports.aashe.org/institutions/georgia-institute-of-technology-ga/report/2021-03-02/IN/innovation-leadership/IN-47/
110. Keene State College. No. Six No More: Renewable Heat Plant by 2018. https://reports.aashe.org/institutions/keene-state-college-nh/report/2021-03-04/IN/innovation-leadership/IN-48/
111. University of Utah. Long-term 20MW Geothermal Power Purchase and Rate Tariff Leadership (2021) https://reports.aashe.org/institutions/university-of-utah-ut/report/2020-10-21/IN/innovation-leadership/IN-50/
112. University of Guelph. President's Advisory Committee on Sustainability (2021) https://reports.aashe.org/institutions/university-of-guelph-on/report/2020-09-02/PRE/introduction/PRE-2/
113. Times Higher Education (2021) Impact Ranking 2021 https://www.timeshighereducation.com/rankings/impact/2021/overall#!/page/0/length/25/sort_by/rank/sort_order/asc/cols/undefined

TOTAL SCORE OF FIRST 100 UNIVERSITIES RELATED TO THEIR PERFORMANCE ON SELECTED SDGS, ACCORDING TO THE TIMES HIGHER EDUCATION IMPACT RANKING

for dealing with the consequences of climate change, including environmental education measures (23%) and commitment to carbon neutrality (23%). Among worldwide universities that applied for participation in this THE ranking[114], the University at Buffalo (USA) scored the highest by reducing food-related carbon emissions by half by 2030, encouraging students and staff to switch off electrical devices to eliminate energy-wasting behaviours and developing zero-carbon commuting pathways for the campus community. It was followed by Miguel Hernández University of Elche (Spain), University of British Columbia (Canada), Arizona State University (USA), and Comillas Pontifical University (Spain).

Similarly, universities' ranking for SDG 12 (responsible consumption and production) accounts for research into consumption and production (weight 27%), operational measures (26.7%) that include policies on ethical sourcing of food and supplies, appropriate disposal of hazardous waste, amount of waste sent to landfill and amount recycled minimising the use of plastic and disposable items, as well as the proportion of recycled waste (27%) and publication of a sustainability report (19.3%). The top 5 universities that scored the highest were University of Manchester (UK), Newcastle University (Australia), University College Cork (Ireland), Arizona State University (US), and Manchester Metropolitan University (UK).

The methodology for ranking universities according to SDG7 (affordable and clean energy) includes research into clean energy (weight 27%), university measures towards affordable and clean energy (23%), energy use (27%), and energy-affiliated activities in the community

114. Top universities for climate action. Times Higher Education (2021) https://www.timeshighereducation.com/student/best-universities/top-universities-climate-action

(23%). Based on the data provided by participating universities, King Mongkut's University of Technology Thonburi (Thailand), University at Buffalo (USA), University of Newcastle (Australia), Comillas Pontifical University, and University of Jaén (both Spain) ranked the highest.

Assessing universities based on their performance in SDGs – especially related to CFP – is challenging due to unspecified, vague, or non-standardised descriptions of weighing factors, with some of them being qualitative by nature. For example, a university may commit to achieve zero carbon in 5 or 50 years. In doing so, the university will subsequently specify the amount of effort put into achieving the goal that is reasoned by the availability of necessary resources, variable across universities. That said, however, participation in ranking systems provides a positive push to universities and helps reconsider the sustainability policies and actions.

The Green Metric is another initiative to rank universities based on their sustainability efforts[115], by infrastructure (weight 15%), energy and climate change (21%), waste (18%), water (10%), transportation (18%), and education and research (18%). In this list, Wageningen University (Netherlands), University of Nottingham (UK), University of Groningen (Netherlands), Nottingham Trent University (UK), and University of California, Davis (US) top the ranks.

It is clear that many of the sustainability rankings mainly focus on management aspects, climate action in general, and scientific activity around sustainability but do not provide a critical assessment of the universities' carbon emissions, as universities select the emission sources that they want to report on. Moreover, most of data provided by universities is self-reported and thus cannot be critically evaluated currently, as to the best of our knowledge there is no external agency that validates the collected information. Else, the scarce records of CFP measurement by universities from Asia, Africa and South America in the global rankings could lie in the necessity of universities to sign up for membership in order to be ranked, as well as in lacking financial support for implementation of environmentally friendly practices.

As mentioned by Helmers et al.[116], comparing and ranking universities by their CFP is almost impossible, due to such reasons as the unstructured and dissimilar approaches employed for calculating CFP, usage of contextually inappropriate tools (intended for industry and not for universities), lack of transparency in the CFP measurement, and unavailability of specific data. Although the above lists ranking systems that compare the general sustainability efforts of some universities, there is no ranking system that specifically compares CFPs of universities to date. The information available in public platforms is not validated by external agencies, which means that there is no means of verification for the reported numbers. It would be helpful if the identification of emission factors that are relevant to universities were standardised across all universities. Although universities cannot be quantitively compared due to their respective unique journeys toward sustainability, the aspiration of a university to be evaluated, ranked, and compared with other universities indicates about its commitment to environmentally-friendly activities.

115. Green Metric. https://greenmetric.ui.ac.id/
116. Helmers, E., Chang, C.C., et al. (2021) Carbon footprinting of universities worldwide: Part I—objective comparison by standardized metrics. Environ Sci Eur 33, 30

Toward a General Framework for University Carbon Footprint Measuring

Countering the selective reporting of emission factors

As emphasised before, the majority of universities worldwide include only selected emission factors in calculating the CFP. For example, according to the analysis of emission sources from 33 universities across all continents, performed by Valls-Val et al.[117], three quarters of universities included Scope 1 emissions from stationary combustion and vehicle fleet and only ~30% included leakage of refrigerants. It can be explained by the fact that not all universities participating in the analysis are research-intensive and possess laboratories with complex equipment.

As for the emissions coming under Scope 2, all universities in the mentioned study included purchased energy and only one (Keele University in the UK) – generated energy. This provides evidence of a lack of ability among universities to adopt on-campus infrastructure to produce their own energy. If a university generates its own energy, the emissions linked to energy storage (including storage in electrical vehicles) should also be considered[118].

The university's emissions under Scope 3 are categorised into materials consumption, transportation, and others. Emissions linked to water consumption were reported by 40% of universities, to paper consumption – by 55%, to food – by 30%. It is important to emphasise that since no standardised metrics are adopted to calculate emissions produced by materials consumption, the tallying of data can give an overestimated result. For example, food consumption by students and staff at university is related to its supply chain, cooking methods, cleaning, and food and waste disposal etc. These factors might inflate carbon emissions scores by calculating individual items multiple times. A clear recording of all the contributing parameters that are collected by a university would facilitate assessment of the emissions.

Around one quarter of the participating universities reported data on laboratory chemicals and electronic equipment and only two included emissions connected to the use of fertilisers. These parameters are tightly linked with the research focus of a university as well as the availability of agricultural facilities or greenhouses. Transport emissions include business travel, commuting and additional transport supplies.

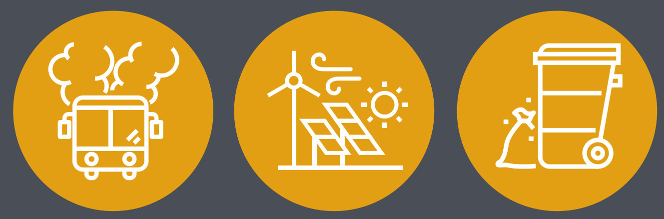
Among participating universities, approximately 70% included emissions from business travel and commuting into the calculation of the CFP and only 10% considered emissions from transport supplies. Given that the emissions from transport are the second biggest contributor to the CFP, it is surprising to observe that some universities (as Dipoengoro University in Indonesia[119] or Mea Fah Luang in Thailand[120]) omit either commuting or

117. Valls-Val, K., Bovea, M.D. (2022) Carbon footprint assessment tool for universities: CO2UNV. Sustain Prod Consum 29, 791-804.
118. WildCAP 2021 The University of New Hampshire's Climate Action Plan (2021). https://unh.app.box.com/s/he282os6o9l2k8s4o8dio53wefjaeuft
119. Budihardjo, M.A., Syafrudin S., et al (2020) Quantifying carbon footprint of Diponegoro University: non-academic sector. IOP Conf Ser Earth Environ Sci 448, 012012.
120. Laingoen, O., Kongkratoke, S., et al. (2016) Energy consumption and greenhouse gas emission evaluation scenarios of Mea Fah Luang University. MATEC Web Conf 77, 1-5.

business travel in their tallies. It can be explained by challenges in collecting data that might not be formally tracked by the university or personal data protection regulations.

Other emissions under Scope 3 include waste (data collated by 70% of universities), wastewater (40%), construction (18%), and transmission and distribution losses from electricity (30%). The amount and quality of the reported information is highly dependent on the collection efforts by the university.

Universities tend to selectively report their carbon emissions due to the unavailability of information, challenges with collecting the emission data, privacy protection issues, and a general lack of understanding on how to calculate emissions from upstream and downstream activities.



SCOPE 1 SCOPE 2 SCOPE 3

A general CFP framework for universities

Based on the breakdown of emission factors relevant for universities performed by Valls-Val et al.[121] and on the previous discussion, we suggest that the most relevant data on sources of emission to collect for universities would be the following:

1. **Scope 1:** stationary combustion (from different types of fuels), vehicle fleet (separated by number of vehicles, fuel type and run distance), and refrigerants leakage (including type of refrigerant, its volume and equipment it is being used for).
2. **Scope 2:** the amount of purchased and generated electricity, the type of electricity (green or carbon-based) with the distribution across all university buildings, and the amount of electricity used by university-owned electric vehicles.
3. **Scope 3:** emissions caused by consumption of water, paper (recycled and virgin) and food, treatment of wastewater (the amount of used energy), usage of laboratory chemicals (the amount of chemicals being collected for recycling) and electronic equipment (laptops, desktop computers, printers, toners etc), from commuting (separately for students and staff and including different means of transport) and from business trips (distance and means of transport), by generation of waste (including hazardous waste, lamps and luminaires, batteries and toners, and the mode of management: recycling or landfill).

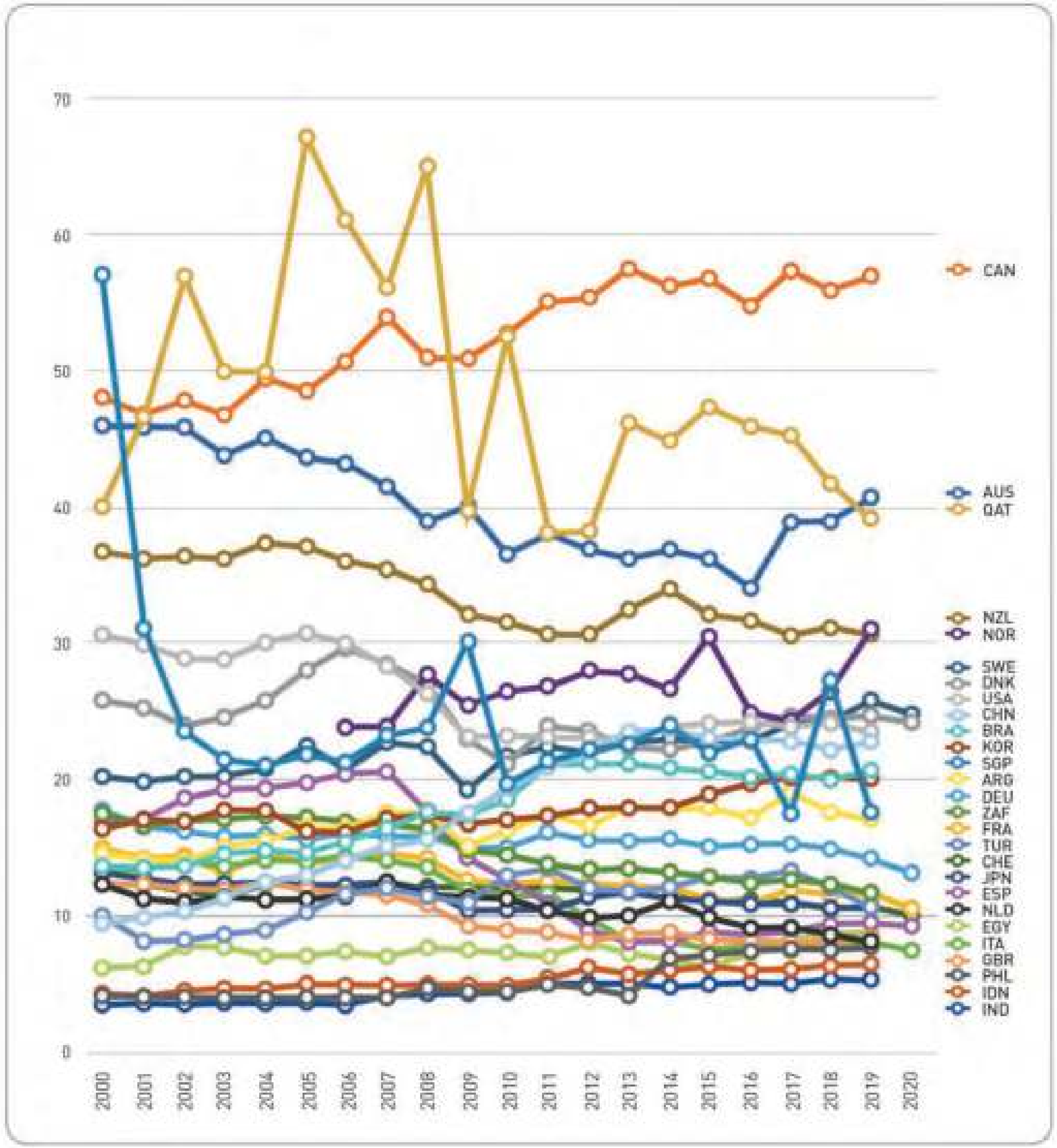
The visualised table to facilitate university's CFP measurement, accompanied by the units of measurement, is provided in Appendix 1.

121. Valls-Val, K., Bovea, M.D. (2022) Carbon footprint assessment tool for universities: CO2UNV. Sustainable Production and Consumption, 29, 791-804, https://doi.org/10.1016/j.spc.2021.11.020.

Toward including Scope 3 emissions

Universities are consistent in their reporting on Scope 2 (purchased and generated electricity) which is typically easy to measure, mostly through utility bills. Surprisingly, Scope 1 emissions, while being clearly defined, are often improperly recorded. The reason for this could be in difficulties in gathering the necessary data. This can be caused by a lack of technological abilities and on information being scattered across different offices. Besides, there is an ambiguity in categorising the sources of green or carbon-based energy owned by universities. For example, generation of green and carbon-based energy on

MATERIAL CONSUMPTION IN SELECTED COUNTRIES (TONNES PER CAPITA)



OECD (2022), Material consumption (indicator). doi: 10.1787/84971620-en campus is included in Scope 2, but the utilisation of generated carbon-based energy is reported under Scope 1.

Scope 3 emissions are the most encompassing, and universities choose which emissions to report based on availability of data. While access to personal data is understandably limited and hampers transparent and reliable collection of travel and commuting data, universities sometimes choose not to report the second biggest contributor of emissions. It also indicates that each university is unique in its regulatory policies, location, academic and research load, calling for scrupulous evaluation of every specific case. Inconsistency in requirements towards obligation or only recommendation to report certain emissions, as suggested by ISO 14064, PAS 2050 or GHG protocol, also complicates standardisation of emission sources across all universities[122]. Listing all emission sources relevant for universities and encouraging universities to systematically report their emissions could facilitate CFP tracking.

The transparency in CFP reporting underlaid by consistent inclusion of all sources that generate emissions could assist the comparison of data and information and would improve measurement robustness.

On transparency as a factor of CFP and sustainability measurement progress

Transparency in reporting carbon emissions was the most debated issue for COP26[123]. The Enhanced Transparency Framework developed at COP26 suggested that countries demonstrate progress in implementation rather than to report their progress in meeting their sustainability pledges. It is led by the principles of collaboration, mobilisation, and action. It aims to incentivise all actors to realize the importance of transparent climate-relevant data and information[124]. In 2022, the G20 produced Climate Transparency Reports, where it reviewed climate-friendly actions taken by countries based on 100 indicators for adaptation, mitigation, and finance with the aim to highlight good practices and gaps[125]. Other examples include Corporate Emissions Reduction Transparency report, elaborated by Australian Government in 2022 - a new voluntary initiative for eligible companies to present a snapshot of their climate-related commitments, progress, and net emissions position. It presents this in one place, using a standardised framework[126].

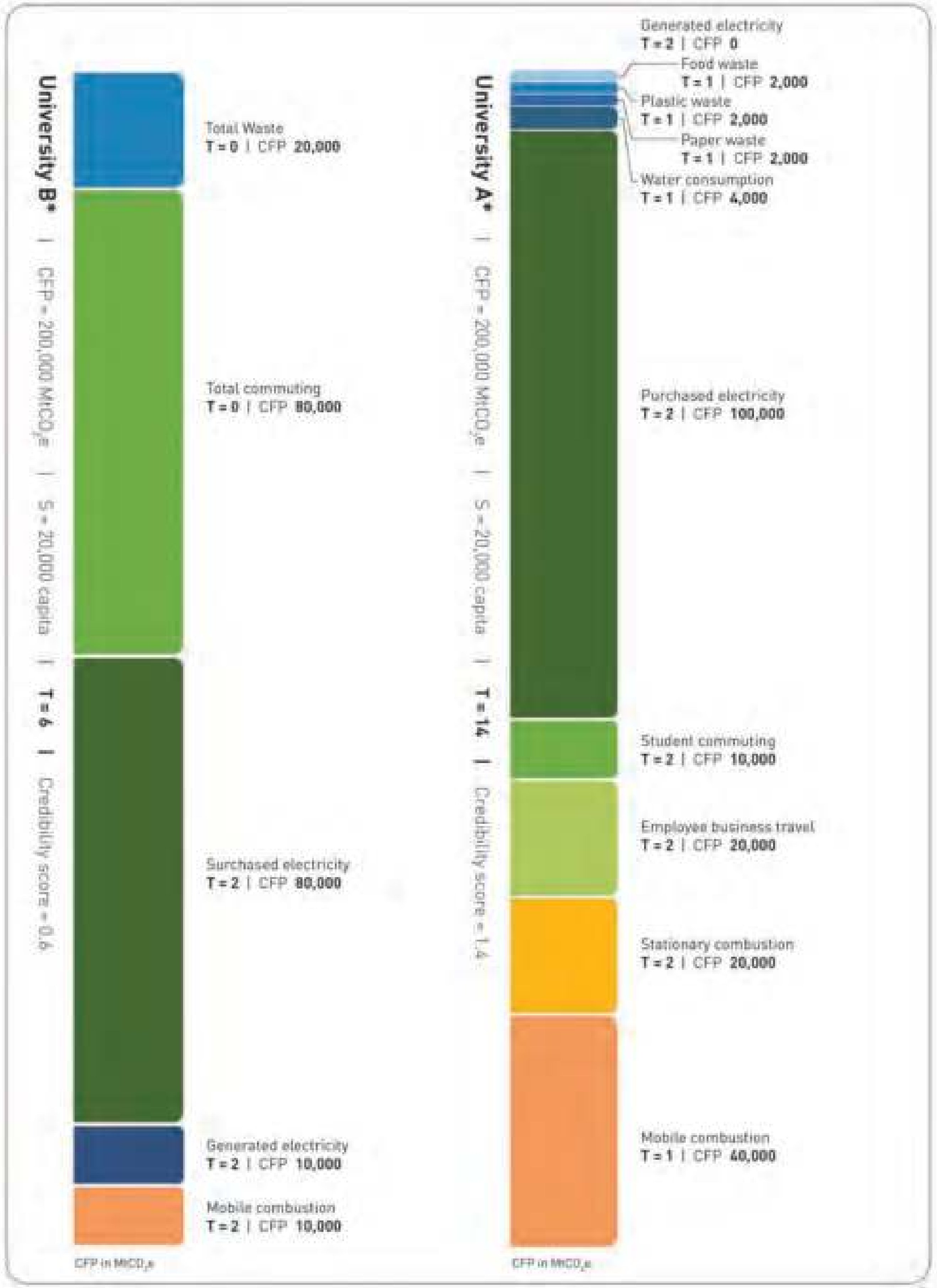
Fagotto and Graham from the Transparency Policy Project at Harvard University's Kennedy School of Government[127] argued that transparent reporting of GHG emissions benefits organisations. Doing so, according to the authors, unveils avenues for opportunities to assess each emission source and identifies ways to decrease emissions. It could also expedite the transfer to less carbon-intensive products. Moreover, disclosure of emissions could promote public trust and help an organisation gain a competitive advantage. While many governmental organisations encourage and promote transparent reporting of climate actions, none of them lay the foundation of incentivising organisations, including universities, to report full breakdowns of their emissions.

Consistent tracking of emissions generated by a university from variety of sources could instil public trust in reporting and demonstrate a university's intention towards dynamic changes. Moreover, thorough collation of emissions could lead to a shift from what is easy to measure to what is important to measure.

The absence of a standardised approach to CFP measurement as well as a lack of transparency and strict requirements on CFP reporting that could be imposed by controlling agencies complicate the comparison among universities and question the reliability of data.

122. Lange O, Plath J, Dziggel TF, et al. (2022). A Transparency Checklist for Carbon Footprint Calculations Applied within a Systematic Review of Virtual Care Interventions. Int J Environ Res Public Health. 18;19(12):7474.
123. The Guardian (2021). Transparency over emissions remains a sticking point at Cop26 (2021). https://www.theguardian.com/environment/2021/nov/06/transparency-over-emissions-remains-a-sticking-point-at-cop26
124. Momentum towards Universal Participation in the Enhanced Transparency Framework. https://unfccc.int/momentum-universal-participation-ETF
125. Climate Transparency (2021) The Climate Transparency Report 2021. https://www.climate-transparency.org/g20-climate-performance/g20report2021#1531904804037-423d5c88-a7a7
126. Australian Government. Clean Energy Regulator (2022) Corporate Emissions Reduction Transparency report. https://www.cleanenergyregulator.gov.au/Infohub/Markets/cert-report
127. Fagotto, E., Graham, M. (2007) Full Disclosure: Using Transparency to Fight Climate Change. Issues in Science and Technology, XXIII, 4.

ILLUSTRATION OF HOW CFP MEASUREMENT CAN DIFFER AMONG UNIVERSITIES



Toward a CFP score that takes a university's transparency into account

The analysis of available CFP ranking systems and metrics brings up evidence of persistent inconsistency in reporting of results. This is caused by a non-standardised approach to measuring CFP across different universities and universities selectively including emission factors because of unavailability or sensitivity of data. With this in mind, we propose that a combination of a CFP metric with a measure of information transparency would provide a viable indicator of universities' commitment to carbon-neutral policies and would indicate the credibility of the reported CFP data. While not all universities can collect or provide the data required for the calculation of a standardised CFP for a variety of reasons (technological, bureaucratic, or legal), they should not be discouraged to participate in comparing their CFP with other universities and their transparency should be rewarded and reflected in their CFP score.

In order to reward the comprehensive reporting and measuring of Carbon, we suggest introducing a CFP Score defined by CFP against the transparency of a university in reporting its footprint (T). We propose to weigh the CFP of a university by their Transparency. When a university tracks its CO_2 output very comprehensively and reports this clearly, then it receives a high score for transparency. This high score in transparency in turn tempers its CO_2 footprint so that a university is rewarded for being transparent. This will give value and context to the university's CFP score. The combined score assessment would enable the majority of universities to compete with others not only by the reduction of GHG emissions, but also by increasing the transparency and availability of their data. It can potentially empower the offices in charge of collecting and processing data to account for and address existing gaps in fact gathering.

It is important to mention that including certain types of emissions that are the biggest contributors to the university's CFP (such as energy consumption in buildings under Scope 2 and mobility and commuting under Scope 3) are more important to be included into the overall CFP, compared to factors that contribute less (such as shipment, due to its low volume, or energy consumed by electric vehicles, due to low energy consumed by electric vehicles).

We suggest adding more weight for transparency for the reporting of factors that contribute most. For example, if a university reports data on purchased or generated energy, it receives 2 points for each item. If it does not, it receives 0 points. The same principle would be applied for student and employee commuting and business travel. Reporting data on each of abovementioned factors adds 2 points each. In agreement with this assumption of a CFP vs T score, we suggest the following ways to evaluate the Transparency of collected information.

- **Transparency Scope 1.** If data is reported on all three contributing types of emissions (consumed energy, leakage from refrigerants, and fuel for mobile combustion), a university receives 3 points (1 point for each item). Under Scope 1 a university can receive a maximum of 3 points.
- **Transparency Scope 2.** If data is reported on purchased and generated electricity, a university receives 4 points (2 points for each item). If data is reported on electricity consumed by electric vehicles, a university receives 1 point. Under Scope 2 a university can receive a maximum of 5 points.
- **Transparency Scope 3.** If data is reported on the consumption of water, paper, electric and electronic equipment and laboratory chemicals, a university receives 4 points (1 point for each item). For reporting about waste generation, a university receives 4 points (1 point per reporting of non-hazardous, hazardous, food waste, and electrical and electronic equipment waste). If a university reports about emissions under commuting travel it receives 4 points (2 points each for reporting about students and employees separately). If it reports about emissions under business travel, it also receives 4 points (2 points each for reporting about students and employees separately). If it reports about shipment mode, it receives 1 point. Altogether, under Scope 3 a university can receive a maximum of 17 points.

The type of purchased or generated energy (be it green energy or fuel-derived) is not relevant for the calculation of transparency (T). As such, some universities may produce zero emissions under certain scopes (e.g., a university generates green energy on campus and records zero emissions in Scope 2). Nevertheless, they should still assign 2 points in the calculation of T score for reporting this data. Thus, if a university provides information completely transparently and reports all required emission sources, it can receive a maximum of 25 points.

The size of a university (by the number of students, faculty, academic and non-academic staff) is another important parameter that pre-defines the total CFP. We suggest including the size of a university in the calculation of a CFP Score as well. A large university will have more difficulty collecting all the required data to be transparent about its CFP. Therefore, the proposed formula for calculating a CFP Score is as follows:

$$CFP\ Score = \frac{S{*}T}{CFP}$$

where S is the size of university and is measured in the number of capita (including students and staff), T is Transparency of reported data and has a value from 0 to 25 (see Appendix 1 for calculation model), and the university's CFP indicates the total GHG emissions from all relevant sources and is measured in $MtCO_2e$. The higher the Transparency and the lower the CFP are, the higher the CFP score will be. More information on the CFP score calculation and examples are provided in Appendix 1.

Conclusion

We identified the contributing emission factors that are most essential in calculating a university's CFP and have evaluated what factors should be accounted for considering academic research and educational facilities and services. Often, reporting on these essential data is limited, explained by a lack of technological tools to collect the data, or legal and policy barriers that block access to the data (e.g., privacy matters), or administrative constraints when there is no dedicated office or role to collect and process the information.

Nevertheless, universities are still eligible to participate in global assessments or rankings developed by the Association for the Advancement of Sustainability in Higher Education, Times Higher Education or the Green Metric which makes the applicability of the ranking to compare universities questionable. One of the approaches that can potentially address this problem is a combined score that estimates both CFP and the availability of carbon-related data. Reporting CFP with considerations of how transparent a university is could encourage universities to report more comprehensively and to assess the obstacles in the way of a more comprehensive and transparent reporting of their CFP.

An NTU approach toward CFP measuring

Based on the need for data transparency in universities' reporting of CFP, we suggest a general framework for universities and NTU, specifically via the NTU Carbon Footprint Score that includes emission factors inherently relevant for universities and a measure of transparency. We specify contextual factors that impact CFP such as geographical location, climate, community size, available infrastructure, research orientation, availability of information on emission and absorption factors, and envisioned approaches toward changing climate-related behaviours of people. A proposed data collection framework for determining the CFP is provided in Appendix 1.

Toward an Environmental Impact Factor for research

As an organisation, NTU needs to reduce its carbon footprint. Having a strong strategy and dedicated framework in place to do that is essential. There are many unique aspects about universities that require a fit-for-purpose framework and tool to determine their CFP in a comprehensive way. Naturally, data collection and data analysis need to provide insights to create new policies and implement processes and innovations to continuously reduce a university's CFP.

However, universities – as accelerators of science, technology, and innovation – have another role in countering climate change that is not quantified in any CFP effort. It is the impact of the research done at the university on reversing climate change and solving the negative consequences of climate change.

Climate change and pollution, leading to raising sea levels, drought, food shortage, increased inequality, loss of biodiversity, and eventually loss of the conditions for humanity to thrive on earth require radical innovations and solutions provided by science and technology. Similarly, the necessity of human-centred change, a better understanding of the role of human behaviour, psychology, and communication in achieving sustainability, and the role of culture, art, diplomacy, and law are essential to find a truly sustainable way of living on Earth.

As challenges related to climate change exacerbate, people are left with many questions on what the right actions are. Universities have the role to give guidance and to find quantitatively and qualitatively robust information on which actions, behaviours, policies, and innovations are needed. This societal impact that universities and university research and education can have on people's lives, climate change, and its consequences is not reflected in any CFP measure or scientific impact metric. While we argue that this framework for measuring the CFP of universities and the transparency of their CFP data is a major step forward, we concurrently advocate for the development of incentives, measures and frameworks to determine the environmental impact factor for university research and education.

An NTU Framework for Carbon Footprint Measurement

The local Singaporean context

Singapore is in the equatorial monsoon region of Southeast Asia, and its climate is characterised by uniformly high temperatures and nearly constant precipitation throughout the year. The average monthly temperature varies from about 29°C in June to 25°C in January. Singapore has mainly low-lying terrain less than 15 metres above sea level, making it highly susceptible to sea level rise and flooding. Soils developed from the sedimentary rocks are variable, but many contain compacted layers that restrict plant roots and impede soil drainage. The wettest and windiest period is during the northeast monsoon (November–March), and the period of the least rainfall and the lightest winds is during the southwest monsoon (May–September)[128]. Consistently elevated temperatures require air-conditioning of buildings. Singapore has a well-equipped drainage system that allows the collection, treatment, and reuse of wastewater.

Despite having limited natural resources, in particular renewable energy (solar, wind, and hydropower), Singapore boasts internationally acclaimed standards of higher education scholarship, which creates promise for advancements in technological and policy solutions for sustainable development. With regard to this, the Singaporean government announced the Singapore Green Plan 2030 in February 2021 to spearhead the national agenda on sustainable development for the next 10 years with the goal to achieve its long-term net zero emissions goal "as soon as viable". The five pillars of the plan include:

1. **City in Nature** (to increase nature parks' land area by over 50% from 2020 baseline and to add 1000 hectares of green spaces by 2035)
2. **Sustainable Living** (to reduce household water consumption to 130 litres per capita per day, the amount of waste to landfill per capita per day by 30% and two-thirds of net carbon emissions from the education sector by 2030)
3. **Energy Reset** (to raise the sustainability standards of buildings through the Singapore Green Building Masterplan, to reduce energy consumption at existing House Development Board towns by 15%, and to increase the national EV charging point targets from 28,000 to 60,000 by 2030)
4. **Green Economy** (to develop Jurong Island to be a sustainable energy and chemicals park by 2030)
5. **Resilient Future** (to build climate resilience and enhance national food security, to complete formulation of plans for coastline protection against rising sea levels by 2030, to produce 30% of the nation's nutritional needs through locally produced food by 2030).

To achieve these aims, Singapore intensively explores the application of photovoltaics and solar panels. Furthermore, the Singapore government aims to support enterprises in improving their sustainability and developing necessary capabilities. It also launched the Eco Stewardship Programme aiming to increase awareness among Singaporeans about the Green Plan and required actions.

Singapore Green Plan 2030 is built on a solid foundation of long-term planning, intensive development, and implementation of sustainable practices by Singaporean enterprises, universities, industries, and governmental agencies. NTU occupies a special place as a long-term partner with prompt development and adoption of initiatives that aim to decrease GHG emissions, water usage and waste generation as well as to educate the university community about environmentally friendly initiatives.

128. Leinbach, T.R., Annajane, K., et al. (2022) "Singapore". Encyclopedia Britannica, https://www.britannica.com/place/Singapore

The NTU context

NTU is a national research-intensive university based in Singapore, in a tropical climate. It is the second oldest autonomous university in Singapore and is considered one of the top universities in the world. It has also been ranked first amongst young universities by the QS World University Rankings since 2015 as of April 2021. NTU has been listed as one of the World's Most Beautiful Universities. As a relatively large university, it has more than 24,000 full-time enrolled undergraduate students, 9,500 graduate students and almost 8,000 employees, including teaching staff[129].

NTU's main (Yunnan Garden) campus, located in western Singapore, covers 200 hectares (490 acres) of land, making it the largest university campus in Singapore. It also has two other campuses in Singapore's healthcare and start-up districts (Novena and One-North, respectively).

NTU's main campus houses Singapore's largest on-campus residence infrastructure including 24 halls of residence for undergraduates, each with a capacity of between 500 and 659 residents, and two graduate halls. Every hall has communal facilities like lounges, air-conditioned reading rooms, pantries, and laundry rooms with washing machines and dryers. Transportation to and around NTU is provided by means of campus shuttle buses as well as public transit buses. Novena Campus is situated close to LKCMedicine's partner teaching hospital, Tan Tock Seng Hospital in downtown Novena for medical teaching and research at the Lee Kong Chian School of Medicine. The new 20-storey Clinical Sciences Building was completed in 2016. The CSB is home to LKCMedicine researchers, with the laboratories interconnected through collaborative spaces.

NTU's commitment to developing innovative solutions to global sustainability challenges is evidenced by its tangible progress in the area. For example, NTU has a total of 62 Platinum Green Mark Awards: 60 for building projects, one for the rejuvenated Yunnan Garden, and a District Award for the campus. NTU has eight Zero Energy Buildings and two Super Low Energy Buildings. NTU received Green Mark awards for most of its non-residential buildings in 2019[130]. Notably, 100% of all buildings in NTU larger than 2,000 m2 are Green Mark Platinum certified. NTU has also received ABC Waters Certification for two projects – the ponds at Crescent/Pioneer Halls and Yunnan Garden for the Sustainable Water Management. It was also named the first winner of BCA's highest GreenMark Platinum Star Champion award in 2016 for having 51 Green Mark Platinum awards.

For creating an inventory of emission factors for NTU, three boundaries should be considered: organisational, operational, and temporal (establishing the baseline). Inventory data can be gathered from the relevant university departments. The organisational data should include information on budget, campus population, physical size, amount of purchased, and generated electricity; emissions arising from the usage of university's fleet, air travel and commuting; refrigeration; the amount of produced solid waste and used paper; and chemicals.

129. NTU Facts and Figures (2021) https://www.ntu.edu.sg/about-us/facts-figures

130. BCA Awards 2019 (2019) https://www.bca.gov.sg/greenmark/others/gm2019.pdf

NTU's data on GHG emissions is collected by several offices. For example, the Office of Development and Facilities Management tallies electricity consumption in kWh per building by submetering the air conditioning, lighting, plug loads, receptacles etc. It also quantifies water consumption in m3 per building via water metering and waste production in tonnes. Waste also includes recyclables (paper, plastic, metal, and glass). The Office of Housing and Auxiliary Services oversees the campus bus fleet that is rented from external providers and its fuel consumption. NTU's Shared Services Finance department collects data from employees (flight itinerary or taxi receipts for example) for the business travel of employees.

It is worth mentioning that currently the information on carbon emissions collected by NTU is mostly limited to Scope 1 and 2 with insufficient coverage of Scope 3 factors. Identifying the most contributing factors to NTU's CFP for Scope 3, demarcating offices responsible for the collection of information and evaluating the impact of student and staff behaviour on CFP should become short-term goals.

NTU has unique features that underline its approach to sustainable practices and reducing CFP. Located in the tropics and heavily dependent on air-conditioning, NTU has effectively harnessed technology and design to construct or renovate buildings with energy efficiency in mind. Covering the roofs of buildings with photovoltaic panels covers their energy need completely. Relative scarcity of clean water in Singapore coupled with frequent rain led to the development of drainage systems, including for the NTU campus. This allows wastewater to be collected and reused, reducing carbon emissions under Scope 3. It is important to note, that by owning a vast green area and neighbouring jungles, NTU has an opportunity to explore carbon reduction by including carbon absorption factors into calculating its CFP.

NTU, as a research-intensive university, has many laboratories that besides consuming electricity and refrigerants also produce waste, including toxic waste, which requires energy for its disposal or treatment otherwise. The remote location of NTU's main campus leads to increased commuting time and extensive use of private transport. To address this drawback, the country's Mass Rapid Transit (MRT), governed by its Land Transport Authority, plans to complete building an MRT network extension to NTU campus in 2029. Interconnectedness of NTU with global universities postulates the need of international travel to conferences and meetings which greatly inflates the GHG emissions under Scope 3.

Sustainability initiatives are not new for NTU – it has been recognised for its activities in reducing and recycling waste and conservative energy use since 2011. These are largely driven by students indicating the interest among the younger generation and an urge to influence the NTU community to change their habits and behaviours. With more than 20,000 students and staff staying on campus, NTU can be viewed as a living lab, having been provided with the opportunity to explore climate-related behaviours and test the suitability of behavioural interventions.

For NTU, the Scope 1 emissions are predominantly caused by the combustion of fuels across campus, the exhaust from the fleet of vehicles it maintains and those from air-conditioning its buildings.

Therefore, the main information to be gathered for Scope 1 concern:

- Emissions from stationary combustion (from different types of fuels)
- Emissions from mobile combustion (the vehicle fleet separated by number of vehicles, fuel type and run distance)
- Emissions from refrigerants leakage (refrigeration, air-conditioning units, including type of refrigerant, its volume, and the equipment it is being used for)

For Scope 2, the main emissions relevant to NTU are those related to GHG emissions released in the atmosphere from the consumption of purchased electricity, leading to the following to be gathered:

- Amount of purchased and generated electricity
- Types of electricity (green or carbon-based)

- Distribution of electricity across all university buildings
- Amount of electricity used by university-owned electric vehicles

For Scope 3, NTU's operations will contribute largely to the consumption of water, paper, and food as well as those products used for academic operations such as the use of lab chemicals, generation of waste and use of electronic equipment. Singapore being a small country with a focus on international academic competitiveness means that airline travel is a likely contributing factor. NTU campus is in the far west of Singapore with on-campus accommodation. Therefore, staff and students require commuting to and from campus. This leads to the following most relevant Scope 3 emissions to be tracked for NTU:

- Emissions caused by consumption of water, paper (recycled and virgin) and food
- Emissions from the treatment of wastewater (the amount of used energy)
- Emissions from the usage of laboratory chemicals (the amount of chemicals being collected for recycling)
- Emissions from electronic equipment (laptops, desktop computers, printers, toners etc.)
- Emissions from commuting (separately for students and staff and including the different means of transport)
- Emissions from business travel (distance and means of transportation)
- Emissions from generation of waste (types of waste including hazardous waste, lighting, batteries and toners, and the method of management: recycling or landfill)

As there is a large variety of emission factors that may contribute to NTU's total CFP, it is important to revise each of them toward reducing carbon emissions. For example, to decrease the CFP of an existing building, renovation with the minimum use of materials to achieve the required functionality and extensive use of zero carbon and sustainably sourced materials should be the first steps in eco-friendly construction[131]. The materials are required to possess the functional flexibility that may facilitate subsequent reuse and repair. Expanding the use of alternative energy and wide adoption of electric vehicles on campus may significantly decrease the overall CFP. It is also necessary to mention that recycling of materials can be largely adopted to decrease the university's total emission.

It is necessary to remember that university campuses with lush vegetation in the form of parks and gardens or those that border jungle and forest have a unique opportunity to offset their carbon emissions due to carbon absorption. Forests were recognised as an important resource for carbon mitigation by the Kyoto Protocol[132]. Besides, nature-based solutions have value-added benefits as preserving and maintaining biodiversity, cooling campus, supporting mental health of students and staff, promoting physical activities etc. Enhancing carbon absorbing potential on campus by adopting vertical garden and green rooftop systems also requires careful investigation of carbon absorption rate as it largely differs among types of plants. For example, woody plants absorb more carbon[133], whereas grassland soils have higher capability of carbon retention as compared to leafy plants[134]. NTU campus has the potential to leverage its vast green territories and its remote location that borders jungle area to estimate biological sequestration of CO_2. An inventory of vegetation on NTU campus should be conducted. This would provide necessary data to understand carbon absorption potential and the effect of complex green ecosystems on total CFP.

131. What is Embodied Carbon? (2020) Retrieved from https://www.sgbc.sg/about-green-building/sgbc-embodied-carbon-pledge
132. UN (1998) Kyoto Protocol. To The United Nations Framework Convention On Climate Change. Retrieved from https://unfccc.int/resource/docs/convkp/kpeng.pdf
133. Jung, J., Ha, G., Bae, K. (2016) Analysis of the factors affecting carbon emissions and absorption on a university campus – focusing on Pusan National University in Korea. Carbon Managem, 7 (1-2), 55-65.
134. Terrer, C., Phillips, R.P., Hungate, B.A. et al. (2021) A trade-off between plant and soil carbon storage under elevated CO2. Nature 591, 599–603.

Suggested units of measurement for NTU's CFP

As described previously in the section "Agreeing on a Standard Unit of Measurement", universities apply different units for measuring the amount or volume of emission sources based on their type (energy, water, waste, travel etc). For example, water use can be measured in litres, gallons, tonnes, or cubic meters. However, the CFP is reported in $kgCO_2e$ which requires introduction of energy conversion factors to translate various units of measurement into $kgCO_2e$. Moreover, energy conversion factor comprises the greenhouse effect of CO_2, NO_2 and CH_4 gases combined. These conversion factors are available for different measure units[135,136,137].

In order to calculate NTU's total CFP and to ensure sufficiently detailed elaboration of contributing emissions, we suggest using the following units of measure:

- For Scope 1 emissions, the fuel consumed for stationary combustion is measured in kWh of produced energy, leakage from refrigerants – in kg, fuel for mobile combustion – in L.
- For Scope 2 emissions, purchased, generated electricity and electricity consumed by electric vehicles is measured in kWh.
- For Scope 3, consumption of water is measured in m3, of paper – in kg, of food – in kg, of electric and electronic equipment – in units, of laboratory chemicals – in kg, waste – in kg. The emissions produced by shipment is measured in kg of a parcel per km of travelled distance. The CFP produced by commuting and air travel provides the most accurate description when measured in person per km units as compared to the amount of consumed fuel. It accounts for carpooling and public transport crowding. Due to differences in transport modes preferred by NTU's community (employees are likely to commute by cars while students who live on campus may prefer bicycles, shuttle buses or carpooling), it is necessary to separate students and employees. It is important to note, that calculation of CFP produced by consumption of electric and electronic equipment and chemicals is complicated due to lack of information about their emission factors. Also, generated waste that ends up in recycling allows for offsetting the total CFP.

The measuring and tallying of the GHG emissions produced by all NTU's emission sources provides total CFP, measured in $kgCO_2e$ (or $MtCO_2e$). However, an absolute value is not indicative of the university's unique features (such as the size of community, area, research intensity etc.) and may be misleading upon comparison with other universities. Instead, the suitable option could be providing the relative value of the university's CFP per student, employee, or capita.

Further, we attempt to investigate how NTU's prior investments in developing sustainability initiatives and its focus on commitment toward zero-carbon future shape the university's policies, research, education, and collaboration.

135. Valls-Val, K., Bovea, M.D. (2022) Carbon footprint assessment tool for universities: CO2UNV. Sustainable Production and Consumption, 29, 791-804, https://doi.org/10.1016/j.spc.2021.11.020.
136. Carbon Trust (2020) https://www.carbontrust.com/resources/conversion-factors-energy-and-carbon-conversion-guide
137. Asian Development Bank (2017) Guidelines for estimating Greenhouse Gas Emissions of Asian Development Bank projects. https://www.adb.org/sites/default/files/institutional-document/296466/guidelines-estimating-ghg.pdf

NTU'S Carbon Footprint, a Shared Vision

NTU's history of sustainable practices

NTU has taken its sustainability initiatives seriously since the early 2010s. In 2015 the first Sustainability report was established according to the Global Reporting Initiative (GRI) Standards (with four guiding principles: stakeholder inclusiveness, sustainability context, materiality, and completeness). The data analysis for the report was done in accordance with the STARS guidelines and the International Sustainable Campus Network/Global University Leader Forum, Sustainable Campus Charter.

In 2015, NTU pledged to reduce energy, GHG emissions, water, and waste intensity by 35% in 5 years and 50% by 2025, compared to the baseline of 2011. By 2030, NTU has an ambition to convert the campus to net zero water consumption and as close as possible to net zero waste and net zero emissions. To achieve this, the Green Mark Platinum Certification of more than 230 campus buildings was announced. By 2017, GHG emissions of the campus were reduced by 37% despite its increase in surface area, and solar energy contributed toward 5% of the total energy use. The majority of NTU's GHG emissions (more than 90%) belong to Scope 2, followed by business travel under Scope 3 (more than 9%).

NTU also actively promotes recycling by increasing the number of recycling bins around campus (especially in living areas), giving out reusable water bottles, non-plastic straws and cutlery, and biodegradable shopping bags. Due to infrastructure upgrades, water consumption per square meter was reduced by 17% in 2017 as compared to 2011. NTU also invested in resource-efficient projects such as Waste-to-Energy Research Facility (based on high-temperature slagging gasification technology) in collaboration with the National Environment

Agency and the Renewable Energy Integration Demonstrator Singapore project at Semakau Island.

In 2021, NTU announced a Sustainability Framework[138] that highlighted its commitment to developing innovative solutions to deal with global sustainability challenges and pledged to support efforts for on-campus test bedding projects in areas including innovative green energy, lower carbon footprint and waste management technologies. It has additionally emphasised the reduction of GHG emissions, as well as water and waste volumes, but did not consider revision of all emission sources relevant to NTU's campus.

Some of the initiatives NTU plans to embark on to drive down NTU's energy consumption include investments in smart technology to regulate temperature on a real-time basis; adopting state-of-the-art materials to improve energy efficiency in its buildings; and continuing research in sustainability to expedite reductions in its carbon footprint.

While ramping up efforts to embed solar panels and photovoltaics on campus, NTU will explore sourcing its electricity from renewable sources together with its utility providers. If there are residual gross carbon emissions, NTU will purchase carbon offsets from internationally reputable sources, such as The Gold Standard, to achieve carbon neutrality by 2035.

138. NTU Sustainability Framework (2021). https://www.ntu.edu.sg/docs/default-source/corporate-ntu/ntu-sustainability-framework-2021.pdf?sfvrsn=612773ab_2

Moreover, the Ministry of Sustainability and the Environment in Singapore has widely implemented behavioural nudges, along with a circular economy model and sustainable growth, to help Singapore face climate change . It will help overcome existing barriers in adopting more environmentally friendly behaviours.

The challenges that NTU seeks to address on its way to sustainable practices and the reduction of CFP are:

- How can we equip the younger generation with the necessary knowledge and tools to be the trailblazers in developing and implementing sustainability practices?
- What are the lessons that COVID-19 taught us in promoting sustainability practices?
- How can research partnerships be leveraged to accelerate search for sustainability solutions?
- How can the remoteness of NTU's location be harnessed to amplify research on sustainability?
- What is the future of technology in supporting sustainability innovations on the NTU campus?

These actions will be discussed in the following sections.

Educating future generations

Besides offering 200 electives related to sustainability across its vast curricular programmes, NTU has also introduced an interdisciplinary Minor in topics such as Environmental History, Environmental Sustainability, Environmental Management, Environmental Humanities, and Sustainability for undergraduates[140]. At the undergraduate level, sustainability will constitute a core component of the common interdisciplinary core curriculum introduced in August 2021. To produce a new generation of scientists with leading-edge knowledge and skills in AI to address critical environmental challenges, NTU launched an interdisciplinary PhD programme in AI and Sustainability.

It is also important to influence the existing habits of the NTU community. So, what strategies should the university develop to help its staff and students drastically reduce the CFP? We estimate how existing instruments that can assist to overcome barriers in adopting climate-friendly behaviours in households can be extrapolated to the scale of a university[141].

1) One approach is bringing environmental awareness through education, which can be operationalised via enhancing academic curricula or supporting events aimed at influencing environmentally-friendly attitudes.
2) Displaying CFP for meals, products, or during activities and comparing it with more sustainable options is another way to build better understanding[142].
3) Setting up goals, providing incentives for, and gamifying the journey to a more sustainable behaviour can lead to the growth of extrinsic motivation.
4) Leveraging the sense of cohesion and belonging to a university community that is committed to zero carbon activities is a part of building intrinsic motivation.
5) A boost in motivation can also be achieved through building competency or self-efficacy, with possible development and use of edutainment apps, competitions, or hackathons. It is important to remember, that while an individual approach matters, the community plays a significant role in determining and shaping behaviours.

139. How behavioural science helps Singapore tackle climate change (2020) https://govinsider.asia/inclusive-gov/mse-how-behavioural-science-helps-singapore-tackle-climate-change/
140. NTU Sustainability Framework (2021). https://www.ntu.edu.sg/docs/default-source/corporate-ntu/ntu-sustainability-framework-2021.pdf?sfvrsn=612773ab_2
141. Stankuniene, G., Streimikiene, D., et al. (2020) Systematic Literature Review on Behavioral Barriers of Climate Change Mitigation in Households. Sustainability 12(18), 7369
142. Brunner, F., Kurz, V. et al. (2018) Carbon Label at a University Restaurant: Label Implementation and Evaluation. Ecol Econ 146, 658–67.

Among other tools assisting in adopting climate-friendly behaviours, one can recognise a focus on providing information about possible economic and health benefits. Involvement of economic instruments that might include incentives for studying in communal facilities, using a fan instead of air-conditioning, or using public transport, as well as imposing fees for excessive use of hot water, driving a car to the campus, or not turning off the electric equipment. E-bike rentals along with dedicated bike lanes, car-sharing schemes, and free public transit passes also have the potential to change the behaviours of students and staff. Installation of adjustable thermostats and light controls in offices, tutorial rooms, and lecture theatres can provide both personalised and sustainable approaches in reducing CFP. Students and staff can also benefit from regulative tools as receiving certificates for the best energy performance/lowest use of private transport during certain period etc. Competitions between schools or residential halls for implementing the best practices that lead to CFP reduction can also be organised.

The information about necessary steps in mitigating CFP should be communicated via public campaigns (fairs, community programs, calls for sharing best practices) that highlight the connection between increasing CFP and certain eco-friendly action.

Communicating CFP impactfully

Communication of climate change and the importance of exhaustive CFP measurement counters major hurdles. Among them, ClimateXChange[143] separates (1) spatial and temporal dissonance, (2) language barriers, (3) logical fallacies and a dichotomised perception of climate action, and (4) informational deficit model. Overwhelming amount of data and quantitative information could also shave off users' interest. With the purpose of addressing abovementioned problems, the solutions could be found in shaping the messages about relevant for the area climate problems, avoiding scientific jargon and emphasising on the personal impact. It is also necessary to disentangle the CFP and economic growth or technological progress. Creation of engaging visualised content, giving the voice to the communities and framing climate message with cultural and personal context in mind should be the major tools to deliver the importance of sustainable practices to NTU community. This requires accurate investigation of community's perceptions towards different types of messages and their ability to trigger effective action. Researchers in NTU have already significantly contributed to understanding climate-related habits[144,145,146,147,148] and media effects of pro-climate messages[149,150].

We argue that transparent reporting and clear communication of emission data and its breakdown, when coupled with eco-friendly activities, could provide tangible evidence of individual contribution into fighting the climate change. Visualisation of a NTU's CFP that comprises emissions breakdown on a dashboard with dynamic change of parameters and possible actions leading to the immediate reduction of emissions could emphasise the importance of

143. CimateXChange (2020) Communicating the Climate Crisis. Retrieved from https://climate-xchange.org/communicating-the-climate-crisis/
144. Rosenthal, S., Dahlstrom, M.F. (2019) Perceived Influence of Proenvironmental Testimonials, Environ Comm 13 (2), 222-238.
145. Rosenthal, S. (2022) Information sources, perceived personal experience, and climate change beliefs. J Environ Psychol, 81, 101796.
146. Rosenthal, S., Yu, M.S.C. (2022) Anticipated guilt and anti-littering civic engagement in an extended norm activation model. J EnvironPsychol, 80, 101757.
147. Rosenthal, S., Linder, N. (2021) Effects of bin proximity and informational prompts on recycling and contamination. Resourc Conserv Recycl, 168, 105430.
148. Linder N, Rosenthal S, Sörqvist P, et al. (2021) Internal and External Factors' Influence on Recycling: Insights From a Laboratory Experiment With Observed Behavior. Front Psychol, 22(120, 699410.
149. Leong, A. D., Ho, S. S. Perceiving online public opinion: The impact of Facebook opinion cues, opinion climate congruency, and source credibility on speaking out. New Media & Society. 2020.
150. Yang, X., Wei, R., et al. (2021) If Others Care, I Will Fight Climate Change: An Examination of Media Effects in Addressing the Public Goods Dilemma of Climate Change Mitigation. Int J Comm 15, 21.

individual impact and encourage students and staff take more eco-friendly actions. Moreover, NTU could set the example to other Singapore universities in transparent reporting of CFP as well as demonstrate to Singapore community how to operationalise CFP reduction.

Besides, we plan to translate current report into action by empowering students to continually track the reporting of NTU's emissions and to design activities that promote environmentally friendly behaviour.

Blended universities

The COVID-19 pandemic forced universities to transfer education and conferences online. The reduction of air and land travel contributed to the worldwide temporary plunge in emissions[151], implying that the approach of virtual participation in the activities should be leveraged more[152]. Additionally, the ability to participate in the events remotely supports women with family care responsibilities and early career researchers[153]. However, given the choice of the participation mode, academics prefer in-person forms of education and meeting, despite being informed about the produced CFP.

This perception can be tweaked with full organisational support and policy enforcement from university, as well as by arranging hybrid or multi-site conferences[154]. Moreover, students and employees have adjusted to the Work-From-Home (WFH) mode (or remote work) and have mastered the use of virtual tools which could be leveraged to synchronise distant learning and work. For example, a group of students or institute's employees could synchronise their work from home during certain days and time without the need to come to campus. It would result in less energy used for lighting or air-conditioning in a lecture room or office, as well as at home. On the contrary, work in office in shifts could lead to an increased CFP, as in this case both office and home locations generate carbon emissions.

The classes could also be scheduled in the daytime when no artificial lighting is required. However, on its own, behavioural mediation has a negligible impact on overall reduction of CFP[155], so it requires a strong foundation of scientific and technological innovation solutions[156].

A testbed for sustainability

NTU has interdisciplinary research institutes such as Energy Research Institute @ NTU (ERIAN), Nanyang Environment & Water Research Institute (NEWRI), Earth Observatory of Singapore (EOS), and the Singapore Centre for Environmental Life Sciences Engineering (SCELSE) focusing on various themes (energy, water etc.) around sustainability. Taking a strong research implementation focus, NTU became an attractive partner for government and industry stakeholders that led to the development of unique capabilities.

With the purpose of testing electric vehicles, NTU pioneered the Centre of Excellence for Testing & Research of Autonomous Vehicles (CETRAN). It partnered with Volvo to launch a

151. COVID-19 caused only a temporary reduction in carbon emissions – UN report (2021) https://www.unep.org/news-and-stories/press-release/covid-19-caused-only-temporary-reduction-carbon-emissions-un-report
152. Klöwer, M., Hopkins, D., et al. (2020) An analysis of ways to decarbonize conference travel after COVID-19. Nature 583, 356–359.
153. Arsenault, J., Talbot, J., et al. (2019) The environmental footprint of academic and student mobility in a large research-oriented university. Environ Res Lett 14, 95001.
154. Thaller, A., Schreuer, A., et al. (2021) Flying High in Academia—Willingness of University Staff to Perform Low-Carbon Behavior Change in Business Travel. Front Sustain 2, 790807.
155. Nisa, C.F,. Bélanger, J.J., et al. (2019) Meta-analysis of randomised controlled trials testing behavioural interventions to promote household action on climate change. Nat Commun 10, 4545.
156. Stern, P.C. (2020) A reexamination on how behavioral interventions can promote household action to limit climate change. Nat Commun 11, 918 (2020).

driverless bus, with the Centre for Infocomm Technology that brings together experts in Smart Mobility, Smart Environment and Smart Living, with Free2Move that trials electric bike-sharing service, and with BlueSG for an electric shuttle bus.

Strong collaboration with Surbana Jurong allowed for innovation in sustainable urban solutions, including improved energy efficiency, indoor thermal comfort, and storage of liquefied natural gas[157]. NEWRI, besides exploring wastewater treatment and reclamation, worked with two semiconductor and wafer fabrication companies to help them decrease total water consumption by 10%, as well as with food and beverage industry to reduce water usage by 50%.

In order to address the increasing volume of generated e-waste, NTU partnered with France's Alternative Energies and Atomic Energy Commission (CEA) to set up the NTU Singapore-CEA Alliance for Research in the Circular Economy (SCARCE) to focus on innovative recycling research. Alliance to End Plastic Waste (AEPW) joined NTU to commit a total amount of S$1.2 million to fund innovative solutions for the global plastic waste problem. Building local food safety capabilities to support growing innovation in food production and manufacturing and developing new food safety standards became possible after establishing the Future Ready Food Safety Hub (FRESH) Programme.

However, multi-stakeholder collaboration should not be limited only to technology partners. Local community plays an essential role in adopting, iterating and benefitting from the technology. Engaging community and ensuring citizen participation in data collection and decision-making process should become a cross-sectoral tool in developing viable solutions for battling climate change.

It should be mentioned that besides research for sustainability, it is important to promote sustainable research. The research practices should be reconsidered toward less waste generation and decreased use of toxic chemicals and water. New advancements are required in the area of carbon capture and utilisation. Having little space for wide adoption of renewable energy in Singapore, limited by landscape and climate, NTU seeks to elaborate and implement carbon sequestration technology that is still in its nascent state. Exploring the available approaches to carbon capture, transport and storage should be prioritised along with methods of reducing GHG. Also, active involvement of stakeholders in innovating sustainability solutions underlines the necessity to provide access to a platform for testing sustainability inventions in a vibrant real-world environment such as the NTU campus.

A living lab experiment

NTU provides the conditions for adopting the role of an innovation centre or living lab by collecting and analysing data about climate-related habits of the university community. This includes information from sensors, self-reported data, data gathered by university units and from open data sources about meal preferences, travel patterns, use of air-conditioning and lighting etc. This would also allow students to gain insight into the sustainability of their day-to-day lives on campus. The collected information would provide a rich understanding of factors that impact the university's CFP as well as any existing gaps in knowledge gathering.

Additionally, having an opportunity to see a tangible measure of how a specific action impacts university's CFP, students and staff would adopt behavioural changes and become susceptive to personalised interventions.

157. Surbana Jurong-NTU Corporate Laboratory. https://www.ntu.edu.sg/sj-ntu

Sustainability decision support systems

NTU has committed to investing in smart technology to regulate temperature on a real-time basis and adopting state-of-the-art materials to improve energy efficiency in its buildings. Currently, sensor data collected in NTU is used only for calculating total energy consumption, consumption from chillers, energy production from the grids and solar panels and detecting faults in the energy systems. Other data such as weather, events in buildings and occupancy also affect the energy consumption of a building. In 2017, a collaboration between NTU and Siemens was initiated to apply deep learning and statistical approaches to analyse and process extracted sensor data and to understand non-sensor data, with the aim of optimising building performance. An NTU campus visualisation for sustainability needs to contain measured data from sensors and self-reported by staff and students. It is our aim to apply our capability in AI and machine learning to develop automated support systems to optimise power consumption for a sustainable campus. Apps, personalised interventions, and real time visualisations are envisioned to motivate our students and staff to adopt energy-conserving and waste-reductive behaviours.

The continuous measurement and modelling of CFP-related data allows for new trends to be discovered. This will empower NTU to identify new and effective strategies to reduce waste and carbon emissions. It would also allow for flexibility and preparedness when changes need to be introduced to the CFP framework, for instance when a new guideline is developed by the Singapore government or the IPCC.

The unifying theme of the Sustainability Framework is NTU's conviction that its efforts in sustainability begin with its own actions on and off campus. NTU's belief in 'walking the talk' culminates in its distinct approach that tests and puts into practice its teaching and research advances in sustainability on its 200-hectare Smart Campus. It also places a strong emphasis on sharing its best practices and innovations with the world and by working closely with industry and government for the benefit of local and global society. NTU draws together a wide range of existing and new activities and aspirations, encompasses the actions of all employees and students, and spans all aspects of the university's mission in education, research, innovation and service to society and humanity.

Appendix 1

A standardised format for CFP measuring for universities

The table below enlists the contributing emission factors for all Scopes. It also provides basics to calculate the Transparency score. The standard units of measurement are provided for each factor (kWh, kg, persona per km etc). They must be translated to the kg of CO_2e with the help of conversion factors specific for each country and each fuel type. A university may use this table to understand the completeness of collected emission data. It important to note that a university may or may not collect information on a specific factor, but it should report this fact under the Transparency (T) score. Also, if a university reports emissions generated by "total waste" or "total travel", it obtains 0 points as it does not provide detailed breakdown of the specific type of emission factor.

CHEATSHEET/CHECKLIST FOR COMPLETE ASSESSMENT OF UNIVERSITY'S CARBON FOOTPRINT (CFP) AND DATA TRANSPARENCY (T)

SCOPE 1

Stationary combustion (Fuel combustion in fixed installations)

- **CFP**
  - ○ Building
  - ○ Department
  - ○ Cluster
    - ○ Fossil fuel
      - ○ Fuel type
      - ○ Amount of fuel spent ☐ L
      - ○ Amount of produced energy ☐ kWh
    - ○ Biomass fuel
      - ○ Fuel type
      - ○ Amount of fuel spent ☐ L
      - ○ Amount of produced energy ☐ kWh
    - ○ Waste-derived fuel
      - ○ Fuel type
      - ○ Amount of fuel spent ☐ L
      - ○ Amount of produced energy ☐ kWh
- **T**
  - Is the data collected and reported?
    - ○ Yes - *1 point*
    - ○ No - *0 point*

SCOPE 1

Leakage of refrigerants (refrigerators, air-conditioning) or fire suppressants

- **CFP**
  - ○ Building
  - ○ Department
  - ○ Cluster
    - ○ Refrigerant
      - ○ Type
      - ○ Equipment type
      - ○ Initial quantity ☐ kg
      - ○ Annual leakage ☐ kg
    - ○ Fire suppressant
      - ○ Type
      - ○ Equipment type
      - ○ Initial quantity ☐ kg
      - ○ Annual leakage ☐ kg
    - ○ Purchased industrial gases for laboratory experiments
      - ○ Type
      - ○ Equipment type
      - ○ Initial quantity ☐ kg
      - ○ Annual leakage ☐ kg
- **T**
  - Is the data collected and reported?
    - ○ Yes - *1 point*
    - ○ No - *0 point*

SCOPE 1

Mobile combustion (vehicle fleet)

- **CFP**
  - ○ Building
  - ○ Department
  - ○ Cluster
    - ○ Car
      - ○ Fossil fuel
      - ○ Biomass fuel
      - ○ Waste-derived fuel
        - ○ Distance travelled ☐ km
        - ○ Fuel type
        - ○ Amount of fuel spent ☐ L
    - ○ Bus
      - ○ Fossil fuel
      - ○ Biomass fuel
      - ○ Waste-derived fuel
        - ○ Distance travelled ☐ km
        - ○ Fuel type
        - ○ Amount of fuel spent ☐ L
    - ○ Other
      - ○ Fossil fuel
      - ○ Biomass fuel
      - ○ Waste-derived fuel
        - ○ Distance travelled ☐ km
        - ○ Fuel type
        - ○ Amount of fuel spent ☐ L
- **T**
  - Is the data collected and reported?
    - ○ Yes - *1 point*
    - ○ No - *0 point*

SCOPE 2

Energy purchased for building needs

- **CFP**
  - ◯ Building
  - ◯ Department
  - ◯ Cluster
    - ◯ Green energy
      - Purchased energy:
        - ◯ Electricity
        - ◯ Steam
        - ◯ Heat
        - ◯ Cooling
        - ◯ Other
          - ◯ Amount of purchased energy [ ] kWh
    - ◯ Non-green energy
      - Purchased energy:
        - ◯ Electricity
        - ◯ Steam
        - ◯ Heat
        - ◯ Cooling
        - ◯ Other
          - ◯ Amount of purchased energy [ ] kWh
- **T**
  - Is the data collected and reported?
    - ◯ Yes - *2 point*
    - ◯ No - *0 point*

SCOPE 2

Electricity consumed by electric/hybrid vehicles

- **CFP**
  - ◯ Car
    - ◯ Green energy
      - ◯ Amount of purchased energy [ ] kWh
    - ◯ Non-green energy
      - ◯ Amount of purchased energy [ ] kWh
  - ◯ Bus
    - ◯ Green energy
      - ◯ Amount of purchased energy [ ] kWh
    - ◯ Non-green energy
      - ◯ Amount of purchased energy [ ] kWh
  - ◯ Other
    - ◯ Green energy
      - ◯ Amount of purchased energy [ ] kWh
    - ◯ Non-green energy
      - ◯ Amount of purchased energy [ ] kWh
- **T**
  - Is the data collected and reported?
    - ◯ Yes - *1 point*
    - ◯ No - *0 point*

SCOPE 2

Energy generated

- **CFP**
  - ◯ Building
  - ◯ Department
  - ◯ Cluster
    - ◯ Green energy
      - ◯ Electricity
      - ◯ Steam
      - ◯ Heat
      - ◯ Cooling
      - ◯ Other
    - ◯ Non-green energy
      - ◯ Electricity
      - ◯ Steam
      - ◯ Heat
      - ◯ Cooling
      - ◯ Other
        - ◯ On-site energy generation facility sells carbon certificates
- **T**
  - Is the data collected and reported?
    - ◯ Yes - *2 point*
    - ◯ No - *0 point*

SCOPE 3

Consumption/purchase of materials

Tap water consumption

- **CFP**
  - ◯ Amount of consumed water [ ] m^3
- **T**
  - Is the data collected and reported?
    - ◯ Yes - *2 point*
    - ◯ No - *0 point*

Paper consumption

- **CFP**
  - ◯ Building
  - ◯ Department
  - ◯ Cluster
    - ◯ Student
      - ◯ Recycled
      - ◯ Virgin
        - ◯ Amount of consumed paper [ ] kg
    - ◯ Employee
      - ◯ Recycled
      - ◯ Virgin
        - ◯ Amount of consumed paper [ ] kg
- **T**
  - Is the data collected and reported?
    - ◯ Yes - *1 point*
    - ◯ No - *0 point*

Electrical and Electronic Equipment Consumption

CFP
- ◯ Building
- ◯ Department
- ◯ Cluster
  - ◯ Laptop — ◯ Amount of purchased equipment [ ] units
  - ◯ Desktop — ◯ Amount of purchased equipment [ ] units
  - ◯ Printer — ◯ Amount of purchased equipment [ ] units
  - ◯ Toner — ◯ Amount of purchased equipment [ ] units

T
- Is the data collected and reported?
  - ◯ Yes - *1 point*
  - ◯ No - *0 point*

Laboratory Chemicals Consumption

CFP
- ◯ Building
- ◯ Department
- ◯ Cluster
  - ◯ Acid — ◯ Subtype — ◯ Amount of consumed chemicals [ ] kg
  - ◯ Base — ◯ Subtype — ◯ Amount of consumed chemicals [ ] kg
  - ◯ Organic — ◯ Subtype — ◯ Amount of consumed chemicals [ ] kg
  - ◯ Inorganic — ◯ Subtype — ◯ Amount of consumed chemicals [ ] kg
  - ◯ Other — ◯ Subtype — ◯ Amount of consumed chemicals [ ] kg

T
- Is the data collected and reported?
  - ◯ Yes - *1 point*
  - ◯ No - *0 point*

Waste generation

CFP
- ◯ Building
- ◯ Department
- ◯ Cluster
  - ◯ Paper — Management: ◯ Landfill ◯ Recycling — ◯ Amount of collected waste [ ] kg
  - ◯ Plastic — Management: ◯ Landfill ◯ Recycling — ◯ Amount of collected waste [ ] kg
  - ◯ Glass — Management: ◯ Landfill ◯ Recycling — ◯ Amount of collected waste [ ] kg
  - ◯ Construction waste — Management: ◯ Landfill ◯ Recycling — ◯ Amount of collected waste [ ] kg

T
- Is the data collected and reported?
  - ◯ Yes - *1 point*
  - ◯ No - *0 point*

Food waste

CFP
- ◯ Building
- ◯ Department
- ◯ Cluster
  - ◯ Amount of collected waste [ ] kg

T
- Is the data collected and reported?
  - ◯ Yes - *1 point*
  - ◯ No - *0 point*

SCOPE 3

Transport

Commuting by students

CFP
- ◯ Car — ◯ Subtype — ◯ Distance travelled [ ] km — ◯ Amount of travel distance [ ] persona per km
- ◯ Car — ◯ Subtype — ◯ Distance travelled [ ] km — ◯ Amount of travel distance [ ] persona per km
- ◯ Public transport — ◯ Subtype — ◯ Distance travelled [ ] km — ◯ Amount of travel distance [ ] persona per km
- ◯ Other — ◯ Subtype — ◯ Distance travelled [ ] km — ◯ Amount of travel distance [ ] persona per km

T
- Is the data collected and reported?
  - ◯ Yes - *2 point*
  - ◯ No - *0 point*

Commuting by employees

CFP
- ◯ Car — ◯ Subtype — ◯ Distance travelled [ ] km — ◯ Amount of travel distance [ ] persona per km
- ◯ Car — ◯ Subtype — ◯ Distance travelled [ ] km — ◯ Amount of travel distance [ ] persona per km
- ◯ Public transport — ◯ Subtype — ◯ Distance travelled [ ] km — ◯ Amount of travel distance [ ] persona per km
- ◯ Other — ◯ Subtype — ◯ Distance travelled [ ] km — ◯ Amount of travel distance [ ] persona per km

T
- Is the data collected and reported?
  - ◯ Yes - *2 point*
  - ◯ No - *0 point*

Business travel by students

CFP
- ◯ Train — ◯ Distance travelled [ ] km — ◯ Amount of travel distance [ ] persona per km
- ◯ Airplane — ◯ Distance travelled [ ] km — ◯ Amount of travel distance [ ] persona per km
- ◯ Other — ◯ Distance travelled [ ] km — ◯ Amount of travel distance [ ] persona per km

T
- Is the data collected and reported?
  - ◯ Yes - *2 point*
  - ◯ No - *0 point*

Business travel by employees

CFP
- ◯ Train — ◯ Distance travelled [ ] km — ◯ Amount of travel distance [ ] persona per km
- ◯ Airplane — ◯ Distance travelled [ ] km — ◯ Amount of travel distance [ ] persona per km
- ◯ Other — ◯ Distance travelled [ ] km — ◯ Amount of travel distance [ ] persona per km

T
- Is the data collected and reported?
  - ◯ Yes - *2 point*
  - ◯ No - *0 point*

Shipment

CFP
- ◯ Car — ◯ Parcels weight [ ] kg — ◯ Distance travelled [ ] km — ◯ Amount of travel distance [ ] kgkm
- ◯ Train — ◯ Parcels weight [ ] kg — ◯ Distance travelled [ ] km — ◯ Amount of travel distance [ ] kgkm
- ◯ Airplane — ◯ Parcels weight [ ] kg — ◯ Distance travelled [ ] km — ◯ Amount of travel distance [ ] kgkm
- ◯ Other — ◯ Parcels weight [ ] kg — ◯ Distance travelled [ ] km — ◯ Amount of travel distance [ ] kgkm

T
- Is the data collected and reported?
  - Yes - *1 point*
  - ◯ No - *0 point*

Calculation of a CFP Score

After applying conversion factors that differ in each country and obtaining the amount of GHG emissions (in $MtCO_2e$) for each Scope, the following table needs to be filled in to calculate the CFP Score as described in section "Toward a CFP Score that takes a university's transparency into account".

CFP data obtained for emission sources must be translated to the Mt of CO_2e with the help of conversion factors that are specific for each country and for each fuel type and summarised.

T data for all emission sources should be summarised.

Size of a University (S)		capita
CFP		
Scope 1		$MtCO_2e$
Scope 2		$MtCO_2e$
Scope 3		$MtCO_2e$
Total CFP		$MtCO_2e$
T		
Scope 1		points
Scope 2		points
Scope 3		points
Total T		points

The formula for calculating Credibility Score is as follows:

$$CFP\ Score = \frac{S*T}{CFP}$$

where S is the size of university and is measured in the number of capita (including students and staff), T is Transparency of reported data and has a value from 0 to 25, and the university's CFP indicates the total GHG emissions from all relevant sources and is measured in $MtCO_2e$.

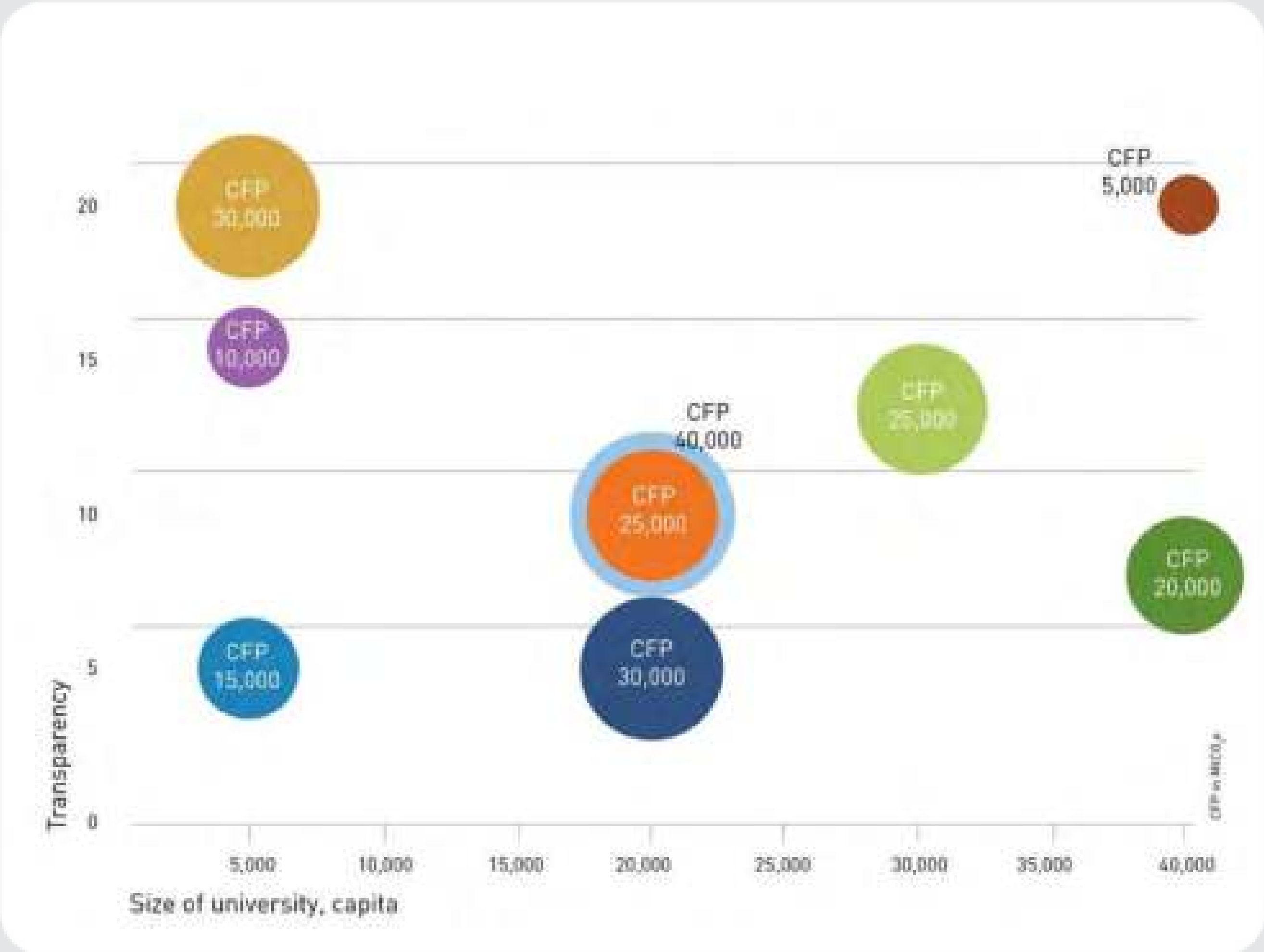
For example, university A collects data on stationary and mobile combustion, purchased energy and business travel of employees, and reports on absence of renewable energy resources on campus. It obtains CFP 200,000 $MtCO_2e$ and T equal to 14. University B, in turn, collects information on stationary and mobile combustion, purchased and generated energy, paper consumption, total waste generation, commuting by students and business travel by employees and obtains CFP 200,000 $MtCO_2e$ and T equal to 11. The two universities are similar in size and have 20,000 students and employees. The CFP scores, according to a formula for CFP Score provided in the section "Toward a CFP Score that takes a university's transparency into account", are: for university A 1.4, for university B – 2.2. A higher CFP score indicates more transparent reporting of emission data. This incentivises universities for conducting full revision and reporting of their emission sources.

The visualisation of another example (on the left) demonstrates that while universities can report similar CFP scores, they might exclude most contributing emission factors or collect less-detailed data. It lowers their Transparency and CFP score, accordingly.

A proposed visualisation of the CFP score is provided below. It depicts universities that differ in their population size, CFP and T. Universities recording lower CFP and higher T are located in the top left corner of the graph. Universities with higher CFP and lower T are located at the right bottom of the graph

A proposed visualisation of the CFP Credibility score is provided below.

VISUALISATION OF CREDIBILITY SCORE



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