QUANTIFYING THE ECOLOGICAL FOOTPRINT OF MIDDLE EAST TECHNICAL UNIVERSITY: TOWARDS BECOMING A SUSTAINABLE CAMPUS

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ABSTRACT

QUANTIFYING THE ECOLOGICAL FOOTPRINT OF MIDDLE EAST TECHNICAL UNIVERSITY: TOWARDS BECOMING A SUSTAINABLE CAMPUS

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The Ecological Footprint is an eco-based sustainability indicator that aims to provide insight into the delicate balance between human consumption patterns and the Earth’s regenerative capacity.

The primary objective of this thesis is to carry out a preliminary comprehensive quantification of the Ecological Footprint of the Middle East Technical University (Ankara Campus), which is one of the biggest public universities in Turkey. In addition, the study aims to present ‘*a static snapshot*’ of the impacts caused by METU, especially on the environment, for a target year. This study also sets its goal to investigate possibilities for contributing to campus operations, policy development and educational curricula towards becoming a sustainable campus. The objectives of this thesis are also in line with the *2011-2016 METU Strategic Plan*, where one of its strategies is to become a sustainable campus.

EF is a quantitative method to understand the current situation and suggest a framework for action within the context of developing sustainability. The calculation of EF provides a basis for determining strategies to become a sustainable campus. Within the scope of the thesis, the main aspects of a sustainable campus, namely energy use, transportation, waste & recycle, food consumption and built-up land was investigated comprehensively. These investigations involve a component-based approach that calculates EF for each component separately for the year 2012.

The Ecological Footprint of Middle East Technical University is computed to be 46,451 global hectares, of which %70 is food (32649 gha), %19 energy (8843 gha), %8 transportation (3563 gha) and %3 other components (Waste &recycle 1184 gha, Built up 210gha). METU campus area is 4350 hectares and Ecological Footprint calculated as 45824 hectare (EF of food 36477 ha, energy 7019 ha, transportation 1110 ha, waste & recycle 941 ha and built-up 277 ha) which shows 41000 hectare is required to fulfill consumption made in METU campus. When compared with the National EF per capita 2.7 and EF per capita values for a number of universities worldwide (ranging from 0.9 to 2.66), METU can be considered to have a tolerable ecological footprint per capita 1.62 (where EF per capita of food 1.14; energy 0.31; transportation 0.12; waste &recycle 0.04; built-up 0.01). Nevertheless, certain regulations might possibly help reduce current EF values, especially for food, energy, and transportation. This preliminary study is the first comprehensive EF quantification of a university campus in Turkey and is hoped to contribute to METU's strategy of achieving the status of a sustainable campus.

Key Words: Institutional Ecological Footprint, University campus, METU, Campus sustainability, Green campus, SDI

ÖZ

ORTA DOĞU TEKNİK ÜNİVERSİTESİ NİN EKOLOJİK AYAKİZİ:
SÜRDÜRÜLEBİLİR KAMPÜS OLMA YOLUNDA BİR ADIM

Galioğlu, Yeliz
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Eylül 2015, 138 sayfa

Ekolojik Ayakizi bir ekoloji temelli sürdürülebilirlik göstergesi olup temel amacı insanliğin tüketim alışkanlığıyla Dünya'nın kendini yenileme kapasitesi arasındaki hassas denge hakkında farkındalık sağlamaktır.

Bu tezin temel hedefi Türkiye'nin en büyük devlet üniversitelerinden olan Orta Doğu Teknik Üniversitesi'nin (Ankara kampüsü) Ekolojik Ayakizinin kapsamlı bir şekilde incelenmesi için yapılan başlangıç sağlayacak bir çalışma olmasıdır. Bunun yanında, bu çalışma ODTÜ kampüsü'nün çevreye olan etkisinin hedef yılındaki anlık durumunun aktarılmasını da hedeflemektedir. Bu tez çalışması, ODTÜ'nün sürdürülebilir kampüs olabilmesi için üniversite yönetimine, müfredat ve gelişim statejilerinin oluşturulmasına katkı verecek olanaklarının araştırılmasını amaç edinmektedir. Bu tezin hedefi aynı zamanda stratejilerinden biri sürdürülebilir kampüse dönüşmek olan 2011-2016 ODTÜ Stratejik Planının hedefiyle de paraleldir.

EA, sürdürülebilirliğin gelistirilmesi kapsamında, mevcut durumun anlaşılması ve eylem çerçevesinin belirlenmesine katkı sağlayan sayısal bir yontemdir. EA hesaplamaları bir kampüsün sürdürülebilir olması için gerekli stratejilerin belirlenmesine zemin oluşturmaktadır. Tez çalışması kapsamında, enerji kullanımı, ulaştırma, atık-geri dönüşüm, gıda tüketimi ve yapılı alan gibi sürdürülebilir bir kampüsün temel unsurları kapsamılı bir şekilde araştırılmıştır. Bu araştırmalar, bileşenlerin herbiri için EA hesabını içermektedir. Tümevarıma dayanan unsur odaklı yaklaşım 2012 yılı hesaplamaları için kullanılmıştır.

Orta Doğu Teknik Universitesi'nin Ekolojik Ayakizi 46451.46 global hektar olup, bunun %70'i yiyecek (32649 gha), %19'u enerji (8843 gha), %8'i ulaştırma (3563 gha) ve %3'ü diğer bileşenlerden (atık ve geri dönüşüm 1184 gha, yapılı alan 210 gha) oluşmaktadır. ODTÜ nün kampüs alanı 4350 hektardır ve hesaplanan Ekolojik Ayakizi ise 45824 hektardır (Bunun; 36477 ha'ı yiyecek, 7019 ha'ı enerji, 1110 ha'ı ulaşım, 941 ha'ı atık ve geri dönüşüm ve 277 ha'ı yapılı alandır). Bu sonuçlara göre, 2012 yılında ODTÜ'deki tüketimin bu oranlarda gerçekleşebilmesi için 41000 hektarlık ek alan gerekmiştir. Kişi başı ulusal EA değeri 2.7 ve diğer üniversitelerin 0.9 – 2.26 arasında değişen kişi başı EA değerleri ile karşılaştırıldığında, ODTÜ'nün kişi başı EA değeri olan 1.62 (Bileşenlere göre kişi başı EA değerleri 1.14'ü yiyecek; 0.31'u enerji; 0.12'si ulaşım; 0.04'ü atık ve geri dönüşüm; 0.01'i yapılı alandır) kabul edilebilir düzeydedir. Ancak, yine de özellikle yiyecek, enerji ve ulaştırma alanlarında EA değerini azaltabilecek bazı düzenlemeler ve projeler hayata geçirilebilir. Bilindiği kadarı ile bu ön çalışma Turkiye'de bir üniversite kampüsünün Ekolojik Ayakizinin sayısallaştırıldığı ilk kapsamlı çalışma olup, ODTÜ'nün sürdürülebilir bir kampüs olması stratejisine katkı sağlayacaktır.

Anahtar Kelimeler: Kurumsal Ekolojik Ayakizi, Üniversite Kampüsü, Sürdürülebilir kampüs, Yeşil Kampüs, Orta Doğu Teknik Üniversitesi, SKG, ODTÜ

To my precious family & dear darling

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BC	Biocapacity
CC	Carrying Capacity
CO_2	Carbon Dioxide
CSD	The United Nations Commission on Sustainable Development
EEA	European Environmental Agency
EF	Ecological Footprint
EPA	Environmental Protection Agency
EQF	Equivalence Factor
EUROSTAT	The Statistical Office of the European Communities
FAO	Food and Agriculture Organization
GFN	Global Footprint Network
gha	Global Hectare
ha	Hectare
HEIs	High Educational Institutions
ITC	Integrated Solid Waste Management
IUCN	International Union for Conservation of Nature
LPI	Living Planet Index
NGOs	Non-governmental organizations
OECD	Organisation for Economic Co-operation and Development
SD	Sustainable Development
SDIs	Sustainable Development Indicators
SPI	Sustainability Performance Index
UN	The United Nations
UNCED	The United Nations Conference on Environment and Development
UNCHE	The United Nations Stockholm Conference on Human Environment
UNDP	The United Nations Development Programme
UNEP	The United Nations Environment Programme
WCED	The World Commission on Environment and Development
wha	World Hectare
WWF	World Wildlife Fund
YF	Yield Factor

CHAPTER 1

1. INTRODUCTION

1.1 The Concept of Sustainable Development

Environmental problems as a result of human activities have a very deep-rooted history. Besides those, there has also been a huge inequality between North and South (between developed and developing countries). However, until 1970s these issues were not discussed within the international agenda. Especially environmental problems have not been taken into serious consideration nationally and internationally until approximately forty years ago [1], [2]. Although there had been national-scale environmental problems such as water and air pollution in many countries, especially in Europe, these have shifted to the international level due to transboundary nature of environmental issues since the late 1960s. This shift paved the way for agendas of many international conferences that so far focused on development rights, dependency and equity issues to increasingly include environmental issues as well. The 1972 Stockholm Conference and the following 1992 Rio Conference were turning points for the environmental movement, which generally consider them as *"landmark conferences on environment and development issues"* [2].

The Stockholm Conference on Human Environment (UNCHE) with the theme "Only One Earth" was announced by UN General Assembly in 1972. It was a very successful and large-scale conference with a world-wide attendance of 113 countries [3]. The main purpose of the UNCHE included emphasis of '*stewardship of the Earth*', '*protection and improvement of the human environment*' and '*international co-operation*' [4], [5]. There were three significant outcomes of UNCHE: The Stockholm Action Plan, The United Nations Environment Programme (UNEP), and The Stockholm Declaration. Each of those outcomes has had important effects on environmental issues globally. The Earthwatch program, an environmental assessment program at the global scale, was initiated by the Stockholm Action Plan. In addition, its five main programmes have had impact on several international environmental agreements [2]. UNEP was shaped after the Action Plan and has been playing active and important roles on environmental issues since then [6]. The third outcome of UNCHE was the Stockholm Declaration with its 26 principles, which became a leading visionary document for codes of international law and the background for Sustainable Development (SD) concept [2], [5]. Besides, a further unofficial report called "Only One Earth: Care and Maintenance of a Small Planet" was published in 1972 [7]. This report also indicated that environment and development issues are intertwined, and added that 'current generation has some obligations for future generations' [2], [7]. Thus, it gave significant clues for the creation of Sustainable Development concept [2], [8].

Within the twenty years since UNCHE was founded, a significant number of studies on environmental issues have been conducted [9, pp. 18–25]. Environmental problems such as air pollution, water pollution, etc. that are subject to environmental treaties have evolved to be more complex, inclusive issues. Such environmental problems have seemed no way to be solved without global cooperation; Caldwell called such problems as "*second generation of environmental problems"* [9, p. 126]. Handl [8] pointed that "*the synthesizing of economic and development considerations in environmental decision-making*" became a prominent issue during that period. In such an atmosphere, United Nations Conference on Environment and Development (UNCED), also known as Rio Conference or the Earth Summit was announced by UN General Assembly in 1992, with the theme "Our Last Chance to Save the Earth". The Report of the World Commission on Environment and Development (WCED), "*Our Common Future*" (also known as the Brundtland Report) became a significant reference for UN General Assembly to call for UNCED [10]. Both inequality between North & South and environmental problems were addressed in the Brundtland Report [11], with which 'Sustainable Development' concept was introduced to the world, especially in a political context. Previously WCED did not bring the concept of Sustainable Development into existence as a concept, although the Stockholm Declaration had many hints[8].

UNCED was called "*the mother of all summits*" because of a broad attendance of many heads of states, delegates, journalists, non-governmental organizations (NGOs), environmentalists and representatives of many groups [2], [10]. The main emphases of UNCED were "*global partnership*" and "*sustainable development*" [2], [8] . Although there were many crucial outcomes of the conference [2], [10] , the main outcomes of UNCED in terms of the SD concept were the Rio Declaration and Agenda 21 [2]. The Rio Declaration [12] with its 27 principles has been key resource for many other steps taken for environment and development issues afterwards [2], [8] . Agenda 21 was a detailed document which internalized the main emphases of UNCED aiming to serve the coordination of "*global partnership*" and "*sustainable development*" towards implementation. It was agreed to be adopted by all 172 participating governments which was an important step for acknowledging the SD concept[13].

With those significant outcomes, UNCHE and UNCED were the first steps to spread SD concept all over the world. Since then, many international institutions, nations, cities, sectors, companies, NGOs, academicians, and individuals have placed the concept at the centre of their understanding. However, there is no universally accepted definition of the SD concept, which makes it argumentative [13]. Nevertheless, possibly the most referred definition of the SD is the one in the Brundtland Report: "*Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs*" [11]. This definition is considered to be the underpinning for many other following definitions that have been made by other groups [14]. Still, this definition has been the cause for some ambiguity for clear understanding, and particularly for implementation. This ambiguity has led relevant groups to interpret 'uncertain parts' of the definition according to their perception. Mebratu [14] tried to classify definitions of SD into three major points of view, namely institutional, ideological or academic. He focused on an '*identification of the source of the crises'*, a '*core approach to the solution*', a '*proposed solution platform*', and a '*key instrument for the solution*' for each group. These elements could vary from one definition to the other; however, all seemed to agree with the existence of an 'environmental crisis' and the 'need for fundamental change' to tackle it. Kates et al. referred to a study of the Board on Sustainable Development by which the definitions of SD had been examined [1], [15]. They determined that diversified definitions generally vary by perceptions of '*what is to be sustained*', '*what is to be developed*' '*how these two should be related*' and '*what should be the time horizon of the future*' [1]. Farley also indicated that the definition of SD (in the Brundtland Report) includes the ideas of need, limit and futurity in a broad and inexact way, causing variation in implementation and understanding of the SD concept [13].

There are two widely accepted depictions that exist among SD explanations: The 'three pillars' and 'triple bottom line' models. The three pillars refer to the integration of economic, environmental and social components in order to manage SD goals. Similarly, the triple bottom line claims that sustainable outcomes can only be reached by regarding all of these three components where they intersect with each other (See Figure 1).

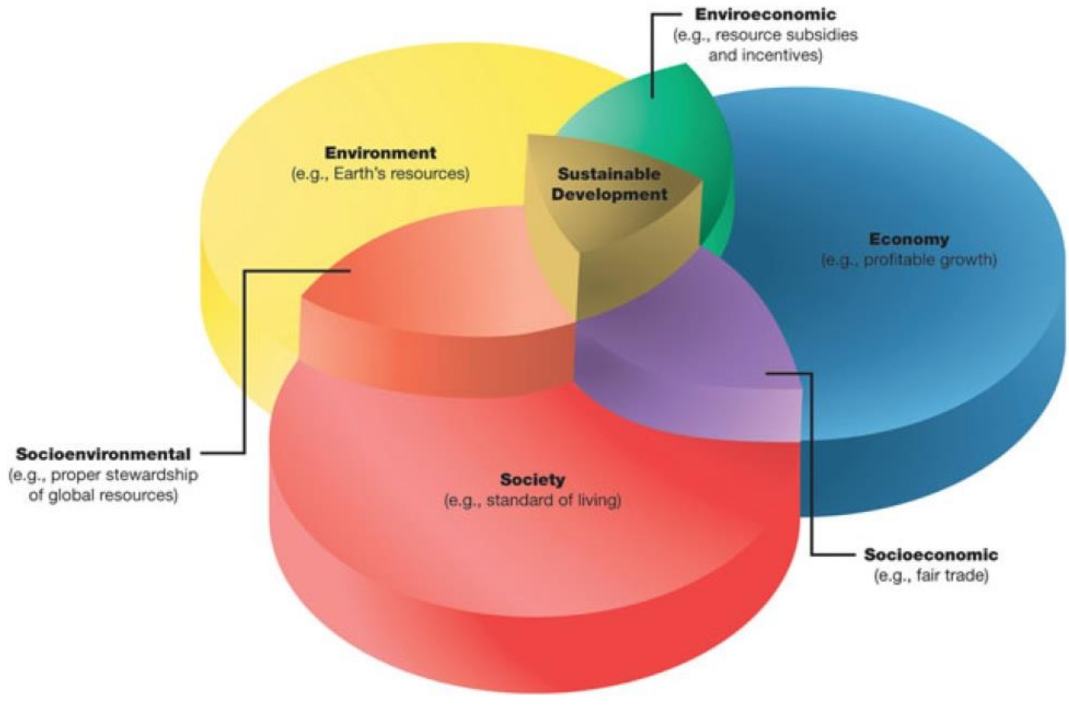

Figure 1: "Triple Bottom Line" of Sustainable Development Concept [16, p. 304]

Contested characteristics of the SD concept could be juggled with anything from the extremes of "sustain only" to "develop mostly" [1]. Due to the variant perceptions of this contested concept, sustainability[1] was further grouped (economically) as ‘weak’ and ‘strong’. Weak sustainability has an anthropocentric view whose focus is on human development and wellbeing. According to weak sustainability, ‘nature’ is a capital and most of the natural resources on earth have substitutes thanks to human technology [17], [18]. This perception implies that as far as natural resources are carefully exploited if –in the meantime-technological solutions are being produced in an attempt to combat the natural resources depletion and pollution, sustainable development can be achieved [17], [19]. This sub-concept of sustainability has been influenced by the neoliberal economic viewpoint, and thus it centres the economic growth along with technology to fulfil ‘economic needs’ as part of environmental resource management [13], [17]. Lélé [20] claimed that growth-oriented definitions of sustainability are incompatible because there are natural limits and they should be taken into consideration by human society and economy; only then ‘sustainability’ could be meaningful [13]. Mazı [17] also determined that any strategy related to sustainability should consider human and environment as a single system, otherwise the conceptualization of SD will be deficient by being ‘mono-lateral’. On the other hand, strong sustainability[2] has an ecocentric concept of the world. If there is little respect to its ‘*assimilative and adaptive capacity*’, natural resources will be exhausted since they are finite. Therefore, controlled use of ecosystem services with regard to their period of regeneration cycle is the common target of strong sustainability [17]. According to this viewpoint, Nature’s biotic rights should not be questionable and must be considered similar to absolute human rights by which it is hinted that ‘the human being is not merely measure of everything’ [17]. The given value to material goods should be reduced from being ‘final aim’ to ‘a means of achieving well-being’. Accordingly, the relationship between nature and people are needed to be defined all over again in order to form healthier ‘ethicosocial limits’ towards nature [21], [22].

The need for balancing natural resource consumption so as not to stress the environment was also underlined by those advocating the integration of ecology

[1] ‘Sustainable Development’ and ‘Sustainability’ will be used interchangeably in this thesis study. (See; Heideger 1999) [16, p. 1121-1123]

[2] In literature ‘environmental sustainability’ term can also be used instead of ‘strong sustainability’ [18]

within economy (See [21], [22], [18], [23]). (Very) Strong Sustainability[3] has been criticised for not being realistic and applicable in todays' neoliberal economy [17], [24]. However, the 'broader' definition of SD still includes a concern for future generations' welfare and therefore it is argued that despite technological improvements, imposing strong requirements on 'man-made capital' and natural resources substitution will possibly still be needed [25]. Besides the arguments related to methodologically differentiated formations of SD, the concept itself is heavily criticised for being an 'oxymoron' [26]. The main criticisms on SD conceptualizations are the following: "Paradoxical growth issue ('*sustained growth*'); Efficiency mechanism of neoliberal economy which causes ecological crisis eventually; Problematic environmental management 'assumptions'[4]; Implying poverty and population growth as the sources of environmental crisis by ignoring the lifestyle of the developed countries; The ambiguity and uncertainty of time period defining for a 'need' and 'future needs' ideas within the SD definitions" [24, pp. 21–32]. On the one hand, it is strongly criticised that even if the SD concept is adopted by many individuals, sectors, cities, countries, etc., there will still be both stagnant or declining social wellbeing and an imbalanced ecosystem worldwide [13]. Thus, the SD concept is likely seen as '*a temporary improvement of the way humans use-up nature*' "[21], [24, p. 296]. On the other hand, it is underlined that "The challenges of sustainable development highly resemble the various and multifaceted diversities of human societies and Earth's natural ecosystem. Due to its flexibility, the SD concept has still been an evolving idea that could be adopted by those many concerned from local to global levels, just as the concept requires diverse participation. Although principles and objectives are distinct or even opposite to each other, synthesizing them in order to actualise a coordinated action worldwide towards achieving SD socially, economically and environmentally is needed. Thus, all critiques are essential for evolving SD concept consciously." [1, p. 20].

[3] Beyond the Strong Sustainability, 'Very Strong Sustainability has been described, too' (See [190, p. 1123])
[4] In spite of all disadvantages, Author concluded by "*the strategy of environmental management can be used for a better use of resources.*" (See; [24, pp. 25–26]).

1.2 Sustainability Indicators

The first international call for sustainable development indicators (SDIs) was made within the Agenda 21. After that the UN Commission on Sustainable Development (CSD) had started working on the SDIs in 1995, and published around 140 indicators covering ‘three pillars’ and institutional aspect of the SD [27], [28]. The CSD’s aim was to conduct a framework study by which progresses towards application of SD goals at governmental level could be estimated [29]. In this context, CSD developed two sets of SDIs between 1994 and 2001, after which have been tested by many groups ranging from local to international [28]. The third revision of CSD indicators covers a core set of 50 indicators which are part of a larger set of 96 indicators of SD [28]. By the third revision, CSD indicator themes were formed under three main aspects which are social, environmental and economic [28] (See Figure 2). Besides CSD, many institutions and organisations have been working on SDIs such as the Organisation for Economic Co-operation and Development (OECD)[5], The Statistical Office of the European Communities (EUROSTAT), The United Nations Development Programme (UNDP), International Union for Conservation of Nature (IUCN), Environmental Protection Agency (EPA), European Environmental Agency (EEA) [30]. The Compendium of Sustainable Development Indicator Initiatives had been mentioned over 500 sustainability indicators in 2000 , scope of which 67 are global, 103 are national, 72 are state or provincial, and 289 are local or metropolitan, approximately [31, p. 3], [32]. This number of SDIs entered to the database of The Compendium of Sustainable Development Indicator Initiatives increased to over 800 within 9 year-time [33, p. 41].

[5] See [34], [191], [192]

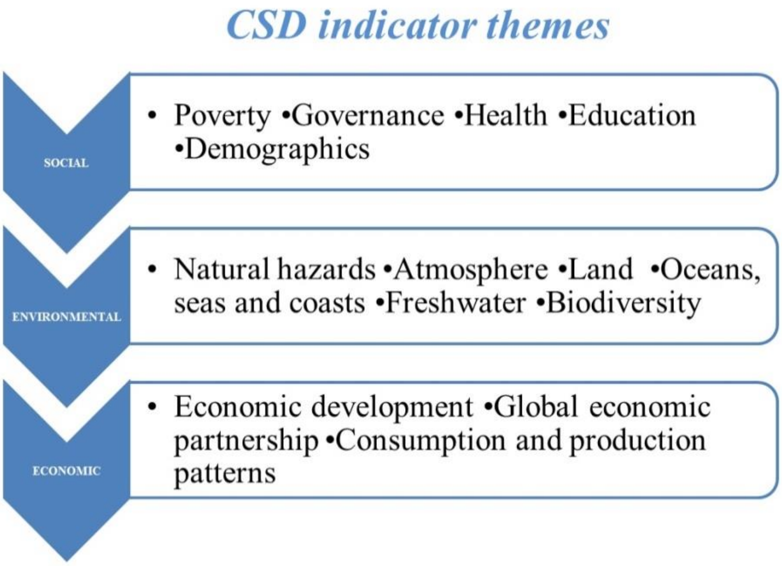

Figure 2: The United Nations Commission for Sustainable Development (CSD) Indicator Themes Adopted [25, p. 9]

Sustainable Development Indicator was defined at Environmental Protection Agency Report as "*a measurable aspect of environmental, economic, or social systems that is useful for monitoring changes in system characteristics relevant to the continuation of human and environmental wellbeing*." [34, p. 6]. According to Godfrey et al. [35], SDIs principally provide '*a manageable amount of meaningful information*' about the all-changing complex environment by intensifying, summarizing and concentrating relevant information of the environment [29]. Warhurst also underlined that '*indicators are an effective way of packaging and conveying performance information to target user groups*' [36, p. 14]. These features make indicators advantageous tools which could serve to the process of policy making and inter-comparison between countries with reference to their performance of adopting SD goals [29]. Singh et al. itemized the major aspects of measurement by which the grouping and evaluation of SDIs could be done [29, p. 195] : The aspects (social, environmental, economic, etc.) of SD being measured by the indicator; the techniques or methods being used and so reached characteristics of index (quantitative or qualitative, subjective or objective, etc.); a comparison of sustainability measure being made or not, (with regard to space and time); an input-output data being considered (or not) in order to measure sustainability; the features of indicator (its content, methodology, focus, applications, etc.) being clear and simple; an availability of data regarding time and space that being used by indicator; a degree of flexibility of the indicator's methodology, purpose, content and application (See also [37, pp. 17–19] and [38]) . In other respects, Chambers et al. pointed out that a good indicator must be '*resonant*', '*valid*' and '*motivational*' and it was also emphasized that an important parameter is to maintain the credibility of the indicator after the simplification process of complex data [39]. On the other hand, Böhringer et al. maintained that any SDI that is to be meaningful must be accountable in terms of normalization which mainly means making data 'comparable', weighting which mainly means identifying the 'correct' interrelationships, and aggregation which mainly means constructing the 'right' functional relationship [32, p. 2]. Main criticisms of SDIs are summarized in Table 1.

Table 1: **Main Criticisms of SDIs and Their References**

Main Criticisms on SDIs	References
SDIs may not be feasible to be used by policy-makers (if SDI is being measured, weighted and/or selected properly).	[29, pp. 197–198]
The theoretical approaches behind many SDIs do not exist, and this causes differences in adopting the SDI set which makes relevant political comparison between countries impossible.	[40, p. 118,127]
Data quality and availability may show alterations by application level and/or place, and it may differ in assumptions significantly.	[29, p. 198] [40, p. 118]
Many factors and/or steps such as 'assumptions in estimating the measurement error in data; mechanism for including or excluding indicators in the index; transformation and/or trimming of indicators; normalisation scheme; choice of imputation algorithm; choice of weights and choice of aggregation system′ may affect objectivity of SDIs. Thus SDIs can be too subjective.	[29, p. 197]
Existing SDIs may not contribute to the better or effective application of SD.	[41, p. 300]
SDI methodologies are likely to be developed deficiently due to its ambiguous definition and policy goals towards SD.	[29, p. 191] [31, p. 13.1]
There is no universally accepted SDI due to salience, credibility, and legitimacy issues.	[31, p. 13.15]

Warhurst categorized the type of indicators and grouped indicator systems[6] according to their different characteristics in his report of '*Sustainability Indicators and Sustainability Performance Management*'[36, pp. 34–37]. He summarized indicator types with ten titles, referring which of SD pillars may be applied by each type of indicator (See Figure 3).

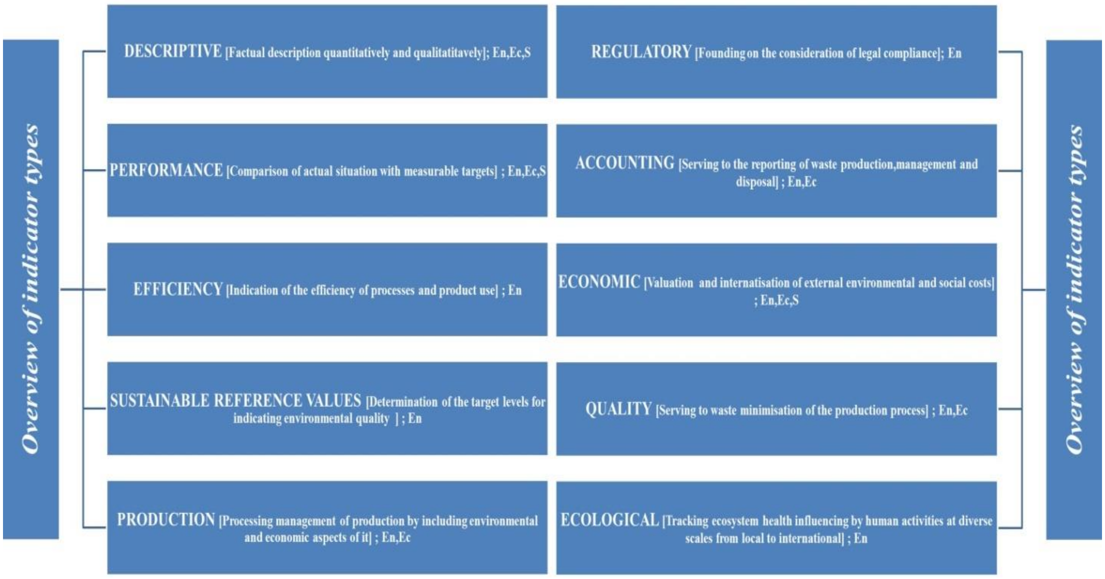

Figure 3: Overview of Indicator Types (En: Environmental, Ec: Economic, S: Social) Adopted from [36, p. 35]

Besides (non-composite) indicators[7], there are composite indicators in order to measure sustainability. These indicators present a particular measure by aggregation of information provided by sub-indicators [29], [40] . Singh et al. pointed out that the important decisions about the composite indicators are: Deciding which phenomenon is intended to be measured and whether it is beneficial to prefer composite indicators; deciding the sub-indicators that are compatible with the phenomenon intended to be measured; determining each sub-indicators' data being high quality and responding to the data which is not reliable or to the gaps between points etc., thus revealing if there is need for result variation according to altered methods prefer to use; determining if the sub-indicators are needed to be considered with reference to their interrelations; deciding to the normalisation and weighting procedures of sub-

[6] See also[193], [194]
[7] See [195, pp. 907–909]

indicators; and testing results variations for their robustness and sensitivity according effects of the chosen procedures for normalising and weighting methods [29, p. 197]. Kulig et al. [40] made an order of the composite indicators which had been introduced between 1973 and 1999 chronologically (See [40, pp. 121–122]). They focused on composite indicators which are based on 'monetary capital approach', and further discussed the possibility of creating an internationally acceptable composite indicator by internalizing 'hybrid capital approach' so as to become sufficient to measure the nonmonetary capital stocks, too. In other respects, Singh et al. grouped indicators under twelve headings under which related indicators were briefly introduced in the article "*Overview of Sustainability Indices*" [29] (See Figure 4).

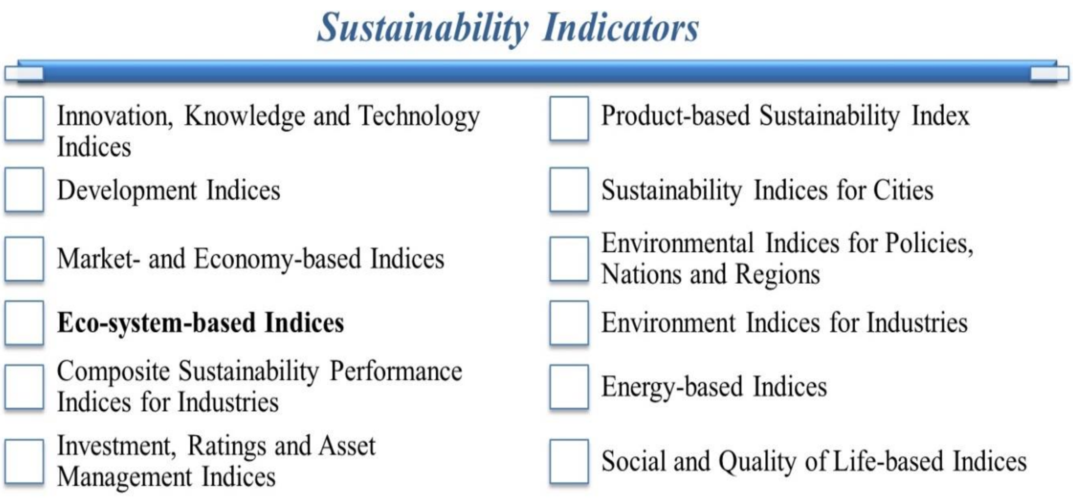

Figure 4: Sustainability Indicators Grouped and Overviewed by Singh et al. Adopted [29, pp. 198–209]

Plenty of indicators exist in the literature. However, in line with the context of this thesis, only Eco-system-based Indicators, under which Ecological Footprint (EF) is also included, will be introduced briefly here. The Living Planet Index (LPI) was developed by World Wildlife Fund (WWF) in 1997 in order to '*measure the changing state of the world's biodiversity over time*' [42, p. 289]. LPI methodology[8] contains the time series data in order to evaluate average rates of change in

[8] For LPI calculation types and methodology details : See [43, pp. 17,140–143], [42, pp. 290–292], [196, pp. 318–320]

terrestrial, freshwater and marine vertebrate species' population size, density or abundance[42, p. 289], [43, p. 136]. WWF published 'Living Planet Report 2014' lastly, which contains the LPI's trend data of 40 years- from 1970 to 2010 [43, p. 136]. Sustainability Performance Index (SPI) developed by Krotscheck and Narodoslawsky is an aggregated index, which provides '*measuring the total environmental impact of human activities of various kinds*' [44]. Narodoslawsky et al. [44] identified SDI as an evaluation system of ecological and industrial processes, whose methodology[9] is based on '*mass and energy balances of the processes to be evaluated*'. Thus, the ecological impact of a (industrial) process can be measured (as an area unit) quantitatively and qualitatively, and associated with the energy and mass flows it entails by SDI [45]. It is stated that SDI may help current technology to be optimized and improved so as to include and minimize environmental pressure it causes [44].

Ecological Footprint

For a clearer understanding, before introducing the indicator termed Ecological Footprint[10] (which is the focus of this study), it should be underlined that there are 3 main types of footprint calculations: 'Ecological Footprint', 'Water Footprint' and 'Carbon Footprint'. Their concerns, approaches, methodologies and results are different in many points from each other. Galli [46, pp. 45–47] listed each footprint type's research question, main message, data source and unit of measure. Table 2 is adopted from that source and summarizes the major characteristics of the footprint types.

[9] For SPI calculation types and methodology details : See [45], [197] , [198]

[10] Also 'Eco-footprint' can be used instead of the 'Ecological Footprint' in the literature.

Table 2: Major Characteristics of the Footprint Types (Adopted from [46, pp. 46–47])

Type	Research Question	Main Message	Unit of Measure
Ecological Footprint	To what extent the biosphere's regenerative capacity is directly and indirectly- embodied in trade- utilized by humans (i.e. Ecological Footprint) compared with how much is available (i.e. biocapacity), at both local and global scale.	To boost recognition of ecological limits and protect the ecosystems' preconditions (e.g., healthy forests, clean waters, clean air, fertile soils, biodiversity) and life-supporting services that facilitate the biosphere to support mankind in the long term.	gha or ha
Carbon Footprint	The overall amount of greenhouse gas emissions (CO_2, CH_4, N2O, HFC, PFC, and SF6) that are directly and indirectly originated by human activities or increased over the life stages of products	The consumption-based perspective of the Carbon Footprint accompanies with the production-based accounting approach adopted by national greenhouse gas inventories (e.g., those considered by the Kyoto Protocol).	kg CO_2 or kgCO_2e (*) (*if other types of greenhouse gases are also included)
Water Footprint	Human allocation of natural capital in terms of the volume of fresh water needed for human consumption.	The Water Footprint notion is mainly intended to clarify the hidden links between human consumption and water use and between global trade and water resources management.	m3/yr (process); m3/ton or liter/kg(product); water volume/time unit (geographical area)

Ecological Footprint (EF) is an indicator placing main emphasis on the necessity for global human society to live within ecological limits of Earth's regenerative capacity so as to assure environment to be sustained [47]. The main purpose of EF is stated as "*to promote recognition of ecological limits and safeguard the ecosystems' life-supporting services enabling the biosphere to support mankind in the long term*" [48, p. 126].

The Ecological Footprint concept had been introduced in 1992 by Rees[11] [49]; developed in 1996 by Wackernagel and Rees [50], and further developed in 2000 by Chambers et al. [39]. Global Footprint Network (GFN) was established under the presidency of Wackernagel in 2003 as a non-profit organization in order to 'accelerate the use of the accounting tool EF' to measure the Earth's biocapacity, ecological footprint and the distributions of them [51]. The role of GFN can be summarized as continuously developing the methodology of EF and seeking the way for standardization of it while creating reliable scientific data source for many counties in order them to calculate their national footprint accounts. GFN has become a consultee for EF studies or applications, and active respondent organization for criticisms made towards EF worldwide. Many academic institutions, consultancies and corporations have become partner with the GFN (See [52]). Among them is WWF, a non-profit foundation established in 1961, which describes its mission as to balance human life being compatible with nature so as to stop the degradation of the Earth's nature [53]. Saving biodiversity and reducing humanity's EF are its major foci as mentioned in 'WWF's Strategic Plan for Conservation' [54]. WWF publishes 'Living Planet Report' every 2 years since 1998 [55]. EF was included in Living Planet Reports first in 2000 [56]. GFN and WWF partnership can be considered as effective in introducing EF globally.

EF is defined as "*a measure of how much area of biologically productive land and water an individual, population or activity requires to produce all the resources it consumes and to absorb the waste it generates, using prevailing technology and resource management practices*"[57]. There are some other related definitions and concepts that may provide better understanding of EF concept. Those are listed inTable 3. In addition, 'carrying capacity' (CC) is one of the fundamental background concepts for EF. Wackernagel et al. [50, p. 48] indicated that they reconceived the 'ecological concept of carrying capacity' following William Cotton (see [58]). In order to include 'human load' into the concept, they accepted CC as "*the maximum load that can safely and persistently be imposed on the ecosphere by*

[11] The pioneer study for EF had been conducted as a concept of 'Appropriate Carrying Capacity' by Mathis Wackernagel under the supervison of Proffesor William Rees in 1990s for his doctoral thesis [39, p. 52]

people" [50, p. 50]. This version of the CC[12] definition puts weight on '*per capita consumption*' of humans besides population increases [58].

Table 3: Major Definitions and Concepts associated with EF [57]

Name	Definition[13]	Relations with EF[14]
Biocapacity (BC)	The capacity of ecosystems to produce useful biological materials and to absorb waste materials generated by humans, using current management schemes and extraction technologies.	EF is demand side while BC is supply side of the concept
Ecological deficit	An ecological deficit occurs when the Footprint of a population exceeds the biocapacity of the area available to that population.	The difference between the BC and EF of a region or country
Ecological reserve	An ecological reserve exists when the biocapacity of a region exceeds its population's Footprint.	The difference between the BC and EF of a region or country
Natural capital	Natural capital can be defined as all of the raw materials and natural cycles on Earth. This capital is defined as the stock of living ecological assets that yield goods and services on a continuous basis.	Footprint analysis considers one key component, life supporting natural capital, or ecological capital for short.
Overshoot (or ecological debt)	Global overshoot occurs when humanity's demand on nature exceeds the biosphere's supply, or regenerative capacity.	Overshoot leads to a depletion of Earth's life supporting natural capital
Global hectare (gha)	A productivity weighted area used to report both the biocapacity of the earth, and the demand on biocapacity (the Ecological Footprint).	The Ecological Footprint is usually measured in global hectares.
Biologically productive land and water	The land and water (both marine and inland waters) area that supports significant photosynthetic activity and the accumulation of biomass used by humans.	The global hectare is normalized to the area-weighted average productivity of biologically productive land and water in a given year.

There are 6 main assumptions that form EF general accounting [59, p. 9266]:

- The resource consumption and waste patterns of people can be followed and quantified.

[12] See also [199], [200]
[13] Definitions made by Global Footprint Network (See [57])
[14] Definitions made by Global Footprint Network –except first sentence-(See [57])

- Required biologically productive area for maintenance of the resource and waste flows forms a basis for measurement of them. Immeasurable flow data might be excluded from quantification process, which causes EF result to be (systematically) underestimated.
- Global hectares representing world average productivity land (or sea area) in a given year can be considered as the common unit of EF measurements, after each area type is weighted proportional to its bioproductivity.
- Since each global hectare produces as much as usable biomass in a relevant year and each global hectare corresponds to a separate type of use, they can be put together to result in total representation of aggregated EF.
- Ecological resource capacity can be specified in terms of global hectares of biologically productive lands, which enables one to compare it with human demand expressed in global hectares.
- If maximum regeneration rate of an ecosystem fall short of human demand living on it, demanded area surpasses supplied area and this is called overshooting.

Our planet is assumed to have nearly 12 billion hectares of biologically productive land and water [57]. The land use types[15] water to be used for EF calculations, are as follows [60, pp. 524–525], [57], [39]:

Cropland: Among the land use categories, cropland (also referred as arable land) is the most biologically productive one, from where production of all crops including oil, livestock feed, fishmeal and rubber were provided. Such characteristics of cropland indicate that physically existing hectares of cropland in the world is smaller than the global hectares of its kind. On the other hand, cropland biocapacity embodying all land used for crop growth cannot exceed the crop production footprint for particular area. World-average yield production and harvest amounts in terms of required area of cropland are used to quantify the footprint for every crop types.

Grazing land: This type of land (also referred as pasture land) includes all grasslands - both cultivated pastures and wild grasslands - in order for livelihood of livestock which may be needed in addition to the provision of crop feeds.

Fishing grounds: "*The annual primary production required sustaining a harvested aquatic species*" forms the basis for defining this land type.

Forest land: All types of forests whether being planted or natural, that are used for supplying forest products, are included into forest land category.

Carbon dioxide (CO_2) uptake land: This is land for CO_2 sequestration (also referred as carbon footprint). Biocapacity of this type of land has not yet been defined clearly . Forest and ocean sequestration capabilities are considered in calculations.

Built-up land: The converted land surfaces on account of infrastructure such as transportation and housing are counted as built-up land. Unless there are no indications to the contrary, it is assumed that built-up land was previously cropland.

Average bioproductivity varies by diverse land types, both between different land use types and different countries [60]. In order to standardize these differences, a world average biologically productive area (usually expressed in global hectares) conceptualized. Normalization and weighting methods for EF calculations are based on using yield factor and equivalence factor so as to convert natural resources consumptions to reach that single unit of land (gha), after which adding up each land (and water) demands will be enough for aggregation [29], [60].

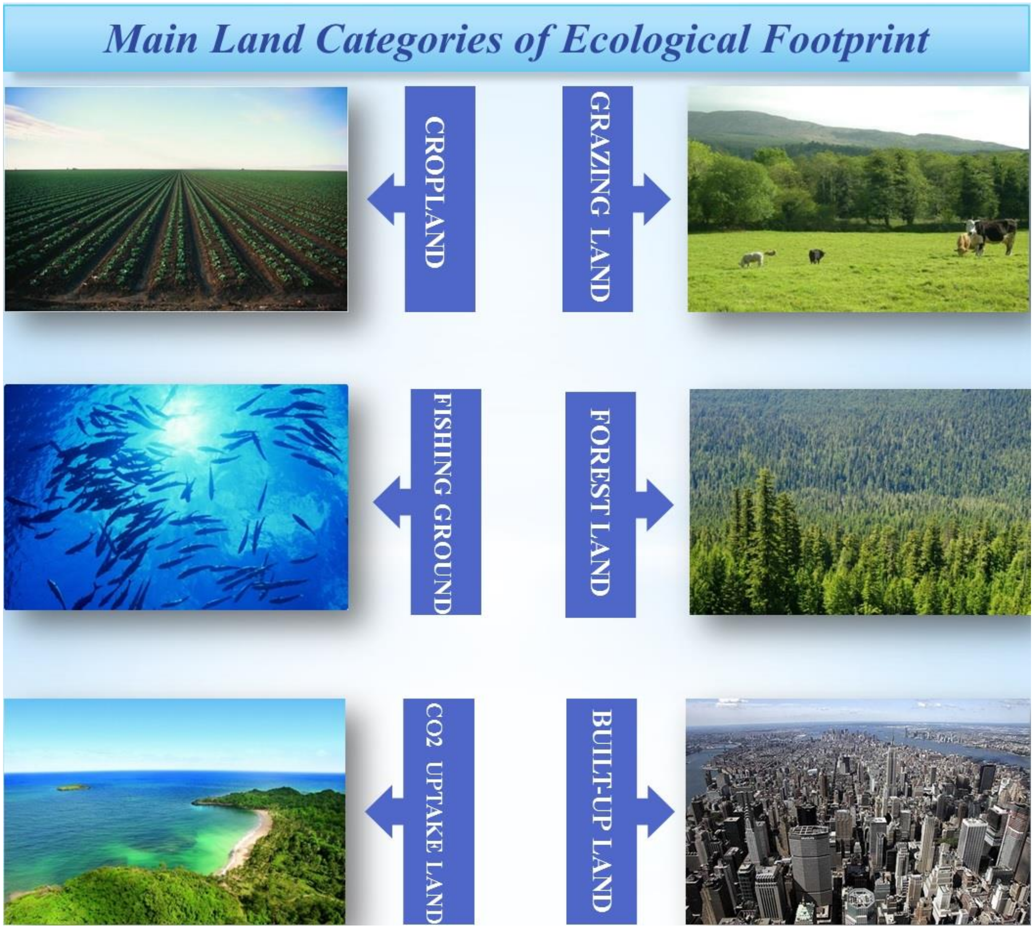

Figure 5: Main land categories used for EF: Photographs were taken from; Cropland [72], grazing land [73], fishing ground [74], forest land [75], CO_2 uptake land [76], built-up land [77]

Yield Factor: Yield is defined as a per area unit of bioproductive land (or water) giving primary products[15] that human can extract [57]. In order to normalize productivity differences of each year and each country, a coefficient 'yield factor' (YF) is used in EF calculations [57]. Thus it means that each land use type, as also each country have different YF. World average values are taken to make comparison possible and in proportion to productivity differences of nations. YF shows how many times one country's specific land use type is more productive than world average of that land use category for a particular year. YF's unit is "wha ha^{-1}" Borucke et al. [60] indicate that YFs can be considered as internalizing some specific natural features (e.g. soil quality, precipitation) and anthropogenic factors (e.g. management practices) into the calculation process. It is calculated as creating '*the*

[15] It is underlined that 'primary product' and 'primary production footprint' terms do not reffers to the ecological concepts, but they are footprint-specific terms [57].

ratio of national average to world average yields' [60]. Main assumptions of YF calculation are [60, p. 522]:

- YF for built-up land is considered equal to the assigned YF value of cropland (since built-up land is assumed to be former agriculturally productive land).
- YF for CO_2 uptake land is assumed to be identical only with forested land YF.
- Unit YF value is assigned for every type of inland waters, due to the lack of available data.

<u>Equivalence Factor:</u> Equivalence Factor (EQF) is a coefficient used for converting land in hectares to a global hectare of EF-specific unit [57]. This step provides different land use types to be added up after scaling each land type according to its bioproductivity with respect to world average productivity of that land type which makes EQF's unit "gha wha^{-1}". Galli et al. [48] pointed out that gha should not be considered as an alternative measure of area; rather it is a unit showing '*the ecological production associated with an area*'. It should also be noted that some of the EF studies do not prefer using gha, rather they use the unit of "ha yr^{-1}", which represents actual physical hectares [48]. Variation in EQF values can be due to the eventually changing land use, different land types and a year they calculated for [57], [59]. This step of EF calculation represents an intent of weighting multiple land types according to their intrinsic capacity to yield natural resources which are directly (e.g. providing food, fibre, etc.) or indirectly (e.g. serving as a carbon sink area) useful for humans [60]. It was indicated that unless there is no strong evidence to contrary, EQF value of built up land is assumed to be equal to that of cropland, and EQF for carbon dioxide sequestration land is assumed to be equal to that for forest land [60].

The EF concept has been adopted and implemented gradually at national, local, regional, municipal and organizational levels (For case studies; see [61], [62] and [63, p. 91]). Li et al. [64] specified 3 researcher groups using Ecological Footprint Analysis (EFA), among which are '*enterprises, school, family and industry*'. EFA has been also implemented at various fields besides those above (See [65]). However, further details will be given here only for the organizational level and particularly for EFA of university campuses and colleges due to narrower scope of this thesis. In order for better understanding of those EFA studies, first major calculation approaches will be mentioned.

Mainly two approaches exist for EF calculations: the ‘compound’ and ‘component-based’ methods. Compound method has been used generally for calculating National Footprint Accounts. It was originally[16] a top-down approach designed by M. Wackernagel [50]. ‘Trade flows’ and ‘energy data’ are taken as primary consumption calculation references [39, p. 67]. A compound calculation method for EF can be seen briefly in Figure 6 (See also [66, pp. 141–143]). GFN has been trying to standardize and improve specially the compound calculation methodology used for National Footprint Accounts. The latest version of ‘*Ecological Footprint Standards 2009*’ [67] can be reached GFN webpage [68].

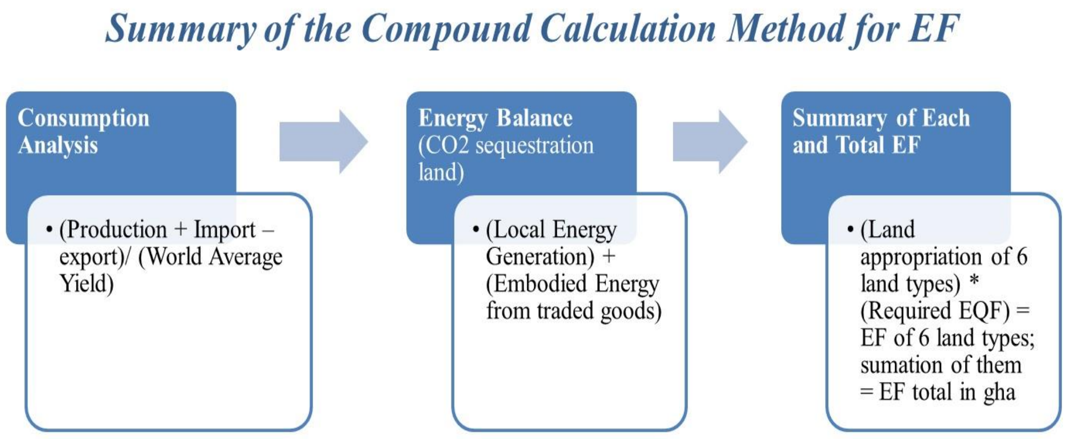

Figure 6: Summary of the Compound Calculation Method for EF (See [39, p. 67], [60, p. 521])

Component method is a bottom up approach used for calculating mainly regional and organizational EF [69, p. 29]. Land categories are same for each method (See Figure 5). However, pre-calculated values of considered components are needed in order to apply this methodology. This requires life cycle data[17] of each component. Life cycle boundaries of components may differ, to the extent of changing the final values dramatically. Scope of the boundaries were explained in ‘*Ecological Footprint Standards 2009*’, among which boundary scope for products [67, p. 13] and for

[16] See also [70, pp. 1–12]

[17] Besides Life Cycle Assesment, Input-Output Analysis and Emergy-based Concept can be adapted to component-base calculation process (See [67], [201])

organizations [67, pp. 14–15] will be summarized only due to their relevance to the topic of this thesis study.

Assigning activities so as to set life cycle boundary for calculating product footprint can change according to the reached step of a process. Activities with regards to generate a product can be counted up to the step of [67, p. 13]:

- purchase
- purchase + disposal
- purchase + disposal + consumer activities about the use of a product
- purchase + disposal + consumer activities about the use of a product + required social infrastructure owing to the use of a product

When organizational footprint calculation is being the topic[18], the most challenging as well as significant two issues are likely to be as '*defining the purpose of an organizational footprint analysis*' and '*the appropriate set of activities to be included*' [67, p. 14].

[18] University campuses are also included in organizational or institutional level respecting EF calculation processes.

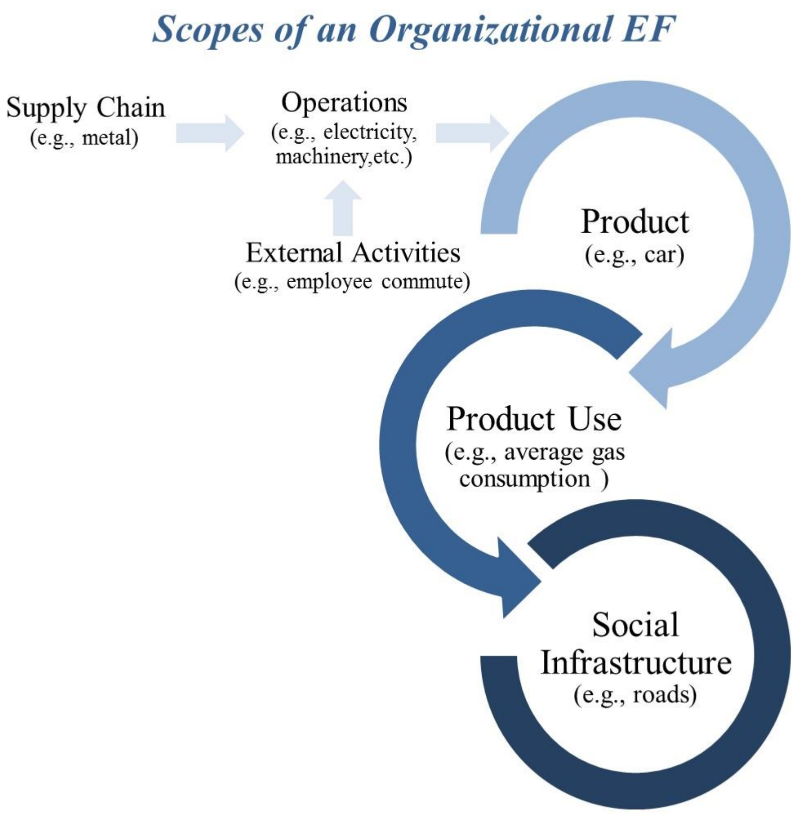

Figure 7: Scopes of an Organizational EF (Adopted from [67, p. 14]**)**

Purposes of each scope in Figure 7 are explained in [67, pp. 14–15]. Among them, Scope iii is explained in detail:

> *Scope iii: 'External Activities'; Purpose*: Employees form EF outside the organization in their personal life. Purpose is to specify how much of this EF is related to organization`s work and try to make these work related consumptions maintainable.

Scopes and/or purposes above should be chosen with respect to the organization's structure and the importance of the questions to be asked for organization's need, which indicate there are no right or wrong set of scopes and/or purposes [67, p. 15].

Chambers et al. [39, pp. 68, 75] mentioned that there are 24 typical components included in calculating regional or organizational EF. Table 4 shows further summarized version of those distinctive components (See also [67, p. 7], [70, p. 21] and [71, p. 30]).

Table 4: Summary of the Major Components Included in Component-based Calculation for EF

Major Components
Food
Mobility/ Transportation
Energy
Housing/ Built-up Area
Water
Consumables
Waste & Recycle

The calculation procedures of each component may change according to many factors (regional differences, local policies, differentiated requirement of each component, available data set, etc.). However, aşağıda formulation [71, p. 20] represents the finalization method for component-based EF calculation.

$$\mathbf{EF} = \sum_{i=1}^{i=n} (\mathbf{D} + \mathbf{N}) \qquad 1$$

Where EF = total ecological footprint; D = direct land use; N = other land requirement; *i* = number of components.

It should be underlined that differentiated calculation procedures and lifecycle data needs of each component make this method '*data-intensive*' [39, p. 69]. This feature of component-based calculation has the advantage to include local data in calculations wherever possible [72, p. 10], and the disadvantage of being highly sensitive to changes in data sets and assumptions [39, p. 69] if data sources are not always in agreement or when estimations vary in reference to changing assumptions, models and sub-methodologies [73, p. 376]. Moreover, some components that are not applicable may need to be omitted from the calculation process due to the sensitivity control of the study [73, p. 376]. One of the most significant emphases made on disadvantages of component method is that this method usually suffers from severe data availability limits which has a crucial role to play when this model is applied by user groups [74, p. 499]. Nonetheless, Simmons et al. [73, pp. 377–379] pointed out two main features of this model: ‘accuracy’ and ‘utility’. Particularly at the sub-national level due to the availability of local data sources rather than (traded) material flows data, component-based EF calculation has an advantage over the compound model in terms of more accurate results. Moreover, utility of component-based models for users, who are decision-makers, organizations or individuals, are higher due to its easiness to apply, and type of results monitoring key anthropogenic effects on the ecological services component by component [73, p. 379]. Klinsky et al. [74, pp. 497–499] mentioned the distinguished main features of compound and component EF calculation models, which are listed below (SeeTable 5).

Table 5: Main Features of Compound and Component EF methods (Adopted from [74, p. 499]**)**

Main Features of Compound and Component EF methods	
Compound Method	**Component Method**
National level*	Local level*
Variables (calculations depends on) may change from50 to 200	Nearly 20 main variables
Variables based on material flows*	Variables based on lifecycle and activities
Easier to reach required data set	Difficult* to reach required data set
EQFs are easy to adopt or used for proceeding study	Some of the conversion factors should be computed again according to that specific study
Many studies conducted	Few studies conducted
Comparable results* (cross-studies)	Problematic comparability of results

* Generally

The component-based calculation method has been used widely for quantifying EF of university campuses and colleges. Some of those studies are listed inTable 6. [19] The most commonly included components to EF calculations of high schools are food, transportation, energy, waste & recycle, water and built-up area [75, p. 5] (See Table 7). Furthermore, paper consumption may be included in some studies as a separate component, such as consumables or materials (i.e. office furniture, cleaning products, etc.). Inter-comparison of results is hardly meaningful, mainly because the EF of universities were calculated in different years, and different studies counting

[19] For more EF studies of universities refer to [123, p. 405].

on multifarious component sets likely to be based on various assumptions and estimations (See [76, pp. 349–350]). Therefore, EF per capita results are possibly more suitable for inter-comparison of different studies. The relation between EF analysis and universities will be further mentioned in Chapter 1.3

Table 6: Some of the EF Analyses Conducted for University Campuses and Colleges

Ecological Footprint Studies for University Campuses & Colleges			
Universities & Colleges	**Countries**	**Year**	**References**
University of Newcastle	Australia	1999	[77]
Holme Lacy College	United Kingdom	2001	[76]
University of Redlands	United States of America	2001	[78]
University of Wales, Swansea	United Kingdom	2002	[79]
Northeastern University	China	2003	[64]
University of Toronto at Mississauga	Canada	2006	[80]
Kwantlen University College	Canada	2006	[75]
Colorado College	United States of America	2006	[81]
Ohio State University	United States of America	2006	[82]
British Columbia Institute of Technology	Canada	2007	[83]
University of Illinois at Chicago	United States of America	2008	[84]
Dunarea de Jos University Galati	Romania	2010	[85]
Marlboro College	United States of America	2011	[86]
Xi'an University of Architecture and Technology	China	2011	[87]

At the national level, there is an Ecological Footprint report for Turkey [88]. Moreover, Turkey's 9th Development Plan paved the way for integrating SD and Footprinting[20] concepts into the agenda of many Governmental Institutes [89, p. 1145]. Regional Footprint studies in Turkey can be exemplified by two studies [90],[91]. Companies and universities, at the organizational level, also started to put or mention the EF concept in their agenda (See [92], [93], [94],[95], [96], [97], [98], [99], [100], [101]).

[20] The concept of Carbon Footprinting has been integrated to Turkey's (non-academic) agenda more widely comparing to the Ecological Footprint concept (For difference; See Table 2). For this reason, the sources only given here on 'footprinting' are include both Carbon and Ecological Footprint-related topics.

Table 7: Components taken into Account for Quantifying Ecological Footprint of Campus

		Components Taken Into Account						
University&Colleges/Countries	Year	Energy	Food	Materials& Waste	Water	Transportation	Built Up	Goods& services
University of Newcastle/Australia	1999		X			X	X	X
Holme Lacy College/UK	2001	X	X	X	X	X	X	
University of Redlands/USA	2001	X		X	X	X		
University of Wales, Swansea/UK	2002	X	X	X	X			
Northeastern University/China	2003	X	X	X	X	X	X	
University of Toronto at Mississauga/Canada	2006	X	X	X	X	X	X	
Kwantlen University College/Canada	2006	X	X	X	X	X	X	
Colorado College/USA	2006	X	X	X		X	X	
Ohio State University/USA	2006	X		X		X		
British Columbia Institute of Technology/Canada	2007	X	X	X	X	X	X	X
University of Illinois at Chicago/USA	2008	X	X	X	X	X	X	
Dunarea de Jos University Galati/Romania	2010	X	X	X	X	X		
Marlboro College/USA	2011	X	X	X	X	X	X	
Xi'an University of Architecture and Technology/China	2011	X	X	X	X	X		

As far as is known there is no comprehensive thesis completed to calculate Ecological Footprint of a university campus in Turkey[21]. However, Gönel led a study[21] in 2004 to calculate the EF of Yıldız Technical University, Beşiktaş-Yıldız Campus, which is the biggest campus in İstanbul [102, p. 2]. Components included in the calculations were natural gas, electricity, transportation, water and paper consumption, of which EF values were given in square meters [103]. The concept of EF has also started to be included in other Turkish academic work recently. Feride Gönel wrote a book [104] on the Ecological Footprint. Ercoşkun [105] wrote a book chapter on the subject of EF methodology used for sustainable tourism. There have been some thesis work that included EF methodology (See [106, pp. 90–111], [107, pp. 30–34], [108, pp. 45–57]). Akıllı et al. [102] quantified the personal EF for the Faculty of Economics and Administrative Sciences at Akdeniz University in Antalya. Increasingly the EF concept is taking a place particularly in Turkish Educational Science literature (i.e.[108], [89], [109], [102], [110], [111], [112], [113]). All those studies pointed out the pedagogical characteristics of the EF concept in teaching

[21] Feride Gönel published a book named '*Ekolojik Ayakizi*' [104]. The book contains a class study led by Gönel which aimed at calculating EF of Yıldız Teknik University, Beşiktaş-Yıldız Campus. However, this study could not be reached directly, although personal communication had also made by author between 12.10.2013, 22.11.2013 and 06.08.2015 via e-mail (gonel@yildiz.edu.tr). The scope of aforesaid study can only be reached from [103] and [102, p. 2] which gave insufficient information in terms of methodological details.

sustainable living. Furthermore, Keleş and Özsoy, academicians specializing in Educational Sciences, improved a personal EF calculation tool that is specific to Turkey, in collaboration with Global Footprint Network (See Figure 8).

Figure 8: View of the Turkey-Specific Personal Footprint Calculator [114]

Many publications discuss the advantages and disadvantages of the EF concept, while some of them were written particularly to criticize the concept[22]. Table 8 contains some of the main criticisms towards the Ecological Footprint. When criticisms made for EF analyses are examined, it is clear that it would be better to carry out the analysis cautiously, and interpretations had better be made after inspecting results elaborately and after thorough deliberation with reference to components, estimations, assumptions and comparisons [103, p. 403]. Besides criticisms addressed aşağıda, the EF approach was even claimed by Giampietro and Saltelli [117] to be a meaningless discussion tool to serve as a model for the SD concept due to its faults, and for all that it has become '*media-friendly'* worldwide due to its features to generate '*reassurance*' rather than '*urgency*' about the '*man's pressure on the planet and its ecosystems*'.[23]

[22] For the more (detailed) critiques of the ecological footprint refer to [124], [125], [202]–[204], [132, p. 211], [205], [206], [207] and [208].
[23] For response was given to Giampietro and Saltelli, see [115].

Table 8: Some of the Disadvantages of and/or Criticisms towards the Ecological Footprint in Literature

Main Criticisms on EF	References
EF cannot be considered as a complete measure of sustainability, so that a need occurs to complement EF by other measures to gain a full understanding of sustainability. Because EF only focuses on a single research question reflecting a single dimension of the sustainability issue-demand on regenerative capacity- and not on sustainability as a whole.	[67, p. 11], [115, p. 629]
What will be the wider application of ecological footprint is not yet clear.	[116, p. 8], [117]
EF is intended to measure impact. It is not designed to get at cause and effect.	[118, p. 218]
EF is not well suited to the protection of environmentally significant features and natural processes when the site is developed. Instead of what land to protect, significant natural areas are only configured into the equation as land consumed.	[118, p. 218]
EF asks the sustainability question from consumption rather than a protection point of view.	[118, p. 218]
Prescription of EF data to declare applicable allocation of EF between individuals or activities cannot be indicated (Even by comparing EF per-capita results with local/global biocapacity availability).	[67, p. 11]
EF method may inform about the current situation, but it is hardly possible to be considered as a tool serving to advocate or support specific strategy, policy or solution just by itself.	[67, p. 11]
Although GFN has been redefining and correcting the EF calculation methodology, there is no specific method accepted as the only standardized calculation methodology.	[119]
Current methodologies of EF are insufficient to reach conclusions as implying any kind of right or limitation requirement of it.	[67, p. 11]
Ecological footprint calculations are complex. Finding and collecting the data may be difficult.	[116, p. 8], [117]

Table 8 continued

Products and organizations do not have a single widely agreed upon set of associated activities. From an analytical perspective, the Ecological Footprint of an organization, regardless of scope, is conducted in a “bottom-up” manner based on a combination of individual product Footprints, selected according to the scope of the organizational study. The set of activities associated with a product Footprint is determined by the scope of the LCA used to determine that product Footprint, which affect the results and their comparability.	[67, p. 10]
Current EF methodologies do not directly addressed depletion of Non-renewable resources; The release of long-lived toxic materials into the biosphere; Greenhouse gases other than carbon dioxide (may be included in future editions, or added as nonconventional elements); Impacts on human health; Other aspects of sustainability, including social health, economic performance, or cultural vitality.	[67, p. 11]
Results of different methods for EF calculation are being hard to distinguish which are more scientific.	[120, p. 125]
There are many serious factors having influence on the accuracy and precision of the results which likely to cause significant biases.	[67, p. 11]
Data availability at local or organizational level is poor which causes EF calculations are not substantially based on direct assessment of the components or the communities.	[121, p. 972]
Data for some essential components of a footprint analysis were not available at the individual or county level.	[122, p. 280]
The strong subjective decisions may be made at some points of calculations such as which primary products should be involved in calculating yield factor of a specific land use.	[120, p. 125]
Underestimates or overestimations made for EF calculation assumptions are likely to generate the results misleadingly.	[121, p. 972]
Aiming toward one integrated indicator comprises the risk of oversimplification, under- or overestimation of unknown components, on their turn resulting in the inability to compare results. Furthermore, omitting certain components can be problematic for comparability purposes of EF analyses.	[123], [124], [125], [126]
Some proxies made for each component based on consumption do not include some factors such as geographical differences, quality of goods and services.	[121, p. 973]

Table 8 continued

The ecological footprint is increasingly described as a comprehensive sustainability indicator when it is not. Many of the misconceptions surrounding the ecological footprint derive from it being oversold as a comprehensive indicator. Overselling the tool creates misunderstandings among policy-makers, planners, and municipal leaders about what the tool achieves, how it can be applied, and what the results mean.	[121, p. 975], [127]
Further research is necessary to provide guidelines on how to efficiently and appropriately apply the EF at different scales for different purposes.	[118, p. 218]
The EF is optimistic at the global scale and policy-misleading at the local one.	[128]
The concept of ecological footprint at the regional level. It does not focus too much on probability. This is partly. It is a result of not reaching local data.	[116, p. 8], [117]
EF models, as all other sustainability models, have flaws, biases, and limitations. They do not provide perfect information or complete clarity. That makes EF model best suited for promoting education and raising awareness, but it is not enough to use alone to be based sources for policy-making and planning processes.	[121, p. 975,976]
EF approach is incomplete in terms of not including the impact of materials such as toxic wastes and ozone depletion.	[63, p. 94], [129], [130], [131]
As the yield of grazing land represents the amount of above-ground primary production available in a year with no significant prior stocks to draw down, and given the fact that soil depletion is not tracked by the Ecological Footprint methodology, an eventual overshoot for this land use type still cannot be shown.	[60], [131]
The lack of attention or differentiation, mainly concerning differences in productive and absorptive capacities, as well as carrying capacities of areas; possible benefits of technological advances; the assumption that land can only be used for a single (or ecological) function; and the role and possible changes in social welfare.	[125], [123]

On the other side, there are various advantages of the EF mentioned in literature. Lambrechts et al. [123] referred EF analysis as a tool that serves the SD in terms of providing systems thinking, future thinking and critical thinking about values and responsibility as well as personal action taking. Furthermore, Moos et al. [118, p.

218] underlined that the EF tool works well in its capacity to '*aggregate land-use impacts and illustrate where trade-offs exist*'. Consistent with this discourse, they referred the EF as a tool providing a combination of '*built form and consumption aspects into an environmental assessment*'. A different approval of the EF model came from Borucke et al. [60] who pointed out the significant improvements have been made in the National EF calculation procedure. At municipal (local) level, one of the advantages of EF was mentioned by Wilson et al. [121, p. 975] as it was indicated that calculations may serve raising environmental awareness and give a chance to educate people on their loads due to their '*consumption patterns and lifestyle choices*'. They added that depending on a density of using direct data sets whether by collecting or purchasing them, the proxies made for calculation became more robust [121, p. 972]. Similarly, Moos et al. [107, p. 218] emphasized that thanks to it is being '*an assessment of a full range of categories',* the EF approach could be considered as creating a perception of the way human lifestyle and built form are interacting with each other. Another positive comment for EF analysis made at institutional scale belongs to Gottlieb et al. [63, p. 92]. They categorized the efficiency of the EF results into two possible ways; an opportunity to perceive results as '*where the greatest impact is occurring*' and results can be displayed as showing the impacts of consumption on ecological footprint in total by ordering their ranks [63, p. 92].

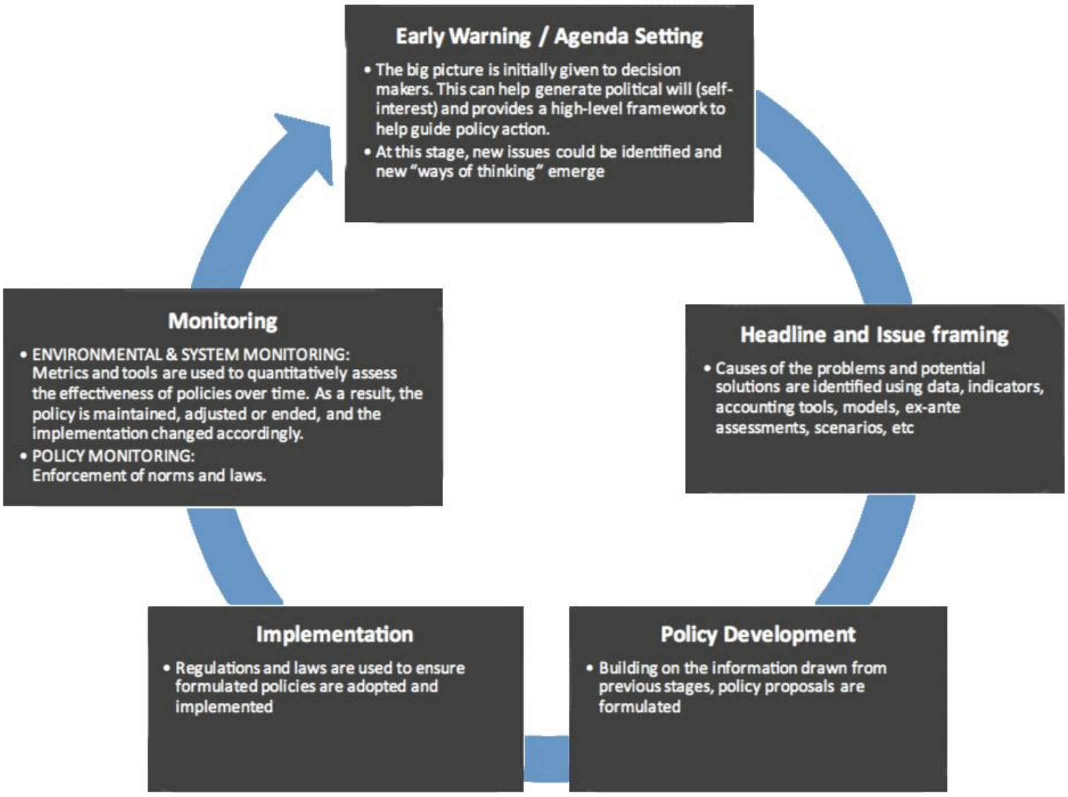

Figure 9: An Exemplification of a Policy Cycle (Adopted from [132, p. 214]**)**

Moos et al. [118, p. 219] referred to Walker and Rees who had described the EF as an analyzing tool, which includes life-cycle processes, that providing communication ground on a significant dimension of SD, thanks to its '*intuitive and visually graphic*' characteristics. On a side note, Moos et al. [118]inferred two other important eventualities of the EF analysis. First, only if the qualified data was used, then its results may serve perception on decision-making processes and preferences. Thus the EF may '*become a useful tool for understanding the pathways to different outcomes*'[118, p. 218]. Second, there is always a vast amount of the raw data should be gathered for any type of EF calculations, which itself may create an opportunity being effective and informative basis for seeking answers to specific questions in planning practice [107, p. 218]. Moos et al. emphasized that although it would be better not to use the EF results directly (i.e. assigning a maximum or minimum EF values) for establishing restrictive development standards, relevant authorities can use the model results for supporting the development proposal processes to be approved [107, p. 218]. As Holmberg et al. [133] stated the EF concept's '*didactic* *strength*' due to expressing results in '*spatial units*' so that it has gradually become '*an attractive tool for communicating, teaching and planning for sustainability*'; also Wilson et al. [121, p. 976] gave notice the inspirational potential of a simplified EF methodology for many people using it may led them to reflect, plan, take action and change their agendas. Venetoulis [78, p. 183] interpreted that thanks to its comprehensive characteristics an EF calculation process at institutional level (for a university) '*meets the interests of those (students, faculty, and research assistants) carrying out a large brunt of the applied interdisciplinary research*'[78, p. 183]. Galli et al. [132, p. 215] examined policy usefulness of the EF for each step of policy cycle (See Figure 9) in order to show how the EF can be included to the cycle (See Figure 10).

Figure 10: Policy Usefulness of the Ecological Footprint for Each Step of Policy Cycle (Adopted from [132, p. 215]**)**

Final merit of the EF approach to be referred here will be related to higher education level. Lambrechts et al. [123, p. 405] implied on their paperwork that although '*getting lost in the numbers*' can be a fairly easy situation while calculating the EF of a campus, what is worth to use and interpret the model for a university, those which are listed below have parallels with the present thesis' goals and objectives (See 1.4):

➢ ‘*A static snapshot*’ giving significant clues to the university about its effect on the nature at a given time period;

➢ An advantageous informational outline work on major components of campus operation regarding their ecological after-effects mainly;

➢ A tool to create perceptual filtering on the subject of higher education-sustainability cooperation and to drive staff and student to use initiative about setting the integration processes in motion.

1.3 What is Sustainable Campus?

Starting in the 1960s and further in the 1990s many steps have increasingly taken towards ensuring to make the university campuses ‘*greener*’ worldwide [78, p. 180]. Universities began to internalize the sustainability concept with its gaining widespread acceptance and popularization among institutions. Furthermore, Higher Education Institutions (HEIs) have been attached importance for sustainable development principles to be promoted understanding and to be ensured implementation& development of the concept [123, p. 402].

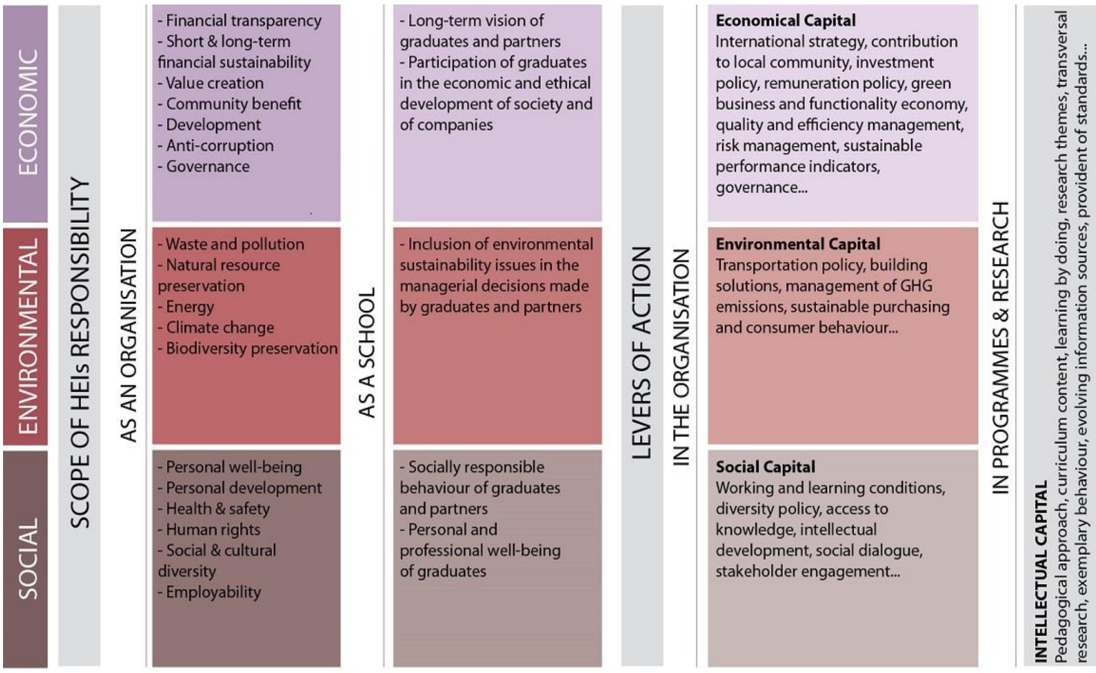

Figure 11:The Scope of HEIs Responsibility (Adopted from [134, p. 10]**)**

As Waas et al. [135] got clear on why HEIs have to play exemplary role to internalize sustainability, they referred to the credo of '*practice what you preach*'. Programming an integration for the SD concept and HEIs without adopting the principles to their own operations and management cannot be possible effectively or realistically [135]. Within this framework, HEIs has responsibilities on the issue which were well-demonstrated in Euromed Management Report [134, p. 10] (See Figure 11).

Table 9: An Intellectual Capital Example from Middle East Technical University (Ankara) [136]

Curriculum Content: Sustainability-related Lessons in Different Departments	
Department Name	**Lessons**
Building science	Principles of green building design and delivery
City and regional planning	Solar energy and urban planning
	Institutional aspects of urban and regional planning
Earth system science	The earth system
	Earth system science: economics and policy
	Sustainable development
	Nature and human use
	Climate change and modelling
	Environment, society and technology
	Energy policy and finance
	Environmental economics
Sociology	Global environmental issues
	Energy, water and environmental policies in and around the European Union
	International environmental law

As in the case with the Sustainability concept, there is no standardized definition of 'Campus Sustainability'. As a matter of fact, universities have been defined what a sustainable campus is for their campuses within the frame of main drivers of the SD concept. Common features included into the definitions have been grouped into 2 [137, p. 5]. First group is 'Ecosystem' which covers the components of air, water, land, materials, energy. Second group is 'People' by which knowledge, community, governance, economy, health topics are considered. Florida State University, for instance, defines sustainable campus as “A sustainable campus is one that develops process or management systems that help create a vibrant campus economy & high quality of life while respecting the need to sustain natural resources and protect the environment. Sustainable programs are those that result from an institution’s commitment to environmental, social, & economic health.” [138]. Apart from that, Konya Food & Agriculture University in Turkey, which has a certificated green campus, defines sustainable campus as “ *‘Green Campus’ defines the education, implementation and communication environment which puts sustainability to the focus point*.” [139].

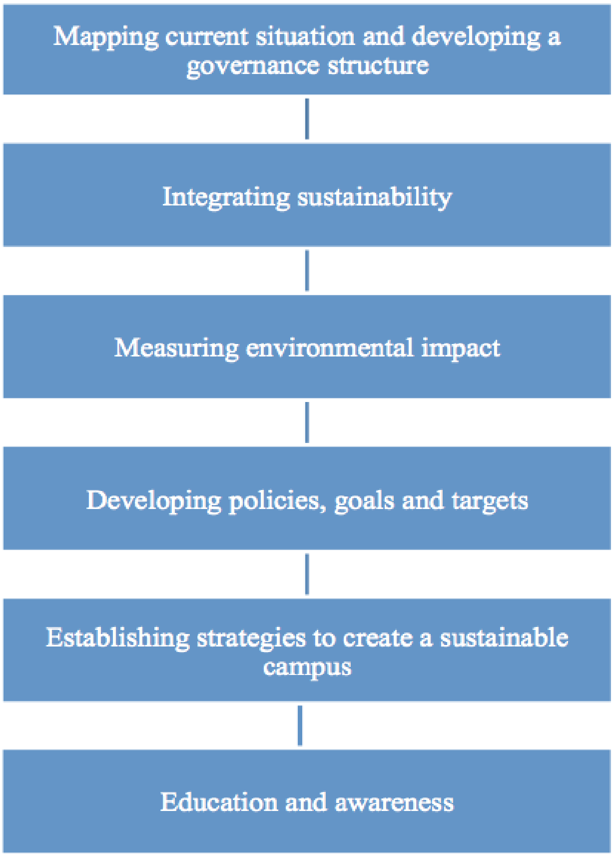

Figure 12: IARU’s 6 steps for university to achieve campus sustainability [140]

However, the steps to be taken that lead a university to have a sustainable campus have been in substantial agreement. Similar or compatible classifications or concerns

have been pointed out in literature. International Alliance of Research Universities (IARU) referred 6 steps in its report [140] (See
Figure 12). On the other hand, Milechin et al. [137, p. 5] referred ‘6 steps that lead to campus sustainability’ (See aşağıda).

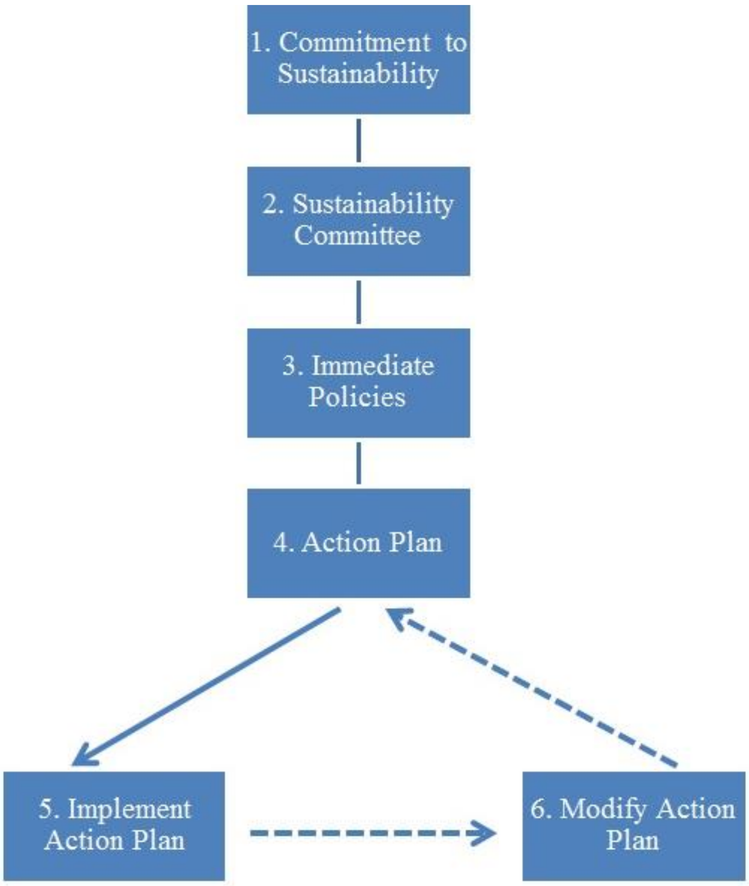

Figure 13: Campus Sustainability steps (Adopted from [137, p. 5])

Since universities are educational centers of intellectual energy and activism and its scale is cut out to implement sustainable methods, campuses have been main subject of the sustainability ideas. In order for a campus to be a sustainable one there must be some vital properties within properties. These properties were classified as 9 titles by Mitchell Thomashow in his book named “*The Nine Elements of a Sustainable Campus*” [141]:

i. Energy

A sustainable campus should reduce greenhouse gas emissions and use renewable energy sources. First step in achieving this is to record data of the energy consumption and production in order to determine greenhouse emission and then secondly an participatory program, which includes as many as campus constituencies as it can, must be put into effects for reducing GHGs and transform energy sources into renewable ones.

ii. Food

Sustainable food services attach importance to local and organic foods. Providing sustainable food services increases food costs and initiate such a program requires participation of campus constituencies and cafeteria staff to be educated. Therefore there must be effective leadership within campus to put into effect such a food action plan.

iii. Materials

Basic idea behind the sustainability of materials is to make them more harmless to the nature and increase their efficiency. Sustainability requires a campus to transform the materials used in campus into sustainable ones and reduce consumption of materials. Similarly, it requires an decisive, participatory action plan cooperating with engineering and chemistry departments.

iv. Governance

As mentioned in the above elements decisive, participatory action plans are essential in transforming a campus into a sustainable one. In order for these action plans to be effective and participatory a transparent governance which take over responsibility and guarantee equity within campus is vital.

v. Investment

In economy terminology investment stands for money spent for an asset in order for it to bring benefit. However an investment's meaning can be expanded. Time, knowledge, talent can be perceived as assets and a sustainable campus should invest time and effort in these kind of assets to promote sustainable implementations and ideas.

vi. Wellness

Fitness, as an indication of wellness, enables species to survive and reproduce in nature. Analogously as a living organism a campus must be fit and well to be a sustainable one. A campus might be a stressful environment, which threatens physical fitness and mental well-being. A sustainable campus must offer facilities, activities and cooperation to relieve this stress.

vii. Curriculum

Curriculum of a university or a college represents its ethos and perceptions. Curriculum committee has responsibility towards not only students but also society, government and all other constituencies of university including family of students. A curriculum of a university whose campus is sustainable must enable its students to comprehend and internalize critical situation about devastation of nature and drive them to prevent this devastation rather than to pursue a successful career.

viii. Interpretation

Interpreting a campus as an ecological place plays crucial role to make a campus a sustainable one since in harmony with curriculum regulation enabling students to observe nature, flora of an ecological place is cut out to motivate students to concern about nature and work hard to protect it.

ix. Aesthetic

In order for a sustainable campus to serve as a model to society, draw attention of regional leaders, enable students to embrace campus and express themselves by means of art of sustainability and to offer an ecological laboratory to people to be in communication with nature, campus aesthetic has a significant role to play.

Figure 14: Green Universities Examples from Turkey: Piri Reis University [142]**; Konya Food & Agriculture University** [139]**; Boğaziçi University** [143] **respectively**

Table 10: Some of the Helpful Resources for HEIs towards becoming Sustainable Campus [144, pp. 57–63]

Some of the Helpful Resources for HEIs towards becoming Sustainable Campus					
International and regional associations	Global Higher Education for Sustainability Partnership (GHESP),	**Online tools and resources**	Charter and Guidelines (ISCN),	**Books and journals**	International Journal of Sustainability in Higher Education (IJSHE),
	University Leaders for a Sustainable Future (ULSF),		Sustainability Tracking and Rating System (STARS) (AASHE),		Solutions,
	Association for the Advancement of Sustainability in Higher Education (AASHE),		Sustainability Assessment Questionnaire (ULSF) ,		Higher Education Quarterly,
	Global University Network for Innovation (GUNI),		Sustainable development on campus: Tools for campus decision makers (IISD),		Journal of Education for Sustainable Development (JESD),
	International Sustainable Campus Network (ISCN),		International Alliance of Research Universities campus sustainability toolkit (IARU),		Perspectives: Policy & Practice in Higher Education,
	COPERNICUS Alliance,		Learning in Future Environments (LiFE) (UK and Australasia),		Campus Ecology, by April Smith and the Student Environmental Action Coalition (1993),
	International Alliance of Research Universities (IARU),		Higher Education Associations Sustainability Consortium (USA),		Ecodemia: Campus Environmental Stewardship at the Turn of the 21st Century, by Julian Keniry (1995),
	Alianza de redes iberoamericanas de universidades por la sustentabilidad y el ambiente - ARIUSA,		Healthy Universities Toolkit (UK),		Greening the Ivory Tower, by Sarah Hammond Creighton (1998),
International agreements and declarations	Talloires Declaration		Good Campus (UK),		Sustainability and University Life, edited by Walter Leal Filho (1999),
	Copernicus Charter,		Sustainable University 21 One-stop Shop (Asitha Jayawardena, UK),		Planet U: Sustaining the World, Reinventing the University, by Michael M'Gonigle & Justine Starke (2006),
	Halifax Declaration,		Sustainable Procurement Centre of Excellence for Higher Education (UK),		Degrees that Matter, by Ann Rappaport and Sarah Hammond Creighton (2007),
	Swansea Declaration,		Environmental Association for Universities and Colleges Resource Bank (UK),		Reinventing Higher Education: Toward Participatory and Sustainable Development (UNESCO, 2007),
	Kyoto Declaration,		Sustainable Development on Campus – Tools for Campus Decision Makers (International Institute for Sustainable Development, Canada),		Financing Sustainability on Campus, by Ben Barlow and Andrea Putman (2009),
					The Nine Elements of a Sustainable Campus, Mitchell Thomashow, (2014)
	The American College & University Presidents' Climate Commitment (ACUPCC),		Virtual Sustainability Platform in Universities,		
	The Scottish Universities and Colleges Climate change Commitment for Scotland		Platform for Sustainability Performance in Education		

There are many fully formed reports being useful source for campus sustainability guidance (See; [145], [144], [146], [147], [140], [148]). There are also recent journal papers have been about campus sustainability (See;[149], [150], [151], [152], [153]). Besides them, there have been significant amount of resources accumulated for campus sustainability topic as seen Table 10. yukarıda information can be deepen from a useful toolkit published by UNEP [144] for greening universities whose main target was to renovate HEIs as becoming green and sustainable campuses.

Some of the global examples for campus greening were listed in Table 11 whose further information could be reached from [144, pp. 67–81]. As one of the case studies around the world, The Middle East Technical University from Turkey was chosen by UNEP to be shown as an successful example for reforestation of campus area [144, pp. 75–76].

Table 11: Global Examples for Campus Greening chosen by UNEP [144, pp. 67–81]

Country	University
Australia	Tyree Energy Technologies Building, University Of New South Wales (UNSW)
Australia	Bond University Mirvac School of Sustainable Development
Brazil	University of Sao Paulo
Brazil	Pontifical Catholic University of Rio Grande do Sul
Canada	Centre for Interactive Research on Sustainability, University of British Columbia (UBC) Vancouver Campus
Canada	University of Northern British Columbia
China	Tongji University, Shanghai Campus Architectural Design & Research Institute
India	TERI University
Kenya	University of Nairobi
Turkey	Middle East Tehnical University
USA	Princeton University
USA	Washington University in St. Louis, Missouri
USA	Harvard University
USA	University of Texas at Dallas

Table 12: Turkish HEIs putting "Campus Greening" on their Agenda

Turkish HEIs putting "Campus Greening" on their agenda		
University Name	**Feature/Activity**	**Source**
Atılım University	Green Campus	[156]
Boğaziçi University	Sustainable Green Campus, 'Net Zero Energy' Project	[154], [152]–[154]
Dokuz Eylül University	Zero Carbon Settlements Lesson	[162]
East Mediterranean University	Sustainable Campus	[157]
Ege University	Green Campus Workshop	[160],[154]
İzmir Institute of Technology	Strategic Plan: Sustainable Green Campus	[155], [159]
İstanbul Teknik Üniversitesi	İTÜ Green Campus Project	[156]
Konya Food and Agriculture University	Certificated Green Campus	[139]
METU - North Cyprus Campus	Green Campus, Green Brain Festival	[157], [158] [158]
Middle East Technical University	Strategic Plan: Sustainable Campus, Sustainable Campus International Competition hosted by METU, METU Sustainable Campus Competition	[159], [160], [159]
Nişantaşı Üniversitesi	First Organic Campus in Turkey	[156]
Piri Reis University	First Green Campus in Turkey	[150], [151]
Sabahattin Zaim University	Sustainable University	[155]
Yeditepe University	Ecology and Sustainability Lesson	[161]

The Middle East Technical University included two significant statements for campus sustainability into '*METU Strategic Plan 2011-2016*' [159]:

> "*Purpose is, by starting "Sustainable and Environmental friendly METU Campus" program, to announce the best implementations at METU campus regarding to its built environment, natural environment and sustainability management from a created website (...)*." [159, p. 50]

> "*Purpose is to improve environmental, social and economic sustainability studies, which is initiated in order for METU to have exemplary sustainable campus, within 'METU Sustainable Campus Project' and to establish METU Sustainable Campus Project office*." [159, p. 54]

Moreover, there have been plenty of studies conducted in METU which have capacity to lead the university campus become greener. Some of those are shown in Table 13.

Table 13: METU Thesis on the Subject that can help making the Campus Greener

METU Thesis on the subject that can help make the campus greener			
Thesis Title	**Year / Type/ Department**	**Main Objective**	**Sources**
"Assessment of Scenarios for Sustainable Transportation at METU Campus"	2013/ MSc / Civil Engineering	"To develop sustainable campus transportation policies, it was important to quantify the current levels of mobility and vehicle emissions within the campus, which was the main motivation behind this study."	
"Domestic Wastewater treatment in Pilot-scale constructed wetlands Implemented in the Middle East Technical University"	2014/PhD/Biotechnology	"To quantify the effect of different filter media on the removal performance of subsurface flow constructed wetlands in the prevailing climate of Ankara."	
"Estimation of Carbon Footprint: A Case Study For Middle East Technical University"	2015/MSc/Petroleum and Natural Gas Engineering	"To create awareness about carbon footprint due to daily human activities and indirectly about the climate change."	
"Multi-criteria Feasibility Assessment of the Monorail Transportation System in METU Campus."	2011/MSc/Industrial Engineering	"To assess the financial, technical and social feasibility of investing in modern Automated People Movers (APM) transportation systems, generally known as monorails, in METU campus which presents a unique opportunity to fulfill the modern-day transportation needs of METU campus."	
"The Dilemma of Flexibility in Spatial Development of Science Parks the Case of METU-Technopolis"	2006/MSc/City and Regional Planning	"The role flexibility in different planning and decision-making approaches is discussed."	

Table 13 continued

"Evaluating Public Transportation Alternatives in the METU Campus with the Aid of GIS."	2005/MSc/Geodetic and Geographical Information Technologies	"To determine a new public transportation mode and route for the METU campus with the aid of GIS by considering the conditions after the new metro route."	
"Sustainable Waste Management in Middle East Technical University-Northern Cyprus Campus"	2014/MSc/ Sustainable Environment and Energy Systems	"To be able to develop o sustainable waste management program"	
"Flora of Middle East Technical University Campus"	2001/MSc/Biological Sciences		
"Hydrogeological Survey of the Middle East Technical University Site"	1963/Geological Engineering		
"University Campus Design: A New Campus for Middle East Technical University in the TRNC: Educational Program and Campus Design Issues "	2010/ MSc/ Sustainable Environment and Energy Systems		

Table 14: METU Sustainable Campus Dreaming: Suggestions made by students in blog 'Sustainable METU' ([161]

METU Sustainable Campus Dreaming: Suggestions made by students in blog 'Sustainable METU'	
To organize the studies according to sustainable campus.	To organize of new competitions like photos, films about sustainable campus.
To educate preschoolers on sustainability on spring festival.	To have sustainable building competition.
To design sustainable places with sustainable transportation tools.	To organize short films about sustainability and showing all campus.
To educate preservice teachers in terms of sustainable campus matters.	To product organic honey on sustainable campus area.
To adapt sustainable campus to other campuses.	To implement TQM (Total Quality Management).
To work for awareness for sustainability.	To organize local food production on campus / Local garden.
Recycling on sustainable campus.	To increase the awareness about sustainability gathering the student clubs' leaderships.

Table 14 continued

To work for awareness of biodiversity about sustainable demo-center.	To organize sustainability week.
To make awareness for production and consumption about sustainability.	To constitute METU scout according to sustainable campus issues.
To improve isolation according to sustainability issues.	To manage mono-rail project in terms of sustainable transportation in campus area.
To create a web-site by means of sustainable matters.	To implement bicycle and pedestrian project for sustainable campus.
To get and keep in touch with sustainable universities to share their experience.	To organize sustainable student society.
To sequester CO_2 from METU heating center by means of sustainable matters.	To manage local energy production according to sustainability tools.
To reduce paper use and waste according to sustainability.	To prepare brochure and children book about sustainability issues.
To organize reuse and recycle the paper to conclude sustainability issues.	To make sub-groups and projects according to sustainability.
To improve online METU system by means of sustainability concerns.	To create a competition/ game like Treasure Hunt to pursue sustainability.
To use rain water by sustainable methods.	To convert one METU bus to run used vegetable oil by means of sustainability.
To plant trees to compensate CO_2 emission for sustainability matters.	To reduce water consumption in terms of sustainable issues.
To improve composting in METU and houses by means of sustainability.	To create a place for hiring bicycles on sustainable campus.
To arrange a program in METU radio including sustainability issues.	To create a sustainable superman character.
To use solar energy to contribute sustainability matters.	To rebuild METU Güneş Evi in terms of sustainability issues.
To use waste for making materials by means of recycling tool of sustainability.	To improve heating system at sustainable campus.
To reduce water consumption in laboratories according to sustainable concerns.	To include sustainability in school books.
To reduce material reduction consumptions in laboratories in terms of sustainability policies.	To create exchange network system by sustainable matters.
To concert your celebration for sustainable policies.	To organize sustainable CUPs.
To organize sustainable camping activities.	To change behavior on technology using in the frame of sustainability policies.
To organize sustainable TÜBİTAK project (camping).	To manage lighting by means of sustainability.
To manage digital databases for thesis by means of sustainability.	To create/increase awareness about sustainability issues on media.
To organize METU currency, LET system in terms of sustainability matters.	To reduce use of nylon on sustainable campus.
To start new courses on sustainability.	To spread use/produce of organic food on sustainable campus.
To manage exchange program between sustainable universities/ METU cloth bags.	To constitute adult education center on sustainability in Ankara.

There were a blog namely '*Sustainable METU*' which was created by METU students. They have been brought together many ideas to make METU campus greener (See Table 14).

A significant attempt was made by METU in 2011. That year, Centre for Science and Society in METU organized a student competition with the aim to create a platform to share ideas for a Sustainable METU Campus -including at least one of discourses of built environment**,** natural environment and management of sustainability**.** The competition encouraged multidisciplinary work of students from different departments/research areas and the output of group work was aimed to be concept development for a sustainable campus [162]. 16 groups of students - 44students in total- took part in competition[163]. Projects ranked among the top three was: 1) '*ReReRe METU*' Project, 2) '*METU-CYCLE*' Project 3)' *Green METU*' Project [164].

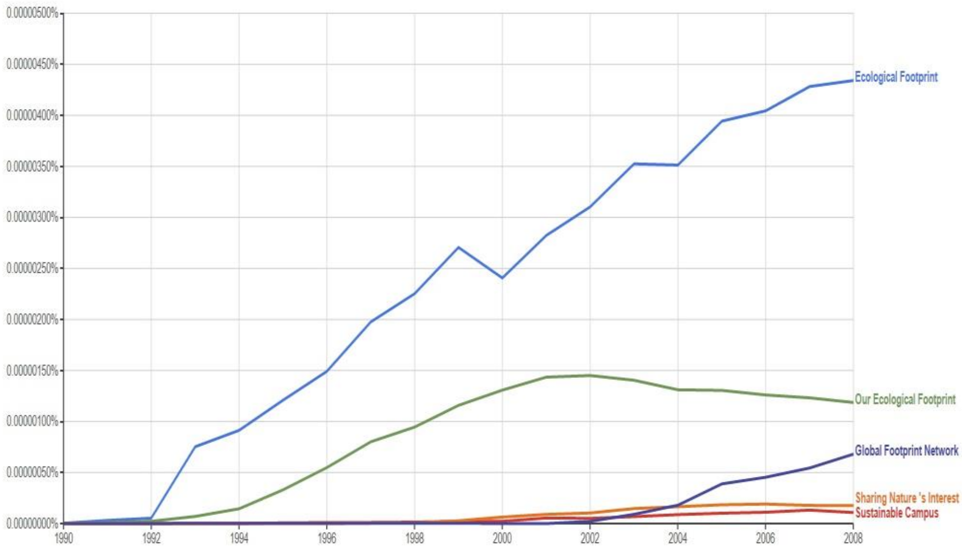

Figure 15: The Graph was given by 'Google Books Ngram Viewer' to show the frequency of the inclusion of certain phrases in books between 1990 and 2008 [165]

Phrases chosen for demonstrating the frequency of their inclusion into books archived as Google Books between 1990 and 2008 were '*Ecological Footprint*', '*Our Ecological Footprint*', '*Global Footprint Network*', '*Sharing Nature's Interest*' and '*Sustainable Campus*'. It is possible to interpret yukarıda graphic as the EF concept gaining more popularity in campus sustainability issues; the ‘Sustainable Campus’ phrase was in books at the end of the 1990s. Moreover, the graph may let doing further research on whether there was a meaningful relationship between publication of the book ‘*Sharing Nature’s Interest’*, -which explain a component-based EF calculation and exemplified its procedures by calculations at regional, local or institutional levels- and ‘Sustainable Campus’ which is way to certify HEIs’ commitment to start or carry on greening their campus. Accordingly, Lambrechts et al. [123, p. 402] determined that “*Performing an ecological footprint analysis also fits within HEIs’ strategy to ‘practice what they preach’, resulting in reports on the ecological footprint of numerous HEIs world-wide.*”.

1.4 Goals and Objectives

The primary objective of the current thesis is to present a preliminary study on a comprehensive quantification of the Ecological Footprint for the Middle East Technical University (Ankara Campus), which is one of the biggest public universities in Turkey. In addition the study aims to be one of the first studies to give ‘*a static snapshot*’[24] of the METU campus’ impacts especially on environment for a target year. This study also sets its goal to investigate possibilities for contributing to campus operations, policy development and educational curricula in becoming a sustainable campus. The objectives of this thesis are also in line with the *2011-2016 METU Strategic Plan*[25], where one of its strategies is to become a sustainable campus.

A significant side objective is to determine how sustainable campus operations are in terms of sustainability. Thus, as possible follow up, METU administration may make decisions to accelerate and deepen its agenda of greening the campus.

The institutional Ecological Footprint calculation is expected to provide METU an opportunity to contribute a systemization of monitoring the university’s sustainability

[24] See [123, p. 405]
[25] See [159, p. 50,54]

performance and to assert her environmental accounting worldwide in line with the strategy to green the campus[26].

This study is also expected to help lead to further studies in other universities that aim the greening of their campuses. However, this preliminary study should neither be expected to be used sufficient as a stand-alone source or an indicator for any kind of policy references or should be used for heavy criticism towards the METU.

[26] See [63, p. 91]

CHAPTER 2

2. METHODOLOGY AND MATERIALS

2.1 The Study Area: Middle East Technical University Ankara Campus

Middle East Technical University (METU) possesses 3 campuses with 43 Undergraduate, 111 Master programs and 67 doctoral programs. The main campus is located in Ankara; the others are located in Cyprus and Erdemli (Mersin). The university has comprehensive educational, social and cultural structure. It has equipped laboratories and universal libraries with several opportunities. The instructors in METU do a doctorate at leading universities in worldwide. There are 418 research and training laboratories, 43 research centre, and also 302 R&D companies in METU techno polis. The METU is the only “high level” university in Turkey which was ranked by institutions of Times Higher Education, QS, Webometrics, HEEACT, URAP and Leiden. METU is the head of the one of three of the European Union projects that Turkey is participated. The total budget of the 107 European Union projects in METU is 284 million euros. The language of instruction is English.

METU campus which is located in central Anatolia region of Turkey with 39.8914° N, 32.7847° E coordinates. Total population of the campus is 28,715 in 2012. At the same year 5195 students reside in 18 dormitories in Ankara. This is the first university in student satisfaction ranking in Turkey (Newsweek Turkey- vol. 91). There 96 student clubs and 37 sport teams in METU.

The study area of the current thesis was determined as METU Ankara campus and Eymir Lake area. Techno polis area has an autonomous characteristic in terms of its governance. Only waste collection of techno polis area has been made by METU central administrative unit. Thus, except waste calculation techno polis area was excluded from the study area. On the other hand, METU has been responsible for management of Eymir lake area.

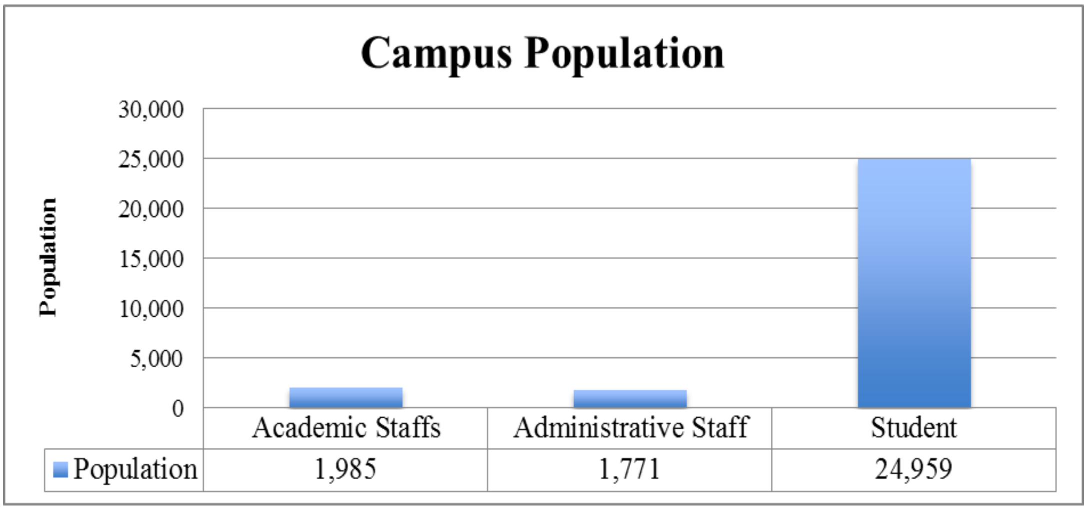

Figure 16: METU Campus Population [166]

The METU Ankara campus is 4350 hectares land with the forest area of 3043 hectares, including the Lake Eymir. It contains over 33 million trees, 500 species of wild flowers, 23 species of mammalians, 9 species of reptiles, 126 species of butterflies and 226 species of birds. METU is the oxygen source of Ankara with these properties. METU forest with natural wealth is the grade 1 natural site area. Furthermore, significant part of forest is grade 1 archaeological site area due to accommodation of several antiquities.

In 1958 forestation project was initiated within METU campus. As a result of this project METU has become the most important green space of Ankara. Within re-forestation program every year 20,000 trees have been planted by students, stuff and alumni. As a result, ¾ of the METU campus have been forested. 3000 hectares of land consist non-irrigated plants. A further 800 hectares of irrigational plants around the built environment and the pedestrian network are irrigated. The landscaping of METU received the Aga Khan Award for Architecture in 1995. This project has made possible the creation of suitable habitats for several species of mammals, birds, fish and butterflies, including some rare endemics.

Not only those who live in METU campus, but also Ankara residences benefit from environmental services which METU forest areas offers. The METU green space act as a noise and wind filter and stabilizes microclimate, presumably making nearby parts of the city much more sustainable and liveable. A UNEP document mentions METU among good examples around the world in its '*Greening Universities Toolkit*' and states that *"Specific research on heat island in and around Ankara has shown beneficial cooling effect around METU campus"* [144].

Sustainable design principles were the basis of the built environment in the campus and this is also reflected in the utilization of local construction materials. There is a current initiative for ecological planning and management of the campus land, by making sure the integrity of the campus is maintained, its natural wealth is protected and improved, and an active protection and education system is established and put into practice.

2.2 General Approaches used for Calculating Ecological Footprint

Since the thesis study aim is to calculate the Ecological Footprint of a university campus, the scale is of concern is institutional. As many authors and practitioners pointed out (See page 12) component-based EF methodology is considered to be more convenient and advantageous for a study of this scale and with this main objective.

Main logic behind the EF calculation can be formulized as below[67, p. 13]:

EF (gha) = [[Quantity (t) / Yield (t/ha)] x Yield Factor (wha/ha) x Equivalence Factor (gha/wha)]

Using local data as much as possible is a crucial point for calculating more valid, actual or applicable Ecological Footprint value. For this thesis study, Global Footprint Network has been requested for license [167] to get ' *National Footprint Accounts 2014 edition- Turkey-data for 2010*' data set [168]. The latest version for Turkey-specific yield and equivalence factors were taken from that GFN data set (Table 15 and Table 16).

Many components were needed to examine in two parts for obtaining total EF value of them. Besides direct land use area requirement, production of any good raises the need for the CO_2 sequestration land. At this point, organizations' purpose determines the scope of life cycle boundary (See Figure 7). In this study, some of the additional values such as 'uplift factor', 'embodied energy' were used to include the effect of 'outside' activities occurring to resume component-based features within the study area.

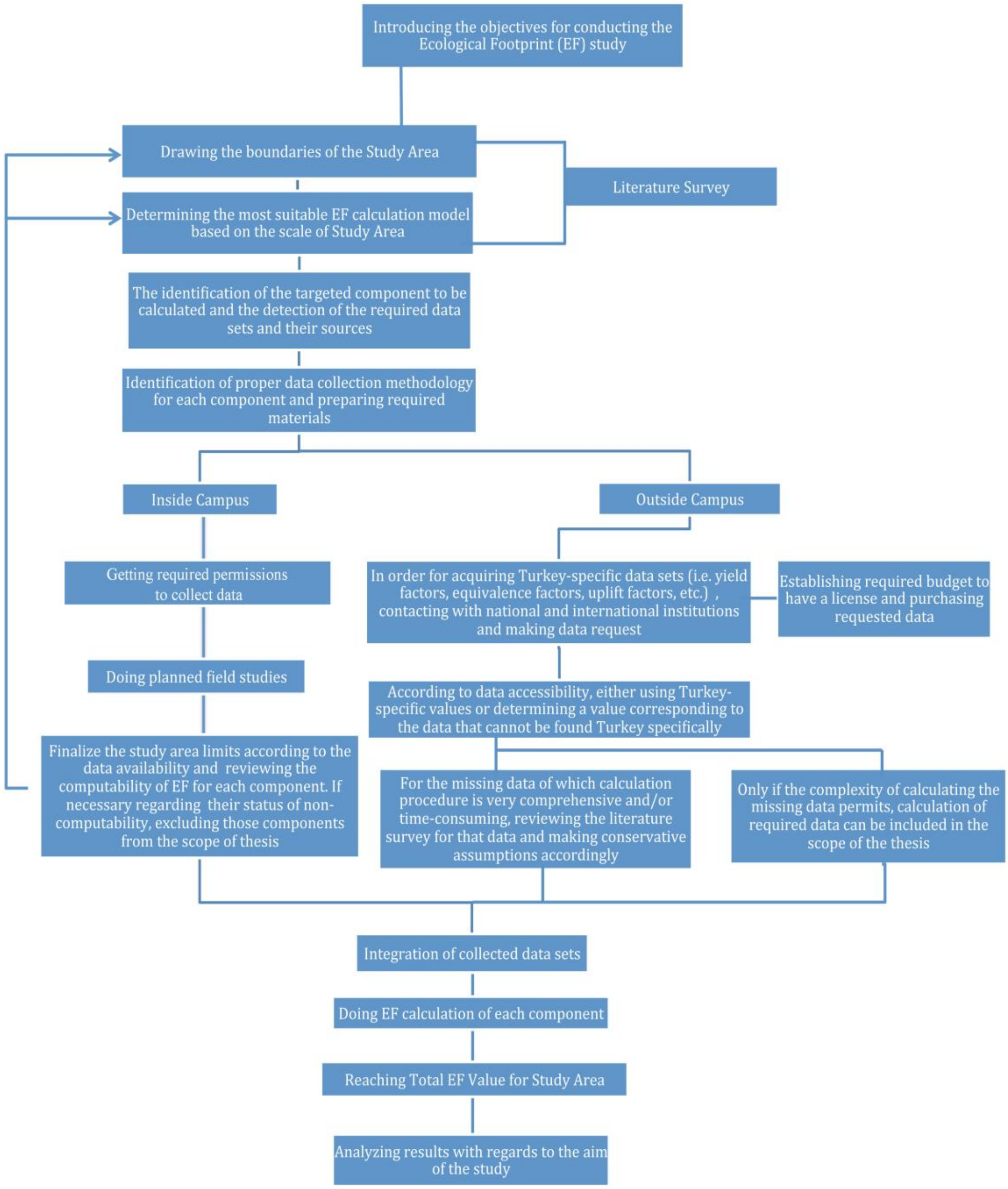

Figure 17: General Methodology of the Current Thesis

Table 15: Equivalence Factors for Turkey (adopted from [168]**)**

Land Use Type	**Equivalence Factor [gha /wha]**
Cropland	2.51
Forest Land	1.26
Grazing Land	0.46
Marine	0.37
Infrastructure	2.51
Inland Water	0.37
Hydro	1.00
Carbon	1.26

Table 16: Yield Factors for Turkey (adopted from [168]

Land Use Type	**Yield Factor [gha /ha]**
Cropland	0.76
Grazing Land	1.32
Marine	1.43
Inland Water	1.00
Forest Land	1.63
Infrastructure	0.76

For instance, embodied energy defining as an indirect energy requirement to produce a good or cultivate a crop, etc. was included in many calculations in the thesis. This indirect energy causes additional CO_2 emission and that CO_2 sequestration land area requirement.

Table 17: Calculation procedure for obtaining "required CO_2 sequestration land area" from "emitted CO_2”

Calculation procedure for obtaining "required CO_2 sequestration land area" from "emitted CO_2 "	
CO_2 sequestration land area =	CO_2 (tonne) x CO_2 to C ratio (tC/tCO_2) x (1-Ocean Absorption Rate per ton) / (Forest Sequestration Rate (tC/ha)) x (Forest Equivalence Factor (gha/ha))

The calculation methodology of obtaining CO_2 due to consumption is different for each component. However, when the total amount of CO_2 is calculated, calculation procedure for obtaining "*required CO_2 sequestration land area*" from "*emitted CO_2* " is the same. In order to subtract the absorbed or sequestrated amount of the CO_2 by the ocean and forests from the total amount, '*Ocean Absorption Rate*' and '*Forest Sequestration Rate*' were used.

Table 18: Carbon Constant Values (Adopted from [168]**)**

CO_2 to C Ratio (tC/tCO_2)	0.27
Forest Sequestration Rate (tC/ha)	0.97
Ocean Absorption Rate per tone	0,28

Finally, after converting the remaining amount of CO_2 to Carbon in order for calculating ecological footprint of relevant component in a unit of global hectare, Turkey-specific forest equivalence factor was used.

ENERGY

In order to calculate Energy Footprint of METU campus for the year of 2012, the total electricity consumption data and the amount natural gas combustion used for heating purposes data were collected. Required data sets were gathered from *Office of Electrical Works*[27] and *Office of Central Heating and Water Support*[28] which are the administrative units participating in campus operation processes.

<u>Electricity Data</u>: The University fulfil all the electricity need from the Başkent Electricity Distribution Incorporated Company which is the main electricity supplier in Ankara [169]. Table 19 shows the total electricity consumption by month for the fiscal year 2012. In order to calculate EF of electricity, data given at Table 20 were also needed. Due to losses during transmission and distribution processes an even higher amount of electricity needs to have been produced than consumed. Including expected loss percentages provides the actual amount of electricity required in a year. Such losses also impact the actual amount of Carbon Dioxide emitted to the atmosphere due to the use of electricity.

[27] After ensuring the necessary conditions (i.e. applying for the written permission from the *Secretary General* to gather required information), the data was applied by hand-delivered and received by e-mail (ozbal@metu.edu.tr)
[28] After ensuring the necessary conditions (i.e. applying for the written permission from the *Secretary General* to gather required information), the data was gathered by personal communication (face to face meeting) with İlhan Sepin, Head of the Unit (sepin@metu.edu.tr).

Table 19 : METU Ankara Campus' Monthly Electricity Consumption [27]

Electricity Consumed in 2012 Year	
Month	**KWh**
January	2153835
February	2779637
March	3022918
April	3486294
May	2895599
June	3148415
July	2637553
August	2027924
September	2228010
October	2552020
November	3101233
December	4008955
Yearly Total	**34042392**

The value of '*CO_2 emissions per kWh from electricity generation for Turkey*' was provided in by the International Energy Agency [170, p. 110] and used to calculate the amount of CO_2 produced for the total electricity consumed. Next step to be deducted is the absorbed or sequestrated amount of the CO_2 by the ocean and forests from the total amount. Finally, after converting the remaining amount of CO_2 to Carbon in order for calculating ecological footprint of electricity in a unit of global hectare, Turkey-specific forest equivalence factor was used (See Table 15).

Table 20: Other Data Used for Process of Calculating the Electricity EF

Data	Value/Unit	Reference
CO_2 Emissions per kWh from Electricity Generation for Turkey (2011)	472 (gr CO_2/ kWh)	[170, p. 110]
The Loss and Leakage Rate, Başkent Inc. (2012)	8.67 (%)	[171]
Transmission System Losses (2012)	2.7 (%)	[172]

Natural Gas Combustion Data: Natural gas is consumed for heating purposes. The data provided (İ. Sepin, pers.comm.) did not cover some parts of the campus[29],

[29] Since the study area was defined as to be excluded the technopark site, any data includes the information or data of this site (See 2)

namely ODTÜKENT Lodgings and Guest House 3. These dwelling units have non-central private use of Natural Gas for heating purposes. In order to estimate natural gas use at those units sketches showing the general plan of lodging types [173] and the number, type and total area of the units with natural gas heating boiler were obtained (See Table 10).

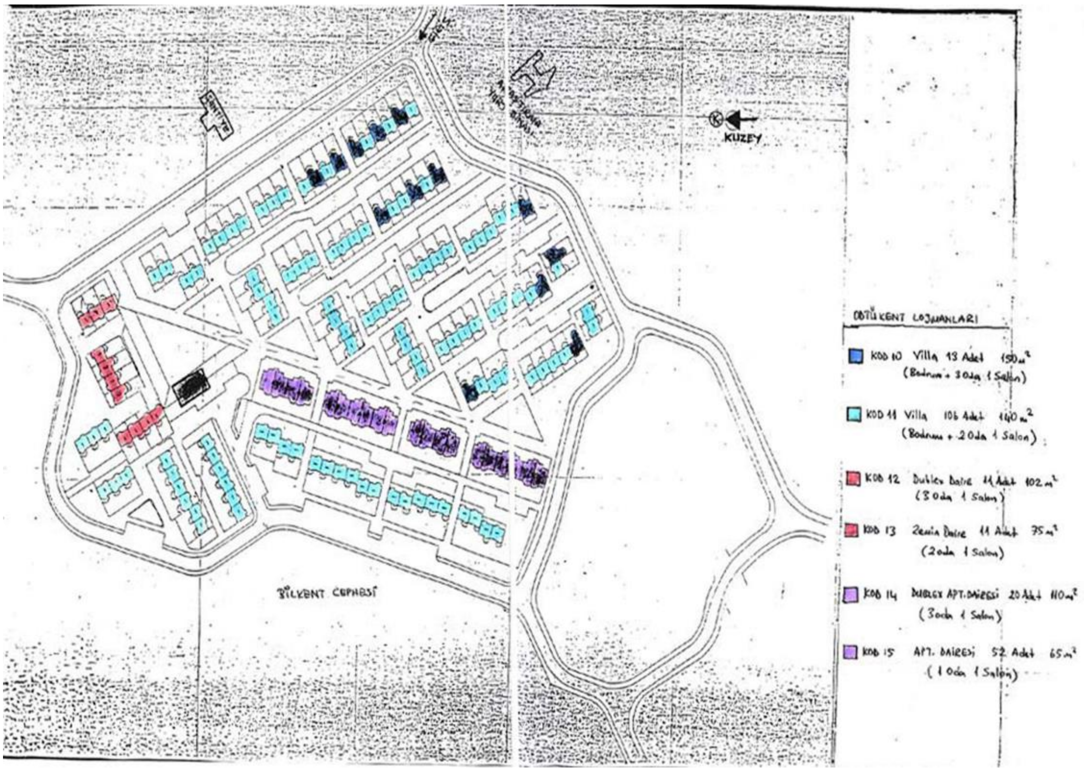

Figure 18: ODTÜKENT General Plan [174]

However, no data was archived for the annual natural gas consumption for heating (and cooking) purposes in those dwelling units. Such lodgings and guest houses are allocated to academicians (faculty members & their families and research assistants), which make it difficult to track data. In order to overcome this deficiency, information on:

i. On average how much natural gas is consumed annually for each unit or in total.
ii. Whether all units were occupied or there were also some vacant (not in-use) dwelling units in 2012.

iii. Whether they were living in those units all year round for the year of 2012 (i.e. some occupants have their own houses usually away from the campus and they may stay there alternately according to their schedule).

need to be collected. Since an additional survey could not be carried put within the limited resources of this thesis work, the calculation of the EF due to heating was not included for the private use, but only for central use.

Table 21: The Dwelling Units with Natural Gas Heating Boiler at the ODTÜKENT [175]

Type[30]	**Number of Housing Units**	**Area (m2)**[31]
Lodging, 15	52	65
Lodging,14	20	110
Lodging,13	11	75
Lodging,12	11	120 (130)
Lodging,11	106	120 (140)
Lodging,10	13	120 (160)
Lodging,16	12	120 (154)
Lodging,17	12	120 (147)
Lodging,18	12	120 (130)
Lodging,19	12	120 (127)
Guest House	8	99 (98.40)
Guest House	16	92 (91.50)
Guest House	8	88 (87.50)
Total	**293**	**1119**

As for the natural gas consumption subject to the central boiler system heating[32], the provided data (See Table 21) and the data shown in Table 22 were used for creating a factor to compute released CO_2 amount in tonnes from the total natural gas consumed in cubic meters.

Table 22: Other Data used for Process of Calculating the Natural Gas EF (Heating)

[30] In order for the detail and representations for the type, see [173], [174]
[31] Each value shown in parenthesis represents 1 different-sized unit area in that group, which was not included into calculations.
[32] Further information could be reached from [182, pp. 54–64] and [187]

Data	Value	Reference
CO_2 Emissions from Natural Gas Combustion (2011)	85.7 (million tons of CO_2)	[170, p. 59]
National Natural Gas Consumption Value (2011)	44.1 (million m3)	[176, p. 71]

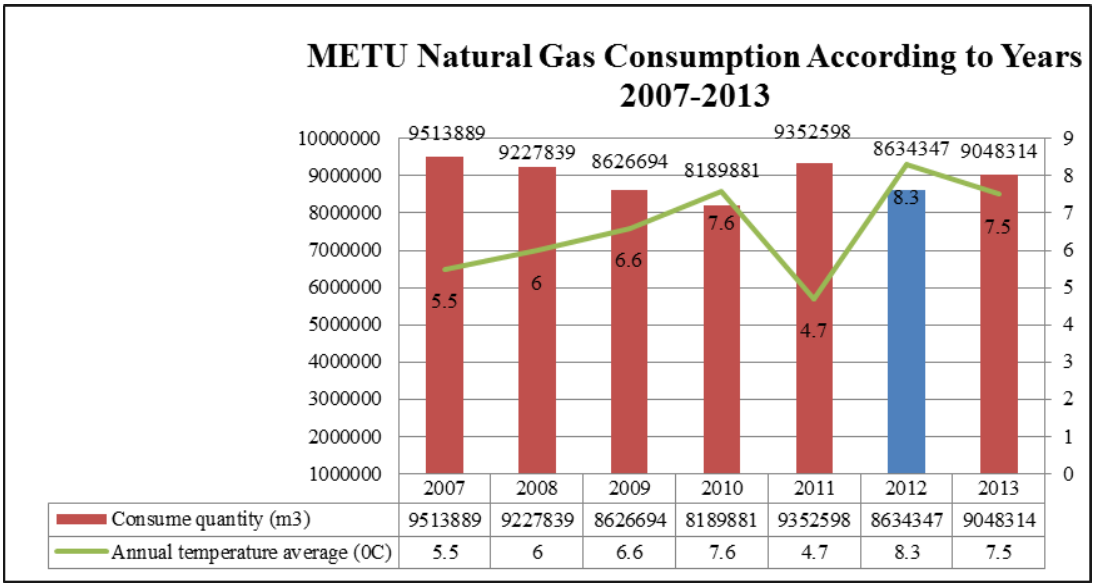

Figure 19: METU Natural Consumption by Year28

Next step to be deducted is the absorbed or sequestrated amount of CO_2 by the ocean and forests. Finally, after converting the remaining amount of CO_2 to Carbon, the country-specific forest equivalence factor was used for EF calculation (See page 97).Ecological Footprint of Energy

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TRANSPORTATION

1. Materials and Methodology for calculation of annual carbon emission and fuel consumption resulting from driving private vehicle

Following literature survey, necessary data was identified based on works by UTM [177], BCIT [83] and Carragher [66] and was requested in writing from University Vehicle Management Directorate and the Traffic Authority. Some type of data such as type of vehicle or motor volume are never collected; furthermore, owner's addresses and other contact information were not shared due to privacy reasons. Thus, the next alternative was to go for survey work and reaching a 5% in terms of sample size was intended. Following the necessary permits, an web-based survey was created using the Survey Monkey software and the link was communicated by email to the department secretariats, administrative and academic authorities. On 20.10.2014 it was requested for 2012 sticker users to participate in the survey; the survey lasted two full months. 343 users responded to the survey, which corresponds to 4% of the 8.438 users with 2012 stickers. Due to lack of information on vehicle type, address, or inconsistent answers 27 questionnaires were excluded from calculations, resulting in 316 valid questionnaires.

The survey requested following types of information:

- Number of days car trips were made to the campus in a week
- Origin point of trip (typically the responder's house)
- Changes in home address during 2012, if so information on the new location and date
- Age of vehicle, brand and type of fuel
- Changes in vehicle type in 2012, if so information on age, brand and fuel type of new vehicle

These information were used to calculate the distance from METU President's Office using Yandex map to the Mukhtar headquarters in relevant neighbourhood where the user lived. Depending on their location in the city, a route with shortest distance to the campus was estimated. Based on the information provided by the users on vehicle type, brand, model, engine options and carbon emissions per kilometre was found using the web page [178] and [179] tool.

Table 23: Grouped Questionnaire sample and fuel consumption and CO_2 emission values estimated

Group	Commuting frequency to and from METU	District	District distance (km)	Vehicle brand /model /age	Fuel type	CO_2 Emission (g/km)	Fuel Consumption (100 km.)
Academic Staff	A)Everyday	100.yıl / All year	2.2	Opel Astra Classic 2013 Model	Gasoline	151	9.6

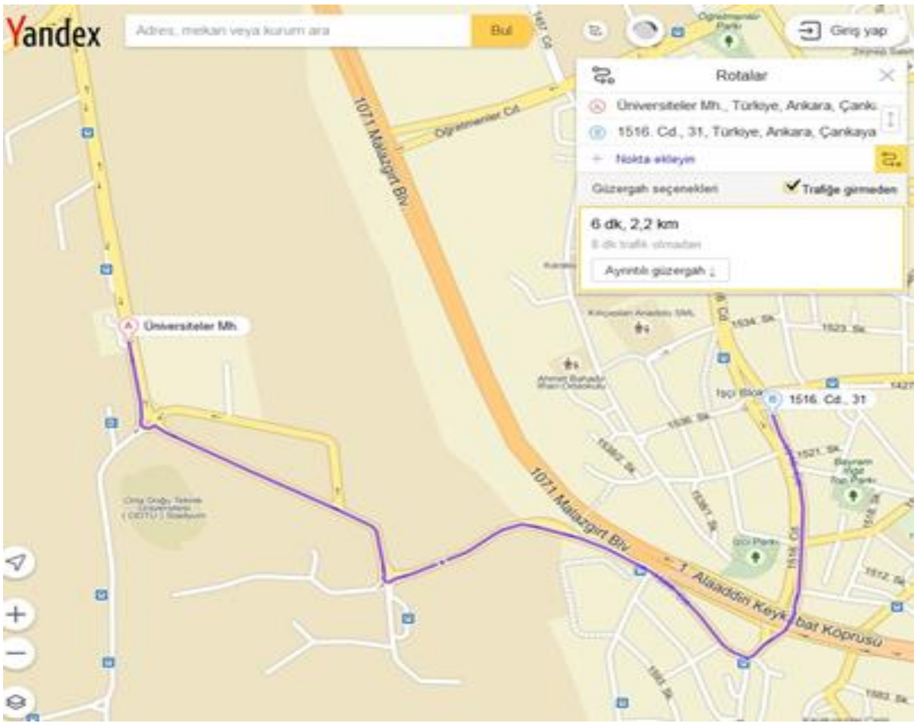

Figure 20: Sample Distance Measurement and Route Estimation by using Yandex Maps

As an example, if the user lives at the 100. Yıl district, the distance between the Mukhtar's office and President's office was calculated as 2.2 km. If the vehicle is an Opel Astra Classic, [178] reveals 151 g/km of CO2 emission from this vehicle using regular gasoline.

In building up [178] and[179], the average fuel consumption of vehicles' were taken from relevant company websites. Similarly, vehicles' fuel consumption data were obtained from the car companies' own websites and [180]. Considering vehicle model and engine type, an urban fuel consumption rate was obtained. For instance, in the Table 23, Opel Astra Classic 2013 Model using gasoline fuel was denoted that it has urban fuel consumption of 9.6 litres per 100 km.

As pointed out earlier, carbon emissions are calculated on a weekly basis. In this case, the user reports visiting METU campus every day, which makes 14 trips and 30.8 km's per week with a total estimated fuel consumption of 2.96 litres. Since the emissions per km for the vehicle is 151 grams, the weekly emissions from this user will be 4650.8 grams.

Calculation of population and activity rate

Interviews, reviews and resources acquired revealed that the population in the campus varies during the year. Since both academic and administrative staff have annual leaves and since students do not always reside at METU it was necessary to calculate an "activity rate" for the population of the campus on a monthly or weekly basis. This was done through assumptions on annual leaves and students visits. For this assumption to be made in an informed manner, a review of the Academic Calendar and 2012 METU activity plan, as well as interviews with the Personnel Department and with academic and administrative staff were carried out. Table aşağıda shows the activity rates estimated in this manner. The activity ratio of the months except the ones shown in Table 24 was assumed as 1 (i.e. everyone of that category attended job or school). Then, the number of operating vehicles in a certain month was acquired by multiplying activity ratio of that month with the number of vehicles.

Table 24: Monthly Population Activity Percentages

Month/Group	February	July	August	September
Administrative Staff	0.95	0.75	0.40	0.85
Academic Staff	0.90	0.70	0.60	0.80
Students	0.05	0.32	1.00	0.20

Carbon Emissions Estimate

Carbon emissions are based on the survey information provided by each participant and information on privately owned vehicle specifications. Total weekly travel distance was initially calculated based on users' weekly data on the frequency and location of travel.

Carbon Emissions = (Distance to and from campus (km)) x (weekly trip frequency (days)) x (specific emission factor of the vehicle (gr/km))

Fuel Consumption Estimate

Fuel consumption estimation is based on the survey information provided by each participant and information on privately owned vehicle specifications. Total weekly travel distance in kilometres was initially calculated based on users' weekly data on the frequency and location of travel. This value was then divided by 100 and multiplied by factory level fuel consumption value (per 100 km) to reach a value in litres.

Fuel Consumption = (Distance to and from campus (km)) x (weekly trip frequency (days)) x (specific fuel consumption (lt/100km)) / 100

Carbon emission value of the vehicles using LPG can be calculated by comparing the value of the vehicle fuel consumed per litre. Nevertheless, this can be misleading because each LPG brand show different values of fuel consumption and carbon emissions of various brands of LPG equipment installed in the same vehicle have different values. Therefore, LPG vehicles in estimating carbon emissions and fuel consumption were treated as if they ran on gasoline.

Creating Ratio on the Carbon Emissions and Fuel Consumption

The methodology is as follows:

1) In order to calculate the total carbon and fuel consumption figures of total number for vehicles with METU stickers in 2012, ratios were calculated based on the survey results.
2) Monthly and weekly campus population was estimated using the information on academic, administrative staff and students' time spent in the campus.
3) Carbon emissions and fuel consumption estimations, based on the information given by each participant in the above mentioned survey, were individually calculated to reach the total value.

4) Diesel and gasoline use for academic, administrative staff and students were grouped. Gasoline surveyed and the total number of vehicles in the relevant group with the number of users' type in diesel vehicle carbon emissions by dividing the average value and average fuel consumption value is calculated.
5) Survey respondents were extrapolated in terms of fuel and sticker type to the total number of vehicles in the Campus in each sticker type.
6) It was assumed that survey respondents show same distribution as the overall campus distribution to reach below distribution based on sticker (i.e. academic, administrative and student) and fuel type (i.e. gasoline, diesel).

Table 25: Estimated Total Gasoline and Diesel Vehicles based on Sticker Type

	Total nuber of vehicles with sticker	Number of Vehicles in the Survey	Gasoline Car Ratio According to a survey	Diesel Car Ratio According to a survey	Total Estimated Gasoline Vehicles on Campus	Total Estimated Diesel Vehicles on Campus
Academic	3316	117	0.68	0.32	2267	1049
Administartive	1941	37	0.62	0.38	1207	734
Student	3181	162	0.67	0.33	2140	1041

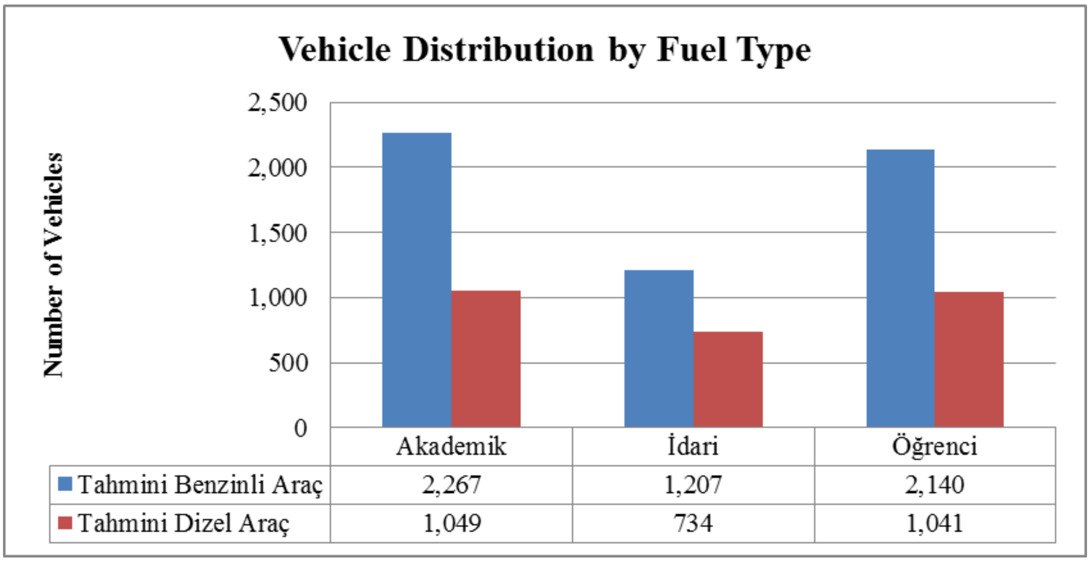

Figure 21: 2012 Vehicle Distribution Based on Sticker and Fuel Type

Total carbon emissions and fuel consumption in the campus were calculated using the estimated distribution presented in Figure 21.

2. Materials and Methodology for calculation of annual carbon emission and fuel consumption resulting from using semi-private and public transportation

TAXI[33]

VIP taxi stand cantered in Mustafa Kemal District serves inside the METU campus. All the vehicles registered in the stand has vehicle tracking system (VTS). Owing to the VTS, data concerning location, daily mileage, route and number of voyages in which vehicle has carried passenger is able to be followed. The following information is gathered via interview with chief of above mentioned stand.

There are 110 vehicles registered to stand 25 of which serve inside the METU Campus. 10 of them are assigned in Dormitories region, 10 in Cultural and Convention Centre and 5 are touring freely.

Each vehicle is driven 200-210 km daily in average. While the number of tours vehicles carrying passenger becomes 20-25 during off-peak periods like summer vacation, it reaches up to 600-700 in education season. At the most intense periods (registration period and periods just before vacation), the number of passenger using taxi becomes 1000. The last but not the least, the most intense day of week is declared as Friday.

80% of journeys are intra-campus, 10% of them are from campus to Yukarı Ayrancı and 10% are through the other regions. The longest distance is informed as the ones from the campus to Airport and it is comprehended that this kind of journey occurs at organization times like conference, exhibition etc.

The second longest distance after airport is Batıkent and this kind of voyages covers only 2% of total voyages.

The brand of vehicles serving in METU Campus is Hyundai Accent at the ages between 0-5. The oldest ones are from 2007. Furthermore, all mentioned vehicles are using LPG type fuel. In that vein, the fuel combustion values of vehicles are taken from [180], while carbon emission amounts are taken from [178].

DOLMUSH

[33] Taxi is considered as a semi-private mode of transportation.

Dolmushes are serving as a shuttle bus between campus and Kızılay, Ulus and Ayrancı districts. The data collected differs according to districts. Because of Dolmushes not having VTS system, the information is taken orally from drivers and staff responsible for voyages' navigations.

i. Kizilay Line

51 vehicles each of which has 14-person capacity are assigned for the shuttle between METU campus and Kizilay. Each vehicle takes at least 4, at most 5 stroll daily including vocation times. The number of passengers has no effect on tour amounts.

Round trip is 37 km long (Yandex map).

Average number of passengers carried in a tour is 20. The amounts of passenger carried during vocation times are 30% of education times.

6 months of year is determined as an active period.

ii. Ulus Line

8 vehicles each of which has 14-person capacity are allocated for being the shuttle between METU campus and Ulus.

Each vehicle takes at least 3, at most 4 stroll daily including vocation times. The number of passengers has no effect on tour amounts.

Round trip is 24 km long (Yandex map).

Average number of passengers carried in a tour is 20. The amounts of passenger carried during vocation times are 50% of education times.

6 months of year is determined as an active period.

The ages of vehicles used are between 0-7.

iii. Ayrancı Line

10 vehicles each of which has 14-person capacity are allocated for being the shuttle between METU campus and Ayrancı.

Each vehicle takes at least 8, at most 9 stroll daily including vocation times. The number of passengers has no effect on tour amounts.

Round trip is 19 km long (Yandex map).

Average number of passengers carried in a tour is 20. The amounts of passenger carried during vocation times are 50% of education times.

6 months of year is determined as active period.

The brands of all vehicles are assumed as Ford Transit. The fuel consumption and carbon emission values of Dolmushes are taken from [181].

METU SERVICES

Information from 2012 are attained from the Directorate of Transportation Affairs of METU. In this way, the information like daily mileages, voyage number, route starting and ending points, the days of service throughout the year are collected for 41 services. All the 41 services are assumed to operate full capacity throughout the year. The vehicles serving for services are 44-year old O 302 Mercedes. The fuel type for all vehicles is diesel. Under the light shed by these information, the fuel consumption value is taken from [182, p. 30]

SHUTTLE BUSSES

According to their routes, Shuttle busses operating in 2012 were classified as red, yellow and grey. Moreover, there are 4 more shuttle busses having route between METU campus and Bus terminal (See Figure X). Information concerning Shuttle busses is also taken from Directorate of Transportation Affairs of METU. The kilometres of distance covered by shuttle busses are acquired directly. The Shuttle busses have same features services have. Consequently, carbon emission and fuel consumption amounts are same.

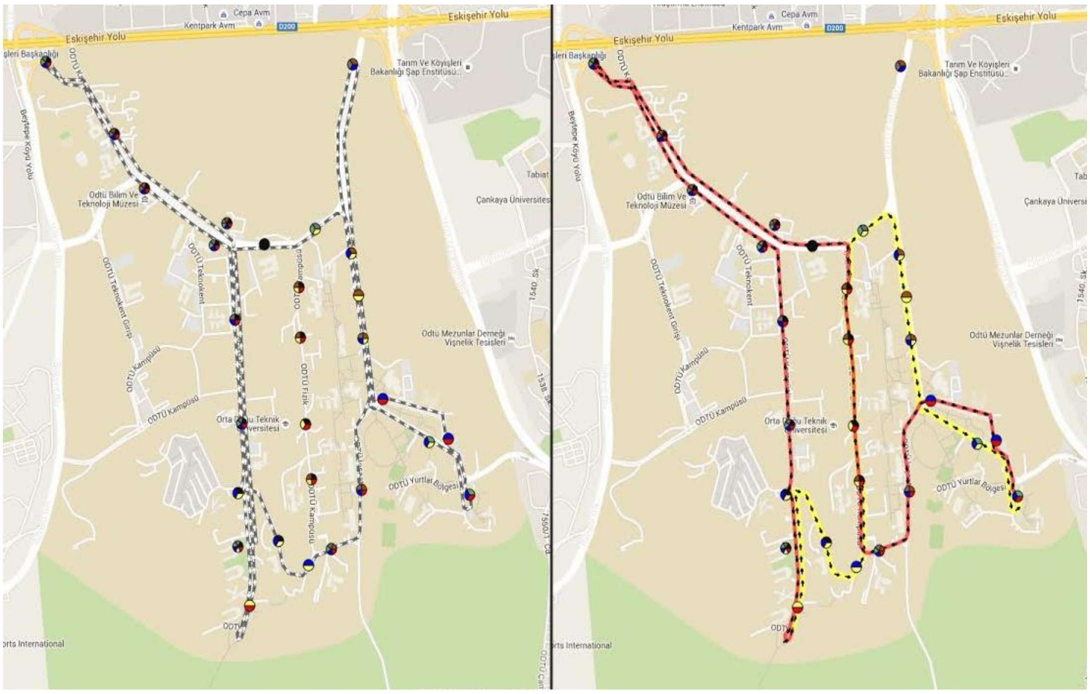

Figure 22: Red &Yellow and Grey Routes of Shuttle Busses

<u>PUBLIC BUSSES</u>

In 2012, 12 public bus lines operated by Ankara Metropolitan Municipality, called EGO busses, were carrying passenger from various districts to METU Campus bidirectional. Following data given in Table 26 were taken from [183].

Table 26: 2012 data of EGO buses having bidirectional services to METU Campus

Route No	Destination to METU starting point	Distance (km)	No of voyages in weekday	No of voyages in Saturday	No of voyages in Sunday	Total kilometres per week
117	Dikmen	13	1			130
132	Çukurambar	33	50	41	20	20526
133	Çukurambar	33	10	10	7	4422
198	Kızılay	18	5			900
206	Yenimahalle	27	3			810
232	Batıkent	27	4			1080
319	Bağcılar	16	2			320
323	Ege Mahallesi	48	2			960
406	Keçiören	41	2			820
417	Aktepe	41	46	36	34	24600
423	Subayevleri	35	2			700
544	Eryaman	89	2			1780
					TOTAL	57048

3. The EF calculation method for each mode of transportation

Even if the material& method process for each group differs during the calculation process of carbon emission amount, the following procedure is followed for EF calculation after this point:

i. The amount of CO_2 produced owing to fuel consumption by vehicles was calculated.

ii. Next step is to include an uplift factor to the calculations in order to reach total carbon emission due to using a vehicle.

iii. After that point, remain steps were parts of standard calculation procedure which selected for quantifying the required land area of CO_2 sequestration. First, the absorbed or sequestrated amount of the CO_2 by the ocean and forests were deducted from the total amount. Second, the remaining amount of CO_2 converted to Carbon. Finally, in order for calculating ecological footprint of transportation in a unit of global hectare, Turkey-specific forest equivalence factor was used.

Uplift Factor: There is an additional energy need occurring due to manufacturing and maintenance of vehicles& roads [66, p. 170]. The carbon emissions arising out of this '*indirect energy*' needs should be included in calculations. Uplift Factor provides an inclusion so as to reach a final carbon emission value used in EF calculations. However, Turkey-specific uplift factor cannot be found. Therefore, a higher value was chosen from the literature [66, p. 170] in order to make a conservative assumption (See page 87).

FOOD

After doing literature survey and preparing a questionnaire which includes proper examples (See [83], [184]) fitting the current studies about EF calculation, required data set about food consumption in METU campus was obtained. Except the main campus in Ankara city centre, cafeterias and restaurants in Eymir Lake land was also included to the questionnaire. Even though Eymir Lake is apart from METU campus, it is included METU land and METU is responsible from its maintenance, so its electricity, water and other consumptions are included in METU consumption. Therefore, restaurants and cafeterias in Eymir Lake land are also included in the survey area.

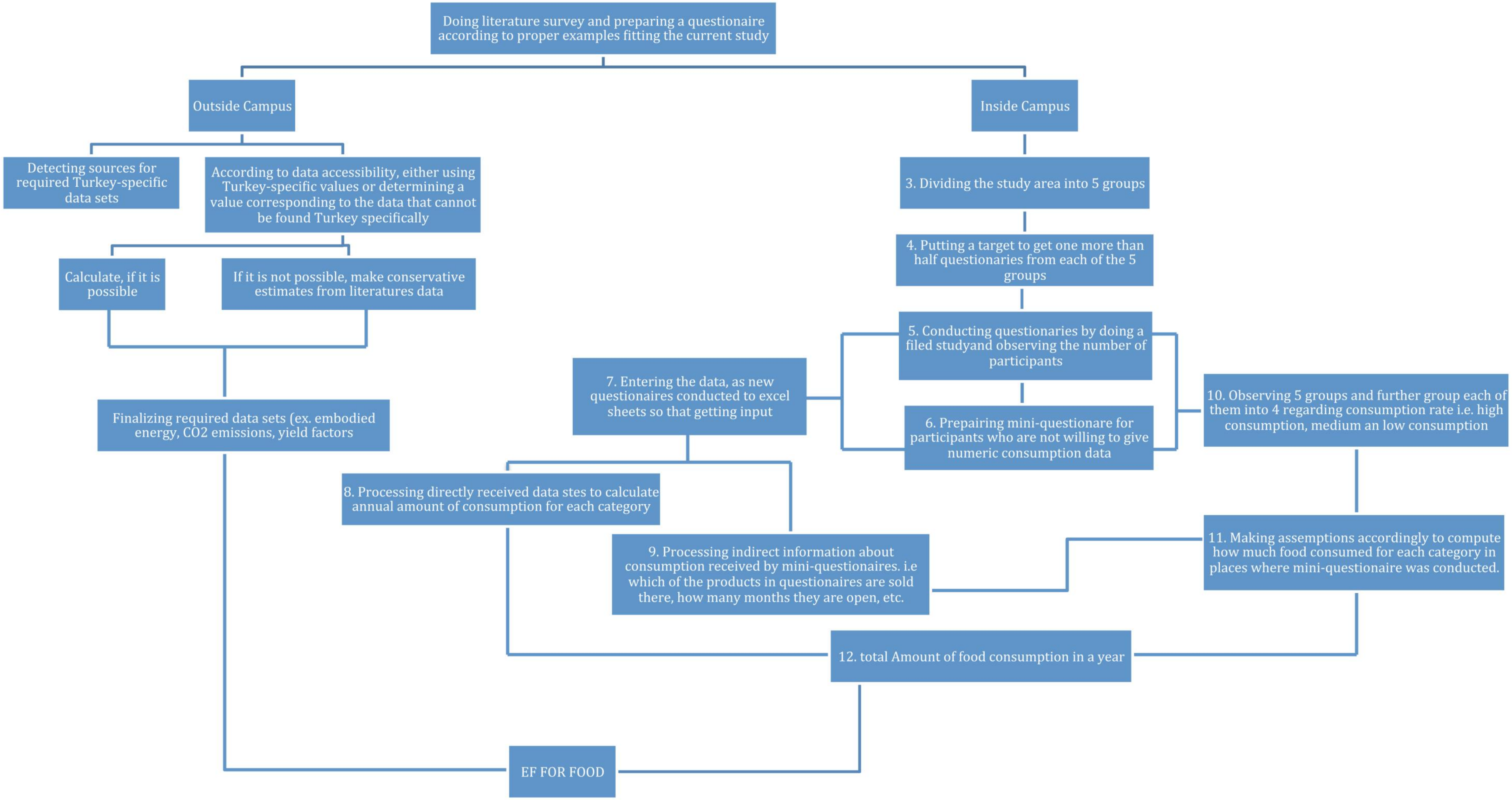

Figure 23: Food Methodology & Materials Scheme

Moreover, food consumption values were obtained from department canteens, restaurants in main campus and dormitory canteens. Products included in the questionnaire were all basic form food. Composite food (fried potatoes) requires some raw materials (e.g. fresh potatoes and vegetable oil). Thus, EF calculation methodology for food component takes account of basic ingredients of those composite foods.

Since some of the owners of the canteens or restaurants were not willing to share exact values of the food consumption some data were noted without numeric values, it is denoted as mini questionnaire (See Figure 19 box no 9). Furthermore, food consumption values were noted by the owner as daily, weekly, monthly or yearly basis; however, all the values were converted into annual values in kilogram. During conversion process, total days when establishments are open and holidays were taken into account. Furthermore for calculation of dormitory canteens, from METU dormitory office, data of dormitories on duty also were taken into account. The most reliable and exact data were taken from the establishments which have food consumption data archive thanks to their account analysis system. Finally, all values were summed under three groups as department canteens, dormitory canteens and restaurants.

Questionnaires were conducted in 7 different sub-groups. These groups were formed according to their location where they clustered. Department canteens were divided into 3 groups, dormitory canteens were divided into 2 groups as central and peripheral, Eymir Lake land is the other group and restaurants on campus including METU cafeteria is final group.

In the sake of protection of privacy, name of the establishment and their owners will not be shared. Totally there are 24 department canteens which form 3 groups. First group consists of 10 canteens and 8 of them gave exact numeric number, second group consists of 6 canteens and 4 of them gave exact numeric number and third group consists of 8 canteens and 5 of them gave exact numeric number. A mini questionnaire was conducted with canteens which their owners are not willing to share exact numeric values. In order to find total department canteens' food consumption, the exact numeric values of 17 canteens were summed and to deal with the remaining 7 canteens whose exact numeric consumption values are unknown, the following strategy was followed.

All department canteens were classified as high, medium and low sales capacity. This classification was based on below criteria:

- Whether it is central or not,
- Whether there is intense student population or other customer groups around it,
- Assortment of sold and cooked goods,
- Observations during semester,
- An interview with owner[34] of two canteens who has 25-year hands on experience in METU campus.

Average consumption values of products were determined in each class. After these 7 canteens were put in high, medium and low sales capacity classes, these average values were attached to them as an exact numeric values. Therefore, this strategy enabled canteens, whose exact numeric consumption values were not known, to be included in the summation.

Table 27: Example of methodology for attaching average value to each product[35]

	Dormitory	Dormitory	Dormitory	Dormitory	Refika Aksoy	Faik Hızıroğlu	Average values of the classes			Total (kg)
Product	Middle	High	Middle	Low	Middle	Middle	Low	Middle	High	
Milk	1	1	1	1	1	1	1,770.00	2,196.20	14,814.00	25,368.80
Yoghurt	1	1	1	1	1	1	1,530.00	3,916.00	2,125.81	19,319.81
Cheese	1	1	1	1	1	1	918.00	726.00	3,499.00	7,321.00
Butter	1	0	0	1	0	1	212.40	8,702.25	285.78	17,616.90
Creama	1	0	0	0	0	0	0.00	498.00	174.00	498.00

There are 2 groups formed for dormitory canteens to make questionnaire. First group consists of 9 canteens and 5 of them gave exact numeric values, second group consists of 5 canteens and 3 of them gave exact numeric values. 6 dormitory canteens whose exact numeric consumption values are not known were handled with the same

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[35] "1" represents the product is sold in that dormitory canteen, and "0" represents does not.

strategy before. Thus through summations of these values, consumptions' estimated sum total of dormitory canteens were obtained.

Since some of the restaurants on Eymir Lake land and METU campus, and the METU cafeteria gave exact numeric values, finding of sum total of last two groups was straightforward. There are 11 restaurants on METU campus considered as a separate group as the restaurants into which METU cafeteria was included, and 6 restaurants on Eymir Lake land. Those groups were formed to be able to systematize questionnaire process. It should be underlined that even though there were many sub-groups for the sake of simplicity of questionnaire process, calculations will be done over 4 main groups which are Department canteens, Dormitory canteens, METU restaurants including METU cafeteria, and Eymir Lake land restaurants.

Figure 24: Four Canteen Groups Formed for making questionnaire systematically

Hence sum total of department canteens was obtained by summing 24 department canteens' consumptions values and sum total of dormitory values was obtained by summing all consumption values of 14 dormitory canteens. Sum total of the other restaurants group was obtained in similar way.

Table 28: Sum Total values of 4 main groups

Groups	Total Food Consumption (kg)[36]
Restaurants Total	2,751,020.14
Canteens Total	1,590,973.74
Dormitory Canteens Total	8,598,335.55
Eymir Lakes Land Restaurant Total	259,691.52
General Total	13,200,020.95

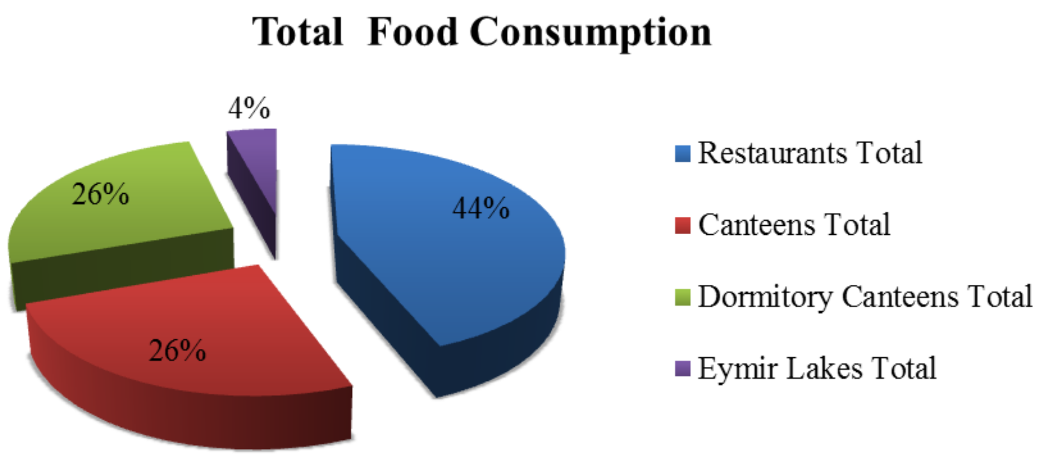

Figure 25: Distribution of the Total Food Consumption by Groups

Sum total of each individual product (e.g. milk, bread, etc.) in all four groups was obtained.

After that point, there were two calculation steps in order to calculate total EF of each product thereby a total EF for food component. First step was to calculate land area required to cultivate raw materials needed to produce composite food or directly basic food itself. Secondly land area required to sequester CO_2 stems from carbon content of foods was also calculated. After that these two were added and total EF for that product was obtained. Finally total EF was found by adding results of those two steps (See page 83).

[36] Units of kg and lt were accepted correspondent to each other.

WASTE & RECYCLE

Materials and Methodology for calculation of annual carbon emission from waste produced in METU campus:

Following the literature survey, methodology for calculation and required data for it, was determined based on Carragher's work [66]. After required data set was determined, it was requested from three source, namely Directorate of Internal Affairs department of METU, Assoc. Prof. Emre Alp from Environmental Engineering Department at METU and ITC. From Directorate of Internal Affairs department it was requested the data of total annual amount of waste produce within METU campus. Since this information was not available, it was requested the department to weight waste produced in METU campus. Therefore data of amount of waste produced in weekdays in November in 2013 was obtained. Moreover Directorate of Internal Affairs informed that at weekend garbage trucks collect waste as half of the amount in a weekday. Assoc. Prof. Dr. Emre Alp from Environmental Engineering Department, who leads a study about waste produced weekly basis, data for amount of waste produced in a week was received. ITC is an integrated solid waste management establishment takes place different part of Turkey. Collected waste in METU is delivered to ITC to be both recycled and incineration. From incineration of garbage electricity is produced in ITC. From ITC, data of how much garbage enters to Mamak landfill and how much energy is produced from it was received.

Table 29: Data of amount of waste produced in November in 2013 within METU campus

Date	Amount of waste(kg)
25.11.2013	12040
26.11.2013	13040
27.11.2013	18040
28.11.2013	11680
29.11.2013	18900
Weekdays Average	14740
Weekend Total	5896
Total Waste in a Week(November)	79596
Total Waste (November)	318384

From Directorate of Internal Affairs department data for amount of waste produced from 25.11.2013 to 29.11.2013 was received. In November campus has full population. In order to estimate waste produced at weekends, reduction of population was taken into account and compared with the value in weekdays. At weekends there are only students who live at dormitories and academicians who live in ‘ODTU Kent’ lodging which is one fifth of the population. Therefore two fifth of the average value yields the weekend total. By assuming that one month is four weeks, total waste in November when campus has full population.

In order to find total annual waste produced in METU one has to take into account that campus has not full population throughout the year. In four months, namely February, July, August, September campus has not full population. In order to take into account population reduction in these months a coefficient was attached to each month. Other eight months has coefficient 1 since campus has full population. Calculation of coefficients is as follows;

There are 24959 students, 2573 academicians and 1369 administrative staff, which yields 28901 as total population of campus according to [166]. In these four months population reduction is not homogenous, i.e. three constituencies’ population reduce independently. Therefore percentage of each constituent was calculated.

- Student Percentage is; 24959/28901x100=86
- Academician Percentage is; 2573/28901x100=9
- Administrative Staff Percentage is; 1369/28901x100=5

Table 30: Coefficient calculation according to population in each month

	Student	Academician	Administrative Staff	Coefficient Calculation	Coefficient
January	1	1	1	((86x1) +(9x1)+(5x1)) /100	1
February	0.2	0.9	0.95	((86x0.2)+(9x0.9)+(5x0.95)) /100	0.3005
March	1	1	1	((86x1) +(9x1)+(5x1)) /100	1
April	1	1	1	((86x1) +(9x1)+(5x1)) /100	1
May	1	1	1	((86x1) +(9x1)+(5x1)) /100	1
June	1	1	1	((86x1) +(9x1)+(5x1)) /100	1
July	0,4	0,7	0,75	((86x0,4)+(9x0,7)+(5x0,75))/100	0,4445

Table 30 continued

August	0.2	0.6	0.4	((86x0,2)+(9x0,6)+(5x0,4))/100	0.246
September	0.4	0.8	0.9	((86x0,4)+(9x0,8)+(5x0,9)) /100	0.461
October	1	1	1	((86x1) +(9x1)+(5x1)) /100	1
November	1	1	1	((86x1) +(9x1)+(5x1)) /100	1
December	1	1	1	((86x1) +(9x1)+(5x1)) /100	1

Table 31: Calculation of total annual waste produced in METU by using the coefficients

Months	**Coefficients**	**Total Waste (November) x Coefficients**
January	1	318384
February	0.3005	95674.392
March	1	318384
April	1	318384
May	1	318384
June	1	318384
July	0.4445	141521.688
August	0.246	78322.464
September	0.461	146775.024
October	1	318384
November	1	318384
December	1	318384
Total annual waste produced in METU		3009366

Therefore total annual waste produced in METU is obtained by summing each month's value. This enables calculations of CO_2 emitted from METU waste in one year by means of embodied energy values of organic waste.

- Annual garbage produced in METU campus; 3009.366 tones
- Embodied energy of organic waste; 10Mj/kg
- Conversion of Mj into kWh; 1Mj=0.28kWh
- Electricity produced from one kg of organic waste; 10x0.28=2.8kWh
- Electricity produced from annual organic waste,
  2,8x3009306=8426224 kWh
- Turkey CO2 emissions per kWh from electricity generation 472 (grCO2/kWh)
- CO_2 emitted from METU waste in one year (tonne)

8426224x472/10^6=3977,178

Total annual waste was accepted that it consists of completely organic waste. However, these values include recyclable wastes which were not separated from organic waste. In ITC these recyclable waste is separated before incineration process, however since this data does not recorded, it was assumed that total annual waste value of METU completely consists of organic waste. If this data were taken into account, emitted CO_2 value would have been bigger, since recyclable materials such as paper and cardboard have bigger embodied energy than organic waste.

In order to obtain CO_2 emission stems from delivery of METU waste from campus to the landfill total number of garbage collection was calculated in one year. Directorate of Internal Affairs department informed that in weekdays garbage is collected two times in a day and at weekend one time in a day, which yields twelve collections each week. Hence calculation CO_2 emission from garbage delivery was found as follows;

- Approximate number of waste collected by garbage truck is; 52x12=624
- Heavy Duty Vehicle Emission Rate(gr CO_2/km) is; 870
- Distance to Mamak Landfill in Ankara (km) is; 75
- CO_2 emitted from METU waste delivery in one year (tonne) is; 624x870x75/10^6=40,716

Table 32: CO_2 emitted from deliver and incineration in METU

Variables	Values Used
Total Waste in METU (t)	3009.306
Electricity produced from one kg of organic waste	2.8kWh
Turkey CO_2 emissions per kWh from electricity generation (grCO_2/kWh)	472
CO_2 emitted from METU waste in one year (tonne)	3977.178
Approximate number of waste collected by garbage truck	624
Heavy Duty Vehicle Emission Rate(grCO_2/km)	870
Distance to Mamak Landfill in Ankara (km)	75
CO_2 emitted from METU waste delivery in one year (tonne)	40,716
CO_2 to C Ratio (tC/tCO_2)	0.27
Forest Sequestration Rate (tC/ha)	0.97
Ocean Absorption Rate per tone	0.28
Forest Equivalence Factor (gha/ha)	1.26

Materials and Methodology for calculation of annual carbon emission recycling process in METU campus:

According to the data sets of materials received from via Assoc. Prof. Dr. Barış Sürücü which are sent to recycling facilities, annual amount of the materials were determined and materials were classified. As a result of this classification of different materials recorded in data set, 5 main recycling groups were formed. For instance newsprint papers, print waste which recorded differently in the data set, were combined to form group 'Paper' and waste metal, tins and cans combined to form group 'Ferrous'. In the data set, all the mass of the input 'metal covered with plastic' were included in the Ferrous group, since mass of the plastic in this input is negligible when compared to metal mass. By the same taken, 5 main recycling groups were formed. As can be seen from Table 33, it was determined that annually 119,18 tone paper, 107,68 tone cardboard, 4,2 tone plastic, 22,45 tone metal and 0,3 tone aluminium are collected in METU campus to recycle. Embodied energy values of these groups were taken from [66]. In order to calculate EF of recycling process in METU, in a fashion similar to waste calculation the coefficient for CO_2 emissions per kWh from electricity generation in Turkey, which is 472 ($grCO_2/kWh$), was used.

In order to be able to make use of this coefficient one has to obtain electricity generation in kWh. Therefore, embodied energies were converted into kWh and by multiplying these kWh values by the coefficient, CO_2 emission were obtained (See page 100).

Table 33: 5 main recycling groups in METU campus

Recycled Waste	**Total Consumption (tone/yr)**	**Embodied Energy (Mj/kg)**	**Mj to kWh conversion**	**CO_2 (tone)**
Paper	119.18	21	700778.4	330.7674048
Cardboard	107.68	21	633158.4	298.8507648
Plastics	4.2	27	31752	14.986944
Ferrous	22.45	10	62860	29.66992
Aluminum	0.3	23	1932	0.911904
			TOTAL	675.1869376

BUILT-UP LAND

In order to calculate Built-up Ecological Footprint, the data of total building area usage, roads in campus and parking lots area were used. Total building area usage data as well as total road area within the university, and number of parking lots data were received from METU Campus Planning Office. Required yield factor and equivalence factor were taken from [168]. BCIT [83] methods for calculation of built-up EF were examined to form methodology. Average sum of built-up and road area in Eymir Lake Land and its perimeter was measured by ‘Google Earth’. Built-up and road areas within study area was accepted as total permeable surface area.

Table 34: Built-up Area in METU Campus (Ankara)

METU Ankara Campus Built-up area	
	Usage Area (m2)
University Buildings	310340
Lodging	55797
Administrative Buildings	6780
Service Buildings	26747
Outdoor Sports Facilities	46947
Indoor Sports Facilities	13688
Health Care Centre	1570
Dormitories and Guest Houses	112228
Social and Cultural Facilities	32441
Shopping and Work Centre	13725
Prayer Places	750
Primary and Secondary Education Buildings	31470
Total	**652483**

Remaining data sets required to calculate EF were proper yield factor and equivalence factor. GFN underlined that assigning a yield factor for built-up area can be complicated and difficult [60, p. 522]. In their revised methodology paper, it was suggested that only if the soil type and regarding area on that soil were not known exactly, built-up area taken into account for EF calculations can be accepted as developing on cropland area. When it comes to equivalence factor, ‘the infrastructure equivalence factor’ was used to express area in terms of global hectare (See page 99).

CHAPTER 3

3. RESULTS AND DISCUSSIONS

3.1 Ecological Footprint of Food [37]

EF due to land use (gha) = [Consumption amount (t) / Yield Factor (t/ha) x Equivalence Factor (gha/ha)]

EF due to CO2 Land (gha) value was calculated following the formula in Table 17.

After that both of them was summed to obtain total EF due to food consumption (See Appendix A).

Table 35: Key Results of Food Component EF

	EF Due to Land use (gha)	EF Due to CO_2 Land (gha)	Total EF (gha)	Total Food Consumption
Restaurants Total	16,230.22	3,951.73	20,181.95	2,751,020.14
Canteens Total	3,538.87	1,657.86	5,196.72	1,590,973.74
Dormitory Canteens Total	4,632.38	1,606.19	6,238.57	1,637,665.05
Eymir Lakes Total	719.75	312.21	1,031.96	259,691.52
General Total	25,121.22	7,527.99	32,649.21	6,239,350.45

[37] (See methodology at page 69)

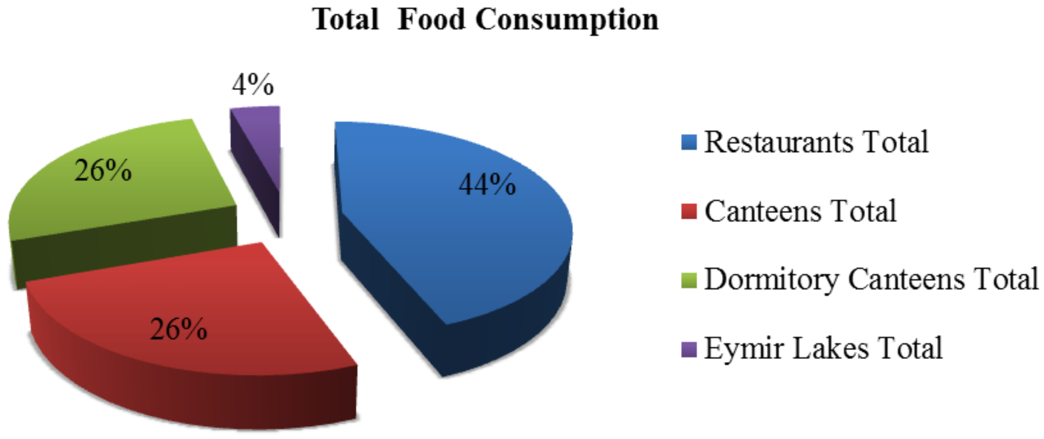

Figure 26: Distribution of the Total Food Consumption by groups

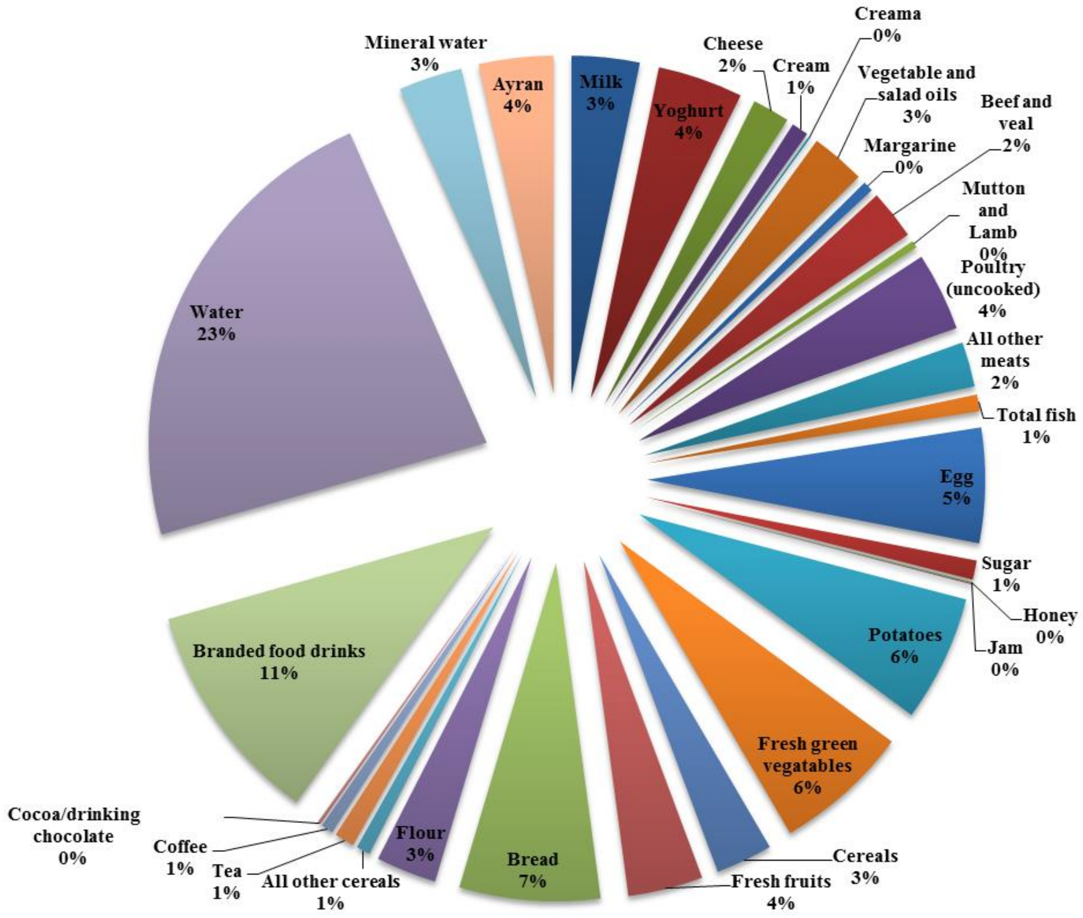

Figure 27: Percentage Distribution of Food Consumption Categories

An Example Calculation for 'Egg' category:

In the light of data received, total number of eggs obtained from all dormitory canteens with which a questionnaire conducted was converted into kilogram assuming that one egg is 80 gram. Liquid eggs data was directly added to calculation and thereby annual consumption was determined. Sum total of egg for dormitory canteens was calculated as 8.207,72 kg in the light of data received. Average value of dormitory canteens with respect to high, middle, low classes yielded as follows;

Table 36: Dormitory Canteens' Average Egg consumption values regarding their scale

Low	Middle	High
849.60	836.44	1,212.20

Average value of their classes was attached to the canteens with which mini questionnaire was conducted. As a result of attaching the average values to the canteens with which mini questionnaire was conducted, it is approximated that egg consumption of these canteens is 5.407,56 kg. Total egg consumption throughout dormitory canteens, therefore, was calculated as 13.615,28 kg.

Table 37: Dormitory Canteens' Total EF for 'Egg' Category

Product	kg	Embodied Energy MJ/t	GWP tCO_2/t	Yield Factor kg/ha	Equivalence Factor (gha/ha)	EF Due to Land (gha)	EF Due to CO2 (gha)	Total EF (gha)
Egg	13,615.28	21.80	5.48	550.00	2.51	62.14	139.01	201.14

In order for EF of total egg consumption of dormitory canteens to be calculated, both grazing land and CO2 land is required to be calculated. Grazing land was calculated, by means of multiplication of total kg by yield factor and equivalence factor. Yield factor for egg is 550 kg/ha and equivalence factor for egg 2.51 gha/ha. These factors were multiplied by 13.615,28 kg which is total egg consumption. EF due to land usage yielded 6.14 gha. On the other hand, EF due to CO2 sequestration land requirement was calculated by the formulation and the coefficients in Table 17.

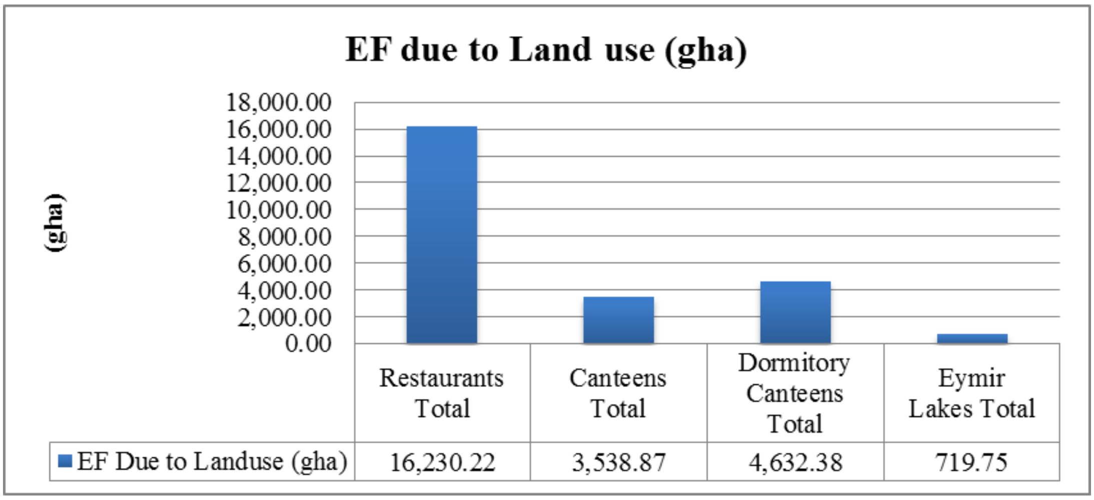

Figure 28: Ecological Footprint due to required land use area for growing plant

Table 38: Total EF for METU cafeteria and other restaurants

	EF Due to Landuse (gha)	EF Due to CO_2 Land (gha)	Total EF (gha)	Total Food Consumption
Other Restaurants	9,466.80	2,661.39	12,128.19	1,897,560.14
METU Cafeteria	6,763.42	1,290.35	8,053.76	853,460.00

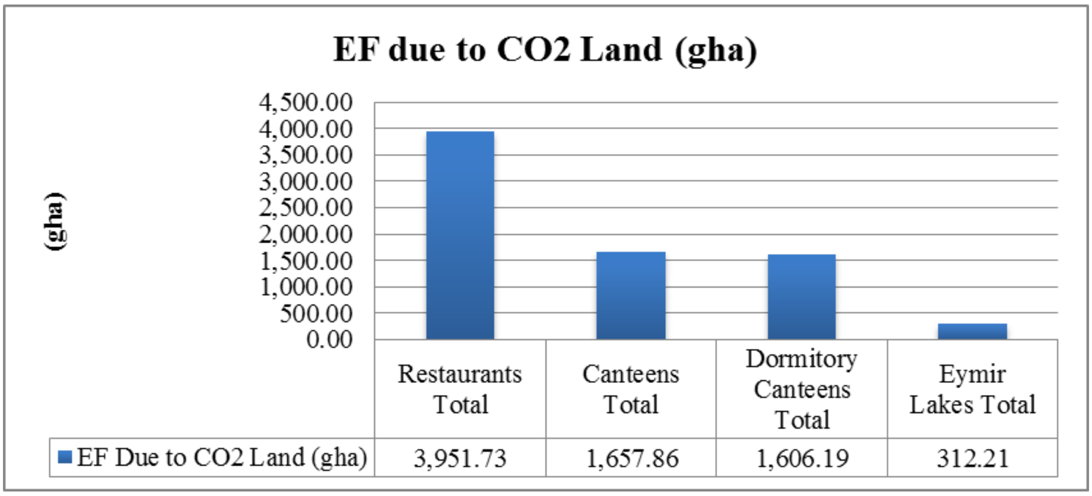

Figure 29: Ecological Footprint due to CO2 sequestration land area requirement for food

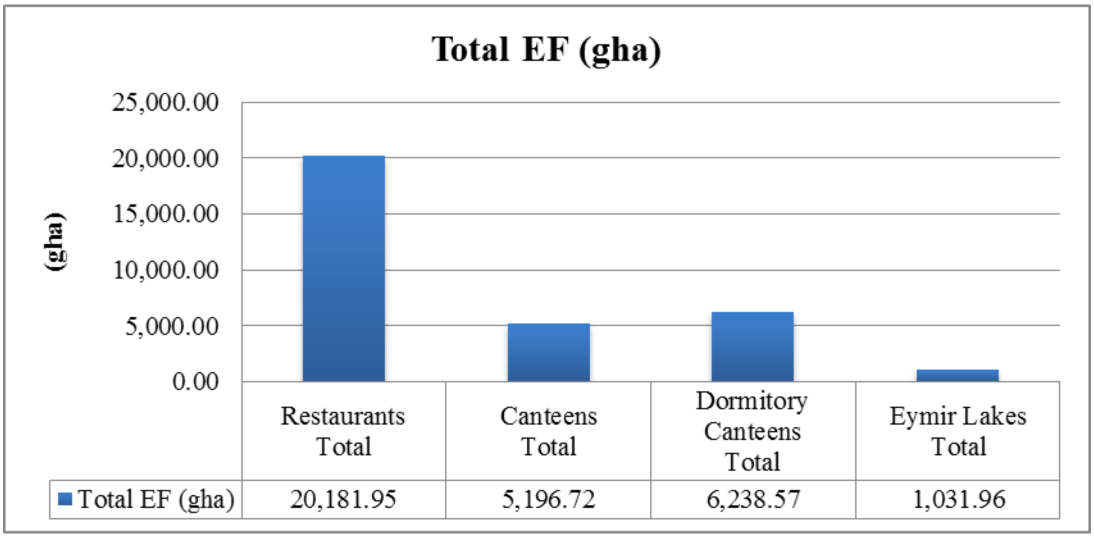

Figure 30: Total Ecological Footprint Values by Groups

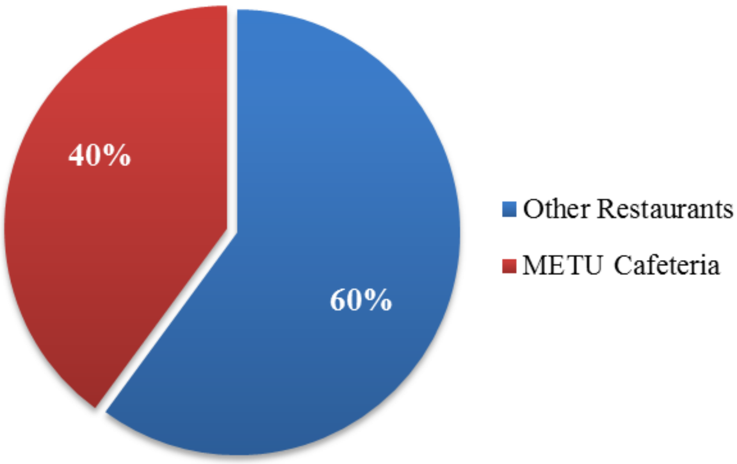

Figure 31: Contribution percentages of METU Cafeteria to Restaurants' Total EF

3.2 Ecological Footprint of Transportation[38]

Calculations were made separately for the vehicles using gasoline and diesel during carbon emission and fuel consumption computations. Weekly carbon emission and fuel consumption for the vehicles consuming diesel and gasoline are as the following:

[38] (See methodology at page 59)

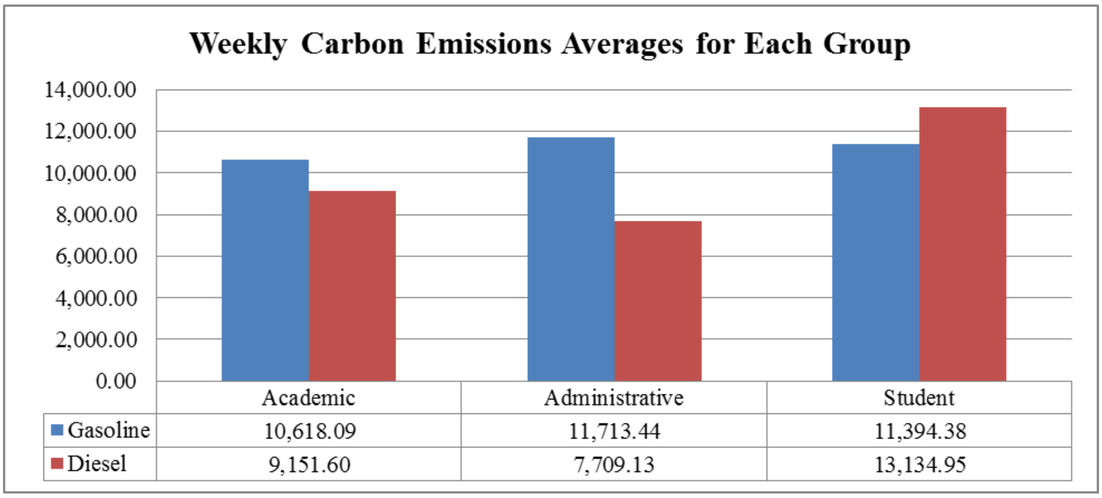

Figure 32: Weekly Carbon Emission Averages for Groups

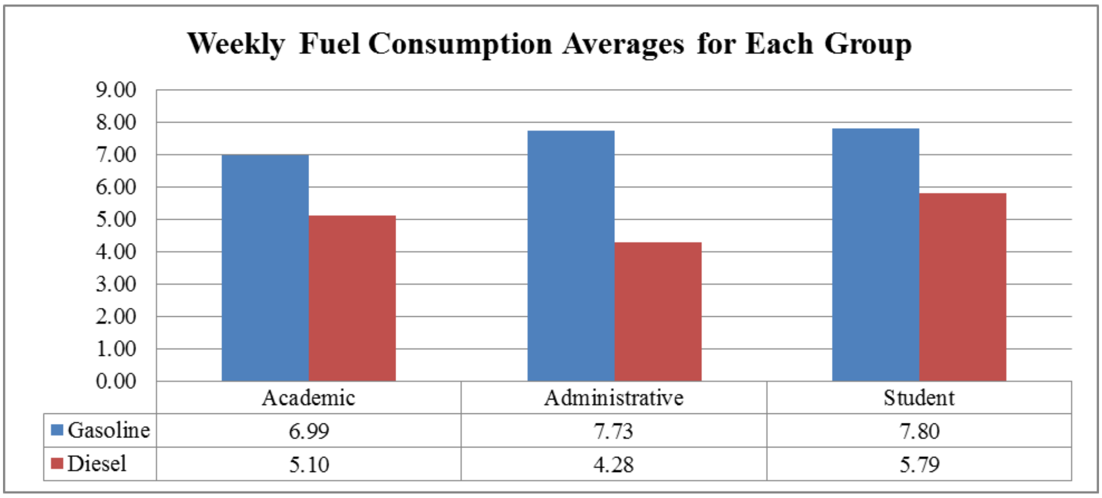

Figure 33: Weekly Fuel Consumption Averages for Groups

1. **The calculation of total annual carbon emission concerning private car ownership inside the Campus;**

The population inside the Campus differs in a year according to months. The main reason paving the way for this is consideration of annual leaves of academicians and administrative personnel and periods of formal education of students. Accordingly, activity ratio distribution is made concerning instantaneous campus population on monthly and yearly basis. Thus, the calculation constitutes the population decrease because of annual leaves and holidays. The Figure 34 dealing with calculation methods are given as below:

MONTH			MAY				JUNE		
WEEK			1	2	3	4	1	2	3
Academic Staff	Total Number of Vehicle		3316	3316	3316	3316	3316	3316	3316
	Active Vehicle Rate		1	1	1	1	1	1	1
	Gasoline	Number of Valid Questionnaires	80	80	80	80	80	80	80
		Approx. Number of Active Vehicle	2267	2267	2267	2267	2267	2267	2267
		Avr. Carbon gr from the Survey	10.618,09	10.618,09	10.618,09	10.618,09	10.618,09	10.618,09	10.618,09
		Total Carbon Emission (gr)	24.071.215,70	24.071.215,70	24.071.215,70	24.071.215,70	24.071.215,70	24.071.215,70	24.071.215,70
		Avarage Fuel lt from the Survey	6,99	6,99	6,99	6,99	6,99	6,99	6,99
		Total Fuel Consumption (lt)	15.846,33	15.846,33	15.846,33	15.846,33	15.846,33	15.846,33	15.846,33
	Diesel	Number of Valid Questionnaires	37	37	37	37	37	37	37
		Approx. Number of Active Vehicle	1049	1049	1049	1049	1049	1049	1049
		Avr. Carbon gr from the Survey	9.151,60	9.151,60	9.151,60	9.151,60	9.151,60	9.151,60	9.151,60
		Total Carbon Emission (gr)	9.600.028,40	9.600.028,40	9.600.028,40	9.600.028,40	9.600.028,40	9.600.028,40	9.600.028,40
		Avarage Fuel lt from the Survey	5,10	5,10	5,10	5,10	5,10	5,10	5,10
		Total Fuel Consumption (lt)	5.349,90	5.349,90	5.349,90	5.349,90	5.349,90	5.349,90	5.349,90

Figure 34: The example for the calculations for academic group on weekly and monthly basis

So as to reach total carbon emission amount, initially, weekly carbon emission amounts are reckoned owing to the multiplication of average carbon emission amounts with the number of active vehicles for the certain week. Then, the values for whole weeks in a year are summed up.

$$\mathbf{CE} = \boldsymbol{C}\ \boldsymbol{x} \sum_{i=1}^{52} (\mathbf{A})(\boldsymbol{i}) \qquad \textbf{(2)}$$

Where; CE= Yearly Total Carbon Emission Value, C= constant value of estimated carbon emission value, A= Number of Active Vehicle and *i*= week

When the methods shown in the sample tables are applied all administrative personnel and students for whole year, 3,669,374,248.19 gr carbon emissions per year is attained. The amount and distribution of carbon emission is given in the Figure 35.

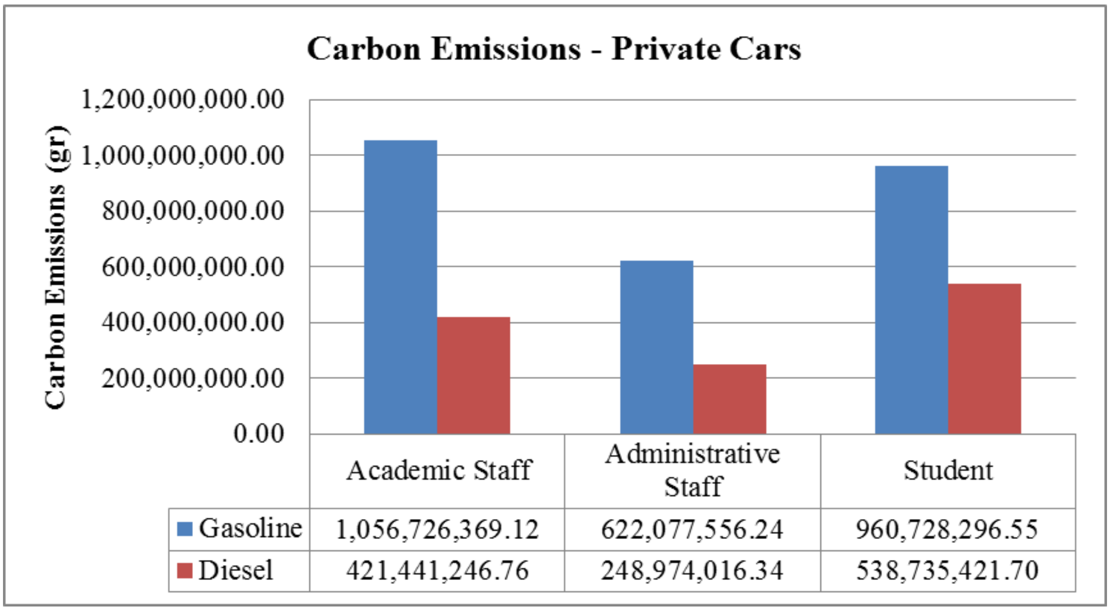

Figure 35: Annual carbon emission amounts of vehicles consuming gasoline and diesel depending on group

The amount of fuel consumption on a yearly basis is 1,763,843.53 lt gasoline and 610,566.66 lt diesel. The graph concerning fuel consumption is given in the following Figure 36.

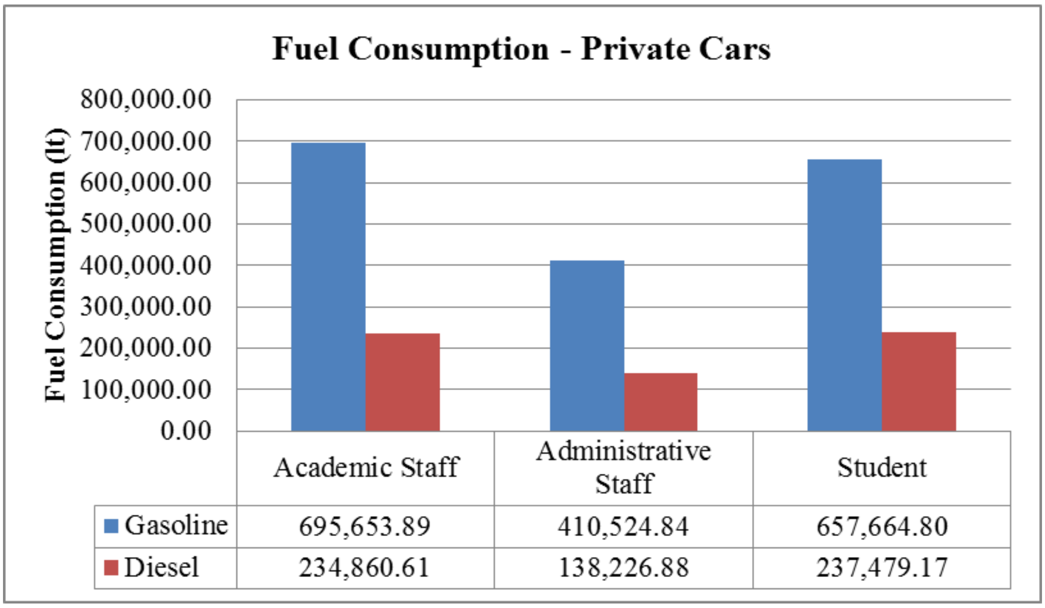

Figure 36: Annual fuel consumption amounts of vehicles consuming gasoline and diesel depending on group

1. **Calculation of annual total carbon emission amount for Taxi and Dolmushes serving inside the Campus Area;**

In order to make conservative estimates, maximum values were used in calculations from all given rages by reporters (i.e. amount of distances covered).

Monthly carbon emission value = (number of vehicles) x (distance covered as km per day) x (carbon emission factor) x 30

$$\mathbf{CE} = \boldsymbol{C}\ \boldsymbol{x} \sum_{i=1}^{12} (\mathbf{A})(\boldsymbol{i}) \qquad \textbf{(3)}$$

Where; CE= Yearly Total Carbon Emission Value, C= constant value of monthly carbon emission value, A= Number of Active Vehicle and *i*= month

Annual carbon emission amount is attained by summing monthly carbon emission amounts which is computed by its multiplication with activity ratio.

Annual fuel consumption = (Annual total distance covered as km) x (Fuel consumption for city (lt/100km) /100

Fuel consumption amounts for taxis and dolmushes are reckoned by using same way with the calculation for private cars.

Table 39: The example of monthly and yearly carbon emission amount for Taxis and Dolmushes

							Activity Ratio			
	Number of vehicle	Daily distance covered km	CO_2 emission amount (gr/km)	Fuel consumption average (lt/100 km)	Monthly total CO_2 emission	Monthly fuel consumption (lt)	January	February	Total annual CO_2 emission	Total annual fuel consumption
Taxi	25	210	112	9.2	17,640,000.00	14,490.00	2	0.05	189,982,800.00	156,057.30
Dolmush (Kızılay)	51	185	172	6.5	48,684,600.00	18,398.25	1	0.3	447,898,320.00	169,263.90
Dolmush (Ulus)	8	96	172	6.5	3,962,880.00	1,497.60	1	0.3	36,458,496.00	13,777.92
Dolmush (Ayrancı)	10	171	172	6.5	8,823,600.00	3,334.50	1	0.3	81,177,120.00	30,677.40
							TOTAL		**755,516,736.00**	**369,776.52**

2. **Calculation of total carbon emission for shuttle services serving inside the campus area;**

Daily distance covered as km for services is multiplied with operation day and total distance as km is determined. The annual carbon emission amount is calculated in accordance with the multiplication of carbon emission amount of service with total km.

Annual carbon emission amount = (distance covered as km) x (number of days in a service year) x (carbon emission factor (gr/km))

Fuel consumption is reckoned by using same way with the calculation for private cars.

The distance covered by shuttle buses are given as total amount. This value is multiplied with diesel bus carbon emission value [182] in order to calculate annual carbon emission amount.

Annual carbon emission amount = (Distance covered weekly (km)) x (carbon emission factor) x 52

Table 40: The example of daily and yearly carbon emission amount for Services and Rings

	Distance covered daily km	Number of service days	Total km	CO_2 Emission Amount (gr/km)	Average fuel consumption (lt/100 km)	Total annual carbon emission	Total annual fuel consumption
Services 1	5887	251	1,477,637.00	1034.61	35.1	1,528,778,016.57	518,650.59
Services 2	482	199	95,918.00	1034.61	35.1	99,237,721.98	33,667.22
Rings			215,318.00	1034.61	35.1	222,770,155.98	75,576.62
					TOTAL	**1,850,785,894.53**	**627,894.42**

3. **Calculation of annual carbon emission amount for Public Busses whose route is passing from METU Campus**

Annual carbon emissions for busses are reckoned by taking total weekly distance taken, each route destination, number of voyages, number of service days into account. Then, total carbon emission amount is found by multiplying above mentioned value with diesel bus carbon emission value[182], as seen in Table 41.

Table 41: The example of weekly and yearly carbon emission amount for public busses

	Distance covered weekly km	Annual Total km	CO_2 Emission Amount (gr/km)	Average fuel consumption (lt/100 km)	Total annual carbon emission	Total annual fuel consumption
Busses	57048	2,966,496.00	1034.61	35.1	3,069,166,426.56	1,041,240.10

4. The EF calculation for each mode of transportation and the total EF value for transportation;

Ecological footprint of all groups is computed by using the same way pursuant to the following formula.

EF transportation = [Total Carbon emission (gr)/1000000] x [Uplift factor] x [CO_2 to C Ratio]x [1-Ocean absorption rate per tonne]/ [Forest Sequestration Rate (tC/ha)]x [Forest Equivalence Factor (gha/ha)]

Accordingly, total carbon emissions amounts for each group are given in the following Figure 37 and Figure 38.

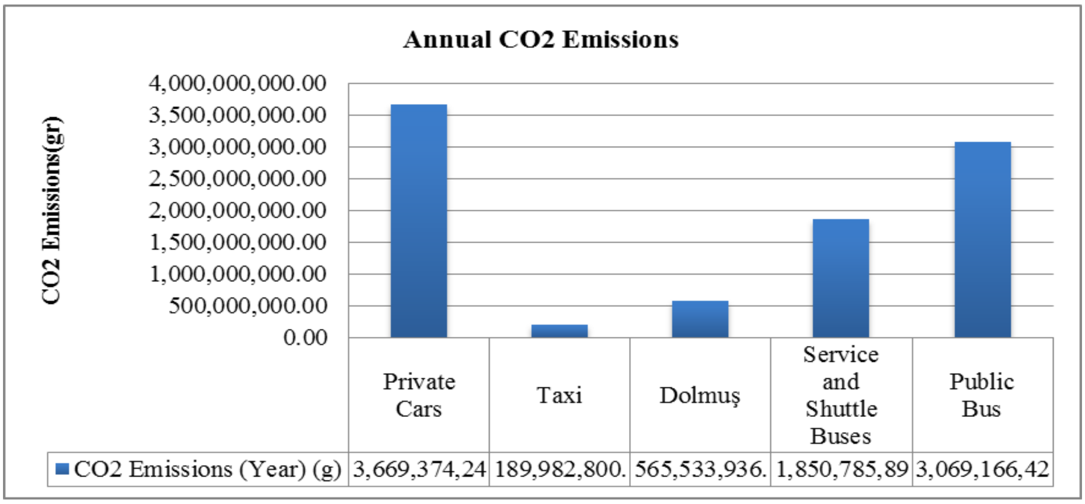

Figure 37: Comparative Graph on annual carbon emission amount

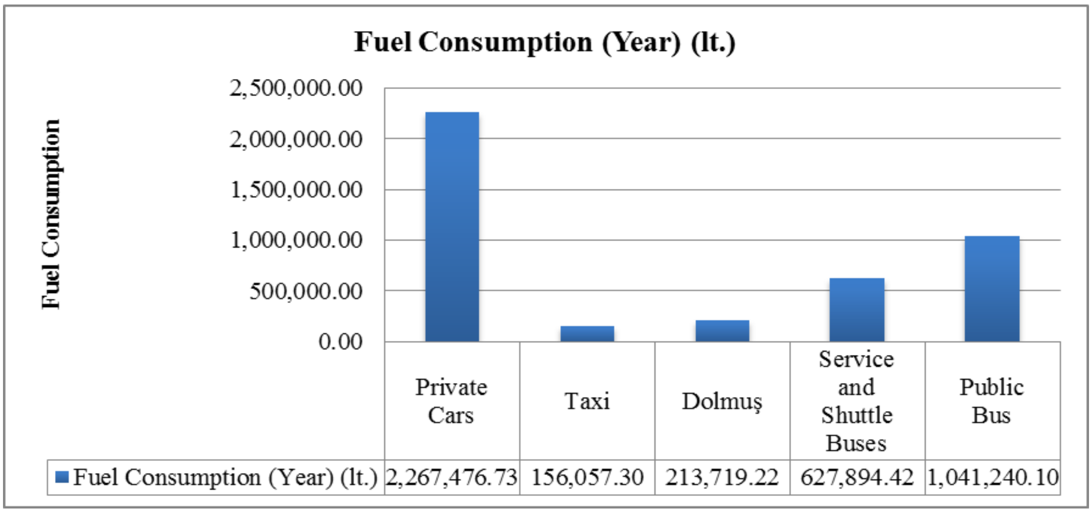

Figure 38: Comparative Graph on Annual Fuel Consumption Amount

The following Table 42 reveals EF calculation in particular to total public transportation. The computation for the remaining groups (i.e. taxi, dolmush, public bus, etc.) was also made in the same way.

The comparisons of the results are shown in the following Figure 39, Figure 40 and Figure 42.

Table 42: The EF calculation steps for total Public Transportation

Public Transportation Total	
Total Carbon Emission (gr)	5,675,469,057.09
Uplift (%)	1.51
CO_2 to C Ratio (tC/tCO_2)	0.27
Forest Sequestration Rate (tC/ha)	0.97
Ocean Absorption Rate per tone	0.28
Forest Equivalence Factor (gha/ha)	1.26
EF (gha)	**2,164.08**

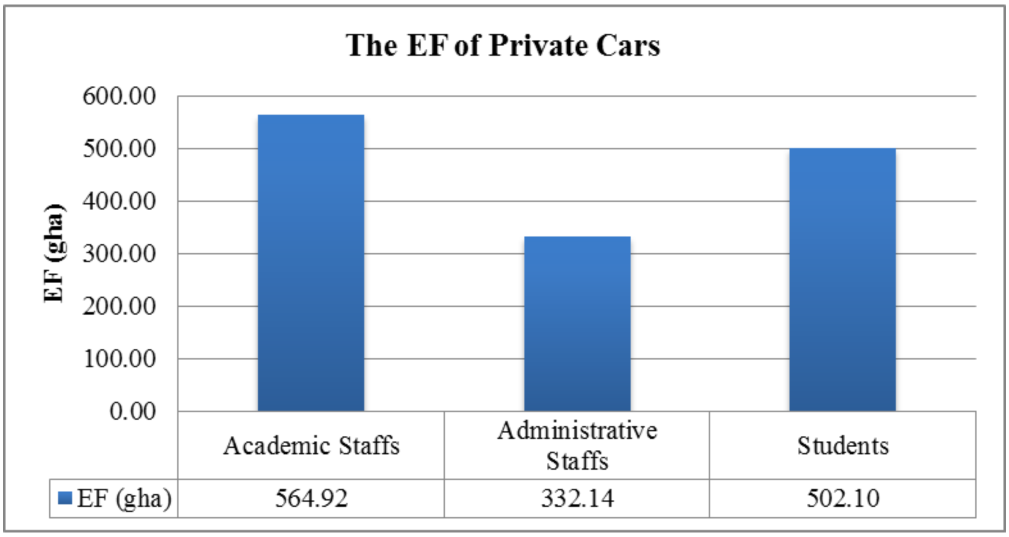

Figure 39: Comparison of EF values of Private Cars

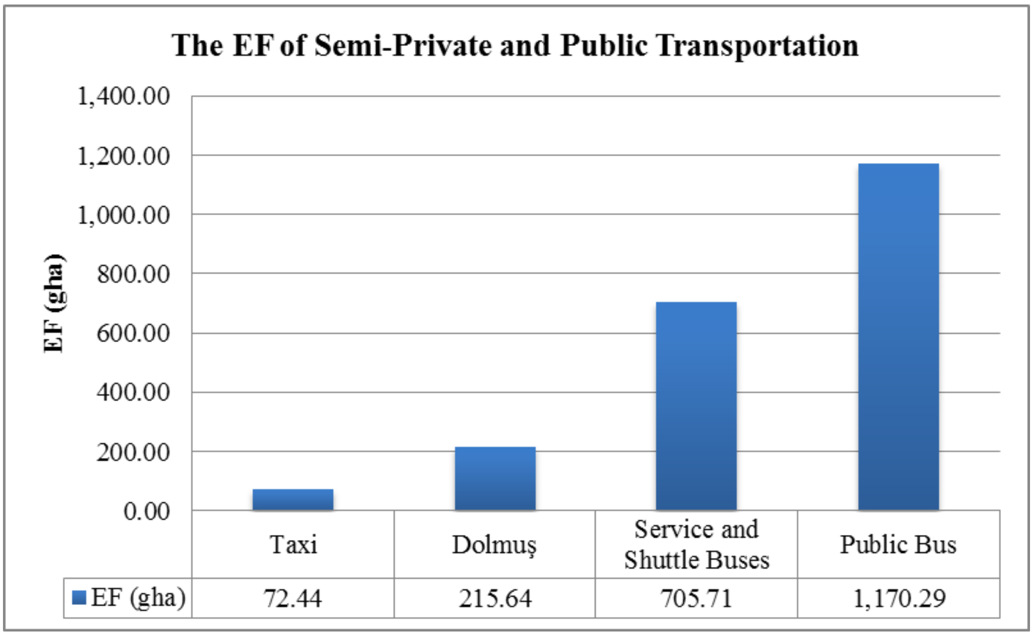

Figure 40: Comparison of EF values of Semi- private and Public Transport

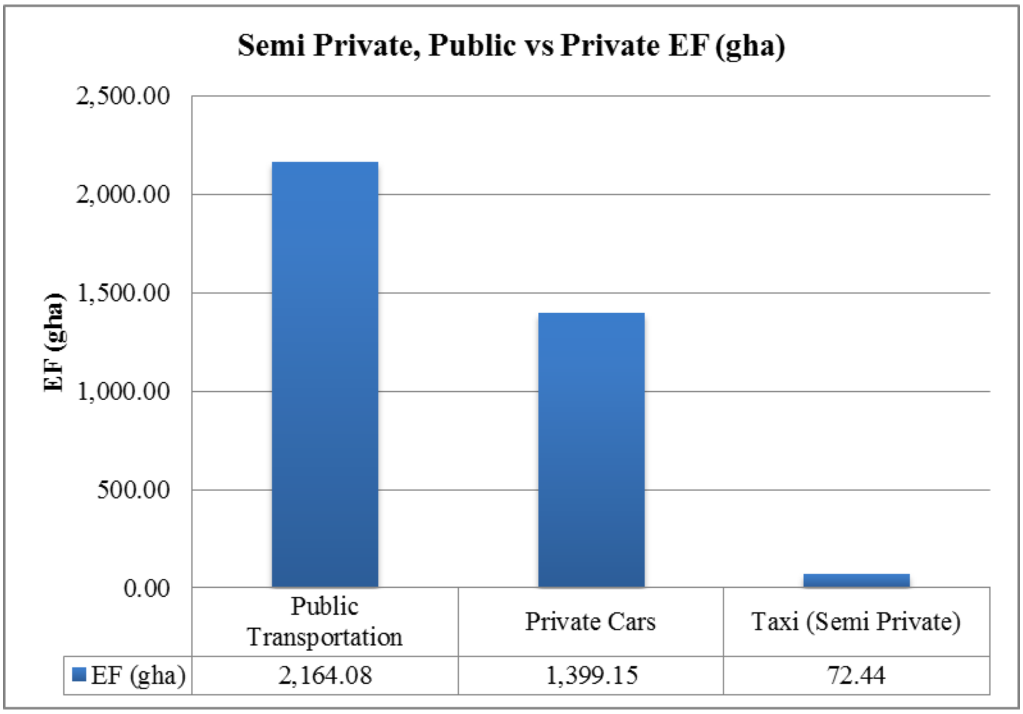

Figure 41: Comparison of Private, Semi-Private and Public EF

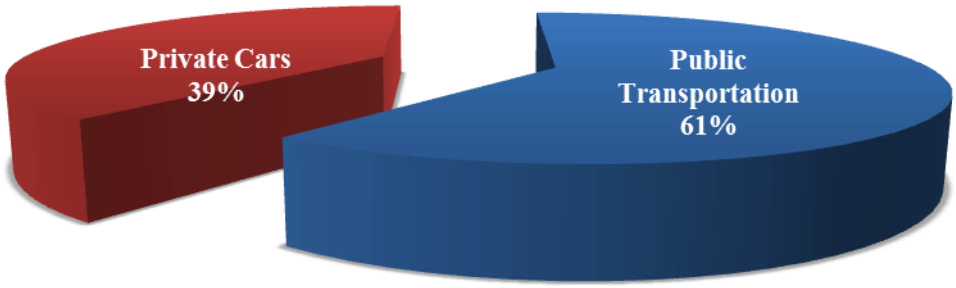

Figure 42: Comparison of total EF values including both private and public vehicles

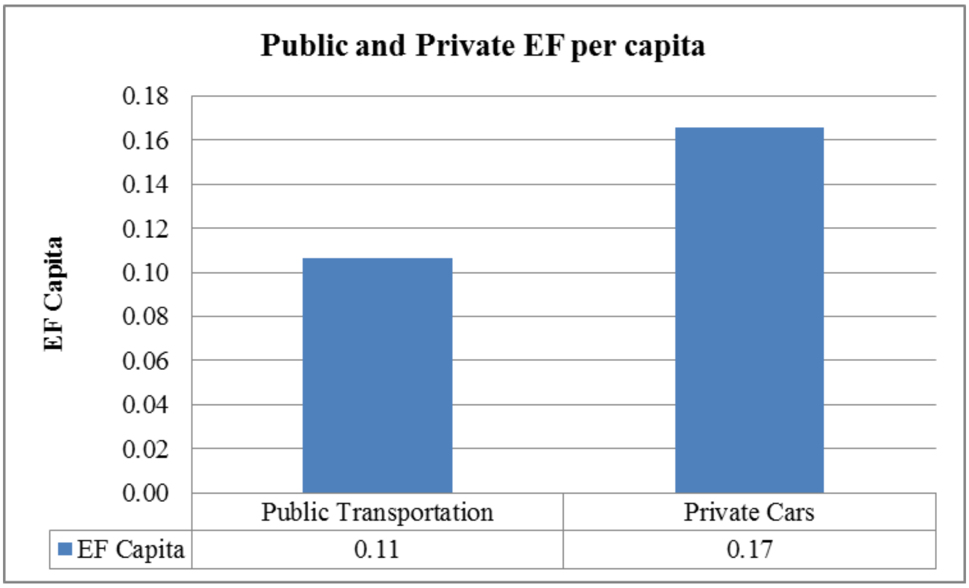

Figure 43: Comparison of EF per capita values for Public and Private Vehicles

EF per capita values of public transportation and private vehicles are shown in Figure 43 .

The EF of transportation component representing total EF amount of all vehicles are reckoned as representing all 3563. 23 gha (See Appendix B).

3.3 Ecological Footprint of Energy [39]

There were two sub-components of Energy EF calculations. Electricity and Natural Gas EF calculations will be given separately whose total value represents the total EF of Energy component.

[39] (See methodology at page 55)

Electricity

Table 43: Data required in order for calculation of Electricity Component EF

Data Sets for Ecological Footprint of Energy Calculation	
METU Electricity consumption in 2012 (kWh)	34042392
Turkey Electricity Transmission System Loss rate (%)	2.7
Başkent Electricity Distribution Inc. lost leakage rate (%)	8.67
Turkey CO_2 emissions per kWh from electricity generation (gr CO2/kWh)	472
Ocean Absorption rate (for every tonne) (%)	28
Forest sequestration rate (tC/ha)	0.97
C to CO_2 Ratio (tC/tCO_2)	0.27
Forest equivalence factor (gha/ha)	1.26

Ecological footprint of energy is computed by using the same way pursuant to the following formula.

EF energy (gha) = [(Electricity consumption of METU (kWh)) x (Average CO_2 emissions per kWh from electricity generation for Turkey in 2011 (grams CO_2/kWh)) x (C to CO_2 Ratio (t C (t $CO_2)^{-1}$)) x (1-ocean absorption rate(for every tonne)) x (forest equivalence factor(gha/ha))] / [(1-percentage of transmission system loss) x (1-percentage of distribution system loss) x (1.000.000gr/1 ton) x (forest sequestration rate(tC/ha))]

EF energy(gha) = [(34.042.392 kwh) x (472 grams CO_2/kWh) x (0,27 t C (t $CO_2)^{-1}$) x (1-0,28) x (1,26 (gha/ha))] / [(1-0,027)x (1-0,087) x (1.000.000gr/1 ton) x (0,97 tC/ha)]

EF energy = 4,567.4 gha

Results show that approximately 4567 global hectare forest land is necessary to sequestrate CO_2 emitted as a result of an annual electricity consumption of the campus.

Natural Gas

Natural gas combustion with heating purposes was also calculated. However, below results do not contain the consumption of non-central (private) use of natural gas within the METU campus (See page 56).

A ratio was calculated in order to get the data which shows how much CO_2 stems from combusting 1 cubic meter natural gas.

Ratio (tCO_2/m^3) = [CO2 Emissions from Natural Gas Combustion (million tons of CO_2)] / [National Natural Gas Consumption Value (million m^3)]

Ratio (tCO_2/m^3) = (85.7) / (44.1 x 10^3) = 0.00195

Total CO_2 emission due to combustion (tonnes) = [Natural Gas Consumption in METU (m^3)] x [Ratio (tCO_2/m^3)]

After that obtaining total CO_2 emitted, in order for calculating the EF value due to natural gas combustion Table 17 was followed. EF was found 4276.28706 gha.

Total EF for Energy Component (gha) = 4567.4 + 4276.28 = 8843,69

3.4 Ecological Footprint of Built-up[40]

Table 44: The EF Calculation Steps for Built-up Component

Built-up EF Calculation	Area (ha)
Total building are of usage in campus	65.25
Built-Up area around Eymir Lake Land	3.71
Main Roads Area	18.59
Linking Roads	2.40
Length and width of the internal roads of the Eymir Lake	5.90
Built-up land usage in Eymir Lake Land	3.71
Car Park Area	10.80
Total Area	110.36
Crop Yield Factor	0.76
Infrastructure Equivalence Factor	2.51
Built-Up EF (gha)	**210.52**

[40] (See methodology at page 81)

Built-up EF is calculated according to the methodology explain in page 82 as 210 gha.

3.5 Ecological Footprint of Waste and Recycle[41]

Table 45: The EF Calculation Steps for Waste Component

Variables	Values
Total Waste in METU (tonne)	3009.306
Electricity produced from 1 kilogram organic waste (kWh)	2.8
Turkey CO_2 emissions per kWh from electricity generation ($grCO_2$/kWh)	472
CO_2 emitted from METU waste in one year (tonne)	**3977.178**
Aprroximate number of waste collected by garbage truck	624
Heavy Duty Vehicle Emission Rate($grCO_2$/km)	870
Distance to Mamak Landfill in Ankara (km)	75
CO_2 emitted from METU waste delivery in one year (tonne)	**40.716**
CO_2 to C Ratio (tC/tCO_2)	0.27
Forest Sequesteration Rate (tC/ha)	0.97
Ocean Absorption Rate per tone	0.28
Forest Equivalence Factor (gha/ha)	1.26
EF due to waste production (gha)	**1004.315**
EF due to delivery of collected waste to the landfill (gha)	**10.28158753**
Total EF(gha)	**1014.597**

After CO_2 emission was obtained, the formulation in Table 17 was followed to reach EF of waste and recycle.

Table 46: The EF Calculation Steps for Recycle Component

CO_2 emitted from METU due to recycle process of 5 main groups	**675,1869376**
CO_2 to C Ratio (tC/tCO_2)	0.27
Forest Sequesteration Rate (tC/ha)	0.97
Ocean Absorption Rate per tone	0.28
Forest Equivalence Factor (gha/ha)	1.26
Total EF(gha)	**170.49**

[41] (See methodology at page 76)

3.6 Total Ecological Footprint of METU

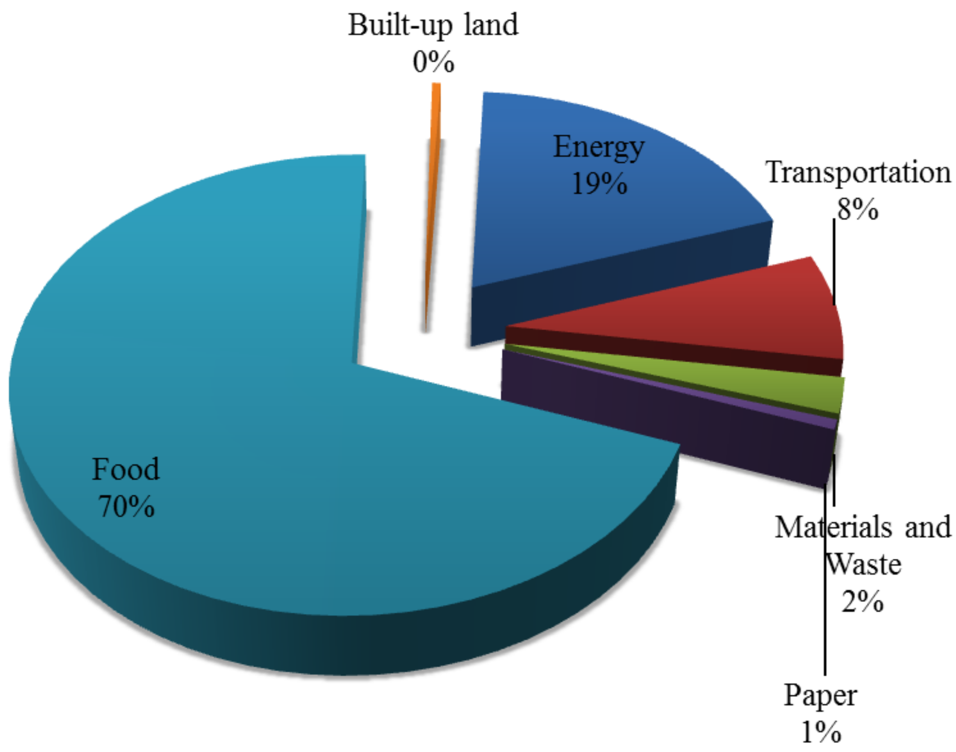

Figure 44: Percentage Distribution of EF values by components

The Ecological Footprint of Middle East Technical University yielded 46451.46 in global hectare, 45823.81 in hectare. Considering total METU area is 4350 hectares, 41.000 hectare-consumption fulfilled from outside of the study area.

Greatest contribution with %70 to the total EF was made by food component. The reasons may be followings: There are more than 60 restaurants and canteens scattered throughout study area; METU has a vast population and around 5000 of this population live in the campus; There is no well recorded data set about yearly food consumption which causes some subjective answers to be given; All the raw materials are supplied outside the campus which causes intensive goods distribution cycle; Restaurants' and canteens' management and maintenance cost are significant that leads additional energy requirement.

Energy component with %19 is the second greatest component. The reasons may be followings: Almost the entire electricity requirement is supplied from outside resources; there are enormous indoor areas to be heated by central heating system and around 5000 of this population live in the campus which requires constant natural gas consumption. It is better to emphasized central heating boiler were automatized which provides substantial energy saving.

The last component which makes significant contribution to total EF is the transportation. The reasons may be followings: There is no direct public transportation lines from some major districts of the city to METU campus and public transportation infrastructure is inadequate in Ankara which causes car ownership to increase vastly in the campus, The vehicles that are used as shuttle busses and services are too old having enormous CO_2 emission rate.

The rest of components make %3 contribution to the EF.

Table 47: EF Values by components and EF per capita Values

	EF (gha)	EF (ha)	EF per capita (28715 Population)
Food	32649.21	36477.03	1.1370
Energy	8843.69	7018.8	0.3080
Transportation	3563.23	1110.44	0.1241
Built-Up	210.52	277	0.0073
Waste and Recycle	1184.82	940.54	0.0413
Total	46451.46	45823.81	1.6177

Per capita values for EF of each component are shown in Table 47. These results revealed that 1.6177 hectare is required to fulfill the consumption of each METU member.

Table 48 and Figure 47 demonstrate the comparison between the METU results and the some other universities. Among the universities compared, Ohio State University, University of Illinois at Chicago and Colorado College comes to the forefront with their EF per capita values. METU EF per capita follows those universities. However, when considering all of the universities compared, except the food consumption, METU has ordinary consumption rate.

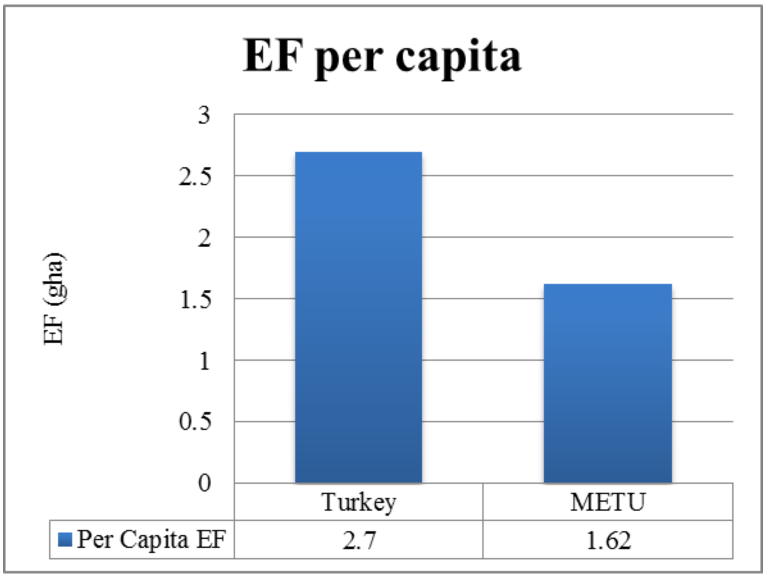

Figure 45: Comparison of EF per capita for Turkey and METU [88]

Considering 2.7 EF per capita values of Turkey, METU has an EF per capita that below the national average.

Comparing EF values for different HEIs is rather meaningless since population values, calculation years and methods, included components, etc. can differ from one study to another. Therefore, EF per capita comparisons have been preferred.

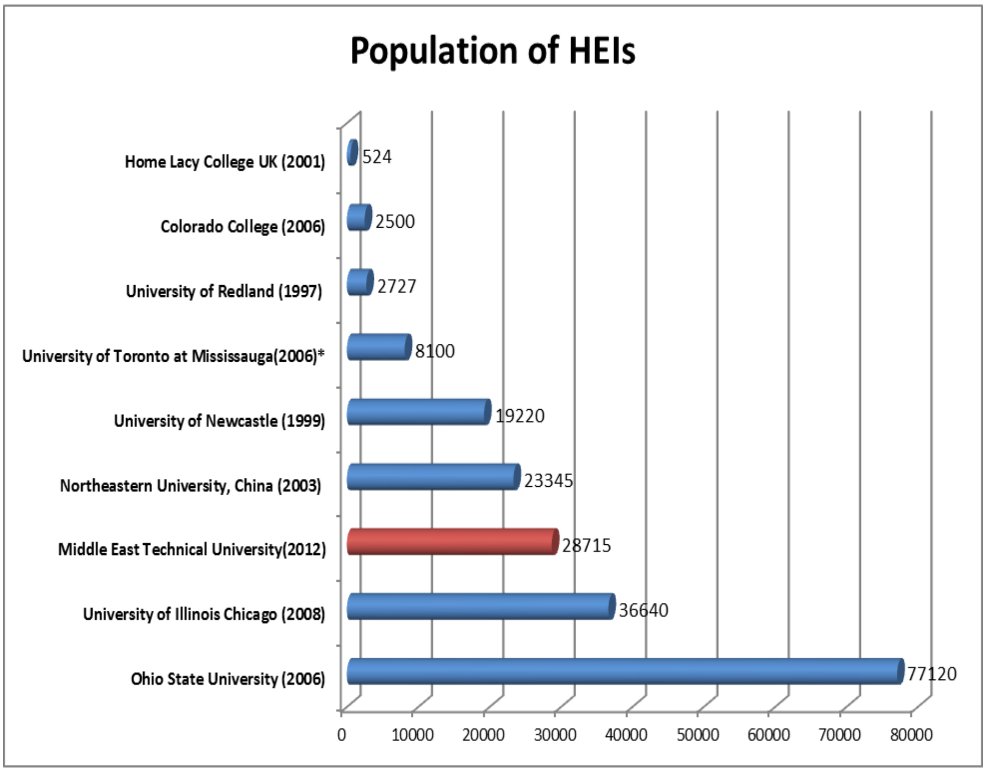

Figure 46: Population of High Education Institutes

Table 48: Comparison of Ecological Footprints for Colleges and Universities

	Middle East Technical University	University of Illinois at Chicago	University of Redlands	University of Newcastle	Holme Lacy College, UK	Northeastern University, China	University of Toronto at Mississauga	Colorado College	Ohio State University, Columbus
Year	2012	2008	1997	1999	2001	2003	2005	2006	2007
Ecological footprint, ha	45824	97601	5700	3592	296	24787	8744	5603	650666
Ratio EF to land area	11.46	1005	40	26	1.23	50	97	154	916
Per capita	1.62	2.66	0.9	0.19	0.57	1.06	1.07	2.24	8.66
Energy	19.04%	72.66%	49.50%	47%	19%	67.97%	69.40%	87%	23.30%
Transportation	7.67%	12.60%	32.50%	46%	23%	0.08%	16.10%	1.40%	72.24%
Materials and Waste	2.55%	11.83%	12.50%	2%	32%	5.74%	4%	na	4.46%
Paper	na	na	na	na	na	2%	na	na	na
Food	70.29%	2.60%	na	2%	25%	21.80%	9.20%	10%	na
Built-up land	0.45%	0.18%	na	2%	1%	0.44%	1.20%	na	w/transport
Water	na	0.14%	5%	1%	w/built-up land	2%	0.20%	1%	na
Source		[84]	[78]	[77]	[76]	[64]	[177]	[81]	[82]

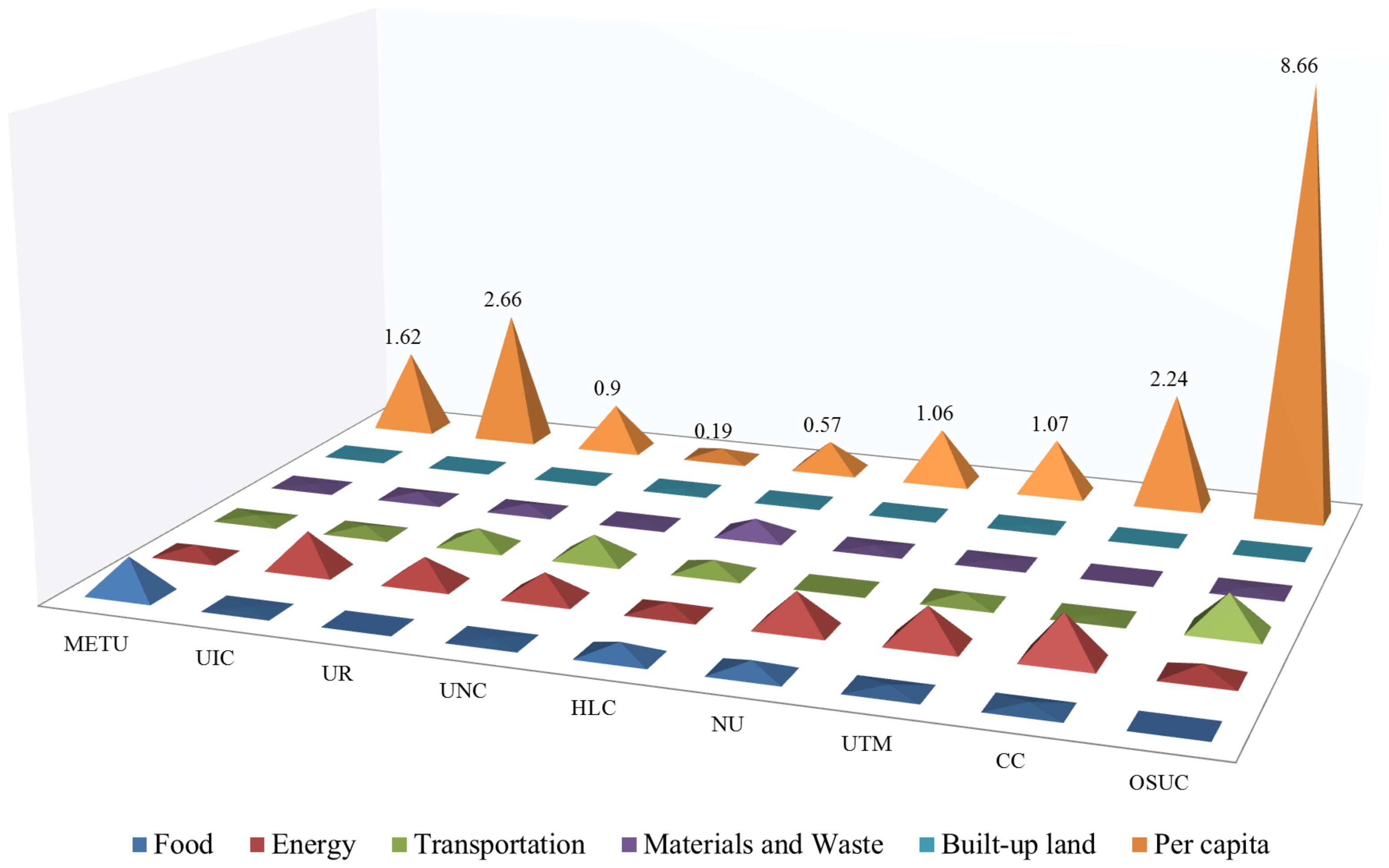

Figure 47: Comparison of Ecological Footprint Components and EF per capita for Colleges and Universities

CHAPTER 4

4. CONCLUSIONS

4.1 Conclusions

The Ecological Footprint is a model whose methodology is based on ecological concepts such as the regenerative capacity of the Earth and carrying capacity of Nature. This model gives insight about the delicate balance between human consumption patterns and the Earth's regenerative capacity, which is important to understand the consequences of particular activities. Using a component-based method, the ecological footprint of each component can be obtained separately. Thus this methodology is considered a bottom-up method. Summing components yields the total ecological footprint. This methodology better suits the objectives of the current thesis. Component-based EF is a quantitative method within the context of developing sustainability to understand the current situation and suggest a framework for action. The calculation of EF will provide a basis for determining strategies towards a sustainable campus.

The primary objective of the current thesis is to present a preliminary study on a comprehensive quantification of the Ecological Footprint for the Middle East Technical University (Ankara Campus), which is one of the biggest public universities in Turkey. In addition the study aims to be one of the first studies to give '*a static snapshot*' of the impacts generated by the METU campus, especially on the environment, for a target year. This study also sets its goal to investigate possibilities for contributing to campus operations, policy development and educational curricula in becoming a sustainable campus. The objectives of this thesis are also in line with the *2011-2016 METU Strategic Plan*, where one of its strategies is to become a sustainable campus.

Transportation, energy use, food consumption, waste & recycle, and built-up land which are also fundamental elements of green campus were investigated comprehensively. The Ecological Footprint of Middle East Technical University yielded 46451.46 global hectares of which %70 is food, %19 energy, %8 transportation and %3 other components. When compared to National EF per capita value and some other universities' EF per capita values, METU has a tolerable EF per capita value.

Nevertheless, 41.000 hectares away from the study area are required to fulfill the current consumption rate. Thus, some regulations and projects might be put into effect to reduce EF values especially for food, energy, and transportation.

When each component whose EF value was calculated is analysed, the study shows that in order for METU to take a step into being a sustainable campus, the food component needs more attention. Underlying reasons why food component has such high EF value may be examined in a detailed way and the in the light of the upcoming results strategies can be revised. On the other hand, results showed that METU has an advantage in food component. Cafeteria (20%) together with department (26%) & dormitory (26%) canteens accounted for almost 70% of all EF for food whose management and guidance are easier compared to other commercial restaurants. Sustainability should be internalized in the food component. Local producers may be preferred when products are purchased. Strategies in order to set a course for reducing and making different uses of food waste may be considered carefully. Moreover, transportation of food products to the campus may be rearranged where it may be possible to reduce resulting CO_2 uptake land area requirement. Furthermore, METU management may lead the way for launching a campaign for '*slow food*' concept within campus. Parallel to that 'food sustainability' training may be provided for restaurant or canteen owners, workers and customers. Addition to that a possibility of introducing small scale '*hobby gardens*' within campus open to METU member use may be considered.

Many universities in Turkey have started to establish renewable energy resources inside their campus to fulfil energy needs. For example, Hacettepe University [185] and Bilkent University [186], both in Ankara, has renewable energy production facilities within their campuses. METU Ankara campus is rather weak in this respect.

Although a positive improvement for METU campus' energy efficiency took place thanks to a transition into a computerized system for controlling central heating boilers in 2007 [187], considering that almost all energy needs are obtained from the outside, this issue should be given priority. On the other hand, METU has an advantage in this respect in the form of a '*Center for Solar Energy Research and Applications*'. This center had run projects that aimed to turn the university into a '*Solar Campus*' [188]. Three main projects were introduced for that: 'Solar Bicycles' project; 'Solar façade' for energy efficient buildings and 'Solar roofs' for heating and cooling [188], [189]. The implementation of those projects may be facilitated in order for METU to have sustainable campus. In addition, METU partially made a change for more efficient lighting systems. Photocells to reduce the time lights are on are being used in some department buildings. Some of the street lights within campus have been changed to be photovoltaic or converted from traditional bulbs to LED lights. Furthermore, small-scale efficiency in energy may be procured by introducing an inter-departmental energy competition and conducting a campaign for saving energy from computer use. Besides, large-scale energy efficiency may be ensured by introducing green infrastructure within the campus. For instance, one department building may be retrofitted as a pilot project in order to gain a LEED certificate[42] so as to call attention to benefits of green building systems within the campus.

Some strategic steps can be taken to improve condition of transportation at METU campus so as to reduce EF of transportation. Priority may be given to develop sustainable transportation strategies for METU campus in a holistic view. One option is to replace 1970 model service and shuttle busses with new ones. Thus, how to set a budget for a new bus fleet with biofuel can be counted as an important strategy. By means of a survey, METU administration may determine the districts outside the campus with the highest car ownership rate among METU members and pave the way to establish direct lines from these districts to METU, in cooperation with the relevant municipal units. In addition, main green parking lots may be created by ecological design at the periphery of the campus, a new Public transportation hub can be established nearby, and a sustainable mode of transportation for distribution from that point to inside campus can be introduced. Another pilot project that may help

[42] LEED cetificate details can be reached from [209].

METU gain reputation worldwide in campus sustainability is to implement 'Solar Taxi' project of '*Designnobis*' team[43]. Together with 'Solar bicycle' project mentioned above the taxi project have the potential to arouse METU members' interest towards sustainability which may help further reduce the transportation footprint. Some other strategies can be developed for increasing car occupancy rate. Hitchhiking is already working well within the campus. Many students at METU use hitchhiking to travel inside campus or to travel just outside the campus. Car sharing has a potential to reduce the transportation EF. Therefore, an application for smart phones can be developed to systematize and expand the scope of carpooling that may be used by informing interested members about their travel time and route to and from the university. Such commuter programs may help increase car-occupancy rates even further.

It can be claimed that METU already successfully deals with waste and recycling issues. A budget has been set from recycling processes within campus to give scholarships. Another advantage of METU is that the collected waste is sent to the Mamak landfill where wastes are further sorted out for recycling and the rest is being used to produce electricity. However, some additional projects may be supported to increase efficient use of organic waste within campus such as composting, and separation of recyclable materials thrown with garbage. Scope of the recycling process may be expanded within the university. For instance, effective paper use and recycling can be provided by announcing inter-departmental competition on seasonal per capita paper use and the amount of paper sent to be recycled.

Natural resource management for METU campus may be started in liaison with the METU administration. This thesis showed that, especially a study of sustainable yield of ground water resources for METU may be a good start point. The campus may be considered as a natural laboratory and further re-design ecologically. It already has some important parts that have been untouched for almost fifty years and contains many native and endemic plants & animals. The Ankara campus is located within a largely urban area which may mean if this land was not used as a university campus; it could have been almost completely built-up now.

---

[43]A sustainable Design Center at METU Techno polis [210].

Perhaps the most important first step is to establish an administrative unit that has the capacity to gather all work done in this field under one roof in order to prepare and manage a campus sustainability action plan.

4.1 Limitations of the Thesis & Recommendations for Further Studies

EF methodology is hard to apply at local and regional scales. Institutional EF calculations have an advantage of collecting data from its own archives. However, even though obtaining local data set is vital in the precise calculations for EF, this study faced setbacks and difficulties in finding proper data sets at institutional, local and national levels. Thus, recording local data sets plays crucial role. Forming embodied energy values for food and waste and recycle materials, uplift factors and corresponding CO_2 emissions provides benefits for further EF studies in Turkey.

Calculating embodied energy table for each food units (i.e. milk, chicken, olive oil, etc.) specific to the university campus can be accomplished, which will serve to calculate EF of food component more robust and accurate. Biocapacity calculations should be made for a better understanding of METU campus' effects on nature.

Self-reporting or data tracking system may help to reach any required data set for particular studies' need. Therefore, the institution should have an active and user-friendly system to record data sets.

METU can pave the way by conducting questionnaires within the campus. A suggestion is to form an online tool on the university website to give an opportunity for the questionnaire conductors to reach significant sample sizes, target relevant groups such as students or academicians, and offer a secured venue for participants. A notification mail might be sent to the target group as soon as a questionnaire is submitted.

During the EF calculations due to lack of direct data many crucial assumptions, estimations were made. It is recommended for further studies to make sensitivity analysis to observe how those may affect the final result.

Although EF calculations at institutional scale are data-intensive, they may enable institution to compare current situation with its objectives and policies and help to point out where to start implementation to make situation better for institution.

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APENDIX A

A. ECOLOGICAL FOOTPRINT OF FOOD

Total Food Consumption in 2012 at METU and Total EF Ecological Footprint of Food

Product	kg	Embodied Energy MJ/t	GWP tCO23/t	Yield Factor kg/ha	Equivalance Factor (gha/ha)	EF Due to Land (gha)	Ef Due to CO2 (gha)	Total EF (gha)
Milk	202,194.74	17.60	3.52	336.00	0.46	276.81	179.72	456.54
Yoghurt	254,231.93	48.88	7.21	34.00	0.46	3,439.61	462.87	3,902.48
Cheese	111,319.29	91.67	13.86	34.00	0.46	1,506.08	389.61	1,895.69
Butter	50,601.25	42.12	12.17	34.00	0.46	684.61	155.51	840.11
Cream	5,388.75	42.12	12.17	34.00	0.46	72.91	16.56	89.47
Vegetable and salad oils	162,823.57	25.79	3.00	262.00	2.51	1,559.87	123.35	1,683.22
Margarine	30,963.67	25.97	3.02	240.00	2.51	323.83	23.61	347.44
Beef and veal	147,998.42	67.90	19.30	24.00	1.49	9,157.40	721.29	9,878.69
Mutton and Lamb	21,697.01	54.70	13.09	52.00	1.49	619.62	71.72	691.34
Poultry (uncooked)	234,169.53	43.02	10.63	734.00	2.51	800.77	628.58	1,429.35
All other meats	134,219.81	85.48	17.17	734.00	1.49	271.55	581.95	853.49
Total fish	49,656.05	209.47	17.23	29.00	0.37	633.54	216.05	849.59
Egg	342,426.68	21.80	5.48	550.00	2.51	1,562.71	473.85	2,036.56
Sugar	57,383.75	14.36	1.67	3,229.00	2.51	44.61	24.20	68.81
Honey	4,063.85	34.66	4.01	3,229.00	0.46	0.58	4.12	4.69
Jam	2,917.03	34.66	4.01	3,229.00	2.51	2.27	2.95	5.22
Potatoes	377,426.31	19.17	1.88	13,385.00	0.46	12.97	179.18	192.15
Fresh green vegatables	404,745.37	14.90	2.00	12,120.00	0.46	15.36	204.41	219.77
Cereals	169,735.85	18.56	4.07	2,641.00	0.46	29.56	174.45	204.01
Fresh fruits	223,922.88	17.59	3.04	12,120.00	0.46	8.50	171.90	180.40
Bread	419,801.22	14.05	1.49	2,650.00	2.51	397.62	157.95	555.58
Flour	180,762.51	9.73	1.15	2,641.00	0.46	31.48	52.49	83.98
All other cereals	42,051.37	18.56	4.07	2,641.00	0.46	7.32	43.22	50.54
Tea	59,460.06	55.16	6.01	696.00	0.46	39.30	90.24	129.54
Coffee	37,004.76	128.92	13.62	696.00	0.46	24.46	127.27	151.73
Cocoa/drinking chocolate	10,266.31	60.51	7.31	408.00	2.51	63.16	18.95	82.11
Branded food drinks	669,252.14	73.94	8.81	3,229.00	2.51	520.23	1,488.88	2,009.11
Water	1,419,243.16	7.77	0.83	Only Energy Land	0.37		297.46	297.46
Mineral water	190,813.70	7.77	0.83	Only Energy Land	0.37		39.99	39.99
Ayran	222,809.48	48.89	7.21	34.00	0.46	3,014.48	405.66	3,420.14
Total	**6,239,350**					**25,121**	**7,527**	**32,649**

APENDIX B

B. CARBON EMISSIONS AND FUEL CONSUMPTION OF TRANSPORTATION

Total Fuel Consumption and Carbon Emissions in 2012 at METU and Total EF Ecological Footprint of Transportation

		MONTH	JANUARY				FEBRUARY				MARCH				APRIL			
		WEEK	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Academic Staff		Total Number of Vehicle	3316	3316	3316	3316	3316	3316	3316	3316	3316	3316	3316	3316	3316	3316	3316	3316
		Active Vehicle Rate	1	1	1	0.9	0.9	0.9	0.9	0.9	1	1	1	1	1	1	1	1
	Gasoline	Number of Valid Questionnaires	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
		Approx, Number of Active Vehicle	2267	2267	2267	2040	2040	2040	2040	2040	2267	2267	2267	2267	2267	2267	2267	2267
		Avr, Carbon gr from the Survey	10,618.09	10,618.09	10,618.09	10,618.09	10,618.09	10,618.09	10,618.09	10,618.09	10,618.09	10,618.09	10,618.09	10,618.09	10,618.09	10,618.09	10,618.09	10,618.09
		Total Carbon Emission (gr)	24,071,215.70	24,071,215.70	24,071,215.70	21,664,094.13	21,664,094.13	21,664,094.13	21,664,094.13	21,664,094.13	24,071,215.70	24,071,215.70	24,071,215.70	24,071,215.70	24,071,215.70	24,071,215.70	24,071,215.70	24,071,215.70
		Avarage Fuel lt from the Survey	6.99	6.99	6.99	6.99	6.99	6.99	6.99	6.99	6.99	6.99	6.99	6.99	6.99	6.99	6.99	6.99
		Total Fuel Consumption (lt)	15,846.33	15,846.33	15,846.33	14,261.70	14,261.70	14,261.70	14,261.70	14,261.70	15,846.33	15,846.33	15,846.33	15,846.33	15,846.33	15,846.33	15,846.33	15,846.33
	Diesel	Number of Valid Questionnaires	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37
		Approx, Number of Active Vehicle	1049	1049	1049	944	944	944	944	944	1049	1049	1049	1049	1049	1049	1049	1049
		Avr, Carbon gr from the Survey	9,151.60	9,151.60	9,151.60	9,151.60	9,151.60	9,151.60	9,151.60	9,151.60	9,151.60	9,151.60	9,151.60	9,151.60	9,151.60	9,151.60	9,151.60	9,151.60
		Total Carbon Emission (gr)	9,600,028.40	9,600,028.40	9,600,028.40	8,640,025.56	8,640,025.56	8,640,025.56	8,640,025.56	8,640,025.56	9,600,028.40	9,600,028.40	9,600,028.40	9,600,028.40	9,600,028.40	9,600,028.40	9,600,028.40	9,600,028.40
		Avarage Fuel lt from the Survey	5.10	5.10	5.10	5.10	5.10	5.10	5.10	5.10	5.10	5.10	5.10	5.10	5.10	5.10	5.10	5.10
		Total Fuel Consumption (lt)	5,349.90	5,349.90	5,349.90	4,814.91	4,814.91	4,814.91	4,814.91	4,814.91	5,349.90	5,349.90	5,349.90	5,349.90	5,349.90	5,349.90	5,349.90	5,349.90
Administrative Staff		Total Number of Vehicle	1941	1941	1941	1941	1941	1941	1941	1941	1941	1941	1941	1941	1941	1941	1941	1941
		Active Vehicle Rate	1	1	1	1	0.95	0.95	0.95	0.95	1	1	1	1	1	1	1	1
	Gasoline	Number of Valid Questionnaires	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23
		Approx, Number of Active Vehicle	1207	1207	1207	1207	1147	1147	1147	1147	1207	1207	1207	1207	1207	1207	1207	1207
		Avr, Carbon gr from the Survey	11,713.44	11,713.44	11,713.44	11,713.44	11,713.44	11,713.44	11,713.44	11,713.44	11,713.44	11,713.44	11,713.44	11,713.44	11,713.44	11,713.44	11,713.44	11,713.44
		Total Carbon Emission (gr)	14,138,126.28	14,138,126.28	14,138,126.28	14,138,126.28	13,431,219.96	13,431,219.96	13,431,219.96	13,431,219.96	14,138,126.28	14,138,126.28	14,138,126.28	14,138,126.28	14,138,126.28	14,138,126.28	14,138,126.28	14,138,126.28
		Avarage Fuel lt from the Survey	7.73	7.73	7.73	7.73	7.73	7.73	7.73	7.73	7.73	7.73	7.73	7.73	7.73	7.73	7.73	7.73
		Total Fuel Consumption (lt)	9,330.11	9,330.11	9,330.11	9,330.11	8,863.60	8,863.60	8,863.60	8,863.60	9,330.11	9,330.11	9,330.11	9,330.11	9,330.11	9,330.11	9,330.11	9,330.11
	Diesel	Number of Valid Questionnaires	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14
		Approx, Number of Active Vehicle	734	734	734	734	697	697	697	697	734	734	734	734	734	734	734	734
		Avr, Carbon gr from the Survey	7,709.13	7,709.13	7,709.13	7,709.13	7,709.13	7,709.13	7,709.13	7,709.13	7,709.13	7,709.13	7,709.13	7,709.13	7,709.13	7,709.13	7,709.13	7,709.13
		Total Carbon Emission (gr)	5,658,500.37	5,658,500.37	5,658,500.37	5,658,500.37	5,375,575.35	5,375,575.35	5,375,575.35	5,375,575.35	5,658,500.37	5,658,500.37	5,658,500.37	5,658,500.37	5,658,500.37	5,658,500.37	5,658,500.37	5,658,500.37
		Avarage Fuel lt from the Survey	4.28	4.28	4.28	4.28	4.28	4.28	4.28	4.28	4.28	4.28	4.28	4.28	4.28	4.28	4.28	4.28
		Total Fuel Consumption (lt)	3,141.52	3,141.52	3,141.52	3,141.52	2,984.44	2,984.44	2,984.44	2,984.44	3,141.52	3,141.52	3,141.52	3,141.52	3,141.52	3,141.52	3,141.52	3,141.52
Student		Total Number of Vehicle	3181	3181	3181	3181	3181	3181	3181	3181	3181	3181	3181	3181	3181	3181	3181	3181
		Active Vehicle Rate	1	1	1	1	0.05	0.05	0.05	0.05	1	1	1	1	1	1	1	1
	Gasoline	Number of Valid Questionnaires	109	109	109	109	109	109	109	109	109	109	109	109	109	109	109	109
		Approx, Number of Active Vehicle	2140	2140	2140	2140	107	107	107	107	2140	2140	2140	2140	2140	2140	2140	2140
		Avr, Carbon gr from the Survey	11,394.38	11,394.38	11,394.38	11,394.38	11,394.38	11,394.38	11,394.38	11,394.38	11,394.38	11,394.38	11,394.38	11,394.38	11,394.38	11,394.38	11,394.38	11,394.38
		Total Carbon Emission (gr)	24,383,966.92	24,383,966.92	24,383,966.92	24,383,966.92	1,219,198.35	1,219,198.35	1,219,198.35	1,219,198.35	24,383,966.92	24,383,966.92	24,383,966.92	24,383,966.92	24,383,966.92	24,383,966.92	24,383,966.92	24,383,966.92
		Avarage Fuel lt from the Survey	7.80	7.80	7.80	7.80	7.80	7.80	7.80	7.80	7.80	7.80	7.80	7.80	7.80	7.80	7.80	7.80
		Total Fuel Consumption (lt)	16,692.00	16,692.00	16,692.00	16,692.00	834.60	834.60	834.60	834.60	16,692.00	16,692.00	16,692.00	16,692.00	16,692.00	16,692.00	16,692.00	16,692.00
	Diesel	Number of Valid Questionnaires	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53
		Approx, Number of Active Vehicle	1041	1041	1041	1041	52	52	52	52	1041	1041	1041	1041	1041	1041	1041	1041
		Avr, Carbon gr from the Survey	13,134.95	13,134.95	13,134.95	13,134.95	13,134.95	13,134.95	13,134.95	13,134.95	13,134.95	13,134.95	13,134.95	13,134.95	13,134.95	13,134.95	13,134.95	13,134.95
		Total Carbon Emission (gr)	13,673,487.86	13,673,487.86	13,673,487.86	13,673,487.86	683,674.39	683,674.39	683,674.39	683,674.39	13,673,487.86	13,673,487.86	13,673,487.86	13,673,487.86	13,673,487.86	13,673,487.86	13,673,487.86	13,673,487.86
		Avarage Fuel lt from the Survey	5.79	5.79	5.79	5.79	5.79	5.79	5.79	5.79	5.79	5.79	5.79	5.79	5.79	5.79	5.79	5.79
		Total Fuel Consumption (lt)	6,027.39	6,027.39	6,027.39	6,027.39	301.37	301.37	301.37	301.37	6,027.39	6,027.39	6,027.39	6,027.39	6,027.39	6,027.39	6,027.39	6,027.39

Table continued

		MONTH	MAY				JUNE				JULY				AUGUST			
		WEEK	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Academic Staff		Total Number of Vehicle	3316	3316	3316	3316	3316	3316	3316	3316	3316	3316	3316	3316	3316	3316	3316	3316
		Active Vehicle Rate	1	1	1	1	1	1	1	1	0.7	0.7	0.7	0.7	0.7	0.6	0.6	0.6
	Gasoline	Number of Valid Questionnaires	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
		Approx, Number of Active Vehicle	2267	2267	2267	2267	2267	2267	2267	2267	1587	1587	1587	1587	1587	1360	1360	1360
		Avr, Carbon gr from the Survey	10,618.09	10,618.09	10,618.09	10,618.09	10,618.09	10,618.09	10,618.09	10,618.09	10,618.09	10,618.09	10,618.09	10,618.09	10,618.09	10,618.09	10,618.09	10,618.09
		Total Carbon Emission (gr)	24,071,215.70	24,071,215.70	24,071,215.70	24,071,215.70	24,071,215.70	24,071,215.70	24,071,215.70	24,071,215.70	16,849,850.99	16,849,850.99	16,849,850.99	16,849,850.99	16,849,850.99	14,442,729.42	14,442,729.42	14,442,729.42
		Avarage Fuel lt from the Survey	6.99	6.99	6.99	6.99	6.99	6.99	6.99	6.99	6.99	6.99	6.99	6.99	6.99	6.99	6.99	6.99
		Total Fuel Consumption (lt)	15,846.33	15,846.33	15,846.33	15,846.33	15,846.33	15,846.33	15,846.33	15,846.33	11,092.43	11,092.43	11,092.43	11,092.43	11,092.43	9,507.80	9,507.80	9,507.80
	Diesel	Number of Valid Questionnaires	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37
		Approx, Number of Active Vehicle	1049	1049	1049	1049	1049	1049	1049	1049	734	734	734	734	734	629	629	629
		Avr, Carbon gr from the Survey	9,151.60	9,151.60	9,151.60	9,151.60	9,151.60	9,151.60	9,151.60	9,151.60	9,151.60	9,151.60	9,151.60	9,151.60	9,151.60	9,151.60	9,151.60	9,151.60
		Total Carbon Emission (gr)	9,600,028.40	9,600,028.40	9,600,028.40	9,600,028.40	9,600,028.40	9,600,028.40	9,600,028.40	9,600,028.40	6,720,019.88	6,720,019.88	6,720,019.88	6,720,019.88	6,720,019.88	5,760,017.04	5,760,017.04	5,760,017.04
		Avarage Fuel lt from the Survey	5.10	5.10	5.10	5.10	5.10	5.10	5.10	5.10	5.10	5.10	5.10	5.10	5.10	5.10	5.10	5.10
		Total Fuel Consumption (lt)	5,349.90	5,349.90	5,349.90	5,349.90	5,349.90	5,349.90	5,349.90	5,349.90	3,744.93	3,744.93	3,744.93	3,744.93	3,744.93	3,209.94	3,209.94	3,209.94
Administrative Staff		Total Number of Vehicle	1941	1941	1941	1941	1941	1941	1941	1941	1941	1941	1941	1941	1941	1941	1941	1941
		Active Vehicle Rate	1	1	1	1	1	1	1	1	0.75	0.75	0.75	0.75	0.4	0.4	0.4	0.4
	Gasoline	Number of Valid Questionnaires	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23
		Approx, Number of Active Vehicle	1207	1207	1207	1207	1207	1207	1207	1207	905	905	905	905	483	483	483	483
		Avr, Carbon gr from the Survey	11,713.44	11,713.44	11,713.44	11,713.44	11,713.44	11,713.44	11,713.44	11,713.44	11,713.44	11,713.44	11,713.44	11,713.44	11,713.44	11,713.44	11,713.44	11,713.44
		Total Carbon Emission (gr)	14,138,126.28	14,138,126.28	14,138,126.28	14,138,126.28	14,138,126.28	14,138,126.28	14,138,126.28	14,138,126.28	10,603,594.71	10,603,594.71	10,603,594.71	10,603,594.71	5,655,250.51	5,655,250.51	5,655,250.51	5,655,250.51
		Avarage Fuel lt from the Survey	7.73	7.73	7.73	7.73	7.73	7.73	7.73	7.73	7.73	7.73	7.73	7.73	7.73	7.73	7.73	7.73
		Total Fuel Consumption (lt)	9,330.11	9,330.11	9,330.11	9,330.11	9,330.11	9,330.11	9,330.11	9,330.11	6,997.58	6,997.58	6,997.58	6,997.58	3,732.04	3,732.04	3,732.04	3,732.04
	Diesel	Number of Valid Questionnaires	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14
		Approx, Number of Active Vehicle	734	734	734	734	734	734	734	734	551	551	551	551	294	294	294	294
		Avr, Carbon gr from the Survey	7,709.13	7,709.13	7,709.13	7,709.13	7,709.13	7,709.13	7,709.13	7,709.13	7,709.13	7,709.13	7,709.13	7,709.13	7,709.13	7,709.13	7,709.13	7,709.13
		Total Carbon Emission (gr)	5,658,500.37	5,658,500.37	5,658,500.37	5,658,500.37	5,658,500.37	5,658,500.37	5,658,500.37	5,658,500.37	4,243,875.28	4,243,875.28	4,243,875.28	4,243,875.28	2,263,400.15	2,263,400.15	2,263,400.15	2,263,400.15
		Avarage Fuel lt from the Survey	4.28	4.28	4.28	4.28	4.28	4.28	4.28	4.28	4.28	4.28	4.28	4.28	4.28	4.28	4.28	4.28
		Total Fuel Consumption (lt)	3,141.52	3,141.52	3,141.52	3,141.52	3,141.52	3,141.52	3,141.52	3,141.52	2,356.14	2,356.14	2,356.14	2,356.14	1,256.61	1,256.61	1,256.61	1,256.61
Student		Total Number of Vehicle	3181	3181	3181	3181	3181	3181	3181	3181	3181	3181	3181	3181	3181	3181	3181	3181
		Active Vehicle Rate	1	1	1	1	1	1	1	1	0.32	0.32	0.32	0.32	0.32	0	0	0
	Gasoline	Number of Valid Questionnaires	109	109	109	109	109	109	109	109	109	109	109	109	109	109	109	109
		Approx, Number of Active Vehicle	2140	2140	2140	2140	2140	2140	2140	2140	685	685	685	685	685	0	0	0
		Avr, Carbon gr from the Survey	11,394.38	11,394.38	11,394.38	11,394.38	11,394.38	11,394.38	11,394.38	11,394.38	11,394.38	11,394.38	11,394.38	11,394.38	11,394.38	11,394.38	11,394.38	11,394.38
		Total Carbon Emission (gr)	24,383,966.92	24,383,966.92	24,383,966.92	24,383,966.92	24,383,966.92	24,383,966.92	24,383,966.92	24,383,966.92	7,802,869.41	7,802,869.41	7,802,869.41	7,802,869.41	7,802,869.41	0.00	0.00	0.00
		Avarage Fuel lt from the Survey	7.80	7.80	7.80	7.80	7.80	7.80	7.80	7.80	7.80	7.80	7.80	7.80	7.80	7.80	7.80	7.80
		Total Fuel Consumption (lt)	16,692.00	16,692.00	16,692.00	16,692.00	16,692.00	16,692.00	16,692.00	16,692.00	5,341.44	5,341.44	5,341.44	5,341.44	5,341.44	0.00	0.00	0.00
	Diesel	Number of Valid Questionnaires	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53
		Approx, Number of Active Vehicle	1041	1041	1041	1041	1041	1041	1041	1041	333	333	333	333	333	0	0	0
		Avr, Carbon gr from the Survey	13,134.95	13,134.95	13,134.95	13,134.95	13,134.95	13,134.95	13,134.95	13,134.95	13,134.95	13,134.95	13,134.95	13,134.95	13,134.95	13,134.95	13,134.95	13,134.95
		Total Carbon Emission (gr)	13,673,487.86	13,673,487.86	13,673,487.86	13,673,487.86	13,673,487.86	13,673,487.86	13,673,487.86	13,673,487.86	4,375,516.12	4,375,516.12	4,375,516.12	4,375,516.12	4,375,516.12	0.00	0.00	0.00
		Avarage Fuel lt from the Survey	5.79	5.79	5.79	5.79	5.79	5.79	5.79	5.79	5.79	5.79	5.79	5.79	5.79	5.79	5.79	5.79
		Total Fuel Consumption (lt)	6,027.39	6,027.39	6,027.39	6,027.39	6,027.39	6,027.39	6,027.39	6,027.39	1,928.76	1,928.76	1,928.76	1,928.76	1,928.76	0.00	0.00	0.00

Table continued

MONTH			SEPTEMBER				OCTOBER				NOVEMBER				DECEMBER				TOTAL
WEEK			1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	
Academic Staff		Total Number of Vehicle	3316	3316	3316	3316	3316	3316	3316	3316	3316	3316	3316	3316	3316	3316	3316	3316	
		Active Vehicle Rate	0,8	0,8	0,8	0,8	1	1	1	1	1	1	1	1	1	1	1	1	
	Gasoline	Number of Valid Questionnaires	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	
		Approx. Number of Active Vehicle	1814	1814	1814	1814	2267	2267	2267	2267	2267	2267	2267	2267	2267	2267	2267	2267	
		Avr. Carbon gr from the Survey	10.618,09	10.618,09	10.618,09	10.618,09	10.618,09	10.618,09	10.618,09	10.618,09	10.618,09	10.618,09	10.618,09	10.618,09	10.618,09	10.618,09	10.618,09	10.618,09	
		Total Carbon Emission (gr)	19.256.972,56	19.256.972,56	19.256.972,56	19.256.972,56	24.071.215,70	24.071.215,70	24.071.215,70	24.071.215,70	24.071.215,70	24.071.215,70	24.071.215,70	24.071.215,70	24.071.215,70	24.071.215,70	24.071.215,70	24.071.215,70	**1.059.133.490,69**
		Avarage Fuel lt from the Survey	6,99	6,99	6,99	6,99	6,99	6,99	6,99	6,99	6,99	6,99	6,99	6,99	6,99	6,99	6,99	6,99	
		Total Fuel Consumption (lt)	12.677,06	12.677,06	12.677,06	12.677,06	15.846,33	15.846,33	15.846,33	15.846,33	15.846,33	15.846,33	15.846,33	15.846,33	15.846,33	15.846,33	15.846,33	15.846,33	**697.238,52**
	Diesel	Number of Valid Questionnaires	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	
		Approx. Number of Active Vehicle	839	839	839	839	1049	1049	1049	1049	1049	1049	1049	1049	1049	1049	1049	1049	
		Avr. Carbon gr from the Survey	9.151,60	9.151,60	9.151,60	9.151,60	9.151,60	9.151,60	9.151,60	9.151,60	9.151,60	9.151,60	9.151,60	9.151,60	9.151,60	9.151,60	9.151,60	9.151,60	
		Total Carbon Emission (gr)	7.680.022,72	7.680.022,72	7.680.022,72	7.680.022,72	9.600.028,40	9.600.028,40	9.600.028,40	9.600.028,40	9.600.028,40	9.600.028,40	9.600.028,40	9.600.028,40	9.600.028,40	9.600.028,40	9.600.028,40	9.600.028,40	**422.401.249,60**
		Avarage Fuel lt from the Survey	5,10	5,10	5,10	5,10	5,10	5,10	5,10	5,10	5,10	5,10	5,10	5,10	5,10	5,10	5,10	5,10	
		Total Fuel Consumption (lt)	4.279,92	4.279,92	4.279,92	4.279,92	5.349,90	5.349,90	5.349,90	5.349,90	5.349,90	5.349,90	5.349,90	5.349,90	5.349,90	5.349,90	5.349,90	5.349,90	**235.395,60**
Administrative Staff		Total Number of Vehicle	1941	1941	1941	1941	1941	1941	1941	1941	1941	1941	1941	1941	1941	1941	1941	1941	
		Active Vehicle Rate	0,9	0,9	0,9	0,9	1	1	1	1	1	1	1	1	1	1	1	1	
	Gasoline	Number of Valid Questionnaires	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	
		Approx. Number of Active Vehicle	1086	1086	1086	1086	1207	1207	1207	1207	1207	1207	1207	1207	1207	1207	1207	1207	
		Avr. Carbon gr from the Survey	11.713,44	11.713,44	11.713,44	11.713,44	11.713,44	11.713,44	11.713,44	11.713,44	11.713,44	11.713,44	11.713,44	11.713,44	11.713,44	11.713,44	11.713,44	11.713,44	
		Total Carbon Emission (gr)	12.724.313,65	12.724.313,65	12.724.313,65	12.724.313,65	14.138.126,28	14.138.126,28	14.138.126,28	14.138.126,28	14.138.126,28	14.138.126,28	14.138.126,28	14.138.126,28	14.138.126,28	14.138.126,28	14.138.126,28	14.138.126,28	**622.077.556,24**
		Avarage Fuel lt from the Survey	7,73	7,73	7,73	7,73	7,73	7,73	7,73	7,73	7,73	7,73	7,73	7,73	7,73	7,73	7,73	7,73	
		Total Fuel Consumption (lt)	8.397,10	8.397,10	8.397,10	8.397,10	9.330,11	9.330,11	9.330,11	9.330,11	9.330,11	9.330,11	9.330,11	9.330,11	9.330,11	9.330,11	9.330,11	9.330,11	**410.524,84**
	Diesel	Number of Valid Questionnaires	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	
		Approx. Number of Active Vehicle	661	661	661	661	734	734	734	734	734	734	734	734	734	734	734	734	
		Avr. Carbon gr from the Survey	7.709,13	7.709,13	7.709,13	7.709,13	7.709,13	7.709,13	7.709,13	7.709,13	7.709,13	7.709,13	7.709,13	7.709,13	7.709,13	7.709,13	7.709,13	7.709,13	
		Total Carbon Emission (gr)	5.092.650,33	5.092.650,33	5.092.650,33	5.092.650,33	5.658.500,37	5.658.500,37	5.658.500,37	5.658.500,37	5.658.500,37	5.658.500,37	5.658.500,37	5.658.500,37	5.658.500,37	5.658.500,37	5.658.500,37	5.658.500,37	**248.974.016,34**
		Avarage Fuel lt from the Survey	4,28	4,28	4,28	4,28	4,28	4,28	4,28	4,28	4,28	4,28	4,28	4,28	4,28	4,28	4,28	4,28	
		Total Fuel Consumption (lt)	2.827,37	2.827,37	2.827,37	2.827,37	3.141,52	3.141,52	3.141,52	3.141,52	3.141,52	3.141,52	3.141,52	3.141,52	3.141,52	3.141,52	3.141,52	3.141,52	**138.226,88**
Student		Total Number of Vehicle	3181	3181	3181	3181	3181	3181	3181	3181	3181	3181	3181	3181	3181	3181	3181	3181	
		Active Vehicle Rate	0	0	0	0,8	1	1	1	1	1	1	1	1	1	1	1	1	
	Gasoline	Number of Valid Questionnaires	109	109	109	109	109	109	109	109	109	109	109	109	109	109	109	109	
		Approx. Number of Active Vehicle	0	0	0	1712	2140	2140	2140	2140	2140	2140	2140	2140	2140	2140	2140	2140	
		Avr. Carbon gr from the Survey	11.394,38	11.394,38	11.394,38	11.394,38	11.394,38	11.394,38	11.394,38	11.394,38	11.394,38	11.394,38	11.394,38	11.394,38	11.394,38	11.394,38	11.394,38	11.394,38	
		Total Carbon Emission (gr)	0,00	0,00	0,00	19.507.173,53	24.383.966,92	24.383.966,92	24.383.966,92	24.383.966,92	24.383.966,92	24.383.966,92	24.383.966,92	24.383.966,92	24.383.966,92	24.383.966,92	24.383.966,92	24.383.966,92	**843.685.255,34**
		Avarage Fuel lt from the Survey	7,80	7,80	7,80	7,80	7,80	7,80	7,80	7,80	7,80	7,80	7,80	7,80	7,80	7,80	7,80	7,80	
		Total Fuel Consumption (lt)	0,00	0,00	0,00	13.353,60	16.692,00	16.692,00	16.692,00	16.692,00	16.692,00	16.692,00	16.692,00	16.692,00	16.692,00	16.692,00	16.692,00	16.692,00	**577.543,20**
	Diesel	Number of Valid Questionnaires	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	
		Approx. Number of Active Vehicle	0	0	0	833	1041	1041	1041	1041	1041	1041	1041	1041	1041	1041	1041	1041	
		Avr. Carbon gr from the Survey	13.134,95	13.134,95	13.134,95	13.134,95	13.134,95	13.134,95	13.134,95	13.134,95	13.134,95	13.134,95	13.134,95	13.134,95	13.134,95	13.134,95	13.134,95	13.134,95	
		Total Carbon Emission (gr)	0,00	0,00	0,00	10.938.790,29	13.673.487,86	13.673.487,86	13.673.487,86	13.673.487,86	13.673.487,86	13.673.487,86	13.673.487,86	13.673.487,86	13.673.487,86	13.673.487,86	13.673.487,86	13.673.487,86	**473.102.679,97**
		Avarage Fuel lt from the Survey	5,79	5,79	5,79	5,79	5,79	5,79	5,79	5,79	5,79	5,79	5,79	5,79	5,79	5,79	5,79	5,79	
		Total Fuel Consumption (lt)	0,00	0,00	0,00	4.821,91	6.027,39	6.027,39	6.027,39	6.027,39	6.027,39	6.027,39	6.027,39	6.027,39	6.027,39	6.027,39	6.027,39	6.027,39	**208.547,69**