

## UNCERTAINTIES OF ESTIMATING A TOWN'S CARBON FOOTPRINT– CASE STUDY EL GOUNA, EGYPT

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### Abstract

Carbon accounting has become a valuable tool for expressing the fossil energy demand of products, organizational entities, or entire countries. About a decade ago, cities also began accounting their carbon emissions. The first major city to do so was London in 2009, stating a carbon footprint of 4.84 tCO<sub>2</sub>eq/(year\*capita) for 2008. Nowadays, multiple rankings compare the carbon emissions of cities. For example, the Urban Land Magazine lists São Paulo as the city with the world's lowest carbon emissions (1.4 CO<sub>2</sub>eq/(year\*capita)). Such listings typically present the depicted emission values as scientifically indisputable numbers. However, a closer look at the applied methodology frequently reveals a wide range of implicit, often undisclosed assumptions at the foundation of the calculations.

This paper analyses the uncertainties of carbon accounting on the city scale, using the example of the Red Sea resort town of El Gouna. The estimated value of El Gouna's carbon footprint for the year 2014 is 14.3 tCO<sub>2</sub>eq/(year\*capita).

Third Scope emissions constitute the majority of El Gouna's carbon footprint. Varying their underlying assumptions only slightly can lead to alterations of the results of more than 50%, questioning the robustness of the findings. To increase the robustness and the comparability of carbon accounting across cities, this paper suggests emphasizing Scope 1 and Scope 2 emissions, while limiting the role of Scope 3 emissions.

**Keywords:** carbon accounting, carbon footprint, city emissions

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## 1. INTRODUCTION

Cities are a major contributor to the causes of climate change. They consume two thirds of the world's energy and are suspected of causing up to 70% of global greenhouse gas (GHG) emissions [1]. Consequently, UN-Habitat declares that “urban centres have become the real battle-ground in the fight against climate change” [2].

Urban areas differ greatly with respect to their GHG emissions. On average, cities that are richer, less dense, and predominantly produce energy from coal emit more greenhouse gases per capita than their poorer, denser, or regenerative counterparts [3]. Other important factors that influence urban carbon footprints include the prevailing types of industries, construction methods, modes of transportation, and the residents' activities and behaviour. Furthermore, the degree of deforestation, land-cover changes, agricultural utilization, quality of waste disposal, types of power generation, and intensity of refrigeration and air conditioning play important roles for the quantity of local GHG emissions [1].

### 1.1. Carbon accounting on the city scale

The first major city to establish its carbon footprint was London in 2009. The estimate yielded 9.6 tCO<sub>2</sub>eq/(year\*capita). As the procedure became more formalized [4], other cities followed, such as Sydney with emissions of 20.3, Toronto with 11.6, or Madrid with 6.9 tCO<sub>2</sub>eq/(year\*capita) [5].

Due to scaling effects, big metropolises can rather easily afford to invest monetary resources and working time into the evaluation of their emissions. The smaller a city, however, the higher the relative burden of the corresponding cost implications tends to be on municipal finances.

After analysing a city's GHG emissions and establishing an overview of the most crucial emitters, the obtained information ought to be transferred into concrete emission reduction measures. For this purpose, big consulting companies, such as McKinsey [6] or Bloomberg [7], offer sophisticated and expensive CO<sub>2</sub>-abatement-cost analyses. However, the high financial demands of such tools render them practically unfeasible for most Egyptian cities – especially the smaller ones –, which are coping with moderate budgets.

The World Bank recently released a free tool for carbon accounting and CO<sub>2</sub>-abatement-cost calculations, called MACTool [8], which is geared to enable local actors to create cost-curves that are similar to the ones offered by commercial consultancies. However, the demand for input data is considerable and requires advanced knowledge of numerous city facilities and insights into financial resources. Most municipalities in Egypt and the MENA-region do not collect the required data, nor do they possess the know-how to process them. It therefore appears prudent to devise an approach that is more suitable for the regionally prevalent circumstances.

## **1.2. Case study El Gouna**

### **1.2.1 The Town**

El Gouna is located about 450 kilometers southeast of Cairo and 25 kilometers north of Hurghada on the Red Sea coast in Egypt. It is a private resort town, owned and managed by Orascom Hotels and Development, a developer with a focus on touristic destinations. While El Gouna is reported to have “between 22,000 to 24,000 residents” [9], the research underlying this publication estimates the amount of people staying in El Gouna to be closer to 14,000 on an annual average – including international tourists and domestic visitors. Fluctuations are substantial: During low season, the number of people present in El Gouna may drop as low as 10,000, whereas it can grow beyond 30,000 during festive seasons. El Gouna is governed by a General Manager and a number of subordinate departments (e.g. Customer Service, Marketing and Communication, Commercial Space, Culture, Security). A corporate charge is levied on El Gouna’s inhabitants to cover services, such as security, street cleaning, garbage collection, as well as the provision and maintenance of town infrastructure. By offering a wide range of typical urban amenities (e.g. hospital, childcare, schools, mosque, church, university campus), El Gouna aspires to become a “fully-fledged” or “self-sufficient” town and consequently markets itself under the slogan “life as it should be”.

### **1.2.2 One town, two carbon footprints**

In 2013, the management of El Gouna commissioned a carbon accounting study, published in 2016, reporting emission of 4.9 tCO<sub>2</sub>eq/(year\*capita) [10]. This result would rank El Gouna within the group of least polluting settlements worldwide, along cities like Copenhagen, whose emissions were below 3 tCO<sub>2</sub>eq/(year\*capita) in 2016 [11]. It would also justify the disputable Global Green City Award, which El Gouna was awarded by the United Nations Environment Program in 2014 [12].

In 2014, Hartenstein et al. also calculated the carbon emissions of El Gouna, estimating 14.9 tCO<sub>2</sub>eq/(year\*capita). The margin of difference between the two studies is remarkable – greater than a factor of three. Possible sources of the diverging results are the subject of the forthcoming analysis and discussion.

## **2. ANALYSIS OF METHODOLOGIES**

### **2.1 General carbon accounting on city scale**

Based on the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories [4], carbon emissions of cities are classified according to their place

of origin (Figure 1). Scope 1 emissions occur directly within the boundaries of the city under investigation. They mainly include the emissions associated with the use of fossil fuels. Furthermore, they include direct emissions stemming from agriculture, forestry, waste and wastewater treatment, and industrial processes. Scope 2 emissions depend on the city's electricity consumption, encompassing power production that occurs outside of the city limits. Scope 3 emissions comprise waste and wastewater treatment processes outside of the city and half the emissions of inbound and outbound traffic. Furthermore, they include the embodied energy (“grey energy”) of all products which are brought into the city.

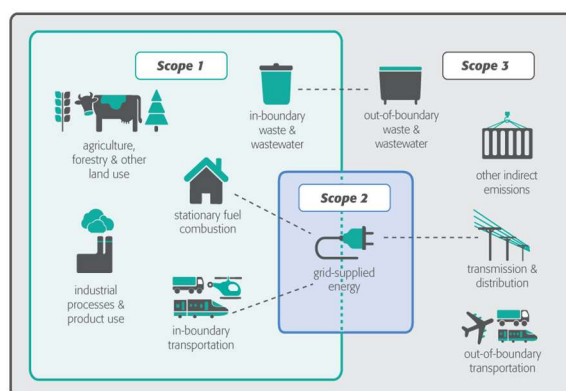


Fig. 1. Scopes of carbon emissions [4]

Small and medium cities often lack the capability to account their emissions, as they lack the resources and expertise to acquire, estimate and process necessary data. To enable municipalities with restricted budgets to establish at least a rudimentary carbon footprint for their settlement, Banhardt et al. [13] published a guideline to estimate urban emissions by means of a makeshift approach, which requires limited means and tools. This process was piloted for the calculation of El Gouna's carbon emission in 2014.

## 2.2 El Gouna's carbon emissions

The overall annual emissions of El Gouna have been calculated by two independent institutions: a contractor working for Orascom Hotels and Development (OHD) in 2013 and an interdisciplinary student group of Technische Universität Berlin Campus El Gouna (TUBCG) in 2014. While the OHD study reports 68,359 tCO<sub>2</sub>eq/a, the TUBCG study lists 253,890 tons. The margin between the two studies seems comprehensible for Scope 1 and Scope 2 emissions, yet the difference between the respective Scope 3 emissions is striking: 7,950 compared to 166,536 tCO<sub>2</sub>eq/a (Figure 2).

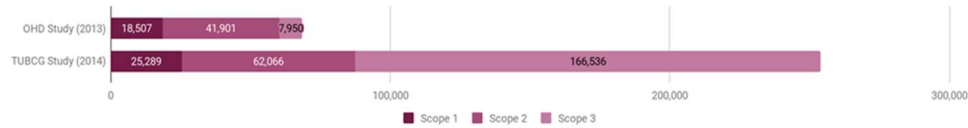


Fig. 2. Annual CO<sub>2</sub> equivalent emissions by Scope and study

In order to offer some insight into why the two analyses came to varying results and to validate the numbers presented in Hartenstein et al. [14], the proceeding sections alter some of the input factors used for the TUBCG study. The results of the OHD study cannot be verified or reproduced as the utilized methodology is not specified in the report [10].

### 3. SCOPE 1 – EMISSIONS INSIDE THE CITY BOUNDARIES

#### 3.1 Overall emissions of Scope 1

According to the TUBCG study, El Gouna emitted 25,289 tCO<sub>2</sub>eq/a within its geographical boundaries in 2014. The majority of these Scope 1 emission, close to 60%, is due to the use of fossil fuels in cars and private yachts. This share is highlighted in blue in Figure 3. Together with combustion in stationary units, such as decentralized power generators (7%, red), and for heating hotel-owned swimming pools (23%, orange), burning fossil fuels accounts for 90% of El Gouna's primary emissions. Further contributors to Scope 1 emissions are the landfill and sewage water treatment processes (8%, green), and Freon leakages from air conditioning units (2%, purple).

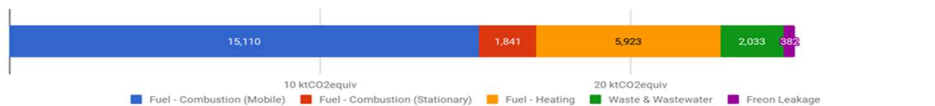


Fig. 3. Scope 1 emissions of El Gouna in 2014, based on Banhardt et al. [13]

In comparison, the OHD study reports Scope 1 emissions of 18,507 tCO<sub>2</sub>eq/a, i.e. 27% less than the TUBCG study.

#### 3.2 Uncertainties of Scope 1 emissions

Combustion-based emissions are proportionate to the amount of fuel burned within the town limits. The TUBCG study obtaining the required data by consulting local fuel suppliers, which provide petrol and diesel for road and marine usage in El Gouna. The fuel quantities were multiplied by emission factors (EF) of  $Ef_{\text{petrol}} = 2.31 \text{ kgCO}_2\text{eq/liter}$  and  $Ef_{\text{diesel}} = 2.68 \text{ kgCO}_2\text{eq/liter}$ , respectively. The emission factors are based on an overview by Davis [15] and are in line with more recent numbers by Isermann [16].

The difference in Scope 1 emissions between the TUBCG and OHD studies could

be the result of increased overall consumption, which in turn can be attributed to a recovery in tourism from 2013 to 2014. Due to the so called “Arab Spring” in February 2011, tourism decreased sharply throughout the following years and began to recover in 2013. According to a report by Germany Trade and Investment (GTAI), tourism related revenue rose by 47% in 2014 [17], resulting in increasing demand for transportation and other fuel-based activities.

#### 4. SCOPE 2 – EMISSIONS DUE TO ELECTRICITY DEMAND

##### 4.1 Overall emissions of Scope 2

El Gouna’s Scope 2 emissions are caused by the town’s electricity consumption. The resort is connected to Egypt’s national grid, with the closest power plant located in Hurghada, 40 km south. The OHD study calculated Scope 2 emissions of 41,901 tCO<sub>2</sub>eq/a whereas the TUBCG study estimated 62,066 tons, i.e. 33% less.

The distribution of the various electricity usages within the TUBCG study is represented in Figure 4. The local industry, outlined in green, consumes a relatively small share of less than 1%. Water supply (including seawater desalination and distribution), highlighted in blue, absorbs 17% of the used electricity. 36% are used for lighting, shown in yellow. Residential hot water production, shown in red, takes about 12%. Air conditioning is represented in purple and takes up about 34%.

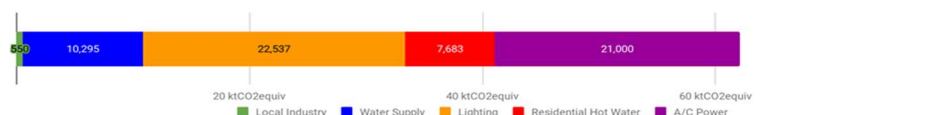


Fig. 4 Scope 2 emissions of El Gouna in 2014, based on Banhardt et al. [13]

##### 4.2 Uncertainties of Scope 2 emissions

The overall carbon emissions of Scope 2 are based on the annual energy demand of El Gouna in 2014: 104,000 MWh, multiplied by  $E_{f_{electricity}} = 596.8 \text{ kgCO}_2\text{eq/MWh}$ . This value is based on the overall electricity mix of Egypt, mainly consisting of gas fired power plants (80%), oil fired plants (15%), hydropower (4%), and a small share of renewables (<1%).

Brander et al. list the emission factors related to electricity production for multiple countries in 2011 [18]. For Egypt, they report  $E_{f_{electricity}} = 500.9 \text{ kgCO}_2\text{eq/MWh}$ , while Mansour et al. state  $E_{f_{electricity}} = 531.5 \text{ kgCO}_2\text{,equiv/MWh}$  for 2013 and 2014 [19]. Assuming these two lower available factors, the equivalent emissions would be reduced to 52,093 and 55,276 tCO<sub>2</sub>eq/a, respectively. Even after these adjustments, the results would still be 20 to 25% above the findings of the OHD

study.

One reason for an increasing power demand is a higher cooling energy demand. According to weather data, the average temperature within the main cooling season (1 May to 31 October) was 31°C in 2013 and 2014, yet cooling degree days increased by 2.2% from 4088 K/d to 4177 K/d [20]. Cooling degree days are a climate indication which directly links to the cooling energy demand of buildings. The rise of cooling degree days between both years of investigation can partially explain the different quantities Scope 2 emissions of the two studies. Further differences might be explained by an increase in the number of tourists from 2013 to 2014, as illustrated above in the section about uncertainties of Scope 1 emissions.

## 5. SCOPE 3 – EMISSIONS BEYOND CITY LIMITS

### 5.1 Overall emissions of Scope 3

The OHD study lists Scope 3 emissions of 7,949 tCO<sub>2</sub>eq/a, whereas the TUBCG study lists 166,536 tons – 21 times more. Figure 5 illustrates the considered emission sources. One of the major contributors are imported building materials (36%, blue): 88 new single-family houses were built in 2014. All of them were erected on the basis of the skeleton method with reinforced concrete.

Food (red, 16%) and other imported products (<1%, yellow) are transported by truck from the Nile delta, Cairo or from overseas to El Gouna. The biggest share of Scope 3 emissions is due to inbound traffic. Total emissions of domestic traffic by car, bus, and plane (9%, green) and of international plane traffic (37%, purple) are split equally between El Gouna and the respective city of origin.

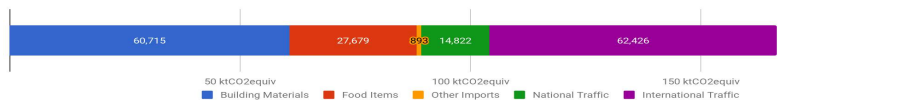


Fig. 5. Scope 3 emissions of El Gouna in 2014, based on Banhardt et al. [13]

### 5.2 Uncertainties of Scope 3 emissions

Scope 3 emissions are based on emission factors for imported products, like steel, concrete, and food, or various means of transportation. Abdrabou et al. [21] use the emission factors by Burk for their calculations of El Gouna's carbon discharge related to building materials [22]. For example, producing 1 kg of steel, concrete or bricks emits 4, 0.8 and 0.14 kg of CO<sub>2</sub>, respectively. For each erected building, the combined emissions amount to 438 tCO<sub>2</sub>, given an estimated demand of 20.3 t<sub>steel</sub>, 400.8 t<sub>concrete</sub>, and 256 t<sub>bricks</sub>.

Burk illustrates that the carbon emissions of steel greatly depend on the form of utilized energy [22]. Countries with a high share of coal-based electricity

production tend to have a high emission factor for their steel products (i.e. Germany: 6.9 kgCO<sub>2</sub>/kg<sub>steel</sub>, China: 7.2 kgCO<sub>2</sub>/kg<sub>steel</sub>). Egypt imports most of its steel, causing additional emissions due to shipping. Hence, it can be assumed that the resulting emission factors per building are even higher than stated by Abdrabou et al. [21].

The carbon emissions of inbound aviation traffic bare further uncertainties. The emission factors used by Banhardt et al. are based on an average travel distance of 3000 km and carbon emissions of 112 gCO<sub>2</sub>/(km \* person) [13]. The website Carbon Independent [23] lists various sources for plane based transport emission, varying from 101 to 180 gCO<sub>2</sub>/(km \* person). Assuming the lower end of the spectrum for domestic and international flights, Scope 3 emissions could be as low as 157,948 tCO<sub>2</sub>eq/a, 6.2% less than the emissions presented by Banhardt et al. Regardless, this alteration cannot explain the low Scope 3 emissions presented in the OHD study.

## 6. DISCUSSION OF RESULTS AND CONCLUSION

Several newly published studies break down the single value carbon footprint into its shares, combining Scope 1 and 2 emissions and separating Scope 3 emissions [23]. Emissions from Scope 1 and 2 sources can be viewed as direct emissions. Without the presence of a city, these emissions would immediately disappear: Cars wouldn't drive, waste water wouldn't be treated, and the electricity output of the connected grid would be reduced. In contrast, Scope 3 emissions are indirect emissions and are shared with another origin or destination. For example, incoming goods would still be produced but sold elsewhere. As shown above, the calculations for Scope 3 emissions are based on factors that can vary significantly and make results less comparable.

In the case of El Gouna, the differences in Scope 1 and 2 emissions between the OHD and TUBCG studies can be partially explained by a varying occupation rates due to changing tourist arrivals or annual fluctuations of the weather. The extensive difference in Scope 3 emissions, however, can be explained only by omitted CO<sub>2</sub> sources in the OHD study. Removing inbound traffic (77,249 tCO<sub>2</sub>eq/a) and emissions caused by imported building materials (60,715 tCO<sub>2</sub>eq/a) from the TUBCG analysis would converge the findings of both studies to comparable levels. It appears prudent, therefore, to limit urban GHG analyses to Scope 1 and 2 emissions and to reduce the significance of the highly volatile Scope 3 emissions, as already piloted by other studies [23].

El Gouna portrays the unique characteristics of an urban lab. Data is abundantly available and innovations and concepts can be implemented and tested easily across town. This exceptional setting allowed for the unhindered execution of the



research for this paper. A detailed carbon footprint could be established and the underlying sources could be analysed. Notwithstanding, the methodology can and should be improved further by tapping into new sources of data, utilizing better calculation methods, making assumptions more realistic, and gaining a deeper understanding of the processes that contribute to the production of city-based GHG emissions.

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## NIEPEWNOŚĆ CO DO OSZACOWANIA ŚLADU WĘGLOWEGO MIASTA - STUDIUM PRZYPADKU EL GOUNA, EGIPCI

### Streszczenie

Bilansowanie emisji węgla jest cennym narzędziem wyrażania zapotrzebowania na energię pozyskiwaną z paliw kopalnych przez produkty, jednostki organizacyjne lub całe kraje. Około dekady temu miasta zaczęły również rozliczać swoje emisje dwutlenku węgla. Pierwszym dużym miastem był Londyn w 2009 r., w którym w 2008 r. odnotowano ślad węglowy w wysokości 4,84 tCO<sub>2</sub>, ekwiwalentu/(rok·na osobę). Obecnie w wielu rankingach porównuje się emisje dwutlenku węgla w miastach. Na przykład Urban Land Magazine wymienia São Paulo jako miasto o najniższej na świecie emisji dwutlenku węgla (1,4 CO<sub>2</sub>, ekwiwalent/(rok·na osobę)). Dokładne przyjrzenie się zastosowanej metodologii obliczeń często ujawnia szeroki wachlarz ukrytych, nieujawnionych założeń dotyczących podstawy obliczeń. W niniejszym opracowaniu przeanalizowano niepewność w zakresie rozliczania emisji dwutlenku węgla w skali miasta na przykładzie miasta uzdrowskiego El Gouna, położonego nad Morzem Czerwonym. Oszacowanie śladu węglowego El Gouna za rok 2014 wynosi 14,3 tony ekwiwalentu CO<sub>2</sub>, ekwiwalentu/(rok·na osobę). Emisje trzeciego zakresu stanowią większość śladu węglowego El Gouna. Zróżnicowanie ich podstawowych założeń tylko w niewielkim stopniu może prowadzić do zmiany wyników o ponad 50%, kwestionując poprawność wyników. Aby zwiększyć poprawność i porównywalność obliczeń dotyczących emisji dwutlenku węgla w skali miasta, w niniejszym artykule sugeruje się podkreślenie znaczenia emisji w pierwszym i drugim zakresie, przy jednoczesnym ograniczeniu roli emisji w trzecim zakresie.

Przetłumaczono przy pomocy [www.DeepL.com/Translator](http://www.DeepL.com/Translator)

Słowa kluczowe: rachunkowość węglowa, ślad węglowy, emisje z miast

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