Proceeding Paper

Assessing the Carbon Footprint of Teleworking: A Case Study of Two Research Projects before and after the COVID-19 Pandemic †

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Abstract: The objective of this study is to assess the carbon footprint (CF) of electricity use and transportation, with a focus on teleworking, through the implementation of two research projects that were initiated before and completed after the COVID-19 pandemic. The study applies an integrated methodology based on the GHG Protocol guidance and DEFRA emission factors to investigate the CF of the projects, both during the pre-pandemic and teleworking period, as well as during the pandemic period with 50% teleworking. The results indicate that telecommuting contributed to a reduction in CO₂ emissions of 49–55%. Furthermore, a 20% reduction in car usage for commuting to and from work resulted in reductions of approximately 30% in transportation. These findings suggest that implementing such measures post-COVID-19 could have a significant impact on reducing greenhouse gas emissions.

Keywords: carbon footprint; teleworking; electricity use; research projects; COVID-19 pandemic

1. Introduction

The carbon footprint (CF) refers to the total amount of greenhouse gases (GHG) emitted, directly or indirectly, either by an individual, organization, product, or event. It includes emissions from various activities such as transportation, energy use, and waste. In the EU, the electricity and transportation sectors are the primary contributors to GHG emissions [1]. Annual CO₂ emissions in the EU amounted to approximately 2.91 billion tons CO₂ in 2019 [2]. The anthropogenic net CO₂ emissions must decline by about 45% from 2010 levels to achieve net zero emissions by 2050 [3].

At the international level, a limited number of studies have evaluated the CF of research, with a predominant focus on singular entities such as research departments or universities [1,4,5], scientific activities and experiments [6,7], conferences [8,9] or particular research projects [7,10]. Notwithstanding the increasing recognition of the carbon emissions associated with research endeavors, a dearth of knowledge concerning the effect of teleworking persists and necessitates further investigation.

Government-imposed restrictions on daily mobility during the COVID-19 pandemic have led to a reduction in individual mobility and an increase in teleworking [11]. Recent studies have focused on examining the impact of teleworking in the post-pandemic era [11,12], the resultant decrease in carbon emissions [13], and the CF associated with...
teleworking and commuting for work in organizations during [14] and after the pandemic [15]. However, there have been no studies conducted on the role of teleworking during scientific projects.

The aim of this study is to evaluate the CF associated with electricity usage and transportation, with a particular focus on teleworking. This will be accomplished by implementing two research projects, which were initiated prior to the COVID-19 pandemic and completed after it. The methodology will be applied to the projects KASTOM “Innovative System for Air Quality Monitoring and Forecasting” and LIFE ASTI “Implementation of a Forecasting System for Urban Heat Island Effect for the Development of Adaptation Strategies”.

2. Materials and Methods

The emission sources associated with project activities, specifically electricity and transportation (two-way travels for work commuting), were estimated using a methodology based on the study of Liora et al. (2022) [16]. The methodology applied leverages the GHG Protocol Guidance [17] and the Emissions Factors (EF) of the UK Department for Environmental, Food and Rural Affairs (DEFRA) [18], which includes the 2021 Greenhouse Gases Conversion Factors.

Throughout the research projects, the methodology was employed, while accounting for the fact that 50% of employees have been teleworking since the onset of COVID-19. The assessment of the impact of teleworking on electricity consumption was conducted based on the assumption that employees utilized a personal computer or laptop along with an internet connection. The emissions factors of GHG Protocol Tool [19] per country were used.

\[
\text{CF (Teleworking)} \ (\text{tCO}_2\text{e}) = \text{Number of Employees} \times \text{Project Duration} \times \text{Emission Factor GHGs} \times \text{Usage of Equipment} \\
\text{(1)}
\]

2.1. Electricity

The emissions factors [19], the activity data and the average annual electricity consumption per employee [20] were used and multiplied by the appropriate conversion factor to produce the corresponding CF emissions from electricity used by employees who participated in the project. PersonYear are the years that the employees have been working for the project.

\[
\text{CF (Electricity)} \ (\text{tCO}_2\text{e}) = \text{Electricity Consumption} \times \text{Emission Factor GHGs} \times \text{PersonYears} \\
\text{(2)}
\]

2.2. Transportation

To estimate the emissions for different modes of transportation (such as cars, motorbikes, buses, taxis, national rail, light rail, tram/underground, and other modes like cycling and walking), the total distance traveled in kilometers for each mode was multiplied by the corresponding conversion factors.

The main data inputs for the analysis included the total number of two-way trips to and from work, the percentage distribution of travel distance by transportation mode, the estimated distance per daily round trip per person [21], and the percentage distribution of car fleet technology for EU countries (Emisia S.A—2019 as reference year).

\[
\text{CF (Work commuting)} \ (\text{tCO}_2\text{e, mode transport}) = \text{Number of two-way travels} \times \text{Distance} \times \text{Percentage Distribution} \times \text{EF} \\
\text{(3)}
\]
2.3. Lockdown for COVID-19

The first lockdown was implemented in Europe on 21 February 2020. The mandate imposed significant restrictions on the mobility of citizens. These measures resulted in a surge of teleworking, which, in certain Eurozone nations, had only accounted for 5.4% in 2019, but rose to levels exceeding 50% [22]. This percentage of telecommuting persisted even after the end of the lockdown, signifying that the pandemic has substantially transformed the work paradigm.

2.4. Description of the Scientific Projects

The initial project under examination, KASTOM, is a research-oriented undertaking that concentrates on collaborating with businesses [23]. The project started in July 2018 and was completed at the end of 2022. A restricted workforce, comprising 37 employees, of which 9 are external experts, sustained the project. It included only four partners from Greece, as shown in Table 1.

Table 1. Overview of partners, staff, and travel in the KASTOM project.

<table>
<thead>
<tr>
<th>Project</th>
<th>No. of Partners</th>
<th>Number of Staff</th>
<th>External Experts</th>
<th>PersonYears</th>
<th>Number of Two-Way Travels</th>
</tr>
</thead>
<tbody>
<tr>
<td>KASTOM</td>
<td>4</td>
<td>28</td>
<td>9</td>
<td>13.55</td>
<td>8264</td>
</tr>
<tr>
<td>LIFE ASTI</td>
<td>6</td>
<td>71</td>
<td>-</td>
<td>28.97</td>
<td>18,582</td>
</tr>
</tbody>
</table>

In contrast to the KASTOM project, the LIFE ASTI prioritizes external outreach and policymaking [24]. Its duration ranged from August 2018 until August 2022, and it consisted of an extensive team of four Greek and two Italian partners. The project has organized numerous events within its framework. The workforce of LIFE ASTI comprised 71 employees, and no external experts.

3. Results and Discussion

Table 2 presents an analysis of CF per employee and per year for electricity and transportation in the research projects KASTOM and LIFE ASTI. The results show that the CF per employee and per year for electricity and transportation were lower during the pandemic period compared to the pre-pandemic period. For instance, in the KASTOM project, the CF per employee for electricity decreased from 1.05 tCO$_2$e to 0.86 tCO$_2$e during the pandemic period. Similarly, the CF per employee for transportation also decreased from 0.12 tCO$_2$e to 0.11 tCO$_2$e during the pandemic period.

Table 2. Comparison of CF per employee and per year for electricity and transportation in KASTOM and LIFE ASTI Projects.

<table>
<thead>
<tr>
<th>KASTOM</th>
<th>Before Pandemic</th>
<th>After Pandemic</th>
<th>Total Project Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emission Source</td>
<td>tCO$_2$e/employee</td>
<td>tCO$_2$e/year</td>
<td>tCO$_2$e/employee</td>
</tr>
<tr>
<td>Electricity</td>
<td>1.05</td>
<td>9.21</td>
<td>0.86</td>
</tr>
<tr>
<td>Transportation</td>
<td>0.12</td>
<td>1.01</td>
<td>0.11</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>LIFE ASTI</th>
<th>Before Pandemic</th>
<th>After Pandemic</th>
<th>Total Project Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity</td>
<td>0.81</td>
<td>18.91</td>
<td>0.69</td>
</tr>
<tr>
<td>Transportation</td>
<td>0.13</td>
<td>3.11</td>
<td>0.12</td>
</tr>
</tbody>
</table>

The KASTOM project exhibited a decrease in CF per year of 55% for electricity and 40% for transportation during the pandemic, whereas the LIFE ASTI project showed a reduction of 49% for electricity and 47% for transportation. These reductions in CF can be linked to the implementation of teleworking, as supported by previous research [15,25].
which indicated that e-workers were able to reduce their CF by almost 62% due to transport emissions and that teleworking resulted in an overall reduction of 1.86 tCO₂ per year in GHG emissions.

3.1. Contribution of Teleworking

Based on the findings illustrated in Figure 1, which displays the electricity and teleworking in tCO₂ per year before and after the pandemic, it is evident that the implementation of teleworking during the pandemic resulted in a substantial reduction in CF for electricity. Specifically, for KASTOM, the CF per year for electricity decreased from 9.21 tCO₂ before the pandemic to 4.15 tCO₂ after the pandemic. Similarly, for LIFE ASTI, the CF decreased from 18.91 tCO₂ to 9.67 tCO₂. These results indicate the potential effectiveness of teleworking as a strategy to mitigate carbon emissions and promote environmental sustainability.

3.2. Case Study of Reducing CF of Transportation

Examining the contribution of different modes of transportation to total CF, as evident in Table 3, it becomes apparent that cars exhibit the highest emissions for both research projects. A mitigation scenario was implemented to decrease car usage, as during the pandemic, and promote sustainable modes of transportation, specifically cycling and walking, for employees commuting to and from work. This initiative aimed to reduce car usage by 20%. The findings demonstrate that the tCO₂ per employee decreased to 0.20 for the KASTOM project and 0.21 for the LIFE ASTI project, respectively. These reductions of 30% indicate that substituting cars with environmentally friendly means of transportation can significantly enhance GHG emission levels.

Table 3. CF (tCO₂) comparison of transportation modes in KASTOM and LIFE ASTI Projects.

<table>
<thead>
<tr>
<th>Mode of Transportation</th>
<th>KASTOM</th>
<th>LIFE ASTI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cars</td>
<td>2.76</td>
<td>7.29</td>
</tr>
<tr>
<td>Motorbikes</td>
<td>0.21</td>
<td>0.41</td>
</tr>
<tr>
<td>Buses</td>
<td>0.30</td>
<td>0.75</td>
</tr>
<tr>
<td>Taxi</td>
<td>0.05</td>
<td>0.11</td>
</tr>
<tr>
<td>National rail</td>
<td>0.00</td>
<td>0.03</td>
</tr>
<tr>
<td>Light rail/Underground</td>
<td>0.09</td>
<td>0.18</td>
</tr>
</tbody>
</table>

4. Conclusions

This study provides an analysis of the CF attributed to the consumption of electricity and transportation, with an emphasis on teleworking, by utilizing two research projects.
conducted during both pre- and post-pandemic periods. The findings indicate that telecommuting had a substantial impact on reducing CO$_2$ emissions during the pandemic, as well as reducing car usage for work commuting, highlighting the potential of these practices to mitigate significantly GHG emissions. The research contributes to the existing literature on CF related to research endeavors, specifically in the context of mitigating carbon emissions in the electricity and transportation sectors. The findings have implications for policy development aimed at mitigating the impact of climate change.

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**References**


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