Long-Term Projection of Transport-Related Social Cost of Greenhouse Gas Emissions in Qatar

Maryam Al-Jabir and Rima J. Isaifan *

Division of Sustainable Development, College of Science and Engineering, Hamad Bin Khalifa University, Qatar Foundation, Doha P.O. Box 34110, Qatar; maal43786@hbku.edu.qa
* Correspondence: risaifan@hbku.edu.qa

Abstract: The transportation sector has garnered significant attention recently due to its substantial impact on greenhouse gas (GHG) emissions, which have contributed to global warming and adversely impacted human health and the environment. This study estimates the social cost of carbon (SCC) in Qatar pertaining to road transportation, explicitly focusing on the greenhouse gases (GHGs) of carbon dioxide, methane, and nitrous oxide for the years 2030, 2040, and 2050. The Low Emissions Analysis Platform (LEAP) was utilized to formulate various scenarios: (1) a public transport scenario in comparison to the baseline scenario; (2) a scenario with improved fuel economy in comparison to the baseline scenario; and (3) a scenario with improved fuel economy in comparison to the public transport scenario. Once the scenarios were developed, the emission reduction values were derived. Subsequently, the Social Cost of Carbon Explorer tool was employed to assess the SCC for each gas. According to the study findings, when comparing the public transport scenario with the baseline scenario, it was observed that the total SCC benefit in 2030, 2040, and 2050 would amount to USD 380,005,861. Furthermore, when comparing the scenario in which fuel economy is improved to the baseline scenario, the total SCC benefit would amount to USD 3,363,559. In conclusion, upon comparing the scenario of improved fuel economy with that of public transportation, it is determined that the total SCC benefit would amount to USD 5,980,883. The calculation of the SCC is expected to provide valuable insights for decision making pertaining to the economic implications of different strategies to mitigate greenhouse gas emissions in Qatar.

Keywords: social cost; GHG emission reduction; Qatar; carbon; transport

1. Introduction

It is evident today that climate change has become a global issue of concern, and each country has a crucial role to play in addressing it. The greenhouse gases (GHGs) in the atmosphere affect the climate, the economy, and the overall well-being of individuals. Various sectors bear responsibility for generating these emissions, with transportation playing a significant and noticeable role in this regard. According to [1], three-quarters of global transportation CO₂ emissions are generated by road transport. Within road transport, passenger vehicles such as cars and buses are responsible for the majority, contributing to 45.1% of the total emissions, while trucks carrying freight make up the remaining 29.4%. Given that the entire transportation sector is responsible for 21% of the overall emissions, and road transport contributes to three-quarters of these emissions, it can be concluded that road transportation alone accounts for 15% of the total CO₂ emissions. Like many other countries in the Middle East, Qatar has experienced significant economic growth in the past few decades. Qatar is a peninsula surrounded by water on all sides, except for the south, where it shares a border with Saudi Arabia [2]. It extends approximately 200 km from north to south and 100 km from east to west. Based on a report by CNBC Arabia, Qatar has achieved the top ranking in the world index of countries with the highest economic growth over 20 years from 1997 [3]. This growth has been accompanied by
substantial infrastructure development and population growth [4]. These remarkable
dancements have coincided with heavy traffic and industrial operations fueled by their
significant economic gains from oil and gas reserves [5]. Based on the mid-year population
estimates provided by the Planning and Statistics Authority, the population in mid-2016 was
2.6 million, showing an increase of 1.4 million from 2007 [6]. Due to this rapid population
growth, there has been a corresponding increase in urbanization, building constructions,
infrastructure development, civil works, and vehicle ownership [7]. Considering the entire
population of Qatar in 2016 (2.6 million), it has become even more evident that there is a
significant dependency on private vehicles in the country, as reflected in the high average
of 520 vehicles per 1000 capita. This ratio has remained relatively stable since the previous
report in 2014, where it was slightly higher at 532 vehicles per 1000 capita [8]. When
comparing Qatar to other neighboring Gulf countries, Kuwait reported a similar rate of
527 vehicles, Saudi Arabia had 336, the United Arab Emirates reported 313, and Oman
reported 215 per 1000 capita for the same year. The rise in vehicle ownership has resulted in
a notable escalation in atmospheric pollution and GHG emissions, particularly within the
sector of road transportation. In order to foster economic growth and cater to the expanding
population, the Qatari government made significant investments in the construction of
new roads, highways, and airports. These infrastructural developments were aimed at
providing essential support to the country’s growing needs. The transport network in Qatar
currently comprises a highly developed road network, a growing public transportation
system, and a modern aviation sector. Nevertheless, these advancements have also brought
up a considerable number of challenges. The population growth and expansion of economic
activities have resulted in substantial concerns around traffic congestion and heightened
carbon emissions.

One key element to assess this issue is considering the social cost of carbon (SCC).
It is a monetary value estimation of the economic harm resulting from releasing one ton
of carbon (or any other GHG) into the atmosphere [9]. The release of these gases has the
capacity to cause various forms of harm, such as detrimental impacts on agricultural
yields, adverse effects on human health [10,11], destruction of property and infrastructure
resulting from rising sea levels, and the occurrence of severe weather phenomena, as well
as negative implications for biodiversity and ecosystems [12]. Therefore, the SCC assigns
a monetary value to the cost of carbon emissions arising from a specific source. In the
absence of this particular value, decision makers may encounter challenges in selecting
a remedial policy due to the constraints posed by limited and inadequate information.
The quantification of these emissions and the valuation of their impacts facilitate the as-
sessment of costs and benefits. Hence, calculating the SCC is vital for several compelling
reasons. The reasons include but are not limited to implementing policies and initiatives
to mitigate GHG emissions [13], assessing policies, and providing guidance for decisions
that impact GHG emissions [14]. The computation of SCC encompasses a series of four
sequential procedures that are executed utilizing dedicated computational models. These
steps include (1) making reasonable predictions regarding future emissions by considering
factors such as population growth, economic development, and other relevant variables;
(2) modeling future climate responses, including sea level increase and temperature rise;
(3) evaluating the potential economic consequences that may arise from these climatic
changes, encompassing various sectors such as health, agriculture, and energy consump-
tion; and (4) conducting an evaluation of prospective future losses and translating them into
their current monetary worth, subsequently aggregating them to ascertain the overall extent
of damages [15]. Several reviews have been conducted on the social cost of carbon [16,17]
and its application [18,19], as well as meta-analyses [20,21]. Many have acknowledged the
importance of the SCC and have used it to assess GHG emissions in different industries in
their respective countries. One such study is [22], which analyzed the GHG emissions and
social costs associated with Iranian thermal power plants. Another study [23] examined the
potential for achieving a low-carbon society in Pakistan by 2050. It forecasted future CO₂
emissions and analyzed the marginal abatement cost of the energy system under different
scenarios, including a high-carbon society (HCS) and a low-carbon society (LCS). The study also highlighted the reduction in CO\(_2\) emissions and the associated costs of transitioning to a low-carbon society.

This study aims to identify the most cost-effective approach for electricity generation, assess the potential for reducing power consumption, and explore strategies to optimize the energy system for lower GHG emissions. Considering Qatar’s specific context, the transportation sector emerges as a significant contributor to GHG emissions. According to [24], it is classified as the fourth largest emitter, following electricity and heat, fugitive emissions, manufacturing, and construction sectors. Although various studies have been conducted on the emissions produced by road transportation in different regions globally, there is a need for more research findings specifically focused on the Gulf region, particularly Qatar. The emphasis on road transportation is justified by the fact that the emissions from this sector are easily noticeable to the general populace. This makes it a readily understandable topic suitable for raising awareness and motivating behavioral changes. Moreover, the country exercises more extraordinary jurisdiction over road transportation policies and regulations within its territorial boundaries than other transportation modes. As a result, conducting research in this field will contribute to endeavors to reduce emissions. Hence, this research aims to build upon the outcomes of the study titled “Low Transportation Emission Analysis and Projection Using LEAP: The Case of Qatar” [25] by conducting additional calculations to determine the SCC associated with the reduction in emissions. In this paper, we analyze the social cost of carbon to provide a comprehensive assessment of the environmental and economic implications of road transportation-related emissions. The preceding study significantly contributed to this field by employing the LEAP tool, which was a novel application in the context of Qatar using actual data on vehicle counts and classifications [25]. This adoption of the LEAP tool allowed for a deeper understanding of GHG emissions from road transportation in Qatar. Building upon this foundational research, this study seeks to further advance knowledge by examining the social cost of carbon associated with these emissions. By comparing different scenarios, this research will show the cost benefits of reducing emissions in Qatar’s road transportation sector.

2. Methods

This study examines GHG emissions and the social costs associated with Qatar road transportation for 2030, 2040, and 2050. The year 2030 has been selected because it is considered significant for several reasons, especially in the context of global sustainability, climate action, and international development. Furthermore, its selection is aligned with Qatar’s 2030 vision [26] and is associated with the projected timeline for the attainment of the sustainable development goals (SDGs) [27]. The selection of the year 2040 is based on its positioning between 2030 and 2050, thereby offering valuable insights into the country’s advancement towards attaining its overarching objectives. The selection of the year 2050 is based on its significance as a crucial milestone for achieving the goals of sustainable development objectives and the implementation of climate action measures.

2.1. The LEAP Tool

In accordance with our previous research [25], the LEAP tool [28] was employed to assess the present and prospective emissions of various vehicle categories and fuel types, given the limited extent of existing studies in this field. The LEAP tool, developed by Stockholm Environment Institute, is extensively utilized for energy policy, climate change mitigation, and planning to reduce air pollution [29]. The tool incorporates a technology–environment database (TED) that gathers information from credible sources such as the Intergovernmental Panel on Climate Change, the US Department of Energy, and the International Energy Agency [30]. The database offers extensive information on different technologies, which can help in making accurate assessments of their implications in energy and environmental planning. LEAP has been widely adopted by numerous organizations across more than 190 countries. The tool has a substantial influence on
shaping energy and environmental policies on a global scale. An illustrative case is its application in California, where LEAP played a pivotal role in energy forecasting and the identification of alternative fuels [31]. In Mexico, it was employed to assess the feasibility of potential future scenarios, considering both moderate and high utilization of biofuels in the transportation and electricity generation industries [32]. In Lebanon, an assessment was conducted to identify mitigation options for reducing emissions from electricity generation, with a particular focus on utilizing renewable energy resources [33]. In Iran, LEAP was utilized to analyze energy consumption patterns and various emission sources within the consumption sector [34].

2.2. Data Collection

Various data types were entered into the LEAP tool, including the type of vehicles, fuel used (gasoline and diesel), mileage (km), and energy intensity (liters per vehicle km). The data were gathered from multiple sources, including the local emission-testing company (Fahes) and some literature reviews. Fahes provides comprehensive vehicle inspections that adhere to approved standards for road traffic safety and pollution control. The previously mentioned data specifically refer to the historical data collected between 2017 and 2021. These data are essential for establishing the baseline scenario.

2.3. Model Structure

In our previous study, three vehicle categories were considered: light-duty vehicles (private, governmental, and diplomatic), heavy-duty vehicles (public transportation and private transportation), and motorcycles (private motorcycles).

2.4. Scenarios and Assumptions of the LEAP Tool

This study examines three scenarios: (1) the public transport scenario versus baseline; (2) the improved fuel economy scenario versus baseline; and (3) the improved fuel economy scenario versus the public transport scenario. The baseline scenario in LEAP usually depicts the future based on current trends, assuming that there will be no major policy changes or significant shifts in technology adoption. The model uses historical data, current policies, and technological advancements to predict energy consumption, GHG emissions, and other important indicators. Two assumptions were made for the public transport scenario, following the methodology used in the paper [35]. The first assumption is a 1% increase in the growth rate of public transportation, while the second assumption is a 1% decrease in the growth rate of private vehicles. Our aim in the improved fuel economy scenario was to enhance the efficiency of vehicles by reducing the amount of fuel consumed per kilometer traveled. This improvement was achieved by utilizing the “interp” function. This scenario involves three assumptions. The initial assumption is a 10% improvement in fuel economy by 2030, followed by a 20% improvement by 2040, and ultimately a 30% improvement by 2050.

2.5. The Social Cost of Carbon

Once the data were input and different scenarios formed, LEAP calculated the emissions reduction values. This paper presents an extension of the existing methodology in which we aim to estimate the SCC for the same GHGs. To achieve this, the Social Cost of Carbon Explorer tool was utilized. SCC Explorer serves as a valuable resource for enhancing comprehension of the RFF-Berkeley Greenhouse Gas Impact Value Estimator (GIVE) model [36]. The model demonstrates how choices about intermediate assumptions can significantly impact the final US dollar value of the SCC. The tool comprises four distinct modules: the socioeconomic module, the climate module, the damages module, and the discounting module. Our primary focus lies on the last module. In the discounting module, future economic damages are translated into present-day US dollars. This module exclusively provides a single parameter, namely the discount rate, which signifies the quantification of future impacts in relation to their present-day counterparts. Additionally, the
model generates a single output known as the “social cost of carbon”. This value represents the economic damage incurred due to the emission of an additional ton of carbon dioxide into the Earth’s atmosphere. The generated result presents the average social cost of carbon value, a prevalent practice as SCC is frequently employed as the primary estimation in benefit–cost analysis. The Social Cost of Carbon Explorer tool includes various greenhouse gases, specifically nitrous oxide, methane, and carbon dioxide. These gases were essential for our study. The tool estimates the social cost of carbon for GHG emissions spanning from 2020 to 2100. However, our specific focus revolves around three particular years: 2030, 2040, and 2050. Table 1 displays the social cost of carbon estimates obtained from the tool, specifically for the GHGs being studied within the same timeframe mentioned. The estimations are measured in terms of US dollars per ton of CO$_2$, US dollars per ton of N$_2$O, and US dollars per ton of CH$_4$, considering a discount rate of 2%. To quantify the benefits of reducing emissions in US dollar amounts, these estimations (values from Table 1) are multiplied by the reduction values obtained from LEAP in each scenario.

Table 1. The social cost of carbon, nitrous oxide, and methane per ton for 2030, 2040, and 2050.

<table>
<thead>
<tr>
<th>Year</th>
<th>Social Cost of Carbon (USD per ton CO$_2$)</th>
<th>Social Cost of Nitrous Oxide (USD per ton N$_2$O)</th>
<th>Social Cost of Methane (USD per ton CH$_4$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2030</td>
<td>226</td>
<td>68,853</td>
<td>2916</td>
</tr>
<tr>
<td>2040</td>
<td>263</td>
<td>82,072</td>
<td>4067</td>
</tr>
<tr>
<td>2050</td>
<td>329</td>
<td>99,665</td>
<td>5447</td>
</tr>
</tbody>
</table>

Once the results for each scenario are obtained, the values are then converted into present-day US dollars. Formula (1) demonstrates the method for calculating the value in today’s equivalent US dollars [37]:

\[
\text{Presentvalue} = \frac{C}{(1 + r)^n}
\]

where the variable “$C$” denotes the projected cash flow, measured in US dollars. The variable “$r$” signifies the discount rate, expressed as a decimal. Lastly, the variable “$n$” represents the number of periods measured in years. In order to calculate the SCC benefits related to the reduction in emissions in 2030, we can use the variable “$c$” to represent the resulting benefit value. This value is obtained by multiplying the SCC estimation values by the LEAP reduction value for a specific year. Similarly, the variable “$r$” can be replaced with 0.02, denoting the discount rate, and the variable “$n$” can be substituted with 7, representing the number of years remaining until 2030. By carrying out this calculation, the resulting value will be expressed in today’s equivalent US dollars. To determine the present values for 2040 and 2050, the variable “$n$” will be substituted with the respective periods of 17 and 27 years.

Our study focuses on assessing the benefits of reducing traffic emissions in Qatar, specifically in terms of the social cost of carbon. There is a significant lack of research in this area within the Qatari context, resulting in a notable deficiency in current understanding. Our method aims to fill this gap by specifically targeting the potential benefits that arise from reducing traffic emissions. Although our approach may not produce groundbreaking outcomes, it is specifically designed to capture the distinctive circumstances of Qatar, thereby offering useful insights. Our analysis enhances comprehension of the social cost of carbon linked to the decrease in traffic emissions in Qatar and establishes the groundwork for future research in this particular field.

3. Results

3.1. Public Transport Scenario versus Baseline Scenario

According to a study conducted in Qatar, a significant proportion of the population relies on private vehicles as their predominant means of transportation [38]. Based on
this fact, a comparison was made between the public transport and the baseline scenario. The implementation of the public transportation scenario assumes that there will be an increase in the number of individuals utilizing public transportation. The baseline scenario postulates that the prevailing patterns in the country’s transportation sector will persist. The comparison of the two scenarios in terms of emissions reduction was conducted through LEAP. Figures 1–3 depict the CO₂, CH₄, and N₂O emissions levels in the public transport scenario compared to the baseline scenario, respectively.

**Figure 1.** CO₂ emissions for 2030, 2040, and 2050 under the public transport scenario compared to the baseline scenario.

**Figure 2.** CH₄ emissions for 2030, 2040, and 2050 under the public transport scenario compared to the baseline scenario.

Table 2 presents the quantified reductions in GHG emissions achieved through implementing the public transport scenario compared to the baseline scenario. The emissions are measured in terms of carbon dioxide equivalents using the 100-year global warming potential (GWP) metric.

**Table 2.** Reduction in GHGs (in tons of carbon dioxide equivalent) from the public transport scenario compared to the baseline scenario.

<table>
<thead>
<tr>
<th>GHG</th>
<th>2030</th>
<th>2040</th>
<th>2050</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon Dioxide</td>
<td>75,914</td>
<td>395,796</td>
<td>1,493,209</td>
<td>1,964,919</td>
</tr>
<tr>
<td>Methane</td>
<td>668</td>
<td>3484</td>
<td>13,151</td>
<td>17,303</td>
</tr>
<tr>
<td>Nitrous Oxide</td>
<td>176</td>
<td>918</td>
<td>3465</td>
<td>4559</td>
</tr>
<tr>
<td>Total</td>
<td>76,758</td>
<td>400,198</td>
<td>1,509,825</td>
<td>1,986,781</td>
</tr>
</tbody>
</table>
The GWP of a GHG refers to the extent of warming it generates during a specific duration, typically 100 years [39]. It is an index, with CO$_2$ being assigned a value of 1 and all other GHGs’ GWP being the number of times more warming they cause than CO$_2$. The data were subsequently transformed into tons by dividing the quantity of each gas by its respective GWP, as indicated in Table 3. The GWP values for carbon dioxide, methane, and nitrous oxide are 1, 28, and 265, respectively [40].

Table 3. Reduction in GHGs (in tons) from the public transport scenario compared to the baseline scenario.

<table>
<thead>
<tr>
<th>GHG</th>
<th>2030</th>
<th>2040</th>
<th>2050</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
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<td>395,796</td>
<td>1,493,209</td>
<td>1,964,919</td>
</tr>
<tr>
<td>Methane</td>
<td>24</td>
<td>124</td>
<td>470</td>
<td>618</td>
</tr>
<tr>
<td>Nitrous Oxide</td>
<td>1</td>
<td>3</td>
<td>13</td>
<td>17</td>
</tr>
<tr>
<td>Total</td>
<td>75,939</td>
<td>395,923</td>
<td>1,493,692</td>
<td>1,965,554</td>
</tr>
</tbody>
</table>

In order to assess the benefits of reducing GHG emissions and compare the impact of public transportation with the baseline scenario, we rely on the social cost of carbon (SCC) estimates provided in Table 1. The reduction values of emissions (measured in tons) for each year were multiplied by the corresponding cost. An excellent example of this can be found in Figure 4, which shows the calculation of SCC for CO$_2$ in 2030.

Figure 4. Compared to the baseline scenario, the SCC for the public transport scenario was calculated by using USD 226 for 2030.
The remaining gases were subjected to the same procedure, after which their monetary value was adjusted to reflect present-day currency. Table 4 presents the final comparison results between the public transport scenario and the baseline scenario, quantified in US dollars.

### Table 4. GHG emission benefit–cost analysis (2030–2050): public transport vs. baseline scenario.

<table>
<thead>
<tr>
<th>GHG</th>
<th>2030 (USD)</th>
<th>2040 (USD)</th>
<th>2050 (USD)</th>
<th>Total (USD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon Dioxide</td>
<td>14,935,821</td>
<td>74,340,286</td>
<td>287,813,963</td>
<td>377,090,070</td>
</tr>
<tr>
<td>Methane</td>
<td>60,925</td>
<td>360,158</td>
<td>1,499,860</td>
<td>1,920,943</td>
</tr>
<tr>
<td>Nitrous Oxide</td>
<td>59,941</td>
<td>175,838</td>
<td>759,069</td>
<td>994,848</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>15,056,687</strong></td>
<td><strong>74,876,282</strong></td>
<td><strong>290,072,892</strong></td>
<td><strong>380,005,861</strong></td>
</tr>
</tbody>
</table>

#### 3.2. Improved Fuel Economy Scenario versus Baseline

The improved fuel economy scenario is a sub-scenario that falls within the public transport scenario. In the given scenario, fuel economy is improved by reducing the amount of fuel consumed per distance covered. Figures 5–7 compare the improved fuel economy scenario and the baseline scenario in terms of CO₂, CH₄, and N₂O emissions.

**Figure 5.** CO₂ emissions for 2030, 2040, and 2050 under the improved fuel economy scenario compared to the baseline scenario.

**Figure 6.** CH₄ emissions for 2030, 2040, and 2050 under the improved fuel economy scenario compared to the baseline scenario.
Once again, the reduction values were obtained using LEAP. Table 5 shows the reduction in emissions of these gases, measured in terms of carbon dioxide equivalents over a 100-year GWP when comparing the two scenarios. Table 6 shows the conversion of these data into tons.

**Table 5.** Reduction in GHG (in tons of carbon dioxide equivalent) from the improved fuel economy scenario compared to the baseline scenario.

<table>
<thead>
<tr>
<th>GHG</th>
<th>2030</th>
<th>2040</th>
<th>2050</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon Dioxide</td>
<td>76,904</td>
<td>401,468</td>
<td>1,517,588</td>
<td>1,995,960</td>
</tr>
<tr>
<td>Methane</td>
<td>670</td>
<td>3495</td>
<td>13,201</td>
<td>17,366</td>
</tr>
<tr>
<td>Nitrous Oxide</td>
<td>178</td>
<td>931</td>
<td>3518</td>
<td>4627</td>
</tr>
<tr>
<td>Total</td>
<td>77,752</td>
<td>405,894</td>
<td>1,534,307</td>
<td>2,017,953</td>
</tr>
</tbody>
</table>

**Table 6.** Reduction in GHG (in tons) from the improved fuel economy scenario compared to the baseline scenario.

<table>
<thead>
<tr>
<th>GHG</th>
<th>2030</th>
<th>2040</th>
<th>2050</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon Dioxide</td>
<td>77</td>
<td>401</td>
<td>1518</td>
<td>1996</td>
</tr>
<tr>
<td>Methane</td>
<td>24</td>
<td>125</td>
<td>471</td>
<td>620</td>
</tr>
<tr>
<td>Nitrous Oxide</td>
<td>1</td>
<td>4</td>
<td>13</td>
<td>18</td>
</tr>
<tr>
<td>Total</td>
<td>102</td>
<td>530</td>
<td>2002</td>
<td>2634</td>
</tr>
</tbody>
</table>

To calculate the benefits gained from emission reduction in both scenarios, we multiplied the values presented in Table 1, which represent the costs derived from the Social Cost of Carbon Explorer tool, with the values in Table 6. In Figure 8, an example is provided of the calculations of SCC for carbon dioxide emissions. The value of 77 GHGs per ton of CO$_2$ was derived from the data presented in Table 6, while USD 226 was obtained from Table 1. Similarly, the social cost of each GHG was calculated by multiplying its reduction emissions in tons by its cost in that specific year. Once the social cost of each gas was computed, these figures were subsequently expressed in today’s equivalent US dollars. They are displayed in Table 7.
Table 6. Reduction in GHG (in tons) from the improved fuel economy scenario compared to the baseline scenario.

<table>
<thead>
<tr>
<th>GHG</th>
<th>2030 (tons)</th>
<th>2040 (tons)</th>
<th>2050 (tons)</th>
<th>Total (tons)</th>
</tr>
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<td>77</td>
<td>401</td>
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<tr>
<td>Methane</td>
<td>24</td>
<td>125</td>
<td>471</td>
<td>620</td>
</tr>
<tr>
<td>Nitrous Oxide</td>
<td>1</td>
<td>4</td>
<td>13</td>
<td>18</td>
</tr>
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Figure 8. The SCC for improved fuel economy scenario compared to the baseline scenario calculated by using USD 226 for 2030.

Table 7. GHG emission benefit–cost analysis (2030–2050): improved fuel economy scenario vs. baseline Scenario.

<table>
<thead>
<tr>
<th>GHG</th>
<th>2030 (USD)</th>
<th>2040 (USD)</th>
<th>2050 (USD)</th>
<th>Total (USD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon Dioxide</td>
<td>15,149</td>
<td>75,318</td>
<td>292,592</td>
<td>383,060</td>
</tr>
<tr>
<td>Methane</td>
<td>60,925</td>
<td>363,062</td>
<td>1,503,051</td>
<td>1,927,038</td>
</tr>
<tr>
<td>Nitrous Oxide</td>
<td>59,941</td>
<td>234,451</td>
<td>759,069</td>
<td>1,053,461</td>
</tr>
<tr>
<td>Total</td>
<td>136,015</td>
<td>672,831</td>
<td>2,554,712</td>
<td>3,363,559</td>
</tr>
</tbody>
</table>

3.3. Improved Fuel Economy Scenario versus Public Transport Scenario

A comparison was made between the improved fuel economy scenario and the public transport scenario. To compare the reduction in GHG emissions in both scenarios, we used the data obtained from LEAP, which quantify these reductions in terms of carbon dioxide equivalents. Figures 9–11 depict the CO2, CH4, and N2O emissions for the two scenarios, respectively. Table 8 displays the quantified decrease in carbon dioxide equivalents over a 100-year GWP between the two given scenarios. These data were later converted into tons, as shown in Table 9.

Figure 9. CO2 emissions for 2030, 2040, and 2050 under the improved fuel economy scenario compared to the public transport scenario.
equivalents over a 100-year GWP between the two given scenarios. These data were later converted into tons, as shown in Table 9.

Figure 9. \(\text{CO}_2\) emissions for 2030, 2040, and 2050 under the improved fuel economy scenario compared to the public transport scenario.

Figure 10. \(\text{CH}_4\) emissions for 2030, 2040, and 2050 under the improved fuel economy scenario compared to the public transport scenario.

Figure 11. \(\text{N}_2\text{O}\) emissions for 2030, 2040, and 2050 under the improved fuel economy scenario compared to the public transport scenario.

Table 8. Reduction in GHGs (in tons of carbon dioxide equivalent) from the improved fuel economy scenario compared to the public transport scenario.

<table>
<thead>
<tr>
<th>GHG</th>
<th>2030</th>
<th>2040</th>
<th>2050</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon Dioxide</td>
<td>990</td>
<td>5672</td>
<td>24,378</td>
<td>31,041</td>
</tr>
<tr>
<td>Methane</td>
<td>2</td>
<td>12</td>
<td>50</td>
<td>64</td>
</tr>
<tr>
<td>Nitrous Oxide</td>
<td>2</td>
<td>12</td>
<td>53</td>
<td>67</td>
</tr>
<tr>
<td>Total</td>
<td>994</td>
<td>5696</td>
<td>24,481</td>
<td>31,172</td>
</tr>
</tbody>
</table>

Table 9. Reduction in GHGs (in tons) from the improved fuel economy scenario compared to the public transport scenario.

<table>
<thead>
<tr>
<th>GHG</th>
<th>2030</th>
<th>2040</th>
<th>2050</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon Dioxide</td>
<td>990</td>
<td>5672</td>
<td>24,378</td>
<td>31,040</td>
</tr>
<tr>
<td>Methane</td>
<td>0.0724</td>
<td>0.4147</td>
<td>1.7823</td>
<td>2.2694</td>
</tr>
<tr>
<td>Nitrous Oxide</td>
<td>0.0081</td>
<td>0.0464</td>
<td>0.1996</td>
<td>0.2541</td>
</tr>
<tr>
<td>Total</td>
<td>990.0805</td>
<td>5672.4611</td>
<td>24,379.9819</td>
<td>31,042.5235</td>
</tr>
</tbody>
</table>

When comparing both scenarios, the benefits of reducing GHG emissions were calculated by multiplying the values from Table 1 with the values from Table 9. Then, using
formula 1, the resulting values were converted into today’s equivalent US dollars. They are presented in Table 10.

Table 10. GHG emission benefit–cost analysis (2030–2050): improved fuel economy scenario vs. public transport scenario.

<table>
<thead>
<tr>
<th>GHG</th>
<th>2030 (USD)</th>
<th>2040 (USD)</th>
<th>2050 (USD)</th>
<th>Total (USD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon Dioxide</td>
<td>194,779</td>
<td>1,065,342</td>
<td>4,698,826</td>
<td>5,958,947</td>
</tr>
<tr>
<td>Methane</td>
<td>184</td>
<td>1204</td>
<td>5688</td>
<td>7076</td>
</tr>
<tr>
<td>Nitrous Oxide</td>
<td>486</td>
<td>2720</td>
<td>11,655</td>
<td>14,860</td>
</tr>
<tr>
<td>Total</td>
<td>195,448</td>
<td>1,069,266</td>
<td>4,716,168</td>
<td>5,980,883</td>
</tr>
</tbody>
</table>

4. Discussion

In the present study, the economic benefit of reducing GHG emissions from the road transportation sector in Qatar was estimated by considering three different scenarios. These scenarios were evaluated for the years 2030, 2040, and 2050. Several studies have examined the SCC for various sectors, including energy [23,41], electricity [42], and agriculture [43]. The results of these studies indicate that the SCC varies significantly across sectors due to differences in emission factors, damage estimates, and economic assumptions.

4.1. Public Transport Scenario versus Baseline

When comparing the two scenarios, it can be seen that the total SCC benefits of reducing CO$_2$, CH$_4$, and N$_2$O will be USD 15,056,687 in 2030, USD 74,876,282 in 2040, and USD 290,072,892 in 2050. Consequently, the total SCC benefit of reducing GHGs during this period will be USD 380,005,861. Additionally, the findings indicate that reducing carbon dioxide emissions will significantly impact the overall economic costs or damages associated with climate change compared to reducing methane and nitrous oxide emissions. Reducing CO$_2$ emissions alone is estimated to provide a benefit of USD 377,090,070 in the considered years. CO$_2$ contributes significantly to greenhouse emissions not only in the transportation sector but also in other sectors. This can be seen from a study on energy planning conducted by [41]. It was stated that the most significant proportion of GHG emissions comes from CO$_2$, which accounts for over 80% of the total emissions. In this study, reducing CO$_2$ emissions has benefits, as emitting more can amplify the impact on the climate system and result in higher social costs. This is because, in the baseline scenario, the current trends are assumed to persist, and private vehicles are currently Qatar’s most common mode of transportation. Hence, reducing their use and switching to public transport will significantly reduce carbon dioxide emissions.

4.2. Improved Fuel Economy Scenario versus Baseline

Comparing the improved fuel economy scenario with the baseline scenario, the benefit of reducing all GHG emissions in 2030 is estimated to be USD 136,015; in 2040, it is estimated to be USD 672,831; and in 2050, is estimated to be USD 2,554,712. This leads to an estimate of the total benefit to be USD 3,363,559. By comparing the two scenarios, reducing carbon dioxide emissions during 2030, 2040, and 2050 will result in a total benefit of USD 383,060. Similarly, reducing methane emissions during the same period will result in a total benefit of USD 1,927,038, and reducing nitrous oxide emissions will yield a total benefit of USD 1,053,461. Thus, methane emissions have the most significant potential benefit compared to carbon dioxide and nitrous oxide emissions.

4.3. Improved Fuel Economy Scenario versus Public Transport Scenario

Comparing the two scenarios, the results indicate that the social cost benefit of CO$_2$, CH$_4$, and N$_2$O will be USD 195,448 in 2030, USD 1,069,266 in 2040, and USD 4,716,168 in 2050. In this respect, the total benefit of reducing GHG emissions is USD 5,980,883. Based again on the comparison results, it is evident that reducing CO$_2$ emissions will have the
most significant impact compared with the other greenhouse gases considered in this study. Reducing CO$_2$ emissions alone during the considered years will result in a benefit of USD 5,958,947. Not only will reducing CO$_2$ emissions have economic advantages, but it will also have significant health benefits. This is because exposure to mild levels of CO$_2$ can result in symptoms like headache and drowsiness, whereas higher levels of CO$_2$ may cause rapid breathing, elevated blood pressure, and increased arrhythmias [44].

5. Conclusions and Recommendations

The transportation sector’s role as a significant emitter of GHG emissions raises concerns about its environmental and human health impacts. In understanding the economic consequences of this industry, the social cost of carbon plays a crucial role. This study specifically examines road transportation in Qatar, which is a significant source of GHG emissions compared to other forms of transportation. This study explores three different scenarios using the LEAP tool. These scenarios are as follows: (1) public transport scenario versus baseline; (2) improved fuel economy scenario versus baseline; and (3) improved fuel economy scenario versus public transport scenario. Based on the findings, it can be determined that the public transport scenario versus baseline yields the highest social cost–benefit, with a total of USD 380,005,861. The second highest social cost–benefit is observed in the improved fuel economy scenario versus the public transport scenario, amounting to USD 5,980,883. Lastly, the improved fuel economy scenario versus baseline ranks third in terms of social cost–benefit, reaching a total of USD 3,363,559. Furthermore, it can be argued that CO$_2$ exhibits the most significant social cost of carbon advantages within road transportation. CO$_2$ is the most prevalent GHG released by this particular sector, and its extended presence in the atmosphere contributes significantly to long-term global warming. Therefore, reducing CO$_2$ emissions can lead to significant climate advantages, as evidenced by the increase in the social cost of carbon values. However, it is justifiable to argue that methane and nitrous oxide exhibit diminished social cost of carbon advantages. While it is true that gases other than CO$_2$ have higher warming potentials per molecule, their emissions from road transportation are generally lower. Moreover, the shorter atmospheric lifetimes of these substances lead to reduced long-term consequences. In light of the present analysis, it is of the utmost importance for policymakers and stakeholders within the road transportation sector in Qatar to place significant emphasis on reducing CO$_2$ emissions. This prioritization is essential in order to maximize the benefits associated with the SCC effectively. Efforts should also be directed towards reducing and managing methane and nitrous oxide emissions, albeit with a relatively low priority, to make additional contributions to the overall mitigation of climate change. Policymakers must incorporate the SCC into decision-making processes and treat it as a critical factor in policy design. Implementing cost-effective measures can help achieve maximum sustainability while fostering economic development. Governments, industries, and individuals must work together closely to achieve these objectives. This will require rigorous monitoring and evaluation to identify areas that need improvement and address any challenges that may arise. Our study has implications at both the local and global levels. Although our primary focus is on Qatar, the tools and methodologies we utilized have broader applicability, extending the relevance of our findings beyond this specific country. Our research combines local relevance with broader global insights, making valuable contributions to informed decision making in Qatar. Additionally, it helps advance the global conversation on climate economics and policymaking.

In our analysis of the social cost of carbon, we built upon our previous work. However, it is crucial to acknowledge that the previous study had a limitation concerning data availability. This limitation also applies to our current analysis. Specifically, we encountered challenges related to vehicle count availability and some data elements that were not easily accessible or directly obtainable. Nonetheless, we mitigated these limitations by supplementing our data requirements with information from other countries and utilizing global databases. This approach ensured that our analysis was comprehensive and
thorough, including factors such as energy intensity. Based on the findings of this study, we have shown that reducing GHG emissions can lead to significant savings. To this end, we recommend a series of policy and technology interventions, including investments in sustainable transportation modes, continued monitoring and evaluation of climate policies, education and awareness-raising campaigns, and future research in various sectors. By implementing these recommendations, policymakers can adopt a sustainable, long-term strategy for addressing the adverse effects of climate change on society. Investigating the social cost benefits of lowering greenhouse gas emissions in road transportation identifies essential areas for additional research and analysis. This paper has focused on calculating the social cost benefits of reducing GHG emissions in road transportation in Qatar. However, there are several areas that could be expanded upon in future work. The same method can be extended to other industries contributing to GHG emissions, such as aviation and shipping. Further research should be undertaken to apply this method to these sectors, which would help identify potential emission reductions and social cost savings associated with implementing policy and technological interventions.

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