Supporting Electric Vehicle Usage in Eilat Through Charger Placement

by

Paige Agostini

Steve Rosario

Nathaiel Rubin

Jenna Young

Supporting Electric Vehicle Usage in Eilat Through Charger Placement

An Interactive Qualifying Project
submitted to the faculty of
WORCESTER POLYTECHNIC INSTITUTE
in partial fulfillment of the requirements for the
degree of Bachelor of Science

by
Paige Agostini
Steve Rosario
Nathaniel Rubin
Jenna Young

Date:
28 February 2024

Report Submitted to:

Avi Naim
Eilat Municipality

Elad Topel
Eilat Municipality

Professors Isa Bar-On and Michele Femc-Bagwell
Worcester Polytechnic Institute

Abstract

Eilat, Israel, is committed to reaching net zero emissions by 2030. To help reduce its transportation emissions, we evaluated Eilat's current charging network and designed an expansion to accommodate additional electric vehicles. We provided a deployment plan and a cost estimation to assist in implementation. We calculated Eilat's current transportation emissions to understand how they will change by 2030. We found that the implementation of this expansion should result in greater EV use and reduced transportation emissions.

Acknowledgments

We would like to acknowledge all the amazing people who made our project possible. Each one of you played a vital role in the success of our project and contributed to the meaningful experience we had on IQP.

We would like to especially thank our advisors, Professor Isa Bar-On and Professor Michele Femc-Bagwell, for their ongoing support and encouragement throughout the course of our project. Professor Bar-On – you provided insight and support, and continually pushed our team to reach heights we had not thought to be possible. Professor Femc-Bagwell – you provided our team with encouragement, alongside reminders to look at the bigger picture that our work is a part of.

We would also like to acknowledge our sponsors, Avi Naim, Elad Topel, and Assaf Adamon. We appreciate the time you took to support our team and the effort you put into guiding our project. Your insight into Eilat benefited our work significantly.

Thank you to Adam Burger and Louise Peter of Santa Clara Valley Transportation Authority (VTA). Your insight into the municipal side of electric vehicle charging and implementation was invaluable to our team.

Finally, we would like to thank Professor Seth Tuler for your support in the preparation for our project – the research you assisted our team in setting us up for a successful term and project. Additionally, we send our gratitude to Philip Waterman and Paige Wilkins – having the help and support of our librarians was monumental in the research, formatting, and mechanics for our project.

Executive Summary

Challenge

As the European Union looks to reduce the climate impact of cities, it created the Smart Cities Missions, where unique cities were selected to reach climate neutrality by 2030, and serve as a framework for other cities to follow. Eilat, Israel joined this mission to preserve the city's tourism industry which has been threatened by global warming, and to act as a model for other tourism-based cities.

Eilat's journey to climate neutrality is closely tied to retaining optimal comfort for tourists in a city that has summer temperatures often surpassing 40°C/104°F. Eilat aims to maintain the comfort of both residents and tourists while still reducing their greenhouse gas emissions by encouraging the switch from internal combustion engine vehicles to electric vehicles (EV) through the construction of effective EV charging infrastructure. Eilat's EV infrastructure will serve as a framework for other cities, especially those with large tourism industries and unique climates, wishing to reduce their climate impact without hindering their primary economic sector. To help Eilat reduce its transportation emissions and expand its EV infrastructure, we completed the following objectives:

1. Calculate the emissions from the transportation sector.
2. Evaluate the current EV charging network and its usage in Eilat.
3. Identify additional charging sites and corresponding infrastructure to expand Eilat's charging network.
4. Assess the cost of EV chargers on the municipality and users.

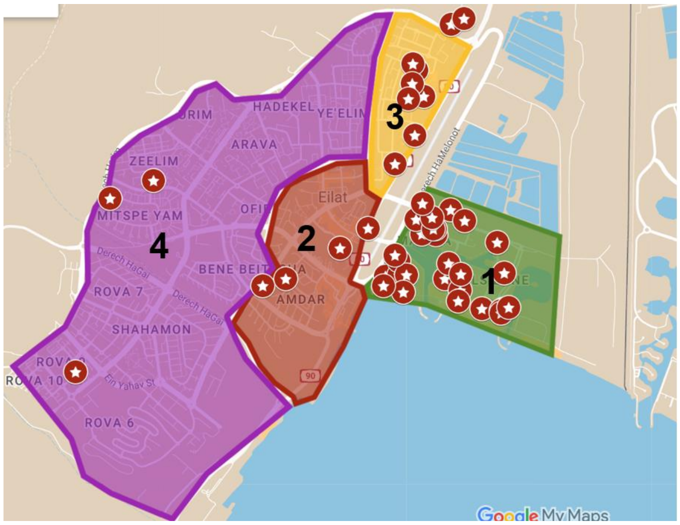
To complete these objectives, we obtained data from the Israeli Central Bureau of Statistics and the municipality. The European Environment Agency's road transportation emission inventory methodology was used to calculate Eilat's transportation emissions. Crowdsourced data from Google Maps and Cello Charge were used to identify the placement, cost per use, and capacity of the current chargers in Eilat. Eilat's Geographic Information System (GIS), provided by the municipality, was used to identify the location and number of parking spaces in all parking lots in Eilat. Eligible parking lots for EV chargers were identified using location modeling, and recommendations from city planning journals. The cost of the installation was estimated using information from the municipality's previous EV charger purchases.

Findings

Emissions Calculations

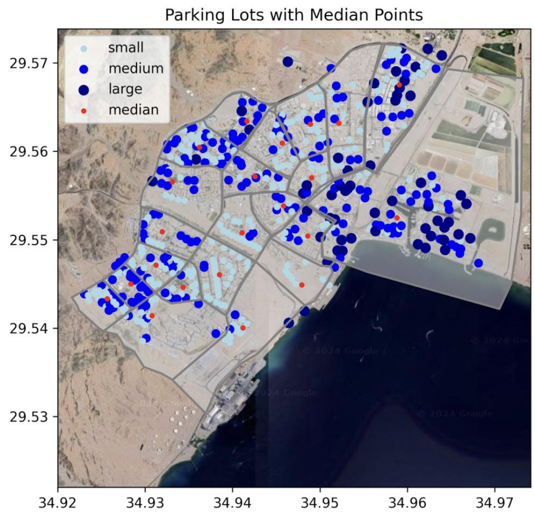
In 2022 Eilat's transportation sector emitted 84,170 tonnes of CO_2 equivalent. This number is 7.3% higher than in 2019, the result of an increase of vehicles on Eilat's roads. 74% of Eilat's 2022 transportation emissions came from passenger cars such as private vehicles and taxis. It is projected that in 2030 Eilat's transportation sector will emit 97,740 tonnes of CO_2 equivalents given current trends in Eilat vehicle numbers, an 85% increase over 2022.

Current EV Charging Network Evaluation

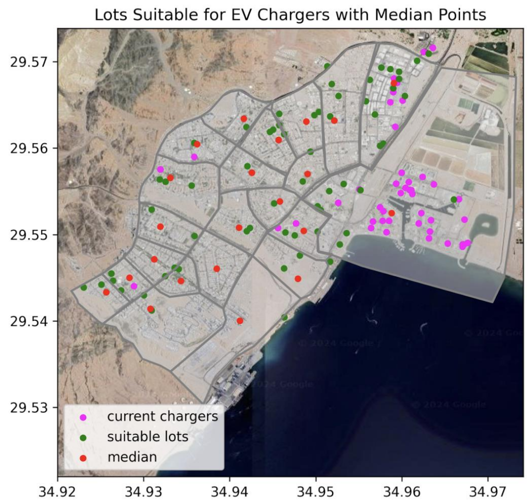


As of February 2024, Eilat has around 145 EV chargers spread across 45 charging sites. The majority of the sites are located in hotel and resort parking lots, and 62% of the chargers are medium 22 kW. EV drivers typically charge their vehicles between 11:00 and 20:00 hours.

Charging Network Expansion



531 parking lots were found in Eilat. The Simple Median Modeling method was used to determine the centroid of each neighborhood, based on the size and location of each lot. Identifying all parking lots allowed us to get a clearer image of the distribution of locations of interest throughout the city.



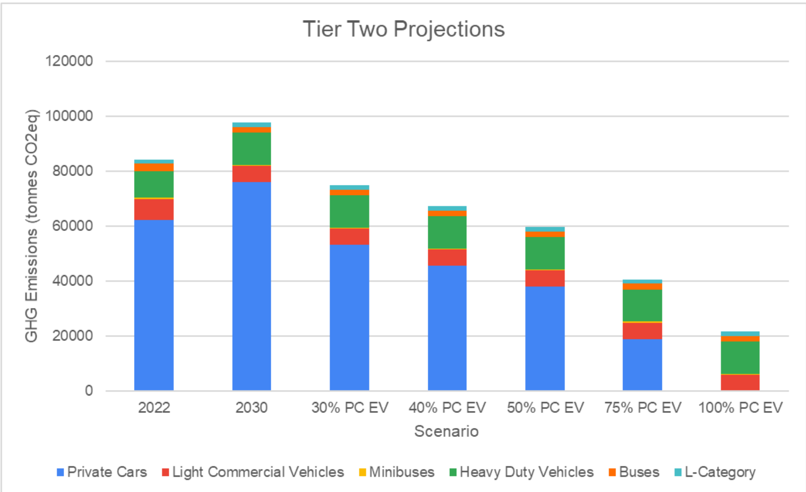
64 parking lots were identified as eligible for the placement of EV chargers. 20% of parking spaces were designated for EV chargers, as recommended by the City of Chicago, resulting in the recommended placement of 821 charge points (Mayor's Press Office, City of Chicago, 2020).

Cost of Implementation Estimation

We estimate the total cost of implementation to be ₪23 million or 6.2 million USD. This cost includes the charger and installation fees but excludes the infrastructure necessary to integrate the charger into the existing power grid.

Recommendations

Emissions Calculations

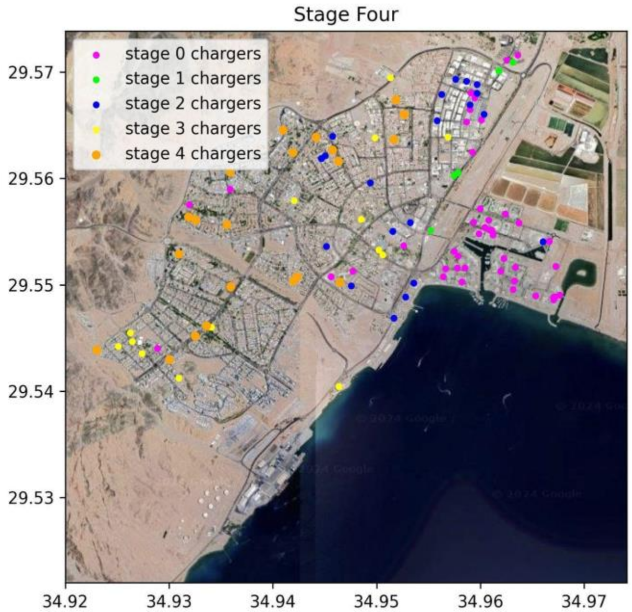


We recommend that the Eilat Municipality foster the usage of electric vehicles throughout the city in order to reduce the emissions from the city's transportation sector. This implementation will lead to a drastic reduction in the city's emissions while supporting a growing number of vehicles in the city. Should 30% of passenger cars in Eilat be electric in 2030, the city is projected to emit 74,910 tonnes of CO_2 equivalents, and if 100% of passenger cars are electric in 2030, the city's transportation missions are expected to be just 21,650 tonnes of CO_2 equivalents.

Current EV Charging Network Evaluation

Additional EV charging sites must be placed in the residential, municipal, and industrial areas of Eilat to increase EV usage and adoption throughout the city. Each site should feature medium, 22kW chargers equipped with Type 2 ports. Also, fast, 50kW, or ultra-fast, 350kW chargers with Type 2 CCS ports should be installed at sites designated for commercial use.

Charging Network Expansion



The construction of EV chargers should be deployed in four stages. Each stage places chargers at places of interest, including gas stations in Stage One, shopping centers in Stage Two, schools, municipal buildings, and areas of recreation in Stage Three, and residential lots in Stage Four. An evaluation should be made of the existing network before the next stage can be implemented.

Cost of Implementation Estimation

The cost of installation may change with consideration of the distances from the chargers to the nearest light stations. Additionally, costs of maintenance and software are not included in the cost calculated.

To recover the investment made by the city of Eilat, a combination of a fixed rate charge tariff and a time-of-use volume cost tariff should be implemented on the users. The fixed-rate charge will cover the cost of installation and maintenance and will cost a single amount based on the capacity of the charger, while the time-of-use volume cost will directly cover the amount of electricity used, and will change costs based on city-wide peak electricity usage times.

Conclusions

The city of Eilat is in a unique position to influence the reduction of greenhouse gases in Israel, the European Union, and across the globe. The city can serve as a role model to other small, tourism-based cities located in demanding climates. Many cities are aiming to reduce their emissions from the transportation sector by encouraging the adoption of EVs. Eilat's placement of public chargers has the potential to serve as a foundation for smaller cities with fewer resources to accomplish this goal.

Authorship Page

Section	Primary Authors
Abstract	Steve Rosario
Acknowledgement	Jenna Young
Executive Summary	Paige Agostini, Jenna Young, Steve Rosario, Nathaniel Rubin
1. Introduction	Steve Rosario, Jenna Young, Paige Agostini, Nathaniel Rubin
2.1.1: Climate Change in Israel	Paige Agostini
2.1.2: European Union's Climate Neutral and Smart Cities Mission	Jenna Young
2.1.3: Eilat: Climate and Demographics	Paige Agostini
2.1.4: Transition to Climate Neutrality in Eilat	Paige Agostini
2.1.5: Transportation in Eilat	Steve Rosario
2.1.6: Electric Vehicles	Steve Rosario
2.1.7: Electric Vehicle Transition in Eilat	Steve Rosario
2.1.8: Comparing Eilat's Strategies to Other Cities	Steve Rosario, Nathaniel Rubin
2.2: Calculating Eilat's Transportation Emissions	Jenna Young
2.2.1: Greenhouse Gases	Jenna Young
2.2.2: Vehicle Technology	Jenna Young
2.2.3: Previous Calculations	Jenna Young
2.2.4: EEA Road Transportation Emissions Methodology	Jenna Young
3.1: Calculating Eilat's Current Transportation Emissions	Jenna Young
3.1.1: Tier One	Jenna Young
3.1.2: Tier Two	Jenna Young
3.1.3: Tier Three	Jenna Young

3.1.4: Emission Projections	Paige Agostini, Jenna Young
3.2: Evaluating Current EV Infrastructure	Steve Rosario
3.3: Charging Network Expansion	Paige Agostini
3.4: Map Display	Nathaniel Rubin
3.5: Cost of Implementation Estimations	Nathaniel Rubin
3.6: Tariffs	Paige Agostini
4.1: Results from Calculating Eilat's Current Emissions	Jenna Young
4.1.1: Tier One Emissions	Jenna Young
4.1.2: Tier Two Emissions	Jenna Young
4.1.3: Tier Three Emissions	Jenna Young
4.1.4: Electric Vehicle Usage and Emissions Projection	Paige Agostini, Jenna Young
4.2: Evaluating Eilat's Current EV Charging Grid	Steve Rosario
4.3: EV Charging Network Expansion	Paige Agostini
4.4: Implementation Cost Estimate Results	Nathaniel Rubin
4.5: Cost on User Recommendations	Paige Agostini
5.1: Eilat's Current Emissions	Jenna Young
5.2: Projecting Eilat's Emissions	Jenna Young, Paige Agostini
5.3: Eilat's Current EV Charging Grid	Steve Rosario
5.4: EV Charger Network Expansion	Paige Agostini
5.5: Cost Evaluation	Nathaniel Rubin
5.6: Tariffs	Paige Agostini
5.7: Software Recommendations	Nathaniel Rubin
6: Conclusion	Steve Rosario

Note. All sections were edited by all authors.

Table of Contents

Table of Figures

Table of Tables

Table of Equations

Chapter 1: Introduction

Cities are responsible for 70% of carbon dioxide (CO_2) emissions worldwide ("100 Climate-Neutral and Smart Cities by 2030: Info Kit for Cities," 2022). Since CO_2 is a major greenhouse gas (GHG) of concern, it is no surprise that a major focus has been put on its sources. Eilat, a coastal city located on the southern tip of Israel, is a forerunner in Israel in the transition to low-carbon technology (Sofer & Potchter, 2005). The city runs exclusively on solar power during the day and will soon run on solar throughout the night (Zohar et al.). Eilat's commitment to being a climate-conscious city is further proved by joining the European Union's Climate Neutral and Smart Cities Mission. To mitigate climate change, the EU plans to lower emissions produced by cities through this mission ("100 Climate-Neutral and Smart Cities by 2030: Info Kit for Cities," 2022).

Although Israel is not a part of the European Continent, it consistently retains close ties with the EU through Horizon Europe. The country began working with the EU in the 1960s with a trade agreement. As a result of their ties, Israel will often participate in EU plans and goals (Voltolini, 2015). During the Cities Mission's call for expressions of interest, cities associated with Horizon Europe were invited to participate. Four cities from Israel expressed interest in participating in the mission (European Commission, 2022); ultimately, Eilat was selected to join the Cities Mission as an associated member.

The city of Eilat has an interest in reducing GHG emissions because climate change will negatively impact the tourism industry in Eilat, the basis of its economy (Lee et al., 2022). Therefore, as part of the city's goal of reducing all GHG emissions by 2030, this project aims to help Eilat's municipality by evaluating the current GHG emissions of its transportation sector and reducing those emissions through the proposal to expand Eilat's EV charging network. We have formulated the following objectives to accomplish these goals:

1. To evaluate the GHG emissions of Eilat's transportation sector
2. To evaluate Eilat's current EV charging network and its usage.
3. To identify additional charging sites and corresponding infrastructure to expand Eilat's charging network.
4. To assess the cost of EV chargers on the municipality and users.

Chapter 2: Background

2.1: The Response to Climate Change

2.1.1: Climate Change in Israel

Climate change is one of the largest concerns of the 21st century; it is a result of industrial human activity which releases greenhouse gases (GHG) into the atmosphere, raising temperatures and causing unpredictable weather patterns (United Nations, 2023). In Israel, it is projected that by the beginning of the next century, national average temperatures will increase by 3-5^{o}C, with greater temperature variability throughout the year as a result of climate change (Maldonado & Aviv, 2011). In addition to this, there is expected to be a 10% reduction in precipitation by 2100, putting a strain on Israel's desert climate (Israel Ministry of Environmental Protection, 2020). To mitigate the negative effects on the health and economy of Israel caused by climate change, the nation joined the Paris Agreement, a legally binding treaty on climate change signed by participating nations to limit global warming to 1.5^{o}C. This treaty requires transformative change on a nation's emissions of greenhouse gases (UNFCCC, 2023). Israel has pledged to reduce its GHG emissions to zero by 2050.

2.1.2: European Union's Climate Neutral and Smart Cities Mission

The European Union's Climate Neutral and Smart Cities Mission (The Cities Mission) aims to produce one hundred smart and climate-neutral cities by 2030, as a means of creating a long-term strategy that complies with the Paris Agreement. Participating cities are challenged to reduce direct emissions, emissions produced within city boundaries, and indirect emissions, emissions produced outside of city boundaries for the city, to zero. This mission aims for these cities to act as hubs of innovation and experimentation to enable the rest of Europe to be smart and climate-neutral by 2050. To accomplish this, cities selected for the mission must have at least 50,000 inhabitants, come from diverse climates, and demonstrate ambition and a high level of commitment to becoming a climate-neutral city ("100 Climate-Neutral and Smart Cities by 2030: Info Kit for Cities," 2022). These criteria ensure that The Cities Mission creates diverse solutions for all cities to reach climate neutrality.

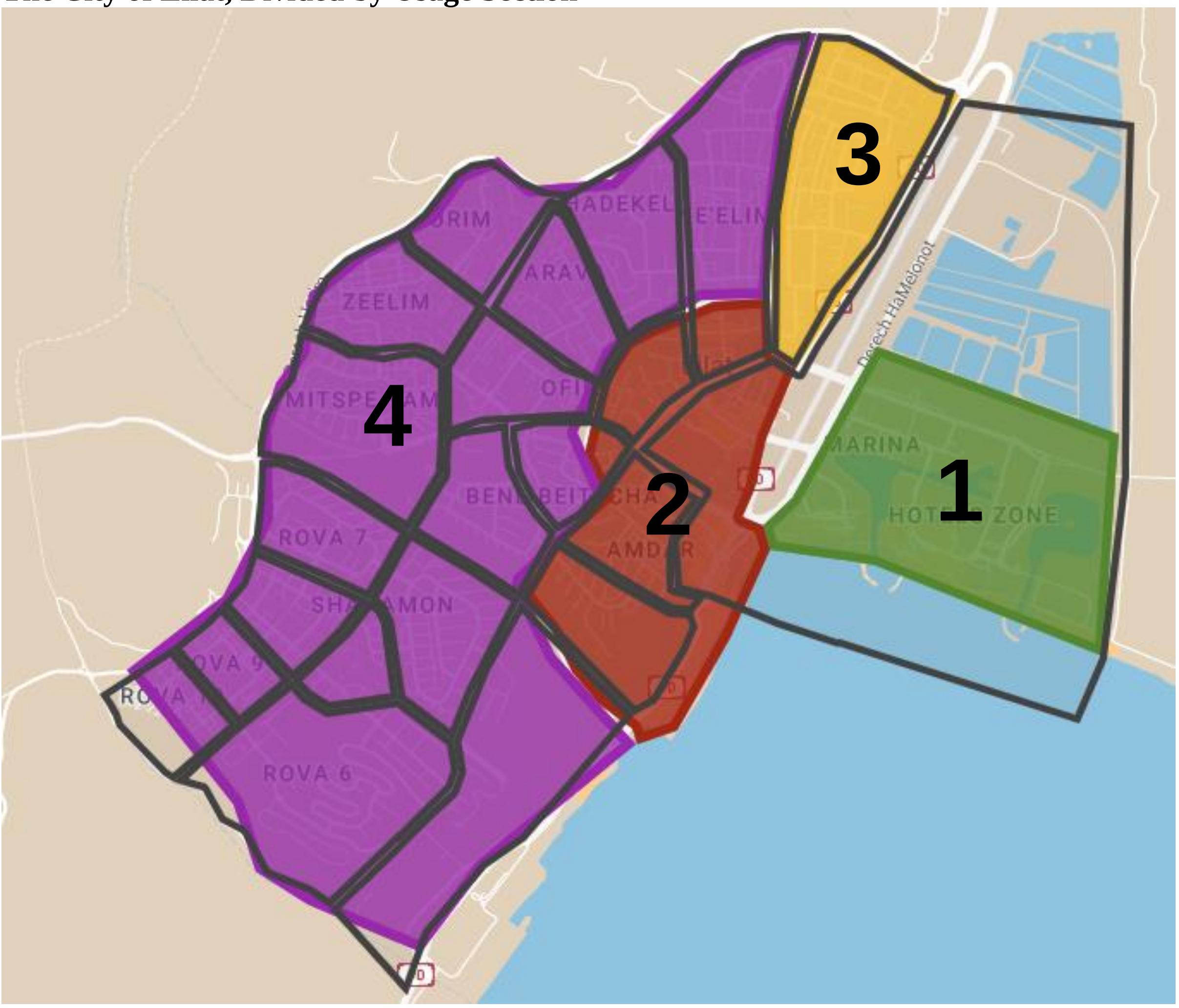
2.1.3: Eilat: Climate and Demographics

Eilat was chosen for the EU's Cities Mission in 2022 as an associate of the EU through Horizon Europe. It was chosen as a model city because of its unique climate, location, and economy. Eilat is located in the southernmost part of Israel, at the edge of the Negev Desert and the Gulf of Aqaba in the Red Sea. The city has a desert climate, where the average annual temperature is 21.4^{o}C, with temperatures reaching over 40^{o}C in the summer. The city receives only 30mm of rain annually (*Eilat Climate*, n.d.). Hills and mountains surround the westernmost side of the city, while the Southeast side is surrounded by water. In 2022, the city was home to 52,753 residents; annually, the city sees up to three million tourists, many of whom visit in the summer (Israel Central Bureau of Statistics, 2023). To accommodate these tourists, Eilat has fifty-one hotels, an international airport, and countless bars, restaurants, and attractions (Tourist

Israel, 2022). The significant number of tourists visiting Eilat provide jobs to the city's residents, making its economy reliant on tourism. The city is divided into four sections and 21 neighborhoods, as shown in Figure 1.

Figure 1

The City of Eilat, Divided by Usage Section



Note. From *Google Earth [Eilat - Google Earth]* by Google, Retreived February 21, 2024 (https://earth.google.com/web/search/eilat/@29.62742694,34.95406645,133.97194914a,64664.51651002d,35y,0.00000088h,0t,0r/data=CnAaRhJACiUweDE1MDA3MWUzMjQ3OTVlMGI6MHhmZTFkOTVmODU1NzdmNmRiGTb-RGXDjj1AIVWfq63YeUFAKgVlaWxhdBgCIAEiJgokCdFFDVx3lT1AEcAeJ5PIiD1AGRJmuhFEf0FAIfl2tDQLc0FAMikKJwolCiExaWhOWF9ObzlsSDNGU3dOcTUySXBfQ1dGR3VuYUpNQ2QgAToDCgEw). Copyright TerraMetrics, 2023, Map data, 2023. Reuse is authorized by Google Earth.

Section One (green) of the city contains the majority of resorts, hotels, and attractions. It is meant to service mainly tourists. Section Two (red), is a predominantly commercial zone, and is home to hotels, as well as schools, the municipality, and bars and restaurants. This section acts as a buffer between tourist zones, and section Four (purple), the residential zone, which mainly features multi-family dwellings, schools, and parks used by residents of the city. Section Three (yellow) is the commercial area of the city, which exclusively contains stores and businesses.

As climate change affects Israel, Eilat may see a decrease in tourism as temperatures during peak months become unbearable. A major draw to Eilat is the Red Sea, home to the only coral reef in Israel. Rising ocean temperatures will lead to the coral becoming bleached, and then dying (*Rising Ocean Temps Raise New Concerns for Coral Reefs*, 2023). This will put a strain on the economy of Eilat, as the reefs are one of the main attractions for tourists. As a result, becoming climate-neutral is a key step to maintaining the city's economy.

2.1.4: Transition to Climate Neutrality in Eilat

Before joining the EU Cities Mission, Eilat updated its power grid to run on renewable energy. The tourist industry in Eilat requires significant energy draws to operate, especially in the summer (*Planning a Vacation in Eilat*, n.d.). Eilat, being the southernmost city in Israel, is on the edge of the power grid. Prior to the energy transition, the city had poorly maintained infrastructure causing transmission losses. When the grid was overwhelmed, a substation run on petroleum was required to provide power to the city (Zohar et al., 2022). In 2002, the Eilat and Eilot municipalities constructed a plan for renewable energy generation to provide economic and social resilience to the region. The transition to photovoltaic (PV) solar energy led Israel to become the second-highest producer of solar energy, producing 8.7% of the world's PV energy (International Energy Agency, 2020). This transition, in part due to the ideal location just south of the Negev Desert, was made possible by cooperation between the two municipalities, and funds from a green-technology investment firm (*Eilat-Eilot Innovations in Renewable Energy Technology: A Response to Global Warming and Climate Change - Israel*, 2024). By the end of 2020, 100% of Eilat's daytime electricity consumption was powered by 15 PV solar power plants, with plans to expand its power production to cover nighttime needs by 2025 (Zohar et al., 2022). The city also has plans to promote sustainable agriculture through water conservation techniques and promote educational and awareness programs in schools and areas of high tourism (*Eilat-Eilot Environmental Unit*, n.d.). The Interuniversity Institute for Marine Sciences in Eilat is a research institution that is dedicated to understanding the effects of climate change and other human activity on marine life in the Red Sea (Ayalon et al., 2020). This research will contribute to the continued biodiversity of the reefs, and will find ways to mitigate the effects of the rising ocean temperature. Despite what Eilat has accomplished so far, there is still more work that needs to be done to ensure the goal of zero emissions is met by 2030, specifically in the transportation sector.

2.1.5: Transportation in Eilat

The transportation sector accounts for 74.5% of global GHG emissions. Most of these emissions come from passenger cars and buses powered by internal combustion engines (ICE) (Ritchie & Roser, 2023). Israelis prefer to travel using private vehicles rather than using public transportation. Haim Bleikh at the Taub Center for Social Policy Studies in Israel conducted a study that found that 60% of Israelis commuted to work in a personal vehicle in 2016, while only 22% utilized public transportation (Weissburg, 2018). Eilat is well-suited for this lifestyle; the city features car-centric infrastructure, with approximately 4000 public parking spots available (Administration of Tourism, supervision and beaches in Eilat, 2023), and public transportation within Eilat is limited to just eleven bus lines run by the company Egged (Transportation in Eilat, n.d.). The majority of cars on Israeli roads are ICE vehicles, contributing to the city's transportation emissions. Eilat must therefore make sweeping changes to its transportation sector for it to meet the Cities Mission’s 2030 goal.

Use of public transportation, walking or cycling, and use of electric vehicles are all options for reducing emissions from the transportation sector in Eilat. Each has its unique advantages and disadvantages. Public transportation can be designed and implemented in a socioeconomically equitable manner, since it is low-cost for the user, and can be made accessible throughout the city. Any GHGs that are produced from public transportation are collective among all users, as opposed to just a few people, as is the case with private cars. Despite its benefits, public transportation only gets the user ‘close’ to their destination which may present challenges during Eilat’s hot summers. Additionally, some forms of public transportation are not suited for a city as small as Eilat, such as rapid transit systems. Since few Israelis choose public transportation over private vehicle travel, coupled with the high cost of implementation (Flyvbjerg et al, 2008), investing in expanding Eilat’s public transportation is not a viable option. Even if such a transportation system were installed, a significant shift in Israeli transportation culture would not occur by the 2030 deadline.

Walking and cycling can both prove advantageous for GHG reduction. Walking and cycling do not produce any GHG emissions and can have health benefits for citizens. Despite these benefits, Eilat has car-centric urban planning, meaning that it is not planned in a way such that walking and biking are effective at getting users to their daily needs. Additionally, Eilat’s climate and topography complicate travel via walking and cycling – summer temperatures soar above 40°C/104°F and can make walking and biking unpleasant, and in some cases dangerous (The Weather in Eilat, 2021). When accounting for the city’s hills in residential areas, walking and cycling lose their appeal for residents. Electric bikes could potentially skirt these concerns but would require both infrastructural and cultural shifts.

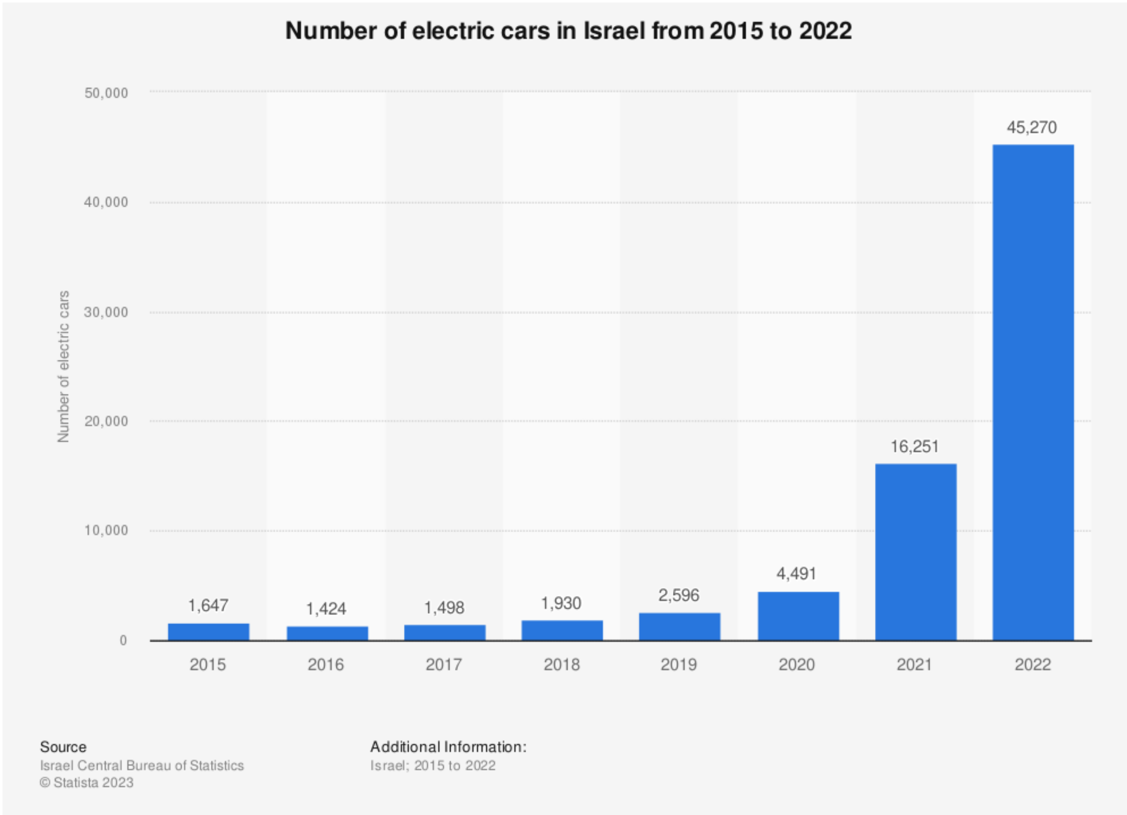
Electric vehicles (EVs) are a transportation method that do not produce any tail-pipe emissions, and work well with the Israeli affinity for personal vehicles. This form of transportation used within the city would therefore not contribute to direct GHG emissions in Eilat. However, they have the drawbacks of requiring new infrastructure, such as charging stations, and producing indirect emissions from battery production and disposal. Additionally, purchasing EVs is not socioeconomically equitable. Many EVs continue to cost more than an average Internal combustion Engine (ICE) vehicle (Ben-Gedalyahu, 2023). Furthermore, it will take time until EVs are common in the used car market. According to our sponsor, Israelis tend to buy used cars, resulting in continued use of ICE vehicles. These two factors make EVs less accessible to lower-income people, and prioritizing them as the main form of transportation in Eilat could cause a disparity in transportation between different socioeconomic groups. However, the cultural preference for private vehicles over other forms of transportation, along with the steady increase in the number of cars on Israeli roads suggests that shifting private vehicles to EVs can reduce the GHG emissions of the transportation sector (Central Bureau of Statistics, 2023). For these reasons, EVs were selected as the form of transportation to be used to reduce transportation sector GHG emissions.

2.1.6: Electric Vehicles

EVs provide several benefits compared to ICE vehicles in terms of GHG emissions. EVs have a higher production emission output than ICE vehicles, but throughout the lifetime of both vehicle types, EVs produce up to 89% less emissions than their ICE counterparts (Buberger et al., 2022). Additionally, EVs continue to become more accessible to consumers. Improvements in battery technology allow EVs to travel further than in the previous decade, and overall EV costs, including purchasing, maintenance, and charging, have decreased. In 2018, the Israeli government passed a law banning the sale of new gas-powered vehicles by 2030 (Johnson, 2018), compelling vehicle manufacturers to develop and release more EV options to consumers. In the late 2010s, there were less than 2000 EVs on Israeli roads, a number which has grown to over 45,000 at the present day as shown in Figure 2 (Israel Central Bureau of Statistics, 2023). Israel is gradually transitioning many of its private vehicles to electric ones. Since many domestic tourists arrive in Eilat using personal vehicles, many EVs will end up on the streets of Eilat.

Figure 2

Number of Electric Cars in Israel from 2015 to 2022



Note. From Israel Central Bureau of Statistics, 2023 (https://www.statista.com/statistics/1358744/number-of-electric-cars-in-israel/) Copyright European Union, 2023. Reuse is authorized by Statista.

It is important to consider the charging infrastructure needed to support this rise in EVs. There are three primary types of charging available for EVs: slow, medium, and fast (Moloughney, 2021). Slow chargers are well-suited for domestic and private settings. These chargers operate at 3.7 kW to 11 kW and 10-16 A of current. Although charging times depend on the car being charged, it will take up to 12 hours on average for an EV to charge completely. Medium chargers typically operate at 11 kW to 22 kW and 16-32 A of current. These chargers are fast enough to be used in public areas such as offices or shopping centers. However, medium chargers still take six to eight hours to fully charge a vehicle. Finally, fast chargers operate at greater than 22 kW and greater than 32 A of current. These chargers are used in places where vehicles need to be charged as fast as possible, such as at highway service centers (Falvo et al., 2014). Fast chargers can charge an EV battery up to 80% in about 20 minutes (Heilweil, 2023). Advancements in charging technology have allowed EVs to become a viable solution to mitigating GHG emissions in the transportation sector.

2.1.7: Electric Vehicle Transition in Eilat

The charging infrastructure currently in place in Eilat forms a baseline from which an improved EV charging grid can be formed. Eilat has numerous EV chargers of varying speeds distributed by private companies. By 2025, there are expected to be 87,000 EVs operating in Israel creating a demand for publicly available EV chargers, especially fast chargers.(Liebes et al., 2018).

Following the identification of Eilat's current EV charging network, recommendations for new charger placement can be made. By increasing the number of EV chargers in the city, the Eilat Municipality can promote EV use within the city while assuaging consumers' feelings of range anxiety (Shrestha et al., 2022). Range anxiety is a negative consumer sentiment towards EVs encompassing a general fear of not being able to reach one's destination due to a lack of EV range (Heilweil, 2023). Additional EV chargers will encourage commuters to use EVs instead of ICE vehicles since the infrastructure to enable them to complete their trip will exist. Cities with effective EV charging infrastructure consider how public EV chargers service operational stakeholders. Operational stakeholders include EV charger users, charge point operators, network operators, and electricity suppliers (Lopez, 2022). The context for the placement of the EV charger should consider the users' destination, length of stay, and time of use, while the energy capacity of the charge point sites and the cost of installation will concern the other stakeholders. Because of Eilat's unique circumstances as a tourist-based economy, additional considerations will be made as to how the charging network will service residents and tourists. In Eilat, two types of charging should be considered; daytime charging, which is done at places of recreation or occupation, and nighttime charging, which is done at places of residency (including hotels). The type of charger at daytime destinations will vary based on demand. For example, a user who is going to a store will have a different motivation for charging than a user going to an office building. Night-time public charging is part of a long-term strategy since it will encourage the use of EVs by people who cannot or will not install chargers in their homes. This project will mainly focus on daytime charging since it will have the most immediate impact on the city, but recommendations for night-time charging solutions will be made as well. An additional place of interest includes gas stations, since, as cities move towards net-zero carbon emissions from transportation, gas stations will likely be converted to EV fast charging stations.

In this report, we recommend implementing the new EV chargers in stages to set realistic goals for the municipality to meet. After we identify the most beneficial locations for the new EV chargers, we estimate the cost of purchasing and installing the chargers at each site. This estimation aims to advise the municipality on budgeting for the implementation. To recover the sunken costs, we provide guidance on selecting and implementing the appropriate tariffs.

2.1.8: Comparing Eilat's Strategies to Other Cities

Other cities, including those not affiliated with the EU Cities Mission, are also striving to reduce their GHG emissions. One such city is Honolulu, the most populous city and the capital of the US state of Hawaii. It occupies roughly twice the area of Eilat and has a population of

343,421, 6.5 times larger than that of Eilat (United States Census Bureau, 2022). Honolulu's economy is also based on tourism (Department of Business, Economic Development & Tourism, n.d.). Another similarity is that the city has committed itself to reducing its emissions. In June 2017, city leaders and the state's governor signed two bills that committed the state to goals outlined in the Paris Climate Agreement. In short, the city wishes to reduce emissions in ground transportation, electricity, and waste by 80% from 2015 levels by 2045 (City & Council of Honolulu, 2021). In response to the commitment, the city developed the 2020-2025 Climate Action Plan (CAP). This plan outlines various strategies that the city will take to reduce emissions. When comparing the two cities' emission reduction strategies, Eilat is ahead in its energy sector since it is running on 100% solar energy during the day. In contrast, at the time of the CAP's issuing in 2021, 35% of O'ahu's (the island that Honolulu is located on) emissions were from electricity production. Since then, Honolulu has taken strides in implementing solar energy in its city. It now has the highest wattage of solar energy per resident of any city in the US and has even repealed legislation limiting the height of rooftop structures to encourage homeowners to install solar panels on their homes (Pforzheimer & Neumann, 2022; Relating to Height Limits for Rooftop Structures, 2022). Thus, both cities are leading their respective countries in terms of solar power.

In the transportation sector, both cities must account for the emissions from personal vehicles. The car ownership rate in O'ahu is much higher than in Eilat as there are 1.1 registered passenger cars per eligible driver compared to around 0.5 cars per resident in Eilat. In Honolulu, personal vehicles are responsible for 90% of transportation sector emissions (City & Council of Honolulu, 2021). To mitigate this, Honolulu is implementing electric rail and bus routes throughout the city. The city will route these modes of public transportation through areas of high commuter traffic to reduce the need for personal vehicle travel in those areas. In contrast, implementing a train transport system is not practical for Eilat given time limitations and Israeli's tendency to favor travel in personal vehicles. Both cities are implementing EV chargers to curb transportation emissions. Similar to this project, Honolulu is also implementing EV chargers to encourage EV use. There are now over 500 public EV chargers of various speeds throughout Honolulu (PlugShare, 2024b). This strategy of increasing access to public charging infrastructure succeeded. In 2020, there were 10,700 EVs registered in Hawaii. In 2023, that number grew to 29,239 (US Department of Energy, n.d.). 76% of these are registered on the island of O'ahu (Hawaii EV Association, n.d.). Therefore, installing additional public EV chargers can encourage EV use in a city.

Oslo, similar to both Honolulu and Eilat, is a city that is relying on its intricate EV charging network to support its climate neutrality goals. As part of a 2009 initiative set by Norway, Oslo decided to lower GHG emissions by 95% by the year 2030. In addition to an increase in green public transportation and banning cars in its city's center, a major goal was the mass installation of EV chargers along with incentives to purchase EVs. By 2011, the city had 400 EV chargers installed and they installed more than 300 more in 2014. To convince its citizens to purchase an EV, the city and Norway instated many benefits, such as an exemption from congestion charges and allowing EVs to use bus lanes. This plan saw great success. By 2014, more than 30% of new cars within Oslo were electric or plug-in hybrids. Already Oslo's emissions are 30% lower than in 2009. And as a whole, in 2022 the nation of Norway saw that 79% of new cars being sold were electric. This success resulted in some benefits such as an increase in air quality, as well as Oslo being labeled as "Europe's best electric car city" during an international EV conference (Glasco, n.d.). As Eilat introduces more electric vehicles on its roads, instating the methods used in developing a strong EV charging network such as the one in Oslo, Norway will be vital to the success of this mission.

2.2: Calculating Eilat's Transportation Emissions

Calculations of Eilat's transportation emissions should be performed to quantify the impact that this initiative will have on Eilat's GHG emissions. These calculations will serve as a baseline for the city's emissions and can be repeated following implementation to quantify the outcomes of these changes.

2.2.1: Greenhouse Gases

Greenhouse gases are gases that trap heat within the Earth's atmosphere (Overview of Greenhouse Gases | US EPA, 2015). When heat cannot be released from the atmosphere it causes global temperatures to rise, leading to devastating outcomes across the planet. There are five primary types of greenhouse gases: carbon dioxide, methane, nitrous oxide, fluorinated gases, and water vapor. Water vapor, while the most abundant GHG, is omitted from most emission inventory calculations because scientists generally agree that human contribution to the Earth's water vapor is negligible (*Greenhouse Gases - U.S. Energy Information Administration (EIA)*, 2024).

Carbon dioxide, or CO_2, is produced by burning biological materials such as fossil fuels. Some amount of carbon dioxide is important to keep the Earth warm enough to be habitable (*Climate Change: Atmospheric Carbon Dioxide*, 2023). CO2 is removed from the atmosphere via plant absorption in the biological carbon cycle.

Methane, or CH_4, is produced from energy sources such as coal, natural gas, and oil, as well as from the agriculture industry, especially livestock (*Overview of Greenhouse Gases | US EPA*, 2015). Methane is present in much lower quantities than other GHGs, but its presence is seen as particularly harmful because of the gas's especially powerful heat trapping abilities, as it accounts for 30% of current global temperature rise. Unlike other GHGs, methane has a relatively short atmospheric life of just twelve years (International Energy Agency, 2022).

Nitrous oxide, N_2O, is produced via agriculture, fuel combustion, and wastewater management, amongst other sources. Nitrous oxide also appears naturally in the atmosphere via the nitrogen cycle, when bacteria break down nitrogen in soil and oceans. Nitrous oxide can be removed from the atmosphere via bacteria absorption, ultraviolet radiation, and chemical reactions (*Overview of Greenhouse Gases | US EPA*, 2015).

Fluorinated gases include hydrofluorocarbons, perfluorocarbons, sulfur hexafluoride, and nitrogen trifluoride and occur almost exclusively from human activities including aluminum production and semiconductor manufacturing. In the transportation sector, these gases are less prevalent compared to other GHGs. Fluorinated gases are the most potent GHG and have the longest atmospheric lifetime. These gases are often only removed from the atmosphere when they are exposed to sunlight in the upper atmosphere (*Overview of Greenhouse Gases | US EPA*, 2015).

2.2.2: Vehicle Technology

In 1991 “Euro 0” was released, indicating the start of a new era of European vehicle emission standards (Euro standards) (*Euro Standards*, 2014). There are two primary categories of Euro standards: those denoted by Arabic numerals, and those denoted by Roman numerals. The Arabic numeral standards, Euro 0 through Euro 6, are standards for light-duty vehicles such as cars and vans, whereas the Roman numeral standards, currently Euro I through Euro VI, are for heavy-duty vehicles such as trucks, buses, and coaches (Halleux, 2024). These emissions standards regulate land vehicles sold in the European Union, though nations associated with the European Union, such as Israel, also follow these vehicle emission standards. These standards have led to investments and innovations in the automobile industry to reduce and eliminate vehicle-related air pollutants, providing both environmental and economic benefits (*Euro Standards*, 2014).

2.2.3: Previous Calculations

In 2021, a Worcester Polytechnic Institute Interactive Qualifying Project (IQP) project evaluating the emissions for all of Eilat was completed. For the transportation sector, this project ran three different calculation scenarios. The first method utilized the Baseline Emissions Inventory method from the 15th Forum of the Intergovernmental Panel on Climate Change. Some vehicle types in Eilat were outside the scope of this method. This method concluded that in 2019 Eilat’s transportation sector produced 106,311 tons of CO_2. Both the second and third scenarios used the EEA’s annual fuel consumption method. The second scenario uses annual vehicle distances published by the Israeli Central Bureau of Statistics (CBS), while the third scenario utilizes estimations of annual vehicle distance for trucks and buses as these vehicles' annual distances are largely traveled outside of the city. The second scenario found Eilat’s transportation sector to produce 78,469 tonnes of CO_2 while the third scenario found 72,936 tonnes of CO_2 (Schwartz et al., 2021).

2.2.4: EEA Road Transportation Emissions Methodology

The European Environment Agency (EEA) has published a method for entities (cities, regions, countries, etc.) to inventory their transportation emissions which utilizes the annual fuel consumption of vehicles. This method has three tiers of increasing specificity to calculate transportation emissions. The EEA included a flowchart (Appendix A) in the calculation method to guide users in selecting a calculation method (Ntziachristos & Samaras, 2023).

Vehicle categories are passenger cars, light commercial vehicles (LCV), heavy-duty trucks, buses, and L-category vehicles. Light commercial vehicles are defined as weighing less than 3.5 tons, while heavy-duty trucks are defined as weighing more than 3.5 tons. L-category vehicles include motorcycles, mopeds, mini cars, and all-terrain vehicles. Fuel types are petrol, diesel, liquefied petroleum gas (LPG), and compressed natural gas (CNG). This method utilizes vehicle technology (Euro standards) to classify the emissions standards which vehicles were sold under. Vehicle subcategory is also included. Each subcategory specifies additional information about vehicle categories such as powertrain specifics, vehicle weight or engine size, and classifying vehicles as small, medium, or large.

2.2.4.1: Tier One: vehicle and fuel type

Tier One calculations are based on annual mileage, with respect to vehicle and fuel type. Tier One calculations are the simplest and most general calculations included in the EEA methodology. For Tier One calculations heavy-duty trucks and buses are grouped as heavy-duty vehicles (HDV). Tier One calculations require annual vehicle mileage by vehicle and fuel type. A set of coefficients is provided for typical fuel consumption (in g/km) by vehicle category and fuel type. For each pollutant, an emission factor (EF) is given (in g/kg fuel or kg/g fuel) by vehicle category and fuel type.

2.2.4.2: Tier Two: vehicle type, technology, and fuel type

Tier Two calculations are based on annual mileage, with respect to vehicle type, fuel type, and vehicle technology. The Tier Two calculation method adds another layer of specificity to the emissions calculations in Tier One, while still following very similar methods. Tier Two calculations require annual vehicle mileage by vehicle category, vehicle subcategory, and vehicle technology. The coefficients for fuel consumption are given by vehicle category, vehicle subcategory, and vehicle technology, while the pollutant emissions coefficients are given by vehicle type and vehicle technology. The calculation methodology for carbon dioxide from fossil fuels in Tier Two is identical to that of Tier One, the only difference being that the coefficients used in Tier Two are specific to vehicle technology, rather than just vehicle type and fuel type. This specificity accounts for stricter emissions standards forcing manufacturers to produce vehicles that produce less pollutants.

2.2.4.3: Tier Three: vehicle type, technology, fuel type, and drive type

Tier Three calculations are based on mileage driven by type of driving, engine temperature, vehicle type and technology, and fuel type. Tier Three calculations require the most exhaustive data, but also provide the most accurate emissions calculations. Many of the coefficients utilized in Tier One and Tier Two were derived from Tier Three calculations alongside some generalizations. Tier Three calculations are done for both cold engines and hot engines (referred to simply as “hot” or “cold”), with differing methods for each, as vehicles emit pollutants in varying quantities based on if the engine has warmed up or not. Additionally, Tier Three calculations are based on the type of driving (urban, rural, or highway) and in what quantities each is performed. Finally, Tier Three calculations include methods for emissions corrections based on the age and the cumulative mileage of the vehicle.

Within Tier Three, GHG calculations are unique from the other tiers and one another. CO2 emissions from fuel combustion and oil lubricant consumption rely upon the chemical makeup of carbon, hydrogen, and oxygen in the fuel and the volume of fuel or oil consumed. N2O emissions are based on vehicle category, fuel type, and vehicle technology. CH4 calculations require vehicle type, fuel type, vehicle technology, and drive type (hot or cold, urban, rural, or highway).

Chapter 3: Methods

3.1: Calculating Eilat's Current Transportation Emissions

The Eilat Municipality provided our team with a spreadsheet containing vehicle type, fuel type, vehicle category, vehicle size, vehicle technology, and the proportion of that vehicle for all of Israel (Appendix 1). We acquired data outlining the amount of each vehicle type in Eilat from the CBS, alongside the annual mileage per vehicle for all of Israel, and the annual mileage for private cars in Eilat. The CBS published Eilat's vehicle counts and Israel's annual vehicle mileage by private vehicles, light trucks, trucks, minibuses, buses, taxis, motorcycles, and special vehicles (Table 1).

Table 1

Vehicle Statistics for Eilat from 2022

Type of Vehicle	# of Vehicles	Average Mileage (km)
Private Vehicle	19,345	13,300
Light Truck	1,064	27,700
Truck	633	27,700
Minibus	37	49,400
Bus	50	56,400
Taxi	551	67,700
Motorcycle	1,691	7,500
Special Vehicles	34	18,100

Note. The data for # of Vehicles is from *Regional Statistics* by Israel Central Bureau of Statistics, 2023, (https://www.cbs.gov.il/EN/settlements/Pages/default.aspx?mode=Yeshuv). Copyright 2023 by Israel Central Bureau of Statistics. The data for Average Mileage (excluding private vehicles) is from *Kilometers Traveled 2022* (t01) by Israel Central Bureau of Statistics, 2023, (https://www.cbs.gov.il/en/publications/Pages/2024/Vehicle-Kilometers-Travelled-2022.aspx). Copyright 2023 by Israel Central Bureau of Statistics. The data for Annual Mileage (private vehicles) is from *Kilometers Traveled 2022* (t09) by Israel Central Bureau of Statistics, 2023, (https://www.cbs.gov.il/en/publications/Pages/2024/Vehicle-Kilometers-Travelled-2022.aspx).

Light trucks are defined as weighing less than 3.5 tonnes and heavy trucks as more than 3.5 tonnes. Minibuses weigh less than five tons and can carry up to twenty passengers, while buses carry more than nine passengers. Special vehicles are vehicles for special services such as ambulances, rescue vehicles, and fire brigade vehicles. The vehicle data from the Eilat municipality did not explicitly include taxis or special vehicles, so we aggregated taxis with private cars and light trucks with special vehicles.

We performed a weighted average on each aggregation to find the average annual mileage of private cars/taxis (hereon referred to as Passenger Cars (PC)) and of light trucks/special vehicles. We multiplied the vehicle counts for Eilat (Table 1) with the vehicle proportions for Israel (Appendix B) to estimate the number of vehicles by fuel type and vehicle technology in Eilat (Appendix B). This was done under the assumption that the vehicle proportions in Eilat are the same as that of Israel.

In order to account for tourism, we averaged Eilat's annual tourism rate (3,000,000 tourists per year) to a daily tourist rate (8,219 daily tourists) and assumed four tourists per vehicle (2055 vehicles) to determine how many vehicles from tourism were in Eilat daily. This number was added to Eilat's private vehicle/taxi data to account for vehicles in Eilat due to tourism.

We implemented the European Environment Agency's Annual Fuel Consumption method to calculate Eilat's transportation emissions. Following the EEA's flowchart (Appendix A), we selected Tier Two calculations because mean traveling speed is not available, but vehicle distance by vehicle technology is. Tier One calculations were also performed for redundancy, and a modified version of Tier Three calculations was conducted to calculate methane emissions.

The following variables are used throughout all calculation tiers:

N = number of vehicles
M = average annual mileage
FC = Fuel consumption coefficient
EF = Emission factor

These variables will contain some or all of the following subscripts corresponding to the specificity of each variable:

i = pollutant
j = vehicle category
m = fuel type
k = vehicle technology (Euro emission standard)

M_j is the average annual mileage for vehicles in category j and $N_{j,m,k}$ is the number of vehicles in category j, using fuel type m, and vehicle technology (emission standard) k.

The EEA uses the following vehicle categories: passenger cars, light commercial vehicles, heavy duty vehicles, buses, and L-category vehicles. Passenger cars consisted of the private car/taxi aggregation; light commercial vehicles consisted of light trucks/special vehicle aggregation and minibuses; heavy duty vehicles consisted of heavy trucks.

All calculation tiers contain various coefficients corresponding to some or all of the following factors: vehicle type, fuel type, and vehicle technology. Wherever a coefficient was unavailable, a suitable coefficient was extrapolated based off of ratios between another vehicle type for the corresponding fuel type. For example, if passenger cars had a coefficient of 100 for petrol, and 200 for LPG, and LCVs had a coefficient of 150 for petrol but no existing LPG coefficient, the ratio of petrol*2 was used to extrapolate an LCV LPG coefficient of 300. These extrapolations are explicitly mentioned in each coeffient's table in the Appendix.

For each tier, we converted nitrous oxide and methane (when applicable) to CO_2 equivalents to account for the differences in the climate impact of different GHGs. Nitrous oxide and methane totals were multiplied by 298 and 84, respectively, to find their CO_2 equivalents (*CO2 Equivalents | Climate Change Connection*, 2014). These values were then added together to find the total emissions in CO_2 equivalence (CO_2 eq).

3.1.1: Tier One: Vehicle and Fuel Type

Tier One calculations include passenger cars, light commercial vehicles, heavy-duty vehicles, and L-category. We treated buses as heavy duty vehicles because Tier One does not specifically have a bus category.

For each vehicle grouping and fuel type, the annual mileage was multiplied by the amount of vehicles, fuel consumption coefficient, and pollutant coefficient. This was done for each category, fuel type, and pollutant. The emissions are summed for all fuel types and vehicle categories to produce the emissions total for one pollutant. This procedure was repeated for each pollutant. The process is shown in Equation 1:

Tier One Pollutant Calculation Equation

$$E_i = \Sigma_j(\Sigma_m(N_{j,m} * M_j * FC_{j,m} * EF_{i,j,m})) \quad \textbf{(1)}$$

Where,

E_i = total emissions of pollutant *i*

$N_{j,m}$ = number of vehicles of category *j* and fuel type *m* (given in Appendix B)

M_j = average annual mileage for vehicles in category *j* (given in Table 1)

$FC_{j,m}$ = fuel consumption coefficient for vehicles in category *j* and fuel type *m* (given in Appendix C)

$EF_{i,j,m}$ = emission factor for pollutant *i* for vehicles in category *j* and fuel type *m* (given in Appendix C)

3.1.2: Tier Two: Vehicle Type, Technology, and Fuel Type

Tier Two calculations, although similar in structure to Tier One calculations, account for differences in legislation that have caused vehicle technology to adhere to stricter emissions standards by utilizing fuel consumption coefficients specific to vehicle technology. Equation 2, which contains the calculation of carbon dioxide emissions from fossil fuels, demonstrates this:

Tier Two CO_2 From Fossil Fuels Calculation Equation

$$E = \Sigma_j(\Sigma_m(\Sigma_k(N_{j,k,m} * M_j * FC_{j,k,m} * EF_m))) \qquad \textbf{(2)}$$

Where,

E = total emissions of CO_2 from fossil fuels
$N_{j,k,m}$ = number of vehicles of category *j*, with technology *k*, and fuel type *m* (Appendix B)
M_j = average annual mileage for vehicles in category *j* (Table 1)
$FC_{j,k,m}$ = fuel consumption coefficient for vehicles in category *j*, with technology *k*, and fuel type *m* (given in Appendix D)
EF_m = emission factor for CO_2 for fuel type *m* (same as Tier One, Appendix C)

Since mileage by vehicle type and technology was unavailable, mileage values by vehicle type were assumed to be the same for all vehicle technologies (Table 1). Nitrous oxide and carbon dioxide from oil lubricants are found by multiplying an emission factor (Appendix D) by the annual mileage of vehicles of the corresponding category, technology, and fuel type, shown in Equation 3:

Tier Two Pollutant Equation

$$E_i = EF_{i,j,k,m} \times N_{j,k,m} \times M_j \qquad \textbf{(3)}$$

Where,

E_i = total emissions of pollutant *i*
$EF_{i,j,k,m}$ = emission coefficient for pollutant *i* for vehicles in category *j*, with technology *k*, and fuel type *m* (given in Appendix E)
$N_{j,k,m}$ = number of vehicles of category *j*, with technology *k*, and fuel type *m* (Appendix B)
M_j = average annual mileage for vehicles in category *j* (Table 1)

3.1.3: Tier Three: Vehicle Type, Technology, Fuel Type, and Drive Type

Tier Three calculations traditionally account for hot and cold driving, as well as driving in an urban, rural, or highway setting. Since this data is unavailable for Eilat, Tier Three calculations assumed all driving to be in hot, urban conditions. Carbon dioxide emissions from fossil fuels were calculated using Equation 4:

Tier Three Carbon Dioxide Emissions Equation

$$E_{CO2} = 44.011 \times \frac{N_{j,k,m} * M_j * FC_{j,k,m}}{12.011 + 1.008 r_{H:C,m} + 16.000 r_{O:C,m}} \quad \textbf{(4)}$$

Where,

E_{CO2} = total emissions of CO_2

$N_{j,k,m}$ = number of vehicles of category *j*, with technology *k*, and fuel type *m* (given in Appendix B)

M_j = average annual mileage for vehicles in category *j* (Table 1)

$FC_{j,k,m}$ = fuel consumption coefficient for vehicles in category *j*, with technology *k*, and fuel type *m* (same as Tier Two, Appendix D)

$r_{H:C,\,m}$ = ratio of hydrogen to carbon in fuel type *m* (Appendix F)

$r_{O:C,\,m}$ = ratio of hydrogen to carbon in fuel type *m* (Appendix F)

The EEA published values for $r_{H:C}$ and $r_{O:C}$; we assumed these ratios to be true for the fuel used by vehicles in Eilat, though fuel composition can vary significantly (Ntziachristos & Samaras, 2023, p.43).

We also used Equation 3 to calculate carbon dioxide emitted due to oil lubricant. The values for $r_{H:C}$ and $r_{O:C}$ for oil are 2.08 and 0, respectively. Unique *FC* values for these calculations were used (Appendix G). Vehicles with Euro 6 technology were treated as new, while all other vehicles were treated as old. This assumption was made based on the EEA's recommendation that vehicles with a lifetime mileage of less than 150,000 kilometers be treated as new.

Nitrous oxide emissions in Tier Three were calculated using Equation 2, where *EF* is calculated using Equation 5:

Tier Three Nitrous Oxide Emissions Factor Calculation Equation

$$EF_{N2O} = [a \times M_L + b] \times EF_{base} \quad \textbf{(5)}$$

Where,

EF_{N2O}= nitrous oxide emissions factor

a = coefficient (Appendix H)

M_L= vehicle lifetime mileage

b = coefficient (Appendix H)

EF_{base}= base emission factor (Appendix H)

The lifetime mileage, M_L, of the vehicles was not available, so per the recommendation of the EEA in the calculation method, lifetime mileage was predicted by multiplying the age of the vehicle by the vehicle's annual mileage. Exact vehicle ages were unavailable, so age was estimated using the median year that a vehicle's emission standard was the prevailing standard

(Appendix I). For example, Euro 2 entered effect in 2001 and was the prevailing standard until 2006 when Euro 3 took effect, so vehicles from Euro 2 were treated as cars from 2004. Vehicle age was as of 2022 in line with the data used in these calculations, so Euro 2 vehicles were treated as being 18 years old.

Methane emissions are only calculated in Tier Three. These emissions are calculated using Equation 6:

Methane Calculation Equation

$$E_{CH4} = EF_{j,k,m} \times M_j \times N_{j,k,m} \quad \textbf{(6)}$$

Where,

E_{CH4} = total emissions of methane

$EF_{j,k,m}$= fuel consumption coefficient for vehicles in category *j*, with technology *k*, and fuel type *m* (Appendix J)

M_j= average annual mileage for vehicles in category *j* (Table 1)

$N_{j,k,m}$= number of vehicles of category *j*, with technology *k*, and fuel type *m* (Appendix B)

Methane emissions are based on an emissions factor (Appendix J), the number of vehicles for a specific vehicle category and fuel type (Appendix B), and the annual mileage for those vehicles (Table 1).

3.1.4: Emission Projections

The current and future number of vehicles registered in Eilat were evaluated to gauge the potential number of EVs on Eilat's roads in 2030. Linear extrapolation with smoothing methods was used based on the motor vehicle registration data, by city, from 2015-2022 to predict vehicles registered in Eilat by type. This data also included population data, which was forecast alongside vehicle registration. The rate of population growth and vehicle ownership were compared to current data about the city to assess uncertainty. According to the municipality, the average rate of population growth for the city of Eilat is between 0.8%-1.1%, and the vehicle-to-resident ratio is about 1:2. 2022 was the first year that the CBS published data about electric vehicle ownership in cities. The growth of EV usage was calculated by predicting that 30% of vehicles will be electric in 2030, based on reports by the Israeli Ministry of Energy for the entire country (Rabinovitch, 2023).

We predicted the GHG emissions in Eilat in 2030 by updating the 2022 vehicle data to utilize the projected quantities of each vehicle type. These predictions assume that annual mileage by vehicle type is equivalent to 2022. We determined these emissions in different scenarios of electric vehicle usage in Eilat. Projections were run by reducing the GHG emissions from each vehicle type by the proportion of those vehicles that are electric in each scenario. The scenarios are listed below:

1. No change in EV usage

2. 30% of private vehicles/taxis are EVs
3. 40% of private vehicles/taxis are EVs
4. 50% of private vehicles/taxis are EVs
5. 75% of private vehicles/taxis are EVs
6. 100% of private vehicles/taxis are EVs

3.2: Evaluating Current EV Infrastructure

We gathered information from sources such as Google Maps and Cello Charge, a web application that provides EV users with information about public chargers, that compiled publicly available crowd-sourced data about Eilat's EV charging network. These sources provided information about sites run by a range of companies. The Eilat municipality provided more detailed information regarding certain charging sites run by Greenspot, a company that installs, manages, and maintains public charging sites. This data included details regarding when and for how long the chargers were used between February 2nd and December 31st, 2023. Our sponsors also physically visited and documented various charging sites that were omitted by other sources. The collected data included location, company, wattage, speed, quantity (the number of plugs available at a charging site), and use frequency (uses per year) of existing chargers in Eilat.

Nodes placed on a map created using the Custom Maps feature on Google Maps helped visualize the location data of each charging site. We employed a spreadsheet to record the remaining pieces of data for each charger. We analyzed this data to identify certain trends: which areas of the city had the highest concentration of charging sites and which areas lacked them, where chargers of certain speeds were placed and what the most commonly used charging port types are, and when in a 24-hour period the chargers were used most frequently. The team used the map and location information to evaluate charger placement. Also, we analyzed the Greenspot charger data to understand peak times of use. The starting times of each logged charger use were grouped into 30-minute intervals from 00:00 (midnight) to 23:30. For example, if a charge was initiated at 10:42, it would be placed into the 10:30 group.

3.3: Charging Network Expansion

3.3.1: Assessment of Parking in Eilat

We examined all areas of the city for parking lots that could serve as locations of EV charging sites to diversify the placement and service the most users. Eilat was divided into 21 districts and neighborhoods; these neighborhoods were plotted using the Custom Maps feature of Google Maps. Using maps and information on the geographical information system (GIS) provided by the municipality, parking lots were identified by their geographic position, size, and neighborhood, and then plotted on Google Maps. We defined a parking lot as having four or more parking spaces for cars parked parallel to each other, rather than bumper-to-bumper. Each lot was classified as small (less than 25 parking spaces), medium (25-50 parking spaces), or large (more than 50 parking spaces). Each parking lot was then assigned a weight according to its size, with small lots receiving a weight of one, medium lots two, and large lots three. Parking lots were eliminated from consideration if they were deemed infeasible for EV chargers. For example, if there was no access to substations or light stations, if the parking lot was not publically accessible, or if the lot was not located near significant destinations, such as shops, schools, residential, or government buildings.

The simple median modeling method was used to optimize the placement of EV chargers (Maxus Knowledge, 2014). This method considered the size and location of all parking lots in a neighborhood to find the weighted center. This served a preliminary purpose of identifying the proximity of parking lots from each other with considerations of their size. The coordinate of a median location between all parking lots in each neighborhood was determined using Equation 7:

Median Coordinate Calculation Equations

$$\begin{aligned} W_t &= \Sigma W_n \\ x_t &= \Sigma x_n \\ y_t &= \Sigma y_n \\ \underline{x} &= x_t / W_t \\ \underline{y} &= y_t / W_t \end{aligned} \tag{7}$$

Where:

W_t = total weight of a neighborhood
W_n = weight of lot n
x_n = x-coordinate of lot n
y_n = y-coordinate of lot n
x_t = sum of x-coordinates
y_t = sum of y-coordinates
$\underline{x}$ = median x-coordinate
$\underline{y}$ = median y-coordinate

Using the median points as a guide, new EV charging sites were chosen manually, while also considering size and location. Medium or large lots located nearest to the median points were initially chosen since they theoretically service the most people in that neighborhood. Some charging sites were determined through the destination popularity of daytime charging locations. Locations of interest included shopping centers, education centers, municipality buildings, entertainment and sports centers, and outdoor recreation spaces. These chargers can service both residents and tourists of Eilat. Other sites were placed at overnight parking. These sites were parking areas used by a variety of housing buildings, providing charging for Eilat residents.

Market analysis of the current state of EVs in Israel was conducted using Statista. Statista contained a chart showing the EV distribution in Israel. From it, we determined the type of charger needed to accommodate the majority of EVs in Israel.

We derived a recommendation of the number of chargers to place from a framework used by the city of Chicago for the number of parking spaces in each lot to dedicate to EV charging. Chicago is about 50 times larger than Eilat and is a part of the US Department of Energy's Clean Cities Coalition Network (Clean Cities Coalition Network, n.d.). This has allowed the city to be a national leader in public guidance for the placement of EV chargers at private businesses and homes (Illinois Alliance for Clean Transportation, n.d.). The city guides newly built multi-family residential and commercial parking lots to designate 20% of parking spaces to housing EV chargers (Mayor's Press Office, City of Chicago, 2020). Of the designated charging spots, Chicago allocated roughly 10% for fast chargers in the commercial sectors (Carlton and Sultana, 2022). These specific guidelines for parking lots were coupled with the need for 1.2 kW of public charging per EV, which is the average capacity of public EV chargers in European cities, as published by the EU (International Energy Agency, 2023). We used this number since Eilat is participating in the Cities Mission as part of Horizons Europe. For our calculations, medium chargers have a capacity of 22kW, fast chargers 50kW, and ultra-fast chargers 350kW. We found the number of parking spaces per lot that need EV chargers by counting the individual parking spaces in selected parking lots and designating one-fifth of the spots to EV chargers, with one-tenth of those spots reserved for fast chargers if the location was deemed commercial. Gas stations were a special circumstance since all chargers at these locations were designated as ultra-fast chargers.

3.3.2: Deployment of EV Chargers

We developed a four-stage deployment plan for the installation of EV chargers based on the assumed ease of construction of infrastructure and adaption to user needs. The first stage prioritized the urgency of EV charging needs by placing chargers at gas stations. These are largely accessible areas for both tourists and residents. The second stage also focused on accessibility to chargers but emphasized mixed-use areas. This stage recommended placing chargers at places that provided not only goods and services but also employment. The diversity of motivations for visiting these areas determines the time spent at these locations, and therefore the charger type for these locations integrated these differences. The majority of chargers in this stage were placed at shopping centers. The third stage prioritized places with uniform attendance, either due to employment or known behaviors at these locations. This includes office buildings, schools, municipal buildings, and areas of recreation. These locations featured consistent types of chargers. Finally, stage four represented nighttime charger usage, and recommended that chargers be placed near places of residency, in public areas. Again, due to user behavior, the charger type was consistent here.

Between each stage, we recommended a formal evaluation of the usage of EV chargers be conducted to assess the effectiveness of each stage. These evaluations will inform the municipality if it should continue the expansion as planned or if the next step should be modified.

We calculated the number of vehicles that the charging infrastructure could support, and their associated proportion of total vehicles in Eilat in 2030. . It was ensured that with the fulfillment of all four stages, all registered vehicles in Eilat would be supported by public EV charging.

3.4: Map Display

We used matplotlib.pyplot in Python to plot charger site information. Our points were first exported from the map where we extracted their coordinates into an Excel sheet. The sheets were then saved as .csv files and used as input into the plotting program. Pandas' DataFrames was used to help manage the .csv files. Further details about the code can be found on GitHub in Appendix K.

3.5: Cost of Implementation Estimations

The installation costs for Israel are not readily available. We used minimum and maximum installation costs for EV chargers in the United States in 2019 to assist in installation cost estimations (Table 2) (Nelder and Rogers, 2019).

Table 2

EV Charger Installation Costs in the United States

Capacity (kW)	Cost of Installation (USD)
7.7	2,500
16.8	4,900
50	20,000-35,800
350	128,000-150,000

Our sponsor provided us with a receipt for the installation of 22 kW chargers in Eilat, including the number of chargers and tasks as well as the unit price, as shown in Appendix L.

In order to estimate the installation costs of chargers in Eilat, we treated the 16.8 kW and 7.7 kW chargers as 22 kW and 11 kW chargers, respectively. Using these prices (Table 2), we found the proportional differences in cost between the 16.8 kW charger and the 7.7 kW, 50 kW, and 350 kW chargers. Using these proportions, we found the cost of the 50 kW and 350 kW chargers since we were unable to find an up-to-date source on Israeli installation costs for these chargers.

The proximity of each EV charger to municipal light stations was calculated because this distance impacts installation costs. We did this by calculating the distance using the Haversine formula (Equation 8), which calculates the distance between two points on a curve (*Program for Distance between Two Points on Earth*, 2017).

Haversine Formula

$$acos(sin(lat1) * sin(lat2) + cos(lat1) * cos(lat2) * cos(lon2 - lon1)) * 6371 \quad \textbf{(8)}$$

Where,

lat1 = latitudinal coordinate value of the first point
lon1 = longitudinal coordinate value of the first point
lat2 = latitudinal coordinate value of the second point
lon2 = longitudinal coordinate value the second point
6371 = length of Earth's radius in km

3.6: Cost on User

To pay for the installation, maintenance, and electricity used by the chargers, the cost of services will be apportioned to users in the form of tariffs. Tariffs are costs levied on the user for EV charger usage, which will operate to compensate the investment made by the municipality. Possible tariff implementation plans considered were volume energy charges, demand charges, and combinations of these models. To determine the most suitable tariff system, the objectives and attributes of the system for the city were compiled, based on the municipality's motivation. Due to resource restraints, calculations for user tariffs could not be completed, but recommendations about how to calculate them were made.

Chapter 4: Results

4.1: Calculating Eilat's Current Emissions

4.1.1: Tier One Emissions: Vehicle and Fuel Type

Tier One calculations yielded emissions totals for vehicles in Eilat in 2022 for CO_2 from fossil fuels, CO_2 from lubricant, and N_2O. Fossil fuels emitted 95,460 tonnes of carbon dioxide, while lubricant emitted 249 tonnes of carbon dioxide. 4.8 tonnes of nitrous oxide were emitted, which is equivalent to 1,440 tonnes of carbon dioxide. This resulted in a Tier One total of 97,150 tonnes of carbon dioxide equivalents released from Eilat's transportation sector in 2022 (Table 3).

Table 3

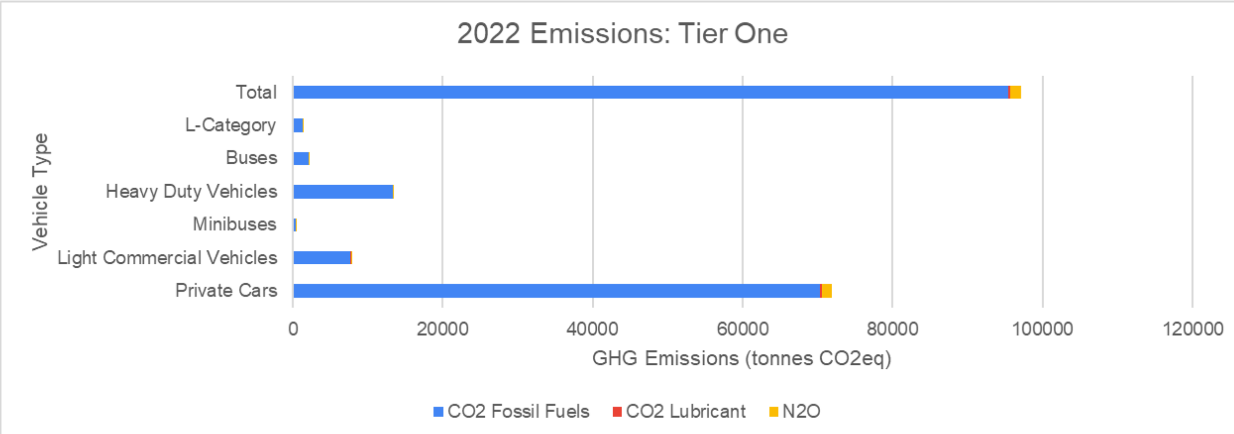
Tier One Emissions Calculations

Vehicle Type	CO_2 Fossil Fuels	CO_2 Lubricant	N_2O	Total (tonnes CO_2eq)	% of Total
Private Cars	70,350	200	1,300	71,850	74
Light Commercial Vehicles	7,740	20	50	7,800	8
Minibuses	460	0	0	470	0.5
Heavy Duty Vehicles	13,350	10	60	13,420	13.8
Buses	2,180	0	10	2,190	2.3
L-Category	1,390	20	10	1,420	1.5
Total	95,460	250	1,440	97,150	100

The most significant portion of emissions in Tier One resulted from private cars (74%), followed by heavy duty vehicles (13.8%), and then light commercial vehicles (8%). This is illustrated in Figure 3.

Figure 3

2022 Tier One Emissions by Vehicle Type



4.1.2: Tier Two Emissions: Vehicle Type, Technology, and Fuel Type

Tier Two GHG calculations included CO_2 from fossil fuels, CO_2 from oil lubricant, and N_2O. These calculations determined that in 2022, vehicles in Eilat emitted 83,680 tonnes of CO_2 from fossil fuels and 163 tonnes of CO_2 from oil lubricant. Vehicles produced 1.08 tonnes of N_2O, which is equivalent to 322 tonnes of CO_2 equivalent. This resulted in a total of 84,170 tonnes of CO_2 equivalents produced by vehicles in Eilat in 2022 (Table 4).

Table 4

Tier Two Emissions Calculations

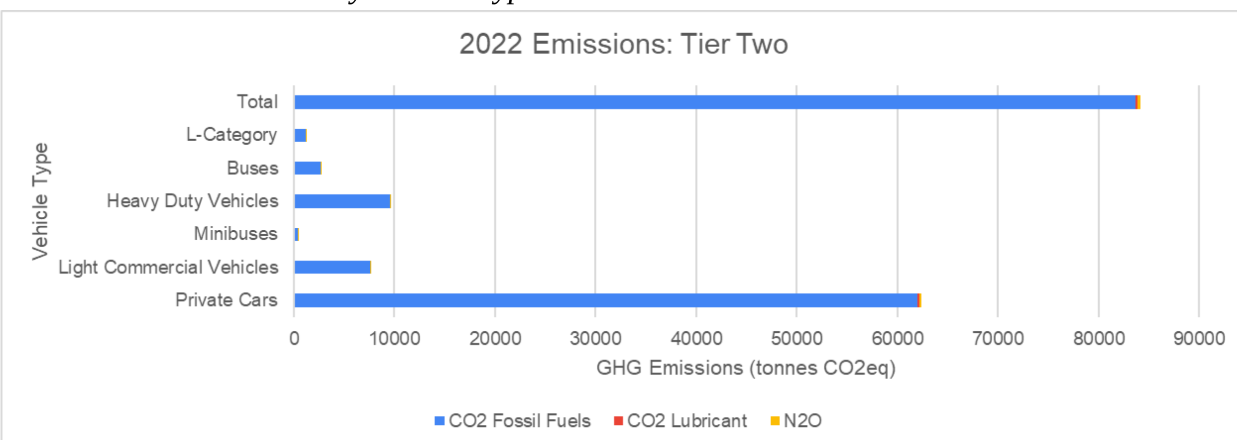
Vehicle Type	CO_2 Fossil Fuels	CO_2 Lubricant	N_2O	Total (tonnes CO_2eq)	% of Total
Private Cars	62,050	130	170	62,350	74.1
Light Commercial Vehicles	7,610	10	50	7,680	9.1
Minibuses	460	0	0	470	0.6
Heavy Duty Vehicles	9,580	10	50	9,650	11.5
Buses	2,730	0	30	2,760	3.3

L-Category	1,250	10	10	1,260	1.5
Total	83,680	160	320	84,170	100

The most significant contributor to Eilat's GHG emissions from transportation in Tier Two is private cars (74.1%) followed by heavy duty vehicles (11.5%) and light commercial vehicles (9.1%). This is illustrated in Figure 4.

Figure 4

2022 Tier Two Emissions by Vehicle Type



4.1.3: Tier Three Emissions: Vehicle Type, Technology, Fuel Type, and Drive Type

Tier Three calculations encompassed CO_2 from fossil fuels, CO_2 from oil lubricant, N_2O, and CH_4. These calculations generated a total of 82,470 tonnes of CO_2 from fossil fuels and 165 tonnes of CO_2 from oil lubricant. Vehicles in Eilat produced 1.75 tonnes of N_2O and 6.16 tonnes of methane, the equivalent of 523 and 517 tonnes of CO_2 equivalent, respectively. This results in a total of 83,680 tonnes of CO_2 equivalents (Table 5).

Table 5

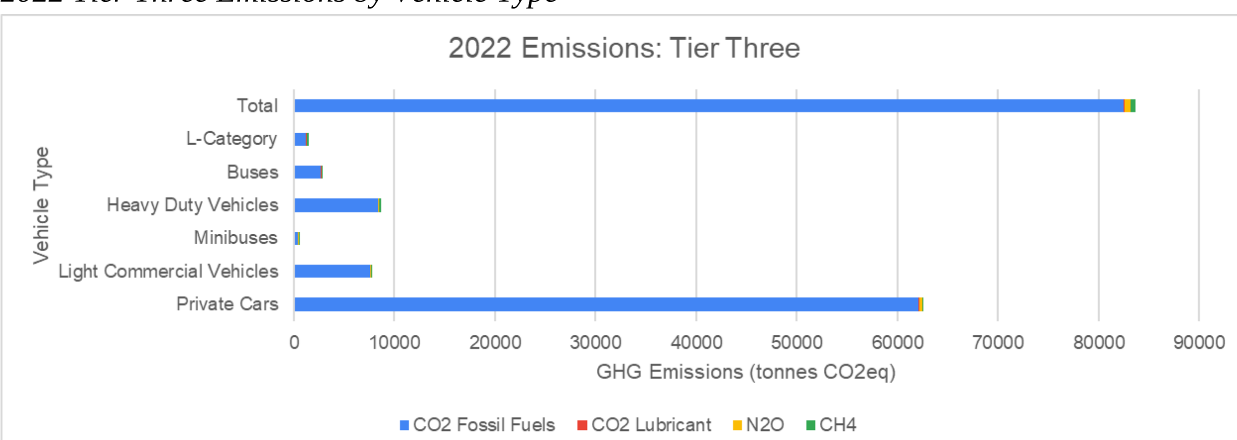
Tier Three Emissions Calculations

Vehicle Type	CO_2 Fossil Fuels	CO_2 Lubricant	N_2O	CH_4	Total (tonnes CO_2eq)	% of Total
Private Cars	62,060	130	280	100	62,570	74.8
Light Commercial Vehicles	7,610	10	80	10	7,720	9.2
Minibuses	460	0	10	0	470	0.6
Heavy Duty Vehicles	8,370	10	110	170	8,660	10.4
Buses	2,730	0	30	40	2,800	3.3
L-Category	1,250	10	10	190	1,460	1.7
Total	82,470	170	520	520	83,680	-

In Tier Three, the most substantial contributor to Eilat's Transportation GHG emissions is private cars (74.8%), followed by heavy duty vehicles (10.4%) and light commercial vehicles (9.2%). This is illustrated is Figure 5.

Figure 5

2022 Tier Three Emissions by Vehicle Type

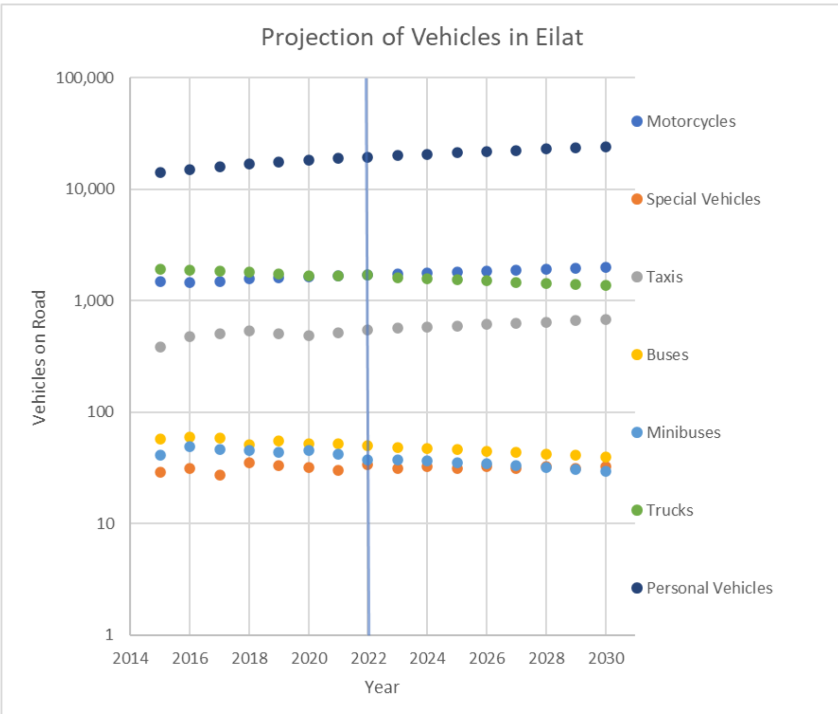


4.1.4: Electric Vehicle Usage and Emissions Projection

Trends from 2015-2022 predict that motor vehicle registry across almost all types of vehicles excluding trucks, buses, and minibuses in Eilat will increase in the coming years, as shown in Figure 6. Personal vehicles, represented by the dark blue dots, will increase most significantly, from 19,345 in 2022 to 24,056 in 2030.

Figure 6

Projection of Motor Vehicles Registered in Eilat, by Type

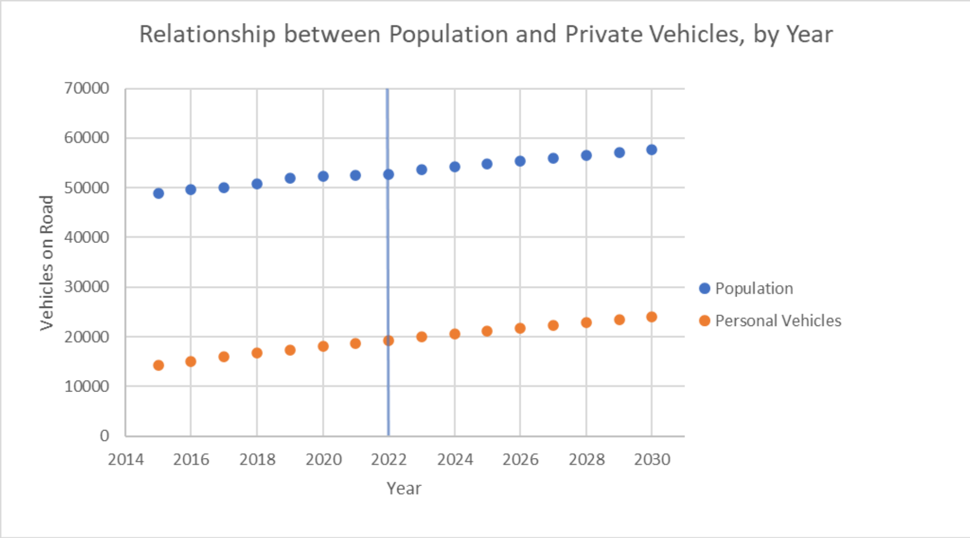


Note. The data for 2015, 2016, 2017, 2018, 2019, 2020, 2021, 2022 are from *MOTOR VEHICLES REGISTERED IN CITIES, BY TYPE OF VEHICLE*, by Israel Central Bureau of Statistics, 2015, 2016, 2017, 2018, 2019, 2020, 2021, 2022. Copyright 2015, 2016, 2017, 2018, 2019, 2020, 2021, 2022 by Israel Central Bureau of Statistics.

The number of personal vehicles in Eilat is expected to increase proportionally with the population. In 2030, the population is projected to be 57,613 in 2030 from 52,753 in 2022, as shown in Figure 7. The average number of personal vehicles per resident from 2015-2022 was 0.33 and is projected to be 0.39 from 2022-2030.

Figure 7

Relationship Between Population and Private Vehicles, by Year



Note. The data for 2015, 2016, 2017, 2018, 2019, 2020, 2021, 2022 are from *MOTOR VEHICLES REGISTERED IN CITIES, BY TYPE OF VEHICLE*, by Israel Central Bureau of Statistics, 2015, 2016, 2017, 2018, 2019, 2020, 2021, 2022. Copyright 2015, 2016, 2017, 2018, 2019, 2020, 2021, 2022 by Israel Central Bureau of Statistics.

In 2022, there were 114 private electric vehicles registered in Eilat. This only makes up 0.5% of personal vehicles in Eilat. This number is expected to increase by 2030 based on user uptake. Note that the Ministry of Energy expects that 30% of vehicles on Israeli roads will be electric in 2030.

Emissions projections were performed utilizing the projected passenger vehicle numbers for Eilat in 2030. Each scenario was predicted in each of the three tiers. Should 30% of passenger cars in 2030 be electric, emissions are projected to be 87,390, 74,910, and 74,210 tonnes CO_2eq for Tier One, Tier Two, and Tier Three, respectively. If Eilat can achieve 100% passenger cars as electric vehicles, transportation emissions are projected to be 26,020, 21,650, and 20,760 tonnes CO_2eq for Tier One, Tier Two, and Tier Three, respectively (Table 6).

Table 6

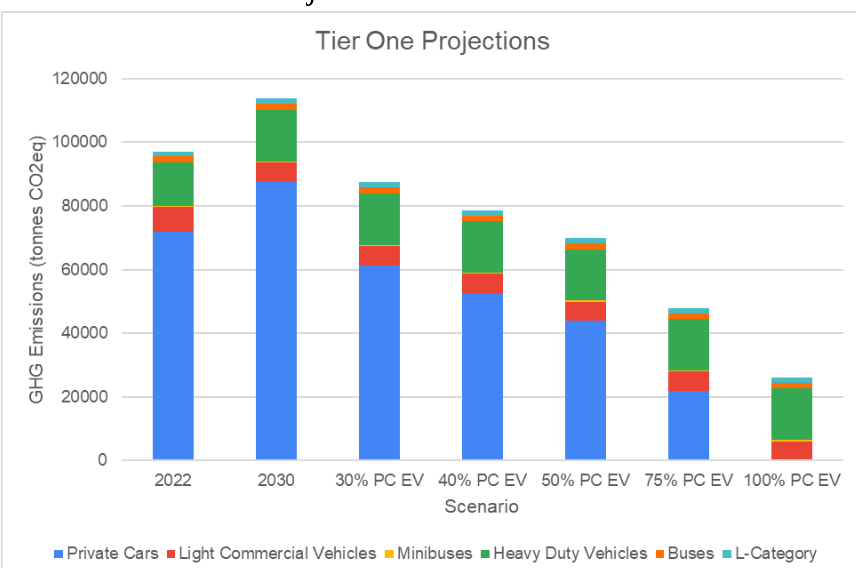
Eilat's GHG Emissions Projections (tonnes of CO_2 equivalents)

Calculation Method	2022	2030	30% PC EV	40% PC EV	50% PC EV	75% PC EV	100% PC EV
Tier One	97,150	113,700	87,390	78,630	69,860	47,940	26,020
Tier Two	84,170	97,740	74,910	67,300	59,700	40,670	21,650
Tier Three	83,680	97,120	74,210	66,580	58,940	39,850	20,760

Tier One projections found that if there is no EV adoption in Eilat, 2030 is projected to have higher emissions than 2022, but if 30% of passenger vehicles are electric, emissions are projected to be less than in 2022 (Figure 8).

Figure 8

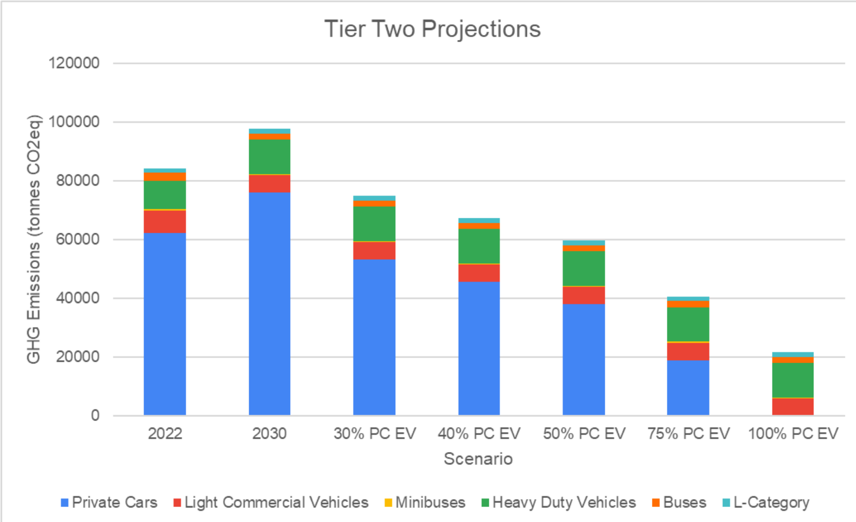
Tier One Emissions Projections



Tier Two projections found that if there is no adoption of EVs in Eilat, transportation GHG emissions in 2030 are projected to be higher than 2022, but should 30% of passenger vehicles be electric, emissions are projected to be less than in 2022 (Figure 9).

Figure 9

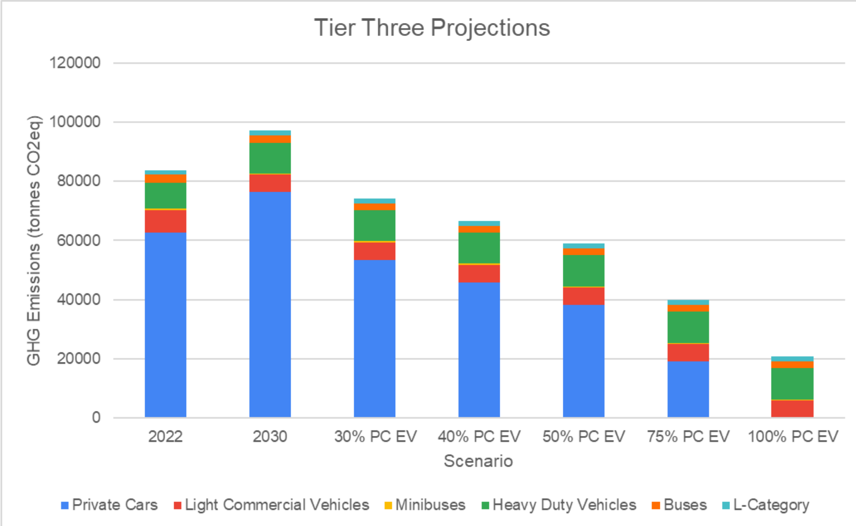
Tier Two Emissions Projections



If there is no adoption of electric vehicles in Eilat, Tier Three projects that 2030 emissions will be higher than 2022, but also finds that if 30% of passenger vehicles are electric, emissions are projected to be less than in 2022 (Figure 10).

Figure 10

Tier Three Emissions Projections



The reduction in GHG emissions in each scenario is compared to 2022 emissions and projected 2030 emissions in the Tier Two scope (Table 7).

Table 7

GHG Emissions Expressed as a Percentage of 2022 Emissions and 2030 Projections

Year Comparison	30% PC EV	40% PC EV	50% PC EV	75% PC EV	100% PC EV
2022	89%	80%	71%	48%	26%
2030	77%	69%	61%	42%	22%

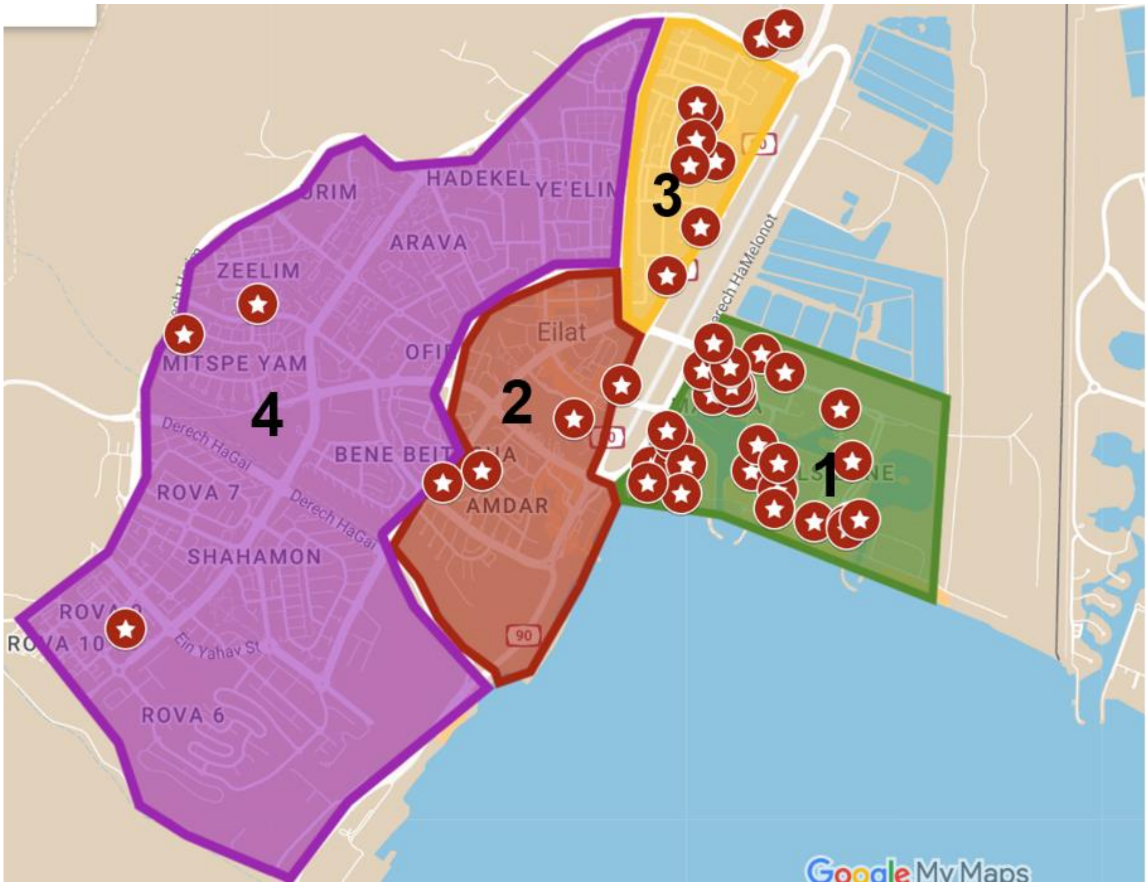
In all projections, there is expected to be a greater decrease in emissions over the 2030 projections than the 2022 calculations. Projections also demonstrate that should Eilat reach 100% electric for passenger cars, emissions will be just over a quarter of 2022 emissions, and less than a quarter of 2030's projected emissions.

4.2: Evaluating Eilat's Current EV Charging Grid

Figure 11 shows a map of the current charging sites in Eilat. Each icon indicates the location of a charger. The map is divided into the four regions of Eilat, based on their usage, as indicated by different colors and numbers. The majority of chargers are in section 1. The infrastructure of the current charging grid has around 8,000kW of public charging, or the capacity to charge 6,600 electric vehicles, or 28% of the projected vehicles in Eilat in 2030. This is based on the EU average of 1.2 kW of charging capacity per electric vehicle (International Energy Agency, 2023). The largest number of chargers are in the area of the hotels, several in the center of the city and very few in one of the residential neighborhoods.

Figure 11

Map of Current EV Chargers in Eilat



Note. From *Google Earth [Eilat - Google Earth]* by Google, Retrieved February 21, 2024 (https://earth.google.com/web/search/eilat/@29.62742694,34.95406645,133.97194914a,64664.51651002d,35y,0.00000088h,0t,0r/data=CnAaRhJACiUweDE1MDA3MWUzMjQ3OTVlMGI6MHhmZTFkOTVmODU1NzdmNmRiGTb-RGXDjj1AIVWfq63YeUFAKgVlaWxhdBgCIAEiJgokCdFFDVx3lT1AEcAeJ5PIiD1AGRJmuhFEf0FAIfl2tDQLc0FAMikKJwolCiExaWhOWF9ObzlsSDNGU3dOcTUySXBfQ1dGR3VuYUpNQ2QgAToDCgEw). Copyright TerraMetrics, 2023, Map data, 2023. Reuse is authorized by Google Earth.

Table 8 shows the amount of each type of charger along with their total capacity. Most of the chargers are medium 22 kW chargers. The total charging capacity is around 8,000 kW.

Table 8

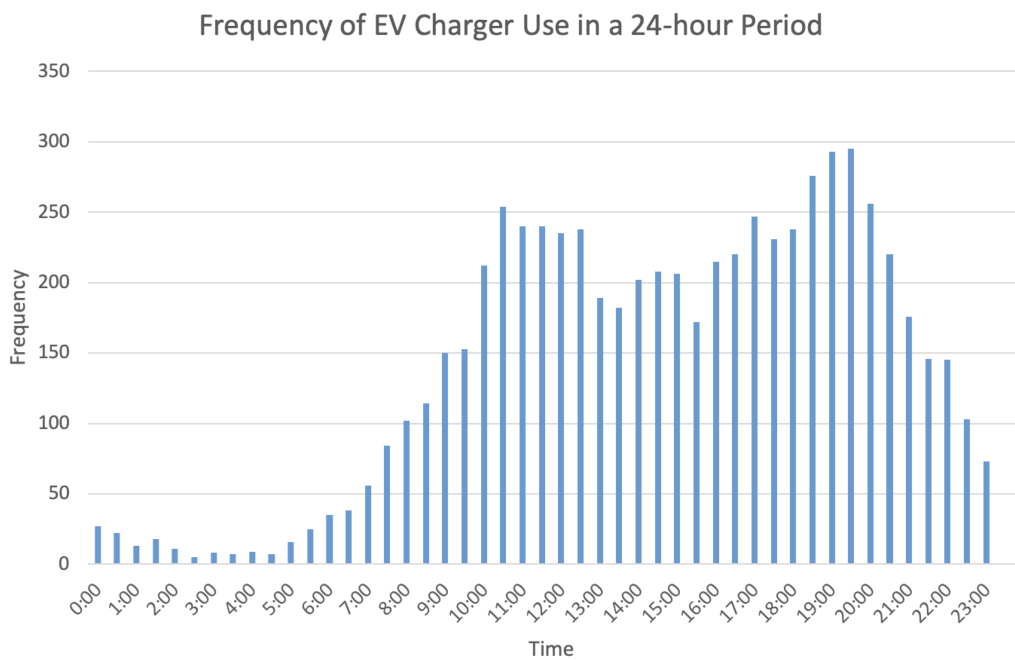
Current Network of EV Chargers in Eilat, by Type

Charger Type	Amount	Capacity (kW)
Slow (11 kW)	16	176
Medium (22 kW)	90	1,980
Fast (50 kW)	21	1,050
Ultra Fast (350 kW)	18	4,722
Total	145	7,928

Figure 12 shows the frequency of charger use in a 24-hour period. Charging occurs most frequently between 11:00 and 20:00 hours.

Figure 12

Frequency of Greenspot Charger Use in a 24-hour Period (Isn't that only for some of the chargers?)



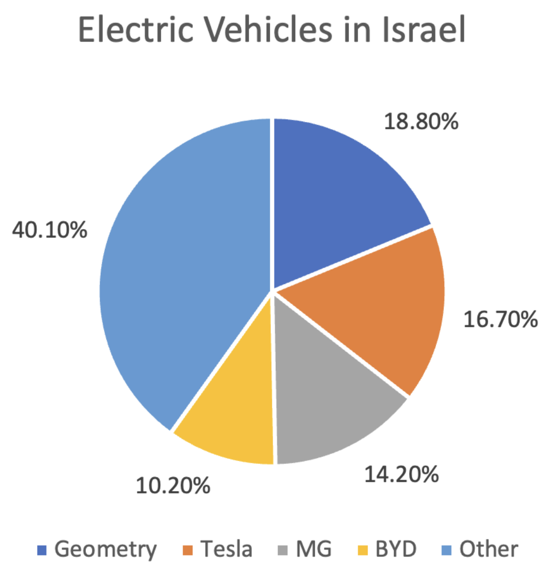
4.3: EV Charging Network Expansion

4.3.1: Market Analysis

In a market analysis of EVs purchased in Israel in 2022 on Statista, the most popular EV manufacturers were found to be Geometry, Tesla, MG, BYD, and others, shown in Figure 13. This determines that the municipality will need to install predominantly Type 2 EV chargers with some CCS2 support which follow a European standard.

Figure 13

Proportions of Electric Vehicles in Eilat



Note. From *Statista Market Insights, 2023* (https://www.statista.com/outlook/mmo/electric-vehicles/israel#unit-sales). Reuse is authorized by Statista.

4.3.2: Assessment of Parking in Eilat

Figure 14 displays all the parking lots identified in Eilat by their size. The parking lots are shown in three shades of blue corresponding to the size of the lot. Small size and light blue are small lots, medium size and blue are medium lots, and large size and dark blue are large lots. The median points of the parking lots by neighborhood based on size are represented by the red dots. There were 531 parking lots found in the city, in every section.

Figure 14

Map of Parking Lots with Median Points

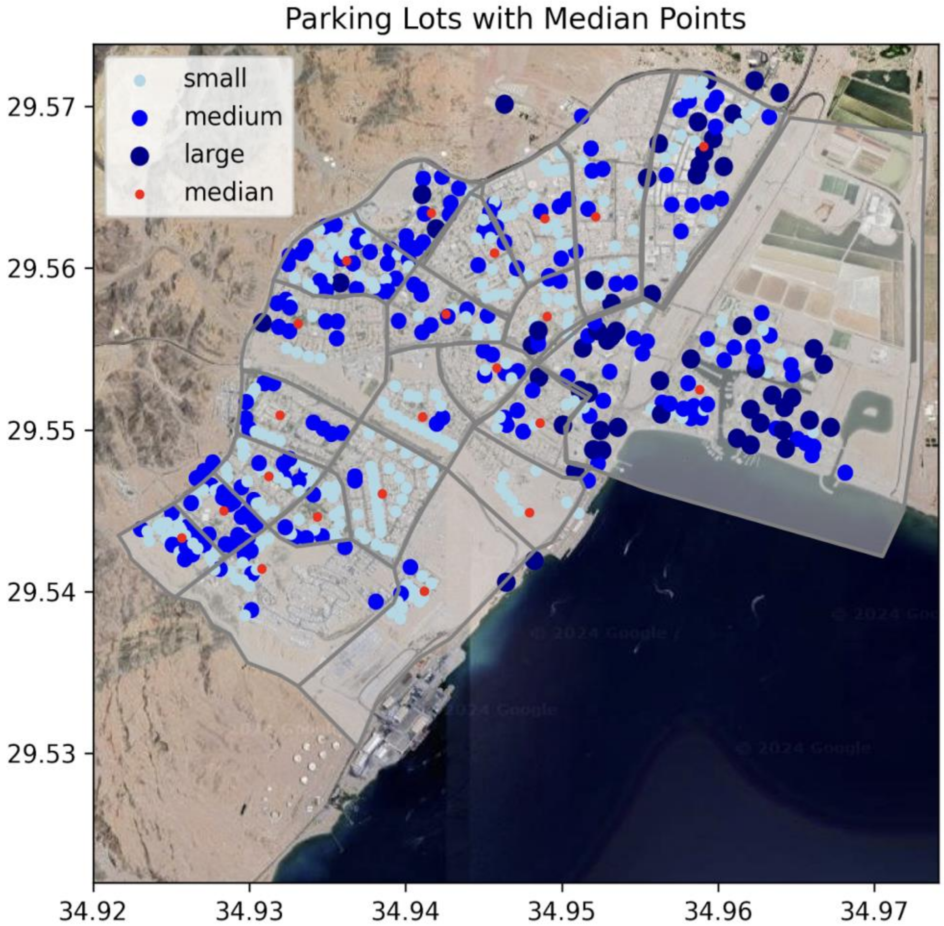
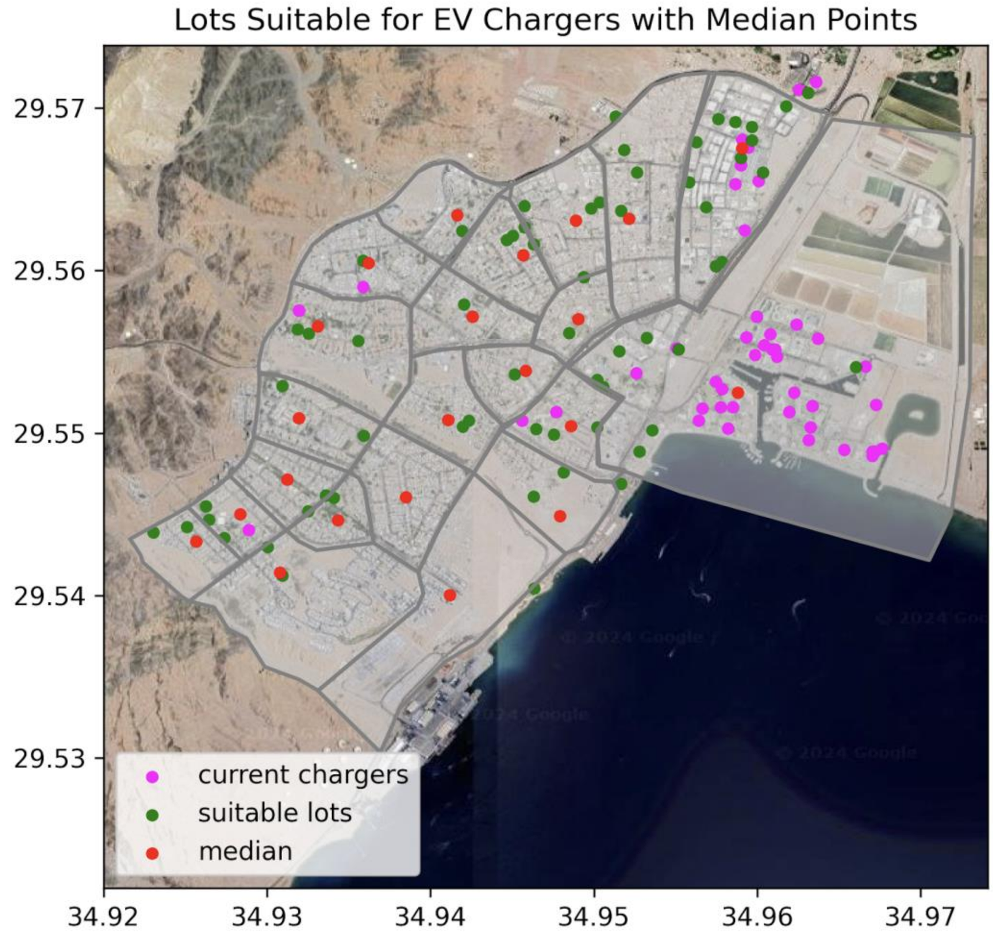


Figure 15 represents the lots that were determined to be suitable for EV chargers. The magenta dots represent the current chargers, while the green dots were the lots chosen for EV charger placement. The red dots represent the median points, for reference. The chargers were chosen at various points around the cities to maximize the amount of people who will be able to charge.

Figure 15

Map of Suitable Lots for EV Chargers and Neighborhood Centroid Locations



In total, 64 parking lots and 792 parking spaces were identified as suitable for EV charger placement.

Figures 16 through 19 demonstrate a staggered EV charger deployment. Stage Zero, shown as the pink dots in each figure, represents the current charging network.

4.3.3: Deployment: Stage One

Figure 16 shows stage one which consists of placing 22 ultrafast charge points at five gas stations, as indicated by the green dots. The magenta dots indicate the existing chargers. Stage one will accommodate 13,024 vehicles, as designated by the EU average of 1.2 kW/EV. This amount of vehicles would represent 54% of the vehicles projected to be in Eilat in 2030.

Figure 16

Stage One: Gas Station Chargers for 54% Uptake of EVs

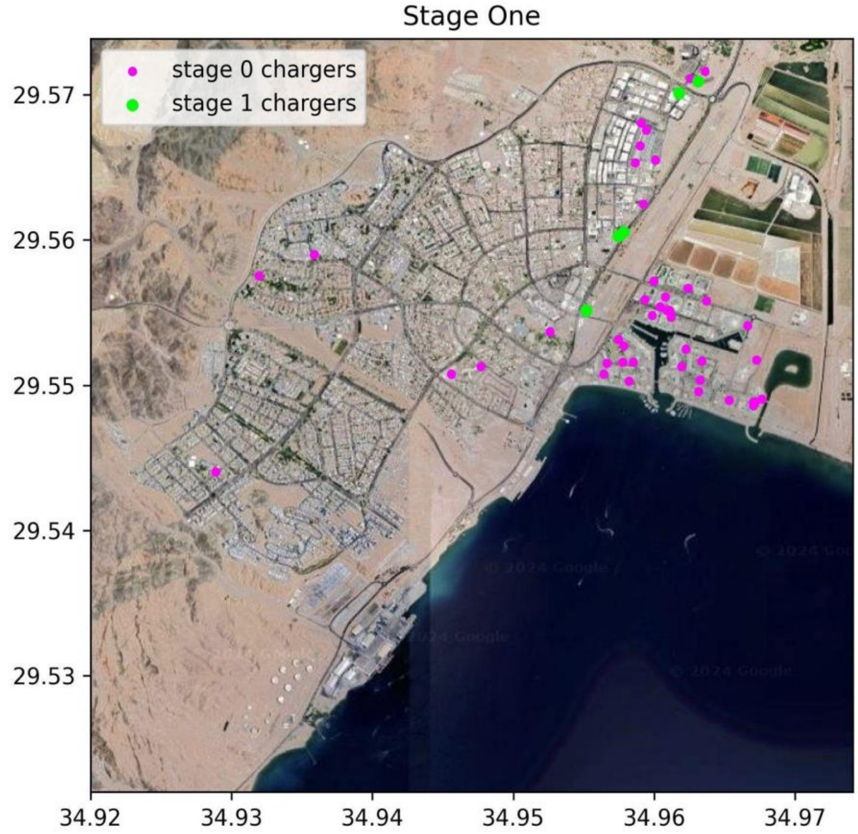


Table 9 describes the number of additional chargers needed, the total chargers in the network, the capacity of the chargers, by type, and the total capacity of the network for Stage One. The total capacity of this network is 12,422 kW, and there are 167 total chargers in this stage. A table of the locations of the charging sites, the number, and the type of charger at each charging site is found in Appendix M.

Table 9

Complete Network for Stage One

Charger Type	Additional Chargers	Total Chargers	Capacity (kW)
Slow (11 kW)	0	16	176
Medium (22 kW)	0	90	1,980
Fast (50 kW)	0	21	1,050
Ultra Fast (350 kW)	22	40	12,422
Total	**22**	**167**	**15,628**

4.3.4: Deployment: Stage Two

Stage Two recommends the placement of additional chargers at shopping centers, shown by the blue dots in Figure 17. Since these chargers are mainly at shopping centers, the majority are located in the commercial sections, away from the residential areas. There is one charger located in the tourist section, at a large shopping mall. The previous stages are shown on the map, since they will be implemented before this stage. The culmination of these placements will accommodate 21,484 EVs, or 89% of vehicles projected to be in Eilat in 2030.

Figure 17

Stage 2: Shopping Centers for 89% Uptake of EVs

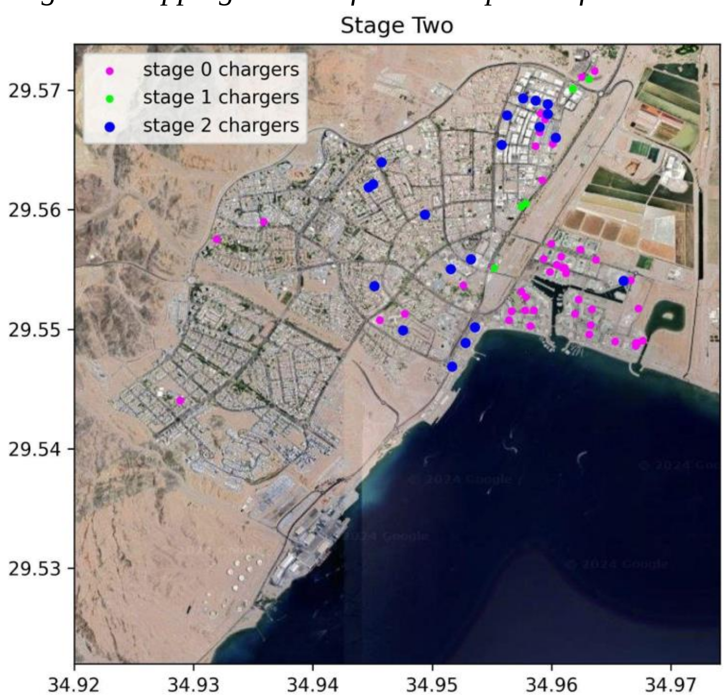


Table 10 describes the number of additional chargers needed, the total chargers in the network, and the capacity of the chargers, by type, for Stage 2. In total, 402 charge points were placed across 19 shopping center parking lots in eight neighborhoods. This would lead to a total of 575 charge points, and a capacity 25,780 kW. A table of the locations of the charging sites, the number, and the type of charger at each charging site is found in Appendix N.

Table 10

Complete Network for Stage Two

Charger Type	Additional Chargers	Total Chargers	Capacity (kW)
Slow (11 kW)	0	16	176
Medium (22 kW)	366	456	10,032
Fast (50 kW)	42	63	3,150
Ultra Fast (350 kW)	0	40	12,422
Total	**408**	**575**	**25,780**

4.3.5: Deployment: Stage Three

Stage three of the implementation plan includes chargers placed at schools, municipal buildings, and areas of recreation. Figure 18 represents the 14 parking lots where 148 medium chargers were placed, across 10 neighborhoods. The yellow dots represent the chargers added in this stage. In this stage, there are more chargers placed in the residential section, and where residents will spend most of their time, either at work or school. The culmination of Stage three chargers would accommodate 23,977 electric vehicles, or a 100% uptake in 2030.

Figure 18

Stage Three: Schools, Municipal, and Recreational Locations for 100% Uptake of EVs

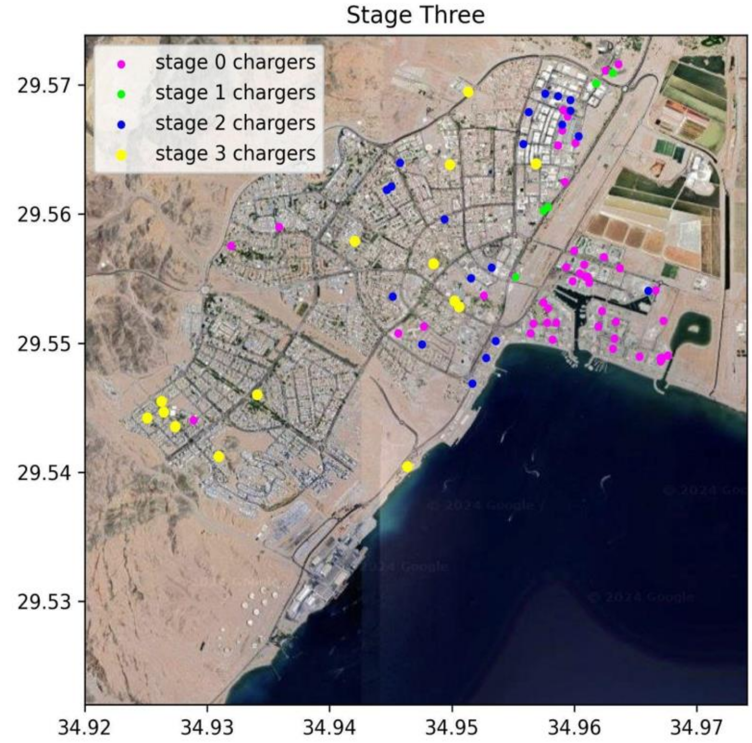


Table 11 describes the number of additional chargers needed, the total chargers in the network, and the capacity of the chargers, by type, for Stage 3. There will be a total of 711 charge points, with a network capacity of 28,772 kW following this stage. A table of the locations of the charging sites, the number, and the type of charger at each charging site is found in Appendix O.

Table 11

Complete Network for Stage Three

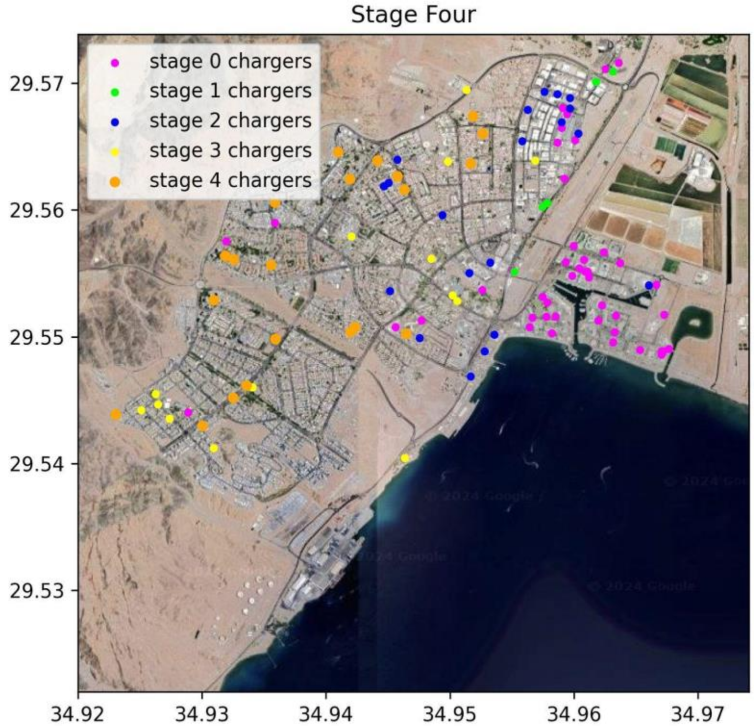
Charger Type	Additional Chargers	Total Chargers	Capacity (kW)
Slow (11 kW)	0	16	176
Medium (22 kW)	136	592	13,024
Fast (50 kW)	0	63	3,150
Ultra Fast (350 kW)	0	40	12,422
Total	**136**	**711**	**28,772**

4.3.6: Deployment: Stage Four

The final stage, Stage 4, includes the placement of EV chargers at public residential parking lots. The total network, including these lots would be able to accommodate 28,047 vehicles, or 117% of the projected vehicles in 2030. The lots chosen can be seen in Figure 19. The additional chargers are located by the orange dots. These charge points are mostly located in the residential section of the city.

Figure 19

Stage Four: Residential Lots for 117% Uptake of EVs



Stage four adds 222 charge points to 21 parking lots in 11 neighborhoods, as shown in Table 12. A table of the locations of the charging sites, the number, and the type of charger at each charging site is found in Appendix P.

Table 12

Complete Network for Stage 4

Charger Type	Additional Chargers	Total Chargers	Capacity (kW)
Slow (11 kW)	0	16	176
Medium (22 kW)	222	814	17,908
Fast (50 kW)	0	63	3,150
Ultra Fast (~ 350 kW)	0	40	12,422
Total	**222**	**933**	**33,656**

Across all four stages, it is recommended that 821 charge points be placed across 20 neighborhoods. This would provide 25,728 kW of additional power to the current 112 EV chargers in the city of Eilat, resulting in 933 public chargers with 33,656 kW of power, with the ability to service 28,047 electric vehicles.

4.3.7: Evaluation

An evaluation of existing EV chargers should be conducted before and in between each implementation stage. This should be a systematic process designed to test the effectiveness, accessibility, and ease of use of the chargers. The International Energy Association provides recommendations for policymakers on the integration of Electric Vehicles into the electrical grid and suggests appraising the network that may be in place prior to expansion (Lopez, 2022). This framework should be used between each stage, as a safeguard for the effectiveness of the system.

One aspect of evaluations will include user feedback about charger usage and placement. Surveying EV charger users, coupled with information about EV registered in Eilat and the number of EVs entering the city due to tourism will generate a framework for the user base of the public EV chargers. It is important to understand the driving habits of the users, including average length of trip, distance traveled, and reason for traveling. Where people prefer to charge, including if they have or would consider installing home chargers, is important to note. Some of this information can be obtained using GPS data, while the rest will require formal surveys. An analysis of charging patterns will also be necessary to determine the frequency of use of specific chargers. Information about charging time, idle time, when a vehicle is plugged in but fully charged, and vacancy time of the chargepoint, as well as vehicle type, can create a clearer image of the usage of each charger. Software can be built into the chargers to collect this information. It is important that users are aware that this information is being collected before they begin charging. Information about the impacts on the electrical grid should also be identified, by tracking maintenance needs, overloading issues, and blackouts throughout the trial period. Once underutilized chargers are identified, user satisfaction is understood, and patterns of maintenance recognized, the municipality can determine if and when the next stage needs to be implemented.

This will also depend on the uptake of EVs by people in Eilat. It is expected that EV uptake will follow a sigmoid logistics “s-curve” function, where a single inflection point signified the midpoint of uptake, and adoption will increase until it reaches 100% (Hill, 2021). The implementation of the stages should follow the registration of EVs in Eilat in accordance to the s-curve it may follow. The stages roughly follow this s-curve, with a rapid increase in charging capacity in the first two stages, and less capacity added as adoption of EVs levels. Ensuring that the municipality is dedicated to understanding the usage of EV chargers as they are implemented will allow for the network to be enduring through the transition to 100% EVs on Eilat’s roads.

4.4: Implementation Cost Estimate Results

Table 13 displays the cost of installation for each type of charger.

Table 13

Cost of Installation for Each Type of Charger

Capacity (kW)	Cost of Installation (₪)
11	5,900.00
22	11,500.00
50	65,500.00
350	326,400.00

Table 14 shows the installation cost for each stage of deployment.

Table 14

Installation Cost for Each Deployment Stage

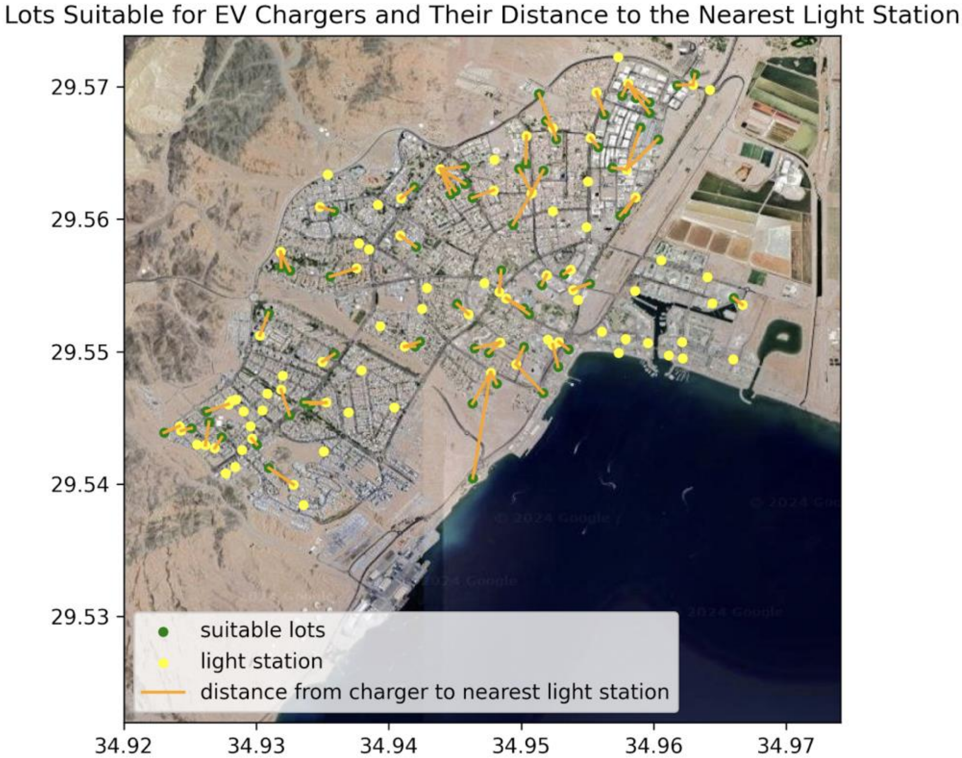
Stage	Cost of Installation (₪)
1	4,324,200.00
2	14,248,200.00
3	1,703,000.00
4	2,554,500.00
Total	22,829,900.00

The total in its USD equivalent is roughly 6.2 Million.

The distance of each charging site to the nearest light station is shown in Figure 20

Figure 20

Distance Between Charging Sites and Light Stations



A greater distance from a charger to a light station will result in a greater increase in price as more infrastructure needs to be built. The distances can be found in Appendix Q.

4.5: Cost on User Recommendations

As a public project, the cost of the EV chargers will be placed on the user in the form of tariffs. Tariffs are necessary to ensure a reasonable timeframe for the city to receive a return on investment for the infrastructure that they construct. For the city of Eilat, the objectives of a tariff include the recovery of costs for the utilities and infrastructure, revenue stability to cover maintenance costs and capacity maintenance of the grid. Table 15 includes a description of the tariff types considered and their perks and drawbacks.

Table 15

Tariff Descriptions

Tariff Type	Description	Advantages	Disadvantages
Energy Volume (₪/kWh)	A variable cost that charges users based on the volume of energy used, in kilowatt-hours. Charges can vary over time to accommodate grid loading.	- Can discourage critical peak loading - Can encourage use during solar overproduction	- Does not cover infrastructure and maintenance cost
Demand (₪/kW)	A variable charge that charges the user based on the instantaneous demand of the service to recover fixed costs.	- Can cover infrastructure and maintenance cost	- Can unequally burden disadvantaged groups - Does not cover energy costs, or mitigate energy overloading
Dynamic Demand and Time-of-Use	A long-term tariff strategy that implements a fixed energy charge on the user, and phases into a fixed demand charge, based on EVSE usage.	- Grows with market maturity, encouraging EV uptake early on - Covers energy and infrastructure costs	- Phasing of implementation can be confusing for users - Does not mitigate energy overloading
Fixed Demand and Time-of-Use	A combination of fixed demand charges to cover infrastructural costs and time-of-use (ToU) energy costs based on critical peak energy time.	- Covers energy and infrastructure costs - Can encourage use during solar overproduction and discourage critical peak loading - Stable throughout the year	- Fixed cost can change as maintenance/ updates are needed

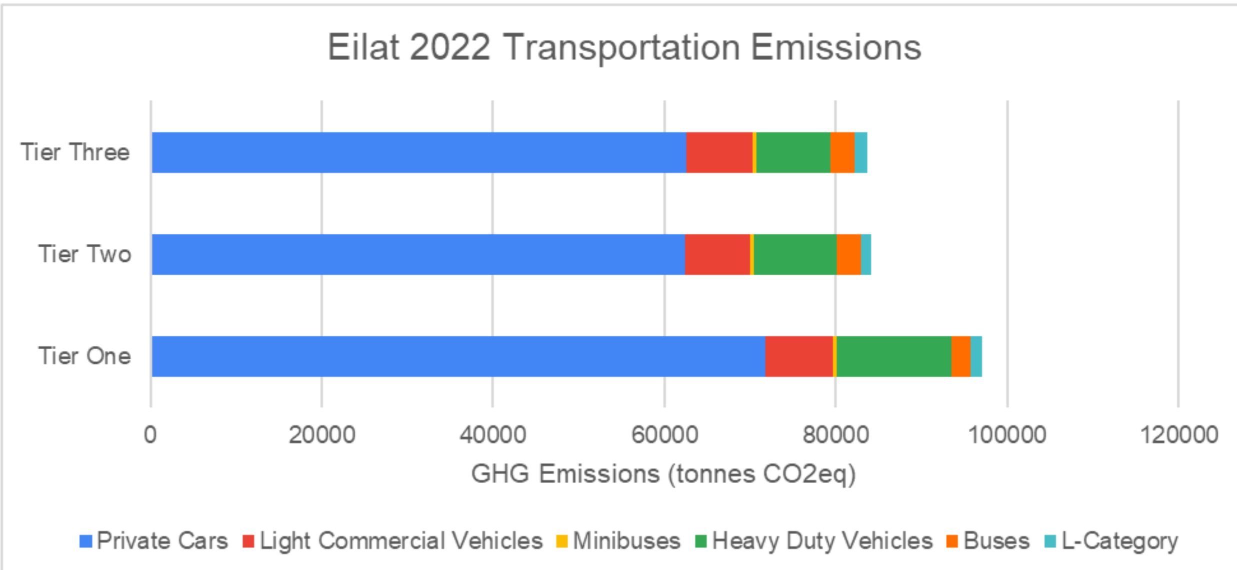
Chapter 5: Discussion

5.1: Eilat's Current Emissions

Three levels of specificity were performed in calculating Eilat's current emissions (Figure 21).

Figure 21

Eilat 2022 Transportation Emissions



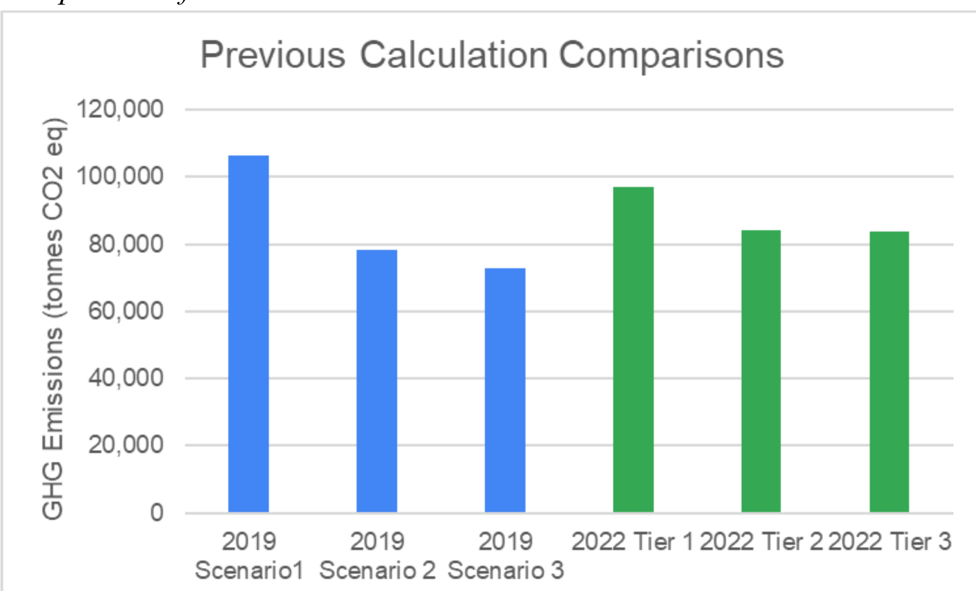
Tier One generated a GHG emission total of 97,150 tonnes of CO_2 equivalent, Tier Two found 84,170 tonnes of CO_2 equivalent, and Tier Three found 83,680 tonnes of CO_2 equivalent. Tier One totals are significantly higher than Tier Two and Tier Three, likely because Tier One does not account for vehicle technology, meaning that the bulk emissions factors accounted for the "worst case scenario" where there is a significant amount of vehicles using older technologies. Tier Three emissions are slightly lower than Tier Two emissions, despite including methane. This difference is attributed to the broad assumptions that were utilized in Tier Three calculations, including assuming that all driving was hot urban driving. Tier Two is the most specific calculation performed that did not make broad assumptions and should be accepted as a general result of these calculations.

Though the calculations for each of the three tiers produced comparable results, assumptions made in each tier contributed to uncertainty in the calculations. In all calculations, the average annual mileage for all vehicle types, excluding private cars, is assumed to be equivalent to that of Israel. This assumption was made on the basis of available data, as there was no data on vehicle mileage specifically for Eilat. This assumption is furthered in Tier Two and Tier Three, where the annual mileage by vehicle type and vehicle technology is assumed to be the same as for each vehicle type in general. There is no indication that this assumption is accurate, but rather this assumption was made by necessity as there is no available data indicating annual mileage by vehicle type and vehicle technology. Tier Three calculations relied on the assumption that all driving done in Eilat was in hot urban conditions. This assumption is not correct but was made in order to perform Tier Three Calculations within the scope of our project. There are no scenarios in which driving can be purely hot driving, as ICE vehicles require time to heat up, during which the emissions are different than under hot conditions. Additionally, not all drive time is in urban conditions, but with data regarding drive type unavailable, this assumption served to bring Tier Three calculations within the scope of this project and allow methane emissions to be quantified.

Despite these assumptions affecting the results, these calculations, especially Tier Two, make sense, since they are on a similar scale to 2019 calculations which included three different calculation scenarios that found 106,311, 78,469, and 72,936 tonnes of CO_2 (Scwartz et al., 2021) (Figure 22).

Figure 22

Comparison of Eilat's 2019 and 2022 Emissions

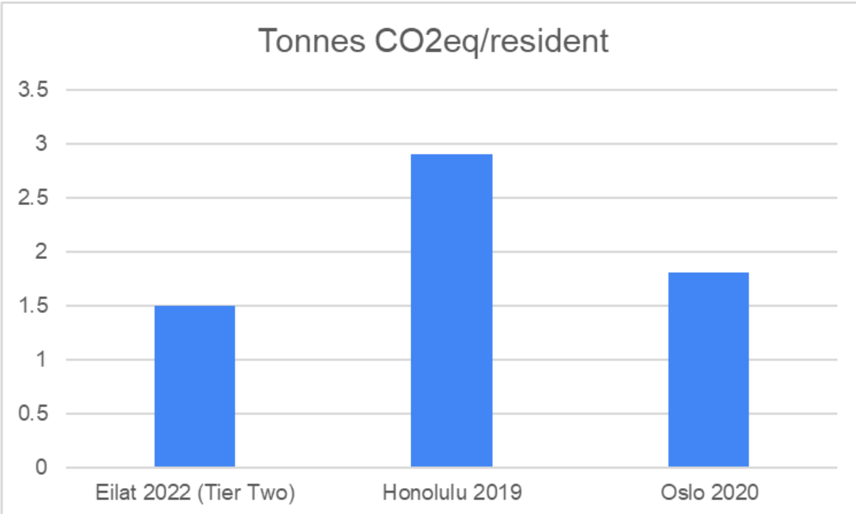


Mileages and calculation methods for our calculations were done similarly to the second scenario. These numbers being similar, despite being three years different, can be explained by there being a higher proportion of newer vehicles in Eilat which emit less pollutants, in combination with an increase in vehicles within the city.

Eilat's emissions can also be compared to other climate conscious cities (Figure 23).

Figure 23

Tonnes of CO_2eq/resident in Eilat, Honolulu, and Oslo



Oslo, Norway is another city that has committed to lowering its GHG emissions by 2030. As a part of this initiative, the city runs annual inventories of its emissions. In 2020, Oslo's road transportation sector emitted 564,517 tonnes of CO_2 equivalents (Oslo Agency for Climate, 2022). Oslo's population in 2020 was 1,041,000, approximately 20 times that of Eilat (*Oslo, Norway Metro Area Population 1950-2024,* 2024). Oslo produced approximately 1.8 tonnes of CO_2 equivalents from road transportation per resident in 2020, while Eilat produced approximately 1.5 tonnes of CO_2 equivalents from road transportation per resident in 2022. This difference may be attributed to the distribution of vehicles in Oslo, coupled with Oslo's larger area. A larger area means that there is more travel of heavy-duty vehicles transporting resources throughout the city. In this sense, Eilat's smaller geography gives the city an advantage in the reduction of GHG emissions over other, larger cities. However, annual average vehicle mileage, vehicle type, vehicle age, and fuel type in Oslo is not known. Therefore, assumptions about the differences in CO2 emissions can just be hypothesized.

Honolulu, in a similar vein to Eilat, is also making efforts to shift its transportation sector to electric power. In 2019, Honolulu's transportation sector, encompassing road, air, and marine travel, emitted 16,200,000 tonnes of CO_2 equivalent (City and County of Honolulu Resilience Office, n.d.). During this same year, Honolulu City and County's population was 974,563 residents (Honolulu City and County Department of Business, Economic Development & Tourism, 2020). This means that Honolulu's transportation sector emitted 16.6 tonnes of CO_2 equivalents per resident, which is significantly higher than Eilat's 2022 emissions per resident, likely due to the amount of air traffic the city receives as a result of tourism. When Honolulu's transportation emissions are stripped down to just the road transportation emissions, on par with Eilat's emissions, the city emits 2,874,500 tonnes of CO_2 equivalents, or 2.9 tonnes of CO_2 equivalents per resident, which is approximately double Eilat's 1.5 tonnes of CO_2 per resident, attributed to Honolulu City and County's large area in comparison to Eilat. Between 2020 and

2023, Honolulu has seen an almost 300% increase in electric vehicles on the roads. These EVs were predicted to have lowered the city's GHG emissions since 2019 (US Department of Energy, n.d.). This increase in EVs is correlated with the city's increased number of EV chargers, meaning that Eilat can expect to see a similar increase in EV usage with increased chargers, decreasing GHG emissions.

5.2: Projecting Eilat's Emissions

In 2030, Eilat's GHG emissions are predicted to be 97,740 tonnes of CO_2 equivalent if no more EVs are adopted in Eilat, a 16% increase over 2022. In this same year, passenger cars are predicted to account for 78% of the city's emissions, a 4% increase over the 74% of GHG emissions passenger cars accounted for in 2022. In order to reduce the effect of passenger cars on Eilat's contribution to global warming and help Eilat reach the Cities Mission 2030 goal of climate neutrality, electric vehicle implementation will be vital. If 30% of passenger cars are electric by 2030, the city's emissions will be reduced by 10% over 2022 and will be 13% less than the predicted 2030 emissions. If this portion is 50%, Eilat's GHG emissions will be 29% less than in 2022 and 39% less than what is projected for 2030. If all of Eilat's passenger cars are electric in 2030, the city's emissions will be 74% less than in 2022 and 78% less than the projected emissions for 2030.

These projections put Eilat on par with their goals of making the transportation sector carbon neutral by 2030. It is important to note that it is not possible for the city to become climate neutral without addressing the emissions produced by buses, trucks, and special vehicles. This will require the municipality to adopt electrified versions of public use vehicles, and for the city to encourage companies to make the switch to EVs. These projections serve as proof that an increase in electric vehicles will create a decrease in emissions, and we believe that an effective way to encourage the adoption of EVs is through the placement of accessible public chargers.

5.3: Eilat's Current EV Charging Grid

There are currently 45 charging sites in Eilat. 29 of these sites (64%) are in the city's tourist sector. Nine sites (20%) are located in the industrial district of the city and are frequently placed in the parking lots of stores. Four sites (9%) are located in Eilat's municipal center. The remaining four sites (9%) are located in the residential district. Three of these chargers are located near each other in Zeelim, while the fourth charger is near the south side of the residential district in Rova 9. Each of these sites has an average of four charging spots. In terms of equipment, all charging sites feature Type 2 chargers. Eight of these sites also feature Type 2 CCS allowing for fast charging capabilities. Only two sites were found to have the CHAdeMO system. Some sites have chargers of varying speeds. Medium chargers are the most common in Eilat as there are 65 medium chargers at the various charging sites. There are also 34 fast chargers and 13 slow chargers.

The residential areas and the municipal center are two areas that currently lack the charging density of the resort area and the industrial area. Placing chargers in appropriate quantities in these areas will spur residents to obtain an electric vehicle since the charging infrastructure is in place to support them. In a similar vein, placing additional EV chargers in areas where public charging availability is limited will encourage outsiders to travel to these parts of the city with their EVs, thus reducing the number of ICE vehicles on the road in those areas, further contributing to a reduction in the city's transportation emissions.

Many charging sites within the hotel and tourist district are located in hotel parking lots and are only available to the guests of their respective hotels. Although these chargers have the potential to service any tourists who travel to the city in EVs, they are not accessible to the residents of the city. Therefore, these chargers cannot fully support the EV needs of the city. However, if these chargers were available for public use, they would be more than enough to support the 114 EVs that are registered in Eilat as of 2022. These EVs require 140 kW of public charging infrastructure to support them whereas Eilat has 8000 kW of charging capacity available. While the current infrastructure is enough to support the EVs registered in Eilat, it is not clear how many EVs enter the city. The proposed charging network should account for growth in EV ownership within the city as well as the increased number of EVs entering the city.

In terms of equipment, we learned that medium chargers equipped with type 2 plugs were the most common throughout all sites. Therefore, the majority of the chargers the team will place should focus on this technology. In cases where fast chargers are necessary, chargers equipped with type 2 CCS2 will be employed. This data is corroborated by the EV market data in Figure 13, as popular EVs are equipped with type 2 CCS2 ports. We do not recommend slow chargers be installed due to their very slow charging speed and low prevalence in Eilat. Likewise, chargers equipped with CHAdeMO ports should also not be installed.

Chargers were used most frequently during the late morning to early evening period. Charging frequency reached a local spike around 11:00. After this time, the charging frequency decreased until 13:00. The frequency steadily increased until reaching an overall maximum at 20:00. Charging was at a minimum in the early morning hours from midnight to 05:00 at which time the frequency began to steadily increase until reaching its local spike around 11:00. Further analysis showed that these chargers were used 0.77 times per day on average in 2023. The busiest charger was used around twice per day while the least popular charger was only used five times in the year. Although these trends were identified after analyzing a large sample of charging logs from February to December 2023, the data may not accurately represent the charging frequency of all of Eilat since the data is only from Eilat's Greenspot chargers. Data from sites run by other companies was not available. However, since around 33% of the chargers are run by Greenspot, the analysis has some merit. Including data from other charging companies and comparing the generated histogram of electricity usage trends of the entire city could further hone the analysis. Nevertheless, the data is indicative of the charging behavior of Eilat's EV users.

5.4: EV Charger Network Expansion

5.4.1: Parking Lot Identification

531 parking lots were identified in the city of Eilat. This count excluded bumper-to-bumper parking, and private driveways. It is possible that this number does not encompass all parking lots in Eilat due to the nature of the identification method. The sizing of each lot was also based on estimates, rather than the actual number of parking spaces, due to time constraints. The simple median modeling method used to identify the centroid between the parking lots in each neighborhood is a method generally used in facility location modeling. Further research concerning location modeling for EV chargers could be conducted. Specifically, running particle distribution methods, which would model driving behaviors to determine the most ideal location for EV chargers, would be the most effective method for EV charger placement.

Following the simple median modeling method and manual choosing of parking lots for EV charger eligibility, we determined that 64 parking lots with 792 parking spots were suitable for EV charger placement. When lots were being eliminated from EV charger placement eligibility, certain lots may have been removed without consideration for local behavior. The remote aspect of this project limited the scope of integration of EV chargers into the network since all measurements and decisions were based on digitized data, rather than fieldwork.

5.4.2: Stages and Evaluation

In the four stages recommended concerning the placement of EV chargers in the city of Eilat, 794 chargepoints, including 720 medium (22kW), 52 fast (50kW), and 22 ultra-fast (350 kW) chargers, are endorsed. The placement of these chargers was contingent on serving the most people in the city of Eilat, which meant placing them at highly accessible, public locations in diverse spots around the city. Due to the nature of the city, fewer parking lots met this criteria in the residential sections of the city. This required the placement of chargers in large residential lots as a long-term solution to public EV charging. The residential sections of Eilat mainly consist of multifamily housing. The installation of private EV chargers may be more difficult in these residences. This is why we chose to focus on the needs of the residents over the needs of the tourists in this city, even though the tourists outnumber the permanent residents annually. Ignoring the necessity for overnight charging for residents can lead to “charging deserts,” or areas where chargers are not accessible, which can increase range anxiety, and decrease the likelihood of EV uptake. Only six chargepoints were placed in the neighborhood which consists of the most popular hotels and attractions for tourists, since the private sector already covers the majority of charging needs in this area. Charging stations at shopping center parking lots and at gas stations will also meet the needs of tourists.

The timeline for the implementation of the stages is contingent on the budget and time allocated for the construction of EV infrastructure, and the effectiveness of the current chargers, and the chargers at each stage. We recommend that the municipality complete stage four by 2030 to meet its sustainability goals in the transportation sector, so long as the evaluation of the chargers is consistent with this projection. While a formal guide on how to evaluate the charging network in the city is not provided, non-government organizations and EU-funded projects can aid in this evaluation. Groups such as Smart Charging ALignment for Europe (SCALE), Electric Vehicles Management for carbon neutrality in Europe (EV4EU), and SOLUTIONSplus all offer modeling software to evaluate EV charger placement and other tools for supporting the shift towards EVs.

The amount of EV chargers placed in the city represents the projection of vehicles on the road in 2030. If all four stages are complete, and if all the personal vehicles in Eilat are electric by 2030, then all residential personal vehicles should be serviced by public charging infrastructure. The installation calculations did not account for the number of tourists entering the city, or the number of people who install home chargers. Additionally, the projection of vehicles is based on data from the past seven years, so trends could change based on user behavior. Therefore, our recommendations are made with the knowledge that expansion beyond what we have placed will be necessary in the future. Other aspects not considered in this project include the electrification of buses, motorcycles, trucks, and minibuses, all of which will need to become electric in order to reach the 2030 goal of climate neutrality. Beyond the electrification of vehicles, we recommend a longer-term, more sustainable solution of implementing a more robust public transportation system and the creation of a walkable or cyclable city through sustainable urban design. This method is effective at making cities more resilient to climate change, and could help Eilat reach climate neutrality through the reduction of emissions.

Our implementation plan and placement of EV chargers around the city are recommended with the intention of equitable access to chargepoints and encouragement of EV uptake by the residents of Eilat.

5.5: Cost Evaluation

The total cost of installing our recommended EV chargers is ₪23 million. However, it is important to note that this final number fails to take important factors into account. One such factor is the distance of the chargers to the nearest light station. Ultimately, a lack of sources resulted in this information being hard to discover. Another factor is that the price of the chargers themselves and other installation fees are dependent on specific companies. We were unable to gather a clear estimate because many companies do not list prices for their public EV chargers. As a result of this, the city of Eilat will have to either issue an RFP (Request for Proposal), a formal announcement and description of their project that welcomes bids from companies, or reach out to a trusted provider. Furthermore, the potential need to invest in specialized software may further increase costs. Since the budget of Eilat and the amount of financial aid from the EU is currently unknown to us, we are unsure of the implications of this cost estimate. Ultimately, it will be up to the city to decide how much of the proposed expansion plan they can afford to implement.

5.6: Cost on User

Although it was not possible to calculate the tariffs necessary to recover the costs by the municipality from the installation of EV chargers, the tariff system and methods needed to implement it are outlined as follows.

Based on motivations, objectives, and attributes that we found would suit the city of Eilat, we determined that the fixed demand and energy tariff was suitable for Eilat. For fixed demand tariffs, a timeline will have to be defined for the return on investment of the installation of EV chargers. Then, usage data of the EV chargers can be estimated, based on charging times. Slow (11kw) chargers can take up to 12 hours to charge a car, meaning that a maximum of two users can charge per day. Medium (22kW) chargers can take between 5-8 hours to charge a vehicle. Therefore, only three users can charge per day. Fast (50kW) chargers can charge in 30-50 minutes, so we can assume that 24 users can charge in a day. Ultra Fast (350kW) chargers can fully charge a vehicle in 5-10 minutes, so up to 144 users can charge per day. Table 16 represents the amount of charges that each charger in Eilat can provide per day, based on stages.

Table 16

Charges Per Day, by Charger Type

Charger Type	Charge Time (Hr)	Charges Per Day
Slow (11kW)	12	2
Medium (22kW)	5-8	3
Fast (50kW)	0.5-1	24
Ultra Fast (350kW)	0.1	144

The steps needed for the city to calculate the actual tariff on the user are outlined as a guideline for the municipality. The fixed charge will cover the costs of installation and maintenance, while the ToU charges, in ₪/kWh, will cover electricity costs. The ToU charges will also discourage peak-time usage, which will mitigate the overloading of the electricity grid (Zinaman et al., 2020).

Each charger type should have its own fixed rate since the installation cost for each type will vary. At each stage of implementation, the cost estimate of the construction of the new EV chargers should be separated based on the type of charger. Then, the cost per charger type should be divided by the number of daily uses multiplied by the timeline of return on investment. Equation 8 can then be used to determine the fixed rate associated with each charging type.

Fixed Rate Cost Equation

$$R_j = \frac{C_j}{n_j * t} \quad \textbf{(9)}$$

Where,

R_j = Rate cost for charger type *j*

C_j =Cost of purchasing and installation for charger type *j*

n_j = number of possible daily uses for charger type *j*

t = return-on-investment timeline, in days

For ToU charging, the municipality will need to obtain citywide energy use data to identify peak block times. Depending on energy use habits, at least three time blocks must be outlined: off-peak, mid-peak, and on-peak. Off-peak charges will be the least expensive, while on-peak charges will reflect the strain on the system (Yong et al., 2023). Again, charges will vary based on charger type, as ultra-fast chargers use more power than slow chargers. Based on the cost of energy, an equilibrium of energy costs should be constructed so that the key principle of rate design, that “customers should pay for grid services and power supply costs based on how much power they use and when they use it,” is maintained (American Public Power Association, 2019). This means that the total cost of electricity used by EV chargers will be distributed to the EV charger users, but will not overcharge them during peak periods.

The two charges – the fixed infrastructural cost and the ToU energy cost – will be combined and users will be charged accordingly. This tariff design will ensure that the municipality recovers sunken costs from the construction and maintenance of the network, avoids paying utilities on electricity, and encourages grid-friendly habits for users without advanced technology.

5.7: Software Recommendations

The use of software to manage and maintain the EV chargers is essential to a working EV system. For the municipality, software will be useful for determining the working status and condition of chargers. Software can determine if a charger has stopped functioning properly or is in need of repairs. Software is also essential to collecting use data of the EVs which can be used to further optimize charging capacity and tariffs. Because the charging habits of residents may differ from those of tourists, it is important that Eilat collects new data of the chargers it installs in the non-tourist districts. Furthermore, software can also provide convenience to the user. A user can see what chargers are currently available and if they are functional or not. Ultimately, a well-connected system will allow for a more efficient and user-friendly charging network. Many chargers already include some software in them. It will be important to plan out a dedicated network ahead of installation and to make the software demands clear to the installer.

Chapter 6: Conclusion

Eilat is an Israeli city leading the country in sustainable infrastructure. With the successful conversion of its electricity network to solar power, Eilat is shifting its focus to minimizing GHG emissions from the transportation sector, the largest source of emissions in the city. To do this, the city aims to increase EV usage. This goal, coupled with the increase in EV popularity throughout Israel, signals a demand for additional EV chargers. These chargers will support EVs currently on the road and foster further adoption of EVs.

The purpose of this paper is to assist the Eilat Municipality in reducing its transportation GHG emissions by calculating its current GHG emissions and proposing an expansion to Eilat's EV charging network. We used the EEA's Road Transportation Emissions methodology to calculate Eilat's transportation GHG emissions. The Tier Two calculations resulted in 84,170 tonnes of CO_2eq emissions released by Eilat's transportation sector in 2022. We ran several simulations that represented Eilat's 2030 emissions given certain EV adoption scenarios. If the city reaches 100% EV adoption by passenger cars, the city is predicted to see a 74% decrease in GHG emissions over 2022. The evaluation of Eilat's current EV charging network highlighted that most chargers are located in tourist-frequented areas and are medium-powered chargers with type 2 ports. Using this information and additional data about Eilat's parking lots, 794 additional chargers were suggested for placement using the median modeling method throughout the city. A four-stage deployment plan and tariff recommendations were also formulated. Finally, the installation cost of the expanded charging network is estimated to be ₪23 million (6.2 million USD). In conclusion, the implementation of the proposed expansion of Eilat's EV charging network will result in increased EV use and a reduction of transportation GHG emissions.

References

Administration of Tourism, supervision and beaches in Eilat. (2023). *Appendix to the parking services agreement - parking data* (p. 1). Administration of Tourism, supervision and beaches in Eilat.

American Public Power Association. (2019, August 22). *Implementing the three principles of smart rate design*. American Public Power Association. https://www.publicpower.org/blog/implementing-three-principles-smart-rate-design

Ayalon, I., Rosenberg, Y., Benichou, J. I. C., Campos, C. L. D., Sayco, S. L. G., Nada, M. A. L., Baquiran, J. I. P., Ligson, C. A., Avisar, D., Conaco, C., Kuechly, H. U., Kyba, C. C. M., Cabaitan, P. C., & Levy, O. (2020). Coral Gametogenesis Collapse under Artificial Light Pollution. *Current Biology*, *31*(2). https://doi.org/10.1016/j.cub.2020.10.039

Ben-Gedalyahu, D. (2023, July 10). *Israeli EV sales soar in H1 of 2023, surpassing full-year 2022 figures*. The Jerusalem Post | JPost.com. https://www.jpost.com/business-and-innovation/article-749393

Buberger, J., Kersten, A., Kuder, M., Eckerle, R., Weyh, T., & Thiringer, T. (2022). Total CO2-equivalent life-cycle emissions from commercially available passenger cars. *Renewable and Sustainable Energy Reviews*, *159*, 112158. https://doi.org/10.1016/j.rser.2022.112158

CelloCharge. (2024). מפת עמדות הטענה חשמליים - משרד האנרגיה. Cellocharge.com. https://cellocharge.com/

City & Council of Honolulu. (2021). *One Climate One O'ahu Climate Action Plan 2020 - 2025*. 1–17. https://static1.squarespace.com/static/5e3885654a153a6ef84e6c9c/t/6080c33e91bbf23a20b74159/1619051381131/2020-2025+Climate+Action+Plan.pdf

City and County of Honolulu Resilience Office. (n.d.). *City and County of Honolulu Greenhouse Gas Emissions Inventory*. Resilience Office - City and County of Honolulu Office of Climate Change, Sustainability and Resiliency. Retrieved February 16, 2024, from https://www.resilientoahu.org/ghg

Clean Cities Coalition Network. (n.d.). *Clean Cities Coalition Network: Illinois Alliance for Clean Transportation*. Cleancities.energy.gov. Retrieved February 21, 2024, from https://cleancities.energy.gov/coalitions/illinois

Climate Change: Atmospheric Carbon Dioxide. (2023). NOAA Climate.gov. https://www.climate.gov/news-features/understanding-climate/climate-change-atmospheric-carbon-dioxide#:~:text=Without%20carbon%20dioxide%2C%20Earth's%20natural,causing%20global%20temperature%20to%20rise.

CO2 equivalents | Climate Change Connection. (2014, August 17). Climate Change Connection | Connecting Manitobans to Climate Change Facts and Solutions. https://climatechangeconnection.org/emissions/co2-equivalents/

Department of Business, Economic Development & Tourism. (n.d.). *What are the major industries in the State of Hawaii?* Dbedt.hawaii.gov. https://dbedt.hawaii.gov/economic/library/faq/faq08/

Eilat Climate. (n.d.). Eilat.city. https://eilat.city/en/info/eilat-climate

Eilat-Eilot Environmental Unit. (n.d.). Www.annalindhfoundation.org. Retrieved January 29, 2024, from https://www.annalindhfoundation.org/members/eilat-eilot-environmental-unit

Eilat-Eilot Innovations in Renewable Energy Technology: A Response to Global Warming and Climate Change - Israel. (2024). Unfccc.int. https://unfccc.int/climate-action/momentumfor-change/activity-database/eilat-eilot-innovations-in-renewable-energy-technology-a-response-to-global-warming-and-climate-change

Euro standards. (2014, January 13). ACEA - European Automobile Manufacturers' Association. https://www.acea.auto/fact/euro-standards/

Falvo, M. C., Sbordone, D., Bayram, I. S., & Devetsikiotis, M. (2014). EV charging stations and modes: International standards. *2014 International Symposium on Power Electronics, Electrical Drives, Automation and Motion*. https://doi.org/10.1109/speedam.2014.6872107

Flyvbjerg, Bent & Bruzelius, Nils & Wee, Bert. (2008). Comparison of Capital Costs per Route-Kilometre in Urban Rail. European Journal of Transport and Infrastructure Research. 8. 17-30. 10.18757/ejtir.2008.8.1.3327.

Glasco, J. (n.d.). *Here's how Oslo became the capital of EV cars*. InfraJournal. https://www.infrajournal.com/en/w/oslo-capital-ev-cars

Google. (2023, October 16). *List of charging stations for EV cars in Israel*. Google My Maps. https://www.google.com/maps/d/viewer?mid=1MoueY94f_CdPzQbSTFe7ZE7q0VP5TTYh&hl=en_US&ll=29.56153308052602%2C34.957458711169434&z=14

Greenhouse gases - U.S. Energy Information Administration (EIA). (2024). Eia.gov. https://www.eia.gov/energyexplained/energy-and-the-environment/greenhouse-gases.php

Halleux, V. (2024, January 20). *Development of Euro 7 emission standards for cars, vans, lorries and buses | Legislative Train Schedule*. Legislative Train Schedule; European Parilment. https://www.europarl.europa.eu/legislative-train/theme-a-european-green-deal/file-post-euro6vi-emission-standards#:~:text=Under%20the%20European%20Green%20Deal,trucks%2C%20buses%20and%20coaches).

Hawaii EV Association. (n.d.). *Hawaii Electric Vehicle Association*. Hawaii Electric Vehicle Association. Retrieved February 14, 2024, from https://hawaiiev.org/#:~:text=As%20of%20December%202023%2C%20there

Heilweil, R. (2023, May 24). *What Will It Take to Charge Electric Vehicles Faster?* Smithsonian Magazine. https://www.smithsonianmag.com/innovation/what-will-it-take-to-charge-electric-vehicles-faster-180982221/

Hill, J. (2021, May 27). *Electric vehicle "s-curve" puts global uptake in line with Paris goals*. The Driven. https://thedriven.io/2021/05/27/electric-vehicle-s-curve-puts-global-uptake-in-line-with-paris-goals/

Honolulu City and County Department of Business, Economic Development & Tourism. (2020, March 21). *2019 County Population Estimates Released*. Census.hawaii.gov. https://census.hawaii.gov/whats-new-releases/2019-county-population-estimates/

Illinois Alliance for Clean Transportation. (n.d.). *About*. Illinois Alliance for Clean Transportation. Retrieved February 21, 2024, from https://il-act.org/about/

International Energy Agency. (2022). *Methane and climate change*. IEA. https://www.iea.org/reports/global-methane-tracker-2022/methane-and-climate-change

International Energy Agency. (2023). *Trends in Charging Infrastructure – Global EV Outlook 2023 – Analysis*. IEA. https://www.iea.org/reports/global-ev-outlook-2023/trends-in-charging-infrastructure

International Energy Association. (2020). *Snapshot 2020*. IEA-PVPS. https://iea-pvps.org/snapshot-reports/snapshot-2020/

Israel Central Bureau of Statistics. (2015). לוח 8.- כלי רכב מנועיים הרשומים (1), בערים *BY TYPE OF VEHICLE*. https://www.cbs.gov.il/he/publications/doclib/2016/1641/pdf/t08.pdf

Israel Central Bureau of Statistics. (2016). לוח 8.- כלי רכב מנועיים הרשומים (1), בערים *BY TYPE OF VEHICLE*. https://www.cbs.gov.il/he/publications/doclib/2017/1688/t08.pdf

Israel Central Bureau of Statistics. (2017). לוח 8. כלי רכב מנועיים הרשומים (1), בערים *BY TYPE OF VEHICLE*. https://www.cbs.gov.il/he/publications/doclib/2018/1726/t08.pdf

Israel Central Bureau of Statistics. (2018). לוח 8. כלי רכב מנועיים הרשומים, (1) בערים *BY TYPE OF VEHICLE*. https://www.cbs.gov.il/he/publications/doclib/2019/1762/t08.pdf

Israel Central Bureau of Statistics. (2019). לוח 8. כלי רכב מנועיים הרשומים, (1) בערים *BY TYPE OF VEHICLE*. https://www.cbs.gov.il/he/publications/doclib/2020/1806/t08.pdf

Israel Central Bureau of Statistics. (2020). לוח 8. כלי רכב מנועיים הרשומים, (1) בערים *BY TYPE OF VEHICLE*. https://www.cbs.gov.il/he/publications/doclib/2021/1836/t08.pdf

Israel Central Bureau of Statistics. (2021). לוח 8. כלי רכב מנועיים הרשומים, (1) בערים *BY TYPE OF VEHICLE*. https://www.cbs.gov.il/he/publications/doclib/2022/1872_motor_vehicles/t08.pdf

Israel Central Bureau of Statistics. (2022). לוח 8. כלי רכב מנועיים הרשומים, (1) בערים *BY TYPE OF VEHICLE*. https://www.cbs.gov.il/he/publications/doclib/2023/cars22_1910/t08a.pdf

Israel Central Bureau of Statistics. (2023a). *Kilometers Traveled in 2022*. https://www.cbs.gov.il/en/publications/Pages/2024/Vehicle-Kilometers-Travelled-2022.aspx

Israel Central Bureau of Statistics. (2023b). Motor Vehicles 2022. In *Central Bureau of Statistics*. Central Bureau of Statistics. https://www.cbs.gov.il/en/publications/Pages/2023/motor-vehicles-2022.aspx

Israel Central Bureau of Statistics. (2023c). *Regional Statistics - Eilat*. Www.cbs.gov.il. https://www.cbs.gov.il/EN/settlements/Pages/default.aspx?mode=Yeshuv

Israel Central Bureau of Statistics. (April 2, 2023). Number of electric cars in Israel from 2015 to 2022 [Graph]. In Statista. Retrieved November 14, 2023, from https://www.statista.com/statistics/1358744/number-of-electric-cars-in-israel/

Israel Ministry of Environmental Protection. (2020, November 2). *Climate Change Trends and Impact in Israel*. Gov.il. https://www.gov.il/en/departments/guides/climate_trends_and_impact_in_israel?chapterIndex=1

Johnson, S. (2018, December 7). *The sale of petrol and diesel vehicles in Israel will be banned by 2030*. World Economic Forum. https://www.weforum.org/agenda/2018/12/the-sale-of-petrol-and-diesel-vehicles-in-israel-will-be-banned-in-by-2030/#:~:text=The%20sale%20of%20petrol%20and

Liebes, I., Ayalon, O., Steinmetz, R., van der Ploeg, R., & Hogeveen, P. (2018). *Electric Vehicles Charging Infrastructure in Israel: Implementation Policy and Technical Guidelines*. Samuel Neaman Institute. https://www.neaman.org.il/EN/Electric-Vehicles-Charging-Infrastructure-in-Israel-Implementation-Policy-and-Technical-Guidelines

Lopez, L. (2022). *Grid Integration of Electric Vehicles A manual for policy makers*. https://iea.blob.core.windows.net/assets/21fe1dcb-c7ca-4e32-91d4-928715c9d14b/GridIntegrationofElectricVehicles.pdf

Maldonado, J., & Aviv, T. (2011). *Climate Change in Israel*. https://apps.fas.usda.gov/newgainapi/api/report/downloadreportbyfilename?filename=Climate%20Change%20in%20Israel_Tel%20Aviv_Israel_11-30-2011.pdf

Maxus Knowledge. (2014, February 10). *Facility location planning - Simple Median model*. Www.youtube.com. https://www.youtube.com/watch?v=5vdLithFDrM

Mayor's Press Office, City of Chicago. (2020, April 24). *Chicago City Council Approves Ordinance to Increase Chicago's Electric Vehicle Readiness Citywide*. Www.chicago.gov. https://www.chicago.gov/city/en/depts/cdot/provdrs/conservation_outreachgreenprograms/news/2020/april/chicago-city-council--approves-ordinance-to-increase-chicago-s-e.html

Moloughney, T. (2021, July 1). *What Are The Different Levels Of Electric Vehicle Charging?* Forbes Wheels. https://www.forbes.com/wheels/advice/ev-charging-levels/

Naim, A. (2023, November 14). *Eilat Transport Sponsor Meeting* [Personal communication].

Nelder, C., & Rogers, E. (2019). *Reducing EV Charging Infrastructure Costs*. RMI. https://rmi.org/insight/reducing-ev-charging-infrastructure-costs

Ntziachristos, L., & Samaras, Z. (2023). *1.A.3.b.i-iv Road transport 2023 — European Environment Agency*. Www.eea.europa.eu. https://www.eea.europa.eu/publications/emep-eea-guidebook-2023/part-b-sectoral-guidance-chapters/1-energy/1-a-combustion/1-a-3-b-i/view

Oslo Agency for Climate. (2022). *Greenhouse gas inventory for Oslo, 2009–2020*. Oslo Municipality.

Oslo, Norway Metro Area Population 1950-2024. (2024). Macrotrends.net. https://www.macrotrends.net/cities/22028/oslo/population

Overview of Greenhouse Gases | US EPA. (2015, December 23). US EPA. https://www.epa.gov/ghgemissions/overview-greenhouse-gases

Pforzheimer, A., & Neumann, J. (2022). Shining Cities 2022 The Top U.S. Cities for Solar Energy. In *The Public Interest Network*. https://www.google.com/search?q=shining+cities+2022&oq=shining+cities+2022&gs_lcrp=EgZjaHJvbWUyCwgAEEUYExg5GIAEMgkIARAAGBMYgAQyBggCEEUYPNIBCDI1MTZqMGo3qAIAsAIA&sourceid=chrome&ie=UTF-8#:~:text=New%20York%2C%20NY-,Shining%20Cities%202022,https%3A//publicinterestnetwork.org%20%E2%80%BA%202022/08%20%E2%80%BA%20S...,-PDF

Planning a Vacation in Eilat. (n.d.). Eilat.city. Retrieved January 24, 2024, from https://eilat.city/en/info/planning-a-vacation-in-eilat

PlugShare. (2024a). לב אילת | *Eilat, South District | EV Station*. Www.plugshare.com. https://www.plugshare.com/location/568349

PlugShare. (2024b, February 5). *Urban Honolulu, Hawaii EV Charging Stations | PlugShare*. Www.plugshare.com. https://www.plugshare.com/directory/us/hawaii/urban-honolulu#:~:text=The%20city%20of%20Urban%20Honolulu

Program for distance between two points on earth. (2017, December 24). GeeksforGeeks. https://www.geeksforgeeks.org/program-distance-two-points-earth/

Rabinovitch, A. (2023, September 12). *Israel expects 30% of cars on its roads to be electric by 2030* (S. Singleton, Ed.). Reuters. https://www.reuters.com/business/autos-transportation/israel-expects-30-cars-its-roads-be-electric-by-2030-2023-09-12/

Rising Ocean Temps Raise New Concerns for Coral Reefs. (2023, July 26). National Environmental Satellite, Data, and Information Service. https://www.nesdis.noaa.gov/news/rising-ocean-temps-raise-new-concerns-coral-reefs

Ritchie, H., & Roser, M. (2023, September 27). *Cars, planes, trains: where do CO2 emissions from transport come from?* Our World in Data. https://ourworldindata.org/co2-emissions-from-transport#article-citation

Schwartz, D., Bates, R., & Marcil, S. (2021). *Evaluation of Greenhouse Gas Emissions in Eilat.* : Worcester Polytechnic Institute.

Shrestha, S., Baral, B., Shah, M., Chitrakar, S., & Shrestha, B. P. (2022). Measures to Resolve Range Anxiety in Electric Vehicle Users. *International Journal of Low-Carbon Technologies*, *17*. https://doi.org/10.1093/ijlct/ctac100

Sofer, M., & Potchter, O. (2005). The urban heat island of a city in an arid zone: the case of Eilat, Israel. *Theoretical and Applied Climatology*, *85*(1-2), 81–88. https://doi.org/10.1007/s00704-005-0181-9

Tesla. (n.d.). *Tesla Superchargers in Israel*. Tesla. Retrieved November 19, 2023, from https://www.tesla.com/findus/list/superchargers/Israel

The Weather in Eilat. (2021). Eilat.city. https://eilat.city/en/info/the-weather-in-eilat

Topel, E. (n.d.). *Eilat-Eilot international Conference*. Www.eilatenergy.org. https://www.eilatenergy.org/speakers/

Tourist Israel. (2022, January 31). *40 Israel Travel & Tourism Statistics for 2022*. Tourist Israel. https://www.touristisrael.com/israel-travel-tourism-statistics/53929/

Transportation in Eilat. (n.d.). Eilat.city. https://eilat.city/en/info/transportation-in-eilat

UNFCCC. (2023). *The Paris Agreement*. United Nations Climate Change; United Nations. https://unfccc.int/process-and-meetings/the-paris-agreement

United Nations. (2023). *What Is Climate change?* Climate Action; United Nations. https://www.un.org/en/climatechange/what-is-climate-change

United States Census Bureau (2022). Annual Estimates of Resident Population Change for Incorporated Places of 50,000 or More in 2020, Ranked by Percent Change: July 1, 2021 to July 1, 2022. https://www2.census.gov/programs-surveys/popest/tables/2020-2022/cities/totals/#:~:text=SUB%2DIP%2DEST2022%2DANNCHG.xlsx

US Department of Energy. (n.d.). *Alternative Fuels Data Center: TransAtlas*. Afdc.energy.gov. Retrieved February 14, 2024, from https://afdc.energy.gov/transatlas/#/?year=2022&state=HI

Relating to Height Limits for Rooftop Structures, no. 22-28 (2022). https://hnldoc.ehawaii.gov/hnldoc/measure/2270#:~:text=05%2D22%20CCL-,ORD22%2D028,-Proposed%20Drafts

Weissberg, H. (2018, October 24). Only 22% of Israelis commute on public transport. *Globes*. https://en.globes.co.il/en/article-only-22-of-israelis-commute-on-public-transport-1001257760

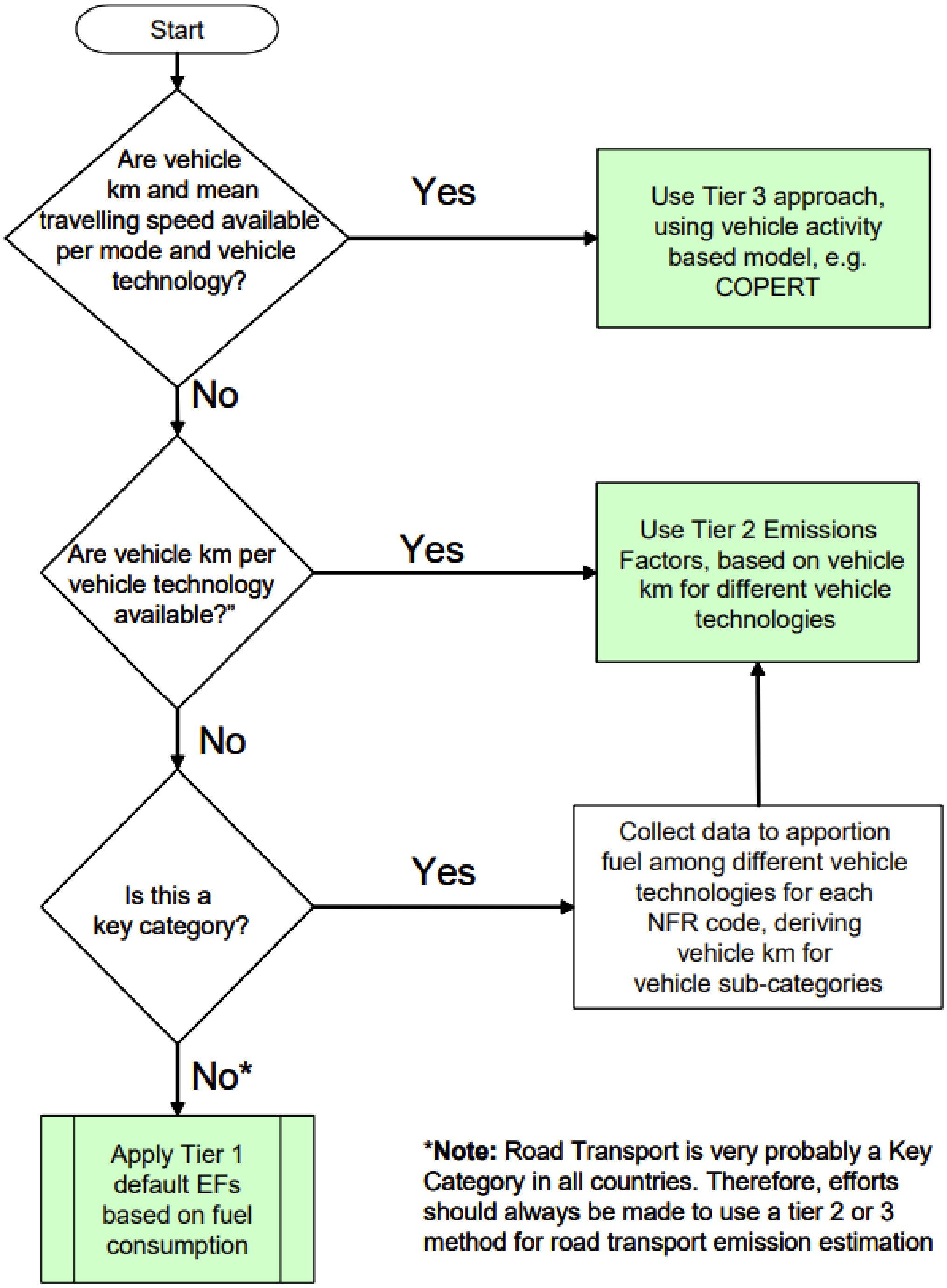
Yong, J. Y., Tan, W. S., Khorasany, M., & Razzaghi, R. (2023). Electric vehicles destination charging: An overview of charging tariffs, business models and coordination strategies. *Renewable and Sustainable Energy Reviews*, *184*, 113534. https://doi.org/10.1016/j.rser.2023.113534

Zinaman, O., Bopp, K., Lee, N., & Beshilas, L. (2020). *Electric Vehicle Supply Equipment: Tariff Design Support to the Lao PDR*. https://www.nrel.gov/docs/fy20osti/77747.pdf

Zohar, T., Parag, Y., & Ayalon, O. (2022). Weaving an innovation network from the middle-out: the case of the renewable energy ecosystem. *Energy, Sustainability and Society*, *12*(1). https://doi.org/10.1186/s13705-022-00364-2

Appendices

Appendix A: EEA Decision Tree From Exhaust Emissions for Road Transport



Note. From *1.A.3.b.i-iv Road Transport 2023 — European Environment Agency* by Ntziachristos et al., Retrieved January 25, 2024 (https://www.eea.europa.eu/publications/emep-eea-guidebook-2023/part-b-sectoral-guidance-chapters/1-energy/1-a-combustion/1-a-3-b-i/view).

Appendix B: Vehicle Data From the Eilat Municipality and Extrapolated Vehicle Counts

Vehicle type	Fuel type	Cat	Engine capacity or weight limit	Euro Standard	Proportion of vehicles	Number of Vehicles
Car						21,951
Car	Petrol	M1	<1400 cc	Euro 0	0.000810229	17.78533007
Car	Petrol	M1	<1400 cc	Euro 1	0.000250418	5.496936005
Car	Petrol	M1	<1400 cc	Euro 2	0.001112358	24.41736423
Car	Petrol	M1	<1400 cc	Euro 3	0.008956673	196.607928
Car	Petrol	M1	<1400 cc	Euro 4	0.033748393	740.8109695
Car	Petrol	M1	<1400 cc	Euro 5	0.10995579	2,413.639555
Car	Petrol	M1	<1400 cc	Euro 6	0.148309036	3,255.531653
Car	Petrol	M1	1400-2000 cc	Euro 0	0.00115942	25.45043109
Car	Petrol	M1	1400-2000 cc	Euro 1	0.001340407	29.42327463
Car	Petrol	M1	1400-2000 cc	Euro 2	0.006939962	152.3391
Car	Petrol	M1	1400-2000 cc	Euro 3	0.039162893	859.664674
Car	Petrol	M1	1400-2000 cc	Euro 4	0.139411046	3,060.21187
Car	Petrol	M1	1400-2000 cc	Euro 5	0.143341628	3,146.492083
Car	Petrol	M1	1400-2000 cc	Euro 6	0.148250644	3,254.249885

Car	Petrol	M1	>2000 cc	Euro 0	0.001347379	29.57632157
Car	Petrol	M1	>2000 cc	Euro 1	0.000851481	18.69085781
Car	Petrol	M1	>2000 cc	Euro 2	0.001207064	26.49625186
Car	Petrol	M1	>2000 cc	Euro 3	0.00401483	88.12953085
Car	Petrol	M1	>2000 cc	Euro 4	0.018734614	411.2435105
Car	Petrol	M1	>2000 cc	Euro 5	0.018403434	403.9737807
Car	Petrol	M1	>2000 cc	Euro 6	0.005809592	127.5263645
Car	Diesel	M1	<1400 cc	Euro 0	9.00577E-06	0.197685634
Car	Diesel	M1	<1400 cc	Euro 1	2.03356E-06	0.044638691
Car	Diesel	M1	<1400 cc	Euro 2	5.81017E-07	0.012753912
Car	Diesel	M1	<1400 cc	Euro 3	1.33634E-05	0.293339972
Car	Diesel	M1	<1400 cc	Euro 4	2.84699E-05	0.62494168
Car	Diesel	M1	<1400 cc	Euro 5	0.000578984	12.70927315
Car	Diesel	M1	<1400 cc	Euro 6	0.000200741	4.406476542
Car	Diesel	M1	1400-2000 cc	Euro 0	2.03356E-06	0.044638691
Car	Diesel	M1	1400-2000 cc	Euro 1	8.71526E-07	0.019130868
Car	Diesel	M1	1400-2000 cc	Euro 2	0.000170819	3.749650082
Car	Diesel	M1	1400-2000 cc	Euro 3	0.0025129	55.16066873

Car	Diesel	M1	1400-2000 cc	Euro 4	0.006200036	136.0969933
Car	Diesel	M1	1400-2000 cc	Euro 5	0.012059306	264.7138173
Car	Diesel	M1	1400-2000 cc	Euro 6	0.032972444	723.7781202
Car	Diesel	M1	>2000 cc	Euro 0	2.58553E-05	0.567549077
Car	Diesel	M1	>2000 cc	Euro 1	0.000395963	8.691790922
Car	Diesel	M1	>2000 cc	Euro 2	0.001334306	29.28935855
Car	Diesel	M1	>2000 cc	Euro 3	0.004924994	108.1085338
Car	Diesel	M1	>2000 cc	Euro 4	0.006307524	138.456467
Car	Diesel	M1	>2000 cc	Euro 5	0.010350243	227.1981856
Car	Diesel	M1	>2000 cc	Euro 6	0.000607454	13.33421483
Car	LPG	M1	<1400 cc	Euro 0	2.32407E-06	0.051015647
Car	LPG	M1	<1400 cc	Euro 1	1.74305E-06	0.038261736
Car	LPG	M1	<1400 cc	Euro 2	2.61458E-06	0.057392603
Car	LPG	M1	<1400 cc	Euro 3	2.55648E-05	0.561172121
Car	LPG	M1	<1400 cc	Euro 4	0.000135668	2.978038416
Car	LPG	M1	<1400 cc	Euro 5	0.000246061	5.401281666
Car	LPG	M1	<1400 cc	Euro 6	6.6817E-05	1.466699862
Car	LPG	M1	1400-2000 cc	Euro 1	6.6817E-06	0.146669986
Car	LPG	M1	1400-2000 cc	Euro 2	5.22916E-05	1.147852066

Car	LPG	M1	1400-2000 cc	Euro 3	0.000322755	7.08479803
Car	LPG	M1	1400-2000 cc	Euro 4	0.001404028	30.81982797
Car	LPG	M1	1400-2000 cc	Euro 5	0.00080529	17.67692182
Car	LPG	M1	1400-2000 cc	Euro 6	0.000206261	4.527638705
Car	LPG	M1	>2000 cc	Euro 0	5.22916E-06	0.114785207
Car	LPG	M1	>2000 cc	Euro 1	6.91411E-05	1.51771551
Car	LPG	M1	>2000 cc	Euro 2	8.57001E-05	1.881201997
Car	LPG	M1	>2000 cc	Euro 3	0.000426176	9.354994338
Car	LPG	M1	>2000 cc	Euro 4	0.00194205	42.62995034
Car	LPG	M1	>2000 cc	Euro 5	0.000516524	11.33822763
Car	LPG	M1	>2000 cc	Euro 6	3.28275E-05	0.720596019
Car	Hybrid	M1	<1400 cc	Euro 3	0	0
Car	Hybrid	M1	<1400 cc	Euro 4	0.000832017	18.26360176
Car	Hybrid	M1	<1400 cc	Euro 5	0.002731944	59.96889349
Car	Hybrid	M1	<1400 cc	Euro 6	0.000852062	18.70361172
Car	Hybrid	M1	1400-2000 cc	Euro 3	1.04583E-05	0.229570413
Car	Hybrid	M1	1400-2000 cc	Euro 4	0.001737242	38.13419642
Car	Hybrid	M1	1400-2000 cc	Euro 5	0.007800448	171.2276435
Car	Hybrid	M1	1400-2000 cc	Euro 6	0.055539158	1,219.140056

Car	Hybrid	M1	>2000 cc	Euro 4	7.90184E-05	1.734532011
Car	Hybrid	M1	>2000 cc	Euro 5	0.001669844	36.65474264
Car	Hybrid	M1	>2000 cc	Euro 6	0.007689765	168.7980233
Car	Electric	M1	<1400 cc	Euro 5	0.000418042	9.176439572
Car	Electric	M1	<1400 cc	Euro 6	0.001783723	39.15450936
Car	Petrol	M2	0-5000 kg	Euro 0	2.58553E-05	0.567549077
Car	Petrol	M2	0-5000 kg	Euro 1	8.71526E-07	0.019130868
Car	Petrol	M2	0-5000 kg	Euro 3	1.74305E-06	0.038261736
Car	Petrol	M2	0-5000 kg	Euro 4	2.03356E-06	0.044638691
Car	Petrol	M2	0-5000 kg	Euro 5	1.19109E-05	0.261455193
Car	Petrol	M2	0-5000 kg	Euro 6	1.24919E-05	0.274209105
Car	Diesel	M2	0-5000 kg	Euro 0	8.71526E-07	0.019130868
Car	Diesel	M2	0-5000 kg	Euro 1	3.77661E-06	0.082900427
Car	Diesel	M2	0-5000 kg	Euro 2	1.62685E-05	0.357109532
Car	Diesel	M2	0-5000 kg	Euro 3	4.29953E-05	0.943789476
Car	Diesel	M2	0-5000 kg	Euro 4	5.43251E-05	1.192490757
Car	Diesel	M2	0-5000 kg	Euro 5	0.000207714	4.559523484
Car	Diesel	M2	0-5000 kg	Euro 6	0.00024577	5.39490471
Car	LPG	M2	0-5000 kg	Euro 3	8.71526E-07	0.019130868

Car	LPG	M2	0-5000 kg	Euro 6	0	0
Car	Diesel	M3	0-5000 kg	Euro 3	0	0
Car	Diesel	M3	0-5000 kg	Euro 6	5.78112E-05	1.269014229
LCV						1,098
LCV	Petrol	N1	≤ 1250 kg	Euro 0	5.49002E-05	0.060280462
LCV	Petrol	N1	≤ 1305 kg	Euro 6	0	0
LCV	Petrol	N1	1250 ≤ 1700 kg	Euro 0	0.009160497	10.05822562
LCV	Petrol	N1	1250 ≤ 1700 kg	Euro 1	0.000658803	0.723365541
LCV	Petrol	N1	1250 ≤ 1700 kg	Euro 2	3.92145E-05	0.043057473
LCV	Petrol	N1	1305 ≤ 1760 kg	Euro 3	0	0
LCV	Petrol	N1	1305 ≤ 1760 kg	Euro 4	0.000564688	0.620027607
LCV	Petrol	N1	1305 ≤ 1760 kg	Euro 5	0.000227444	0.249733342
LCV	Petrol	N1	1305 ≤ 1760 kg	Euro 6	0	0
LCV	Petrol	N1	1700 kg <	Euro 0	0.012195696	13.39087401
LCV	Petrol	N1	1700 kg <	Euro 1	0.004125361	4.529646129
LCV	Petrol	N1	1700 kg <	Euro 2	0.000501945	0.551135651

LCV	Petrol	N1	1760 kg <	Euro 3	0.001364663	1.49840005
LCV	Petrol	N1	1760 kg <	Euro 4	0.014289748	15.69014305
LCV	Petrol	N1	1760 kg <	Euro 5	0.014917179	16.37906262
LCV	Petrol	N1	1760 kg <	Euro 6	0.001772493	1.946197766
LCV	Diesel	N1	1250 ≤ 1700 kg	Euro 1	0.000149015	0.163618396
LCV	Diesel	N1	1250 ≤ 1700 kg	Euro 2	0.000509788	0.559747145
LCV	Diesel	N1	1305 ≤ 1760 kg	Euro 3	0.00035293	0.387517254
LCV	Diesel	N1	1305 ≤ 1760 kg	Euro 4	9.41147E-05	0.103337934
LCV	Diesel	N1	1305 ≤ 1760 kg	Euro 5	0.000133329	0.146395407
LCV	Diesel	N1	1305 ≤ 1760 kg	Euro 6	7.84289E-06	0.008611495
LCV	Diesel	N1	1700 kg <	Euro 0	0.002948927	3.237921948
LCV	Diesel	N1	1700 kg <	Euro 1	0.0394968	43.36748651
LCV	Diesel	N1	1700 kg <	Euro 2	0.036053771	39.58704041
LCV	Diesel	N1	1760 kg <	Euro 3	0.111965115	122.9376961
LCV	Diesel	N1	1760 kg <	Euro 4	0.229882984	252.4115165
LCV	Diesel	N1	1760 kg <	Euro 5	0.258729138	284.0845934

LCV	Diesel	N1	1760 kg <	Euro 6	0.257082131	282.2761796
LCV	LPG	N1	1305 ≤ 1760 kg	Euro 4	1.56858E-05	0.017222989
LCV	LPG	N1	1305 ≤ 1760 kg	Euro 6	0	0
LCV	LPG	N1	1700 kg <	Euro 0	5.49002E-05	0.060280462
LCV	LPG	N1	1700 kg <	Euro 1	0.000203915	0.223898858
LCV	LPG	N1	1700 kg <	Euro 2	3.92145E-05	0.043057473
LCV	LPG	N1	1760 kg <	Euro 3	0.000282344	0.310013803
LCV	LPG	N1	1760 kg <	Euro 4	0.000752918	0.826703476
LCV	LPG	N1	1760 kg <	Euro 5	0.001364663	1.49840005
LCV	LPG	N1	1760 kg <	Euro 6	7.84289E-06	0.008611495
Minibus						37
Minibus	Petrol	M1	1400-2000 cc	Euro 1	0	0
Minibus	Petrol	M1	1400-2000 cc	Euro 6	0	0
Minibus	Petrol	M1	>2000 cc	Euro 1	0	0
Minibus	Petrol	M1	>2000 cc	Euro 6	0	0
Minibus	LPG	M1	>2000 cc	Euro 1	0	0
Minibus	LPG	M1	>2000 cc	Euro 6	0	0
Minibus	Diesel	M1	<1400 cc	Euro 2	0	0

Minibus	Diesel	M1	<1400 cc	Euro 6	0	0
Minibus	Diesel	M1	1400-2000 cc	Euro 2	0	0
Minibus	Diesel	M1	1400-2000 cc	Euro 3	6.32871E-05	0.002341624
Minibus	Diesel	M1	1400-2000 cc	Euro 4	0.002025188	0.074931966
Minibus	Diesel	M1	1400-2000 cc	Euro 5	0.026011012	0.962407443
Minibus	Diesel	M1	1400-2000 cc	Euro 6	0	0
Minibus	Diesel	M1	>2000 cc	Euro 0	0	0
Minibus	Diesel	M1	>2000 cc	Euro 1	0	0
Minibus	Diesel	M1	>2000 cc	Euro 2	0	0
Minibus	Diesel	M1	>2000 cc	Euro 3	0.001392317	0.051515727
Minibus	Diesel	M1	>2000 cc	Euro 4	0.003417505	0.126447693
Minibus	Diesel	M1	>2000 cc	Euro 5	0.00993608	0.36763496
Minibus	Diesel	M1	>2000 cc	Euro 6	0	0
Minibus	Petrol	M2	0-5,000 kg	Euro 1	0	0
Minibus	Petrol	M2	0-5,000 kg	Euro 5	0.000126574	0.004683248
Minibus	Petrol	M2	0-5,000 kg	Euro 6	0.000126574	0.004683248
Minibus	LPG	M2	0-5,000 kg	Euro 1	0	0
Minibus	LPG	M2	0-5,000 kg	Euro 6	0	0
Minibus	Diesel	M2	0-5,000 kg	Euro 1	0.000253149	0.009366496

Minibus	Diesel	M2	0-5,000 kg	Euro 2	0.015125625	0.559648124
Minibus	Diesel	M2	0-5,000 kg	Euro 3	0.054300361	2.009113347
Minibus	Diesel	M2	0-5,000 kg	Euro 4	0.132523258	4.903360547
Minibus	Diesel	M2	0-5,000 kg	Euro 5	0.340231631	12.58857034
Minibus	Diesel	M2	0-5,000 kg	Euro 6	0.414467439	15.33529523
Truck						633
RT	Petrol	N2	3,500-7,500 kg	Euro 0	0.000206303	0.130589779
RT	Petrol	N2	3,500-7,500 kg	Euro 1	0.000561144	0.355204199
RT	Petrol	N2	3,500-7,500 kg	Euro 2	0.000264068	0.167154917
RT	Petrol	N2	3,500-7,500 kg	Euro 3	0.000552892	0.349980608
RT	Petrol	N2	3,500-7,500 kg	Euro 4	0.0005859	0.370874972
RT	Petrol	N2	3,500-7,500 kg	Euro 5	0.001254322	0.793985856
RT	Petrol	N2	3,500-7,500 kg	Euro 6	0	0
AT	Diesel	N3	14,001-20,000 kg	Euro 5	0.001501886	0.950693591
AT	Diesel	N3	14,001-20,000 kg	Euro 6	0.001369852	0.867116132
AT	Diesel	N3	20,001-26,000 kg	Euro 3	0.00015679	0.099248232
AT	Diesel	N3	20,001-26,000 kg	Euro 6	0.00124607	0.788762265

AT	Diesel	N3	28,001-32,000 kg	Euro 0	4.12606E-05	0.026117956
AT	Diesel	N3	28,001-32,000 kg	Euro 1	8.25212E-06	0.005223591
AT	Diesel	N3	28,001-32,000 kg	Euro 2	8.25212E-06	0.005223591
AT	Diesel	N3	28,001-32,000 kg	Euro 3	1.65042E-05	0.010447182
AT	Diesel	N3	28,001-32,000 kg	Euro 4	0.000148538	0.094024641
AT	Diesel	N3	28,001-32,000 kg	Euro 5	0.000396102	0.250732376
AT	Diesel	N3	28,001-32,000 kg	Euro 6	0.000709682	0.44922884
AT	Diesel	N3	32,001-40,000 kg	Euro 0	4.12606E-05	0.026117956
AT	Diesel	N3	32,001-40,000 kg	Euro 1	8.25212E-06	0.005223591
AT	Diesel	N3	32,001-40,000 kg	Euro 2	3.30085E-05	0.020894365
AT	Diesel	N3	32,001-40,000 kg	Euro 3	0.00015679	0.099248232
AT	Diesel	N3	32,001-40,000 kg	Euro 4	0.000148538	0.094024641
AT	Diesel	N3	32,001-40,000 kg	Euro 5	0.000379597	0.240285193

AT	Diesel	N3	32,001-40,000 kg	Euro 6	0.001526642	0.966364364
AT	Diesel	N3	>40,000 kg	Euro 0	0.000165042	0.104471823
AT	Diesel	N3	>40,000 kg	Euro 1	4.95127E-05	0.031341547
AT	Diesel	N3	>40,000 kg	Euro 2	9.07733E-05	0.057459503
AT	Diesel	N3	>40,000 kg	Euro 3	0.000107278	0.067906685
AT	Diesel	N3	>40,000 kg	Euro 4	0.000165042	0.104471823
AT	Diesel	N3	>40,000 kg	Euro 5	0.00054464	0.344757016
AT	Diesel	N3	>40,000 kg	Euro 6	0.001873231	1.185755193
RT	Diesel	N2	3,500-7,500 kg	Euro 0	0.056494005	35.76070506
RT	Diesel	N2	3,500-7,500 kg	Euro 1	0.05659303	35.82338815
RT	Diesel	N2	3,500-7,500 kg	Euro 2	0.024706843	15.63943192
RT	Diesel	N2	3,500-7,500 kg	Euro 3	0.078494153	49.68679909
RT	Diesel	N2	3,500-7,500 kg	Euro 4	0.112979758	71.51618653
RT	Diesel	N2	3,500-7,500 kg	Euro 5	0.201203159	127.3615996
RT	Diesel	N2	3,500-7,500 kg	Euro 6	0	0
RT	Diesel	N2	7,501-12,000 kg	Euro 0	0.000750943	0.475346795
RT	Diesel	N2	7,501-12,000 kg	Euro 1	0.002450879	1.551406574

RT	Diesel	N2	7,501-12,000 kg	Euro 2	0.003333856	2.110330827
RT	Diesel	N2	7,501-12,000 kg	Euro 3	0.008829767	5.589242538
RT	Diesel	N2	7,501-12,000 kg	Euro 4	0.016479481	10.43151154
RT	Diesel	N2	7,501-12,000 kg	Euro 5	0.080053804	50.67405781
RT	Diesel	N2	7,501-12,000 kg	Euro 6	0	0
RT	Diesel	N3	12,001-14,000 kg	Euro 0	0.00011553	0.073130276
RT	Diesel	N3	12,001-14,000 kg	Euro 1	0.000107278	0.067906685
RT	Diesel	N3	12,001-14,000 kg	Euro 2	5.77648E-05	0.036565138
RT	Diesel	N3	12,001-14,000 kg	Euro 3	1.65042E-05	0.010447182
RT	Diesel	N3	12,001-14,000 kg	Euro 4	3.30085E-05	0.020894365
RT	Diesel	N3	12,001-14,000 kg	Euro 6	0.000750943	0.475346795
RT	Diesel	N3	14,001-20,000 kg	Euro 0	0.000247564	0.156707735
RT	Diesel	N3	14,001-20,000 kg	Euro 1	0.000503379	0.318639061

RT	Diesel	N3	14,001-20,000 kg	Euro 2	0.003432881	2.173013921
RT	Diesel	N3	14,001-20,000 kg	Euro 3	0.010447182	6.613066405
RT	Diesel	N3	14,001-20,000 kg	Euro 4	0.014515477	9.188296845
RT	Diesel	N3	14,001-20,000 kg	Euro 5	0.029245509	18.51240706
RT	Diesel	N3	14,001-20,000 kg	Euro 6	0.050296664	31.8377881
RT	Diesel	N3	20,001-26,000 kg	Euro 0	0.000330085	0.208943646
RT	Diesel	N3	20,001-26,000 kg	Euro 1	0.000503379	0.318639061
RT	Diesel	N3	20,001-26,000 kg	Euro 2	0.001378104	0.872339723
RT	Diesel	N3	20,001-26,000 kg	Euro 3	0.003325604	2.105107236
RT	Diesel	N3	20,001-26,000 kg	Euro 4	0.005000784	3.165496241
RT	Diesel	N3	20,001-26,000 kg	Euro 5	0.01211411	7.668231819
RT	Diesel	N3	20,001-26,000 kg	Euro 6	0.024310742	15.38869955
RT	Diesel	N3	26,001-28,000 kg	Euro 0	0	0

RT	Diesel	N3	26,001-28,000 kg	Euro 1	2.47564E-05	0.015670773
RT	Diesel	N3	26,001-28,000 kg	Euro 2	1.65042E-05	0.010447182
RT	Diesel	N3	26,001-28,000 kg	Euro 3	0.000148538	0.094024641
RT	Diesel	N3	26,001-28,000 kg	Euro 4	1.65042E-05	0.010447182
RT	Diesel	N3	26,001-28,000 kg	Euro 5	0	0
RT	Diesel	N3	26,001-28,000 kg	Euro 6	0	0
RT	Diesel	N3	28,001-32,000 kg	Euro 0	3.30085E-05	0.020894365
RT	Diesel	N3	28,001-32,000 kg	Euro 1	0.000264068	0.167154917
RT	Diesel	N3	28,001-32,000 kg	Euro 2	0.001543146	0.976811546
RT	Diesel	N3	28,001-32,000 kg	Euro 3	0.003028528	1.917057955
RT	Diesel	N3	28,001-32,000 kg	Euro 4	0.00599929	3.797550771
RT	Diesel	N3	28,001-32,000 kg	Euro 5	0.025639333	16.22969772
RT	Diesel	N3	28,001-32,000 kg	Euro 6	0.073295319	46.39593666

RT	Diesel	N3	32,001-40,000 kg	Euro 0	8.25212E-06	0.005223591
RT	Diesel	N3	32,001-40,000 kg	Euro 1	8.25212E-06	0.005223591
RT	Diesel	N3	32,001-40,000 kg	Euro 2	4.12606E-05	0.026117956
RT	Diesel	N3	32,001-40,000 kg	Euro 3	0.00042911	0.27162674
RT	Diesel	N3	32,001-40,000 kg	Euro 4	8.25212E-05	0.052235912
RT	Diesel	N3	32,001-40,000 kg	Euro 5	8.25212E-05	0.052235912
RT	Diesel	N3	32,001-40,000 kg	Euro 6	0.000305328	0.193272873
RT	Diesel	N3	>40,000 kg	Euro 0	5.77648E-05	0.036565138
RT	Diesel	N3	>40,000 kg	Euro 1	5.77648E-05	0.036565138
RT	Diesel	N3	>40,000 kg	Euro 2	0.000239311	0.151484144
RT	Diesel	N3	>40,000 kg	Euro 3	0.001114036	0.705184806
RT	Diesel	N3	>40,000 kg	Euro 4	0.005207087	3.29608602
RT	Diesel	N3	>40,000 kg	Euro 5	0.017808072	11.27250972
RT	Diesel	N3	>40,000 kg	Euro 6	0.050651505	32.06240252
RT	LPG	N2	3,500-7,500 kg	Euro 0	0.000132034	0.083577459
RT	LPG	N2	3,500-7,500 kg	Euro 1	6.60169E-05	0.041788729

RT	LPG	N2	3,500-7,500 kg	Euro 3	9.07733E-05	0.057459503
RT	LPG	N2	3,500-7,500 kg	Euro 4	0.000181547	0.114919005
RT	LPG	N2	3,500-7,500 kg	Euro 6	0	0
RT	LPG	N2	7,501-12,000 kg	Euro 3	8.25212E-06	0.005223591
RT	LPG	N2	7,502-12000 kg	Euro 6	0	0
Bus						50
Ubus	Diesel	M2	0-5,000 kg	Euro 3	0	0
Ubus	Diesel	M2	0-5,000 kg	Euro 4	0	0
Ubus	Diesel	M2	0-5,000 kg	Euro 5	0.001692575	1.071399938
Ubus	Diesel	M2	0-5,000 kg	Euro 6	0.010823571	0.541178567
Bus	Diesel	M2	0-5,000 kg	Euro 1	0	0
Bus	Diesel	M2	0-5,000 kg	Euro 2	0	0
Bus	Diesel	M2	0-5,000 kg	Euro 3	0.001336243	0.066812169
Bus	Diesel	M2	0-5,000 kg	Euro 4	0.006592134	0.329606699
Bus	Diesel	M2	0-5,000 kg	Euro 5	0.046634894	2.331744688
Bus	Diesel	M2	0-5,000 kg	Euro 6	0.076655828	3.832791412
Bus	Diesel	M3	<=15,000 kg	Euro 0	4.45414E-05	0.002227072
Bus	Diesel	M3	<=15,000 kg	Euro 1	0	0

Bus	Diesel	M3	<=15,000 kg	Euro 2	8.90829E-05	0.004454145
Bus	Diesel	M3	<=15,000 kg	Euro 3	0.000267249	0.013362434
Bus	Diesel	M3	<=15,000 kg	Euro 4	0.001781658	0.089082892
Bus	Diesel	M3	<=15,000 kg	Euro 5	0.011580776	0.579038796
Bus	Diesel	M3	<=15,000 kg	Euro 6	0.029397354	1.469867712
Bus	Diesel	M3	15,001-18.000 kg	Euro 0	4.45414E-05	0.002227072
Bus	Diesel	M3	15,001-18.000 kg	Euro 1	0	0
Bus	Diesel	M3	15,001-18.000 kg	Euro 2	4.45414E-05	0.002227072
Bus	Diesel	M3	15,001-18.000 kg	Euro 3	8.90829E-05	0.004454145
Bus	Diesel	M3	15,001-18.000 kg	Euro 4	0.001291702	0.064585096
Bus	Diesel	M3	15,001-18.000 kg	Euro 5	0.003162443	0.158122133
Bus	Diesel	M3	15,001-18.000 kg	Euro 6	0.003652399	0.182619928
Bus	Diesel	M3	>18,000 kg	Euro 1	0	0
Bus	Diesel	M3	>18,000 kg	Euro 2	0.000979912	0.04899559
Bus	Diesel	M3	>18,000 kg	Euro 3	0.011224444	0.561222217
Bus	Diesel	M3	>18,000 kg	Euro 4	0.064273306	3.213665316

Bus	Diesel	M3	>18,000 kg	Euro 5	0.188009443	9.400472139
Bus	Diesel	M3	>18,000 kg	Euro 6	0.249654804	12.48274019
UBus	Diesel	M3	<=15,000 kg	Euro 2	0	0
UBus	Diesel	M3	<=15,000 kg	Euro 3	4.45414E-05	0.002227072
UBus	Diesel	M3	<=15,000 kg	Euro 4	0.002717028	0.13585141
UBus	Diesel	M3	<=15,000 kg	Euro 5	0.001826199	0.091309964
UBus	Diesel	M3	<=15,000 kg	Euro 6	0.009932742	0.496637121
UBus	Diesel	M3	15,001-18,000 kg	Euro 1	0	0
UBus	Diesel	M3	15,001-18,000 kg	Euro 2	0	0
UBus	Diesel	M3	15,001-18,000 kg	Euro 3	0.004275979	0.21379894
UBus	Diesel	M3	15,001-18,000 kg	Euro 4	0.012560688	0.628034386
UBus	Diesel	M3	15,001-18,000 kg	Euro 5	0.030332725	1.51663623
UBus	Diesel	M3	15,001-18,000 kg	Euro 6	0.011313527	0.565676362
UBus	Diesel	M3	>18,000 kg	Euro 1	0	0
UBus	Diesel	M3	>18,000 kg	Euro 2	0	0
UBus	Diesel	M3	>18,000 kg	Euro 3	0.000668122	0.033406084

UBus	Diesel	M3	>18,000 kg	Euro 4	0.0049441	0.247205024
UBus	Diesel	M3	>18,000 kg	Euro 5	0.071132689	3.556634448
UBus	Diesel	M3	>18,000 kg	Euro 6	0.135717785	6.78588927
UBus	Electric	M3	15,001-18,000 kg	Euro 5	4.45414E-05	0.002227072
UBus	Electric	M3	15,001-18,000 kg	Euro 6	0.005166808	0.258340386
Motorcycle						1691
Moped	Petrol	L1	< 50 cc	Euro 0	0.000427641	0.270696861
Moped	Petrol	L1	< 50 cc	Euro 1	0.001412512	0.894119934
Moped	Petrol	L1	< 50 cc	Euro 2	0.001626332	1.029468364
Moped	Petrol	L1	< 50 cc	Euro 3	0	0
Motorcycle	Petrol	L1	51 - 150 cc	Euro 0	0.000136068	0.086130819
Motorcycle	Petrol	L1	51 - 150 cc	Euro 1	0.000149026	0.094333754
Motorcycle	Petrol	L1	51 - 150 cc	Euro 2	0.001516182	0.959743415
Motorcycle	Petrol	L1	51 - 150 cc	Euro 3	0.324819386	549.2695824
Motorcycle	Petrol	L1	< 50 cc	Euro 0	0.001833674	3.100741893
Motorcycle	Petrol	L1	< 50 cc	Euro 1	0.001483785	2.509080895
Motorcycle	Petrol	L1	< 50 cc	Euro 2	0.000764571	1.292888846
Motorcycle	Petrol	L1	< 50 cc	Euro 3	0.000920076	1.555849289

Motorcycle	Petrol	L2	< 50 cc	Euro 3	1.94382E-05	0.032870055
Motorcycle	Petrol	L2	51 - 150 cc	Euro 0	0.000233259	0.394440665
Motorcycle	Petrol	L2	51 - 150 cc	Euro 1	0	0
Motorcycle	Petrol	L2	51 - 150 cc	Euro 2	5.18353E-05	0.087653481
Motorcycle	Petrol	L2	51 - 150 cc	Euro 3	0.001775359	3.002131726
Motorcycle	Petrol	L2	151 - 250 cc	Euro 0	0.003667347	6.201483785
Motorcycle	Petrol	L2	151 - 250 cc	Euro 1	0.00165225	2.793954709
Motorcycle	Petrol	L2	151 - 250 cc	Euro 2	0.0048466	8.195600479
Motorcycle	Petrol	L2	151 - 250 cc	Euro 3	0.491217157	830.6482133
Motorcycle	Petrol	L3	251 - 750 cc	Euro 0	0.007626268	12.8960184
Motorcycle	Petrol	L3	251 - 750 cc	Euro 1	0.004729971	7.998380147
Motorcycle	Petrol	L3	251 - 750 cc	Euro 2	0.002572326	4.349803998
Motorcycle	Petrol	L3	251 - 750 cc	Euro 3	0.048148508	81.41912722
Motorcycle	Petrol	L3	>750 cc	Euro 0	0.008734247	14.76961156
Motorcycle	Petrol	L3	>750 cc	Euro 1	0.004580944	7.746376389
Motorcycle	Petrol	L3	>750 cc	Euro 2	0.003038844	5.138685327
Motorcycle	Petrol	L3	>750 cc	Euro 3	0.071707649	121.2576344
Motorcycle	Electric	L3	>750 cc	Euro 3	0.010308744	17.43208605

Appendix C: Tier One Coefficients

Category	Fuel	Typical Fuel Consumption (g/km)	CO2 Fossil Fuels (kg CO2/kg fuel)	CO2 Lubricant (g/kg fuel)	N2O (g/kg fuel)
PC	Petrol	70	3.169	8.84	0.206
	Diesel	60	3.169	8.74	0.087
	LPG	57.5	3.024	8.84	0.089
LCV	Petrol	100	3.169	6.07	0.186
	Diesel	80	3.169	6.41	0.056
	LPG	76.7[a]	3.024	6.07[d]	0.057[g]
HDV	Petrol	300[b]	3.169	2.41[e]	0.169[h]
	Diesel	240	3.169	2.54	0.051
	LPG	230[c]	3.024	2.41[f]	0.052[i]
L-Category	Petrol	35	3.169	53.8	0.059

Note. These coefficients are from *1.A.3.b.i-iv Road Transport 2023 — European Environment Agency* (p.20, p.22, p.23) by Ntziachristos et al., 2023, (https://www.eea.europa.eu/publications/emep-eea-guidebook-2023/part-b-sectoral-guidance-chapters/1-energy/1-a-combustion/1-a-3-b-i/view). Copyright 2023 by European Environment Agency.

[a]1/.75 of the PC LPG value was used in line with the approximate ratios from petrol and diesel. [b]Used LCV petrol*3 in line with the difference over diesel coefficients. [c]Used PC LPG coefficient*4 in line with the diesel conversion between PC and HDV. [d]Used LCV petrol coefficient in line with PC similarities.[d]Used .95*diesel in line with LCV ratio. [f]Used petrol coefficient in line with PC ratio. [g]Used 1.02*diesel in line with PC ratio. [h]Used 3.32*diesel in line with LCV ratio. [i]Used 1.02*diesel in line with PC ratio

Appendix D: Tier Two Fuel Consumption Coefficients

Vehicle category	Sub-category	Technology	FC (g/km)
Passenger Cars	Petrol Mini	Euro 4 and later	49
Passenger Cars	Petrol Small	PRE-ECE to open loop	65
Passenger Cars	Petrol Small	Euro 1 and later	56
Passenger Cars	Petrol Medium	PRE-ECE to open loop	77
Passenger Cars	Petrol Medium	Euro 1 and later	66
Passenger Cars	Petrol Large-SUV-Executive	PRE-ECE to open loop	95
Passenger Cars	Petrol Large-SUV-Executive	Euro 1 and later	86
Passenger Cars	Diesel Small	Euro 4 and later	38[a]
Passenger Cars	Diesel Medium	Conventional	63
Passenger Cars	Diesel Medium	Euro 1 and later	55
Passenger Cars	Diesel Large-SUV-Executive	Conventional	75
Passenger Cars	Diesel Large-SUV-Executive	Euro 1 and later	73
Passenger Cars	LPG	Conventional	59
Passenger Cars	LPG	Euro 1 and later	57
Passenger Cars	2-stroke	Conventional	82

Passenger Cars	Hybrid Petrol Small	Euro 4 and later	34
Passenger Cars	Hybrid Petrol Medium	Euro 4 and later	34[b]
Passenger Cars	Hybrid Petrol Large-SUV-Executive	Euro 4 and later	34
Passenger Cars	PHEV Petrol Small	Euro 6 and later	34
Passenger Cars	PHEV Petrol Medium	Euro 6 and later	34
Passenger Cars	PHEV Petrol Large-SUV-Executive	Euro 6 and later	34
Passenger Cars	PHEV Diesel Large-SUV-Executive	Euro 5 and later	73
Passenger Cars	E85	Euro 4 and later	87
Passenger Cars	CNG	Euro 4 and later	63
Light Commercial Vehicles	Petrol	Conventional	85
Light Commercial Vehicles	Petrol	Euro 1 and later	70
Light Commercial Vehicles	Diesel	Conventional	89
Light Commercial Vehicles	Diesel	Euro 1 and later	80[c]
Heavy-Duty Trucks	Petrol > 3.5 t	Conventional	177[d]
Heavy-Duty Trucks	<=7.5 t	Conventional	125
Heavy-Duty Trucks	<=7.5 t	Euro 1 and later	101
Heavy-Duty Trucks	7.5-16 t	Conventional	182[e]

Heavy-Duty Trucks	7.5-16 t	Euro 1 and later	155[e]
Heavy-Duty Trucks	16-32 t	Conventional	251
Heavy-Duty Trucks	16-32 t	Euro 1 and later	210
Heavy-Duty Trucks	> 32 t	Conventional	297
Heavy-Duty Trucks	> 32 t	Euro 1 and later	251
Buses	Urban CNG buses	HD Euro I	555
Buses	Urban CNG buses	HD Euro II	515
Buses	Urban CNG buses	HD Euro III	455
Buses	Urban CNG buses	EEV	455
Buses	Urban buses, standard	Conventional	366
Buses	Urban buses, standard	Euro I and later	301
Buses	Coaches, standard	Conventional	263
Buses	Coaches, standard	Euro I and later	247
Buses	Urban Diesel Hybrid	Euro VI	225
L-category	Mopeds 2-stroke < 50 cm^3	Conventional	25
L-category	Mopeds 2-stroke < 50 cm^3	Euro 1	20
L-category	Mopeds 2-stroke < 50 cm^3	Euro 2	20
L-category	Mopeds 2-stroke < 50 cm^3	Euro 3 and later	20

L-category	Mopeds 4-stroke < 50 cm^3	Conventional	25
L-category	Mopeds 4-stroke < 50 cm^3	Euro 1	20
L-category	Mopeds 4-stroke < 50 cm^3	Euro 2	20
L-category	Mopeds 4-stroke < 50 cm^3	Euro 3 and later	20
L-category	Motorcycles 2-stroke > 50 cm^3	Conventional	33
L-category	Motorcycles 2-stroke > 50 cm^3	Euro 1	25
L-category	Motorcycles 2-stroke > 50 cm^3	Euro 2	23
L-category	Motorcycles 2-stroke > 50 cm^3	Euro 3 and later	17
L-category	Motorcycles 4-stroke < 250 cm^3	Conventional	32
L-category	Motorcycles 4-stroke < 250 cm^3	Euro 1 and later	36
L-category	Motorcycles 4-stroke 250-750 cm^3	Conventional	37
L-category	Motorcycles 4-stroke 250-750 cm^3	Euro 1 and later	36
L-category	Motorcycles 4-stroke > 750 cm^3	Conventional	45
L-category	Motorcycles 4-stroke > 750 cm^3	Euro 1 and later	46
L-category	Mini cars Diesel	Conventional	34
L-category	Mini cars Diesel	Euro 1	30
L-category	Mini cars Diesel	Euro 2	30
L-category	Mini cars Diesel	Euro 3	30

L-category	Mini cars Diesel	Euro 4	27
L-category	Mini cars Diesel	Euro 5	27
L-category	ATVs	Conventional	47
L-category	ATVs	Euro 1	41
L-category	ATVs	Euro 2	41
L-category	ATVs	Euro 3	41
L-category	ATVs	Euro 4	40
L-category	ATVs	Euro 5	40

Note. These coefficients are from *1.A.3.b.i-iv Road Transport 2023 — European Environment Agency* (p.33) by Ntziachristos et al., 2023, (https://www.eea.europa.eu/publications/emep-eea-guidebook-2023/part-b-sectoral-guidance-chapters/1-energy/1-a-combustion/1-a-3-b-i/view). Copyright 2023 by European Environment Agency.

[a]This coefficient was used for all technologies as there is no coefficient for vehicles before Euro 4. [b]This coefficient was used on Euro 3 vehicles as there is no coefficient for vehicles before Euro 4. [c]This coefficient was multiplied by 1.28 for use in LCVs and minibuses using LPG in line with the PC ratio between diesel and LPG. [d]This coefficient was used for all vehicle technologies as there is no petrol coefficient for newer vehicle technologies. [e]Trucks weighing between 14,001 and 20,000 kg used these coefficients.

Appendix E: Tier Two Emissions Coefficients

Passenger Cars

Type	Tech	N2O	CO2 lube
Petrol Mini	Euro 4 - 98/69/EC II	0.002	0.398
Petrol Mini	Euro 5 - EC 715/2007	0.0013	0.398

Petrol Mini	Euro 6 a/b/c	0.0013	0.398
Petrol Mini	Euro 6 d-temp	0.0013	0.398
Petrol Mini	Euro 6 d	0.0013	0.398
Petrol Small	PRE ECE	0.01	0.663
Petrol Small	ECE 15/00-01	0.01	0.663
Petrol Small	ECE 15/02	0.01	0.663
Petrol Small	ECE 15/03	0.01	0.663
Petrol Small	ECE 15/04	0.01	0.663
Petrol Small	Open Loop	0.01	0.663
Petrol Small	Euro 1 - 91/441/EEC	0.01	0.596
Petrol Small	Euro 2 - 94/12/EEC	0.006	0.53
Petrol Small	Euro 3 - 98/69/EC I	0.002	0.464
Petrol Small	Euro 4 - 98/69/EC II	0.002	0.398
Petrol Small	Euro 5 – EC 715/2007	0.0013	0.398
Petrol Small	Euro 6 a/b/c	0.0013	0.398
Petrol Small	Euro 6 d-temp	0.0013	0.398
Petrol Small	Euro 6 d	0.0013	0.398

Petrol Medium	PRE ECE	0.01	0.663
Petrol Medium	ECE 15/00-01	0.01	0.663
Petrol Medium	ECE 15/02	0.01	0.663
Petrol Medium	ECE 15/03	0.01	0.663
Petrol Medium	ECE 15/04	0.01	0.663
Petrol Medium	Open Loop	0.01	0.663
Petrol Medium	Euro 1 - 91/441/EEC	0.01	0.596
Petrol Medium	Euro 2 - 94/12/EEC	0.006	0.53
Petrol Medium	Euro 3 - 98/69/EC I	0.002	0.464
Petrol Medium	Euro 4 - 98/69/EC II	0.002	0.398
Petrol Medium	Euro 5 – EC 715/2007	0.0013	0.398
Petrol Medium	Euro 6 a/b/c	0.0013	0.398
Petrol Medium	Euro 6 d-temp	0.0013	0.398
Petrol Medium	Euro 6 d	0.0013	0.398
Petrol Large-SUV-Executive	PRE ECE	0.01	0.663
Petrol Large-SUV-Executive	ECE 15/00-01	0.01	0.663

Petrol Large-SUV-Executive	ECE 15/02	0.01	0.663
Petrol Large-SUV-Executive	ECE 15/03	0.01	0.663
Petrol Large-SUV-Executive	ECE 15/04	0.01	0.663
Petrol Large-SUV-Executive	Euro 1 - 91/441/EEC	0.011	0.596
Petrol Large-SUV-Executive	Euro 2 - 94/12/EEC	0.006	0.53
Petrol Large-SUV-Executive	Euro 3 - 98/69/EC I	0.002	0.464
Petrol Large-SUV-Executive	Euro 4 - 98/69/EC II	0.002	0.398
Petrol Large-SUV-Executive	Euro 5 – EC 715/2007	0.0013	0.398
Petrol Large-SUV-Executive	Euro 6 a/b/c	0.0013	0.398
Petrol Large-SUV-Executive	Euro 6 d-temp	0.0013	0.398
Petrol Large-SUV-Executive	Euro 6 d	0.0013	0.398
Diesel Small	Euro 4 - 98/69/EC II	0.001	0.398
Diesel Small	Euro 5 – EC 715/2007	0.004	0.398
Diesel Small	Euro 6 a/b/c	0.004	0.398

Diesel Small	Euro 6 d-temp	0.004	0.398
Diesel Small	Euro 6 d	0.004	0.398
Diesel Medium	Conventional	0	0.663
Diesel Medium	Euro 1 - 91/441/EEC	0.003	0.596
Diesel Medium	Euro 2 - 94/12/EEC	0.005	0.53
Diesel Medium	Euro 3 - 98/69/EC I	0.007	0.464
Diesel Medium	Euro 4 - 98/69/EC II	0.01	0.398
Diesel Medium	Euro 5 – EC 715/2007	0.004	0.398
Diesel Medium	Euro 6 up to 2016	0.004	0.398
Diesel Medium	Euro 6 2017 - 2019	0.004	0.398
Diesel Medium	Euro 6 2020+	0.004	0.398
Diesel Large-SUV-Executive	Conventional	0	0.663
Diesel Large-SUV-Executive	Euro 1 - 91/441/EEC	0.003	0.596
Diesel Large-SUV-Executive	Euro 2 - 94/12/EEC	0.005	0.53
Diesel Large-SUV-Executive	Euro 3 - 98/69/EC I	0.01	0.464

Diesel Large-SUV-Executive	Euro 4 - 98/69/EC II	0.01	0.398
Diesel Large-SUV-Executive	Euro 5 – EC 715/2007	0.004	0.398
Diesel Large-SUV-Executive	Euro 6 a/b/c	0.004	0.398
Diesel Large-SUV-Executive	Euro 6 d-temp	0.004	0.398
Diesel Large-SUV-Executive	Euro 6 d	0.004	0.398
LPG	Conventional	0	0.663
LPG	Euro 1 - 91/441/EEC	0.02	0.596
LPG	Euro 2 - 94/12/EEC	0.008	0.53
LPG	Euro 3 - 98/69/EC I	0.004	0.464
LPG	Euro 4 - 98/69/EC II	0.004	0.398
LPG	Euro 5 – EC 715/2007	0.004	0.398
LPG	Euro 6 - EC 715/2009	0.004	0.398
2-Stroke	Conventional	0.005	na
Hybrid Petrol Small	Euro 4 and later	0.0002	0.398

Hybrid Petrol Medium	Euro 4 and later[a]	0.0002	0.398
Hybrid Petrol Large	Euro 4 and later	0.0002	0.398
PHEV Petrol Small	Euro 6 and later	0.0002	0.398
PHEV Petrol Medium	Euro 6 and later	0.0002	0.398
PHEV Petrol Large	Euro 6 and later	0.0002	0.398
PHEV Diesel Large	Euro 5 and later	0.004	0.398
E85	Euro 4 and later	0.002	0.398
CNG	Euro 4 and 5 & 6 a/b/c	0.001	0.398

Note. These coefficients are from *1.A.3.b.i-iv Road Transport 2023 — European Environment Agency* (p.25) by Ntziachristos et al., 2023, (https://www.eea.europa.eu/publications/emep-eea-guidebook-2023/part-b-sectoral-guidance-chapters/1-energy/1-a-combustion/1-a-3-b-i/view). Copyright 2023 by European Environment Agency.

[a]Earlier vehicle technologies used these coefficients as there is no coefficient for them

Light Commercial Vehicles

Type	Technology	N2O (g/km)	CO2 lube (g/km)
Petrol	Conventional	0.01	6.63E-01
Petrol	Euro 1 - 93/59/EEC	0.025	5.96E-01
Petrol	Euro 2 - 96/69/EEC	0.025	5.30E-01
Petrol	Euro 3 - 98/69/EC I	0.028	4.64E-01
Petrol	Euro 4 - 98/69/EC II	0.013	3.98E-01
Petrol	Euro 5 - EC 715/2007	0.0013	3.98E-01
Petrol	Euro 6 a/b/c	0.0013	3.98E-01
Petrol	Euro 6 d-temp	0.0013	3.98E-01
Petrol	Euro 6 d-temp	0.0013	3.98E-01
Diesel	Conventional	0	6.63E-01
Diesel	Euro 1 - 93/59/EEC	0.003	5.96E-01
Diesel	Euro 2 - 96/69/EEC	0.006	5.30E-01
Diesel	Euro 3 - 98/69/EC I	0.009	4.64E-01
Diesel	Euro 4 - 98/69/EC II	0.009	3.98E-01
Diesel	Euro 5 - EC 715/2007	0.004	3.98E-01
Diesel	Euro 6 a/b/c	0.004	3.98E-01

Diesel	Euro 6 d-temp	0.004	3.98E-01
Diesel	Euro 6 d-temp	0.004	3.98E-01

Note. These coefficients are from *1.A.3.b.i-iv Road Transport 2023 — European Environment Agency* (p.28) by Ntziachristos et al., 2023, (https://www.eea.europa.eu/publications/emep-eea-guidebook-2023/part-b-sectoral-guidance-chapters/1-energy/1-a-combustion/1-a-3-b-i/view). Copyright 2023 by European Environment Agency.

Heavy Duty Vehicles

Type	Technology	N2O (g/km)	CO2 lube (g/km)
Petrol >3.5 t	Conventional	0.006	1.99
Diesel <=7.5 t	Conventional	0.029	4.86E-01
Diesel <=7.5 t	Euro I - 91/542/EEC I	0.005	4.86E-01
Diesel <=7.5 t	Euro II - 91/542/EEC II	0.004	4.86E-01
Diesel <=7.5 t	Euro III - 2000	0.003	4.86E-01
Diesel <=7.5 t	Euro IV - 2005	0.006	4.86E-01
Diesel <=7.5 t	Euro V - 2008	0.017	4.86E-01
Diesel <=7.5 t	Euro VI A/B/C	0.017	4.86E-01
Diesel <=7.5 t	Euro VI D/E	0.017	4.86E-01
Diesel 7.5 - 16 t	Conventional	0.0029	4.86E-01
Diesel 7.5 - 16 t	Euro I - 91/542/EEC I	0.0029	4.86E-01
Diesel 7.5 - 16 t	Euro II - 91/542/EEC II	0.0029	4.86E-01

Diesel 7.5 - 16 t	Euro III - 2000	0.0029	4.86E-01
Diesel 7.5 - 16 t	Euro IV - 2005	0.0029	4.86E-01
Diesel 7.5 - 16 t	Euro V - 2008	0.011	4.86E-01
Diesel 7.5 - 16 t	Euro VI A/B/C	0.009	4.86E-01
Diesel 7.5 - 16 t	Euro VI D/E	0.009	4.86E-01
Diesel 16 - 32 t	Conventional	0.0029	4.86E-01
Diesel 16 - 32 t	Euro I - 91/542/EEC I	0.0029	4.86E-01
Diesel 16 - 32 t	Euro II - 91/542/EEC II	0.0029	4.86E-01
Diesel 16 - 32 t	Euro III - 2000	0.0029	4.86E-01
Diesel 16 - 32 t	Euro IV - 2005	0.0029	4.86E-01
Diesel 16 - 32 t	Euro V - 2008	0.011	4.86E-01
Diesel 16 - 32 t	Euro VI A/B/C	0.009	4.86E-01
Diesel 16 - 32 t	Euro VI D/E	0.009	4.86E-01
Diesel > 32 t	Conventional	0.0029	4.86E-01
Diesel > 32 t	Euro I - 91/542/EEC I	0.0029	4.86E-01
Diesel > 32 t	Euro II - 91/542/EEC II	0.0029	4.86E-01
Diesel > 32 t	Euro III - 2000	0.0029	4.86E-01

Diesel > 32 t	Euro IV - 2005	0.0029	4.86E-01
Diesel > 32 t	Euro V - 2008	0.011	4.86E-01
Diesel > 32 t	Euro VI A/B/C	0.009	4.86E-01
Diesel > 32 t	Euro VI D/E	0.009	4.86E-01

Note. These coefficients are from *1.A.3.b.i-iv Road Transport 2023 — European Environment Agency* (p.29) by Ntziachristos et al., 2023, (https://www.eea.europa.eu/publications/emep-eea-guidebook-2023/part-b-sectoral-guidance-chapters/1-energy/1-a-combustion/1-a-3-b-i/view).

Buses

Type	**Technology**	**N2O**	**CO2**
Urban CNG Buses	Euro I - 91/542/EEC I	0.101	1.86
Urban CNG Buses	Euro II - 91/542/EEC II	0.101	1.59
Urban CNG Buses	Euro III - 2000	0.101	1.59
Urban CNG Buses	EEV	0.101	n.a
Urban Buses Standard	Conventional	0.029	2.65
Urban Buses Standard	Euro I - 91/542/EEC I	0.012	2.05
Urban Buses Standard	Euro II - 91/542/EEC II	0.12	1.48
Urban Buses Standard	Euro III - 2000	0.001	0.861
Urban Buses Standard	Euro IV - 2005	0.012	0.265
Urban Buses Standard	Euro V - 2008	0.032	0.265

Urban Buses Standard	Euro VI A/B/C	0.04	0.265
Urban Buses Standard	Euro VI D/E	0.04	0.265
Urban Hybrid Buses	Euro VI A/B/C	0.04	0.265
Urban Hybrid Buses	Euro VI D/E	0.04	0.265
Coaches Standard	Conventional	0.029	0.663
Coaches Standard	Euro I - 91/542/EEC I	0.009	0.63
Coaches Standard	Euro II - 91/542/EEC II	0.008	0.596
Coaches Standard	Euro III - 2000	0.004	0.563
Coaches Standard	Euro IV - 2005	0.012	0.53
Coaches Standard	Euro V - 2008	0.034	0.53
Coaches Standard	Euro VI A/B/C	0.033	0.53
Coaches Standard	Euro VI D/E	0.033	0.53

Note. These coefficients are from *1.A.3.b.i-iv Road Transport 2023 — European Environment Agency* (p.30) by Ntziachristos et al., 2023, (https://www.eea.europa.eu/publications/emep-eea-guidebook-2023/part-b-sectoral-guidance-chapters/1-energy/1-a-combustion/1-a-3-b-i/view). Copyright 2023 by European Environment Agency.

L-Category

Type	Technology	N2O (g/km)	CO2 lube (g/km)
2-stroke < 50 cc	Conventional	0.001	4.24
2-stroke < 50 cc	Mop - Euro 1	0.001	3.53

2-stroke < 50 cc	Mop - Euro 2	0.001	2.83
2-stroke < 50 cc	Mop - Euro 3 and later	0.001	2.12
4-stroke < 50 cc	Conventional	0.001	4.24
4-stroke < 50 cc	Mop - Euro 1	0.001	3.53
4-stroke < 50 cc	Mop - Euro 2	0.001	2.83
4-stroke < 50 cc	Mop - Euro 3 and later	0.001	2.12
2-stroke > 50 cc	Conventional	0.002	4.24
2-stroke > 50 cc	Mot - Euro 1	0.002	3.53
2-stroke > 50 cc	Mot - Euro 2	0.002	2.83
2-stroke > 50 cc	Mot - Euro 3 and later	0.002	2.12
4-stroke < 250 cc	Conventional	0.002	0.398
4-stroke < 250 cc	Mot - Euro 1	0.002	0.309
4-stroke < 250 cc	Mot - Euro 2	0.002	0.221
4-stroke < 250 cc	Mot - Euro 3 and later	0.002	0.133
4-stroke 250 - 750 cc	Conventional	0.002	0.398
4-stroke 250 - 750 cc	Mot - Euro 1	0.002	0.309

4-stroke 250 - 750 cc	Mot - Euro 2	0.002	0.221
4-stroke 250 - 750 cc	Mot - Euro 3 and later	0.002	0.133
4-stroke > 750 cc	Conventional	0.002	0.398
4-stroke > 750 cc	Mot - Euro 1	0.002	0.309
4-stroke > 750 cc	Mot - Euro 2	0.002	0.221
4-stroke > 750 cc	Mot - Euro 3 and later	0.002	0.133
Mini-cars	Conventional	0.005	0.53
Mini-cars	Euro 1	0.005	0.53
Mini-cars	Euro 2	0.005	0.53
Mini-cars	Euro 3	0.005	0.53
Mini-cars	Euro 4	0.005	0.53
Mini-cars	Euro 5	0.005	0.53
ATVs	Conventional	0.002	0.398
ATVs	Euro 1	0.002	0.309

ATVs	Euro 2	0.002	0.221
ATVs	Euro 3	0.002	0.133
ATVs	Euro 4	0.002	0.133
ATVs	Euro 5	0.002	0.133

Note. These coefficients are from *1.A.3.b.i-iv Road Transport 2023 — European Environment Agency* (p.31) by Ntziachristos et al., 2023, (https://www.eea.europa.eu/publications/emep-eea-guidebook-2023/part-b-sectoral-guidance-chapters/1-energy/1-a-combustion/1-a-3-b-i/view).

Appendix F: Fuel Composition Ratios

Fuel	Ratio of Hydrogen to Carbon	Ratio of Oxygen to Carbon
Petrol	1.86	0
Diesel	1.86	0
LPG	2.525	0

Note. These coefficients are from *1.A.3.b.i-iv Road Transport 2023 — European Environment Agency* (p.44) by Ntziachristos et al., 2023, (https://www.eea.europa.eu/publications/emep-eea-guidebook-2023/part-b-sectoral-guidance-chapters/1-energy/1-a-combustion/1-a-3-b-i/view).

Appendix G: Tier Three Oil Consumption Coefficients

Category	Fuel	Age	FC Coefficient (kg/10000 km)
PC	Petrol	Old	1.45[a,b]
PC	Petrol	New	1.28[a,b]
PC	Diesel	Old	1.49
PC	Diesel	New	1.28
LCV	Petrol	Old	1.45
LCV	Petrol	New	1.28[a]

LCV	Diesel	Old	1.49[a]
LCV	Diesel	New	1.28
Urban Buses	Diesel	Old	8.5
Urban Buses	Diesel	New	0.85
Coaches	Diesel	Old	1.91
Coaches	Diesel	New	1.7
HDV	Diesel	Any	1.56
Mopeds	2-stroke	Old	10.2
Mopeds	2-stroke	New	6.8
Motorcycles	4-stroke	Any	0.43
Mini-cars	Diesel	Any	1.28
ATVs	Petrol	Any	0.43

Note. These coefficients are from *1.A.3.b.i-iv Road Transport 2023 — European Environment Agency* (p.45) by Ntziachristos et al., 2023, (https://www.eea.europa.eu/publications/emep-eea-guidebook-2023/part-b-sectoral-guidance-chapters/1-energy/1-a-combustion/1-a-3-b-i/view). Copyright 2023 by European Environment Agency.

[a]Petrol coefficients were also used for LPG as there are no available LPG coefficients. LPG vehicles are generally altered petrol vehicles so oil consumption is similar. [b]Hybrid vehicles were treated as petrol vehicles.

Appendix H: Hot Urban Constants for Tier Three Nitrous Oxide Calculations

Petrol Passenger Cars

Emission standard	Base EF (mg/km)	a	b
Pre-Euro	10	0	1
Euro 1	23.2	8.81E-07	0.92
Euro 2	11.1	9.21E-07	0.962

Euro 3	1.3	1.85E-06	0.829
Euro 4	1.9	6.61E-07	0.931
Euro 5	2.4	7.83E-07	0.861
Euro 6	2.4	7.83E-07	0.861

Note. These coefficients are from *1.A.3.b.i-iv Road Transport 2023 — European Environment Agency* (p.79) by Ntziachristos et al., 2023, (https://www.eea.europa.eu/publications/emep-eea-guidebook-2023/part-b-sectoral-guidance-chapters/1-energy/1-a-combustion/1-a-3-b-i/view). Copyright 2023 by European Environment Agency.

Petrol Light Commercial Vehicles

Emission standard	Sulpher content (ppm)	Base EF (mg/km)	a	b
pre-Euro	All	10	0	1
Euro 1	0-350	41.5	2.33E-06	0.53
Euro 2	0-350	23.9	2.40E-06	0.68
Euro 3	0-30	7.4	2.81E-06	0.64
Euro 4	0-30	1.2	6.57E-07	0.925
Euro 5	0-30	2.4	7.83E-07	0.861
Euro 6	0-30	2.4	7.83E-07	0.861

Note. These coefficients are from *1.A.3.b.i-iv Road Transport 2023 — European Environment Agency* (p.80) by Ntziachristos et al., 2023, (https://www.eea.europa.eu/publications/emep-eea-guidebook-2023/part-b-sectoral-guidance-chapters/1-energy/1-a-combustion/1-a-3-b-i/view). Copyright 2023 by European Environment Agency.

LPG and Diesel Cars, Diesel LCVs, and L-Category Vehicles

Vehicle Category	Urban Hot
Diesel passenger cars and LCVs	
Conventional	0
Euro 1	2
Euro 2	4
Euro 3/4/5	9
Euro 6 up to 2026 / 2017-2019 / 2020+	11
LGP passenger cars	
Conventional	0
Euro 1	21
Euro 2	13
Euro 3	5
Euro 4	5
Euro 5	2.1
Euro 6	2.1
L-category	
< 50cm^3	1

> 50 cm^3 2-stroke	2
> 50 cm^3 4-stroke	2

Note. These coefficients are from *1.A.3.b.i-iv Road Transport 2023 — European Environment Agency* (p.82) by Ntziachristos et al., 2023, (https://www.eea.europa.eu/publications/emep-eea-guidebook-2023/part-b-sectoral-guidance-chapters/1-energy/1-a-combustion/1-a-3-b-i/view). Copyright 2023 by European Environment Agency.

Heavy Duty Vehicles

HDV Category	Technology	Urban (g/km)
Petrol > 3.5 t	Conventional	6[a]
Rigid 7.5-12 t	Conventional	30
Rigid 7.5-12 t	HD Euro I	6
Rigid 7.5-12 t	HD Euro II	5
Rigid 7.5-12 t	HD Euro III	3
Rigid 7.5-12 t	HD Euro IV	6
Rigid 7.5-12 t	HD Euro V	15
Rigid 7.5-12 t	HD Euro VI	18.5
Rigid and Articulated 12-28 t and Coaches (all types)	Conventional	30
Rigid and Articulated 12-28 t and Coaches (all types)	HD Euro I	11
Rigid and Articulated 12-28 t and Coaches (all types)	HD Euro II	11

Rigid and Articulated 12-28 t and Coaches (all types)	HD Euro III	5
Rigid and Articulated 12-28 t and Coaches (all types)	HD Euro IV	11.2
Rigid and Articulated 12-28 t and Coaches (all types)	HD Euro V	29.8
Rigid and Articulated 12-28 t and Coaches (all types)	HD Euro VI	37
Rigid and Articulated 28-34 t	Conventional	30
Rigid and Articulated 28-34 t	HD Euro I	17
Rigid and Articulated 28-34 t	HD Euro II	17
Rigid and Articulated 28-34 t	HD Euro III	8
Rigid and Articulated 28-34 t	HD Euro IV	17.4
Rigid and Articulated 28-34 t	HD Euro V	45.6
Rigid and Articulated 28-34 t	HD Euro VI	56.5
Articulated > 34 t	Conventional	30
Articulated > 34 t	HD Euro I	18
Articulated > 34 t	HD Euro II	18
Articulated > 34 t	HD Euro III	9
Articulated > 34 t	HD Euro IV	19
Articulated > 34 t	HD Euro V	49
Articulated > 34 t	HD Euro VI	61

Diesel Urban Buses (all types)	Conventional	30
Diesel Urban Buses (all types)	HD Euro I	12
Diesel Urban Buses (all types)	HD Euro II	12
Diesel Urban Buses (all types)	HD Euro III	6
Diesel Urban Buses (all types)	HD Euro IV	12.8
Diesel Urban Buses (all types)	HD Euro V	33.2
Diesel Urban Buses (all types)	HD Euro VI	41.5

Note. These coefficients are from *1.A.3.b.i-iv Road Transport 2023 — European Environment Agency* (p.83) by Ntziachristos et al., 2023, (https://www.eea.europa.eu/publications/emep-eea-guidebook-2023/part-b-sectoral-guidance-chapters/1-energy/1-a-combustion/1-a-3-b-i/view).

[a]LPG vehicles used petrol coefficients because there are no available LPG coefficients for HDVs, and LPG and petrol generally have similar, if not identical, emission coefficients

Appendix I: Vehicle Age by Vehicle Technology

Euro Standard	Year Start	Year End	Median	Age
Euro 0	1992	1997	1995	27
Euro 1	1997	2001	1999	23
Euro 2	2001	2006	2004	18
Euro 3	2006	2006	2006	16
Euro 4	2006	2011	2009	13
Euro 5	2011	2015	2013	9
Euro 6	2015	2022	2019	3

Note. The Year Start data came from *Euro Standards* by Driving Mobility for Europe, 2014, (https://www.acea.auto/fact/euro-standards/).

Appendix J: Methane Emission Coefficients

Vehicle Type	Fuel	Vehicle Technology/Class	Urban Hot
Passenger Cars	Petrol-Hybrid Petrol-PHEV	Conventional	131
Passenger Cars	Petrol-Hybrid Petrol-PHEV	Euro 1	26
Passenger Cars	Petrol-Hybrid Petrol-PHEV	Euro 2	17
Passenger Cars	Petrol-Hybrid Petrol-PHEV	Euro 3	3
Passenger Cars	Petrol-Hybrid Petrol-PHEV	Euro 4 and later	2.87
Passenger Cars	Diesel-PHEV	Conventional	28

Passenger Cars	Diesel-PHEV	Euro 1	11
Passenger Cars	Diesel-PHEV	Euro 2	7
Passenger Cars	Diesel-PHEV	Euro 3	3
Passenger Cars	Diesel-PHEV	Euro 4	1.1
Passenger Cars	Diesel-PHEV	Euro 5 and later	0.075
Passenger Cars	LPG	All Technologies	80[a]
Passenger Cars	E85	All Technologies	2.87
Passenger Cars	CNG	Euro 4, 5 and 6 a/b/c	57.3
Passenger Cars	CNG	Euro 6d-temp and later	6
Light Commercial Vehicles	Petrol	Conventional	131
Light Commercial Vehicles	Petrol	Euro 1	26
Light Commercial Vehicles	Petrol	Euro 2	17
Light Commercial Vehicles	Petrol	Euro 3	3
Light Commercial Vehicles	Petrol	Euro 4 and later	2
Light Commercial Vehicles	Diesel	Conventional	28
Light Commercial Vehicles	Diesel	Euro 1	11
Light Commercial Vehicles	Diesel	Euro 2	7
Light Commercial Vehicles	Diesel	Euro 3	3

Light Commercial Vehicles	Diesel	Euro 4	1.1
Light Commercial Vehicles	Diesel	Euro 5 and later	0.0075
Heavy-duty vehicles and buses	Petrol	All Technologies	140
Heavy-duty vehicles and buses	Diesel	GVW< 16t	85
Heavy-duty vehicles and buses	Diesel	GVW> 16t	175[b]
Heavy-duty vehicles and buses	Diesel-Biodiesel	Urban Buses and Coaches Hybrid Urban Buses	175
Heavy-duty vehicles and buses	CNG	Euro I	6,800
Heavy-duty vehicles and buses	CNG	Euro II	4,500
Heavy-duty vehicles and buses	CNG	Euro III	1,280
Heavy-duty vehicles and buses	CNG	EEV	980
L-category	Petrol	< 50 cm^3 2-stroke	219
L-category	Petrol	< 50 cm^3 4-stroke	219
L-category	Petrol	> 50 cm^3 2-stroke	150
L-category	Petrol	> 50 cm^3 4-stroke	200
L-category	Mini-Cars Diesel	Conventional	28
L-category	Mini-Cars Diesel	Euro 1	11
L-category	Mini-Cars Diesel	Euro 2	7

L-category	Mini-Cars Diesel	Euro 3	3
L-category	Mini-Cars Diesel	Euro 4	1.1
L-category	Mini-Cars Diesel	Euro 5	0.075
L-category	Mini-Cars Diesel	Conventional	200

Note. These coefficients are from *1.A.3.b.i-iv Road Transport 2023 — European Environment Agency* (p.67) by Ntziachristos et al., 2023, (https://www.eea.europa.eu/publications/emep-eea-guidebook-2023/part-b-sectoral-guidance-chapters/1-energy/1-a-combustion/1-a-3-b-i/view). Copyright 2023 by European Environment Agency.

[a]This coefficient was used for LPG LCVs because all other LPG and PC coefficients were the same. This coefficient was multiplied by 3.04 for use on LPG HDVs in line with the ratio between diesel for PCs and HDVs. [b]Trucks weighing 14,001-20,000 tonnes were included in this category.

Appendix K: Code for Mapping
https://github.com/Nat-Rubin/EVSEModeling

Appendix L: Current EV Charging Sites

Location	Name	Speed	Slow Charging Spots	Medium Charging Spots	Fast Charging Spots	Slow Chargers	Medium Chargers	Fast Chargers	Type	Power (kW)	Price ₪/kW	Use Frequency
(34.9624127, 29.5566743)	EV Edge Charging Station	Medium		2			2		Type 2	22		
(34.9619296, 29.5512977)	Afcon Charging Station	Medium		2			2		Type 2	22		
(34.9611882, 29.5546877)	EV Edge Charging Station	Slow Medium	2	2		1	1		Type 2	11 22		
(34.9622509, 29.5524937)	EV Edge Charging Station	Slow Medium	2	4		1	2		Type 2	11 and 22		
(34.9574655, 29.5602683)	Sonol - EVI Charging Station	Fast			2			2	Type CCS CHAdeMO	161		
(34.9637199, 29.5558256)	EVEDGE Charging Station	Medium		2			1		Type 2	22		

(34.9653043, 29.548978)	Afcon Charging Station	Slow Medium	2	1		2	1		Type 2	13 and 22 and 50	1.35	
(34.9671801, 29.5488733)	EV Edge Charging Station	Slow	4			2			Type 2	11	1.35	
(34.9632703, 29.5503514)	EV Edge Charging Station	Unknown Fast		3	2		3	2	Type 2 CCS	Unknown and 50	1.35	
(34.9566436, 29.55152349999999)	Sonol - EVI Charging Station	Slow	2			1			Type 2	11		
(34.9577681, 29.5515841)	Greenspot Charging Station	Slow	4			4			Type 2	11	1.35	
(34.9578295, 29.5527056)	Greenspot Charging Station	Medium		4			2		Type 2	22	1.35	
(34.967028, 29.548851)	Blink Charging Station	Unknown							Unknown	Unknown	1.95	
(34.967032, 29.54860459999999)	EV Edge Charging Station	Unknown		4			4		Type 2	Unknown	1.95	1007
(34.9604254, 29.5554101)	Blink Charging Station	Medium		4			4		Type 2	22		
(34.9594472, 29.5675792)	Tesla Supercharger	Fast			6			6	CCS	250	1.35	
(34.9590831, 29.5680464)	Greenspot Charging Station	Medium		4			4		Type 2	22	1.35	
(34.9598488, 29.5547935)	EV Edge Charging Station	Medium		1			1		Type 2	22	1.35	
(34.9600607, 29.5655254)	Electric Vehicle Charging Station	Medium Fast		7	2		4	1	Type 2 CCS CHAdeMO	22 50	1.35	
(34.9676376, 29.5490441)	EV Edge Charging Station	Slow	2			1			Type 2	11	1.35	
(34.9633674, 29.5516567)	EV Edge Charging Station	Slow Medium	2	4		1	2		Type 2	11 and 22	1.35	

(34.966612031839404, 29.554106419648775)	Greenspot Charging Station	Medium Fast		4	8		2	4	Type 2	22 and 250		
(34.95851536960977, 29.551592456011036)	Greenspot Charging Station	Medium		2			2		Type 2	22		
(34.931934608876574, 29.557558051947826)	Greenspot Charging Station	Medium		2			2		Type 2	22	1.95	1915
(34.93585366992343, 29.559002797894422)	Greenspot Charging Station	Medium		4			2		Type 2	22	1.95	1680
(34.9625585, 29.5711264)	Greenspot Charging Station	Medium		4			2		Type 2	22	1.9	400
(34.9288896, 29.5440538)	Greenspot Charging Station	Medium		4			2		Type 2	22	1.35	
(34.958997, 29.5664832)	Greenspot Charging Station	Medium		2			2		Type 2	22		
(34.96360309999999, 29.57158849999999)	Greenspot Charging Station	Medium		4			2		Type 2	22	1.9	578
(34.9574743, 29.5531766)	Greenspot Charging Station	Medium		2			2		Type 2	22	1.95	468
(34.9593422, 29.5558804)	Paz Charging Station	Fast			2			2	CCS	360	1.9	31
(34.9610977, 29.5551432)	Greenspot Charging Station	Medium		4			2		Type 2	22		
(34.9608992, 29.5551432)	Tesla Supercharger	Fast		8				8	CCS	250	1.35	
(34.9581987, 29.5502663)	EV Edge Charging Station	Unkonwn		2					Type 2	Unknown		
(34.9564224, 29.5507648)	Afcon Charging Station	Medium		6			3		Type 2	22		

(34.9631534, 29.5495548)	EV Edge Charger	Unknown		2					Type 2	Unknown		
(34.9592322, 29.5624758)	Afcon Charging Station	Medium		6			3		Type 2	22		
(34.9586523, 29.5653154)	Afcon Charger	Fast			2			2	CCS	120	1.35	
(34.9672394, 29.5517458)	EV Edge Charger	Unknown Fast		8	2			2	Type 2 and CCS	Unknown and 50	1.35	
(34.9608009, 29.5560996)	EV Edge Charging Station	Medium		1			1		Type 2	22		
(34.9599467, 29.5571738)	Paz Charging Station	Fast			4			4	Type 2 CCS	360	1.35	
(34.9550747, 29.5552071)	Paz Charging Station	Fast			1			1	CCS	N/A	1.35	
(34.9525748, 29.5536817)	Sonol-EVI Charging Station	Medium		2			2		Type 2	22	1.35	
(34.9456002, 29.5507586)	Greenspot Charging Station	Medium		1			1		Type 2	22	1.35	
(34.9477099, 29.5512834)	EV EDGE Charging Station	Medium		2			2		Type 2	22	1.35	

Note: The data was compiled from "EV Map of Israel", by Google, 2023, (https://www.google.com/maps/d/viewer?mid=1MoueY94f_CdPzQbSTFe7ZE7q0VP5TTYh&hl=en_US&ll=29.56153308052602%2C34.957458711694348&z=14). Also from *PlugShare*, 2024, (https://www.plugshare.com/location/568349). Copyright 2024 by Recargo, Inc. Also from "Tesla Superchargers in Israel", by Tesla, n.d., (https://www.tesla.com/findus/list/superchargers/Israel). Copyright 2024 by Tesla. Also from Cello Charge, 2024, (https://cellocharge.com/).

Appendix M: Interactive Charger Placement Map
https://www.google.com/maps/d/edit?mid=1mj4HjS4s7Kw3FcY13Vsh1yXd1jvhVXs&usp=sharing

Appendix N: Stage One Chargers

Location	Name	Slow (11 kW)	Medium (22 kW)	Fast (50 kW)	Ultra Fast (350 kW)	Capacity (kW)

(34.9574648, 29.5602684)	GasStation1	0	0	0	6	2,100
(34.955183, 29.555155)	GasStation2	0	0	0	4	1,400
(34.9631005, 29.5709311)	GasStation3	0	0	0	4	1,400
(34.957848, 29.560524)	GasStation4	0	0	0	4	1,400
(34.9617422, 29.5701168)	GasStation5	0	0	0	4	1,400
	TOTAL	0	0	0	22	7,700

Appendix O: Stage Two Chargers

Location	Name	Parking Spots	Slow (11 kW)	Medium (22 kW)	Fast (50 kW)	Ultra Fast (350 kW)	Capacity (kW)
(34.9660327, 29.5540665)	ShoppingCenter1	30	0	6	0	0	132
(34.9516567, 29.5468615)	ShoppingCenter2	35	0	6	1	0	182
(34.9596611, 29.5680229)	ShoppingCenter3	200	0	36	4	0	992
(34.9451468, 29.5536066)	ShoppingCenter4	60	0	12	1	0	314
(34.9493769, 29.5595858)	ShoppingCenter5	70	0	14	1	0	358
(34.9450258, 29.5621571)	ShoppingCenter6	38	0	8	1	0	226

(34.9446591, 29.561897)	ShoppingCenter7	40	0	8	1	0	226
(34.9457424, 29.5639631)	ShoppingCenter8	40	0	8	1	0	226
(34.9603252, 29.5660512)	ShoppingCenter9	375	0	68	8	0	1,896
(34.9589984, 29.5669246)	ShoppingCenter10	225	0	40	6	0	1,180
(34.9532136, 29.5558562)	ShoppingCenter11	200	0	36	4	0	992
(34.951535, 29.5550276)	ShoppingCenter12	80	0	14	2	0	408
(34.957611, 29.5693396)	ShoppingCenter13	30	0	6	1	0	182
(34.9586695, 29.5691321)	ShoppingCenter14	36	0	6	1	0	182
(34.9596619, 29.5688345)	ShoppingCenter15	29	0	6	1	0	182
(34.9527793, 29.5488571)	ShoppingCenter16	115	0	22	2	0	584
(34.9562671, 29.5678864)	ShoppingCenter17	100	0	18	2	0	496
(34.9535555, 29.5501674)	ShoppingCenter18	163	0	30	3	0	810
(34.9558056, 29.565437)	ShoppingCenter19	100	0	18	2	0	496

(34.9475371, 29.5499006)	ShoppingCenter20	21	0	4	0	0	88
	Total	1957	0	366	42	0	10,152

Appendix P: Stage Three Chargers

Location	Name	Parking Spots	Slow (11 kW)	Medium (22 kW)	Fast (50 kW)	Ultra Fast (350 kW)	Capacity (kW)
(34.9505849, 29.5528293)	Municipal1	100	0	18	0	0	396
(34.9513333, 29.5694663)	Municipal2	32	0	6	0	0	132
(34.9251108, 29.5442194)	Municipal3	18	0	4	0	0	88
(34.9568607, 29.563888)	Recreation1	60	0	12	0	0	264
(34.9502127, 29.553273)	Recreation2	56	0	12	0	0	264
(34.9463399, 29.5404402)	Recreation3	144	0	26	0	0	572
(34.9309495, 29.5412126)	Recreation4	19	0	2	0	0	44
(34.9262389, 29.5454845)	Recreation5	37	0	8	0	0	176
(34.9340661, 29.5460247)	Recreation6	39	0	4	0	0	88
(34.9498218, 29.5638142)	School1	30	0	6	0	0	132

(34.9484832, 29.5561411)	School2	41	0	6	0	0	132
(34.9420449, 29.5579101)	School3	70	0	14	0	0	308
(34.9273953, 29.5435335)	School4	41	0	8	0	0	176
(34.9264297, 29.5446812)	School5	53	0	10	0	0	220
	TOTAL	740	0	136	0	0	2,992

Appendix Q: Stage Four Chargers

Location	Name	Parking Spots	Slow (11 kW)	Medium (22 kW)	Fast (50 kW)	Ultra Fast (350 kW)	Capacity (kW)
(34.9516683, 29.5636916)	Residential1	25	0	6	0	0	138
(34.9464641, 29.5502468)	Residential2	45	0	8	0	0	226
(34.946289, 29.5616049)	Residential3	35	0	8	0	0	176
(34.9457535, 29.5626757)	Residential4	38	0	8	0	0	226
(34.9419371, 29.5624472)	Residential5	180	0	36	0	0	904
(34.9526405, 29.5660196)	Residential6	40	0	10	0	0	226
(34.9358679, 29.5606105)	Residential7	85	0	18	0	0	452

(34.932533, 29.5561182)	Residential8	35	0	8	0	0	182
(34.9318785, 29.5563702)	Residential9	35	0	8	0	0	182
(34.9355724, 29.5556676)	Residential10	72	0	16	0	0	408
(34.935893, 29.5498233)	Residential11	45	0	10	0	0	226
(34.9309146, 29.5529144)	Residential12	45	0	10	0	0	226
(34.9518282, 29.5674187)	Residential13	48	0	10	0	0	270
(34.9230304, 29.5438816)	Residential14	25	0	6	0	0	132
(34.9419577, 29.5503784)	Residential15	25	0	6	0	0	132
(34.9423412, 29.5507611)	Residential16	32	0	6	0	0	132
(34.9335846, 29.5461722)	Residential17	30	0	6	0	0	132
(34.9325117, 29.5451922)	Residential18	25	0	6	0	0	132
(34.9300344, 29.5429941)	Residential19	49	0	10	0	0	220
(34.9441295, 29.563908)	Residential20	44	0	8	0	0	198

(34.9409556, 29.5645596)	Residential21	89	0	18	0	0	396
	TOTAL	1047	0	222	0	0	5,316

Appendix R: Distances from Confirmed Parking Lots to Light Stations

Charger Name	Charger Location	Light Station Name	Light Station Location	Distance (km)
GasStation1	34.9574648, 29.5602684	Point 8	34.958627, 29.5616525	0.180584905
GasStation2	34.955183, 29.555155	Point 69	34.9542698, 29.5539243	0.151298066
GasStation3	34.9631005, 29.5709311	Point 2	34.9629592, 29.5701443	0.073399783
GasStation4	34.957848, 29.560524	Point 8	34.958627, 29.5616525	0.134460928
GasStation5	34.9617422, 29.5701168	Point 2	34.9629592, 29.5701443	0.135347407
ShoppingCenter1	34.9660327, 29.5540665	Point 73	34.9666916, 29.5535326	0.087947908
ShoppingCenter2	34.9516567, 29.5468615	Point 62	34.9495996, 29.5490501	0.303496106
ShoppingCenter3	34.9596611, 29.5680229	Point 3	34.958052, 29.5702575	0.271078962
ShoppingCenter4	34.9451468, 29.5536066	Point 57	34.9460086, 29.5528243	0.119445206
ShoppingCenter5	34.9493769, 29.5595858	Point 13	34.9507738, 29.5619471	0.265410655
ShoppingCenter6	34.9450258, 29.5621571	Point 16	34.9438827, 29.5637867	0.195495361
ShoppingCenter7	34.9446591, 29.561897	Point 16	34.9438827, 29.5637867	0.192666316
ShoppingCenter8	34.9457424, 29.5639631	Point 16	34.9438827, 29.5637867	0.207413356
ShoppingCenter9	34.9603252, 29.5660512	Point 6	34.9579382, 29.5637458	0.338508868
ShoppingCenter10	34.9589984, 29.5669246	Point 6	34.9579382, 29.5637458	0.312758486

ShoppingCenter11	34.9532136, 29.5558562	Point 70	34.9537055, 29.5561825	0.062258305
ShoppingCenter12	34.951535, 29.5550276	Point 67	34.9519095, 29.5558002	0.081806248
ShoppingCenter13	34.957611, 29.5693396	Point 3	34.958052, 29.5702575	0.09696408
ShoppingCenter14	34.9586695, 29.5691321	Point 3	34.958052, 29.5702575	0.123422533
ShoppingCenter15	34.9596619, 29.5688345	Point 3	34.958052, 29.5702575	0.221048478
ShoppingCenter16	34.9527793, 29.5488571	Point 65	34.9523841, 29.5505243	0.158172748
ShoppingCenter17	34.9562671, 29.5678864	Point 5	34.9556745, 29.5695941	0.169005523
ShoppingCenter18	34.9535555, 29.5501674	Point 64	34.9528348, 29.5507296	0.095117873
ShoppingCenter19	34.9558056, 29.565437	Point 9	34.9552298, 29.5661281	0.089812304
ShoppingCenter20	34.9475371, 29.5499006	Point 61	34.9483998, 29.5506977	0.120333851
Municipal1	34.9505849, 29.5528293	Point 60	34.9488646, 29.5540294	0.220352189
Municipal2	34.9513333, 29.5694663	Point 10	34.9523656, 29.5668832	0.261914495
Municipal3	34.9251108, 29.5442194	Point 42	34.9243252, 29.5440165	0.089291884
Recreation1	34.9568607, 29.563888	Point 6	34.9579382, 29.5637458	0.120511303
Recreation2	34.9502127, 29.553273	Point 60	34.9488646, 29.5540294	0.164994653
Recreation3	34.9463399, 29.5404402	Point 63	34.9476959, 29.5484248	0.743207988
Recreation4	34.9309495, 29.5412126	Point 47	34.9328067, 29.5399569	0.236115538
Recreation5	34.9262389, 29.5454845	Point 33	34.9278905, 29.5460305	0.190275846
Recreation6	34.9340661, 29.5460247	Point 50	34.9352675, 29.546151	0.134084808

School1	34.9498218, 29.5638142	Point 12	34.9507791, 29.5620171	0.195340351
School2	34.9484832, 29.5561411	Point 58	34.9483462, 29.5544968	0.150638567
School3	34.9420449, 29.5579101	Point 23	34.9408527, 29.5587603	0.153556399
School4	34.9273953, 29.5435335	Point 39	34.9268693, 29.5427144	0.094853523
School5	34.9264297, 29.5446812	Point 40	34.9261558, 29.5429337	0.162200311
Residential1	34.9516683, 29.5636916	Point 12	34.9507791, 29.5620171	0.181843576
Residential2	34.9464641, 29.5502468	Point 63	34.9476959, 29.5484248	0.215263522
Residential3	34.946289, 29.5616049	Point 14	34.9479236, 29.562192	0.189472542
Residential4	34.9457535, 29.5626757	Point 16	34.9438827, 29.5637867	0.231361645
Residential5	34.9419371, 29.5624472	Point 17	34.9409134, 29.561575	0.138844618
Residential6	34.9526405, 29.5660196	Point 10	34.9523656, 29.5668832	0.084434474
Residential7	34.9358679, 29.5606105	Point 20	34.9347762, 29.5609292	0.12481952
Residential8	34.932533, 29.5561182	Point 25	34.9318269, 29.5575226	0.150184371
Residential9	34.9318785, 29.5563702	Point 25	34.9318269, 29.5575226	0.105210928
Residential10	34.9355724, 29.5556676	Point 24	34.9375676, 29.556288	0.228950638
Residential11	34.935893, 29.5498233	Point 27	34.9349898, 29.5492404	0.113621411
Residential12	34.9309146, 29.5529144	Point 26	34.9302751, 29.5512365	0.168682741
Residential13	34.9518282, 29.5674187	Point 10	34.9523656, 29.5668832	0.077153841
Residential14	34.9230304, 29.5438816	Point 43	34.9241952, 29.544374	0.13707924

Residential15	34.9419577, 29.5503784	Point 53	34.9411986, 29.5503879	0.084412482
Residential16	34.9423412, 29.5507611	Point 53	34.9411986, 29.5503879	0.131526474
Residential17	34.9335846, 29.5461722	Point 50	34.9352675, 29.546151	0.18713994
Residential18	34.9325117, 29.5451922	Point 29	34.9318583, 29.5471235	0.190461408
Residential19	34.9300344, 29.5429941	Point 37	34.9296456, 29.5434279	0.058591925
Residential20	34.9441295, 29.563908	Point 16	34.9438827, 29.5637867	0.029586323
Residential21	34.9409556, 29.5645596	Point 17	34.9409134, 29.561575	0.272090493
			TOTAL	10.20532423