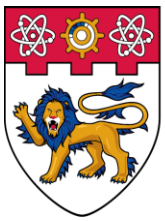


NANYANG TECHNOLOGICAL UNIVERSITY SINGAPORE

X

SHEA.

Project EcoTrek

A proof-of-concept of a mobile application/tool/code to track energy, water consumption, waste and lifestyle metrics to calculate the user's carbon footprint

NTU Clean Energy Club
Task Number: 3

Submitted by

Denis Tan
Julian Paul Lee (Co-Lead)
Kelly Koh
Mahek Merchant (Co-Lead)
Soh Soo Yang

Table of Contents

Executive Summary

Singapore has been ramping up its efforts to address climate change over the years. In 2009, Singapore pledged to reduce emission by 16% from business-as-usual levels by 2020 (NEA, n.d.). In addition, in a survey conducted by the National Climate Change Secretariat (NCCS) in 2019, over 90% of Singaporeans were aware of climate change and its impacts, and 78% were prepared to play their part towards a low-carbon Singapore (Tan, A., 2019). As such, there is a growing demand for items that are environmentally-friendly and trackers that track carbon emission for individuals and households.

This report looks into the process and results of the creation and design of an application graphic user interface (GUI) to calculate the carbon footprint. This will aid in the ease of individuals or households to track their carbon emission and contribute to combating climate change.

Acknowledgments

I would like to extend my sincere gratitude to the following individuals for their dedicated and valuable support throughout this project.

To Ms Rithika Thomas and Mr Chang Chia Chien from Project SHEA, thank you both for your timely replies to our requests for help and for availing yourselves for consultations even during your leave periods. It has been a real pleasure to work with both of you.

To Mr Bryan Lee and Mr Malani Sarvash of NTU Clean Energy Club, thank you both for providing many opportunities to connect with the Project SHEA team. Furthermore, thank you for providing the team with many useful summaries of each meeting and giving great feedback on our work.

I would also like to thank my team for this project for their excellent work.

Thank you, Kelly, Sooyang and Denis for being so responsible, timely and proactive. Each of you have shown me what a great team player looks like and I am glad that we had the chance to work together.

Finally, I would like to thank my fellow Co-Lead for this project, Mahek, for having the courage to step up as Co-Lead for the project and practically taking over my place as the main leader for the team. You have shown great resolve in completing the hard work of coding nearly single-handedly on top of organising the team. Thank you for your great tenacity to see the project through.

Sincerely,

Julian

EcoTrek Co-Lead

1 Introduction

Project EcoTrek is a project organised jointly by NTU Clean Energy Club (NCEC) and Project SHEA. As part of such projects, NCEC students are given the opportunity to work on specific tasks laid out by Project SHEA.

Project EcoTrek evolved from what was originally Task 3.

Task 3

To develop the **proof-of-concept** of a mobile application/tool/code to track **energy, water consumption, waste** and **lifestyle metrics** to calculate the user's carbon footprint based on reference datasets from volunteers.

In brief, the EcoTrek application takes in the input of energy, water consumption, waste and lifestyle metrics and outputs the user's estimated carbon footprint.

In order to be able to calculate the user's carbon footprint from their lifestyle metrics, the EcoTrek application has to refer to datasets detailing the carbon footprint of specific lifestyle metrics. This is elaborated on in Chapter 2 and 3 of this report.

Furthermore, a Graphical User Interface (GUI) is needed to allow the user to have a smooth experience when they input their lifestyle metrics. This is covered in greater detail in Chapter 4 of this report.

Chapter 5 details the possibilities of further development of the EcoTrek app.

Why is the app named 'EcoTrek'?
The thought process in choosing the name 'EcoTrek' is explained below:

- 'EcoTrek' is composed of two parts - 'Eco' and 'Trek'.
- 'Eco' is derived from the word 'Ecology'.
- 'Trek' is a play on the word 'Track' and also plays on the idea of a 'carbon footprint'.
- EcoTrek is therefore a project for *tracking the ecological footprint* of the user.

2 Data Collection

2.1 Electricity Grid Emission Metrics

The electricity grid emission metrics are obtained from the Electricity Grid Emission Factor and Upstream Fugitive Methane Emission Factor, 2005 - 2019 provided by the Energy Market Authority (EMA).

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Electricity Grid Emission Factors															
Average Operating Margin (OM) (kg CO2 / kWh)	0.5255	0.5300	0.5046	0.4965	0.4973	0.5083	0.5085	0.4778	0.4388	0.4277	0.4224	0.4237	0.4210	0.4206	0.4085
Build Margin (BM) (kg CO2 / kWh)	0.4205	0.4225	0.4352	0.4264	0.4208	0.4319	0.4578	0.4164	0.4137	0.4086	0.3941	0.3977	0.4018	0.4031	0.4013
Upstream Fugitive Methane Emission Factor (kg CH4 / kWh)	0.00216	0.00218	0.00225	0.00221	0.00222	0.00222	0.00228	0.00218	0.00218	0.00220	0.00217	0.00216	0.00198	0.00213	0.00212

Table 1: Electricity Grid Emission Factor and Upstream Fugitive Methane Emission Factor, 2005 - 2019

The Grid Emission Factor (GEF) measures the average CO2 emission emitted per MWh of electricity. It can be calculated using the Average Operating Margin (OM) or the Build Margin (BM) method. The OM measures the system-wide emissions factor while the BM measures the emissions factor of newer facilities. More details on the GEF could be found in the “Technical Notes” section of the Singapore Energy Statistics (SES) publication.

The 2017 and 2018 GEF have been revised to include fossil fuel-based carbon emissions from the incineration of non-plastics such as textile, rubber and leather.

2.2 Waste Emission Metrics

The waste emission metrics are obtained from the emission factors for different municipal solid waste (MSW) management systems treatment methods. A total of 6 different methods can be identified.

1) Landfill
2) Incineration
3) Sorting + Composting + Landfill
4) Sorting + Composting + Incineration
5) Sorting + Dry Biomethanization + Landfill
6) Sorting + Wet Biomethanization + Incineration + Landfill

Table 2 Emission factors for different municipal solid waste (MSW) management systems

treatment methods	emission factor /(tons CO_2-eq[a)] /tons of MSW)
landfill	1.97
incineration	1.67
sorting + composting + landfill	1.61
sorting + composting + incineration	1.41
sorting + dry biomethanization + landfill	1.42
sorting + wet biomethanization + incineration + landfill	1.19

Note: a) "CO_2-eq" is "carbon dioxide equivalents"

Table 2: Emission factors for different municipal solid waste (MSW) management systems treatment methods

2.3 Water Consumption Emission Metrics

The water consumption emission metrics are obtained from the 2 tables below.

		System components for NEWater at consumer							
Midpoint impact category	**Value**	**Abstraction of fresh water from reservoir[a]**	**Abstraction of river water**	**Production of desalinated water[b]**	**Production of NEWater[b]**	**Production of water from Waterworks[b]**	**Production of reclaimed Water[b]**	**Collection of wastewater[b]**	**Distribution of Tap water/NEWater[b]**
Climate change	2.19 kg CO_2-Eq	0%	0%	0%	15%	0%	53%	27%	4%
Ozone layer depletion	3.79E-05 kg CFC-11-Eq	0%	0%	0%	12%	0%	88%	0%	0%
Photochemical oxidation	0.00109 kg NMVOC	0%	0%	0%	52%	0%	24%	14%	10%

Human toxicity	0.172 kg 1,4-DCB-Eq	0%	0%	0%	61%	0%	32%	4%	3%
Particulate matter	7.94E-04 kg PM10-Eq	0%	0%	0%	61%	0%	20%	11%	8%
Terrestrial acidification	0.00282 kg SO_2-Eq	0%	0%	0%	48%	0%	32%	12%	9%
Fossil depletion	0.317 kg oil-Eq	0%	0%	0%	36%	0%	36%	16%	12%
Water depletion	0.00344 m^3	0%	0%	0%	46%	0%	32%	13%	9%

[a] Only considers natural freshwater from stormwater collection. Excludes NEWater contribution to reservoir.

[b] Includes operational inputs and emissions, excludes embodied impact of primary flow

Table 3: Midpoint impact results and percentage breakdown for the individual system components contributing to NEWater at consumer based on functional unit of 1m3 of NEWater at consumer

		System components for Tap water at consumer							
Midpoint impact category	**Value**	**Abstraction of fresh water from reservoir [a]**	**Abstraction of river water**	**Production of desalinated water[b]**	**Production of NEWater[b]**	**Production of water from Waterworks[b]**	**Production of reclaimed Water[b]**	**Collection of wastewater[b]**	**Distribution of Tap water/NEWater[b]**
Climate change	1.30 kg CO_2-Eq	0%	0%	33%	1%	52%	4%	2%	7%
Ozone layer depletion	4.82E-06 kg CFC-11-Eq	0%	0%	61%	5%	2%	33%	0%	0%
Photochemical oxidation	0.00127kg NMVOC	0%	0%	41%	2%	47%	1%	1%	9%
Human toxicity	0.255 kg 1,4-DCB-Eq	0%	0%	15%	2%	80%	1%	0%	2%
Particulate matter	8.78E-04kg PM10-Eq	0%	0%	36%	3%	53%	1%	0%	7%

Terrestrial acidification	0.00584 kg SO_2-Eq	0%	0%	19%	1%	74%	1%	0%	4%
Fossil depletion	0.271kg oil-Eq	0%	0%	57%	2%	24%	2%	1%	14%
Water depletion	0.882 m3	56%	43%	0%	0%	0%	0%	0%	0%

[a] Only considers natural freshwater from stormwater collection. Excludes NEWater contribution to reservoir.

[b] Includes operational inputs and emissions, excludes embodied impact of primary flow

Table 4: Midpoint impact results and percentage breakdown for the individual system components contributing to Tap water at consumer based on functional unit of 1m3 of Tap water at consumer

2.4 Transport Emission Metrics

The transport emission metrics are obtained from the tables below. Data for 3 different modes of transport are provided. They are car (4-seater), bus, and MRT respectively.

Mode of transport	**Carbon Footprint ($kgCO_2$)**
Car (4-seater)	0.14 $kgCO_2$/vehicle km
Bus	0.019 $kgCO_2$ per passenger-kilometre
MRT	0.013 $kgCO_2$ per passenger-kilometre

Table 5: Carbon footprint (kgCO2) for each mode of transport

2.5 Food Consumption Emission Metrics

The food consumption emission metrics are obtained from a joint study conducted by Temasek, Deloitte, A*STAR, and Singapore Institute of Manufacturing Technology ("Environmental Impact of Key Food Items in Singapore", 2019). The study analyzes the environmental impact of key food items in Singapore.

The study quantifies the environmental impact of the production, processing and transportation stages of food in Singapore in terms of GHG emissions, energy consumption and water consumption. The study covers 13 key food items which are the 11 items tracked by Singapore Food Agency (SFA) and 2 staples (rice and wheat).

The following tables show the environmental impact of the 13 key food items.

Key Food Items	Specific Food Items	Country Source	Indicators	Units	Total	Production	Processing	Transportation	Percentage of Key Food Item
Chicken (kg meat)	Fresh	Malaysia + processed in Singapore	GHG Emissions	kg CO_2-eq	3.380368	2.995031	0.38144	0.003897	36%
			Energy Consumption	kWh	21.969	20.95033	1.000041	0.018625	
			Water Consumption	litres	543.7095	530.1613	13.54397	0.00432	
	Frozen	Malaysia	GHG Emissions	kg CO_2-eq	3.763021	2.998928	0.761379	0.002714	1%
			Energy Consumption	kWh	23.29289	20.96896	2.310853	0.013085	
			Water Consumption	litres	544.5041	530.1656	14.3	0.00296	
		Brazil	GHG Emissions	kg CO_2-eq	3.63258	2.527702	0.680492	0.424386	46%
			Energy Consumption	kWh	23.63409	19.64725	2.033393	1.953449	
			Water Consumption	litres	554.4439	551.7638	2.157743	0.522355	
Duck (kg meat)	Fresh	Malaysia + processed in Singapore	GHG Emissions	kg CO_2-eq	4.142192	3.812459	0.325677	0.004056	34%
			Energy Consumption	kWh	24.15862	22.69209	1.44714	0.019382	
			Water Consumption	litres	755.3193	753.7943	1.520562	0.004496	
	Frozen	Malaysia + processed in Singapore	GHG Emissions	kg CO_2-eq	4.250369	3.812459	0.433854	0.004056	60%
			Energy Consumption	kWh	24.65039	22.69209	1.938915	0.019382	
			Water Consumption	litres	755.6846	753.7943	1.885818	0.004496	
Mutton (kg meat)	Chilled	Australia	GHG Emissions	kg CO_2-eq	21.2201	13.19894	0.900921	7.120243	30%
			Energy Consumption	kWh	54.4563	18.54286	4.03252	31.88092	
			Water Consumption	litres	559.2277	534.2696	19.57792	5.380136	
			GHG Emissions	kg CO_2-eq	14.34296	13.19894	0.967689	0.176332	

Table 6: Environmental impact of chicken, duck, mutton

Key Food Items	Specific Food Items	Country Source	Indicators	Units	Total	Production	Processing	Transportation	Percentage of Key Food Item
Pork (kg meat)	Fresh	Indonesia + processed in Singapore	GHG Emissions	kg CO_2-eq	9.00934731	7.22039819	1.7484542	0.04049491	17%
			Energy Consumption	kWh	36.3562596	27.8194819	8.35273176	0.18404597	
			Water Consumption	litres	836.689216	825.609536	11.0328988	0.04678044	
	Chilled	Brazil	GHG Emissions	kg CO_2-eq	26.9740328	7.2956226	0.81951735	18.8588928	10%
			Energy Consumption	kWh	118.671078	28.1040681	6.13965788	84.4273521	
			Water Consumption	litres	854.989734	834.045794	6.70111408	14.2428261	
		Australia	GHG Emissions	kg CO_2-eq	18.3298817	7.13954458	4.07009369	7.12024343	4%
			Energy Consumption	kWh	71.2620622	27.5491043	11.8343304	31.8786274	
			Water Consumption	litres	846.825389	817.660082	23.7851704	5.38013636	
	Frozen	Brazil	GHG Emissions	kg CO_2-eq	8.56600375	7.2956226	0.84836555	0.4220156	24%
			Energy Consumption	kWh	36.3957043	28.1040681	6.42275666	1.86887957	
			Water Consumption	litres	841.317456	834.045794	6.7713812	0.50028023	
		Australia	GHG Emissions	kg CO_2-eq	11.4827046	7.13954458	4.16682801	0.17633204	8%
			Energy Consumption	kWh	40.4501858	27.5491043	12.1171432	0.78393822	
			Water Consumption	litres	842.12738	817.660082	24.2590585	0.20823942	
		Netherlands	GHG Emissions	kg CO_2-eq	9.81102315	7.08577643	2.36322208	0.36202464	12%
			Energy Consumption	kWh	39.5040827	27.3518598	10.548284	1.60393892	
			Water Consumption	litres	824.355139	811.824375	12.1017885	0.42897494	
		Spain	GHG Emissions	kg CO_2-eq	9.36335679	7.2956226	1.77765705	0.29007714	6%
			Energy Consumption	kWh	39.9909123	28.1040681	10.6006035	1.28624071	
			Water Consumption	litres	847.050753	834.045794	12.6615132	0.34344598	

Table 7: Environmental impact of pork

Key Food Items	Specific Food Items	Country Source	Indicators	Units	Total	Production	Processing	Transportation	Percentage of Key Food Item
Beef (kg meat)	Chilled	Brazil	GHG Emissions	kg CO_2-eq	38.38723	18.83387	0.694466	18.85889	16%
			Energy Consumption	kWh	106.1078	16.91075	4.763607	84.43343	
			Water Consumption	litres	887.1052	867.0229	5.839463	14.24283	
		Australia	GHG Emissions	kg CO_2-eq	27.49682	18.85724	1.519332	7.120243	8%
			Energy Consumption	kWh	54.65465	16.76855	6.005179	31.88092	
			Water Consumption	litres	867.7766	852.116	10.28049	5.380136	
		New Zealand	GHG Emissions	kg CO_2-eq	29.29078	18.76068	0.632927	9.897177	3%
			Energy Consumption	kWh	65.28326	16.55886	4.411483	44.31291	
			Water Consumption	litres	864.9728	851.6393	5.856836	7.476722	
	Frozen	Brazil	GHG Emissions	kg CO_2-eq	19.9699	18.83387	0.714009	0.422016	36%
			Energy Consumption	kWh	23.73801	16.91075	4.958246	1.869014	
			Water Consumption	litres	873.4112	867.0229	5.887969	0.50028	
		Australia	GHG Emissions	kg CO_2-eq	20.61967	18.85724	1.5861	0.176332	20%
			Energy Consumption	kWh	23.75217	16.76855	6.199621	0.783995	
			Water Consumption	litres	862.934	852.116	10.60978	0.208239	
		New Zealand	GHG Emissions	kg CO_2-eq	19.64468	18.76068	0.648534	0.235474	8%
			Energy Consumption	kWh	22.20997	16.55886	4.605926	1.045184	
			Water Consumption	litres	857.8354	851.6393	5.917614	0.278541	

Table 8: Environmental impact of beef

Key Food Items	Specific Food Items	Country Source	Indicators	Units	Total	Production	Processing	Transportation	Percentage of Key Food Item
Eggs (kg)	Fresh	Malaysia	GHG Emissions	kg CO_2-eq	3.10849	3.045769	0.055363	0.007358	81%
			Energy Consumption	kWh	17.21907	17.00257	0.181337	0.035165	
			Water Consumption	litres	456.1129	455.8614	0.243262	0.008157	
		Singapore	GHG Emissions	kg CO_2-eq	2.955663	2.924229	0.031273	0.000161	19%
			Energy Consumption	kWh	16.92422	16.80427	0.11918	0.000771	
			Water Consumption	litres	455.6971	455.5065	0.190444	0.000179	

Table 9: Environmental impact of eggs

Key Food Items	Specific Food Items	Country Source	Indicators	Units	Total	Production	Processing	Transportation	Percentage of Specific Food Item
Fruits (kg)	Banana	Malaysia	GHG Emissions	kg CO_2-eq	0.382615	0.191647	0.101987	0.088981	41%
			Energy Consumption	kWh	3.538681	2.423172	0.687575	0.427935	
			Water Consumption	litres	147.5876	145.5886	1.902155	0.0969	
		Philippines	GHG Emissions	kg CO_2-eq	0.390919	0.199766	0.101987	0.089166	42%
			Energy Consumption	kWh	3.534318	2.44772	0.687575	0.399024	
			Water Consumption	litres	143.1916	141.1891	1.902155	0.100377	
	Watermelon	Malaysia	GHG Emissions	kg CO_2-eq	0.318382	0.127414	0.101987	0.088981	99%
			Energy Consumption	kWh	2.123419	1.007909	0.687575	0.427935	
			Water Consumption	litres	76.40728	74.40823	1.902155	0.0969	
	Papaya	Malaysia	GHG Emissions	kg CO_2-eq	0.335058	0.14409	0.101987	0.088981	97%
			Energy Consumption	kWh	2.347446	1.231937	0.687575	0.427935	
			Water Consumption	litres	93.18457	91.18551	1.902155	0.0969	
	Pineapple	Malaysia	GHG Emissions	kg CO_2-eq	0.28408	0.093112	0.101987	0.088981	84%
			Energy Consumption	kWh	2.357335	1.241826	0.687575	0.427935	
			Water Consumption	litres	28.76637	26.76732	1.902155	0.0969	
	Orange	Australia	GHG Emissions	kg CO_2-eq	0.50028	0.19825	0.096674	0.205356	24%
			Energy Consumption	kWh	3.012304	1.436364	0.664308	0.911632	
			Water Consumption	litres	172.5841	170.5412	1.811324	0.231592	
		USA	GHG Emissions	kg CO_2-eq	0.996865	0.156613	0.096674	0.743579	31%
			Energy Consumption	kWh	5.372426	1.420645	0.664308	3.287473	
			Water Consumption	litres	173.0522	170.4015	1.811324	0.839338	
		South Africa	GHG Emissions	kg CO_2-eq	0.593861	0.196074	0.101987	0.295801	20%
			Energy Consumption	kWh	3.427926	1.429191	0.687575	1.31116	
			Water Consumption	litres	162.0502	159.8144	1.902155	0.333703	
		Egypt	GHG Emissions	kg CO_2-eq	0.566273	0.180691	0.10312	0.282461	16%
			Energy Consumption	kWh	3.422117	1.477244	0.692538	1.252335	
			Water Consumption	litres	177.4357	175.1955	1.921532	0.318637	

Table 10: Environmental impact of fruits

Key Food Items	Specific Food Items	Country Source	Indicators	Units	Total	Production	Processing	Transportation	Percentage of Specific Food Item
Other Vegetables (kg)	Tomato	Malaysia	GHG Emissions	kg CO_2-eq	0.598867	0.422768	0.101987	0.074113	96%
			Energy Consumption	kWh	3.107066	2.062612	0.687575	0.356879	
			Water Consumption	litres	5.517014	3.53444	1.902155	0.080419	
	Cabbage	China	GHG Emissions	kg CO_2-eq	0.741585	0.534582	0.122128	0.084875	65%
			Energy Consumption	kWh	3.801334	2.699213	0.721776	0.380345	
			Water Consumption	litres	18.90912	16.90804	1.905877	0.095213	
		Indonesia	GHG Emissions	kg CO_2-eq	0.753856	0.579226	0.126156	0.048473	18%
			Energy Consumption	kWh	3.918827	2.967108	0.731996	0.219722	
			Water Consumption	litres	20.74055	18.7585	1.927948	0.054103	
	Carrot	Australia	GHG Emissions	kg CO_2-eq	1.318346	0.743562	0.356276	0.218508	47%
			Energy Consumption	kWh	5.744501	3.240385	1.533757	0.970359	
			Water Consumption	litres	30.05421	24.87218	4.935932	0.246094	
		China	GHG Emissions	kg CO_2-eq	1.173404	0.744659	0.344782	0.083962	31%
			Energy Consumption	kWh	4.967622	3.099317	1.49205	0.376255	
			Water Consumption	litres	28.12657	23.25057	4.781811	0.09419	
		Malaysia	GHG Emissions	kg CO_2-eq	1.063548	0.584422	0.395864	0.083263	18%
			Energy Consumption	kWh	5.007851	2.9295	1.677412	0.400939	
			Water Consumption	litres	28.01693	22.45979	5.466791	0.090347	
	Beansprout	Singapore	GHG Emissions	kg CO_2-eq	0.245715	0.048299	0.185325	0.012091	86%
			Energy Consumption	kWh	2.592055	1.045716	1.492056	0.054283	
			Water Consumption	litres	3.65581	1.649057	1.993202	0.013553	

Table 11: Environmental impact of other vegetables

Key Food Items	Specific Food Items	Country Source	Indicators	Units	Total	Production	Processing	Transportation	Percentage of Specific Food Item
Other Vegetables (kg)	Onion	China	GHG Emissions	kg CO_2-eq	0.990663	0.806908	0.099793	0.083962	8%
			Energy Consumption	kWh	4.438323	3.3841	0.677968	0.376255	
			Water Consumption	litres	23.84281	21.88397	1.86465	0.09419	
		Malaysia	GHG Emissions	kg CO_2-eq	0.843198	0.645356	0.11458	0.083263	15%
			Energy Consumption	kWh	4.351549	3.207886	0.742725	0.400939	
			Water Consumption	litres	23.33236	21.12456	2.117458	0.090347	
		India	GHG Emissions	kg CO_2-eq	1.186481	0.973262	0.11458	0.098639	53%
			Energy Consumption	kWh	5.209529	4.02493	0.742725	0.441874	
			Water Consumption	litres	24.65833	22.4302	2.117458	0.11067	
		Netherlands	GHG Emissions	kg CO_2-eq	1.119623	0.57053	0.101987	0.447106	9%
			Energy Consumption	kWh	5.945777	3.278819	0.687575	1.979383	
			Water Consumption	litres	24.0854	21.67901	1.902155	0.504229	
	Potato	Bangladesh	GHG Emissions	kg CO_2-eq	0.414978	0.202175	0.11458	0.098222	11%
			Energy Consumption	kWh	3.4443	2.261539	0.742725	0.440037	
			Water Consumption	litres	151.2954	149.0677	2.117458	0.1102	
		China	GHG Emissions	kg CO_2-eq	0.396377	0.212621	0.099793	0.083962	45%
			Energy Consumption	kWh	3.310227	2.256003	0.677968	0.376255	
			Water Consumption	litres	154.4677	152.5089	1.86465	0.09419	
		Indonesia	GHG Emissions	kg CO_2-eq	0.371213	0.202175	0.11458	0.054458	8%
			Energy Consumption	kWh	3.251112	2.261539	0.742725	0.246848	
			Water Consumption	litres	151.246	149.0677	2.117458	0.060782	
		Pakistan	GHG Emissions	kg CO_2-eq	0.483097	0.202175	0.11458	0.166341	10%
			Energy Consumption	kWh	3.744994	2.261539	0.742725	0.74073	
			Water Consumption	litres	151.3723	149.0677	2.117458	0.187118	
		USA	GHG Emissions	kg CO_2-eq	1.096731	0.201	0.10312	0.792612	10%
			Energy Consumption	kWh	6.529572	2.332445	0.692538	3.504589	
			Water Consumption	litres	160.4084	157.5925	1.921532	0.894357	

Table 12: Environmental impact of other vegetables

Key Food Items	Specific Food Items	Country Source	Indicators	Units	Total	Production	Processing	Transportation	Percentage of Specific Food Item
Wheat (kg)	Wheat	Australia	GHG Emissions	kg CO_2-eq	0.609043	0.445611	0.033018	0.130414	60%
			Energy Consumption	kWh	5.27265	4.419873	0.25851	0.594268	
			Water Consumption	litres	360.0115	359.826	0.030527	0.154908	
		USA	GHG Emissions	kg CO_2-eq	0.923174	0.490742	0.032978	0.399453	34%
			Energy Consumption	kWh	6.824875	4.770377	0.258532	1.795966	
			Water Consumption	litres	569.3428	568.8287	0.030301	0.483853	
Rice (kg)	Rice	Thailand	GHG Emissions	kg CO_2-eq	2.533341	2.688972	-0.188235	0.032605	40%
			Energy Consumption	kWh	6.270161	6.731953	-0.611380	0.149587	
			Water Consumption	litres	916.221650	917.122100	-0.938770	0.038302	
		India	GHG Emissions	kg CO_2-eq	2.671638	2.954330	-0.330820	0.048128	29%
			Energy Consumption	kWh	6.372628	7.113782	-0.960090	0.218936	
			Water Consumption	litres	937.566055	938.965400	-1.456620	0.057275	
		Vietnam	GHG Emissions	kg CO_2-eq	2.518485	2.688972	-0.221641	0.051153	23%
			Energy Consumption	kWh	6.161840	6.731953	-0.802540	0.232430	
			Water Consumption	litres	916.120389	917.122100	-1.062710	0.061000	
Leafy vegetables (kg)	Chinese Cabbage	China	GHG Emissions	kg CO_2-eq	0.429858	0.240616	0.100878	8.84E-02	53%
			Energy Consumption	kWh	1.697833	0.617993	0.682719	0.397121	
			Water Consumption	litres	49.62431	47.6421	1.883198	0.099014	
		Malaysia	GHG Emissions	kg CO_2-eq	0.43304	0.253411	0.101987	7.76E-02	18%
			Energy Consumption	kWh	1.703154	0.641726	0.687575	0.373853	
			Water Consumption	litres	52.97003	50.98361	1.902155	0.084265	
		Singapore	GHG Emissions	kg CO_2-eq	0.342679	0.238802	0.100878	3.00E-03	5%
			Energy Consumption	kWh	1.319076	0.621921	0.682719	0.014436	
			Water Consumption	litres	49.53329	47.64684	1.883198	0.003258	

Table 13: Environmental impact of wheat, rice, leafy vegetables

Key Food Items	Specific Food Items	Country Source	Indicators	Units	Total	Production	Processing	Transportation	Percentage of Specific Food Item
Leafy Vegetables (kg)	Spinach	Malaysia	GHG Emissions	kg CO_2-eq	0.273495	0.093198	0.102448	0.077848	69%
			Energy Consumption	kWh	1.960628	0.89654	0.689252	0.374835	
			Water Consumption	litres	12.39289	9.948948	2.35945	0.084493	
		Singapore	GHG Emissions	kg CO_2-eq	0.18902	0.084638	0.101334	0.003047	3%
			Energy Consumption	kWh	1.547779	0.848736	0.684378	0.014665	
			Water Consumption	litres	12.11771	9.778871	2.335524	0.003311	
	Lettuce	Malaysia	GHG Emissions	kg CO_2-eq	0.469264	0.289027	0.101987	0.07825	56%
			Energy Consumption	kWh	2.250134	1.185804	0.687575	0.376755	
			Water Consumption	litres	40.51441	38.52732	1.902155	0.084938	
		Indonesia	GHG Emissions	kg CO_2-eq	0.445305	0.290708	0.101987	0.05261	10%
			Energy Consumption	kWh	2.119376	1.192204	0.687575	0.239598	
			Water Consumption	litres	40.49578	38.53501	1.902155	0.058622	
		Singapore (Soil-cultivated)	GHG Emissions	kg CO_2-eq	0.375591	0.271572	0.100878	0.003141	0.2%
			Energy Consumption	kWh	1.826109	1.128276	0.682719	0.015114	
			Water Consumption	litres	37.89475	36.00814	1.8832	0.003415	
		Singapore (Greenhouse soil-cultivated)	GHG Emissions	kg CO_2-eq	0.422315	0.317957	0.101334	0.003023	0.2%
			Energy Consumption	kWh	2.443691	1.744761	0.684378	0.014551	
			Water Consumption	litres	22.6083	20.26949	2.335524	0.003285	
		Singapore (Non-greenhouse hydroponics)	GHG Emissions	kg CO_2-eq	0.26783	0.163904	0.100878	0.003048	0.2%
			Energy Consumption	kWh	1.652446	0.955056	0.682719	0.014671	
			Water Consumption	litres	35.47109	33.58458	1.883198	0.003313	
		Singapore (Greenhouse hydroponics-vertical)	GHG Emissions	kg CO_2-eq	1.537362	1.433359	0.100878	0.003125	(Used in future scenario analysis)
			Energy Consumption	kWh	7.507604	6.809953	0.682719	0.014933	
			Water Consumption	litres	14.00427	12.11761	1.883198	0.003464	

Table 14: Environmental impact of leafy vegetables

Key Food Items	Specific Food Items	Country Source	Indicators	Units	Total	Production	Processing	Transportation	Percentage of Specific Food Item
Fish (kg meat)	Catfish	Vietnam	GHG Emissions	kg CO_2-eq	5.684848	4.577025	1.020249	0.087574	97%
			Energy Consumption	kWh	31.18636	25.98651	4.803454	0.396395	
			Water Consumption	litres	654.0944	650.4875	3.505	0.102	
	Salmon (chilled)	Norway	GHG Emissions	kg CO_2-eq	13.57337	1.638121	0.120767	11.81448	59%
			Energy Consumption	kWh	61.50662	6.420893	2.18004	52.90569	
			Water Consumption	litres	230.5335	221.0685	0.532	8.93	
	Salmon (frozen)	Norway	GHG Emissions	kg CO_2-eq	2.294267	1.715716	0.152069	0.426482	3%
			Energy Consumption	kWh	11.95619	6.72504	3.330744	1.90041	
			Water Consumption	litres	232.9262	231.5402	0.883	0.503	
		Myanmar	GHG Emissions	kg CO_2-eq	2.25376	1.698352	0.460176	0.095233	20%
			Energy Consumption	kWh	14.03711	6.813679	6.78574	0.43769	
			Water Consumption	litres	235.421	231.1164	4.196	0.109	
	Mackerel	Norway	GHG Emissions	kg CO_2-eq	4.685541	3.836092	0.445285	0.404163	23%
			Energy Consumption	kWh	15.16221	11.2934	2.068956	1.799852	
			Water Consumption	litres	2.32103	1.52562	0.319	0.477	
		China	GHG Emissions	kg CO_2-eq	5.557604	3.894808	1.566914	0.095882	31%
			Energy Consumption	kWh	16.02574	11.46626	4.120871	0.438615	
			Water Consumption	litres	5.30352	1.54897	3.644	0.11	
		Japan	GHG Emissions	kg CO_2-eq	5.171631	3.894808	1.096601	0.180222	12%
			Energy Consumption	kWh	15.58262	11.46626	3.305276	0.811086	
			Water Consumption	litres	3.77191	1.54897	2.012	0.211	
	Aquaculture	Singapore	GHG Emissions	kg CO_2-eq	3.73018	2.931717	0.791423	0.00704	81.3%
			Energy Consumption	kWh	20.83571	15.6612	5.140608	0.033898	
			Water Consumption	litres	433.3783	430.527	2.844	0.00764	
	Capture fishing	Singapore	GHG Emissions	kg CO_2-eq	4.262754	3.348328	0.891254	0.023171	18.7%
			Energy Consumption	kWh	16.1133	12.93904	3.062684	0.111578	
			Water Consumption	litres	3.54565	1.74793	1.773	0.0251	

Table 15: Environmental impact of fish

Key Food Items	Specific Food Items	Country Source	Indicators	Units	Total	Production	Processing	Transportation	Percentage of Specific Food Item
Other Seafood (kg meat)	Shrimp (frozen)	Vietnam	GHG Emissions	kg CO_2-eq	5.82830545	4.69009838	1.0417998	0.09640727	10%
			Energy Consumption	kWh	62.6322497	44.1890458	16.863006	1.58019786	
			Water Consumption	litres	0.21483072	0.21224691	0.00247245	0.00011136	
		Malaysia	GHG Emissions	kg CO_2-eq	5.90167102	4.75334663	1.0619243	0.0864001	48%
			Energy Consumption	kWh	60.7669715	42.8353327	16.4322778	1.49936105	
			Water Consumption	litres	0.21402444	0.21164831	0.00228199	9.41E-05	
		Indonesia	GHG Emissions	kg CO_2-eq	6.48815366	5.21829645	1.2098633	0.0599939	8%
			Energy Consumption	kWh	64.1579809	45.7856457	17.3710165	1.00131867	
			Water Consumption	litres	0.22055221	0.21662018	0.00386395	6.81E-05	
		China	GHG Emissions	kg CO_2-eq	7.22324152	5.85517759	1.2781812	0.08988274	20%
			Energy Consumption	kWh	68.5560486	49.5998842	17.4796875	1.47647692	
			Water Consumption	litres	0.23303935	0.23017877	0.00275698	0.00010361	
		Singapore	GHG Emissions	kg CO_2-eq	5.13862442	4.50791726	0.61092601	0.01978115	2%
			Energy Consumption	kWh	52.6379817	41.9781655	10.31654	0.34327609	
			Water Consumption	litres	0.2281306	0.22645048	0.00165857	2.16E-05	
	Crab (frozen)	Indonesia	GHG Emissions	kg CO_2-eq	4.86431293	3.28595477	1.35239889	0.22595927	3%
			Energy Consumption	kWh	110.503004	53.8056526	52.9454732	3.75187822	
			Water Consumption	litres	0.00729949	0.00201923	0.00502252	0.00025773	
		Philippines	GHG Emissions	kg CO_2-eq	4.96840779	3.28595477	1.31968914	0.36276389	1%
			Energy Consumption	kWh	112.509817	53.8056526	52.7774442	5.92672074	
			Water Consumption	litres	0.00706734	0.00201923	0.00462775	0.00042035	
		India	GHG Emissions	kg CO_2-eq	5.04473111	3.28595477	1.39885268	0.35992366	10%
			Energy Consumption	kWh	113.109537	53.8056526	53.4223163	5.88156841	
			Water Consumption	litres	0.00738888	0.00201923	0.00495267	0.00041697	

Table 16: Environmental impact of other seafood

Key Food Items	Specific Food Items	Country Source	Indicators	Units	Total	Production	Processing	Transportation	Percentage of Specific Food Item
Other Seafood (kg meat)	Crab (fresh)	Indonesia	GHG Emissions	kg CO_2-eq	4.79812762	3.28595477	1.32956783	0.18260503	31%
			Energy Consumption	kWh	109.467273	53.8056526	52.5961077	3.06551298	
			Water Consumption	litres	0.00722643	0.00201923	0.00499708	0.00021012	
		Philippines	GHG Emissions	kg CO_2-eq	4.84477302	3.28595477	1.29685807	0.26196018	26%
			Energy Consumption	kWh	110.57516	53.8056526	52.4280787	4.34142868	
			Water Consumption	litres	0.00692868	0.00201923	0.00460231	0.00030714	
		India	GHG Emissions	kg CO_2-eq	4.92228905	3.28595477	1.37602162	0.26031267	11%
			Energy Consumption	kWh	111.193543	53.8056526	53.0729508	4.31493914	
			Water Consumption	litres	0.00725158	0.00201923	0.00492722	0.00030513	
	Squid (fresh)	Malaysia	GHG Emissions	kg CO_2-eq	4.76347232	4.60622846	0.06478344	0.09246042	27%
			Energy Consumption	kWh	70.0891032	65.3686048	3.11779944	1.60269893	
			Water Consumption	litres	0.00276216	0.00245316	0.00020867	1.00E-04	
		Indonesia	GHG Emissions	kg CO_2-eq	4.73865097	4.60622846	0.06478344	0.06763907	1%
			Energy Consumption	kWh	69.6111336	65.3686048	3.11779944	1.12472929	
			Water Consumption	litres	0.00273668	0.00245316	0.00020867	7.49E-05	
		China	GHG Emissions	kg CO_2-eq	4.90059262	4.77173857	0.03769647	0.09115758	2%
			Energy Consumption	kWh	72.1286191	67.7165892	2.9151303	1.49689962	
			Water Consumption	litres	0.00284145	0.00254128	0.00019506	0.00010511	
	Squid (frozen)	Malaysia	GHG Emissions	kg CO_2-eq	4.94249148	4.60622846	0.24492955	0.09133346	6%
			Energy Consumption	kWh	80.2567391	65.3686048	13.303161	1.58497322	
			Water Consumption	litres	0.00363288	0.00245316	0.0010802	9.95E-05	
		Indonesia	GHG Emissions	kg CO_2-eq	4.91439978	4.60622846	0.24492955	0.06324177	17%
			Energy Consumption	kWh	79.7269067	65.3686048	13.303161	1.0551409	
			Water Consumption	litres	0.00360515	0.00245316	0.0010802	7.18E-05	
		China	GHG Emissions	kg CO_2-eq	5.07338584	4.77173857	0.21048969	0.09115758	26%
			Energy Consumption	kWh	81.8982516	67.7165892	12.6847628	1.49689962	
			Water Consumption	litres	0.00367741	0.00254128	0.00103102	1.05E-04	

Table 17: Environmental impact of other seafood

3 Coding Process of the Application Core

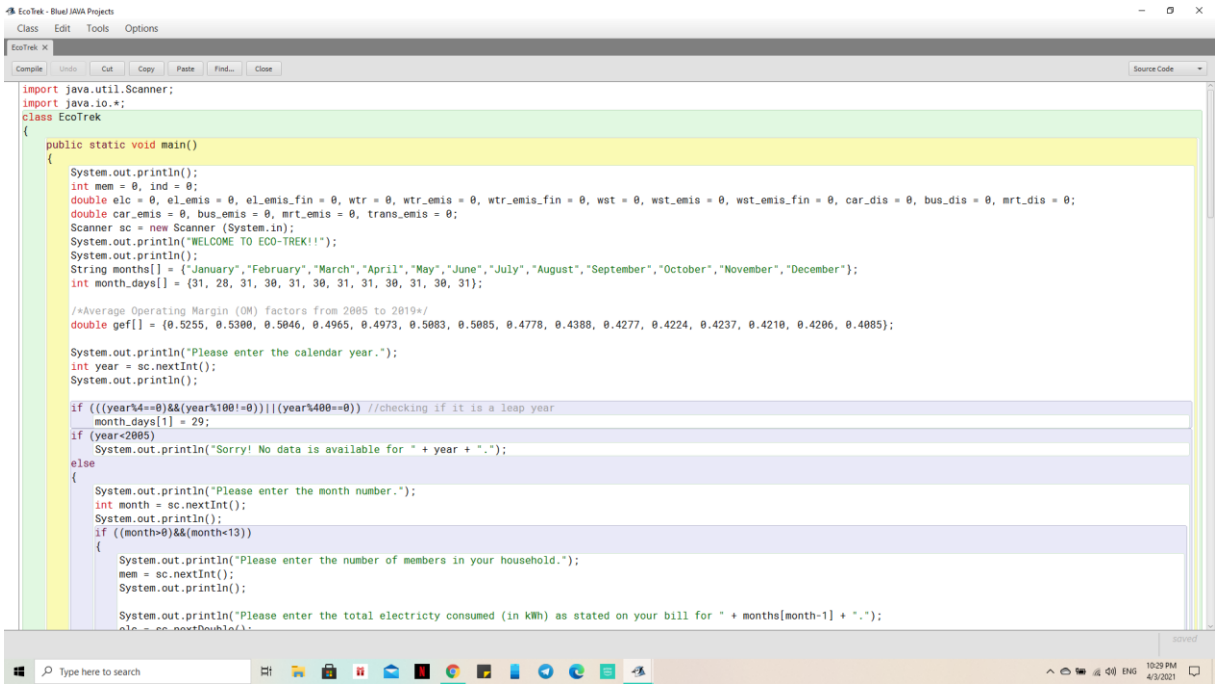
After collecting the data for all the metrics, we translated the calculation steps into program code to compute the approximate carbon footprint of a person. The program was written in JAVA using the BlueJ IDE.

On executing the program, the user will be first asked to input the calendar year, month, and the number of household members. If the user provides a valid input for each field, he will be asked to input the data on energy consumption and lifestyle metrics. Else, the terminal window will display an error message.

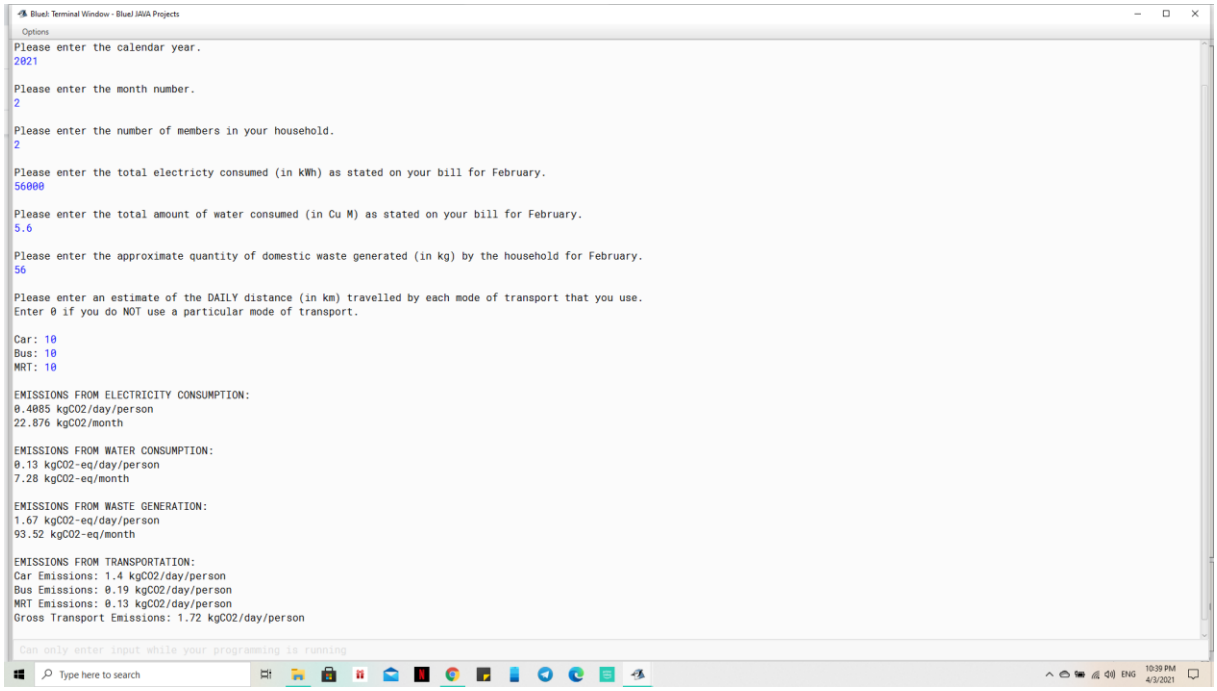
After the user inputs the data on energy consumption and lifestyle metrics, it is first checked for validity. We have put constraints to ensure that the user enters positive values for electricity and water consumption and other metrics. The user can enter 0 when asked to input the distance travelled by a certain mode of transport that he does not use. However, negative values cannot be input for any metric.

If the user provides an invalid input for a particular field, the output for that field will be 0 and the BlueJ terminal window will display an error message. If the user provides a valid input for a particular field, the carbon footprint due to that metric will be computed according to the emission factors in the collected data and displayed in the unit of kgCO2 / day / person.

The program written in BlueJ only calculates the carbon footprint due to electricity, water, waste, and transport. It does not include food emission factors due to coding limitations. Nonetheless, this code forms the basis for designing the graphic user interface (GUI) of the application.



Program Code in BlueJ



Program Output

4 Design of the Application Graphical User Interface (GUI)

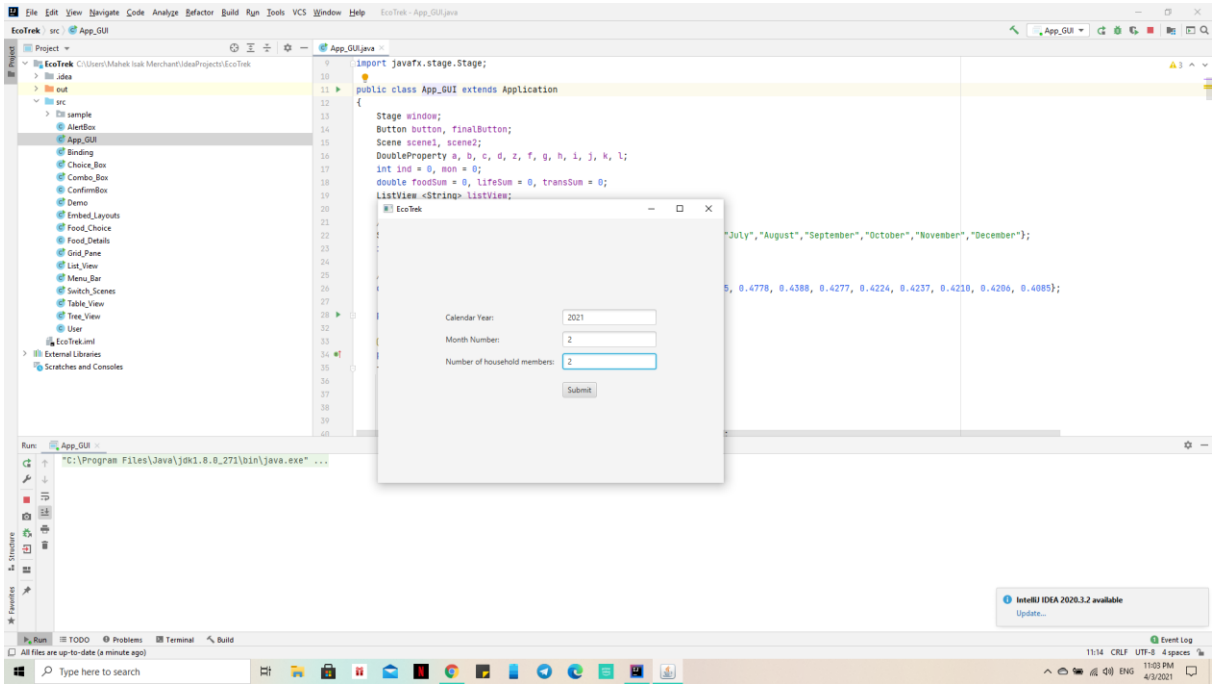
After coding the core of the application in BlueJ, the same program was used to design the graphic user interface (GUI) of the application in JavaFX using IntelliJ IDE. The design was edited over time after incorporating the suggestions from teammates and senior members of the NTU Clean Energy Club.

On executing the program, a popup window will ask the user to input the calendar year, month, and the number of household members. If the user provides a valid input for each field, he will be directed to the main window. Else, the terminal window will display an error message.

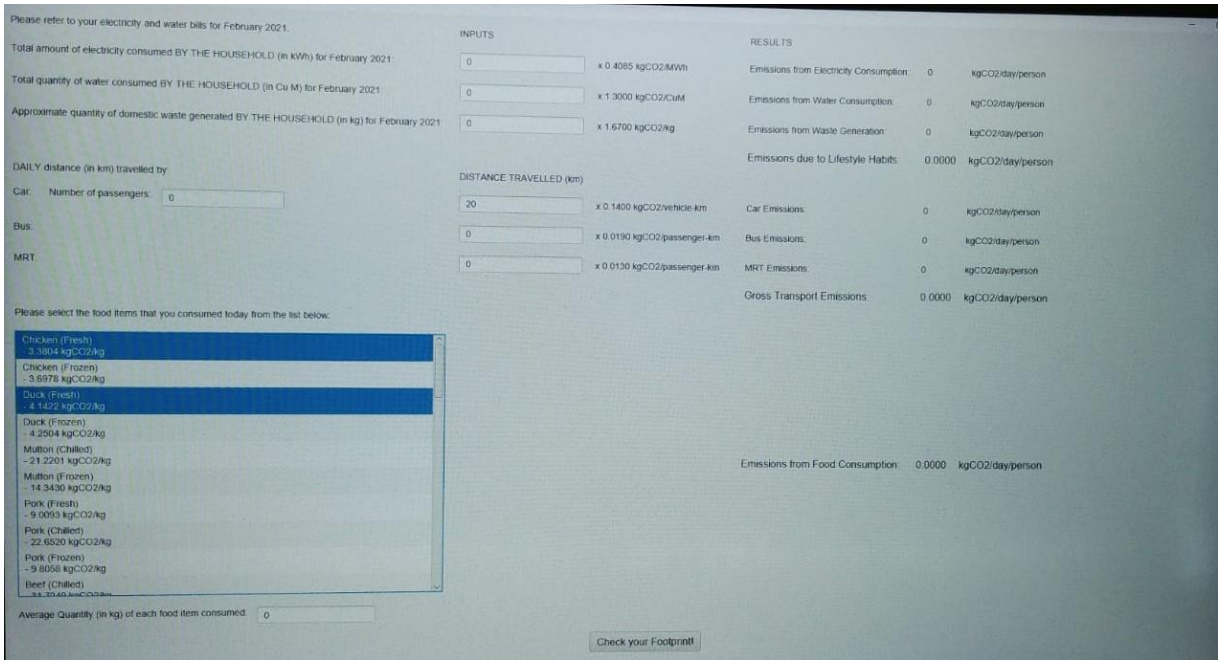
The JavaFX program in IntelliJ is similar to the JAVA program in BlueJ. The emissions due to electricity, water, waste, and transport are computed in the same manner. The output for all the metrics is displayed in the unit of kgCO2 / day / person. In case of an invalid input, the output for that particular field will be 0. No error message will be displayed.

However, unlike the previous program, the GUI asks the user to input the food items that he consumed during the day and the average quantity of each. This is implemented using a List Box that contains a list of food items, out of which one or more options can be selected. If the user provides a valid input for the average quantity of food items consumed, the output is computed according to the food emission factors in the collected data. Else, the output will be 0.

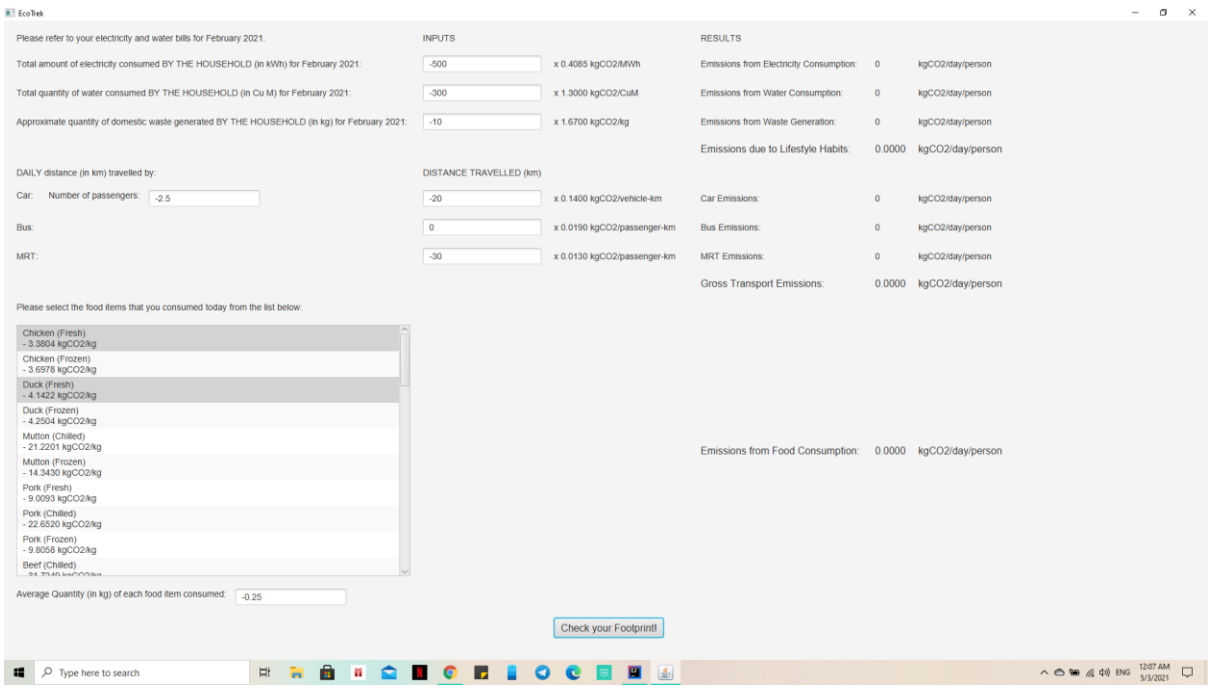
In addition to providing food inputs, the GUI also displays the emission factors for each metric next to the respective field. This measure is expected to increase awareness among the people regarding the actions that cause more pollution than others.



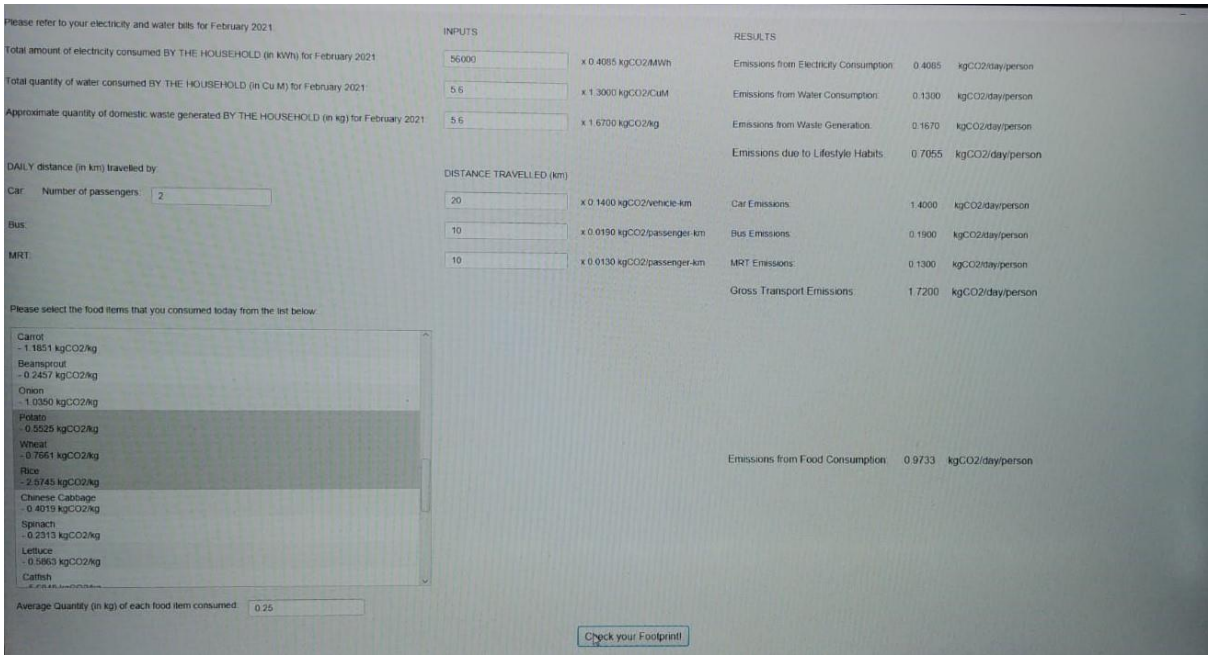
Popup window asking the user to input the calendar year, month, and the number of household members



Checking for invalid inputs



Checking for invalid inputs



Program output after giving valid inputs

5 Possibilities for Future Development

One of the possible ways for future development is via gamification of our application. To encourage more users to use the application, and to retain the users that already exist, elements of games and specifically challenges can be implemented into the application. Games that reward the users for completing challenges are positively reinforcing a specific behaviour. There are various ways in which games and challenges can be introduced into the app, for example a leaderboard, where users can compete on who has saved the most electricity or various metrics, would potentially encourage users to reduce their carbon footprint while using the application. Users could also potentially form teams to encourage and monitor other users to help further encourage usage of the application. Monetary benefits can also be included to help entice users to complete certain challenges such as reducing carbon footprint by 10% in a month. Examples of other applications using this system include popular fitness apps such as 42Race and HealthyWage, where users are rewarded when exercising, thus helping to promote a healthy living.

The Application can also allow advertisements which align with the interests of reducing emissions, such as with eco friendly companies or electric vehicles. This allows users to be introduced to more avenues where they are able to change their daily habits or use more environmentally friendly products while allowing the application to earn some revenue, which could then be used to further develop the application, or allow more companies to get on board.

The application can also be converted to cater to not only individuals and households, but towards industries and companies. More metrics can be added, with the application potentially automatically recording emissions from industries and companies via their systems, and thus allows these companies to also use the application to measure their emission levels, and potentially reduce their emissions. This would allow us to bring the application to a larger audience and thus help to bring greater awareness of the importance of reducing the carbon footprint.

These development goals potentially help to monetise the app, which could help bring aboard government agencies and companies on board thus furthering the development and usage of the application.

6 Conclusion

In conclusion, EcoTrek is a proof-of-concept application that allows its users to calculate their carbon footprint based on their lifestyle metrics.

This report has covered how EcoTrek works as well as how its user interface was created. Furthermore, ideas on how the app can be further developed were explored in the final section.

Hopefully, EcoTrek can be further developed to allow anyone and everyone to calculate their carbon footprint. It is said that the first step of change is awareness. With a greater awareness of their carbon footprint, perhaps humanity can change for the better and secure a brighter future for all of life.

References

Singapore’s efforts in addressing climate change. (n.d.) https://www.nea.gov.sg/our-services/climate-change-energy-efficiency/climate-change/singapore%27s-efforts-in-addressing-climate-change

Tan, A. (2019) More in Singapore aware of climate change, and willing to bear costs and inconvenience to safeguard planet: Survey. https://www.straitstimes.com/singapore/environment/more-in-singapore-aware-of-climate-change-and-are-willing-to-bear-costs-and

Environmental Impact of Key Food Items in Singapore. Ecosperity. (2019). Retrieved from https://www.ecosperity.sg/content/dam/ecosperity/en/reports/Environmental-Impact-of-Key-Food-Items-in-Singapore_Oct2019.pdf.