2019

IMPROVED MOBILE AIR CONDITIONING-GREENHOUSE GAS-LIFE CYCLE CLIMATE PERFORMANCE (IMAC-GHG-LCCP) TOOL –

USER’S GUIDE AND MANUAL

Optimized Thermal
SYSTEMS

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About

Latest Version: **Version 1.0.2.4 (August 2019)**

Software maintained and distributed by:

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Introduction

Life Cycle Climate Performance (LCCP) is a metric to estimate greenhouse gas (GHG) emissions throughout the lifecycle of a refrigerant gas, including emissions from manufacturing and end-of-life recycling. This tool was developed to measure the LCCP of Mobile Air Conditioning (MAC) system refrigerant after the U.S. Environmental Protection Agency (EPA) started providing incentives in the Greenhouse Gas Emissions Rule of 2009. The tool is an adaptation and improvement of the Excel-based GREEN-MAC-LCCP (Global Refrigerants Energy & Environmental-MAC-LCCP) with a focus on simplicity and ease-of-use.

This concept was first applied in the late 1990's by Oak Ridge National Laboratory (ORNL) and General Motors (GM) for the evaluation of alternative refrigerant options for R134a. ORNL originally proposed a metric called Total Equivalent Warming Impact (TEWI) in 1997. This metric can be used to estimate how a MAC system is contributing to global warming.

In 2017, Optimized Thermal Systems, Inc. (OTS) was contracted by the Society of Automotive Engineers (SAE)[1] to develop the next generation of the model originally developed at GM.

This document is designed to guide the user through the program and complete a successful simulation.

[1] SAE does not endorse or authorize the **IMAC-GHG-LCCP software**.

Installation and Setup

1. Hardware & Software Requirements

The hardware requirements for the installation of this software are as follows:

- Dual Core Intel/AMD Processor 2.0 GHz, 4GB RAM, 1GB Disk space
- Monitor resolution of 1366 x 768 or higher

The software requirements for the installation of this software are as follows:

- Microsoft Windows Operating System (Windows 7, 8.1, 10)
- Microsoft Office 2007-2016

2. Installation

The LCCP package will be delivered as a .zip folder. To install and run the LCCP package it needs to be unzipped and extracted into the desired folder.

Directions are as follows:

1. Download the .zip file in any desired folder from the email.

2. Extract the .zip file by right-clicking on the folder and selecting *"Extract All"* as shown in *Figure 1.*

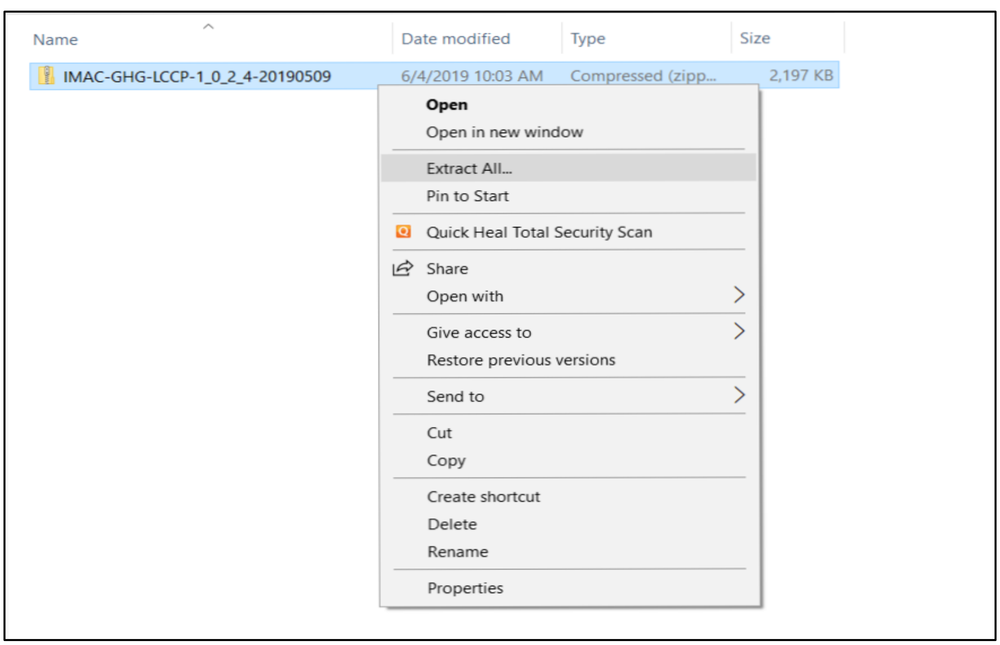


Figure 1. Extracting the package from the .zip file

3. From the pop-up screen, extract the package into the desired path and folder as shown in *Figure 2*.

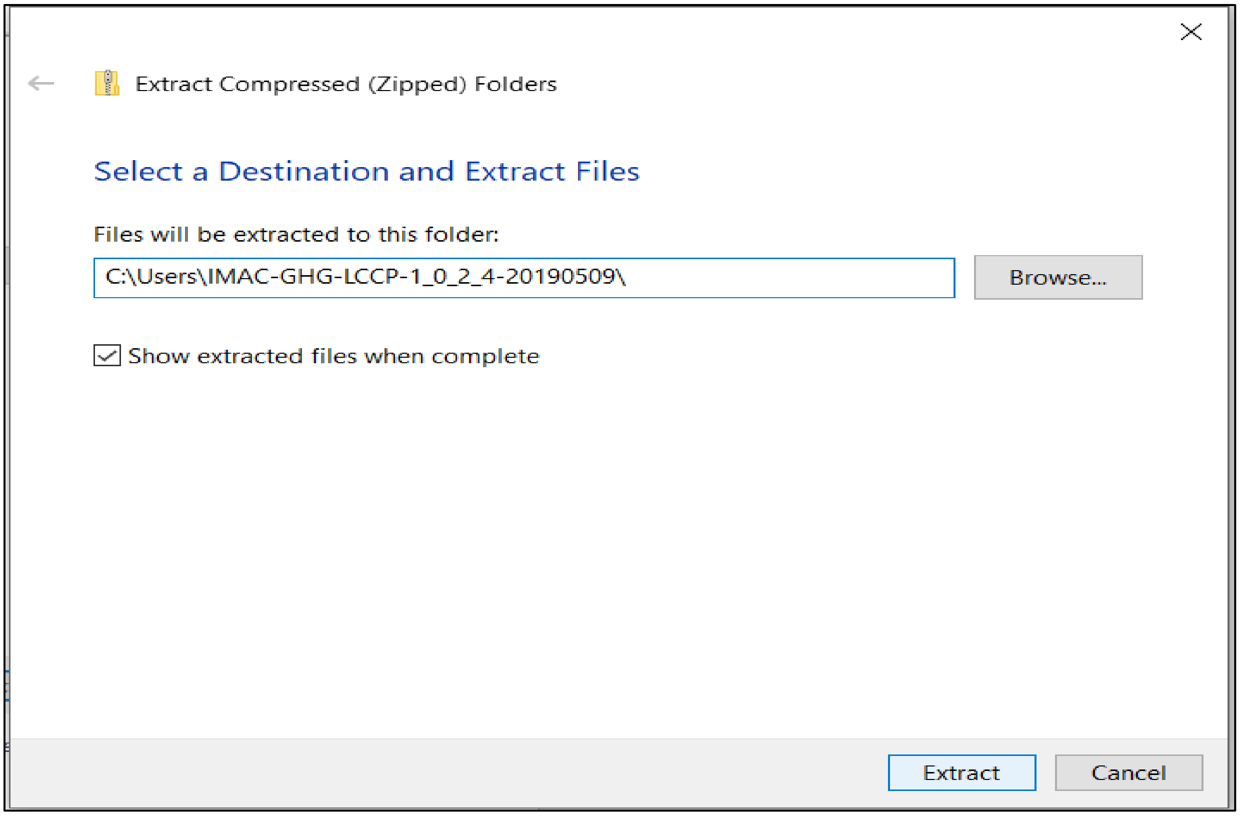


Figure 2. Selecting the path and folder for the package to be extracted

4. Once the package is extracted in the desired folder, the application can be accessed from it anytime the user wishes to run the program. Open the folder containing the tool, which will have the same name as the .zip file, and double click the *"LCCP2017"* icon to run the application as shown in *Figures 3 and 4*.

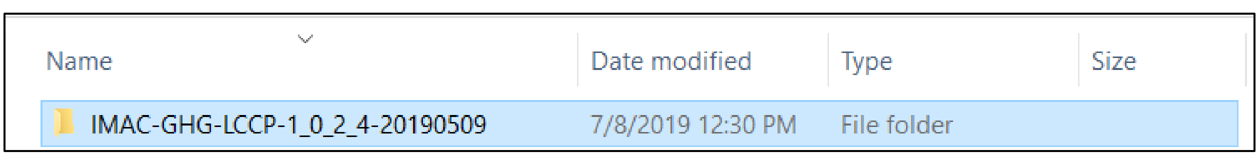


Figure 3. Opening the folder which contains the application

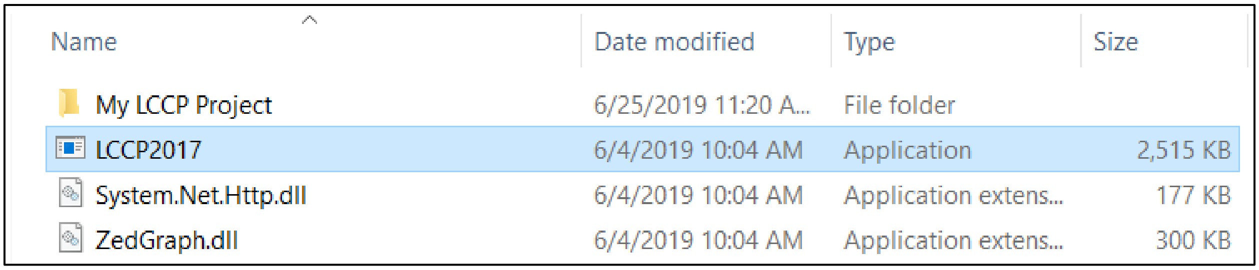


Figure 4. Running the application

5. On opening the application, click "*Enter*" to start the simulation or click "*About LCCP*" to learn more about it. A picture of the start-up screen is shown in *Figure 5*.

Figure 5. Starting the program

On selecting "*Enter*" the program will start, and the user will have to go through nine different input screens before the simulation can be run. All previous screens are saved automatically when the user moves onto the next screen. The simulation results are obtained as an Excel file which opens automatically after simulations are run. The directions to open the results file at a later stage can be obtained in the ***Viewing Results*** section or by clicking here.

Input Screen Walkthrough

This section is a walkthrough for each of the input screens for the IMAC-GHG-LCCP simulation tool. All screens have pre-defined data loaded in the input boxes. Instructions on how to load pre-defined data to complete some input screens are provided in their respective sections.

1. System Selection

The program begins with the Systems Selection screen shown in Figure 6. The user can choose to evaluate six unique systems simultaneously. There are four pre-defined refrigerants supported along with a user-defined refrigerant option.

The available pre-defined refrigerants are:

I. R-134a
II. R-1234yf
III. R-744
IV. R-152a

The screen includes the following inputs:

I. Project name
II. Number of systems
III. Name of all systems
IV. Type of refrigerant to be compared with an option of a user defined refrigerant

The available refrigerants and the input boxes can be seen in *Figure 6*.

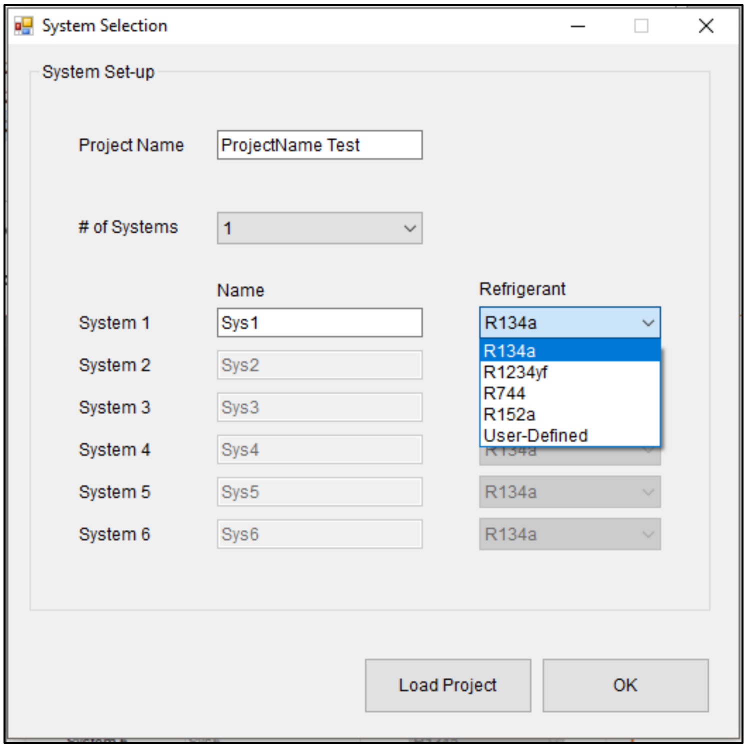


Figure 6. Selecting the system

On this screen, the user can also load a project that was previously developed by following the steps shown below:

1. Click on the *"Load Project"* button as seen in *Figure 6* to open the folder that has all previously saved projects. Select the required project that is required as shown in *Figure 7.*

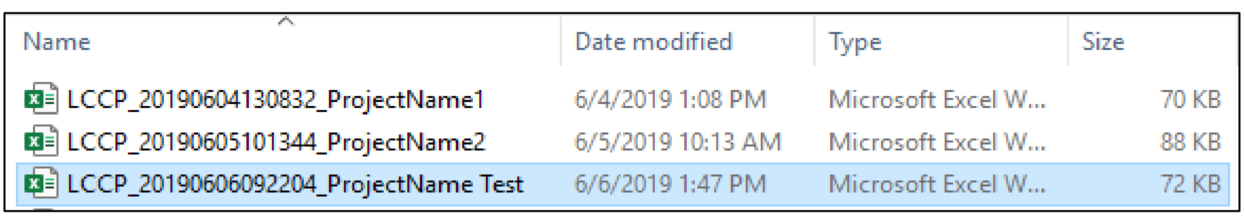


Figure 7. Loading a project file

2. Select the project that is to be worked on and let it load. The program will then refill all input boxes with the project data. *Figure 8* shows the completed screen after loading the project. Once complete, the screen will show a message *"Project loading complete".*

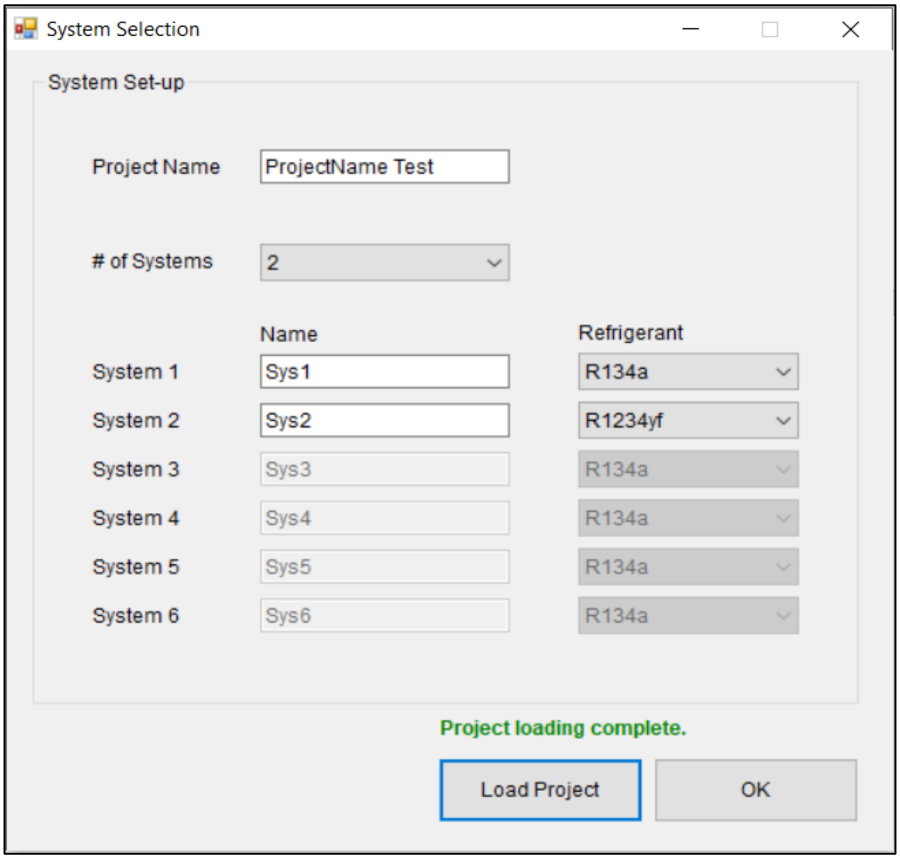


Figure 8. Loading of a previous project

2. Refrigerant Data

The Refrigerant Data screen shows the refrigerant characteristics for each system. The refrigerants come with pre-loaded data unless the user-defined refrigerant is selected.

Figure 9 shows the parameters that the user needs to provide if pre-defined refrigerants are used. They are:

I. Option of adding a recycle for refrigerant during servicing. Default: Yes
II. J2727 Leakage rate (g/y)

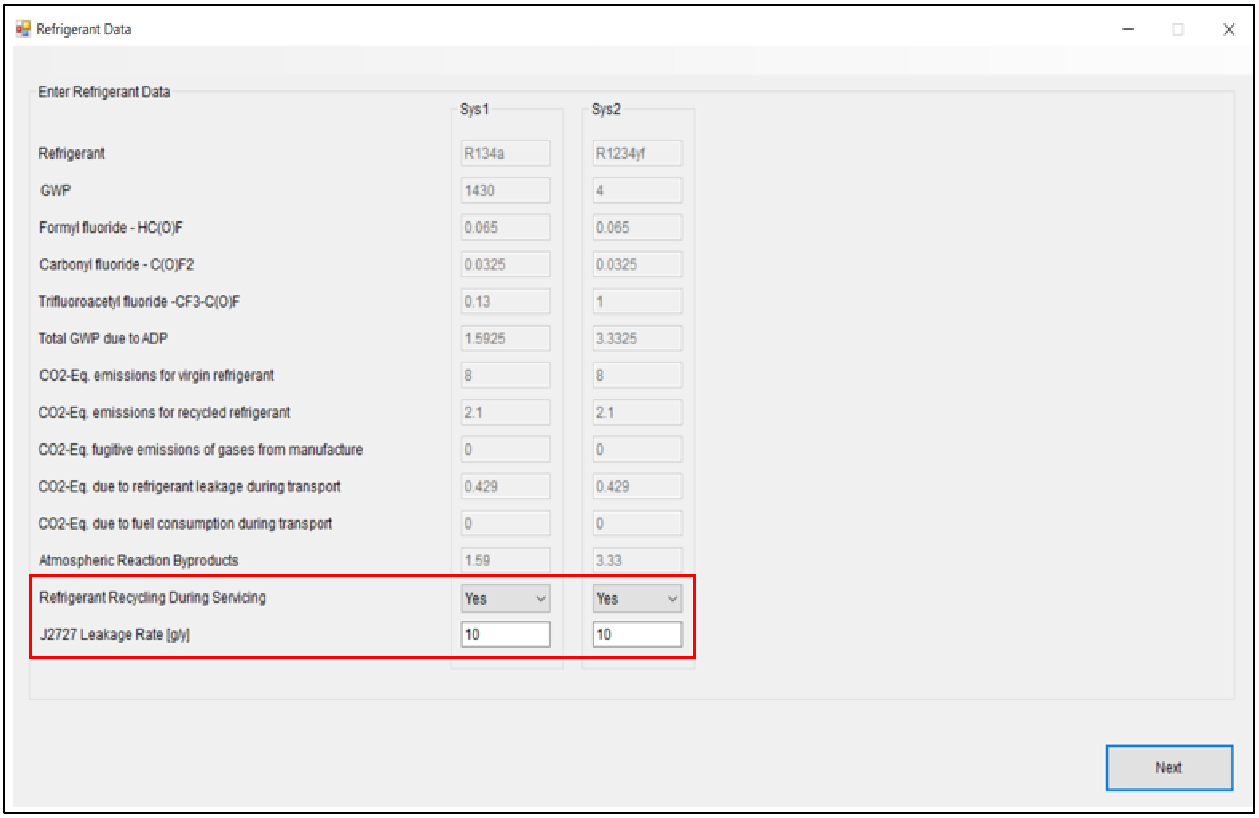


Figure 9. Providing data for pre-defined refrigerant

The user needs to define many more parameters if user-defined refrigerant is selected. They are listed below, and an example can also be seen in *Figure 10*.

Data to be entered if using user defined refrigerant:

I. GWP (Global Warming Potential)
II. Formyl fluoride-HC(O)F
III. Carbonyl fluoride-C(O)F2
IV. Trifluoroacetyl fluoride-CF3-C(O)F
V. CO_2-Eq. emissions for virgin refrigerant (g)
VI. CO_2-Eq. emissions for recycled refrigerant (g)
VII. CO_2-Eq. fugitive emissions of gases from manufacture (g)
VIII. CO_2-Eq. due to refrigerant leakage during transport (g)
IX. CO_2-Eq. due to fuel consumption during transport (g)
X. Refrigerant Recycling During Servicing (Y/N)
XI. J2727 Leakage rate (g/y)

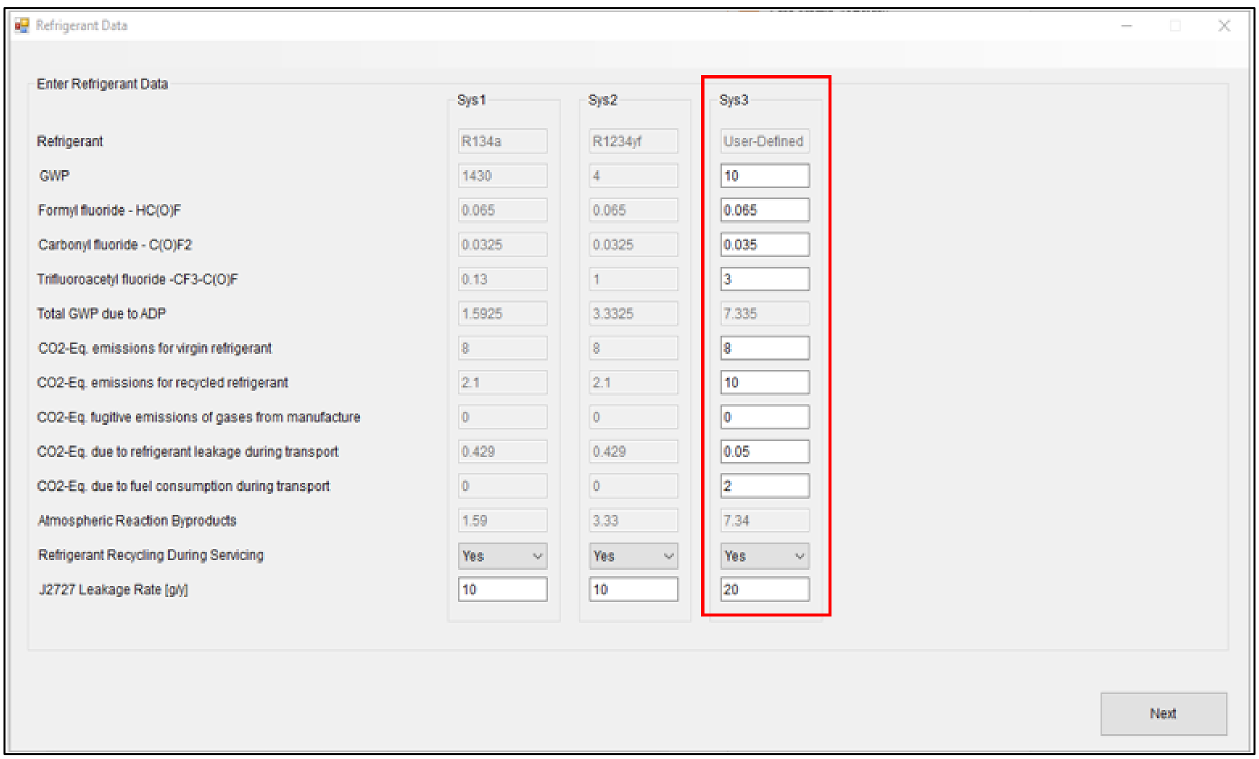


Figure 10. Providing data for a user-defined refrigerant

3. Parameter Selection

The Parameter Selection screen allows the user to select cities for evaluation, select the vehicle details, and modify the default vehicle servicing leakage rates. The city selection determines the weather bin data used to estimate the vehicle emissions. Cities from all around the world are available for comparison. The cities are categorized based on their region.

All vehicle data is pre-loaded, but the user can make modifications.

Data to be entered on this screen:

I. City Selection
II. Vehicle type
    i. Large
    ii. Mid-Size
    iii. Small
    iv. Truck
    v. Dual-AC
III. Pulley ratio
IV. Incremental Engine Efficiency (%)
V. Fuel type
    i. Diesel
    ii. Gasoline
    iii. Ethanol
    iv. Methanol
VI. Transmission type
    i. 6 speed auto
VII. Leakage rates
    i. Estimated loss before service is required (g)
    ii. Leaks from professional service (g/service)
    iii. Leaks from DIY service (g/service)
    iv. %DIY service

The user has the option to choose the type of vehicle type for each system. Each system uses the same refrigerant and the same vehicle in all selected cities to generate results.

Note: The leakage rates vary by region.

The procedure to complete this input screen is as follows:

1. Select the region that needs to be compared from the drop-down menu and select the country and city as shown in *Figure 11*. To add the cities to the simulation, select all the cities needed and click *"Add Selected Cities"*.

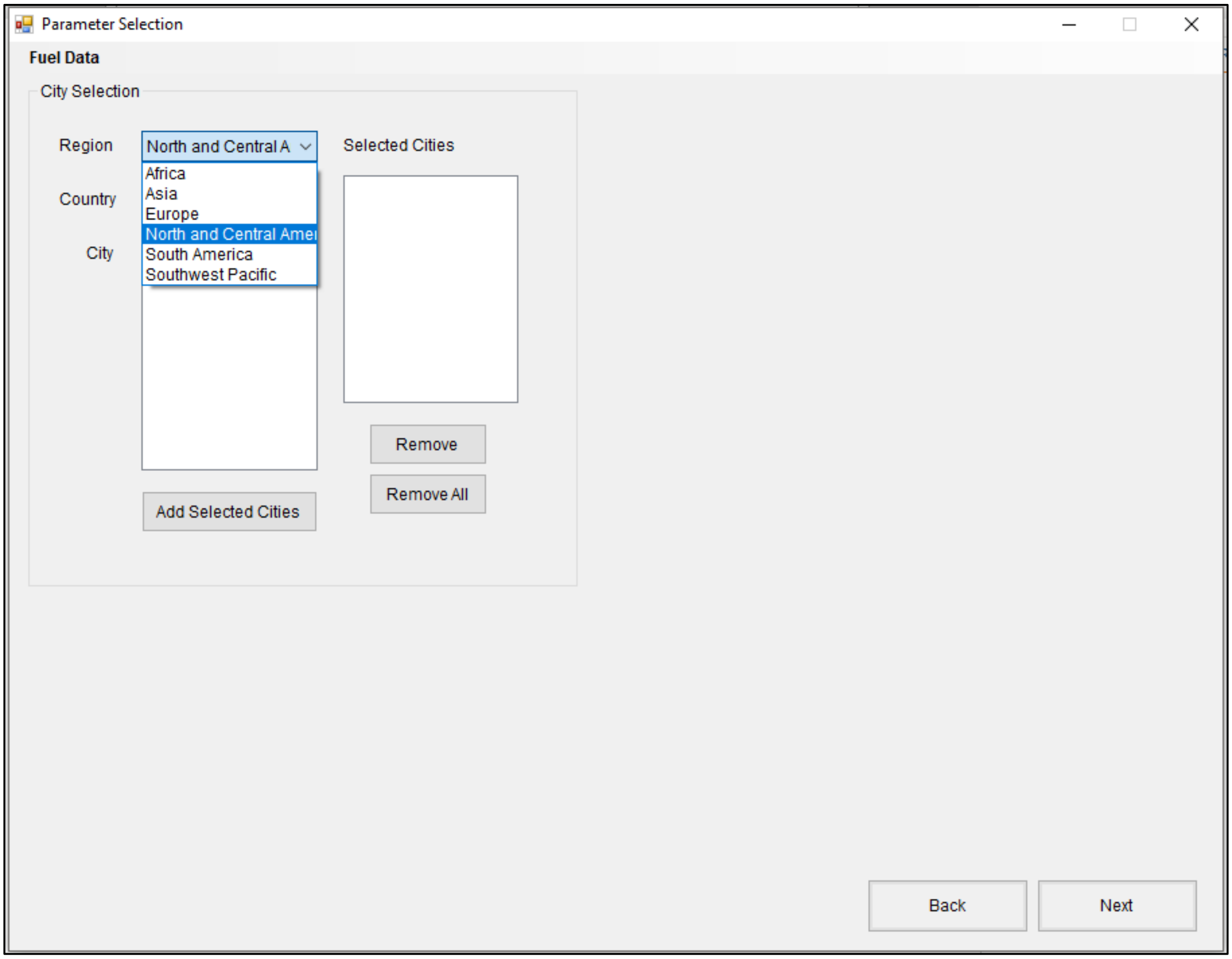


Figure 11. Choosing cities for comparison

2. After selecting all cities in Step 1 and as shown in *Figure 11*, the screen will update to show more input boxes to choose the type of vehicle and fuel for each system from drop-down menus. A representation of the completed screen can be seen in *Figure 12*.

3. Adjust all parameters for the vehicle type and leakage rates for all systems in use and press *"Next"* to advance to the next screen.

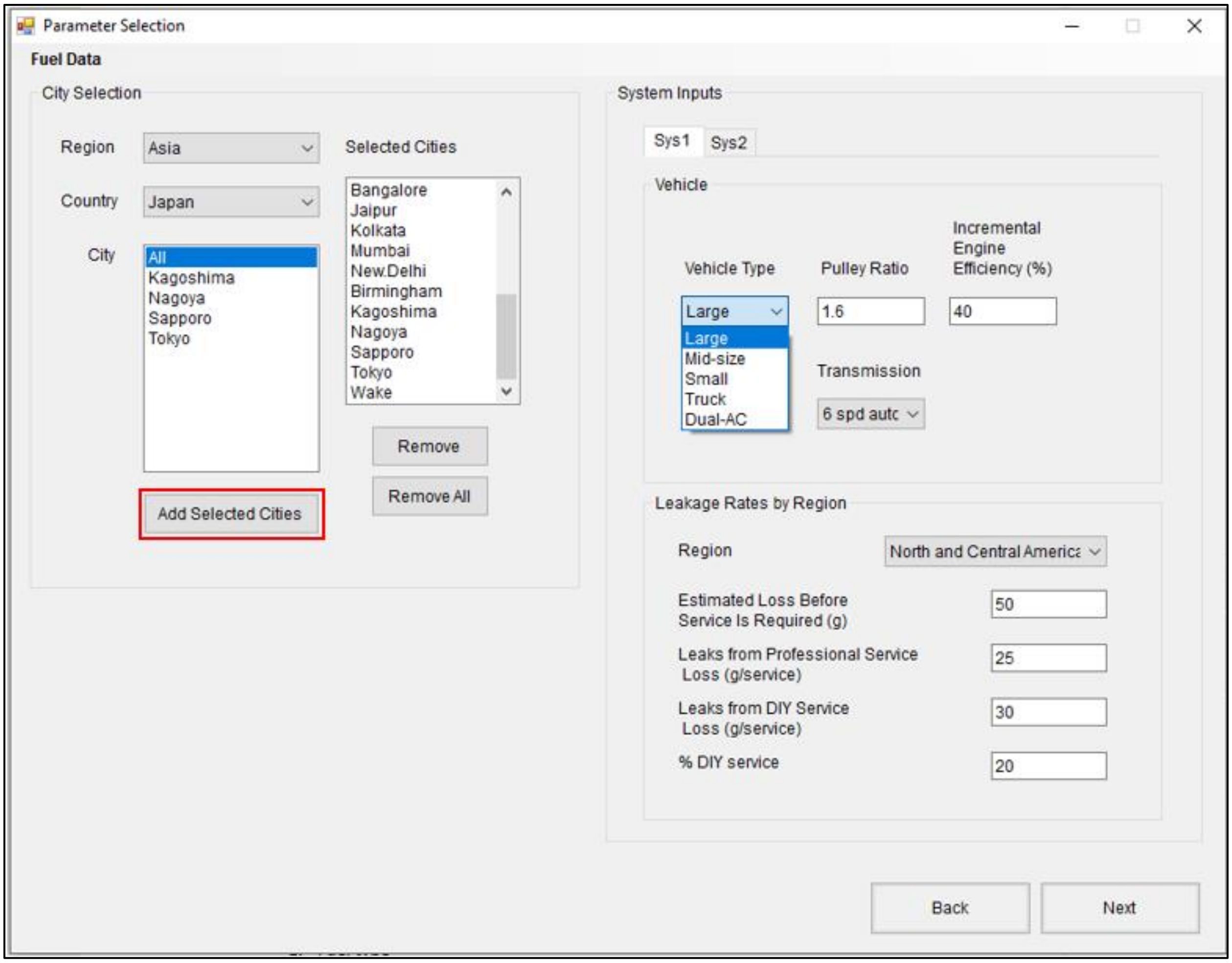


Figure 12. Choosing type of vehicle and assigning parameters

Similarly, some cities can be removed by selecting the cities that were added and clicking on *"Remove"*. If the user desires to restart the selection of cities, the user can select the *"Remove All"* option. The *"Remove All"* option gives an output such as that obtained in *Figure 13*.

The system and vehicle inputs are not cleared, but cities need to be selected again and vehicle parameters can be assigned again as can be seen in *Figure 13*.

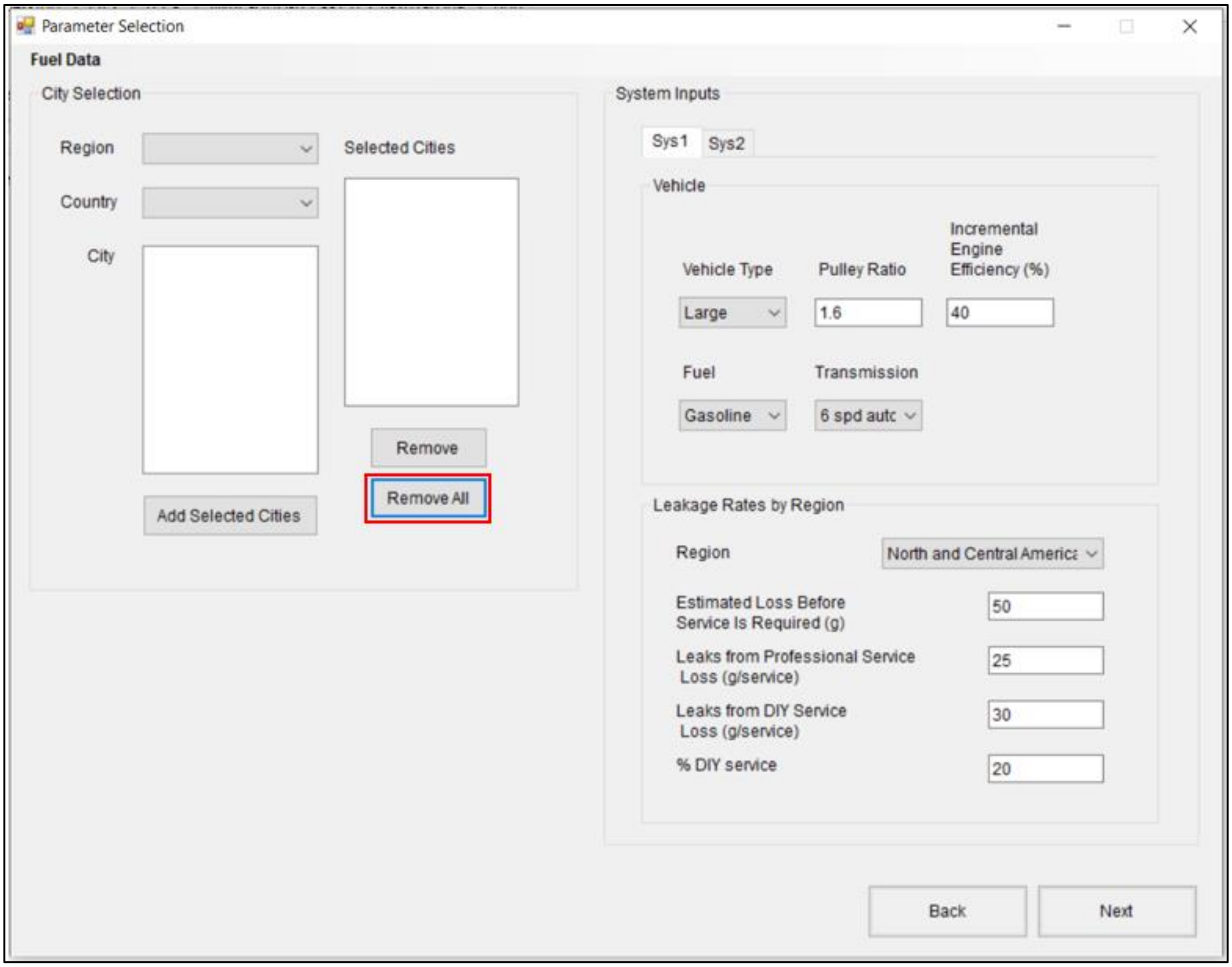


Figure 13. Removing all selected cities

4. Vehicle Usage Parameters

The Vehicle Usage Parameters screen allows the user to modify the assumed vehicle population and vehicle usage details of each selected city. Each city has pre-loaded default values. The values are applied for all systems. *Figure 14* shows the input screen.

Input data:

I. Driving distance (km/year)
II. Driving time (s/year)
III. Vehicle Lifetime (years)
IV. % manual air conditioners
V. % automatic air conditioners
VI. Amount of time the AC stays on based on the ambient temperature (°C)

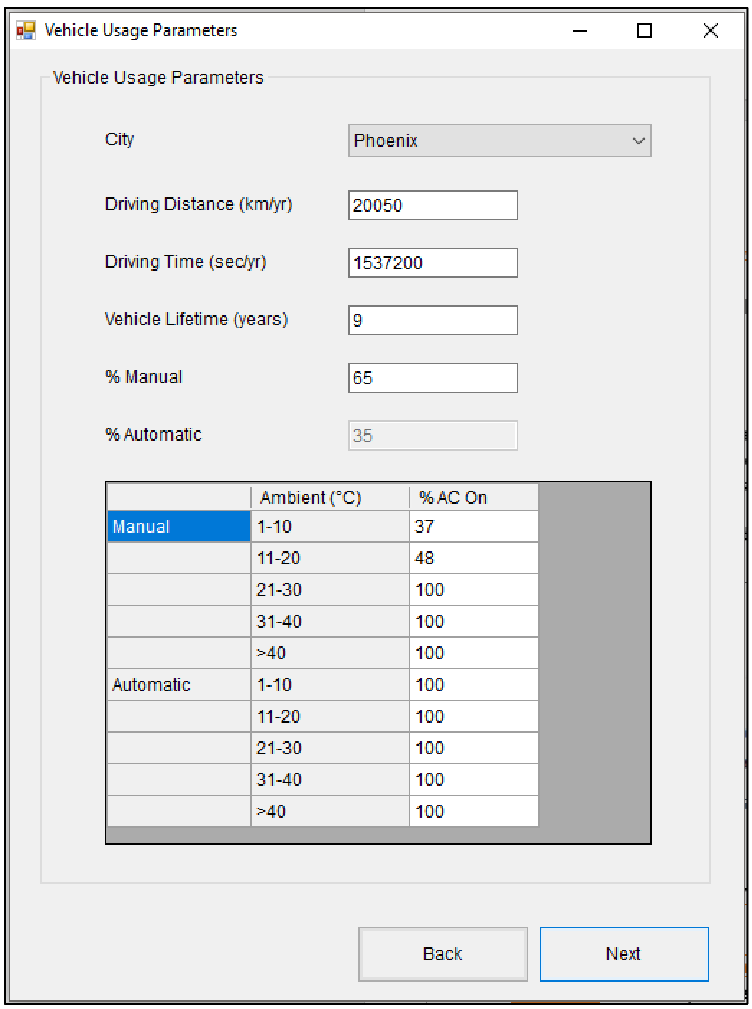


Figure 14. Setting vehicle usage parameters

5. Component Mass Input

The Component Mass Input screen allows the user to load and modify the total mass and distribution of the components and materials of the MAC system. All formulas are hard coded. All components are set to be made of standard materials; the total percentage of materials for each component must add to 100%. User-input is allowed, but a standard dataset is available which can be loaded manually. Every system can have unique mass-component values.

Input data (in kg):

I. Refrigerant Charge
II. Lubricant
III. Piping/Hoses
IV. Sensors
V. Condenser
VI. Receiver/Accumulator
VII. Evaporator
VIII. Expansion Device
IX. Chillers
X. Water Plumbing

The standard dataset can be loaded by following the steps below:

1. Click on the *"Load Data"* button on the screen to open the folder in which the component data is stored as shown in *Figure 15*.

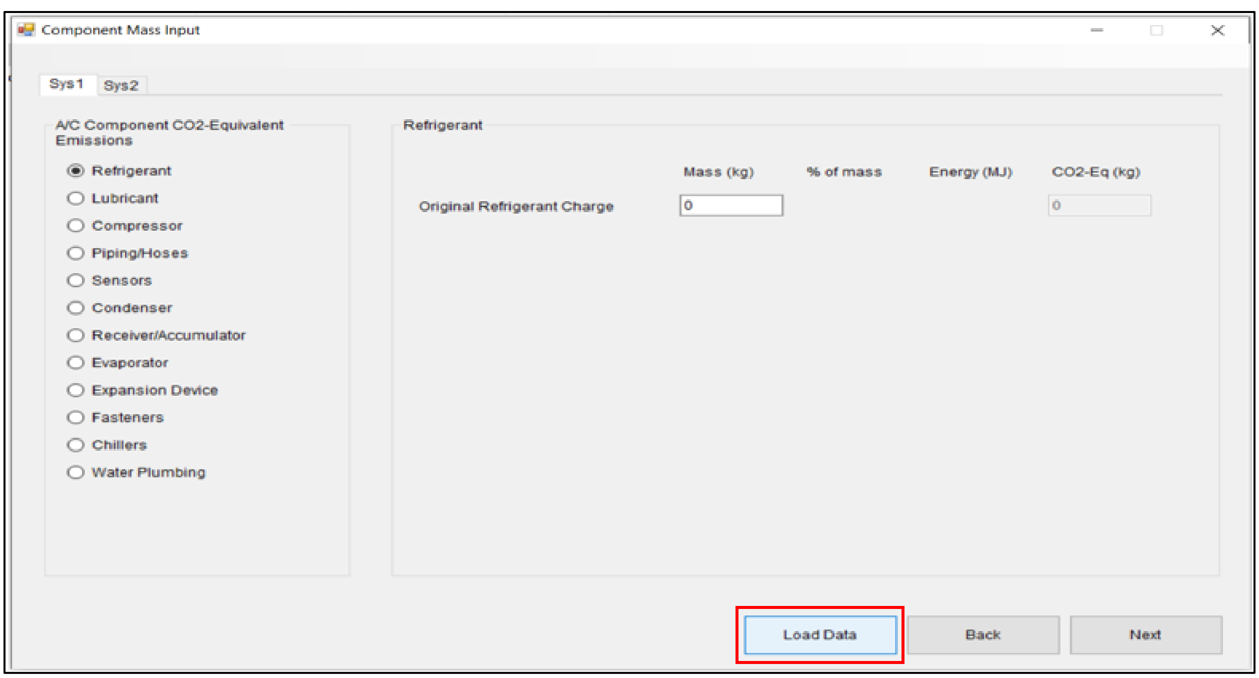


Figure 15. Loading the pre-defined data

2. Select the file, *"Component Mass Data"* and click *"Open"* as shown in *Figure 16*. The data will be filled in all sections automatically and the process is completed when the screen shows *"Input loading complete"* at the bottom. A representation is shown in *Figure 17*.

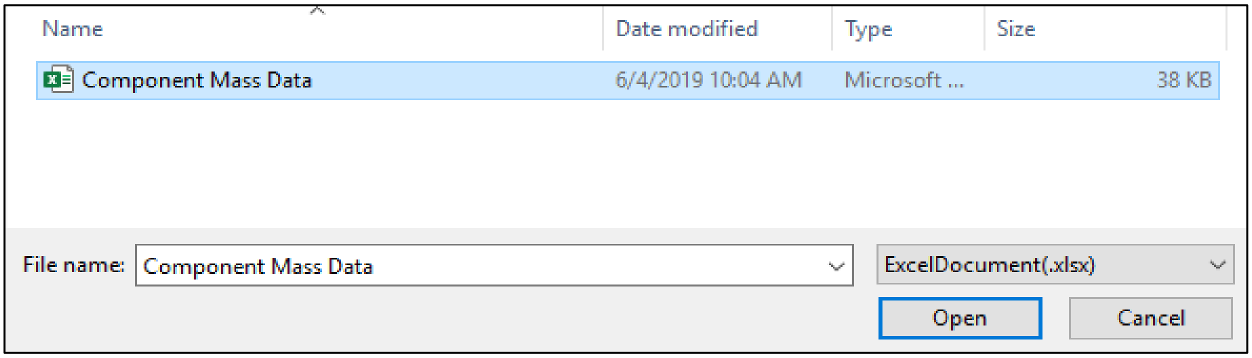


Figure 16. Selecting standard dataset for component mass values

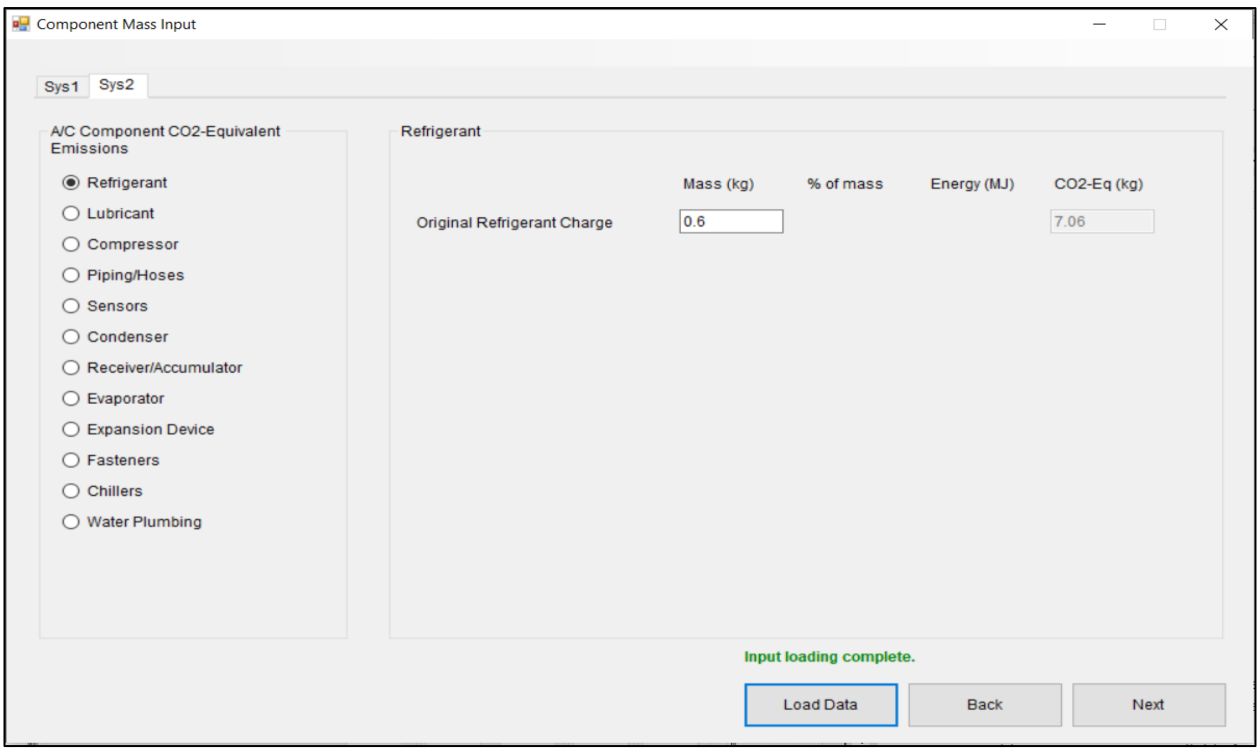


Figure 17. Assigning component mass values

6. Fan Power Input

The Fan Power Input screen allows the user to modify assumptions for the power consumption of the cooling fan at a range of ambient temperatures and vehicle speeds. All systems come with pre-loaded default values but can be modified as required. Each system can have its own values.

Input data is specified for the following Ambient Temperatures:

I. 15°C
II. 25°C
III. 35°C
IV. 45°C

Figure 18 shows the default values available for each ambient temperature.

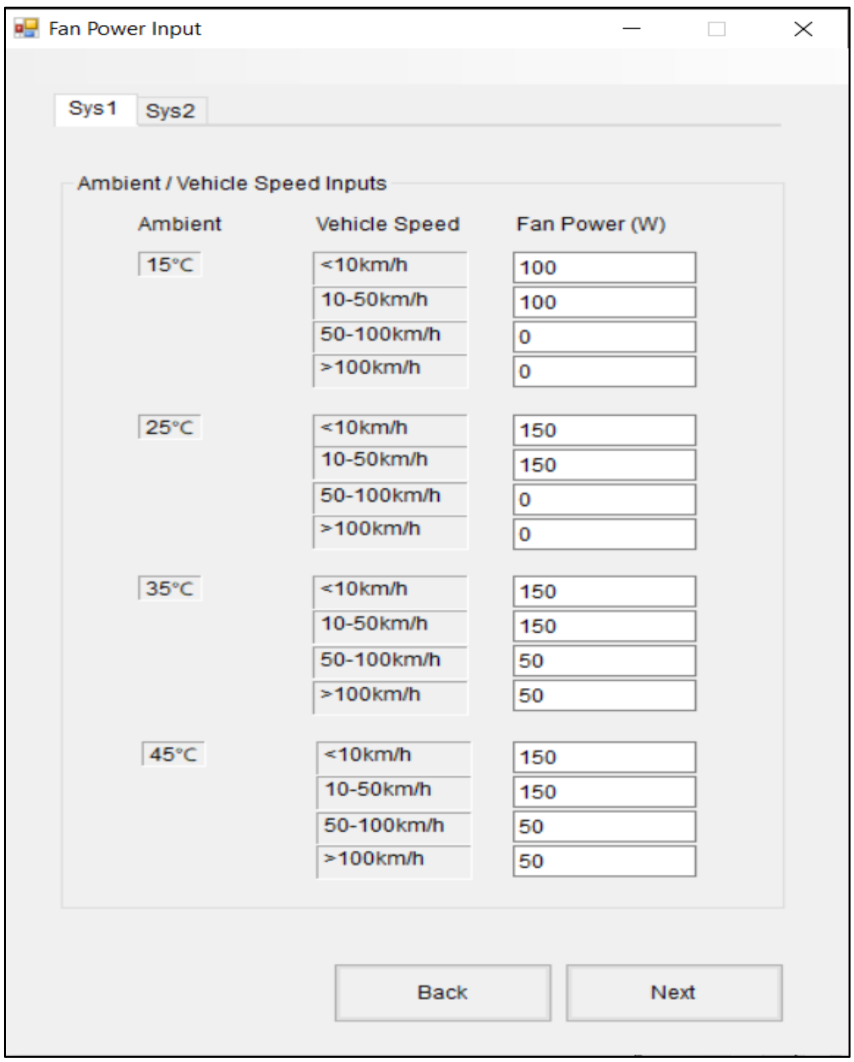


Figure 18. Assigning power values for the fan based on ambient temperature

7. AC System Mechanism

The A/C System Question screen allows the user to specify whether the MAC system is belt-driven or electrically driven. This determines what inputs are required for the Capacity and Power Input screen.

Specify if the system will be:

I. Belt-driven
II. Electrically-driven

The same driving mechanism is used for all systems. *Figure 19* shows the available options.

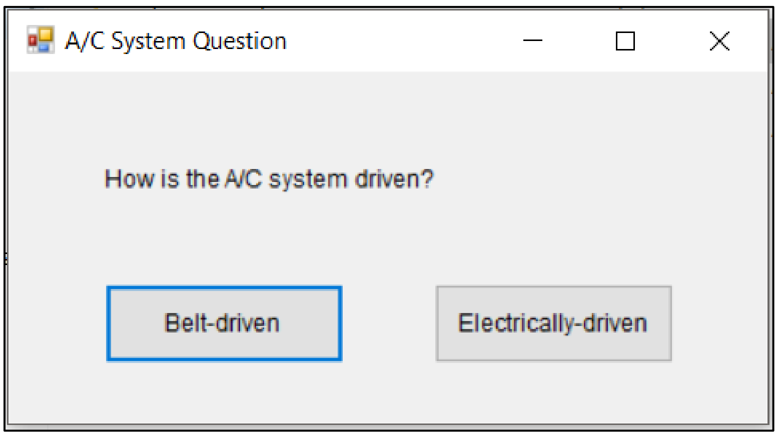


Figure 19. Choosing a mechanism

8. Capacity / Power Input

The Capacity and Power Input screen asks the user to enter cooling capacity and power consumption of the MAC system of a range of ambient conditions and compressor RPMs / vehicle speeds. All input values are in kW. The data is entered based on the ambient temperature and percentage of relative humidity.

The belt-driven mechanism uses compressor speed for calculations and the electrically-driven mechanism uses vehicle speed. All speeds are to be measured at the following conditions:

Compressor speeds required for belt-driven mechanisms:

I. 900 RPM [+15K]
II. 900 RPM
III. 1800 RPM
IV. 2500 RPM
V. 4000 RPM

Vehicle speeds required for belt-driven mechanisms:

I. 10 km/hr [+15K]
II. 10 km/hr
III. 30 km/hr
IV. 60 km/hr
V. 100 km/hr

All data is calculated on the following temperature parameters:

I. 15^oC x 80% RH [10^oC control]
II. 15^oC x 80% RH [3^oC control]
III. 25^oC x 80% RH [10^oC control]
IV. 25^oC x 80% RH [3^oC control]
V. 25^oC x 50% RH [10^oC control]
VI. 25^oC x 50% RH [3^oC control]
VII. 35^oC
VIII. 45^oC

Figures 20 and 21 give a representation of capacity input screens for the belt-driven and the electrically-driven mechanisms, and *Figures 22 and 23* give a representation of power input screens for the belt-driven and the electrically-driven mechanisms and highlight all the speeds and temperature parameters mentioned above.

Default data is available and can be loaded from a file. Belt-driven and the electrically-driven systems have different files and different values associated with them. User input and modification is allowed, but the user needs to input values that correspond to the speeds and temperature conditions mentioned above.

The default data can be loaded by following the steps below:

1. Click on *"Load Data"* on the screen to open the folder in which the capacity/power data is stored. *Figures 20 and 21* show the capacity input screens for the belt-driven and the electrically-driven mechanisms respectively. *Figures 22 and 23* show the power input screens for the belt-driven and the electrically-driven mechanisms respectively.

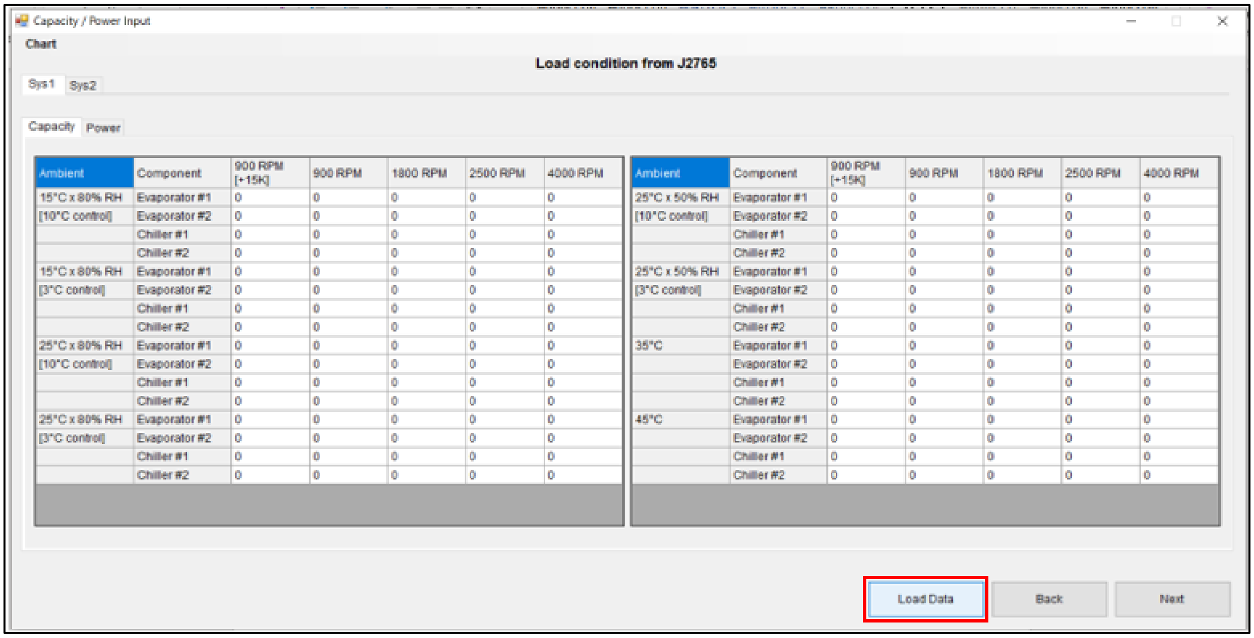


Figure 20. Capacity input screen for Belt-Driven mechanism

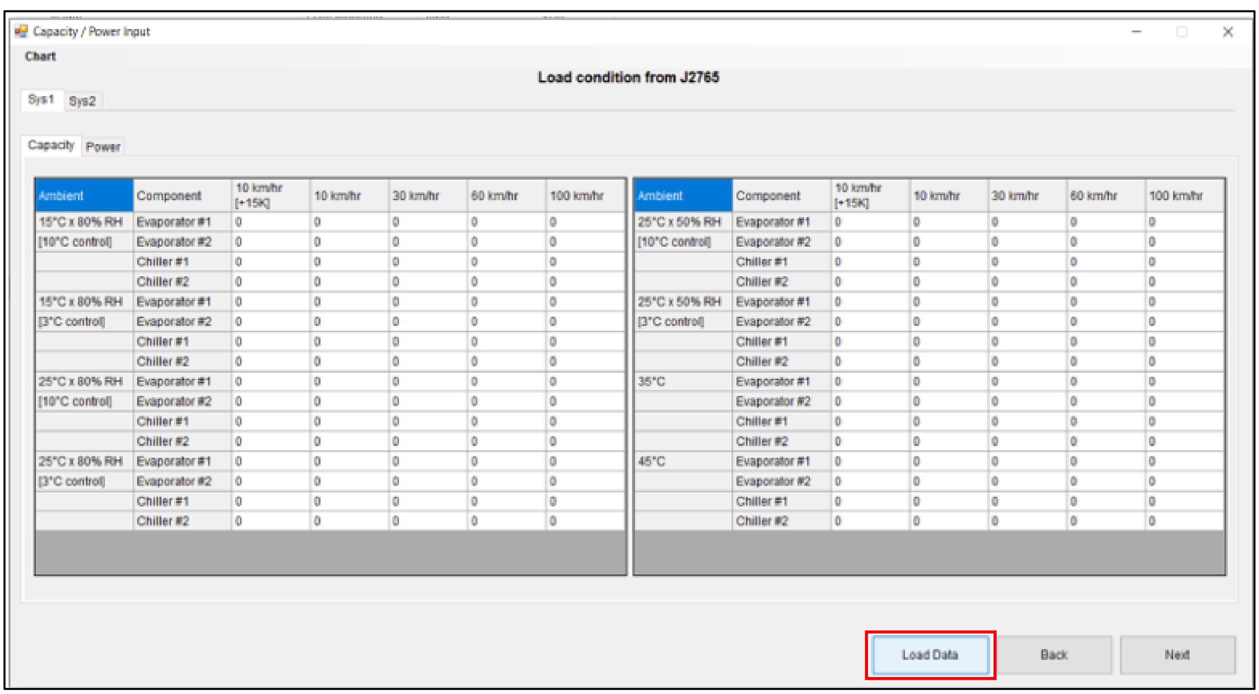


Figure 21. Capacity input screen for Electrically-Driven mechanism

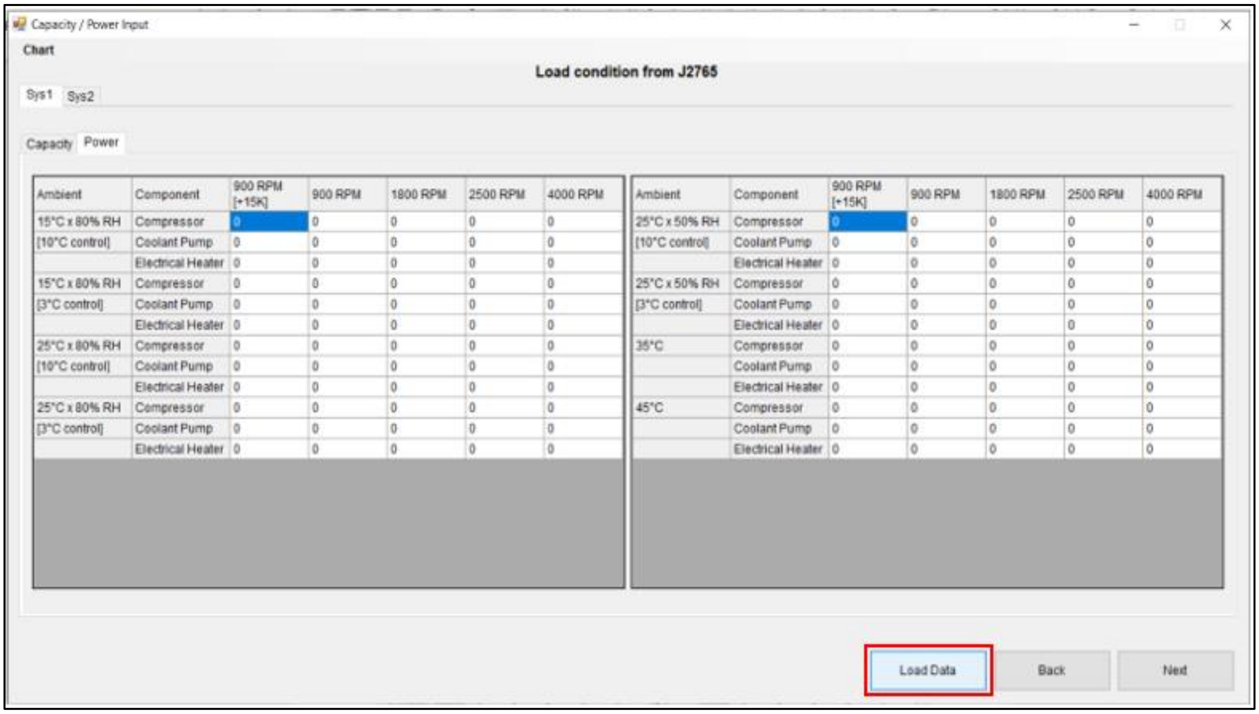


Figure 22. Power input screen for a Belt-Driven mechanism

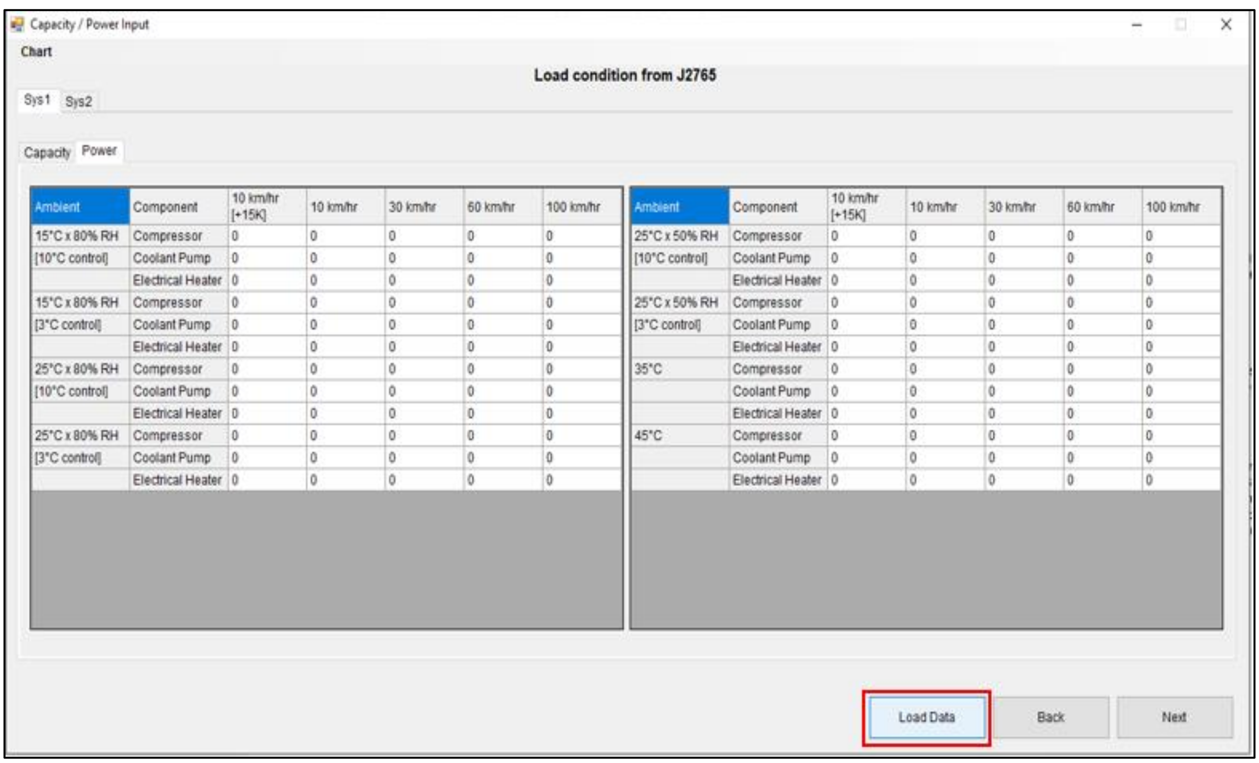


Figure 23. Power input screen for an Electrically-Driven mechanism

2. Select the file, *"Belt Driven-Capacity and Power Data"* for the belt-driven mechanism or the *"Electrically Driven-Capacity and Power Data"* for the electrically-driven mechanism and click *"Open"* to load the data as shown in *Figure 24*.

   Note: The program opens the "*Capacity Data*" sub-folder in the "*My LCCP Project*" main folder by default. User will have to navigate to their desired file/folder.

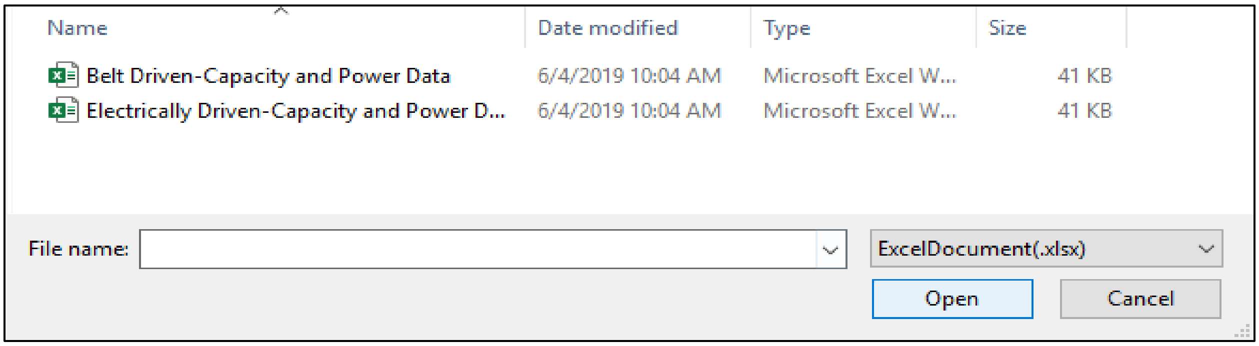
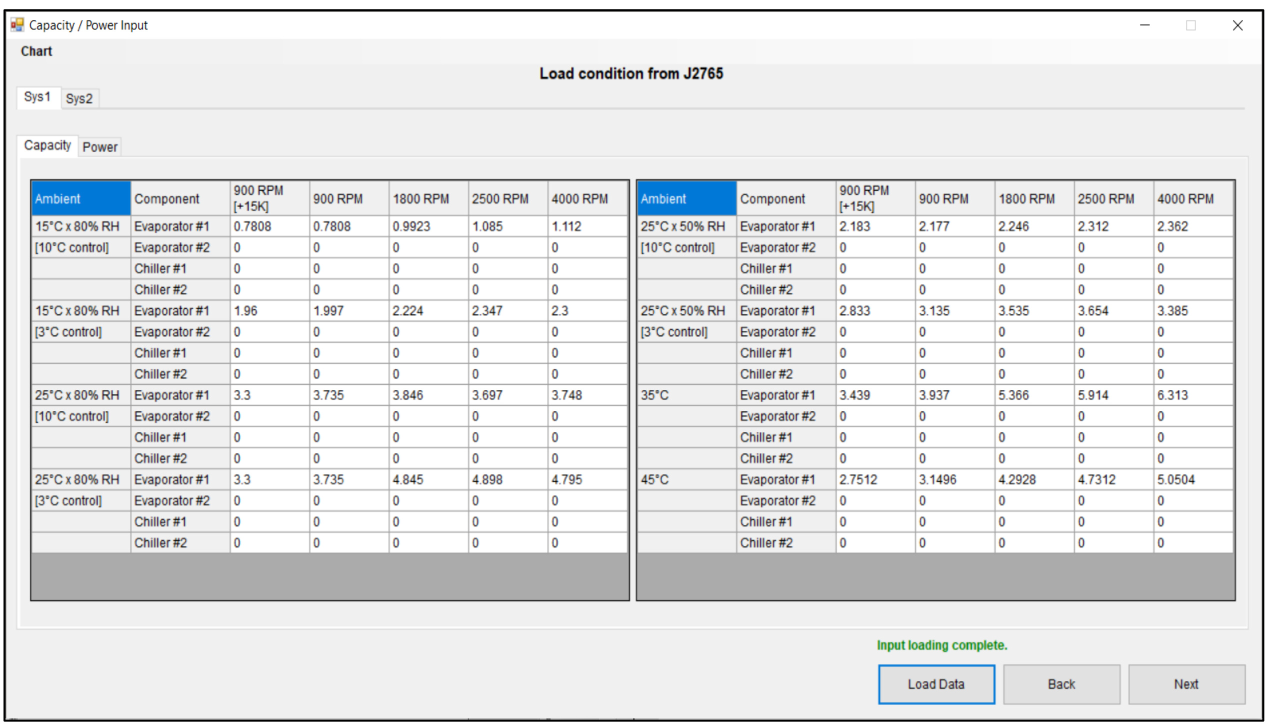


Figure 24. Selecting data for type of AC mechanism

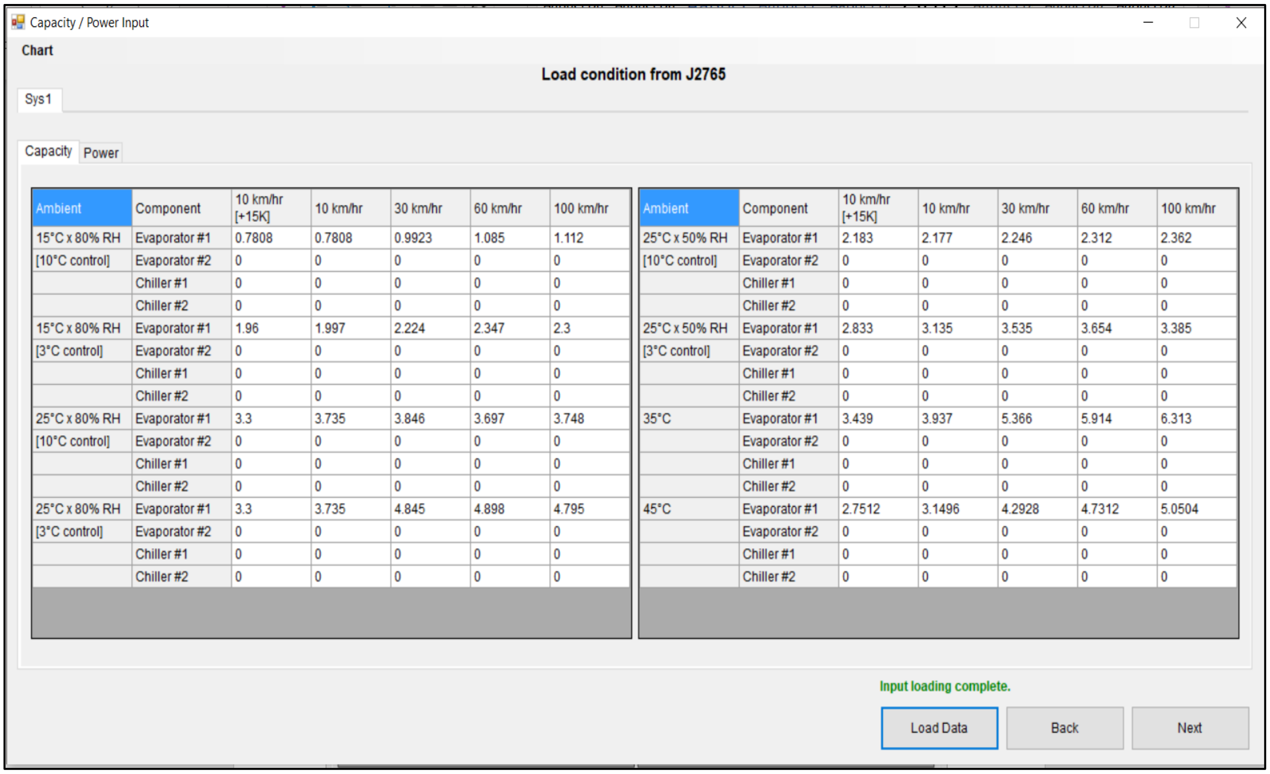
Figure 25 and *Figure 26* show capacity data samples for belt-driven and electrically-driven mechanisms respectively and *Figure 27* and *Figure 28* show power data samples for the belt driven and electrically-driven mechanisms respectively.



Ambient	Component	900 RPM [+15K]	900 RPM	1800 RPM	2500 RPM	4000 RPM
15°C x 80% RH	Evaporator #1	0.7808	0.7808	0.9923	1.085	1.112
[10°C control]	Evaporator #2	0	0	0	0	0
	Chiller #1	0	0	0	0	0
	Chiller #2	0	0	0	0	0
15°C x 80% RH	Evaporator #1	1.96	1.997	2.224	2.347	2.3
[3°C control]	Evaporator #2	0	0	0	0	0
	Chiller #1	0	0	0	0	0
	Chiller #2	0	0	0	0	0
25°C x 80% RH	Evaporator #1	3.3	3.735	3.846	3.697	3.748
[10°C control]	Evaporator #2	0	0	0	0	0
	Chiller #1	0	0	0	0	0
	Chiller #2	0	0	0	0	0
25°C x 80% RH	Evaporator #1	3.3	3.735	4.845	4.898	4.795
[3°C control]	Evaporator #2	0	0	0	0	0
	Chiller #1	0	0	0	0	0
	Chiller #2	0	0	0	0	0

Ambient	Component	900 RPM [+15K]	900 RPM	1800 RPM	2500 RPM	4000 RPM
25°C x 50% RH	Evaporator #1	2.183	2.177	2.246	2.312	2.362
[10°C control]	Evaporator #2	0	0	0	0	0
	Chiller #1	0	0	0	0	0
	Chiller #2	0	0	0	0	0
25°C x 50% RH	Evaporator #1	2.833	3.135	3.535	3.654	3.385
[3°C control]	Evaporator #2	0	0	0	0	0
	Chiller #1	0	0	0	0	0
	Chiller #2	0	0	0	0	0
35°C	Evaporator #1	3.439	3.937	5.366	5.914	6.313
	Evaporator #2	0	0	0	0	0
	Chiller #1	0	0	0	0	0
	Chiller #2	0	0	0	0	0
45°C	Evaporator #1	2.7512	3.1496	4.2928	4.7312	5.0504
	Evaporator #2	0	0	0	0	0
	Chiller #1	0	0	0	0	0
	Chiller #2	0	0	0	0	0

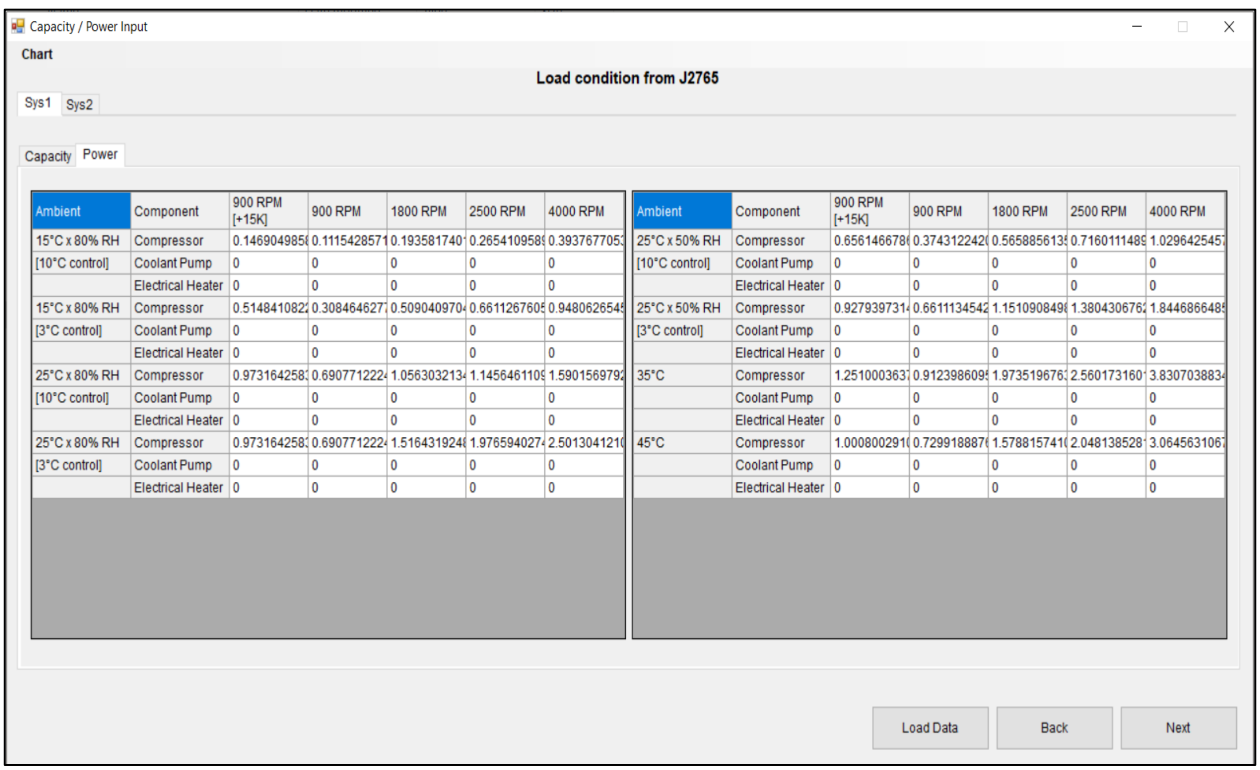
Figure 25. Capacity data for a belt-driven AC system



Ambient	Component	10 km/hr [+15K]	10 km/hr	30 km/hr	60 km/hr	100 km/hr
15°C x 80% RH	Evaporator #1	0.7808	0.7808	0.9923	1.085	1.112
[10°C control]	Evaporator #2	0	0	0	0	0
	Chiller #1	0	0	0	0	0
	Chiller #2	0	0	0	0	0
15°C x 80% RH	Evaporator #1	1.96	1.997	2.224	2.347	2.3
[3°C control]	Evaporator #2	0	0	0	0	0
	Chiller #1	0	0	0	0	0
	Chiller #2	0	0	0	0	0
25°C x 80% RH	Evaporator #1	3.3	3.735	3.846	3.697	3.748
[10°C control]	Evaporator #2	0	0	0	0	0
	Chiller #1	0	0	0	0	0
	Chiller #2	0	0	0	0	0
25°C x 80% RH	Evaporator #1	3.3	3.735	4.845	4.898	4.795
[3°C control]	Evaporator #2	0	0	0	0	0
	Chiller #1	0	0	0	0	0
	Chiller #2	0	0	0	0	0

Ambient	Component	10 km/hr [+15K]	10 km/hr	30 km/hr	60 km/hr	100 km/hr
25°C x 50% RH	Evaporator #1	2.183	2.177	2.246	2.312	2.362
[10°C control]	Evaporator #2	0	0	0	0	0
	Chiller #1	0	0	0	0	0
	Chiller #2	0	0	0	0	0
25°C x 50% RH	Evaporator #1	2.833	3.135	3.535	3.654	3.385
[3°C control]	Evaporator #2	0	0	0	0	0
	Chiller #1	0	0	0	0	0
	Chiller #2	0	0	0	0	0
35°C	Evaporator #1	3.439	3.937	5.366	5.914	6.313
	Evaporator #2	0	0	0	0	0
	Chiller #1	0	0	0	0	0
	Chiller #2	0	0	0	0	0
45°C	Evaporator #1	2.7512	3.1496	4.2928	4.7312	5.0504
	Evaporator #2	0	0	0	0	0
	Chiller #1	0	0	0	0	0
	Chiller #2	0	0	0	0	0

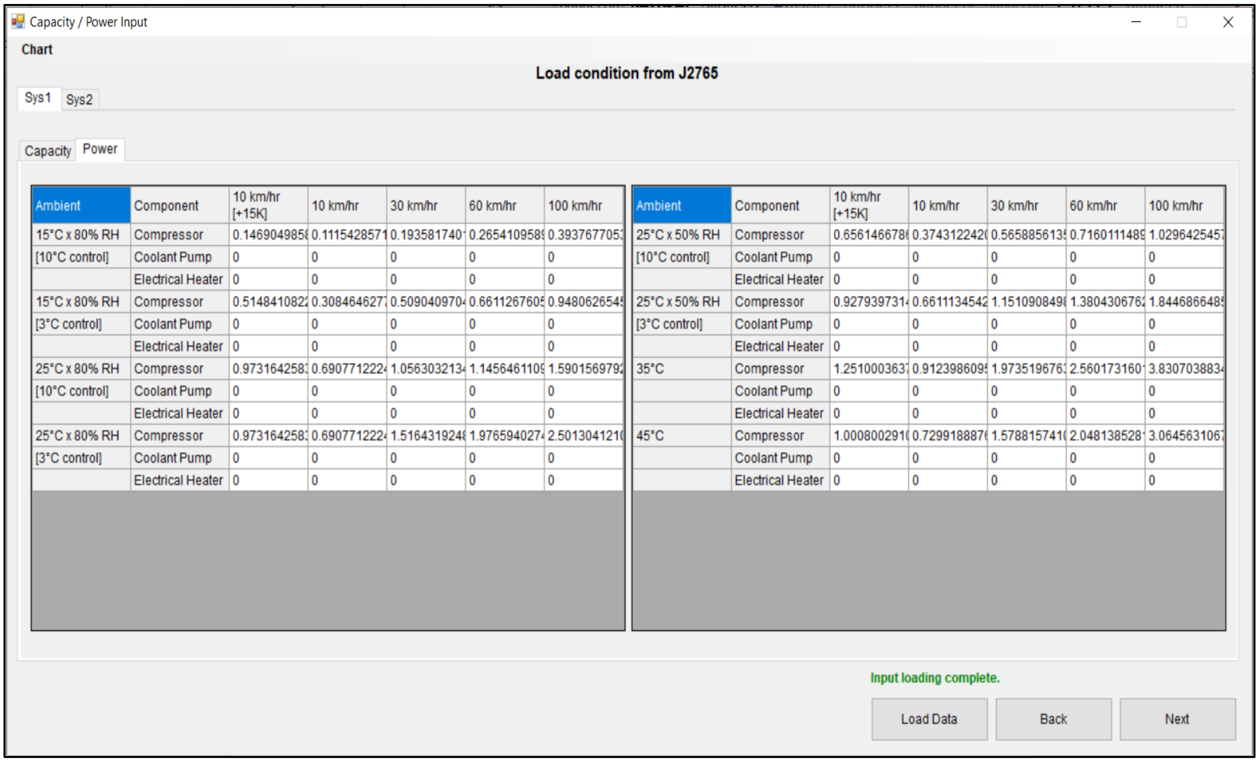
Figure 26. Capacity data for an electrically-driven AC system



Ambient	Component	900 RPM [+15K]	900 RPM	1800 RPM	2500 RPM	4000 RPM
15°C x 80% RH	Compressor	0.146904985	0.1115428571	0.193581740	0.265410958	0.393767705
[10°C control]	Coolant Pump	0	0	0	0	0
	Electrical Heater	0	0	0	0	0
15°C x 80% RH	Compressor	0.514841082	0.308464627	0.509040970	0.661126760	0.948062654
[3°C control]	Coolant Pump	0	0	0	0	0
	Electrical Heater	0	0	0	0	0
25°C x 80% RH	Compressor	0.973164258	0.690771222	1.056303213	1.145646110	1.590156979
[10°C control]	Coolant Pump	0	0	0	0	0
	Electrical Heater	0	0	0	0	0
25°C x 80% RH	Compressor	0.973164258	0.690771222	1.516431924	1.976594027	2.501304121
[3°C control]	Coolant Pump	0	0	0	0	0
	Electrical Heater	0	0	0	0	0

Ambient	Component	900 RPM [+15K]	900 RPM	1800 RPM	2500 RPM	4000 RPM
25°C x 50% RH	Compressor	0.656146678	0.374312242	0.565885613	0.716011148	1.029642545
[10°C control]	Coolant Pump	0	0	0	0	0
	Electrical Heater	0	0	0	0	0
25°C x 50% RH	Compressor	0.927939731	0.6611134542	1.151090849	1.380430676	1.844686648
[3°C control]	Coolant Pump	0	0	0	0	0
	Electrical Heater	0	0	0	0	0
35°C	Compressor	1.251000363	0.912398609	1.973519676	2.560173160	3.830703883
	Coolant Pump	0	0	0	0	0
	Electrical Heater	0	0	0	0	0
45°C	Compressor	1.000800291	0.729918887	1.578815741	2.048138528	3.064563106
	Coolant Pump	0	0	0	0	0
	Electrical Heater	0	0	0	0	0

Figure 27. Power data for a belt-driven AC system



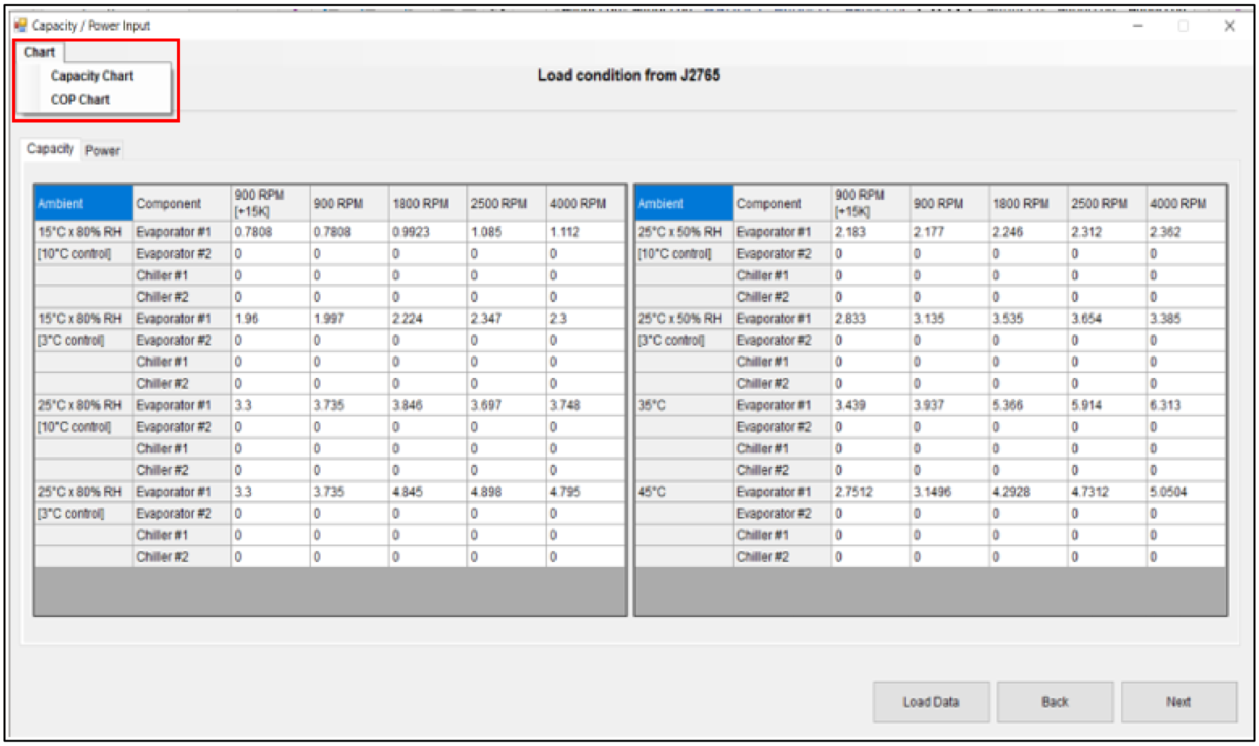
Ambient	Component	10 km/hr [+15K]	10 km/hr	30 km/hr	60 km/hr	100 km/hr
15°C x 80% RH	Compressor	0.1469049858	0.1115428571	0.193581740	0.2654109589	0.393767705
[10°C control]	Coolant Pump	0	0	0	0	0
	Electrical Heater	0	0	0	0	0
15°C x 80% RH	Compressor	0.514841082	0.308464627	0.509040970	0.661126760	0.948062654
[3°C control]	Coolant Pump	0	0	0	0	0
	Electrical Heater	0	0	0	0	0
25°C x 80% RH	Compressor	0.973164258	0.690771222	1.056303213	1.145646110	1.590156979
[10°C control]	Coolant Pump	0	0	0	0	0
	Electrical Heater	0	0	0	0	0
25°C x 80% RH	Compressor	0.973164258	0.690771222	1.516431924	1.976594027	2.501304121
[3°C control]	Coolant Pump	0	0	0	0	0
	Electrical Heater	0	0	0	0	0

Ambient	Component	10 km/hr [+15K]	10 km/hr	30 km/hr	60 km/hr	100 km/hr
25°C x 50% RH	Compressor	0.656146678	0.374312242	0.565885613	0.7160111489	1.029642545
[10°C control]	Coolant Pump	0	0	0	0	0
	Electrical Heater	0	0	0	0	0
25°C x 50% RH	Compressor	0.927939731	0.6611134542	1.151090849	1.380430676	1.844686648
[3°C control]	Coolant Pump	0	0	0	0	0
	Electrical Heater	0	0	0	0	0
35°C	Compressor	1.251000363	0.912398609	1.973519676	2.560173160	3.830703883
	Coolant Pump	0	0	0	0	0
	Electrical Heater	0	0	0	0	0
45°C	Compressor	1.000800291	0.729918887	1.578815741	2.048138528	3.064563106
	Coolant Pump	0	0	0	0	0
	Electrical Heater	0	0	0	0	0

Figure 28. Power data for an electrically-driven AC system

There is also an option to check if the capacity and power data is being used as intended by selecting the *"Chart"* option at the top left corner of the screen. The drop-down menu has an option of "*Capacity Chart"* or a "*COP Chart"*. An illustration is shown in *Figure 29*. On selecting any one of these options, a graphical representation of the capacity and power parameters is shown.

Representations of the "*Capacity Chart"* is shown in *Figure 30* and for the "*COP Chart"* is shown in *Figure 31.*



Ambient	Component	900 RPM [+15K]	900 RPM	1800 RPM	2500 RPM	4000 RPM
15°C x 80% RH	Evaporator #1	0.7808	0.7808	0.9923	1.085	1.112
[10°C control]	Evaporator #2	0	0	0	0	0
	Chiller #1	0	0	0	0	0
	Chiller #2	0	0	0	0	0
15°C x 80% RH	Evaporator #1	1.96	1.997	2.224	2.347	2.3
[3°C control]	Evaporator #2	0	0	0	0	0
	Chiller #1	0	0	0	0	0
	Chiller #2	0	0	0	0	0
25°C x 80% RH	Evaporator #1	3.3	3.735	3.846	3.697	3.748
[10°C control]	Evaporator #2	0	0	0	0	0
	Chiller #1	0	0	0	0	0
	Chiller #2	0	0	0	0	0
25°C x 80% RH	Evaporator #1	3.3	3.735	4.845	4.898	4.795
[3°C control]	Evaporator #2	0	0	0	0	0
	Chiller #1	0	0	0	0	0
	Chiller #2	0	0	0	0	0

Ambient	Component	900 RPM [+15K]	900 RPM	1800 RPM	2500 RPM	4000 RPM
25°C x 50% RH	Evaporator #1	2.183	2.177	2.246	2.312	2.362
[10°C control]	Evaporator #2	0	0	0	0	0
	Chiller #1	0	0	0	0	0
	Chiller #2	0	0	0	0	0
25°C x 50% RH	Evaporator #1	2.833	3.135	3.535	3.654	3.385
[3°C control]	Evaporator #2	0	0	0	0	0
	Chiller #1	0	0	0	0	0
	Chiller #2	0	0	0	0	0
35°C	Evaporator #1	3.439	3.937	5.366	5.914	6.313
	Evaporator #2	0	0	0	0	0
	Chiller #1	0	0	0	0	0
	Chiller #2	0	0	0	0	0
45°C	Evaporator #1	2.7512	3.1496	4.2928	4.7312	5.0504
	Evaporator #2	0	0	0	0	0
	Chiller #1	0	0	0	0	0
	Chiller #2	0	0	0	0	0

Figure 29. Viewing the Chart option

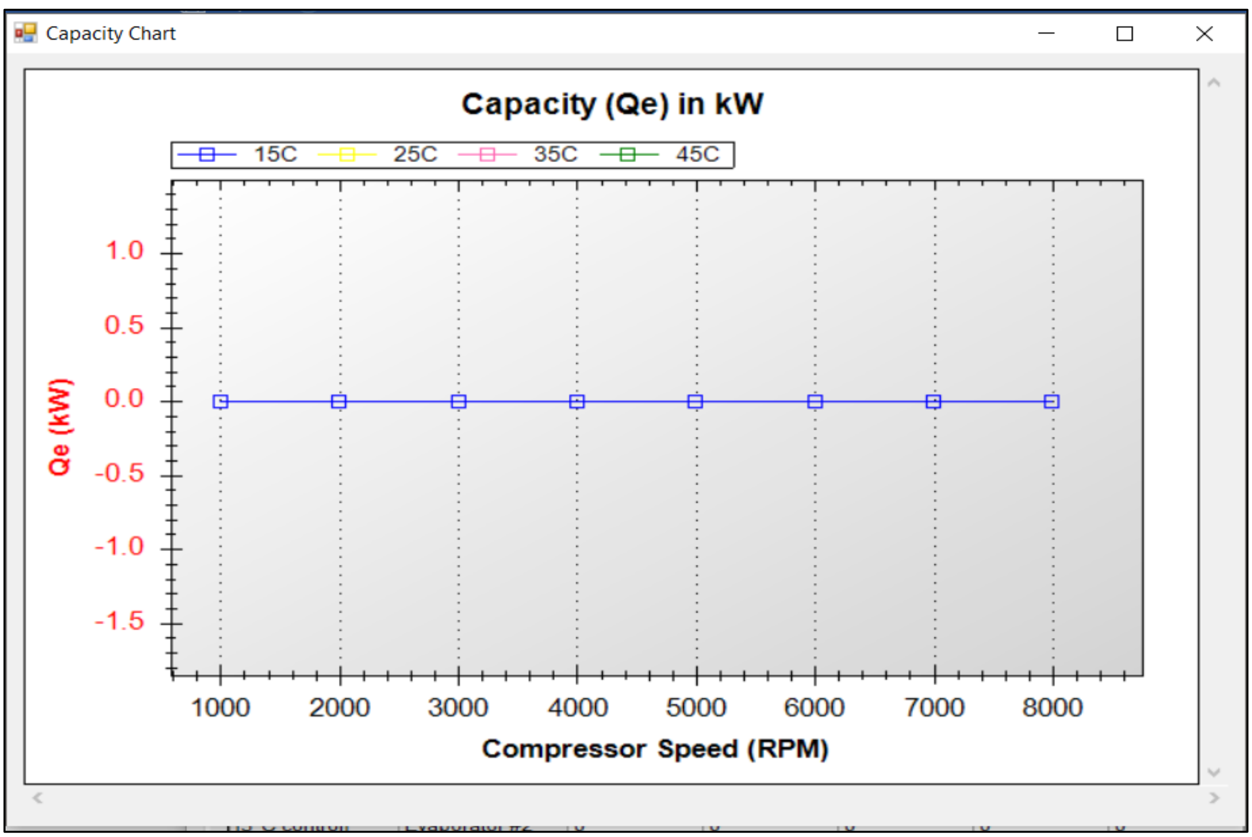


Figure 30. Representation of the Capacity Chart

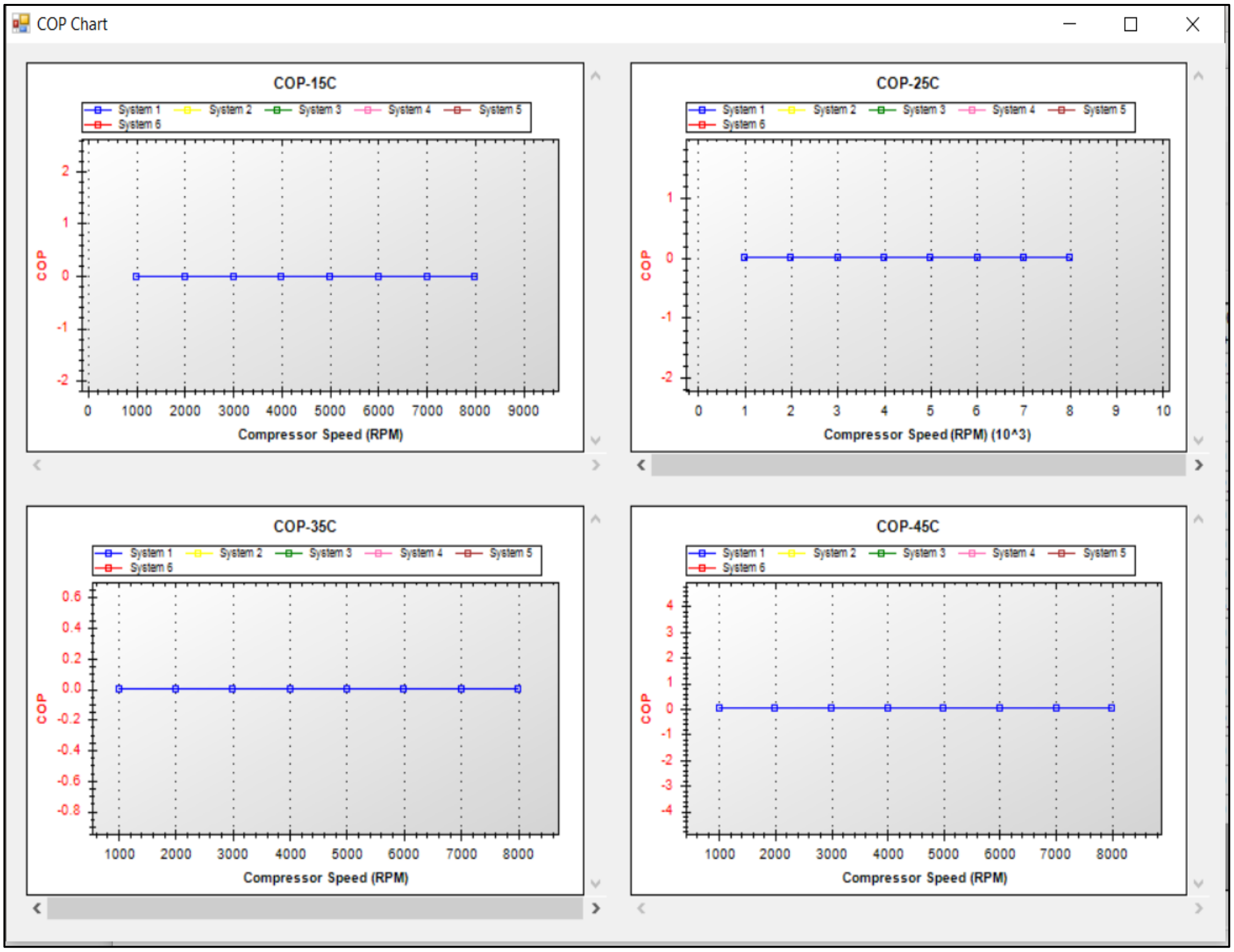


Figure 31. Representation of the COP charts

9. Drive Cycle Input and Simulation Output

The Drive Cycle Input screen allows the user to see which drive cycle the software has automatically selected for use based on the selected cities.

The drive cycles available for use are:

I. FTP
II. SC03
III. NEDC
IV. India
V. JC08
VI. AC17

The drive cycles are shown in *Figure 32.*

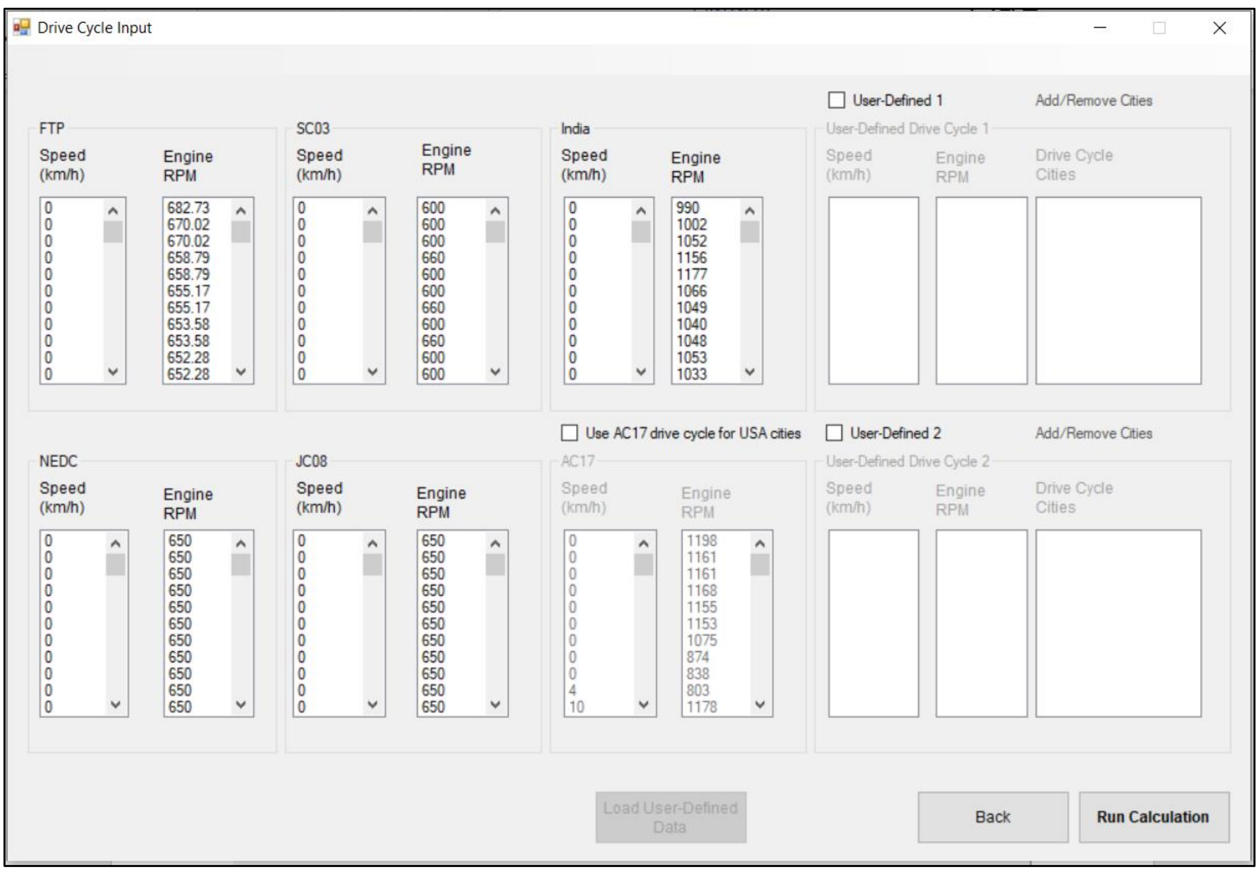


Figure 32. Selecting drive cycles

The default drive cycle for US cities are FTP and SC03. There is an option to use the AC17 drive cycle for US-based cities. To use this cycle, click on the checkbox as shown in *Figure 33*. Choosing this option automatically unchecks the FTP and SC03 drive cycles. The change in drive cycle selection can be seen in *Figures 32 and 33*. India, Europe and Japan have their own drive cycles viz. India, NEDC and JC08 respectively. All African, Australian and South American countries are assumed to be using NEDC.

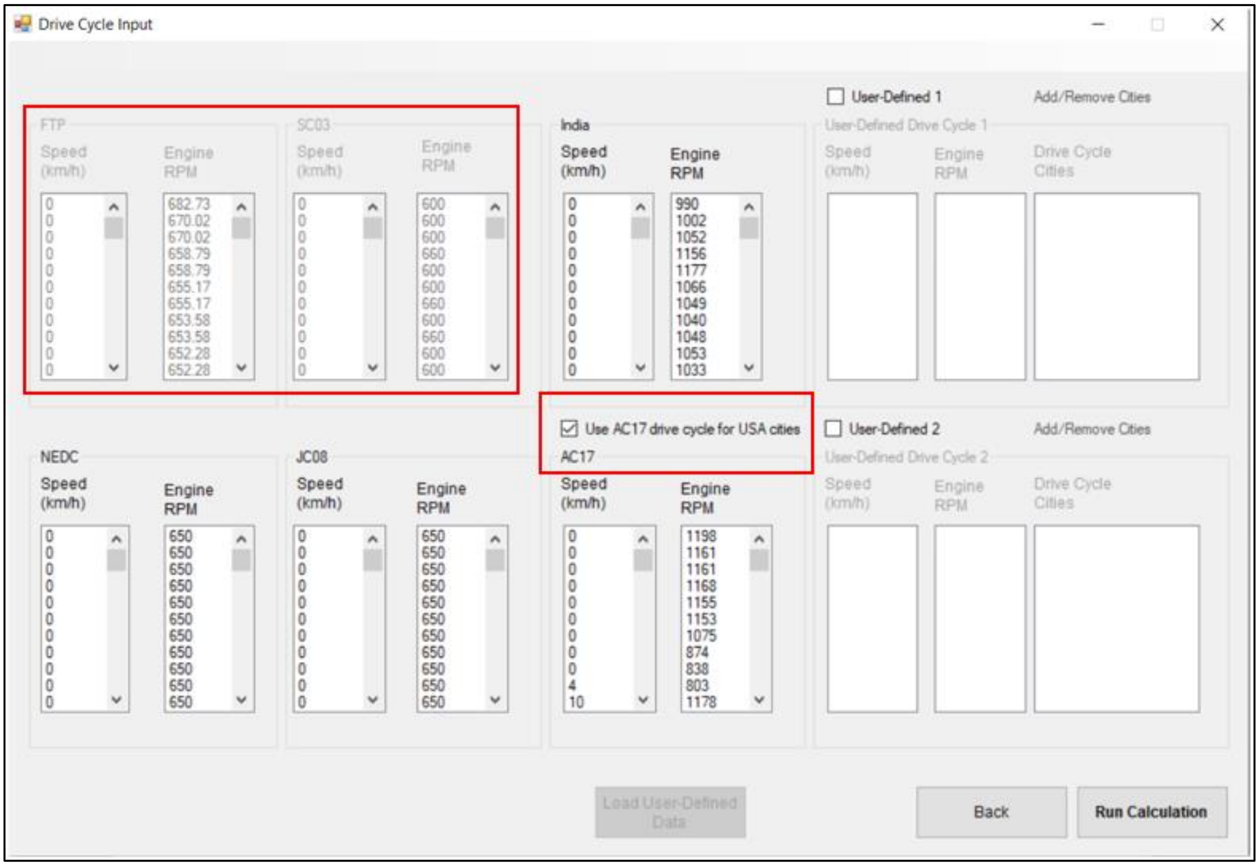


Figure 33. Choosing AC17 drive cycle instead of the standard cycles for USA cities

The user has the option to upload a custom drive cycle. Two different user-defined cycles can be compared.

To choose a user defined option: (Steps are shown for one user-defined data. A repeat of the same steps can be used to fill the second user-defined data)

1. Check the *"User-defined 1"* button as seen in the red box in *Figure 34*.

2. Click on *"Add/Remove Cities"* as shown in *Figure 34*. From the pop-up screen, select the cities that the driving cycle will be used on. After selecting the cities, click *"Add Selected Cities"* and click *"OK"* to continue as shown in *Figure 35*.

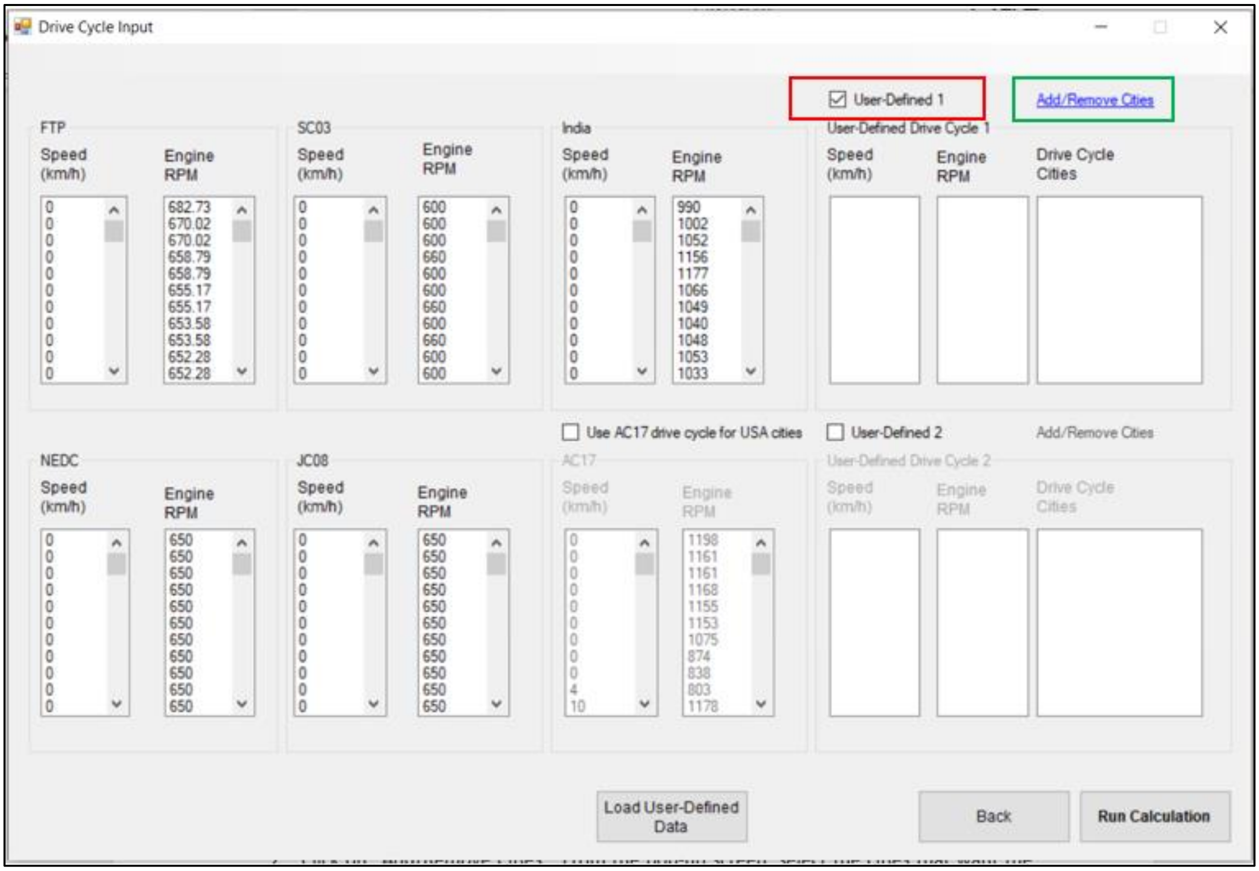


Figure 34. Choosing a User-Defined driving cycle

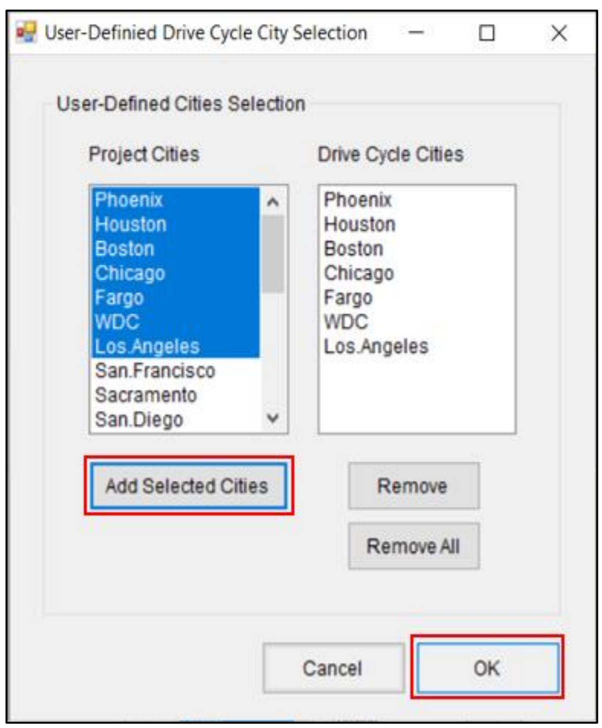


Figure 35. Choosing cities to be included in the driving cycle

3. Select *"Load User-Defined Data"* to load the speeds (km/h) and Engine RPM data for the user defined cycle as shown in *Figure 36*. Open the path in which the data is saved, select the data and click *"Open"* to load it in the program. A representation of the file is shown in *Figure 37*.

   Note: The program opens the "*Engine RPM*" sub-folder in the "*My LCCP Project*" main folder by default. User will have to navigate to their desired file/folder.

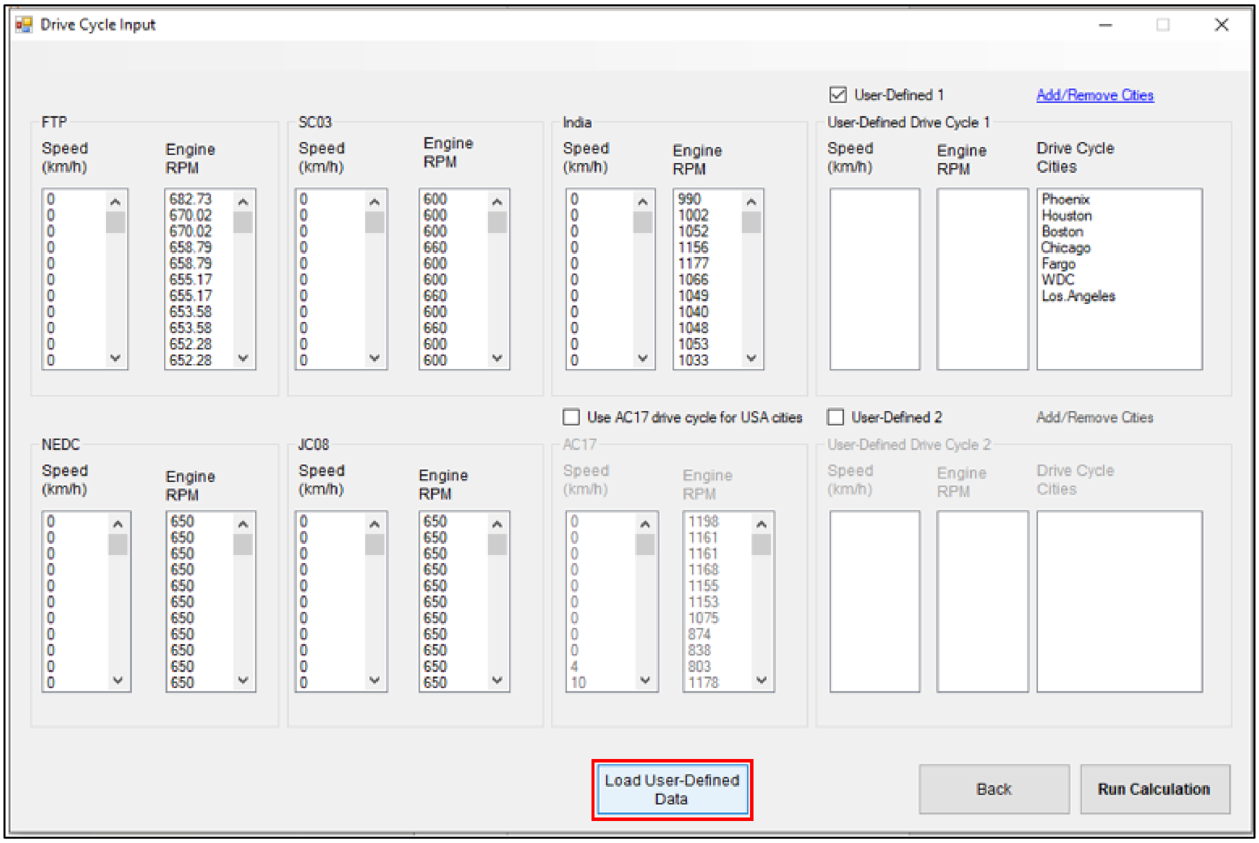


Figure 36. Loading User-defined data

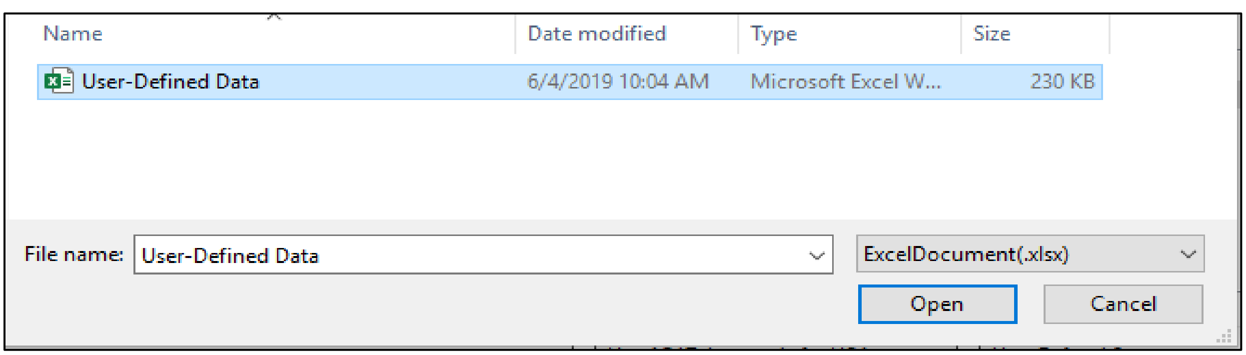


Figure 37. Opening the file containing user-defined data

4. Once the loading is complete, the screen will display a message saying *“Drive cycle load complete”* as shown in *Figure 38*. The program inputs are complete, and calculations can now be run by selecting the “*Run Calculations*” button as highlighted below.

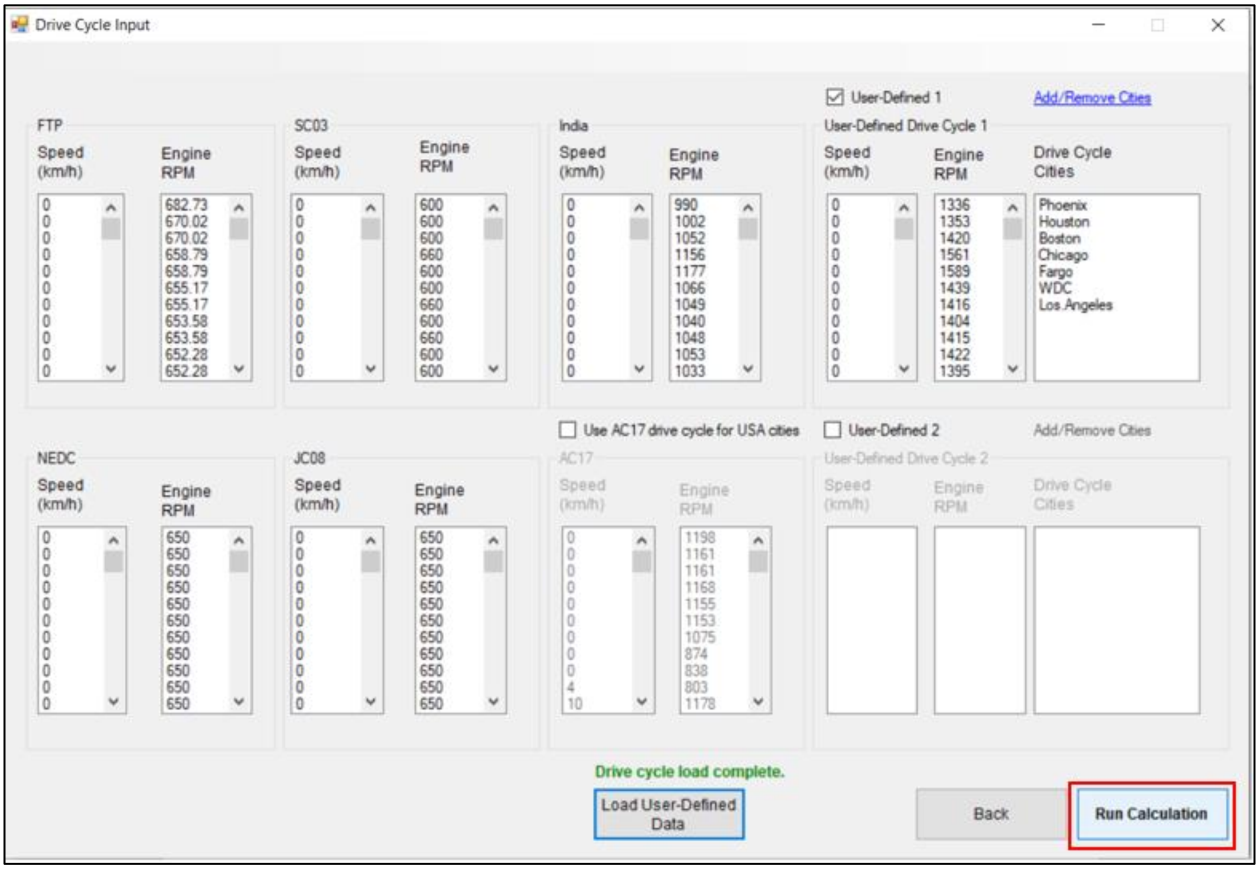


Figure 38. Complete drive cycle screen

The user can remove the selected cities in the user-defined section by clicking on *"Add/Remove Cities"* as shown in *Figure 34*. From the pop-up screen, select the cities that need to be removed. After selecting the cities, click *"Remove All"* and click *"OK"* to continue as shown in *Figure 39*. The same steps can be followed for removing single cities as well.

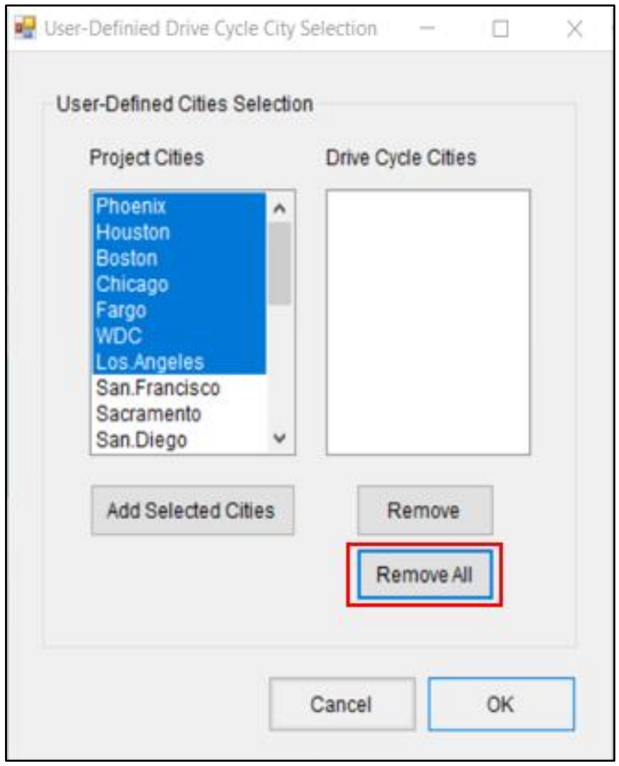


Figure 39. Removing cities from user-defined selection

After selecting the appropriate driving cycle, and clicking run calculations, the results are exported in an excel file which opens after the calculations run. A representation of the final screen can be seen in *Figure 40*. Refer to the ***Viewing Results*** section to learn how to open the output file at a later stage or be clicking here.

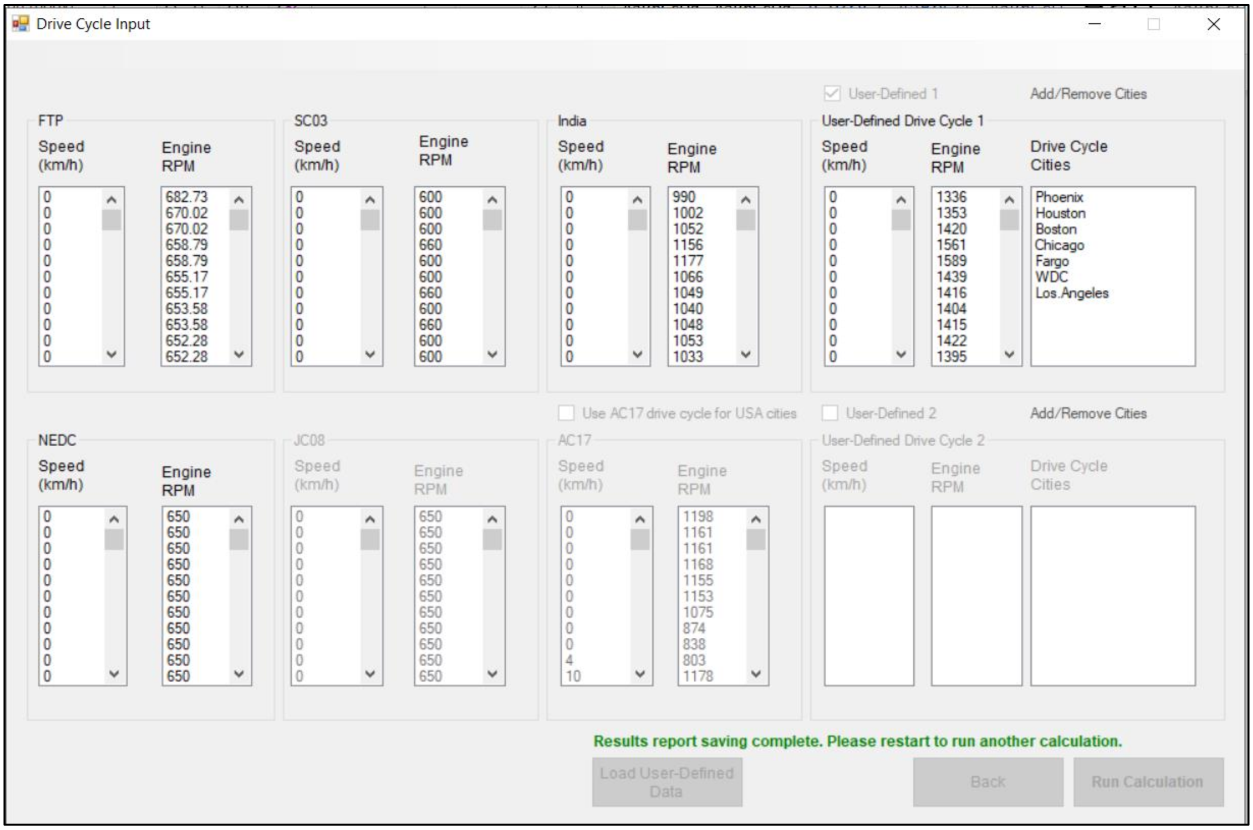
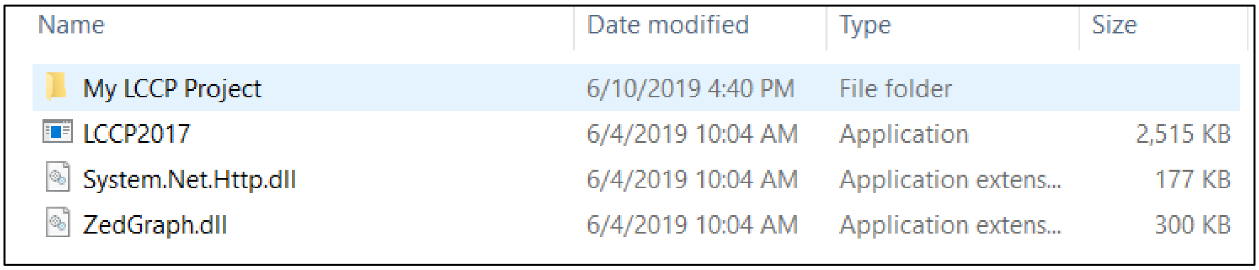


Figure 40. Final screen showing successful calculation

Viewing Results

The output file can be loaded at a later stage by following the steps shown below:

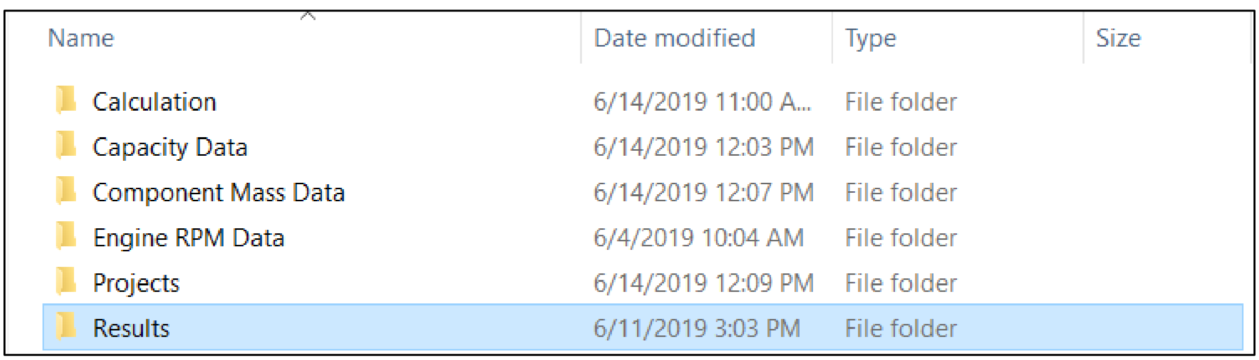
1. Open the folder in which the tool is saved and enter the folder *"My LCCP Project"* as shown in *Figure 41.*



Name	Date modified	Type	Size
My LCCP Project	6/10/2019 4:40 PM	File folder	
LCCP2017	6/4/2019 10:04 AM	Application	2,515 KB
System.Net.Http.dll	6/4/2019 10:04 AM	Application extens...	177 KB
ZedGraph.dll	6/4/2019 10:04 AM	Application extens...	300 KB

Figure 41. Accessing the results

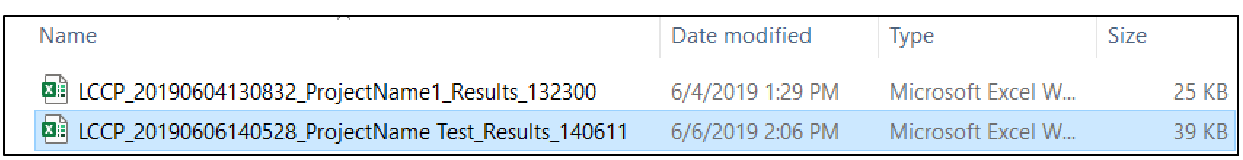
2. Open the folder *"Results"* to access the folder in which all the results are saved as shown in *Figure 42*.



Name	Date modified	Type	Size
Calculation	6/14/2019 11:00 A...	File folder	
Capacity Data	6/14/2019 12:03 PM	File folder	
Component Mass Data	6/14/2019 12:07 PM	File folder	
Engine RPM Data	6/4/2019 10:04 AM	File folder	
Projects	6/14/2019 12:09 PM	File folder	
Results	6/11/2019 3:03 PM	File folder	

Figure 42. Opening the folder containing all results

3. Find and open the excel-file that is desired. *Figure 43* shows a sample file name.



Name	Date modified	Type	Size
LCCP_20190604130832_ProjectName1_Results_132300	6/4/2019 1:29 PM	Microsoft Excel W...	25 KB
LCCP_20190606140528_ProjectName Test_Results_140611	6/6/2019 2:06 PM	Microsoft Excel W...	39 KB

Figure 43. Selecting the desired file

The results sheet consists of six sheets, viz. *Sheet 1, Chart 1, Chart 2, Chart 3, Weighted, Chart 4*. The contents of the sheets are briefly explained below:

I. A summary and comparison of all the systems that were used for evaluation across all cities is available in *Sheet 1*. A sample of the sheet is shown in *Figure 44*.

	A	B	C	D	E	F	G	H	I
1		Cities	Phoenix	Houston	Boston	Chicago	Fargo	WDC	Los.Angele
2	**Sys1**	**Total Lifetime Equivalent Warming Impact (kg CO2)**	8714	13340	15110	9092	8527	14930	26120
3		**Total Lifetime Direct Contribution (kg CO2)**	1307	1291	1143	1145	1015	1147	1158
4		**Total Lifetime Indirect Contribution (kg CO2)**	7407	12040	13970	7948	7512	13780	24960
5		Total Contribution per Lifetime Driving Distance (g CO2/km)	48.29	75.46	85.37	51.45	47.25	82.72	144.7
6		Total Annual Equivalent Warming Impact (kg CO2/year)	968.2	1482	1679	1010	947.4	1659	2902
7		Total Annual Direct Contribution (kg CO2/year)	145.2	143.5	127	127.2	112.8	127.5	128.7
8		Total Annual Indirect Contribution (kg CO2/year)	823	1338	1552	883.1	834.6	1531	2773
9		**Direct Contribution Due to Refrigerant Leakage**							
10		Lifetime Refrigerant Emissions due to Leakage (kg refrigerant)	0.913	0.9021	0.7985	0.7997	0.709	0.8013	0.809
11		GWP of Refrigerant (kg CO2/kg refrigerant)	1430	1430	1430	1430	1430	1430	1430
12		Lifetime Equivalent CO2 Emissions Due to Leakage (kg CO2)	1306	1290	1142	1144	1014	1146	1157
13		**Direct Contribution Due to Atmospheric Breakdown Products**							
14		Atmospheric Breakdown Due to Refrigerant Manufacture (kg CO2)	0.000477	0.000477	0.000477	0.000477	0.000477	0.000477	0.000477
15		Atmospheric Breakdown Due to Refrigerant Leakage (kg CO2)	1.452	1.434	1.27	1.272	1.127	1.274	1.286
16		Lifetime Contribution Due to Atmospheric Breakdown Products (kg CO2)	1.452	1.435	1.27	1.272	1.128	1.274	1.287
17		**Indirect Contribution Due to A/C System Components**							
18		Energy from Manufacturing of A/C System Components (MJ)	1751	1751	1751	1751	1751	1751	1751
19		Equaivalent CO2 from Manufacturing of A/C System Components (kg CO2)	100.1	100.1	100.1	100.1	100.1	100.1	100.1
20		Energy from End of Life Disposal of A/C System Components (MJ)	43.82	43.82	43.82	43.82	43.82	43.82	43.82
21		Equaivalent CO2 from End of Life Disposal of A/C System Components (kg CO2)	4.052	4.052	4.052	4.052	4.052	4.052	4.052
22		Total CO2 Equiv. Emissions for A/C System Components (kg CO2)	104.1	104.1	104.1	104.1	104.1	104.1	104.1
23		**Indirect Contribution Due to A/C Power Consumption**							
24		Total CO2 Equiv. Emissions Due to A/C Power Consumption (kg CO2)	6615	11270	13190	7171	6723	12990	24170
25		**Indirect Contribution Due to Transportation Fuel Use**							
26		System Total Weight (kg)	30.92	30.92	30.92	30.92	30.92	30.92	30.92
27		Incremental Fuel Use (Liters/kg/km)	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005
28		Lifetime Fuel Use (Liters)	279	273.2	273.6	273.2	279	279	279
29		Annual Fuel Use (Liters/yr)	31	30.36	30.4	30.36	31	31	31
30		Lifetime Transportation Fuel Use CO2 Emissions (kg)	675	661	662	661	675	675	675
31		Annual Transportation Fuel Use CO2 Emissions (kg/year)	75	73.5	73.6	73.5	75	75	75
32		**Indirect Contribution Due to Recover/Recycle/Recharge Equipment**							
33		Horse Power of Equipment	0.333	0.333	0.333	0.333	0.333	0.333	0.333
34		Time per Cycle (hours)	1	1	1	1	1	1	1
35		BTU per Cycle	9413	9413	9413	9413	9413	9413	9413
36		Weight of CO2/BTU (kg/BTU)	0.000196	0.000196	0.000196	0.000196	0.000196	0.000196	0.000196
37		Equipment CO2 per Cycle (kg/cycle)	1.848	1.848	1.848	1.848	1.848	1.848	1.848
38		Lifetime Equipment CO2 Emissions (kg CO2)	12.94	12.94	11.09	11.09	9.24	11.09	11.09
39	**Sys2**	**Total Lifetime Equivalent Warming Impact (kg CO2)**	9381	15290	17660	9984	9354	17500	31240
40		**Total Lifetime Direct Contribution (kg CO2)**	5.081	5.001	4.854	4.863	3.36	4.874	4.931
41		**Total Lifetime Indirect Contribution (kg CO2)**	9376	15280	17660	9979	9351	17500	31230
42		Total Contribution per Lifetime Driving Distance (g CO2/km)	51.99	86.51	99.79	56.5	51.84	96.99	173.1
43		Total Annual Equivalent Warming Impact (kg CO2/year)	1042	1699	1962	1109	1039	1945	3471
44		Total Annual Direct Contribution (kg CO2/year)	0.5645	0.5557	0.5393	0.5403	0.3733	0.5416	0.5479

Figure 44. Representation of the comparison sheet (Sheet 1)

II. *Chart 1* contains a bar graph marking the differences between the systems in terms of lifetime CO_2-eq emissions across all cities used for evaluation. A representation is shown in *Figure 45*.

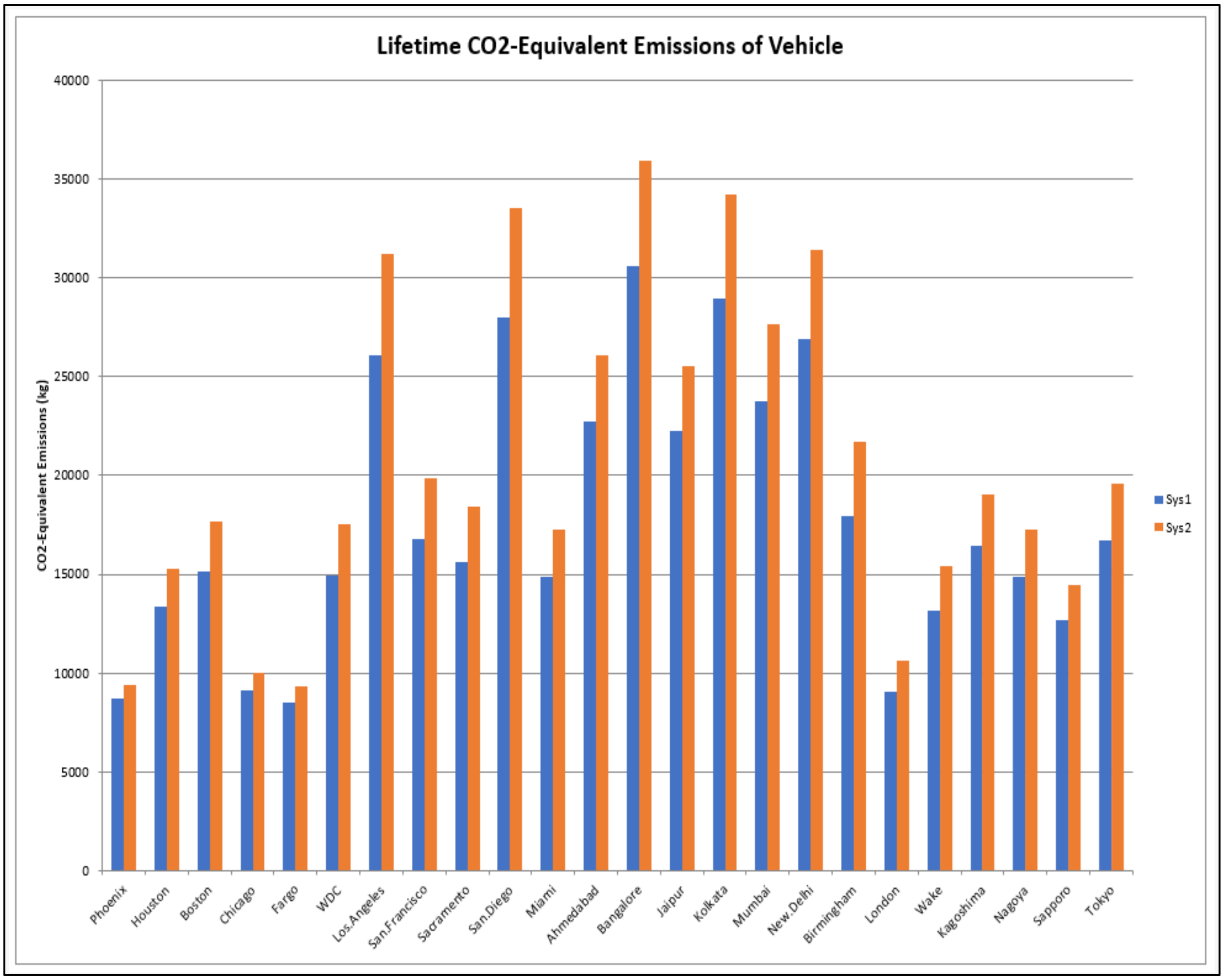


Figure 45. Graph of cumulative CO_2 – equivalent emissions across all cities during the lifetime of the vehicle (Chart 1)

III. Annual CO_2-equivalent emissions for each system across all cities are available in *Chart 2*. A representation is shown in *Figure 46*.

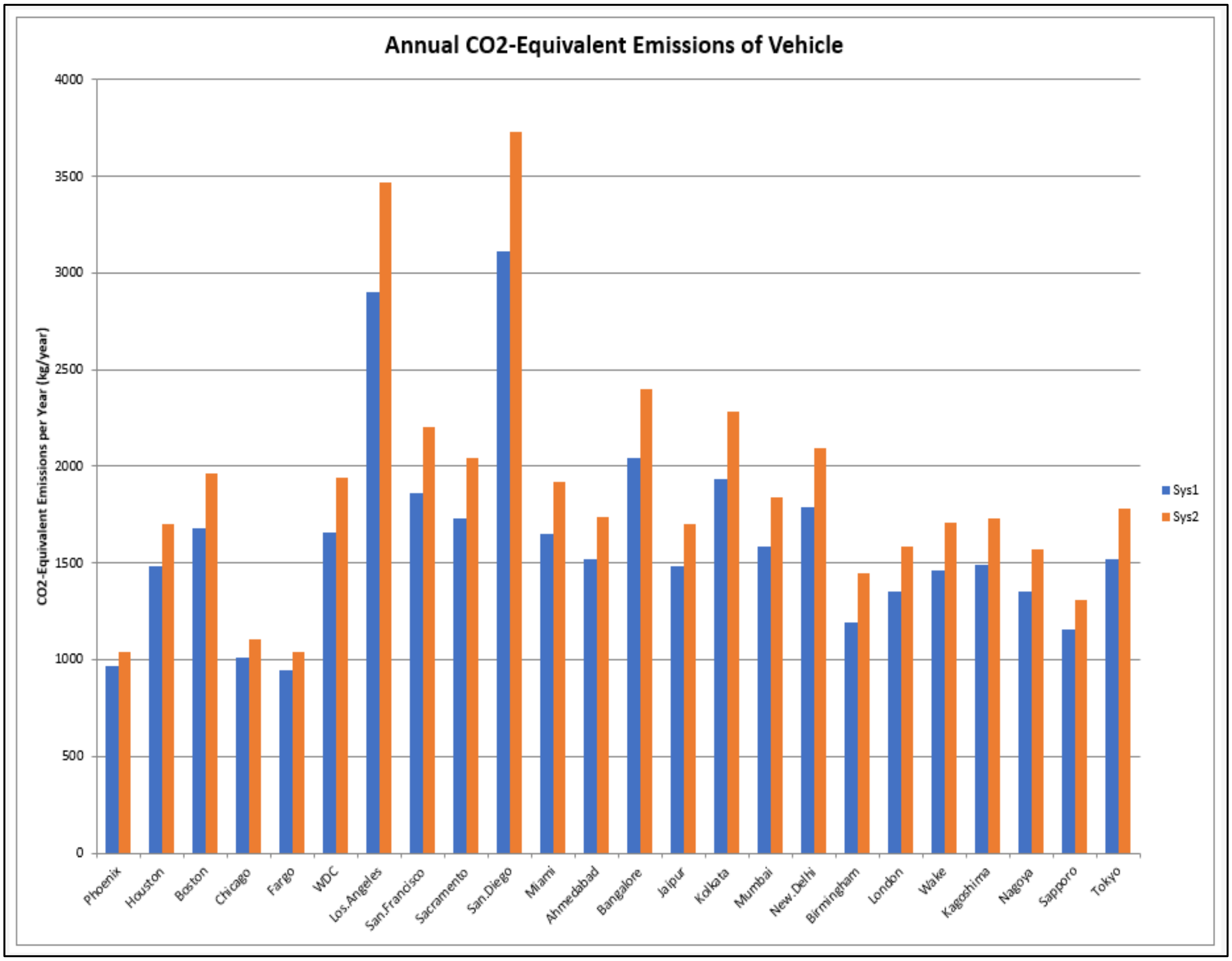


Figure 46. Graph of annual CO_2 – equivalent emissions across all cities during the lifetime of the vehicle (Chart 2)

IV. *Chart 3* contains a bar graph comparison of CO_2-equivalent emissions for each system per kilometer, across all cities. A sample of the sheet is shown in *Figure 47*.

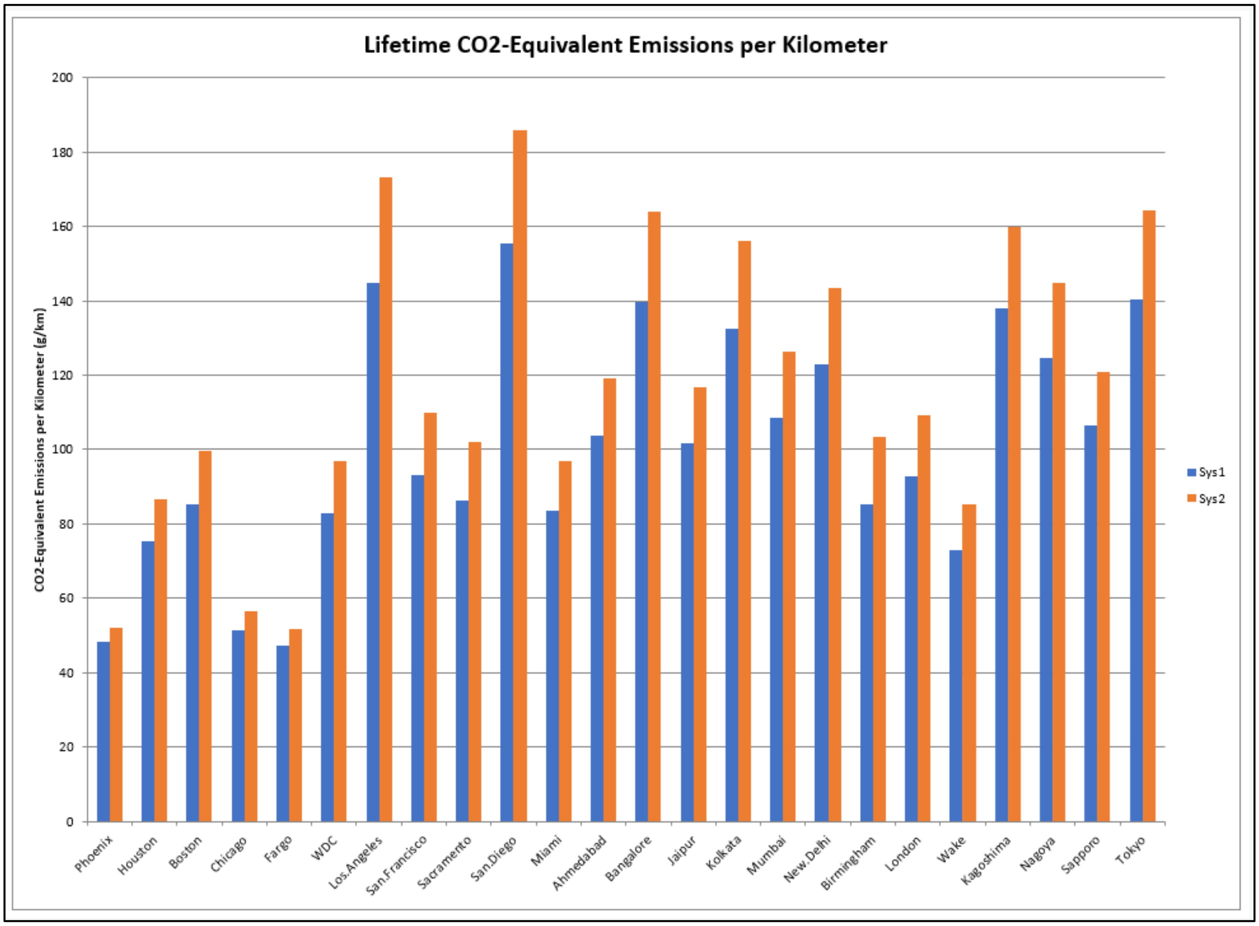


Figure 47. Graph of CO_2 – equivalent emissions across all cities per kilometer during the lifetime of the vehicle (Chart 3)

V. The *Weighted* tab gives a comparison of the amount of CO_2 emitted in all GREEN-MAC USA cities across all systems. If GREEN-MAC USA cities weren't selected for simulations, this screen would be blank. *Figure 48* shows a sample of a filled sheet.

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	**Indirect Contribution, Weighted (GREEN-MAC USA Cities)**	Phoenix	Houston	Boston	Chicago	Fargo	WDC	Los Angeles	San Francisco	Sacramento	San Diego	Miami	Sum
2	Percent of total vehicles in these cities	4.5%	16.3%	13.2%	22.5%	4.5%	12.4%	5.0%	5.7%	5.0%	5.0%	5.8%	**100%**
3	Driving Distance (km/yr)	20,050	19,635	19,665	19,635	20,050	20,050	20,050	20,050	20,050	20,050	19,832	
4													
5	**Annual MAC Operation Contribution (kg CO2/year)**												
6	Sys1	734.9	1251.8	1465.4	796.8	747.0	1443.2	2685.2	1649.3	1516.7	2896.3	1421.9	
7	Sys2	954.5	1612.4	1875.9	1023.0	951.9	1856.7	3383.2	2116.5	1955.7	3641.5	1833.1	
12													
13	**Weighted MAC Operation Contribution per Mile (g CO2/mi)**												Weighted Average
14	Sys1	2.65	16.72	15.83	14.69	2.70	14.36	10.77	7.54	6.09	11.62	6.69	**109.67**
15	Sys2	3.45	21.54	20.26	18.86	3.44	18.48	13.58	9.68	7.85	14.61	8.63	**140.36**

Figure 48. Comparison of all GREEN-MAC USA cities

VI. *Chart 4* graphically compares all the systems for the GREEN-MAC USA cities with respect to the amount of CO_2-equivalent emissions per mile emitted. If GREEN-MAC USA cities weren't selected for simulations, this screen would be blank. *Figure 49* shows a sample of a filled sheet.

Figure 49. Graphical comparison of GREEN-MAC USA cities w.r.t emissions per mile