Tariff Design and Analysis tool

Final report of project AP944, "An expanded open source modelling tool for assessing how different network and retail tariffs, and distributed energy options, impact on small energy consumers"

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1 Executive summary

The document introduces the two versions of the Tariff Design and Analysis (TDA) tool, developed by the Centre for Energy and Environmental Markets (CEEM), at the University of New South Wales, with support from the Australian PV Institute (APVI). The initial TDA project was supported by Energy Consumers Australia (ECA) in 2016 which resulted in the development of the first version of the TDA tool. The extended version was then developed as part of the second tranche of funding received from the ECA in 2018. The open source TDA tool aims to assist stakeholders, including consumer advocates and researchers, to investigate how different tariff structures impact on the expected bills of different types of residential consumers, while also estimating how well the tariffs align these customer bills with their impact on longer-term network costs. The tool builds on research and analysis undertaken by CEEM.

The main outcomes of the project are:

- Development of a new version of the TDA tool with new features including incorporation of retail tariffs and end-user technologies
- Collaborations with advocacy stakeholders through providing the tool and through ongoing assistance in using the tool in range of tariff analyses
- Holding several workshops to introduce the tool and facilitate users' engagement as well as multiple meetings to demonstrate the tool
- Ongoing IT and tool development support to the users
- Use of the improved tool for network tariff determinations including a submission to the SAPN tariff structure statement 2020/25 and for customer impact analysis for Energy Queensland
- Project outcome dissemination through several workshops, publications, conferences, meetings, and lectures in UNSW courses

1.1 Project team

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Steering Committee:

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1.2 Acknowledgements:

The project team wishes to thank the Steering Committee as well as the following people for their great help and advice throughout the project:

- Rose McGrath (QCOSS)
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- Craig Chambers (ARENA)
- Luke Marshall (UNSW)
- Mohammad Dehghani (UNSW)
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Contents

2 Introduction

2.1 Context

The open source TDA tool aims to help researchers and other stakeholders involved in electricity tariff design and use, to explore the impacts of different network and retail tariff structures on the bills of different types of residential consumers, while also estimating how well the tariffs align these customer bills with their impact on longer-term network costs.

The development of the first version of the TDA with ECA funding over 2016-17 was highly successful in assisting the stakeholders in providing evidence-based contributions and advocacy to tariff determination processes. The new version of the TDA has been developed with funding from ECA in 2018 to include a range of new features and continue the engagement with stakeholders. Among other new features such as the new platform and visualisation options, the expanded TDA tool is designed to include two new features, namely: incorporating retail tariffs and end-user technologies including rooftop solar, battery and demand response. The tool can be also used by individual users to examine the impact of different tariffs using their load profile.

2.1.1 Cost reflective tariffs

The AEMC's Power of Choice review almost six years ago both reflected, and has helped drive, a renewed focus on consumer engagement and interests in the governance of the Australian National Electricity Market. One key outcome was the 2014 rule change requiring network businesses to introduce more cost reflective tariffs that better align network cost drivers with consumer incentives. In practice, the complexities of network costs, existing network regulatory frameworks and issues of consumer acceptance have created a challenging and contested space for tariff reform.

The rule states that network tariffs should be based on the long-run marginal costs (LRMC) of providing the network service, and that the revenue to the network should reflect the efficient costs of providing the services to each consumer class. However, DNSPs are able to determine how to calculate their LRMC, how this is reflected in the tariff design and how residual costs should be collected. As DNSP tariff structures must balance efficient pricing considerations with fairness and the ability of consumers to understand and respond to the tariffs, there is considerable scope for a variety of tariff designs to emerge. In recent submissions, DNSPs have put forward a number of tariffs of varying structure and complexity. It is challenging to assess how each tariff will impact on different consumer groups, and how well they can provide efficient price signals and address existing cross-subsidy issues.

It is possible for groups or individuals to make submissions to the regulator regarding tariff design. However, given significant information asymmetry between network service providers and other stakeholders, including both consumers and regulators; advocacy organisations lack the resources to put forward robust, evidence-based analysis of the impact of proposed tariffs on different electricity consumer groups and the incentives these tariffs might provide to customers. The TDA has been developed by CEEM to assist stakeholders, including consumer advocates and researchers, to investigate how different tariff structures impact on the expected bills of different types of residential consumers, while also estimating how well the tariffs align these customer bills with their impact on longer-term network costs.

2.1.2 The significant role of retail tariffs

Small energy consumers do not directly engage with network businesses or their tariffs. Instead, these are bundled into the retail tariffs offered by different retailers in a competitive retail market. It is these tariffs which determine consumer bills and set the incentives for possible changes to consumer behaviour. One key question is the implications of how more cost reflective network tariffs are actually bundled into retail tariffs. For example, a network tariff with TOU and peak demand charge components may conceivably be bundled into far simpler retail tariffs. What are the implications of this for the incentives consumers see to reduce their contribution to network cost drivers? What might be the implications for different customer classes such as low income or families with young children? More generally, there are growing concerns about the effectiveness of current retail market arrangements. Policy makers, regulators and consumer advocates can benefit from analysis tools that can assess the implications of different retail offerings for consumers.

2.1.3 End user technologies

Australia has the highest penetration of residential PV systems in the world. A key driver has been rising electricity costs that make such systems increasingly attractive ways to save money. Small energy user deployment of battery energy storage systems is also now growing rapidly, although from a relatively small base. Finally, households have increasing options to shift and manage their load profile through smart remotely controlled appliances. All these options offer the potential for households to reduce their electricity bills. However, the extent of these savings depends on the retail tariffs that they pay. For the network businesses and retailers themselves, these highly engaged consumers present both challenges as well as opportunities to improve the efficiency of their own operations. There are also potentially major equity implications between different consumers. Again, policy makers, regulators, and consumer advocates can benefit from analysis tools that can assess the implications of these different energy options for consumers.

2.2 Project Outcomes

The main aim of the tariff design and analysis tool is to facilitate evidence-based discussions and analysis of the proposed tariffs and in particular their impact on different user groups. In this section we review the major outcomes of the project.

2.2.1 Development of new version of the TDA tool with new features

We have developed the new version of the tool in the Python programming language[1]. The main reason for moving from Matlab to Python was to make the tool available to a broader open-source development community. We have also been improving the tool by adding a significant number of new features based on stakeholders' feedback. The ongoing improvements include connection to the live tariff database, addition of retail tariffs, addition of distributed resources and end user technologies such as battery and demand response, and new visualisations. A detailed description of the tool is available in section 4 and 5 of this document.

[1] The user interface has been designed in Java script and HTML, but the entire background calculations and analyses are coded in Python. For more information refer to the github repository

2.2.2 Collaborations with advocacy stakeholders

We have been in regular contact with a range of stakeholders and had meetings and discussions with many, including the AER, Ausgrid, PIAC, ATA, TEC, NSW Government and Energy Queensland. The steering committee was established, and the project's progress has been discussed with them in meetings and through ongoing contact. The expanded tool is used in the Renewable Energy Policy course at UNSW. It is publicly available for all interested stakeholders and all code and data are freely accessible through the CEEM webpage and associated GitHub account[1]. New tariff structure templates have been added to the tool as they are introduced by different network providers and a representative list of retail tariffs have been also added to the tool.

2.2.3 Workshops to introduce the tool and facilitate users' engagement

We have held three workshops in 2018 and 2019.

1. Workshop at the Asia-Pacific Solar Research conference (APSRC 2018), Dec 2018 - Sydney: The first formal workshop was well attended and provided useful feedback and included a panel discussion (speakers from ARENA and AER). The workshop generated significant discussion and feedback from a range of attendees from universities, governments, SME, regulator, network businesses, ARENA, local govt, and CSIRO. This feedback was collated and resulted in further improvement and extension of the tool.
2. Workshop at the APSRC 2019, Dec 2019 – Canberra: the second workshop was also well attended by more than 20 participants from different organisations. In this workshop the new stable version of the tool was presented to the audience with live demo of the main features, and the recent customer impact analysis using the tool for Energy Queensland was presented. This resulted a fruitful discussion on potential further enhancements.
3. Final workshop in Sydney, Dec 2019: the workshop was also successful in generating a good discussion by attendees from different organisations including the steering committee members.

In addition to the formal workshops, we have had several individual workshops for stakeholders in which we demonstrated the tool's features. This included AER, Ausgrid, AEMC, PIAC and TEC.

2.2.4 Ongoing IT and tool development support

We have been assisting interested stakeholders to use the tool and have been adding features based on the feedback received through the first workshop, and ongoing discussions. The tool was made available through different platforms to increase engagement (e.g. GitHub for the open source community[2], CEEM's website[3] and ResearchGate[4] for the academic community, and CEEM's social media).

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[1] https://github.com/UNSW-CEEM/TDA_Python
[2] https://github.com/UNSW-CEEM/TDA_Python
[3] http://www.ceem.unsw.edu.au/cost-reflective-tariff-design
[4] https://www.researchgate.net/project/Tariff-Design-and-Analysis-TDA-Tool

2.2.5 Use of the improved tool for the network tariff determinations

We have made a submission to the SAPN Tariff Structure Statement 2020/25 and Pricing Proposal 2019/20. This was structured in order to be relevant to TSS and PPs from other DNSPs, whilst also presenting analysis of SAPN's new proposed tariffs using the tool. We have also been undertaking detailed tariff analysis for Energy Queensland of their TSS and PP. The presentation slides containing the main elements of the EQ project are attached in conjunction with this report.

2.2.6 Project outcome dissemination

In addition to the workshops, meetings, submissions, and engagement with network providers, we have presented the tariff tool as part of a conference paper at the APSRC 2019 and will be presenting a full peer-reviewed research paper to the IEEE Power and Energy Society General Meeting to be held in Montreal in August 2020. The paper has been attached to this report.

3 Conclusions and remarks

In this document an overview of the Tariff Design and Analysis tool developed by the Centre for energy and Environmental Markets has been provided. The tool is open source and publicly available and was developed to assist all energy stakeholders to explore the impacts of different network and retail tariffs on different users. The extension of the TDA was part of the project AP944, "An expanded open source modelling tool for assessing how different network and retail tariffs, and distributed energy options, impact on small energy consumers" and was funded by ECA. The complexity of tariff design and need for evidence-based discussion over the impact of tariffs on different user groups has been the main motivation for undertaking this project. The range of different analyses made available by this tool is extensive and this tool is expected to assist a wide range of stakeholders to analyse existing and new tariffs. In this final report of the project we also reviewed the main outcomes of the project including collaboration with the stakeholders, holding workshops and meetings to facilitate the user engagement, and publications and reports prepared as part of this project.

Appendix A: Tariff Design and Analysis tool

This section describes the tool and its main features. The previous version of the tool was developed in Matlab while the new version is developed in Python. The full set of codes and dataset are publicly available and open-source in two different github repositories for Matlab and Python versions:

- Version 1 (Matlab): https://github.com/UNSW-CEEM/TDA_Matlab
- Version 2 (Python): https://github.com/UNSW-CEEM/TDA_Python

While both versions share the basic features, some of the new features including some advanced visualisations and analysis of end-user technologies and wholesale electricity price have been only implemented in the new version (Python), and there is no intention to update those features and database in the previous version (Matlab). However, that version is still available for download and functional.

A.1 Term of use

TDA is open source software for assessing existing and proposed new tariffs. TDA is free software and can be redistributed and/or modified under the terms of the GNU General Public License as published by the Free Software Foundation version 3. For more information about GPL 3 please refer to: https://www.gnu.org/licenses/gpl-3.0.en.html. All load and tariff data currently in the tool are publicly available and free to use. The terms of use for any further load and/or tariff data will be disclosed if added later to the tool. The Centre for Energy and Environmental Markets (CEEM) does not guarantee the accuracy of the data nor the outputs generated by the tool and therefore accept no responsibility for any liability arising from its use.

A.2 Installation

This version of TDA tool is developed in Python and packaged in an executable function file so that it can be run from any Windows/Mac platform (even from a USB flash memory). You can find the software by one of the following ways:

1- CEEM's page on GitHub where you can also download the Python (or Matlab) source code:
https://github.com/UNSW-CEEM/TDA_Python
or https://github.com/UNSW-CEEM/TDA_Matlab
2- CEEM website along with description of the project and related research undergoing at CEEM:
http://www.ceem.unsw.edu.au/cost-reflective-tariff-design
3- Researchgate project page where you can follow the project to track ongoing updates:
https://www.researchgate.net/project/Tariff-Design-and-Analysis-TDA-Tool

The TDA tool can be downloaded from these sources. You can download the TDA_win.zip (the matlab version also has TDA_mac.zip for Mac OS) from the Github or other sources and unzip it in a non-shared folder (e.g. not dropbox etc.) on your own computer and keep the whole contents of the folder as deleting the original files of the software may result in its failure. Then click on run.vbs (for Python

version) or tda.exe (for Matlab version). This will open the software GUI where you can start your modelling. The Python version of TDA software will not need any prerequisite on your computer and should run without problem. If there is any problem in running the software please get in touch by creating a new issue here and we will be in touch asap. To run the Matlab version, however you need to install the Matlab Compiler Runtime in your computer before you can run the tool. You should install Compiler Runtime version 9.1 to run the TDA application. MCR is a standalone set of shared libraries that enables the execution of compiled MATLAB applications or components on computers that do not have MATLAB installed. The MCR can be downloaded installed for free from this link (size ~900mb). Please note you need to install the version R2016b (9.1). If you have administrator rights on your computer, download, unzip and run the MCR_R2016b_win64_installer.exe (for windows) or MCR_R2016b_maci64_installer.dmg.zip (for Mac) and follow the interactive install (you may need to use comment "./install" and probably your computer username and password for macOS). To install the MATLAB Runtime as a user without administrator rights on Windows follow the steps below:

1- Use the MATLAB Runtime installer to install it on a Windows machine where you have administrator rights.
2- Copy the folder where the MATLAB Runtime was installed to the machine without administrator rights. You can compress the folder into a zip file and distribute to multiple users.
3- On the machine without administrator rights, add the mcr_root\runtime\arch directory onto the user's path environment variable (You don't need administrator rights for adding directories to a user's path environment variable).

More information can be found here. The MCR needs to be installed only once. For any additional updates of the software, it is only necessary to run the software.

A.3 Database

There are different sources of data available in the tool. It includes load data and tariff data. The original load data (available in TDA) includes Ausgrid 300 homes (three years, with and without solar contribution), and Smart Grid Smart City load profiles. The tariff data was obtained from multiple documents available online. New load data and tariff data can be imported to the tool and used for analysis as described later in this report.

A.3.1 Smart Grid Smart City

The Smart Grid Smart City (SGSC) project[1] aimed to collect data from more than 8000 residential homes. Some of the homes also have demographic survey data. In this tool we have used 5000 homes which had data available for 2013, and their survey data. The half hourly power consumption of residential users as well as their demographic information are available within the tool.

[1] More information is available in https://data.gov.au/dataset/ds-dga-4e21dea3-9b87-4610-94c7-15a8a77907ef/details?q=smart%20grid%20smart%20meter

A.3.2 Ausgrid 300 solar homes

The half hourly data of Ausgrid 300 solar homes[1] spans from July 2010 to June 2013 and can be selected for one year at a time. As the gross solar generation is also available for these homes, the new net load (subtracting PV generation from load) is also made available in the tool.

A.3.3 Electricity Network Tariffs

A large number of existing and proposed network tariffs from different states are available in the tool. The complete list of tariffs and parameters are available at CEEM's API centre[2]. You can also click on tariff info (from Menu: Tariff) to open the information about the specific tariff which you have selected. You can also modify any of the tariffs in the tool or create a new tariff as described later in this wiki.

A.3.4 Electricity Retail Tariffs

A list of sample tariffs were obtained from website Energy Made Easy[3]. The list is not exhaustive, and the purpose is to just provide some examples from different states. You can select the tariff and change the values or start a new tariff from scratch. The list of available tariffs could be also found in the CEEM's API centre.[4]

A.3.5 Wholesale Electricity Price

The wholesale electricity price of different NEM States have been obtained from AEMP energy data repository through NEMOSIS[5]. The analysis using the wholesale electricity price is not available in the Matlab version.

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[1] More information is available in https://www.ausgrid.com.au/Industry/Our-Research/Data-to-share/Solar-home-electricity-data

[2] http://api.ceem.org.au/electricity-tariffs/network

[3] https://www.energymadeeasy.gov.au/

[4] http://api.ceem.org.au/electricity-tariffs/retail

[5] https://github.com/UNSW-CEEM/NEMOSIS

Appendix B: Users guide for Matlab version

As mentioned, TDA is available in two versions. The first version is built in Matlab and has the basic features and can be found and installed from the CEEM's github repository. The new version is built in Python and extends the functionality of the Matlab version in multiple ways. This section reviews the features of Matlab version, while next section will introduce the Python version. Some of the contents of the next version will be repetitive, but in order to make the section complete and useful for Python users, we had to repeat ourselves a bit.

TDA tool offers a range of different analysis and result visualisations as described in this section. In summary the tool allows users to:

- Create projects and add analysis to different projects for later referral
- Choose from the existing load profiles (more than 5000 annual household load profiles)
- Filter the load profiles based on the available demographic information
- Import new load profile and demographic information
- Visualise the individual and aggregate load profiles using multiple methods including seasonal pattern, peak analysis, annual energy distribution, daily interquartile range, etc
- Apply the network tariffs available in the tool (60+ tariffs for different Australian States) to calculate the annual bill based on any subset of the load profiles
- Apply the retail tariffs available in the tool
- Modify the parameters of the tariffs to investigate the impacts on annual bills
- Investigate different components of the network bill (DUOS, TUOS, and NUOS) to calculate the revenue for different sectors (distribution, transmission, etc). This can also be done for the retail component where retail tariffs are available
- Adjusting the network peak time to see the impact on the tariffs based on the coincident peak demand
- Create different types of new tariffs including, flat rate, time of use, block usage, demand charge, etc
- Compare the results of multiple analyses in different visualisation platforms including single variable comparison, dual variable comparison, and individual cases
- Export the figures, and copy them into clipboard to incorporate in any report
- Export the results to excel file to do further analysis on the results outside the tool The rest of this section introduces different parts of the tool and gives instructions on how to work with the tool.

B.1 Running the tool

The TDA tool does not need to be installed in your computer. You only need to run the tool and do the analysis. In order to import and export the data properly (such as selecting load data, exporting result, etc), you need to keep all contents of the TDA folder. If you save a project, or create a new load/tariff, it will be also saved in this folder. Windows users need to run the TDA.exe and work with the tool. But if you are using Mac, each time you open the software, it will ask you to locate the TDA folder in your computer. Once asked, you should find the TDA folder and open it and then work with the tool. The main panel of the tool (with some loaded data and analyses) is shown below:

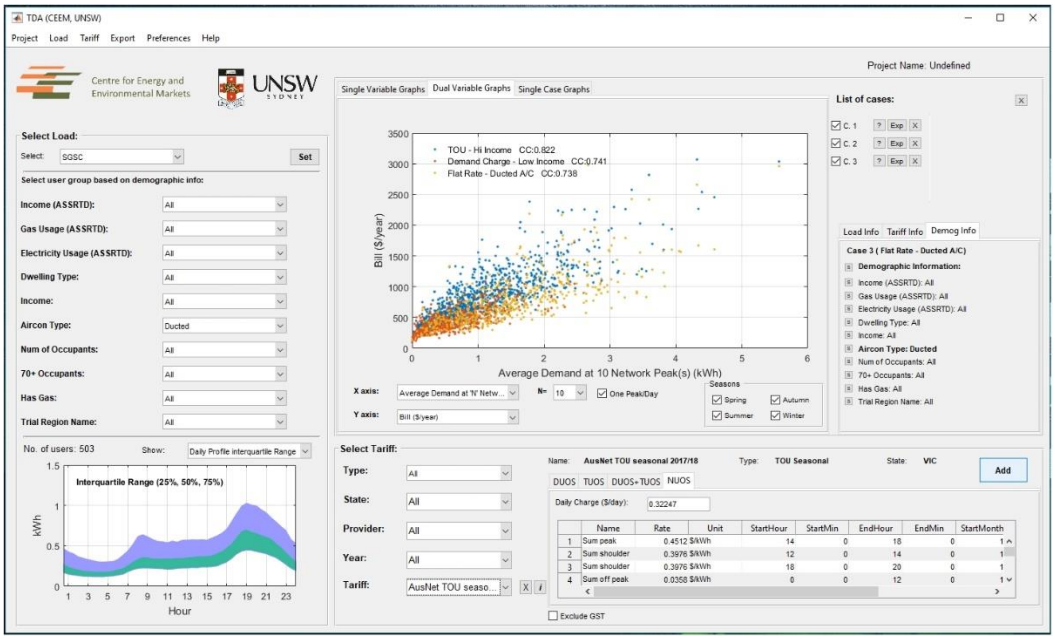


Figure 1 Main interface of Matlab version

B.2 Menu bar

B.2.1 Project

While you are working with the tariff tool, you may want to save your current session for later referral. You can "save" the project, and later "open" the project with your saved analysis loaded in the tool. You can also delete any of the previously saved projects. You can also restart the tool to delete all analysis currently displaying on the tool and restart your analysis. If you do not save the project, the project name will be shown as "undefined" and any analysis will be lost if you close the software. Restarting the tool does not delete any project or load data. But any analyses after the last save will be lost. You cannot restore any deleted projects!

B.2.2 Load

Using this menu, you can import new load data, delete any of the existing load data, or restore to the original load data list. Importing new load data is explained later. You can also define the network load as described later. We will provide new load data as it becomes available. In that case you can just download the load data (.mat file) and put it in the "Data" directory in the TDA folder. You can check for new updates by clicking on Menu: Help > Check for Update. You can also set the maximum amount of missing data allowed as well as the down-sample rate (where a smaller percentage of the sample can be randomly selected, as described later. By restoring the load data, any new load data you created will be lost.

B.2.3 Tariff

You can create new tariffs, obtain the excel file with all the parameters of all the tariffs used in this tool and also reset the tariff lists to the original list of tariffs. We will provide new tariff data as it becomes available. As new tariffs are generally introduced every year, new versions will be made

available and you can download them and copy them in the “Data” directory in the TDA folder as advised in the update page. NOTE. By resetting the tariffs, any new tariffs you have created or modified will be lost and this cannot be undone!

B.2.4 Export

You can export the figure currently showing in the tool (ctrl+E) or copy it to the clipboard (ctrl+C) so you can paste it in another document, email, etc. You can also export the data directly from the figure (ctrl+D) or export the whole case’s results as described in following sections.

B.2.5 Preferences

Using this menu, you can specify some options such as ‘ask to name new cases’, ‘confirm before exiting the tool’, and ‘confirm before deleting some items’.

B.2.6 Help

The option “About” provides information about the software. You can click on any of three options (CEEM webpage, Researchgate project page, or GitHub page) for more information, updates, and comments about the software. You can also open the instruction file via the “Users’ Guide” option and give feedback on the software, and subscribe to receive the latest news of the software. Please note that due to some issues with internet security programs, the options to send feedback or subscribe may not work properly in some cases.

B.3 Selecting load

You can select one of the existing load datasets in the tool by choosing from the dropdown list as shown in Figure 1. Before importing, you can specify the maximum allowed missing data from the menu: Load > Maximum Allowed Missing Data (%). The default value is 5%, which means only homes with less than 5% missing intervals will be loaded. You can change this each time you select a new load. You can also down-sample the load data to speed up the calculation by selecting from menu: Load > Down-sample Users (Random Selection). The default option is 100% (full data) which loads the whole dataset. 50% means randomly selecting 50% of the homes, and so forth. Please note, each time you press “Set”, a new subset will be randomly selected, so multiple selection of one load dataset with the same down-sample value will result in different users being selected.

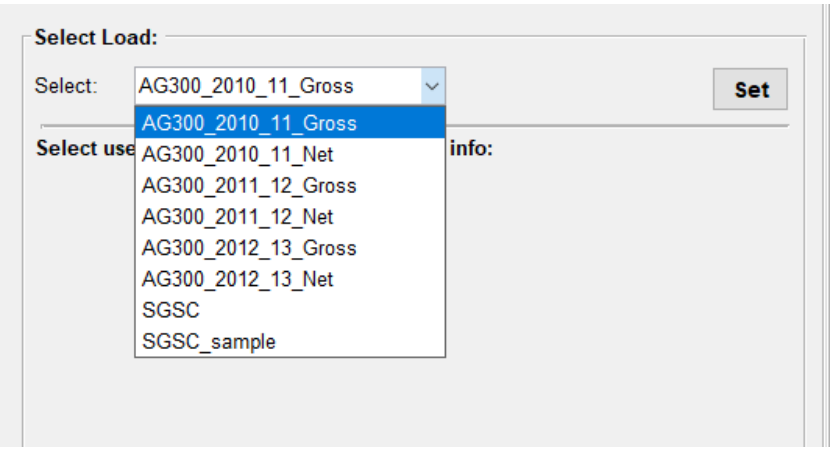


Figure 2 Load selection

You can see the number of homes loaded into the software in the below part of the "Select Load" panel. Each dataset can be selected, and the analysis can be done based on the whole or part of that dataset which is grouped by demographic information. If the demographic information is available for any load data, it will be shown below the dropdown list (see above figure). You can then filter the load based on any part of the demographic information. The number of homes obtained with any particular filter is shown. There is also a set of diagrams which show the individual or aggregate behaviour of the selected load profile. So, you can see the load pattern while selecting the filters. In some of the figure options, you can see and compare the filtered load (by missing data%, down-sampling, and demographic filters) with the whole dataset. This is particularly useful if you want to check if important information (e.g. load profile on a peak day) is similar in the down-sampled load and the whole dataset. If you see a significant difference you may load the demand data again to randomise the users and load a new group. You can change the diagram type from the dropdown list. You can choose the following options:

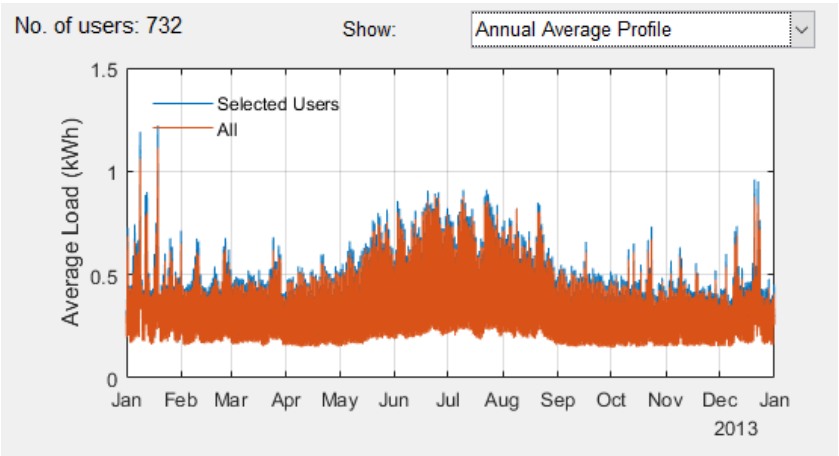


Figure 3 Annual Average Profile

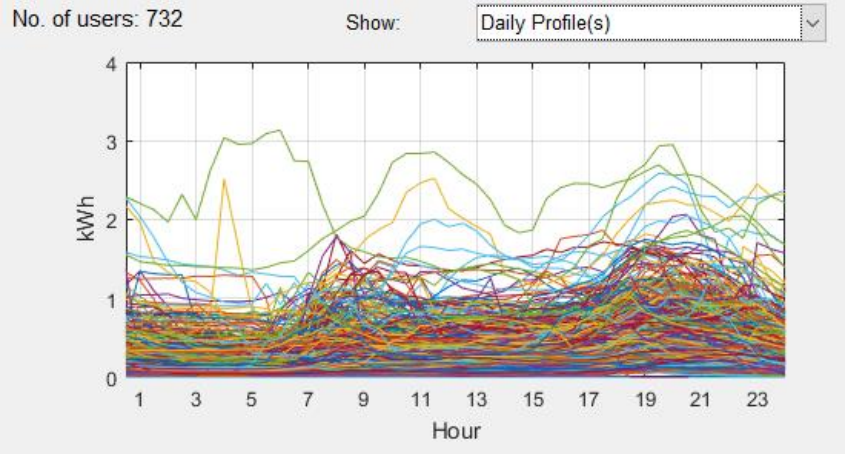


Figure 4 Daily Profiles

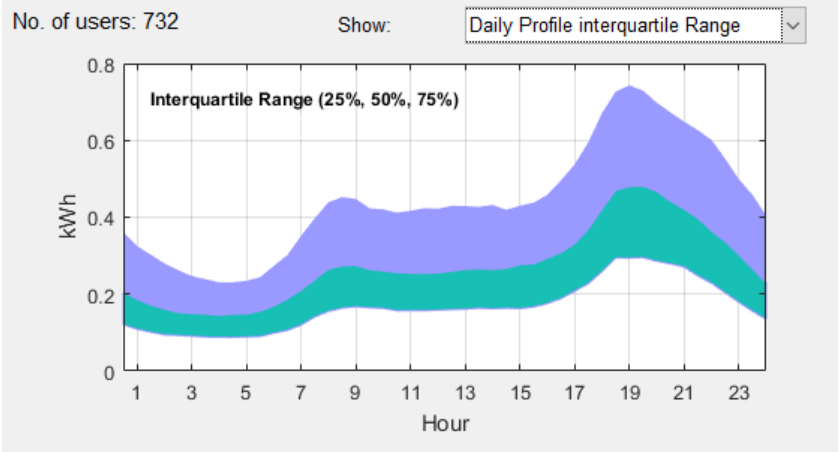


Figure 5 Daily Profile Interquartile Range (25%, 50%, and 75% of load)

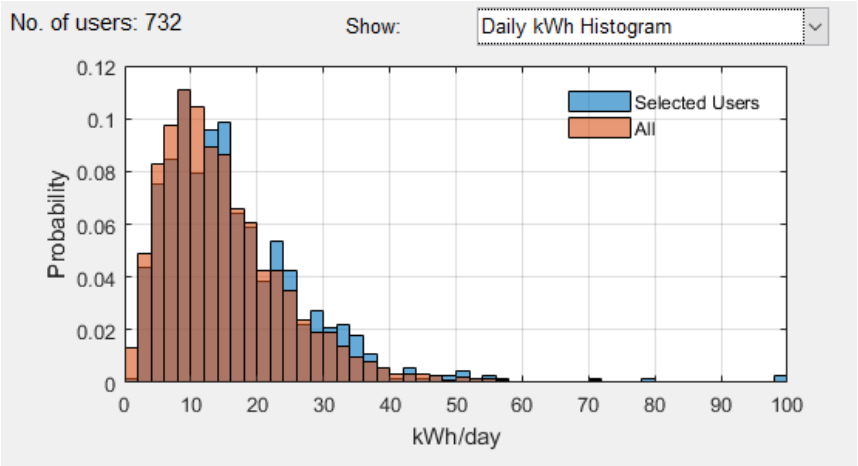


Figure 6 Daily kWh Histogram

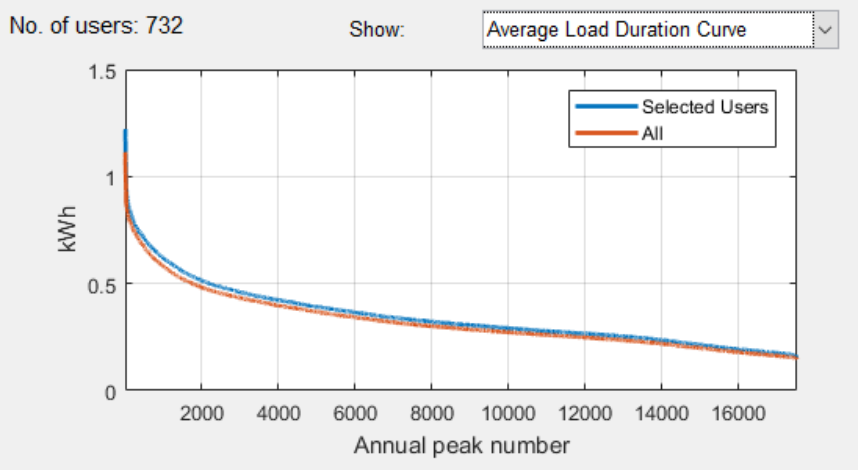


Figure 7 Average Load Duration Curve (sorted aggregate load profile in kW in descending order)

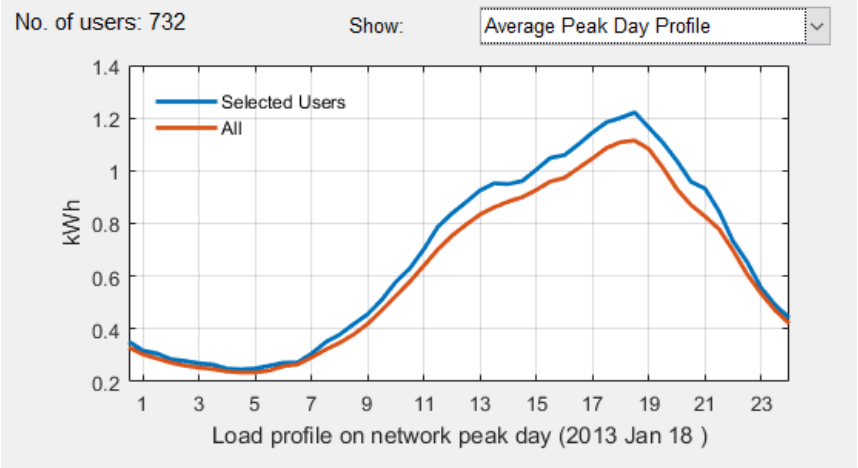


Figure 8 Average Peak Day Profile (daily pattern in highest aggregate peak day)

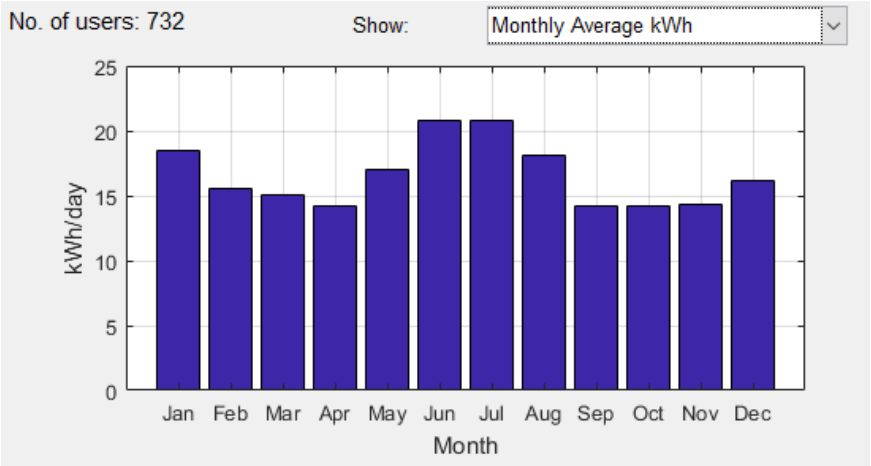


Figure 9 Monthly Average kWh

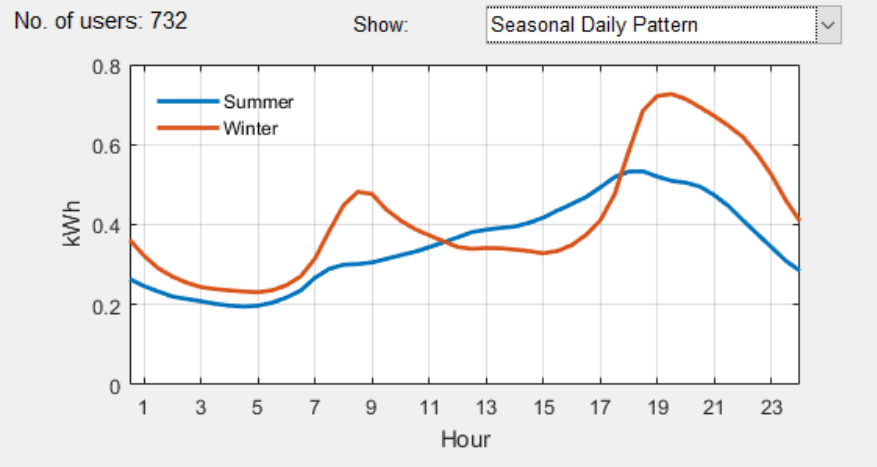


Figure 10 Seasonal Daily Pattern (average daily load pattern in summer and winter months)

B.3.1 Generate new load data

You can also import a new load data by clicking on the "Import load data" on the main menu option "Load". Press the "Create new" button and upload the excel file containing the load profile from your computer. The excel file should contain two sheets with names "Load", and "Info" containing the half hourly data and demographic information. If there is no "Info" sheet, the software will not import the demographic information, and if there is no "Load" sheet, the import will not be processed and an error message will be shown.

B.3.2 Load Sheet Format

The first column of the load data sheet should contain the timestamp of the load profile and it should be exactly one-year of data. The data should be half hourly with the timestamp showing the end of each time period. Therefore, for example if the data is for year July 2012 to June 2013, it should start with 1 July 2012 00:30:00 and end with 30 June 2013 00:00:00. Please note the tool can handle only one year of data. However, you can analyse more years of load data by uploading them as separate years. The first row of the "Load" sheet should contain the home numbers and the following rows will contain the actual load data in kWh. Any empty cell or non-numeric data will be considered as a missing value. Any negative values will be considered but please note the tariff tool does not calculate any premium for exporting power, so the negative values will be ignored in the tariff calculation, but they will have an impact on the network load if you choose the network load to be calculated based on the aggregation of the household load data. The network load is described in more detail later. Please note the tool only works with a half hourly load profile. You should convert your load data to half hourly (by averaging higher resolution data such as 15 min data or repeating lower resolution data such as hourly).

B.3.3 "Info" sheet format

Any information about the household can be put in this sheet, and once imported it will show up in the demographic information section. This can be the type of household, dwelling type, income group, etc. A maximum of 10 types of demographic info can be put in the excel file. The tool will group the information and let the tool operator filter the homes based on any of the demographic info when

selecting the load data. If you want to include more than 10 types of demographic info, you can upload the same load profile but with different demographic info. The first row of this sheet should contain the type of info (for example: “Dwelling type”). The first row contains the Home numbers (to match with the home number in the “Load” sheet).

B.3.4 Sample file

A sample file is also provided that you can use as a reference for the required format. You can also paste your load and info data into this file and save as a new file on your computer and load that when creating a new load dataset. You can open this file by pressing “Open sample file” option. Please note, failing to follow the required format will result in an unsuccessful load import. If you receive an error, make sure you follow the instructions carefully. The home IDs should be in “number” format (i.e. do not use home 1, etc.) and these numbers will be used to match the load and demographic information so please make sure they are identical. If you have or know of any load data which can be made available, please let us know so we can put the load data into the tool. Another option is to send us your excel files containing the load and demographic data, and we will create the “.Mat” file for you - so you just need to put the mat file in the TDA folder, Data directory instead of importing the load yourself. We won’t of course make the data available without your permission.

B.3.5 Network load

When you create a new load file, an assumed network load profile is also created by summing all the households’ data over the year. You can specify in the tool if you want to use this network load for finding the network peak time or instead use a new network load. Under the menu “Load”, select the option “Network load”. You can select the network load profile to be the aggregation of the selected database load profiles, or the aggregation of the filtered load profile (only selected homes with specified demographic information), or based on a synthetic network load profile which you have previously created (see below figure). You can create a new synthetic network load profile by uploading a new csv file. You can have only one synthetic network load profile at a time so if you want to check multiple network load profiles you will need to upload the desired load profile each time. In order to create the new synthetic network load profile, put the network load in a csv file with the first column being the timestamp, and the second column being the network load. The first row will be ignored. You can also open the sample file, paste your new network load (or only adjust the load at timestamps you want) in that and save it as a new file in your computer, then import it as the synthetic network load file. The sample file provided has a flat rate of value 1 so you can increase the values in different months, days, and hours to see the impact of different network load peak times. As the tool analyses only one year of load data, the network load should also be one-year of data. Also, the “year” of each timestamp is not considered. e.g. you can import network load for 2014, and use the load of 2013 and the tool will assume the network load is for 2013.

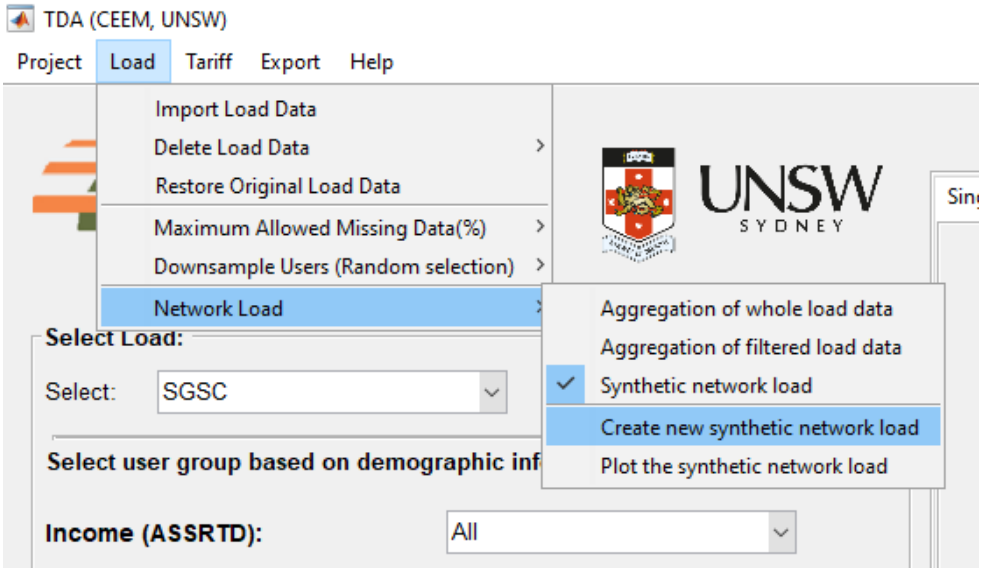


Figure 11 Creating a synthetic network load

Once you create a new synthetic network load profile, you can plot it and see the load pattern as well as the monthly peak times and value (see below figure). It will allow you to quickly observe the monthly peak time and confirm if the network load profile looks correct. You can also plot the synthetic network load profile (or the network load profile based on the other two options) by choosing it in menu "Load > Network Load > Plot network load pattern".

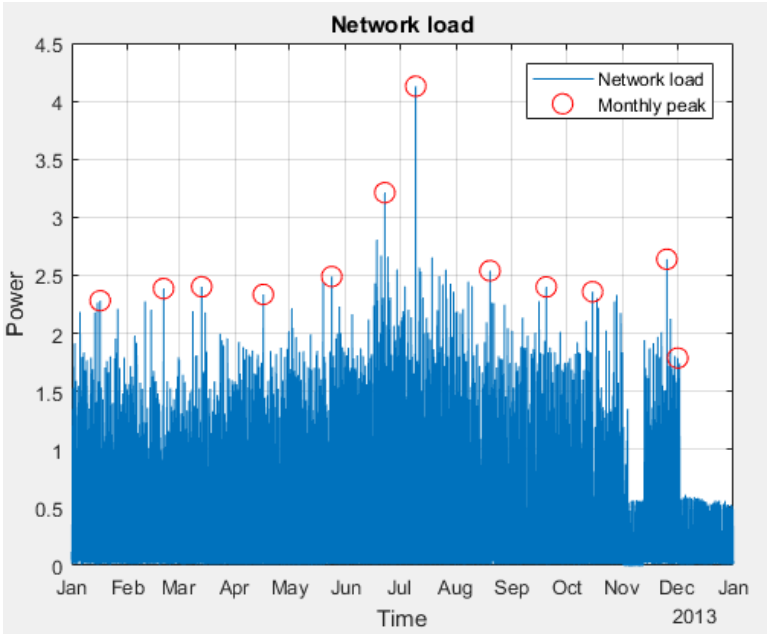


Figure 12 Plotting the network load

B.4 Selecting a Tariff

Once the load data has been selected, the tariff should be selected. The state, type, provider, and year can be used to filter the tariffs. Below figure shows the tariff selection panel. The "Tariff Info" option

in the “Tariff” menu will open an excel file containing all the information and parameters of the network tariffs used in this tool. The rates shown are GST inclusive. If you want to exclude the GST, you can tick the “Exclude GST” option. Once a tariff is selected, the options for deleting the tariff or the available information for the tariff will appear in the “x” and “i” buttons respectively located beside the tariff dropdown list. The info button will open a folder with all the documents used to provide the tariff details for the selected provider (e.g. AusGrid).

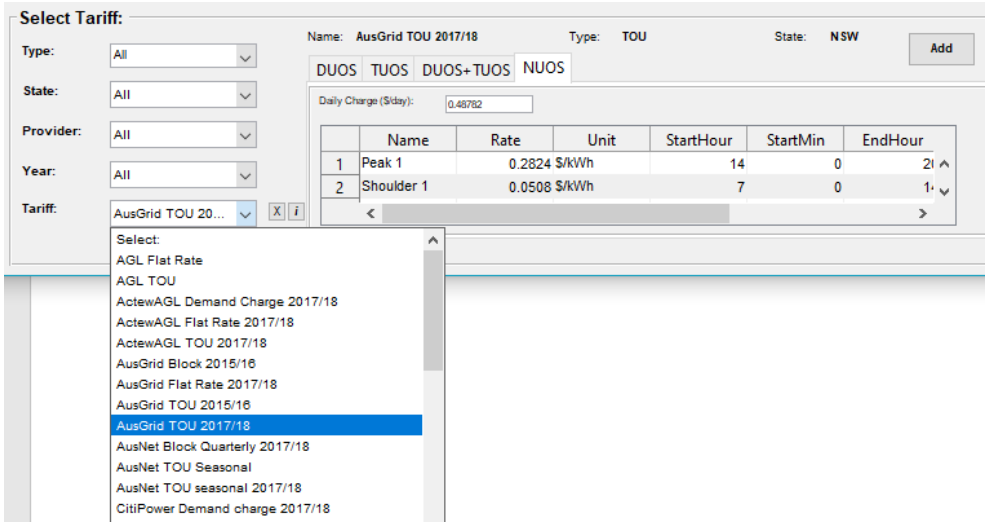


Figure 13 Selecting tariff

B.4.1 Tariff components

When using a network tariff, you can choose whether you want to apply the whole tariff (NUOS) or only a component of the tariff. NUOS is “Network Use Of System” which is made up of DOUS, “Distribution Use of System”, and TUOS, the “Transmission Use of System”. Some NUOS tariffs might include other components (e.g. NSW Climate Change Fund or the Qld Solar Bonus Scheme). You can choose DUOS (to evaluate the distribution revenue), TUOS (to evaluate the transmission revenue), DUOS+TUOS (to evaluate both), and NUOS (to evaluate the actual tariff). By moving between tabs you can choose which component you want to apply. When using a retail tariff, you can only use the entire tariff (which is in DUOS tab, so you should select DUOS tab for those).

B.5 Adding analysis

Once you have selected the tariff (from the dropdown list) and the tariff component (by selecting the tab), you can click on “Add” to add the analysis to the graphs. This will apply the selected component of the tariff to the selected subset of the load and perform a variety of analyses which are described later in this document. Please note when you add the analysis, the tool will generate the network load data based on the option you have selected (i.e. based on the whole database, filtered database, or synthetic network load which was described before). Before adding the analysis, make sure the network load profile is selected properly. Once the analysis has been added to the diagrams, you cannot change the network load for this analysis. In order to do so, you may consider deleting the analysis (case) and then undertaking the analysis again using a new network load profile. When you

add a new case, the tool will ask if you want to pick a name for the new case. If you choose No, or close the dialog box, the new case will be named as Case + number. You can disable this option (asking for naming the new case) in menu Options.

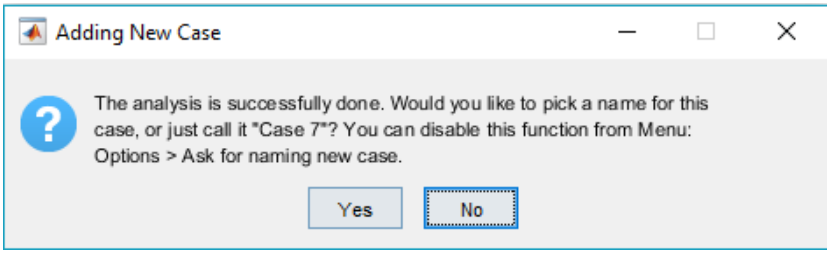


Figure 14 Pop-up message for saving case

B.5.1 Creating new tariff

The components of the tariff including daily charge, energy cost, and others are shown in the panel. Any of the shown components can be adjusted to create a new tariff. Once any component of a tariff is changed, the modified tariff can be saved with a new name into the list of existing tariffs. When you edit a component, the saving option will appear. Please note, if you change any component of a tariff it won't automatically change in other components of that tariff. For instance, if you edit the demand window starting hour in DUOS, it won't change this parameter in the TUOS, DUOS+TUOS, and NUOS even if you save the tariff. As a result, the DUOS+TUOS might no longer be the addition of DUOS and TUOS. You can also create a new tariff from scratch by selecting it from menu, "Tariff > Create New Tariff". There are currently seven types of tariff which you can create:

- **Flat rate**, where a flat constant rate applies to the kWh usage
- **Flat rate seasonal**, where the rates are different in different seasons
- **Block**, where the rates are different for different levels of kWh
- **Block quarterly**, where rates are different for different levels of kWh in each quarter
- **Time of use**, where rates are different in different times of the day
- **Time of use seasonal**, where rates are different in different times of the day and different months
- **Demand charge**, where the tariff is applied to the household peak demand (kW) or the household demand at the time of the network peak (kW) instead of (or in addition to) the kWh

The following tables show the tariff options and parameters.

Flat rate:

Parameters	Values
Daily charge ($/day)	Non-negative value
Energy cost ($/kWh)	Non-negative value

Flat rate seasonal:

Parameters	Values	Comment

Daily charge ($/day)	Non-negative value	
Energy cost ($/kWh)	Non-negative value	
StartMonth	1-12	Start month of the season
EndMonth	1-12	End month of the season

Block:

Parameters	Values	Comment
Daily charge ($/day)	Non-negative value	
Energy cost ($/kWh)	Non-negative value	
High Bound (kWh)	Non-negative value	The high bound of the block

Block Quarterly:

Parameters	Values	Comment
Daily charge ($/day)	Non-negative value	
Energy cost ($/kWh)	Non-negative value	
High Bound (kWh)	Non-negative value	The high bound of the block in quarter

Time of Use:

Parameters	Values	Comment
Daily charge ($/day)	Non-negative value	
Energy cost ($/kWh)	Non-negative value	
StartHour	0 to 23	Start hour of the time period
StartMin	0 or 30	Start minute of the time period
EndHour	0 to 23	End hour of the time period
EndMin	0 or 30	End minute of the time period
Weekday	Logical (true or false)	Select if the tariff should be applied on weekdays
Weekend	Logical (true or false)	Select if the tariff should be applied on weekends

Time of Use Seasonal:

Parameters	Values	Comment
Daily charge ($/day)	Non-negative value	
Energy cost ($/kWh)	Non-negative value	
StartHour	0 to 23	Start hour of the time period
StartMin	0 or 30	Start minute of the time period
EndHour	0 to 23	End hour of the time period
EndMin	0 or 30	End minute of the time period
StartMonth	1 to 12	Start month
EndMonth	1 to 12	End month
Weekday	Logical (true or false)	Select if the tariff should be applied on weekdays
Weekend	Logical (true or false)	Select if the tariff should be applied on weekends

Demand Charge:

Parameters	Values	Comment

Daily charge ($/day)	Non-negative value	
Energy cost ($/kWh)	Non-negative value	
Demand charge ($/kW/month)	Non-negative value	
StartHour	0 to 23	Start hour of the time period
StartMin	0 or 30	Start minute of the time period
EndHour	0 to 23	End hour of the time period
EndMin	0 or 30	End minute of the time period
StartMonth	1 to 12	Start month
EndMonth	1 to 12	End month
Weekday	Logical (true or false)	Select if the tariff should be applied on weekdays
Weekend	Logical (true or false)	Select if the tariff should be applied on weekends
NetworkPeak	Logical (true or false)	Select if the tariff should be applied on the demand at network peak (coincident peak)
NumberofPeaks	Natural number (1,2,…)	Number of peak periods on which tariff should be applied
DemandWindowTSNo	Natural number (1,2,…)	The average of this number of half hourly periods before the peak demand (including the peak demand timestamp) will be considered. Default value is 1.
MinDemandkW	Non-negative value	Minimum demand in kW. Any value below this will convert to this limit.
MinDemandCharge	Non-negative value	Minimum demand charge in $. Any charge below this will convert to this limit.
TimeGroup	Natural number (1,2,…)	Condition groups. All rows with the same TimeGroup will be considered as one demand charge. For example you can specify the demand charge based on 7-10am and 4-9pm in two rows and then use the same TimeGroup for both of them. This means one demand charge will be applied to the peak and both time periods will be considered to find the peak demand.
DayAverage	Logical (true or false)	Select if the tariff should be applied on the average demand in the time period of the day (instead of just the peak demand).

You can select a name and specify the provider, state, and year. You can also include some info about the tariff for your own reference. Once you save the tariff and select this tariff from the dropdown list, you can hover over the tariff name and the info will appear. You should put the DUOS, TUOS, and

NUOS “rates” separately and they can be different and even zero in some components (e.g. demand charge in the TUOS component in some demand tariffs is zero). However, the other parameters (such as StartHour, ..) cannot be different in different components. As opposed to the “modify tariff” option, here if you change a tariff parameter (e.g. start hour, end hour, etc) in one component (e.g. DUOS) it will change in other components as well. So if you really need a different parameter in different tariff components you can create the tariff, select it in the “Select Tariff” panel, and then edit the parameter in only one component. If you need to add more rows to the parameters table, you can press ‘+’ to add a row. This will add the row to all components tabs. You can also delete the last row by pressing ‘-‘. If the NUOS component of your tariff is equivalent to DUOS+TUOS, you can click on the button below to fill the NUOS rates based on the DUOS+TUOS. You can also modify the rates afterwards. Once you finish everything you can press “Add” to save this tariff in the list of tariffs. The new tariff will be checked for consistency and the software will prompt an error message if it finds any problem in the tariff. You may later delete this tariff by selecting it from the select tariff dropdown list and press -. You can also reset all tariff lists to the original list provided by this tool by selecting from menu, Tariff > Reset Tariff.

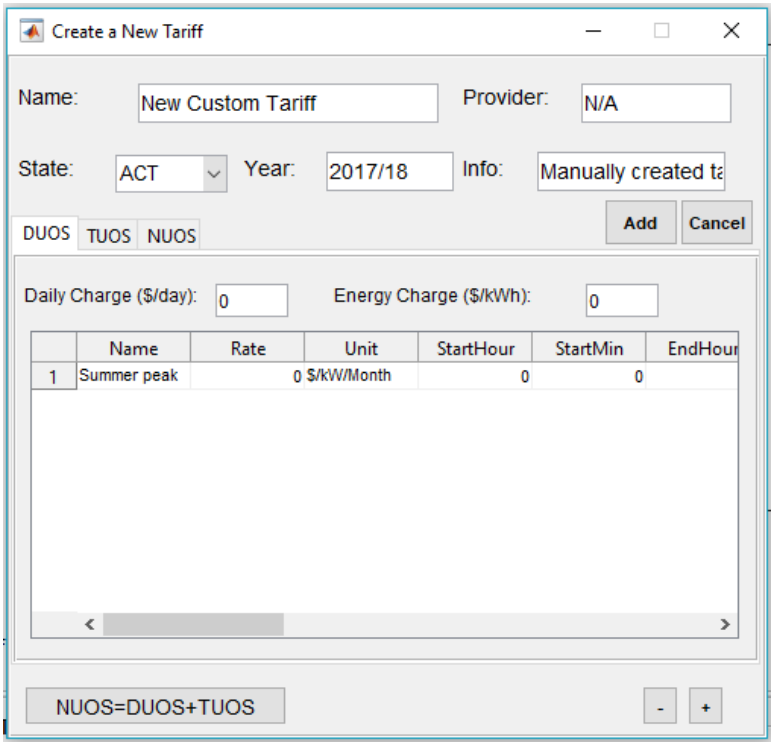


Figure 15 Creating a new tariff

Please note the tool may not be able to catch all possible errors in the tariff design, so please make sure all components of the tariff are designed as intended before saving the tariff.

B.6 Visualising the analysis

After selecting the data and adjusting the tariff (if applicable), the analysis can be performed, and the results can be shown on the graphs by pressing the “Add” button. Depending on the load size, complexity of the tariff, and your computer’s specification, adding the analysis to the plot window may take up to a few minutes. When you add a new case, the tool will ask if you would like to pick a

name for the new case. It will appear in the graphs, exported data, and case information panels. If you select “No”, it will be saved as “Case + the number of case”. Please note, when you delete one case, the name of the other cases will be updated. So for instance, if you delete case 3, case 4 and 5 will be renamed to case 3 and 4 respectively and so on. More analyses can be added to the plot by selecting a different user group or tariff and pressing “Add” again. Up to 10 analyses can be added to the diagrams. There are three types of diagrams used for analysis, titled “Single Variable Graphs”, Dual Variable Graphs”, and “Single Case Graphs”. When adding the analyses (cases), you can see the list of all cases beside the plotting panel where you can show/hide the graphs, display the information of the cases, export the case to excel file, and delete the case. Figure 8 shows different components of the plotting panel.

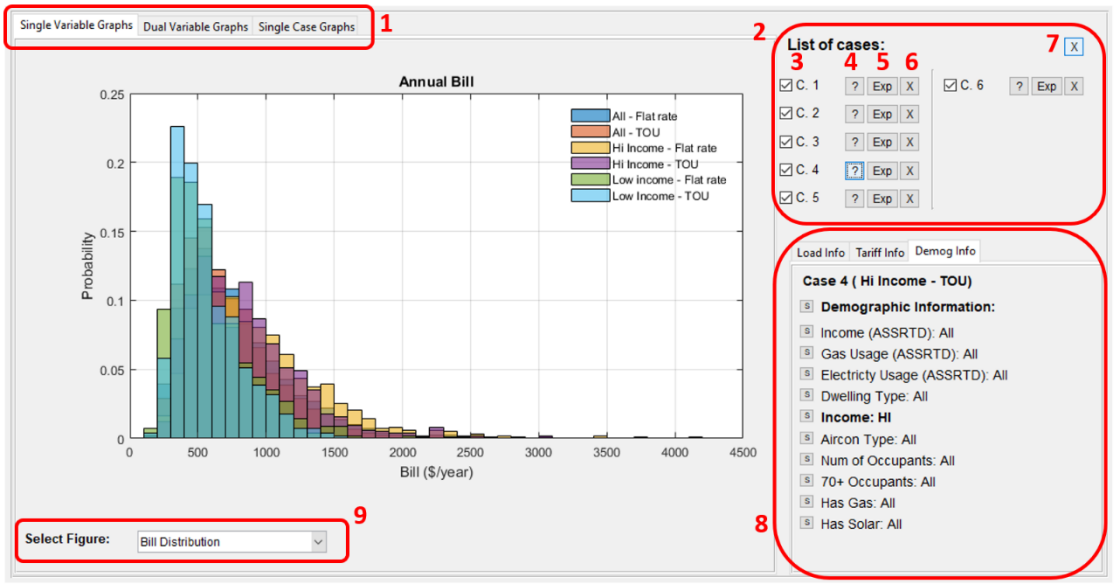


Figure 16 Main components of the visualisation interface 1- Select the graph type, 2- List of cases, 3- Hide/show one case, 4- Display the case information in info panel, 5- Export the result to excel, 6- Delete the case, 7- Clear all cases, 8- Info panel, 9- Select the plot option

B.6.1 Export figure

You can export the figure currently displayed on the plotting panel. The figure will pop out of the panel with more options (zoom, pan, etc). Also, you can save the figure in multiple standard figure formats. For this option, click on menu Export > Export Figure or simply press ctrl + E.

B.6.2 Copy figure

You can also copy the figure in the clipboard and then paste it in any document (word, email, etc). The figure might not be exactly the same as what is being shown on the panel for some figure options (aspect ratio, etc). You can also take a screenshot of the figure, or export the figure and then insert it into your document. You can also print the figure to pdf after exporting it for better quality. For this option refer to menu: Export > Copy Figure (Ctrl + C).

B.6.3 Copy Data

If you want to access the underlying data of the figures you can copy the data of the current figure to the clipboard and paste it in any excel file, etc. You can find this option in menu: Export > Copy Data (Ctrl + D).

B.6.4 Info panel

In the info panel, you can see the load info (Case number, Number of users, load database, and network peak time calculation method), Tariff info (Tariff name, type, State, selected component, and tariff parameters), and Demographic info based on the available demographic information. If any of the demographic options were selected to filter the load, it will be shown in bold font (below figure). You can click on the "S" buttons beside the demographic information items to run a quick statistical analysis on the results grouped by the options available for that demographic info. For example, Figure 10 shows the statistical analysis results of one case for demographic information "Income". You can copy the table in the clipboard by clicking on "Copy Data". You can then paste in an Excel file, or any document for any further work on the statistical analysis results. The table contains the mean, standard deviation, min and max of analysis results (annual kWh, annual peak, demand at network peak, average daily kWh, annual bill, and Unitised annual bill) for all users within the same demographic option. By clicking on the "S" button beside "Demographic Information" you can see a statistical analysis of all the homes in this case (not grouped based on any demographic information). Of course, for demographic information items which have already been selected in filtering the load (and shown in bold font in the list), there will be only one group in the statistical analysis.

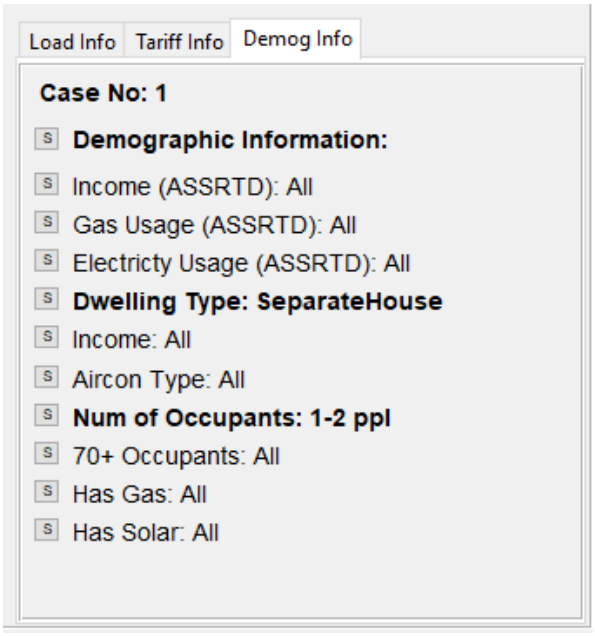
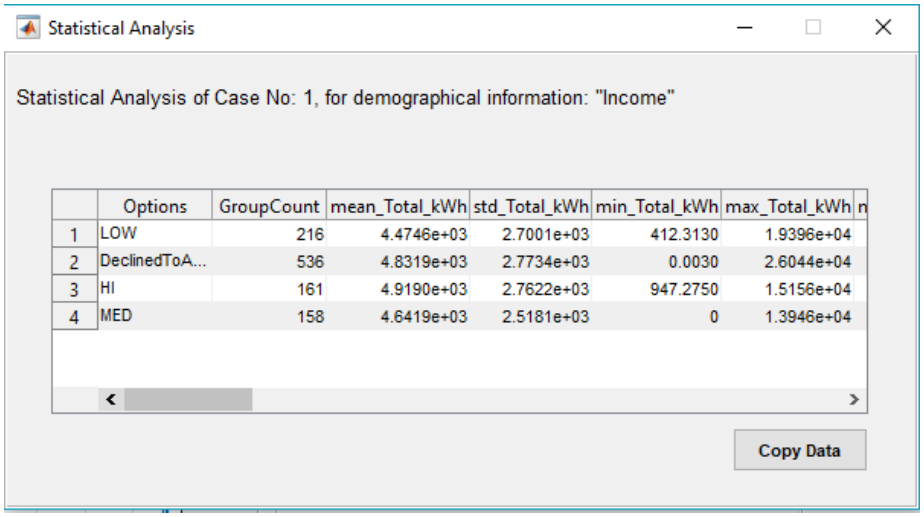


Figure 17 List of demographic information



	Options	GroupCount	mean_Total_kWh	std_Total_kWh	min_Total_kWh	max_Total_kWh	n
1	LOW	216	4.4746e+03	2.7001e+03	412.3130	1.9396e+04	
2	DeclinedToA...	536	4.8319e+03	2.7734e+03	0.0030	2.6044e+04	
3	HI	161	4.9190e+03	2.7622e+03	947.2750	1.5156e+04	
4	MED	158	4.6419e+03	2.5181e+03	0	1.3946e+04	

Figure 18 Statistical Analysis of one case grouped by demographic information "Income"

In the following, different graph types are introduced.

B.7 Single Variable Graphs

In this diagram panel, the graphs based on one variable are shown. You can select one of the options from the dropdown list to see the following figures.

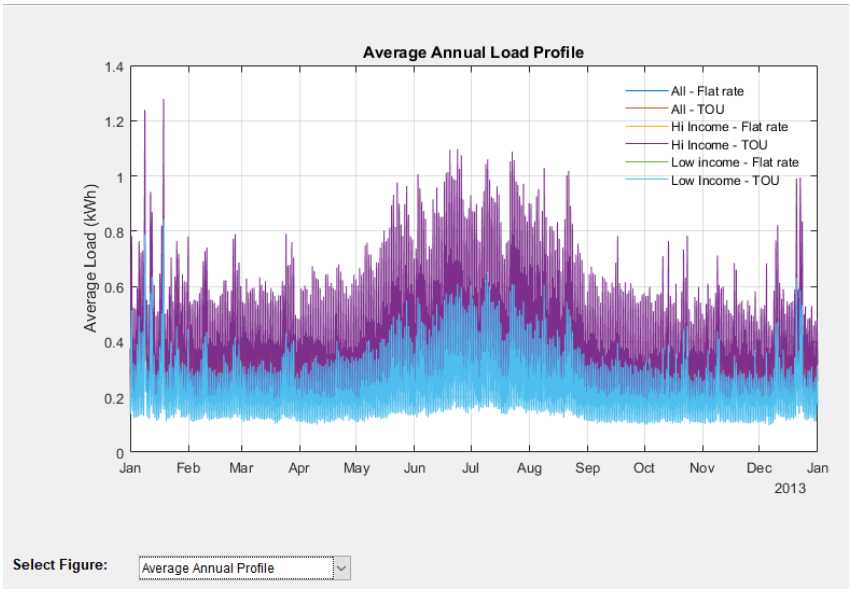


Figure 19 Average Annual Profile

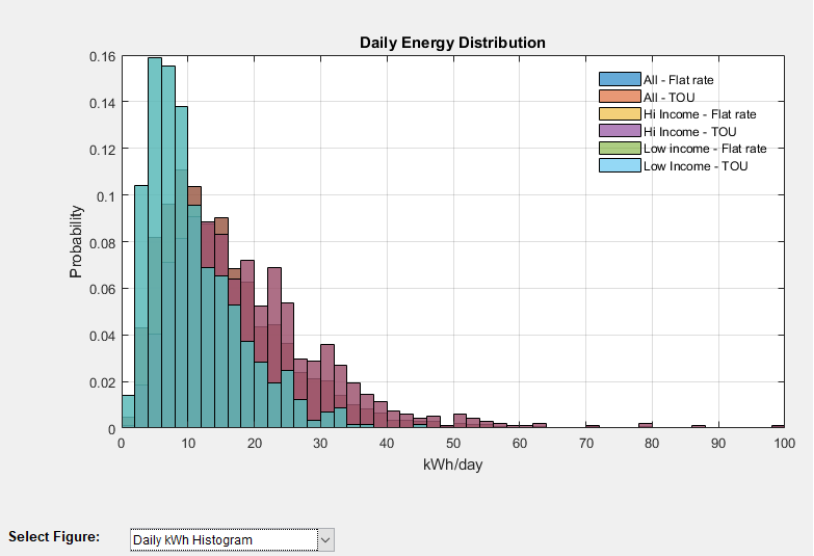


Figure 20 Daily kWh Histogram

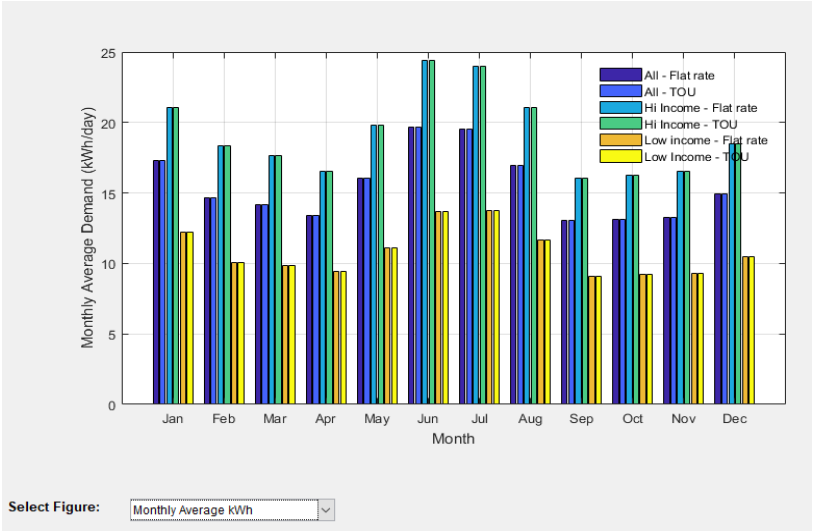


Figure 21 Monthly Average kWh

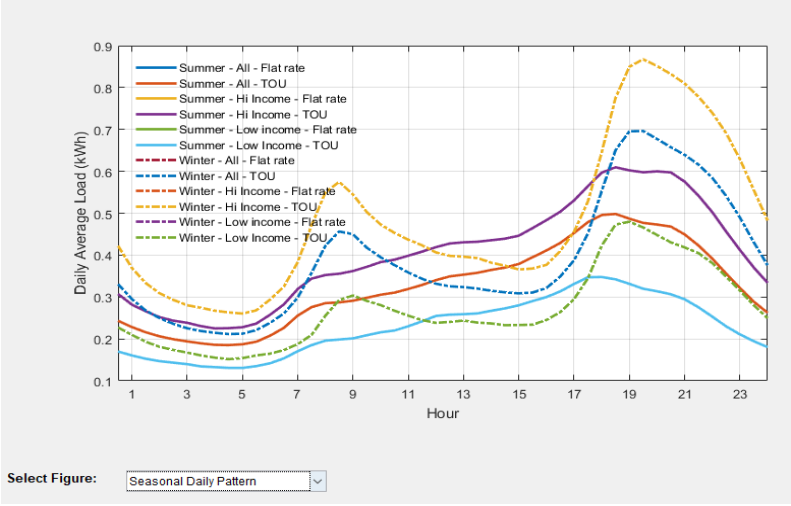


Figure 22 Seasonal Daily Pattern

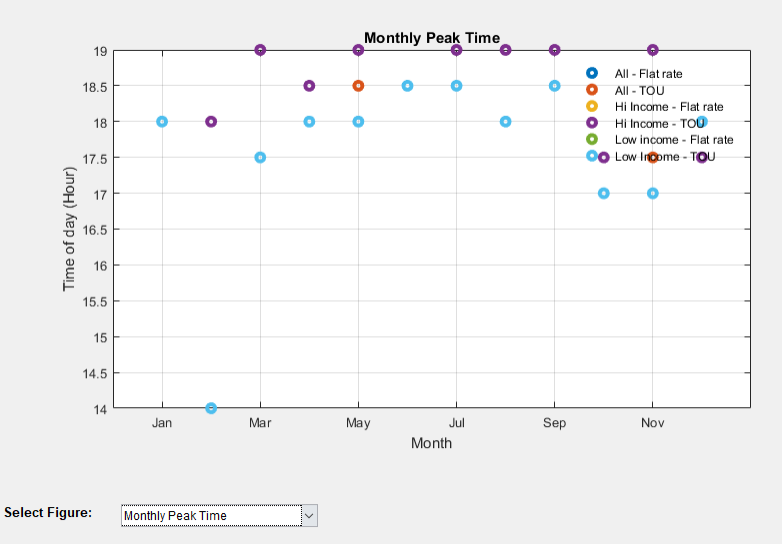


Figure 23 Monthly Peak Time

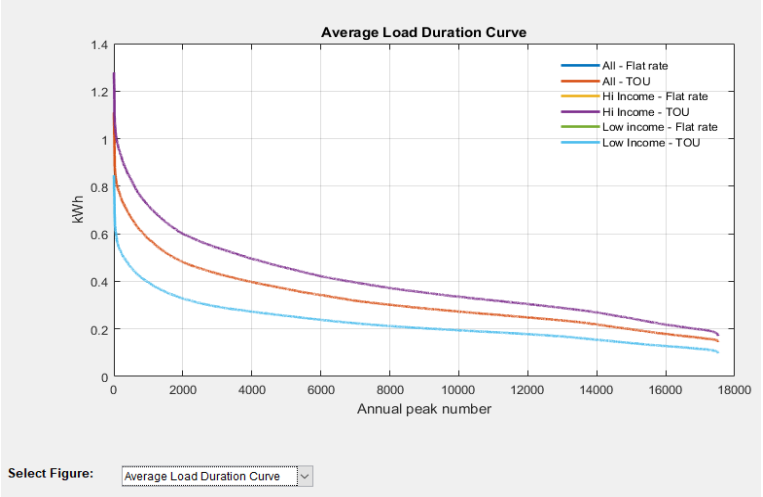


Figure 24 Average Load Duration Curve

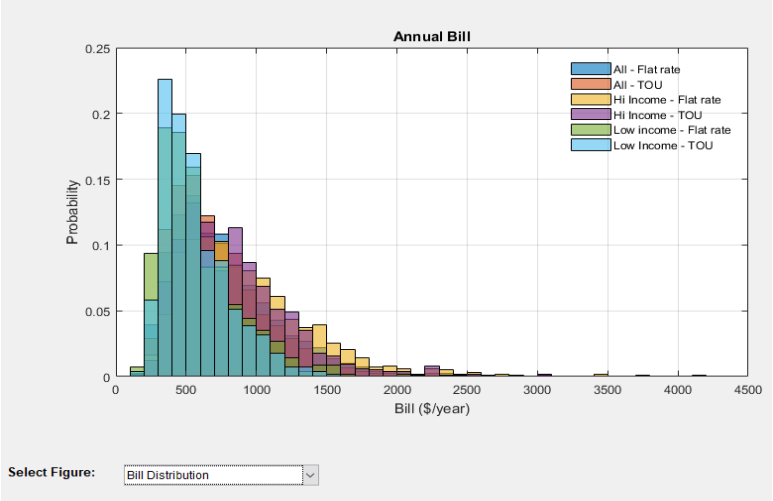


Figure 25 Bill Distribution

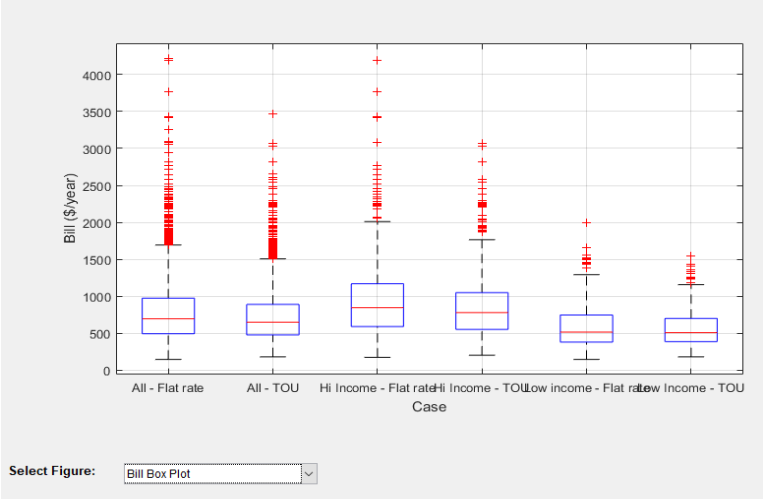


Figure 26 Bill Box Plot

Once you add more analyses to the diagram, they will show up together in both single variable and dual variable diagram panels. If you click on any point in a graph the values of x and y axis will be shown in a data tip. You can add multiple data tips to the graph by holding shift and clicking on a new point in the graph. You can use left and right arrow keys to move between points (or groups in boxplot option). Please note if you use a similar load profile for multiple cases (e.g. to test the impact of different tariffs on similar user group), the graphs showing the characteristics of the load (and not the bill), will be similar and therefore you will see one plot for them. As an example, in the graph mentioned above we have two sets of monthly peak points instead of three. In boxplot you can see the Median, Maximum, Minimum, number of points and number of finite outliers.

B.8 Dual Variable Graphs

In this diagram panel, multiple variables can be compared together by selecting them in the x or y axis. The following results can be shown:

- Annual kWh
- Average Demand at “N” Network Peaks (coincident demand)
- Average Demand at “N” Network Monthly Peaks (coincident demand)
- Average Demand at Top “N” Peaks (non-coincident demand)
- Average Demand at Top “N” Monthly Peaks (non-coincident demand)
- Average Daily kWh
- Average Daily Peak
- Bill ($/year)
- Unitised Bill (kW)

Average demand at “N” network peaks (and “N” monthly peaks) is calculated based on the network peak option selected. You can select the number of peaks (N) from the dropdown list. You can also specify if you want to allow only one peak period per day. Please note if you don’t tick this option, multiple peak periods in a single day may be considered. You can also specify which season is included.

Average Demand at Top “N” peaks (and “N” monthly peaks) are the average demand at the top peaks of each home. Again you can allow more that one peak per day and also filter the seasons. Average

daily kWh and average daily peaks are also calculated for each home and can be selected from the dropdown list. Unitised Bill is defined as the customers' annual bill divided by the annual bill of a reference customer with constant demand throughout the year (1 kW or 0.5kWh in all half hour periods). The purpose of this unitised bill is to make it independent of the value of the tariff components, so different tariffs with different component values can be compared to each other based only on their structure and not their rates. The unit for this bill is kW as the reference customer's bill considered is $/kW. For more info about the application of the Unitised Bill refer to our paper on cost-reflective tariff design here.

The correlation coefficient (CC) of the X and Y data of the plot is also calculated and shown in the legend for each case. Next figure shows some examples of different plotting options. Please note that while you can change the number of peaks, multiple peaks per day, and seasonal filtering and update the figure, they are not updated in the saved data for exporting to an excel file. However, you can access this updated data by copying the data from figure. Please note, if the number selected for "N" is higher than the total available peaks (e.g. selecting 100 peaks for the monthly peak and selecting one peak/day), a warning will be shown, and the total available peak times will be considered instead of "N". Therefore if this happens, the x or y label (showing the number of peaks) may not be valid for all cases. For example it may be Average of top 100 peaks while the actual number of available peaks for different cases currently showing in the graph could be lower.

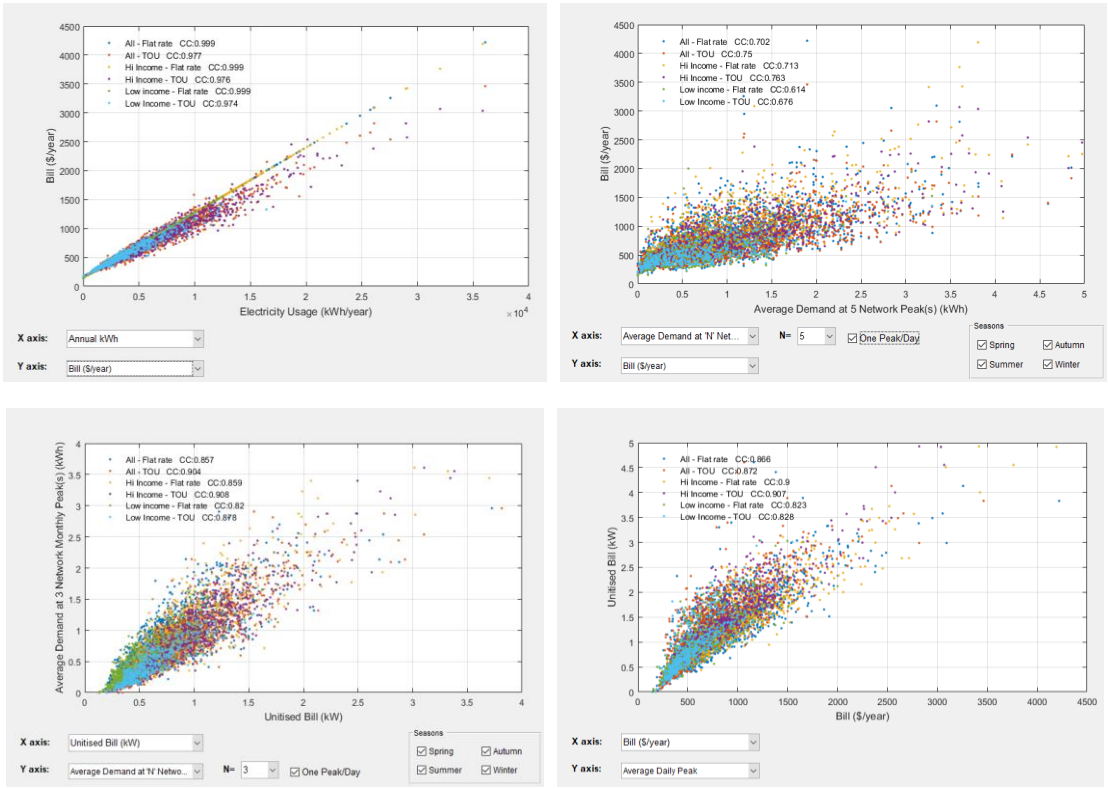


Figure 27 Examples of Dual Variable Diagram

B.9 Single Case Graphs

As some results can not be plotted for more than one case, a third type of diagram can be used for single cases. You can select the case number and the variable to be shown on the plot. The following options are possible:

B.9.1 Bill Components

This graph shows the components of the bill, in different ways as follows:

B.9.2 Bill Components Pie Chart

Daily Profile Interquartile Range Please note, Bill Component here means the portion of the bill (Daily, Energy, Capacity Charge, etc) and should not to be confused with DUOS, TUOS, etc. In the first option (Bill Components), you can specify the parameter used to sort the bills. The default parameter is the total bill.

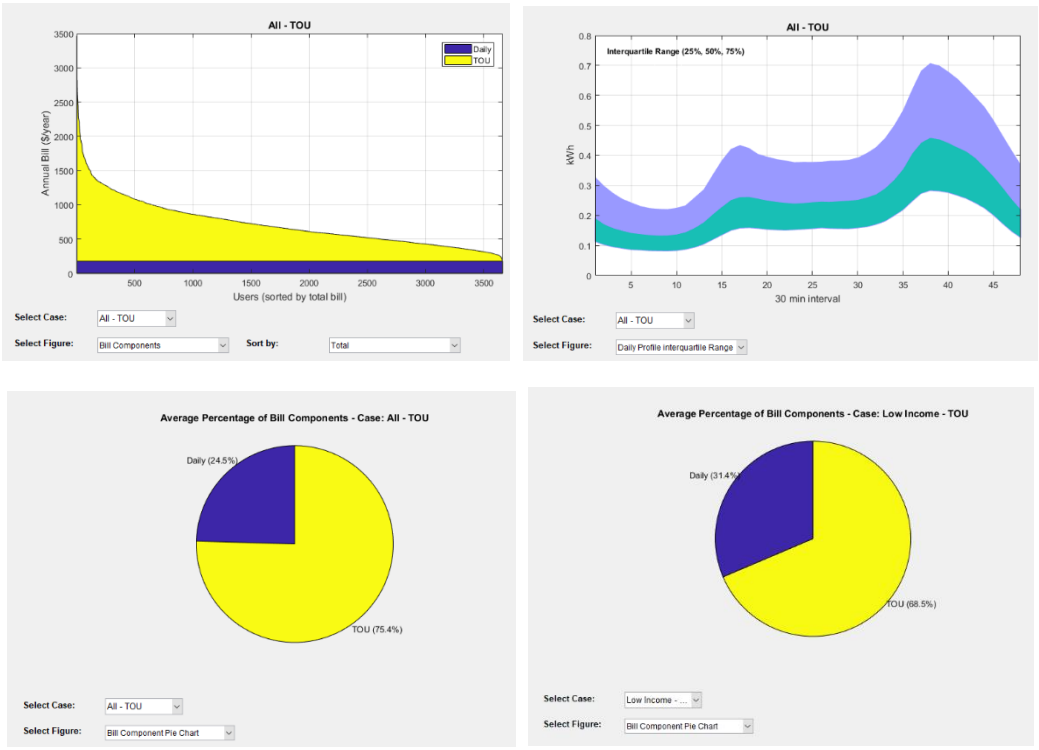


Figure 28 Examples of single case graph

B.10 Exporting the results

While you can directly copy the data of the current figure to the clipboard and paste it where you want, you can also export the result of individual or all cases to an excel file. You can click on the “Exp” button beside the case name in the list of cases to export the result of that case. Alternatively, you can use the menu: Export > Export Results. Next figure shows an example of an exported result. Please note there currently seems to be an issue with saving the results while working in a network drive or shared folder (e.g. OneDrive folder, etc) due to automatic syncing, etc. It is therefore recommended

that you place and run the TDA folder on a non-shared folder which is not being synced with the internet.

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
Results produced by TDA developed by Centre for Environmental and Energy Market (CEEM) UNSW on: 17 Nov 2017																			
Tariff:	AusGrid Flat Rate 2017/18																		
No. of Use	566																		
Database:	SGSC																		
Customer	Income (A	Gas Usage	Electricty	Dwelling	Income	Aircon Ty	Num of O	70+ Occup	Has Gas	Has Solar	Annual_k	Demand_	Demand_	Annual_P	Monthly_	Average_I	Average_I	Bill	Unitised_Bill
8145987	MED	MED	MED	Separate	LOW	SplitSyste	1-2 ppl	N	Y	N	3253.448	0.651	0.2235	3.161	2.262167	8.913556	1.331178	510.9914	0.451005
8145997	MED	MED	MED	Separate	LOW	SplitSyste	3-4 ppl	N	Y	N	2118.828	0.541	0.185167	2.528	1.9585	5.805008	0.917359	382.8258	0.337885
8147611	MED	MED	HI	Separate	LOW	SplitSyste	3-4 ppl	N	Y	N	7416.716	0.162	0.539667	3.289	2.668917	20.31977	1.735805	981.27	0.866077
8147859	HI	LOW	MED	Separate	LOW	Ducted	1-2 ppl	N	N	N	5857.307	0.281	0.472667	2.976	2.615333	16.04742	2.007132	805.1207	0.710606
8148065	HI	MED	LOW	Separate	LOW	SplitSyste	3-4 ppl	N	N	N	3219.678	0.135	0.23225	2.838	2.320917	8.821036	1.105849	507.1768	0.447638
8150103	MED	MED	LOW	Separate	LOW	SplitSyste	1-2 ppl	Y	N	N	4500.238	0.323	0.566	2.894	2.24675	12.32942	1.245616	651.8275	0.575308
8154329	LOW	LOW	MED	Separate	LOW	SplitSyste	3-4 ppl	N	N	Y	6376.311	1.271	0.730167	3.302	2.756	17.46935	1.753003	863.7469	0.76235
8154379	HI	LOW	LOW	Separate	LOW	SplitSyste	1-2 ppl	Y	N	N	1540.434	0.099	0.109083	2.904	2.01575	4.220367	0.96394	317.491	0.28022
8155143	LOW	LOW	LOW	Separate	LOW	No Aircon	1-2 ppl	N	Y	N	3549.595	0.131	0.425083	2.96	2.101667	9.724918	1.155427	544.4439	0.48053
8156681	LOW	MED	LOW	Separate	LOW	No Aircon	1-2 ppl	Y	N	N	2753.196	0.134	0.12675	2.242	2.038833	7.543003	1.527814	454.4834	0.401131
8158061	LOW	MED	MED	Separate	LOW	SplitSyste	1-2 ppl	N	Y	N	5003.256	0.923	0.616667	2.661	1.873667	13.70755	1.010537	708.6479	0.625458
8158169	LOW	MED	LOW	Separate	LOW	SplitSyste	1-2 ppl	Y	N	N	4981.792	0.342	0.778167	4.128	2.5795	13.64875	1.693389	706.2234	0.623318

Figure 29 A sample of exported results to excel

Appendix C: Users guide for Python version

This section reviews the features of the new version of TDA built in Python. As mentioned before, some of the contents in this section is repeated as they were available in the Matlab version too.

TDA tool is designed to assist stakeholders to investigate how different tariff structures impact on the expected bills of different types of residential consumers. The tool offers a range of different analysis and result visualisations as described in this section. In summary the tool allows users to:

- Create projects and add analysis to different projects for later referral
- Choose from the existing load profiles (more than 5000 annual household load profiles)
- Filter the load profiles based on the available demographic information
- Import new load profile and demographic information
- Visualise the individual and aggregate load profiles using multiple methods including seasonal pattern, peak analysis, annual energy distribution, daily interquartile range, etc
- Apply end user technologies to the load including adding solar, battery and demand response strategy and create a new load profile based on these technologies.
- Apply the network and retail tariffs available in the tool (100+ tariffs for different Australian States) to calculate the annual bill based on any subset of the load profiles
- Modify the parameters of the tariffs to investigate the impacts on annual bills
- Investigate different components of the network bill (DUOS, TUOS, and NUOS) as well as other sectors (retail and wholesale market) to calculate the revenue for different sectors (distribution, transmission, etc).
- Adjusting the network load pattern (and hence peak time) to see the impact on the tariffs based on the coincident peak demand
- Create different types of new tariffs including, flat rate, time of use, block usage, demand charge, etc
- Compare the results of multiple analyses in different visualisation platforms including Bill info, Load info, Variable correlations, and Bill components.
- Export the figures, and copy them into clipboard to incorporate in any report
- Export the results to excel file to do further analysis on the results outside the tool The rest of this section introduces different parts of the tool and gives instructions on how to work with the tool.

C.1 Opening the graphical user interface

The TDA tool does not need to be installed in your computer. You only need to run the tool and do the analysis. In order to import and export the data properly (such as selecting load data, exporting result, etc), you need to keep all contents of the TDA folder. If you save a project, or create a new load/tariff, it will be also saved in this folder. Windows users need to run the vbs.run and work with the tool. When running the tool the main page will appear as shown in below figure. The menu in the left hand side has the steps of completing an analysis. You can navigate through the pages and change any of them. If the small green light beside the option appears, it means this steps has been completed.

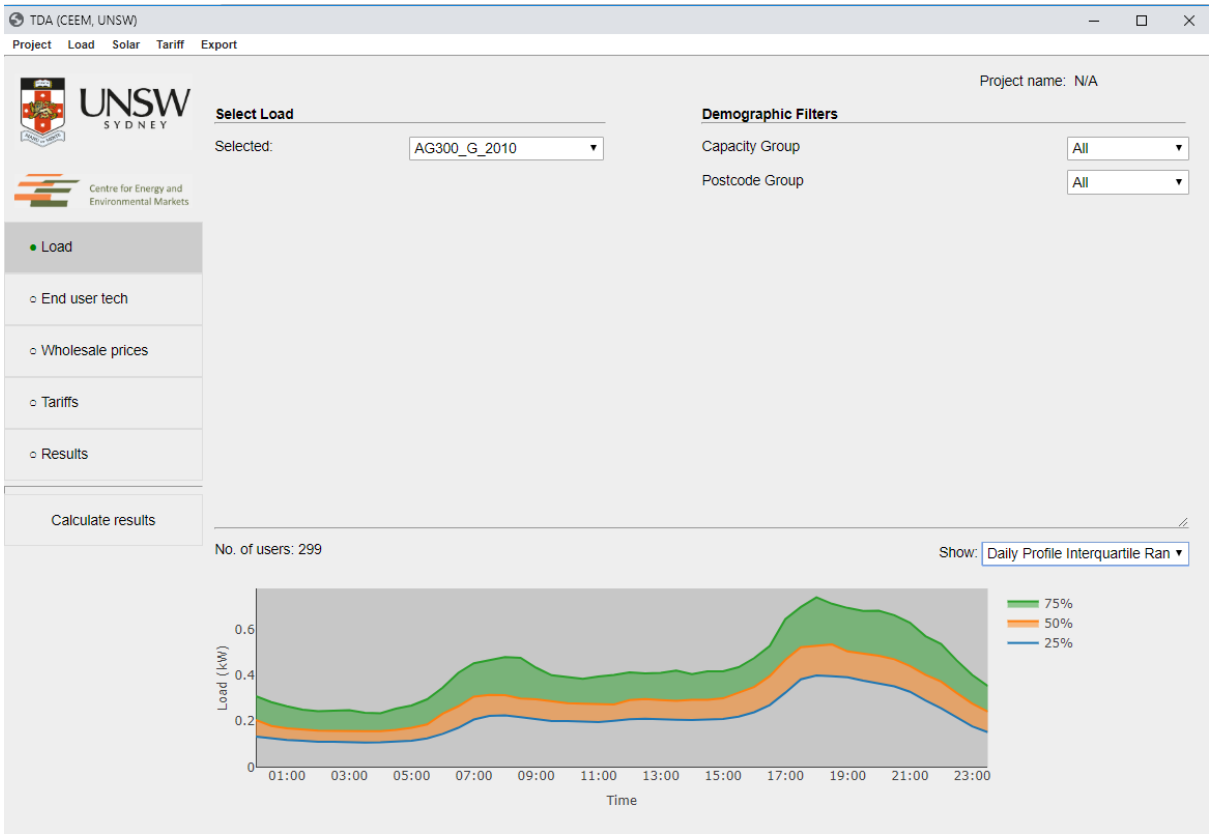


Figure 30 Main GUI of the Python version

C.2 Load

You can select one of the existing load datasets in the tool by choosing from the drop-down list under title "**Select Load**". Before importing, you can specify the maximum allowed missing data from the menu: Load > Maximum Allowed Missing Data (%). The default value is 5%, which means only homes with less than 5% missing intervals will be loaded. You can change this each time you select a new load. You can also down-sample the load data to speed up the calculation by selecting from menu: Load > Down-sample Users (Random Selection). The default option is 100% (full data) which utilises the whole dataset. 50% means randomly selecting 50% of the homes, and so forth. Please note, each time you select a load profile from the drop-down list, a new subset will be randomly selected, so multiple selection of one load dataset with the same down-sample value may result in different users being selected.

You can see the number of homes loaded into the software in the below part of the panel. Each dataset can be selected, and the analysis can be done based on the whole or part of that dataset which is grouped by demographic information. If the demographic information is available for any load data, it will be shown on the right side under title "**Demographic Filters**". You can then filter the load based on any of the demographic information. The number of homes obtained with any particular filter is shown. There is also a set of diagrams which show the individual or aggregate behaviour of the selected load profile. So, you can see the load pattern while selecting the filters. In some of the figure options, you can see and compare the filtered load (by missing data, down-sampling, and demographic filters) with the whole dataset. This is particularly useful if you want to check if important information

(e.g. load profile on a peak day) is similar in the down-sampled load and the whole dataset. If you see a significant difference you may load the demand data again to randomise the users and load a new group. You can change the diagram type from the dropdown list. You can choose the following options shown in the below figures:

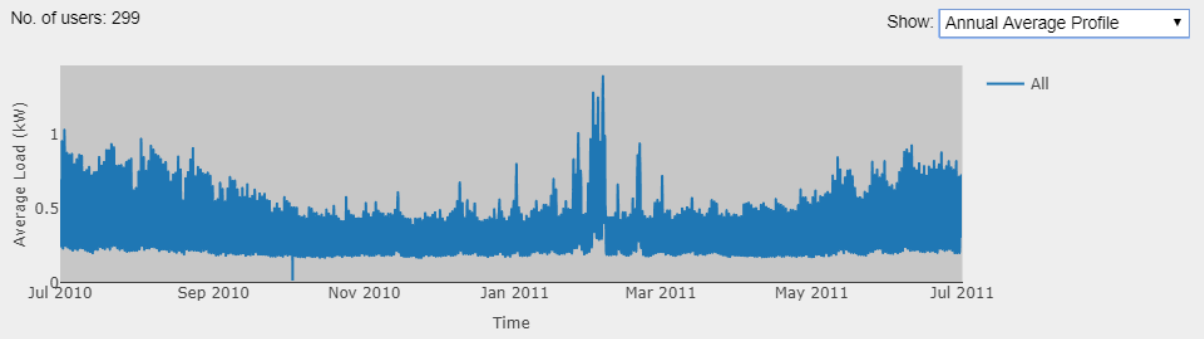


Figure 31 Annual Average Profile

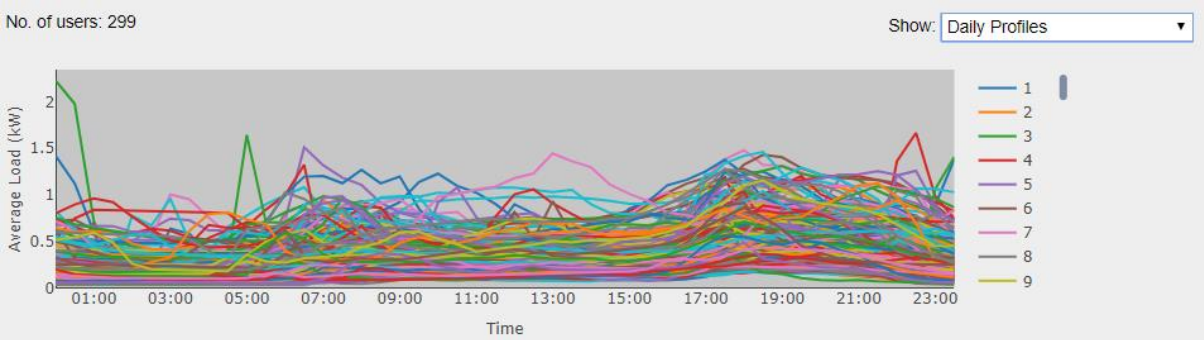


Figure 32 Daily Profiles

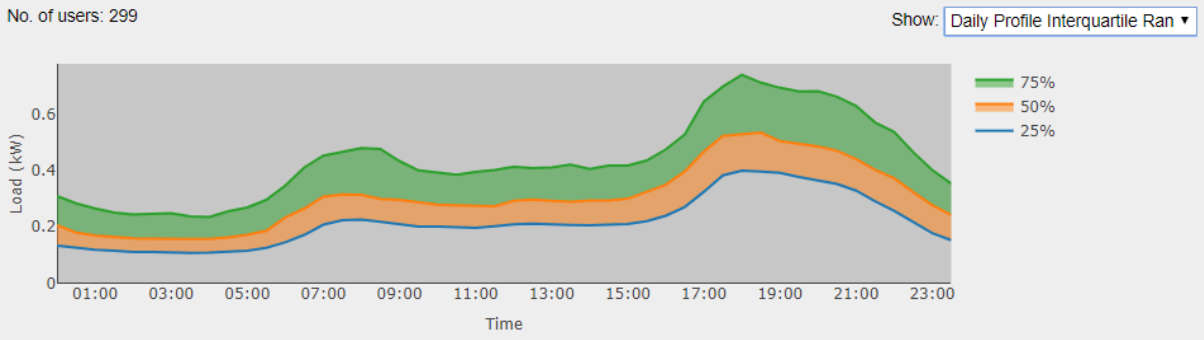


Figure 33 Daily Profile Interquartile Range (25%, 50%, and 75% of load)

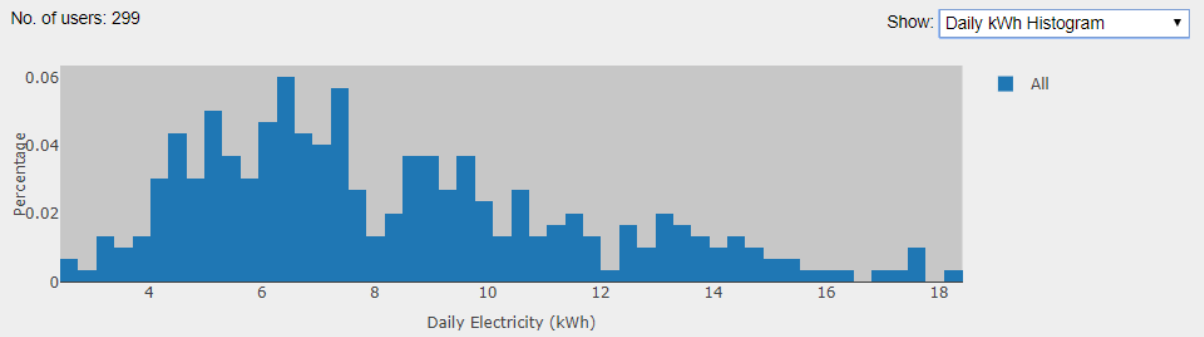


Figure 34 Daily kWh Histogram

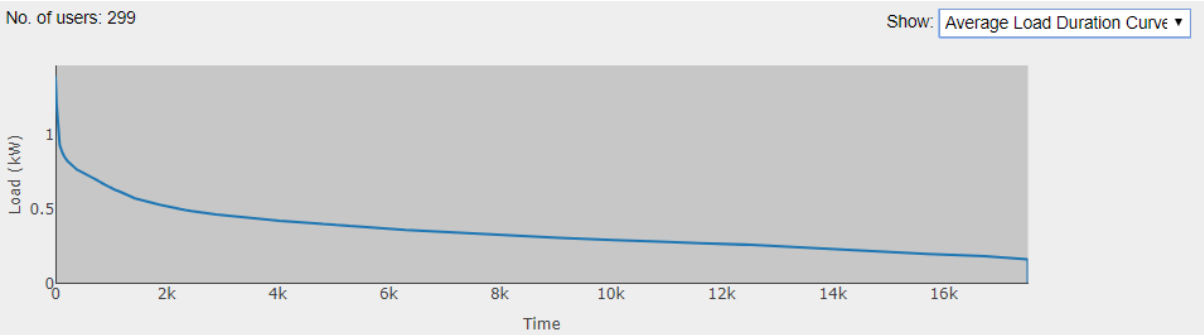


Figure 35 Average Load Duration Curve (sorted aggregate load profile in kW in descending order)

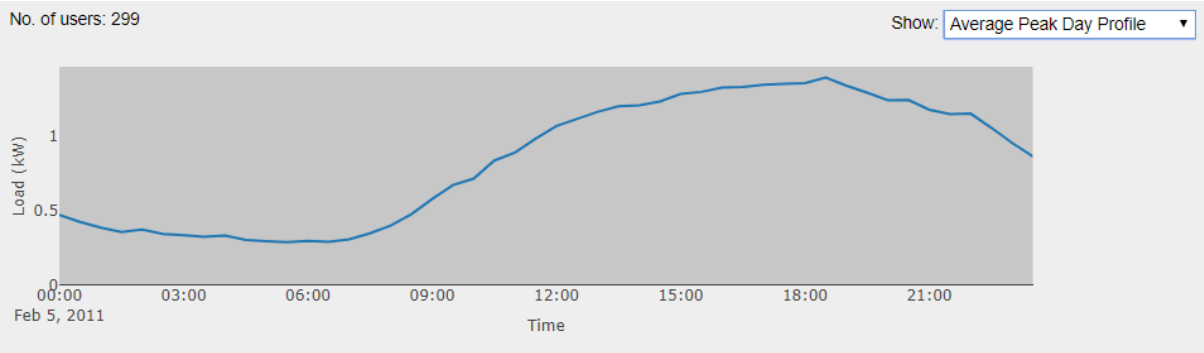


Figure 36 Average Peak Day Profile (daily pattern in highest aggregate peak day)

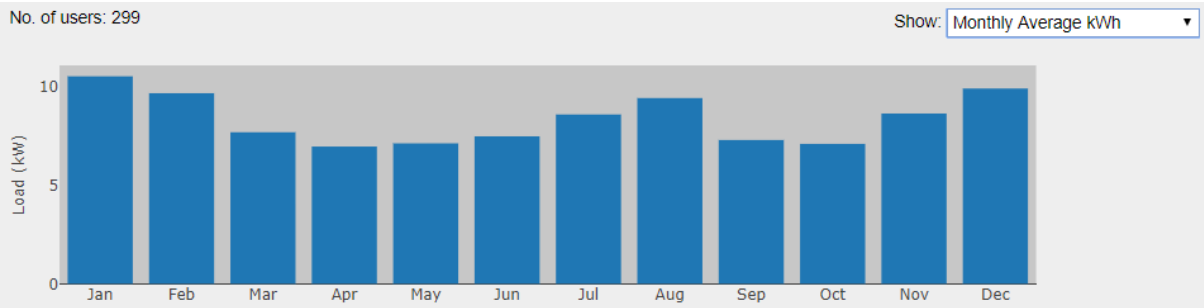


Figure 37 Monthly Average kWh

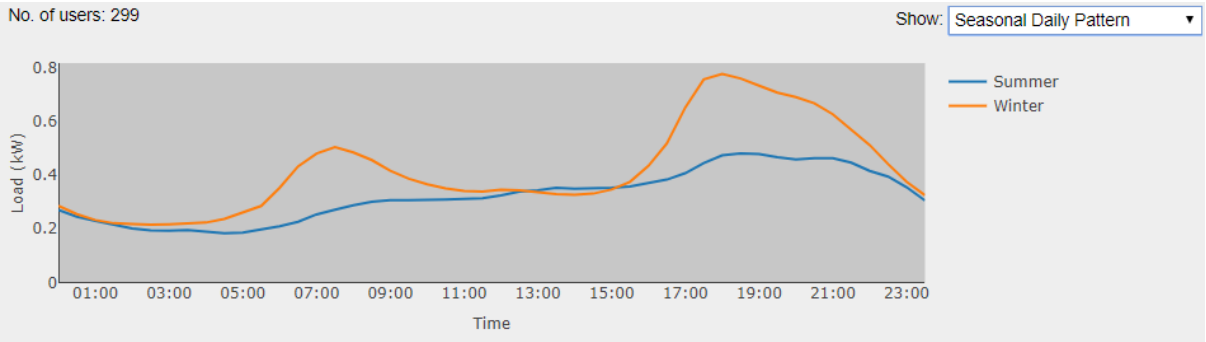


Figure 38 Seasonal Daily Pattern (average daily load pattern in summer and winter months)

C.3 End user technologies

The second page in the tool lets the user to assign solar, battery and demand response to the customers. The percentage of customers for each technology as well as the solar system size and battery size and other factors can be tuned before making the new net load profile. This net load profile will be used to apply tariff. Once the new net load is created the average pattern of solar, battery, demand response, and gross and net load are visualised.

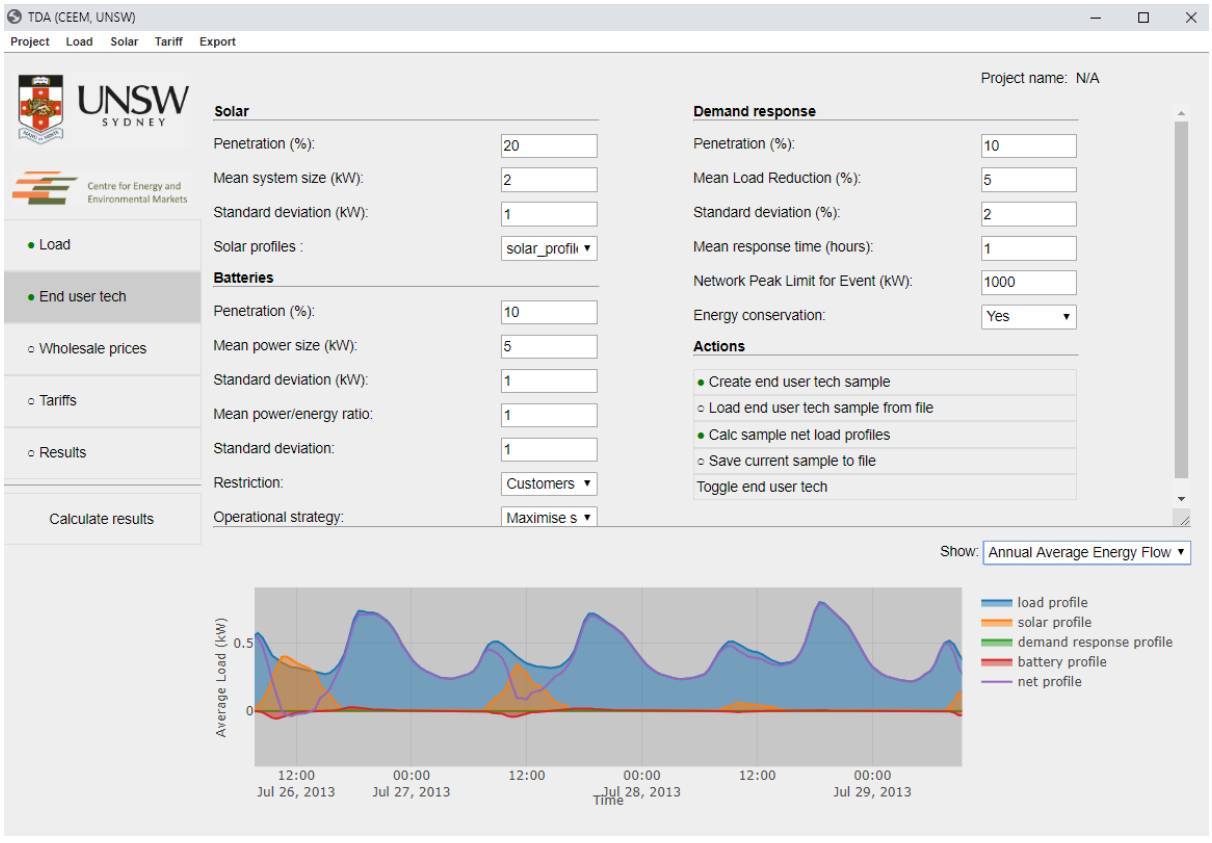


Figure 39 Selecting the parameters of Solar, Battery and Demand response options

C.4 Wholesale prices

The tool users can select the wholesale price of different NEM regions from 2012 onward to be incorporated into the modelling. The wholesale price is used to see how much the retailer have paid for the actual energy bought from the wholesale market.

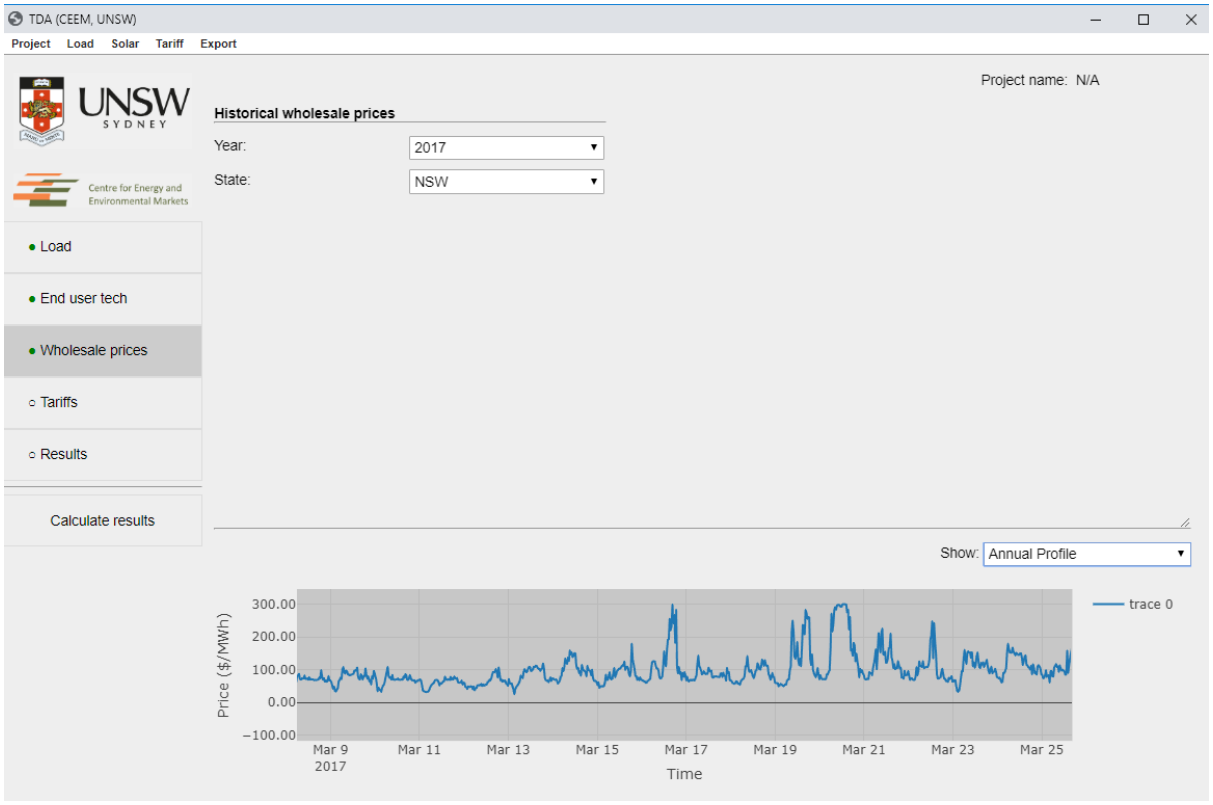


Figure 40 Selecting year and region to get the wholesale energy market data

C.5 Tariffs

Once the load data (and optionally end user tech and wholesale prices) have been selected, the tariff should be selected. Network tariff, retail tariff, or both can be selected. The state, type, provider, and year can be used to filter the tariffs. Once a tariff is selected, the parameters are appearing below. The parameters can be changed and tariff can be saved as a new tariff. For network tariff three components of DUOS, TUOS, and NUOS are shown and can be independently configured. NUOS is "Network Use Of System" which is made up of DOUS, "Distribution Use of System", and TUOS, the "Transmission Use of System". Some NUOS tariffs might include other components (e.g. NSW Climate Change Fund or the Qld Solar Bonus Scheme). In the final result and visualisations you can see the impact of those components separately e.g. DUOS (to evaluate the distribution revenue), TUOS (to evaluate the transmission revenue), DUOS+TUOS (to evaluate both), and NUOS (to evaluate the actual tariff).

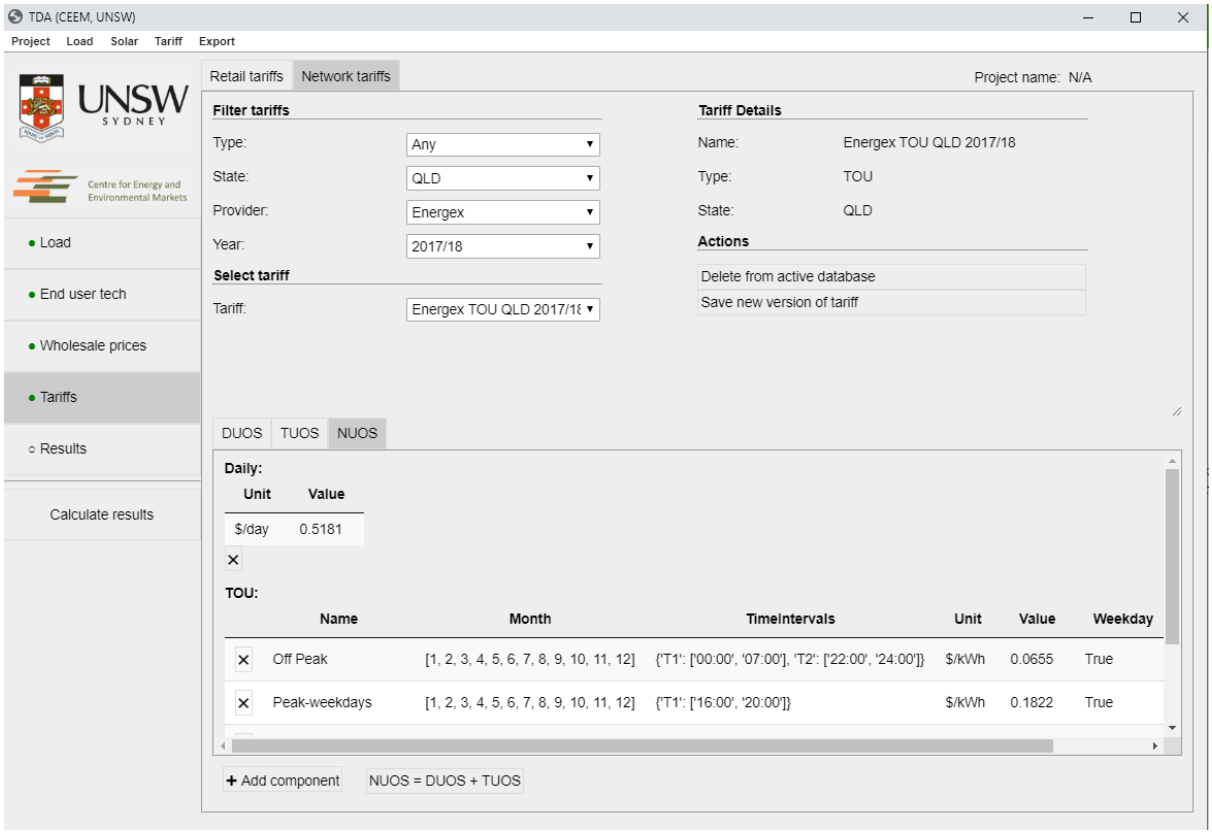


Figure 41 Selecting network and retail tariffs

The tariff parameters can be seen and adjusted in the tables below the tariff component tabs. The specific format of entering month and timeintervals should be followed. You can delete or add new rows to the tables (e.g. adding a new TOU rate). The tariffs may also have Feed-in Tariff (FiT) which is also shown and adjustable. You can also put a FiT_TOU which is a time varying FiT with different values for solar rebate for peak and off peak times.

By clicking on + button, you can add a new line to the table, and by clicking on the **+ Add component** add a new component (e.g. flat rate or TOU). You can also click on **NUOS = DUOS + TUOS** to automatically populate the NUOS using the values of DUOS and TUOS tables.

C.6 Results

After selecting the tariffs, you should press **Calculate results**. This will apply the selected tariffs to the selected subset of the load and perform a variety of analyses which are described later. Please note when you add the analysis, the tool will generate the network load data based on the option you have selected (i.e. based on the whole database, filtered database, or synthetic network load which was described before). Before adding the analysis, make sure the network load profile is selected properly. Once the analysis has been added to the diagrams, you cannot change the network load for this analysis. In order to do so, you may consider deleting the analysis (case) and then undertaking the analysis again using a new network load profile. When you add a new case, the tool will ask if you want to pick a name for the new case. If you choose No, or close the dialog box, the new case will be named as Case + number. This name will appear on the graphs and also in the other results. You can add multiple cases to the analysis (different load profiles, or different filters, or different tariffs). The

results will be automatically shown in the visualisation page and will be ready to download if you wish to work with the result data outside the tool.

C.7 Visualisation of the results

There are four types of visualisations in the tool as follows:

- Bill Info
- Load Info
- Variable Correlations
- Bill components

This section describes each type and provides some examples.

C.7.1 Bill info

The bill distribution and box plots for all components of all cases.

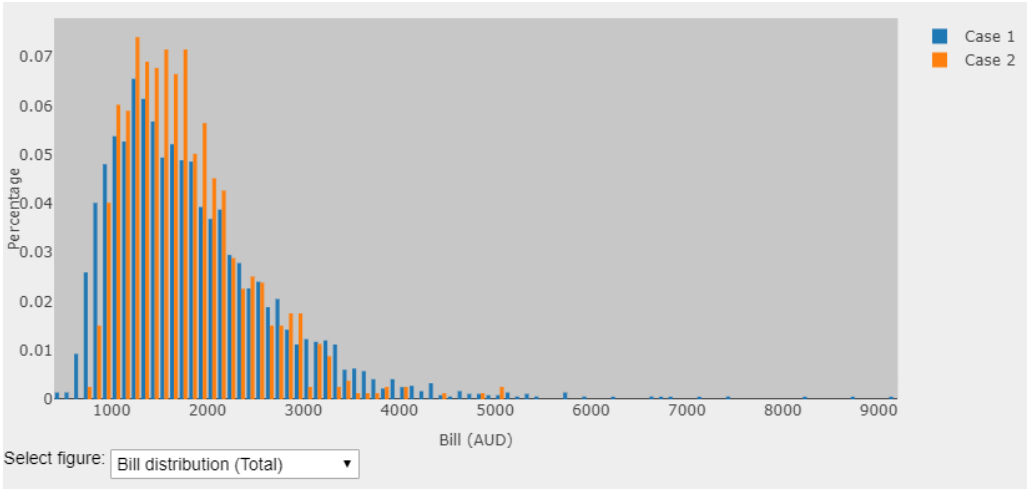


Figure 42 Histogram of the Bill for two sample case studies

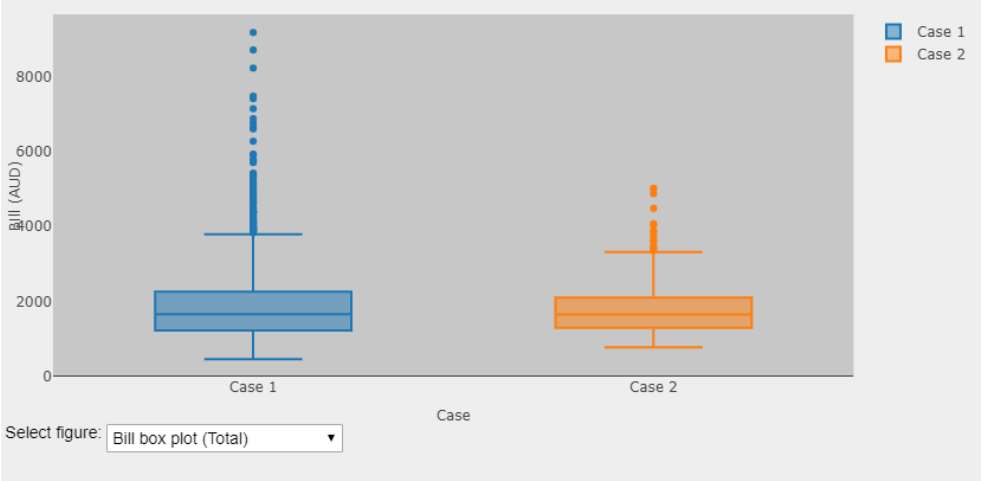


Figure 43 Boxplot of the Bill for two sample case studies

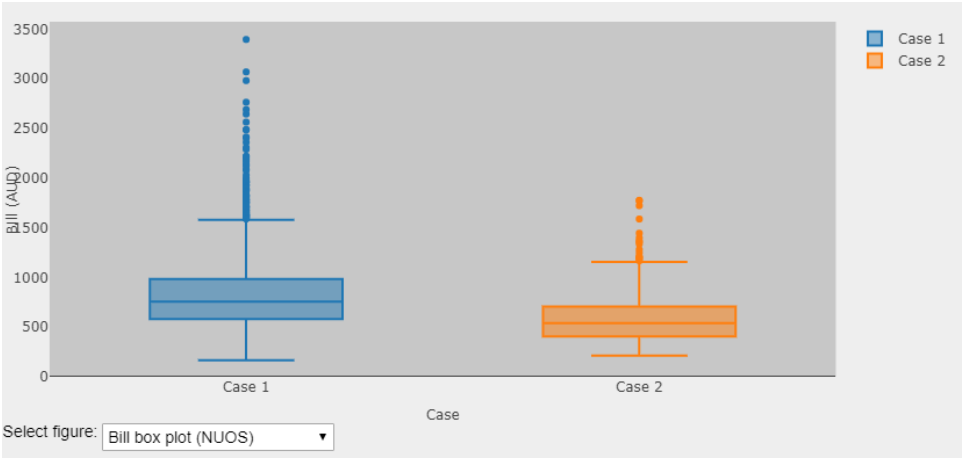


Figure 44 boxplot of the NUOS component of the bill for two sample case studies

C.7.2 Load info

The information regarding the load profiles including:

- Average Annual Profile
- Daily kWh Histogram
- Monthly Average kWh
- Seasonal Daily Pattern
- Monthly Peak Time
- Average Load Duration Curve

Following figures show some examples:

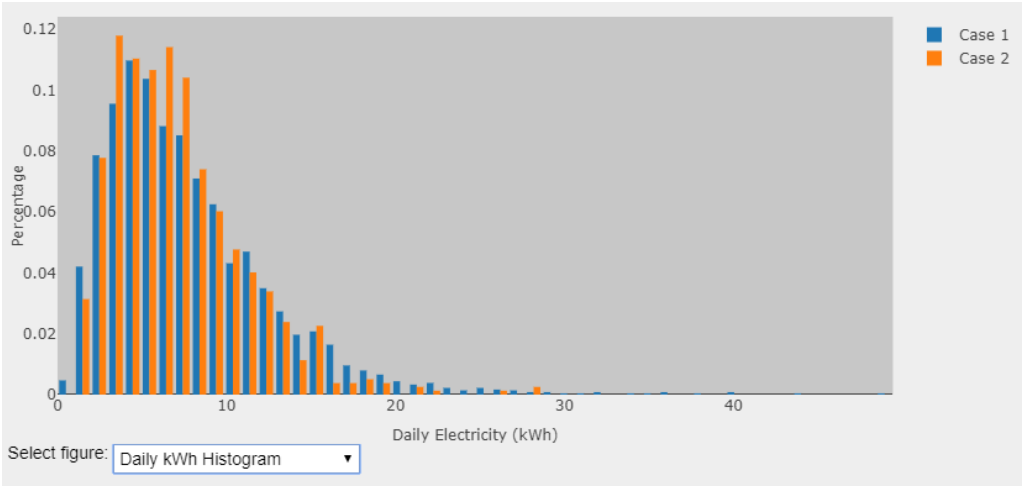


Figure 45 Histogram of the kWh in two sample case studies

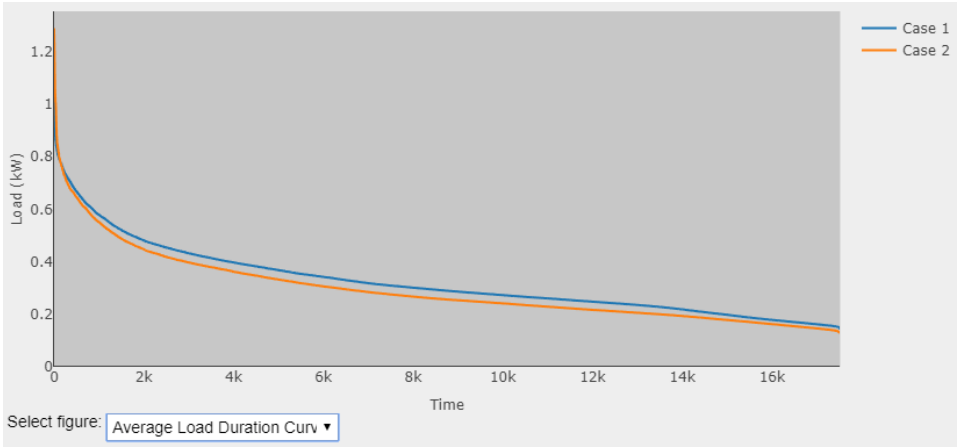


Figure 46 Load duration curves of two sample case studies

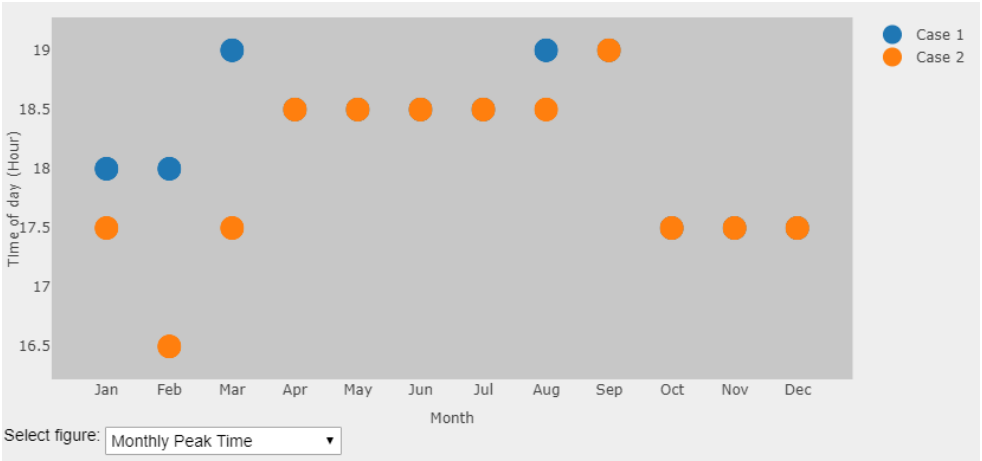


Figure 47 Monthly peak times in two sample case studies

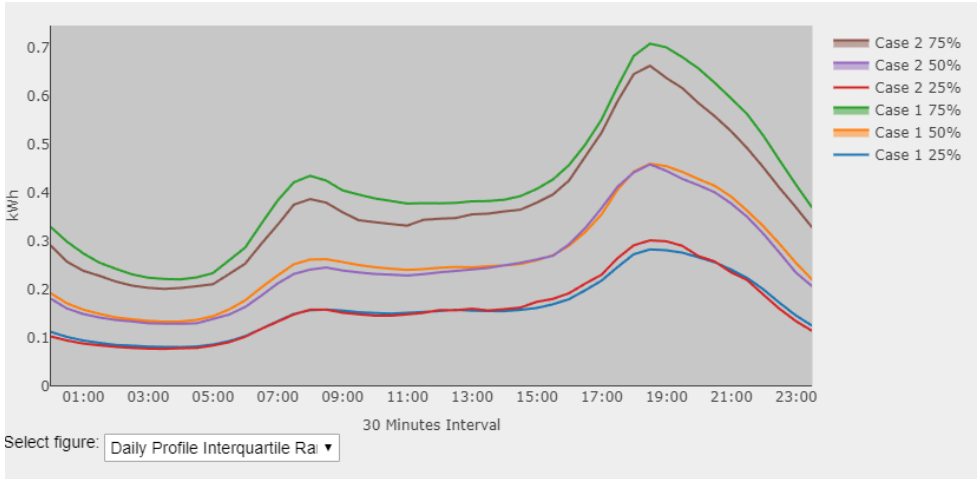


Figure 48 Interquartile range of the load profiles in two case studies

C.7.3 Variable correlations

Plotting different variables against each other to show the correlation of them. The X-axis and Y-axis can be changed to any of the parameters including:

- Annual kWh
- Average Demand at “N” Network Peaks (coincident demand)
- Average Demand at “N” Network Monthly Peaks (coincident demand)
- Average Demand at Top “N” Peaks (non-coincident demand)
- Average Demand at Top “N” Monthly Peaks (non-coincident demand)
- Average Daily kWh
- Average Daily Peak
- Bill NUOS ($/year)
- Bill DUOS ($/year)
- Bill TUOS ($/year)
- Bill Retailer ($/year)
- Bill Wholesale ($/year)
- Bill Total ($/year)

Average demand at “N” network peaks (and “N” monthly peaks) is calculated based on the network peak option selected. You can select the number of peaks (N) from the dropdown list. You can also specify if you want to allow only one peak period per day. Please note if you don’t tick this option, multiple peak periods in a single day may be considered. You can also specify which season is included.

Average Demand at Top “N” peaks (and “N” monthly peaks) are the average demand at the top peaks of each home. Again you can allow more that one peak per day and also filter the seasons. Average daily kWh and average daily peaks are also calculated for each home and can be selected from the dropdown list.

The correlation coefficient (CC) of the X and Y data of the plot is also calculated and shown in the legend for each case in the Variable correlations graph. Following figures illustrate some example plots:

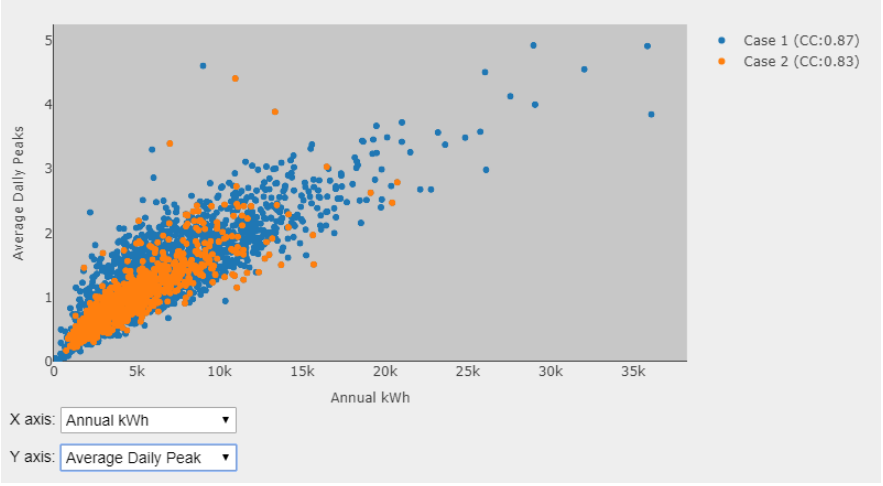


Figure 49 Average daily peak vs annual kWh

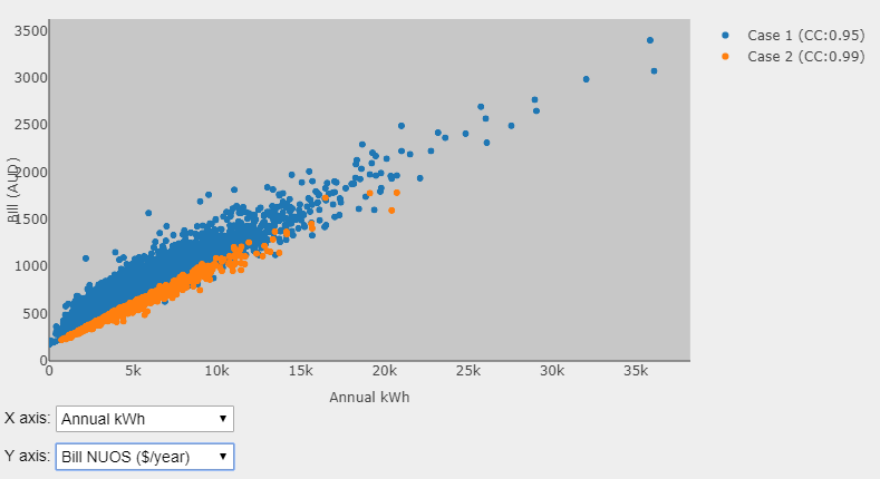


Figure 50 Total NUOS bill vs annual kWh

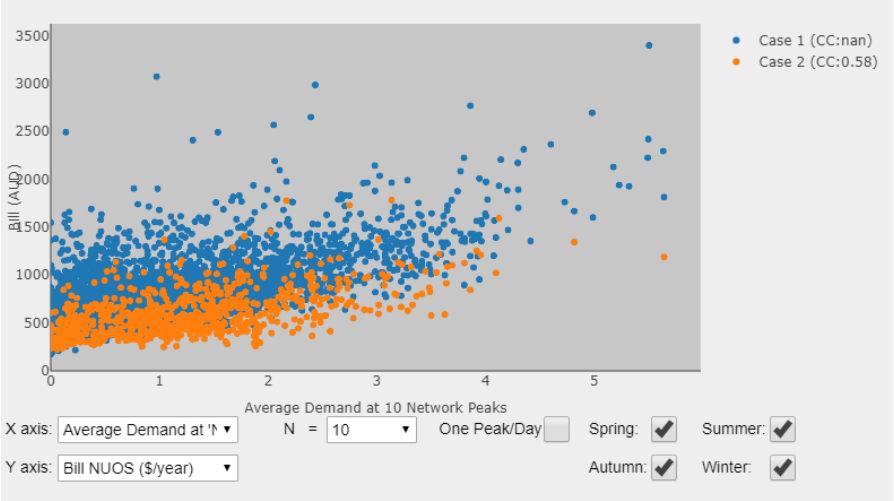


Figure 51 NUOS component of the Bill vs Average demand at the times of network peak

Please note that while you can change the number of peaks, multiple peaks per day, and seasonal filtering and update the figure, they are not updated in the saved data for exporting to an excel file. However, you can access this updated data by copying the data from figure. Please note, if the number selected for "N" is higher than the total available peaks (e.g. selecting 100 peaks for the monthly peak and selecting one peak/day), a warning will be shown, and the total available peak times will be considered instead of "N". Therefore if this happens, the x or y label (showing the number of peaks) may not be valid for all cases. For example it may be Average of top 100 peaks while the actual number of available peaks for different cases currently showing in the graph could be lower.

C.7.4 Bill components

To show the bill Components in area and pie chart plots for all user. If you add more analyses to the diagram, they will show up together in all diagram panels. You can hover over the figures and see the underlying data.

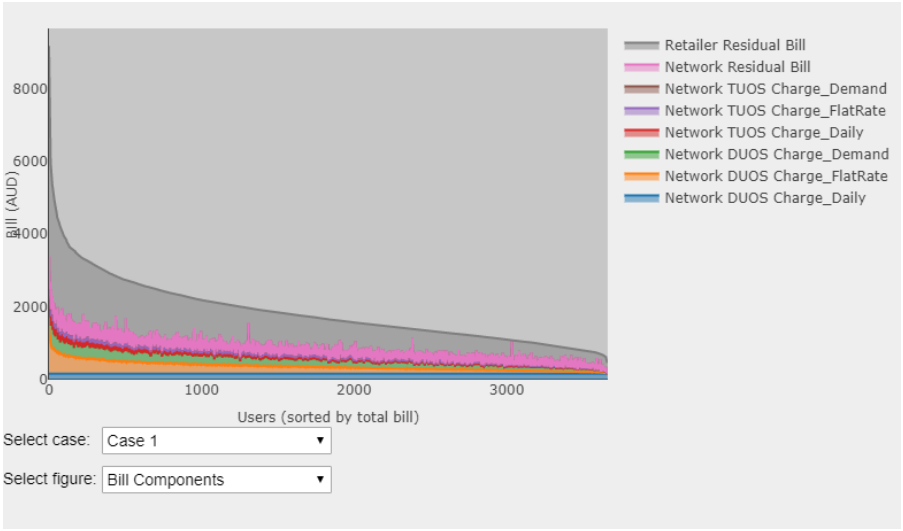


Figure 52 contribution of different components to the total bill for all customers (sorted by the total bill of customers)

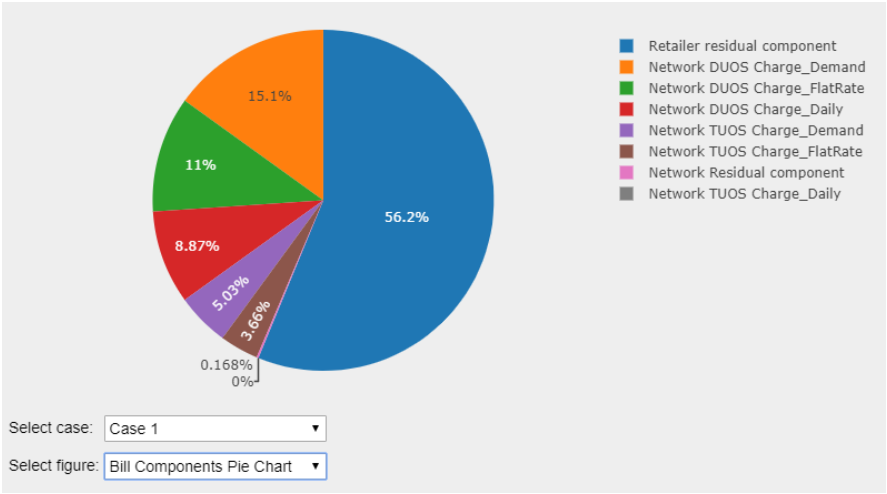


Figure 53 Pei chart of the components of the bill (average of all customers)

Please note if you use a similar load profile for multiple cases (e.g. to test the impact of different tariffs on similar user group), the graphs showing the characteristics of the load (and not the bill), will be similar and therefore you will see one plot for them. In boxplot you can see the Median, Maximum, Minimum, number of points and number of finite outliers.

C.7.5 Export figure

You can export the figure currently displayed by clicking on the picture icon on top of the figure. You can also find other options such as zoom and pan there.

C.7.6 Info panel

In the info panel, you can see the load info (Case number, Number of users, load database, and network peak time calculation method), Tariff info (Tariff name, type, State, and tariff parameters), wholesale price details and Demographic info based on the available demographic information.

C.7.7 Exporting the results

While you can directly copy the data of the current figure to the clipboard and paste it where you want, you can also export the result of cases to an excel file. You can use the menu: Export > Export Results to export the results or right click on any plot and export the underlying data to csv.

C.8 Menu bar

C.8.1 Project

While you are working with the tariff tool, you may want to save your current session for later referral. You can "save" the project, and later "load" the project with your saved analysis loaded in the tool. You can also restart the tool to delete all analysis currently displaying on the tool and restart your analysis. If you do not save the project, the project name will be shown as "N/A" and any analysis will be lost if you close the software. Restarting the tool does not delete any project or load data. But any analyses after the last save will be lost.

C.8.2 Load

Using this menu, you can import new load data, delete any of the existing load data, or restore to the original load data list. Importing new load data is explained later. You can also define the network load as described later. We will provide new load data as it becomes available. In that case you can just download the load data (.feather file) and put it in the "Data" directory in the TDA folder. You can check for new updates on CEEM's cost reflective tariff design page[1]. You can also set the maximum amount of missing data allowed as well as the down-sample rate (where a smaller percentage of the sample can be randomly selected, as described later. By restoring the load data, any new load data you created will be lost.

C.8.3 Solar

You can import solar data and save it as solar data profile and then use it in your analysis by adding it to your users load profile.

C.8.4 Tariff

You can create new tariffs, check the source of selected tariff, reset network and retail tariffs and update the tariffs. The source of tariff data is CEEM's API centre which has the latest list of Network and Retail tariffs. By updating the tariffs, it gets the list of tariffs from those APIs. You can check the version of your tariffs and only update if the new version is available. An example of a network tariff shown on the CEEM's API page is shown below:

[1] http://www.ceem.unsw.edu.au/cost-reflective-tariff-design

Figure 54 An example of CEEM tariff API page

C.8.5 Export

You can export the results to excel file. You can also right click on any figure and choose to export to CSV or copy to clipboard.

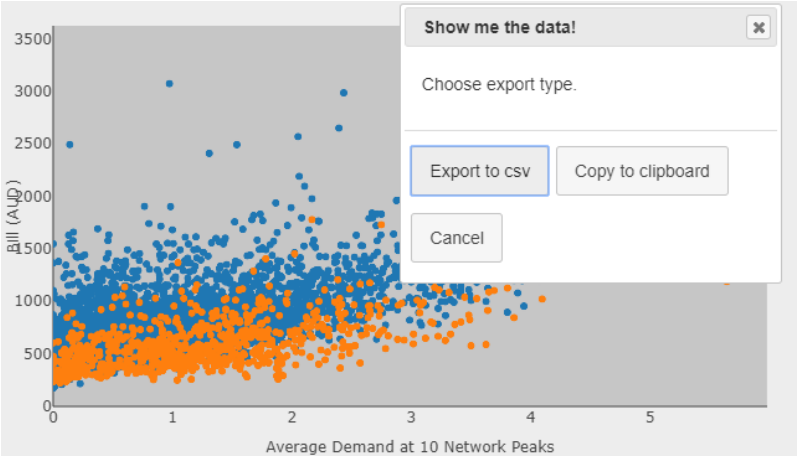


Figure 55 Exporting the data shown on figure by right-clicking on the graph

C.8.6 Info

By clicking on this menu, you can navigate to the CEEM's cost reflective tariff design page.

C.9 Generate new load data

You can also import a new load data by clicking on the “Import load data” on the main menu option “Load”. Press the “Create new” button and upload the excel file containing the load profile from your computer. The excel file should contain two sheets with names “Load”, and “Info” containing the half hourly data and demographic information. If there is no “Info” sheet, the software will not import the demographic information, and if there is no “Load” sheet, the import will not be processed and an error message will be shown. When you create a new load profile, it will sit only in your local computer and won't be uploaded to the internet and therefore can't be accessible to any other. While you can download somethings in the tariff tool (for instance the list of updated tariffs), you never upload anything to the cloud, so any change you make (e.g, new tariffs, or load profiles) will not be available to others.

C.9.1 Load Sheet Format

The first column of the load data sheet should contain the timestamp of the load profile and it should be exactly one-year of data. The data should be half hourly with the timestamp showing the end of each time period. Therefore, for example if the data is for year July 2012 to June 2013, it should start with 1 July 2012 00:30:00 and end with 30 June 2013 00:00:00. Please note the tool can handle only one year of data. However, you can analyse more years of load data by uploading them as separate years. The first row of the “Load” sheet should contain the home numbers and the following rows will contain the actual load data in kWh. Any empty cell or non-numeric data will be considered as a missing value. Any negative values will be considered but please note the tariff tool does not calculate any premium for exporting power, so the negative values will be ignored in the tariff calculation, but they will have an impact on the network load if you choose the network load to be calculated based on the aggregation of the household load data. The network load is described in more detail later. Please note the tool only works with a half hourly load profile. You should convert your load data to half hourly (by averaging higher resolution data such as 15 min data or repeating lower resolution data such as hourly).

C.9.2 “Info” sheet format

Any information about the household can be put in this sheet, and once imported it will show up in the demographic information section. This can be the type of household, dwelling type, income group, etc. The tool will group the information and let the tool operator filter the homes based on any of the demographic info when selecting the load data. If you want to include more than 10 types of demographic info, you can upload the same load profile but with different demographic info. The first row of this sheet should contain the type of info (for example: “Dwelling type”). The first row contains the Home numbers (to match with the home number in the “Load” sheet).

C.9.3 Sample file

A sample file is also provided that you can use as a reference for the required format. You can also paste your load and info data into this file and save as a new file on your computer and load that when creating a new load dataset. You can open this file by pressing “Open sample file” option. Please note, failing to follow the required format will result in an unsuccessful load import. If you receive an error, make sure you follow the instructions carefully. The home IDs should be in “number” format (i.e. do not use home 1, etc.) and these numbers will be used to match the load and demographic information so please make sure they are identical. If you have or know of any load data which can be made available, please let us know so we can put the load data into the tool. Another option is to send us your excel files containing the load and demographic data, and we will create the read-to-use file for you - so you just need to put the mat file in the TDA folder, Data directory instead of importing the load yourself. We won’t of course make the data available without your permission.

C.9.4 Network load

When you create a new load file, an assumed network load profile is also created by summing all the households’ data over the year. You can specify in the tool if you want to use this network load for finding the network peak time or instead use a new network load. Under the menu “Load”, select the option “Network load”. You can select the network load profile to be the aggregation of the selected database load profiles, or the aggregation of the filtered load profile (only selected homes with specified demographic information), or based on a synthetic network load profile which you have previously created (see below figure). You can create a new synthetic network load profile by uploading a new csv file. You can have only one synthetic network load profile at a time so if you want to check multiple network load profiles you will need to upload the desired load profile each time. In order to create the new synthetic network load profile, put the network load in a csv file with the first column being the timestamp, and the second column being the network load. The first row will be ignored. You can also open the sample file, paste your new network load (or only adjust the load at timestamps you want) in that and save it as a new file in your computer, then import it as the synthetic network load file. The sample file provided has a flat rate of value 1 so you can increase the values in different months, days, and hours to see the impact of different network load peak times. As the tool analyses only one year of load data, the network load should also be one-year of data. Also, the “year” of each timestamp is not considered. e.g. you can import network load for 2014, and use the load of 2013 and the tool will assume the network load is for 2013.

Once you create a new synthetic network load profile, you can plot it and see the load pattern as well as the monthly peak times and value (see below figure). It will allow you to quickly observe the monthly peak time and confirm if the network load profile looks correct. You can also plot the synthetic network load profile (or the network load profile based on the other two options) by choosing it in menu “Load > Network Load > Plot network load pattern”.

C.10 Creating new tariff

The components of the tariff including daily charge, energy cost, and others are shown in the panel. Any of the shown components can be adjusted to create a new tariff. Once any component of a tariff is changed, the modified tariff can be saved with a new name into the list of existing tariffs. When you

edit a component, the saving option will appear. Please note, if you change any component of a tariff it won't automatically change in other components of that tariff. For instance, if you edit the demand window starting hour in DUOS, it won't change this parameter in the TUOS and NUOS even if you save the tariff. You can also create a new tariff from scratch by selecting it from menu, "Tariff > Create New Tariff". There are currently seven types of tariff which you can create:

- **Flat rate**, where a flat constant rate applies to the kWh usage
- **Flat rate seasonal**, where the rates are different in different seasons
- **Block**, where the rates are different for different levels of kWh
- **Block Daily**, where rates are different for different levels of kWh in each day
- **Block Monthly**, where rates are different for different levels of kWh in each month
- **Block Quarterly**, where rates are different for different levels of kWh in each quarter
- **Block Annual**, where rates are different for different levels of kWh in each year
- **Time of use**, where rates are different in different times of the day
- **Time of use seasonal**, where rates are different in different times of the day and different months
- **Demand charge**, where the tariff is applied to the household peak demand (kW) or the household demand at the time of the network peak (kW) instead of (or in addition to) the kWh

You can select a name and specify the provider, state, and year. You can also include some info about the tariff for your own reference. Once you save the tariff and select this tariff from the dropdown list, you can hover over the tariff name and the info will appear. You should put the DUOS, TUOS, and NUOS "rates" separately and they can be different and even zero in some components (e.g. demand charge in the TUOS component in some demand tariffs is zero). However, the other parameters (such as StartHour, ..) cannot be different in different components. If you change a tariff parameter (e.g. start hour, end hour, etc) in one component (e.g. DUOS) it will change in other components as well. If you need to add more rows to the parameters table, you can press '+' to add a row. This will add the row to all components tabs. You can also delete the last row by pressing 'X'. If the NUOS component of your tariff is equivalent to DUOS+TUOS, you can click on the button below to fill the NUOS rates based on the DUOS+TUOS. You can also modify the rates afterwards. Once you finish everything you can press "Save new version of tariff" to save this tariff in the list of tariffs. The new tariff will be checked for consistency and the software will prompt an error message if it finds any problem in the tariff. You may later delete this tariff by selecting it from the select tariff dropdown list and press -. You can also reset all tariff lists to the original list provided by this tool by selecting from menu, Tariff > Reset Tariff.

Please note the tool may not be able to catch all possible errors in the tariff design, so please make sure all components of the tariff are designed as intended before saving the tariff.

After selecting the data and adjusting the tariff (if applicable), the analysis can be performed, and the results can be shown on the graphs. Depending on the load size, complexity of the tariff, and your computer's specification, adding the analysis to the plot window may take up to a few minutes. When you add a new case, the tool will ask if you would like to pick a name for the new case. It will appear in the graphs, exported data, and case information panels. If you select "No", it will be saved as "Case + the number of case". Please note, when you delete one case, the name of the other cases will be

updated. So for instance, if you delete case 3, case 4 and 5 will be renamed to case 3 and 4 respectively and so on. More analyses can be added to the plot by selecting a different user group or tariff and pressing “Calculate results” again. When adding the analyses (cases), you can see the list of all cases beside the plotting panel where you can show/hide the graphs, display the information of the cases, export the case to excel file, and delete the case.