



# PCDG

## Positive Cities and Distribution Grids

**PCDG v1.0 User Guide**

Authors:

Pedro Crespo del Granado

Dylan Manning

Nithish Kini Ullal

Seyed Nasar Hashemipour

Paul E. Seifert

Raquel Alonso Pedrero

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**Introdution**

Deployment of distributed generation technologies, especially solar photovoltaic, have turned regular consumers into active contributors to the local supply of electricity. This development along with the digitalisation of power distribution grids (smart grids) is setting the scene to a new paradigm: Peer to Peer (P2P) electricity trading and the emergence of local flexibility markets. Microgrids, small communities or individual buildings can become net positive producers. This has led to create multiple mathematical models and simulation environments to represent the interactions of positive buildings and distribution grids.

In this regard, Positive Cities and Distribution Grids (PCDG) mod provides a user friendly window to analyse:

- End-user benefits on engaging in P2P trade
- Role of battery storage
- Showcase and quantify P2P trade benefits among buildings
- Analyse the overall benefit for the community

In short, with PCDG, you can analyze your neighborhood's electricity trade, as well as investigate the economic benefits of investing in renewable power generation for your home. To use this app, you need some data from your neighborhood, specifically the electrical demand of each house over a time period and the electricity price in this period. Additionally, you can specify if any houses have installed solar panels or wind turbines as well as their electricity generation in the period. Batteries may also be included.

The model is based on the optimization model developed in **"Local electricity market designs for peer-to-peer trading: The role of battery flexibility „A Lüth, JM Zepter, Pedro Crespo del Grenado, R Egging Applied Energy 229, 1233-1243.**

This document serves as a user guide for the PCDG application. Each chapter will cover the features present in each of the tabs in the application.

# Contents

# List of Figures

# List of Tables

# Acronyms

| | |
|---|---|
| KPI | Key Performance Indicator |
| P2P | Peer to Peer |
| PCDG | Positive Cities and Distribution Grids |

# 1 Download and Setup

This section explains steps to download and install the PCDG application on your computer.

## 1.1 Download

To download the application please visit the **PCDGModel-LocalCommunities** repository at GitHub by **LocalEnergyMarkets**.The repository would appear as shown in Figure 2. There are two ways to get access to the app. Firstly, you can clone the repository to your computer or **download** [1] the contents as a ZIP file.

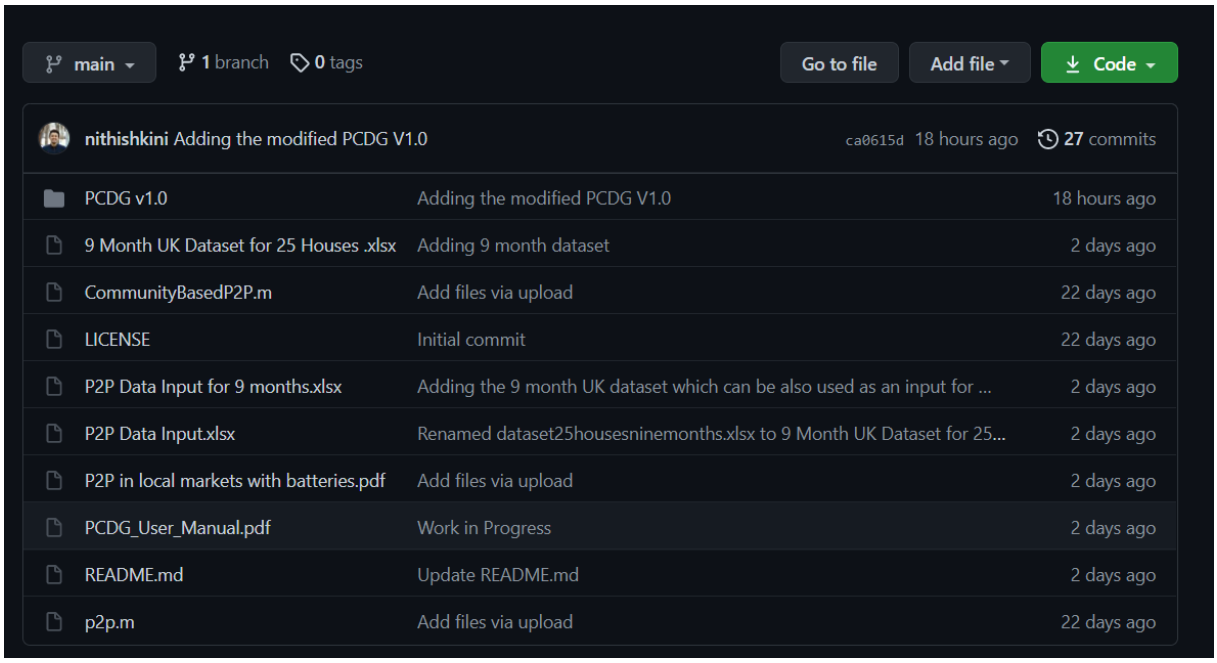


Figure 2: Snapshot: GitHub Repository

[1] Clicking on download will download the ZIP file

## 1.2 Setup

### 1.2.1 Step 1- Setting up PCDG on your computer

After cloning the repository or downloading the PCDG app as a ZIP file and extracting the folder, a folder as shown in Figure 3 is created at your desired location.

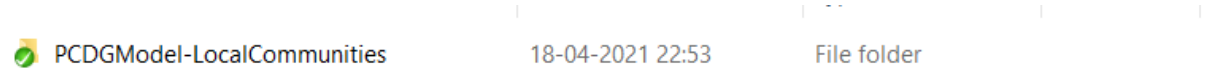


Figure 3: Snapshot: Local folder

The contents of the folder is shown in Figure 4.

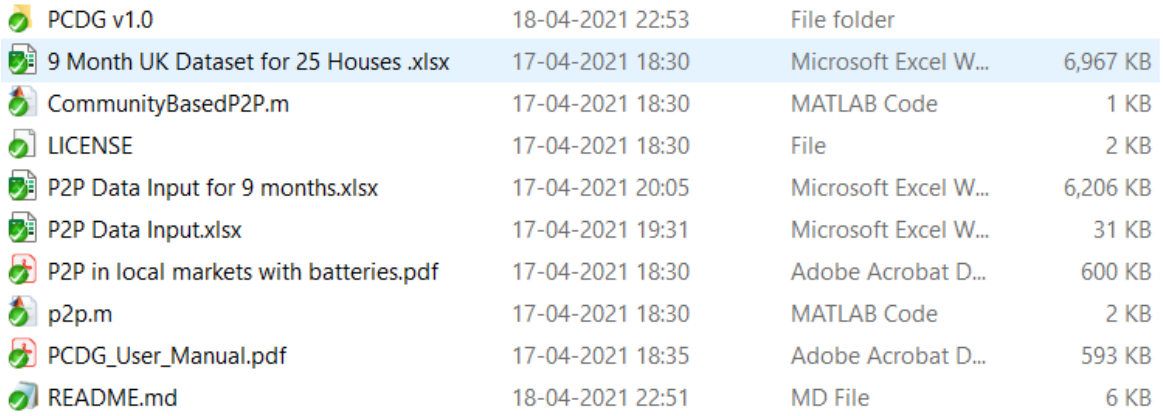


Figure 4: Snapshot: Contents of the Local folder

The folder PCDGv1.0 contains further folders required to run the PCDG application. The contents are shown in Figure 5.


Figure 5: Snapshot: Contents of the PCDGv1.0

### 1.2.2 Extended Step 1 for non-MATLAB users only

If you do not have any version of MATLAB installed on your computer please click on the folder **Step-1 (non MATLAB users only)** shown in Figure 5. Clicking on the folder will display the installer **MyAppInstaller_web.exe** as shown in Figure 6. Run the .exe file to start the installation of MATLAB Runtime which is necessary for the PCDG application to run on your computer. Please skip to Step 2 if you currently have any version of MATLAB installed.


Figure 6: Snapshot: Contents of the Step-1 (non MATLAB users only) folder

### 1.2.3 Installing Matlab Runtime

Please follow the following steps to install MATLAB Runtime. It is free to download the application and does not require any licences. Double click on the **MyAppInstaller_web.exe** to begin the installation process. The following window appears as shown in Figure 7. To continue with the installation please click on **Next** >.

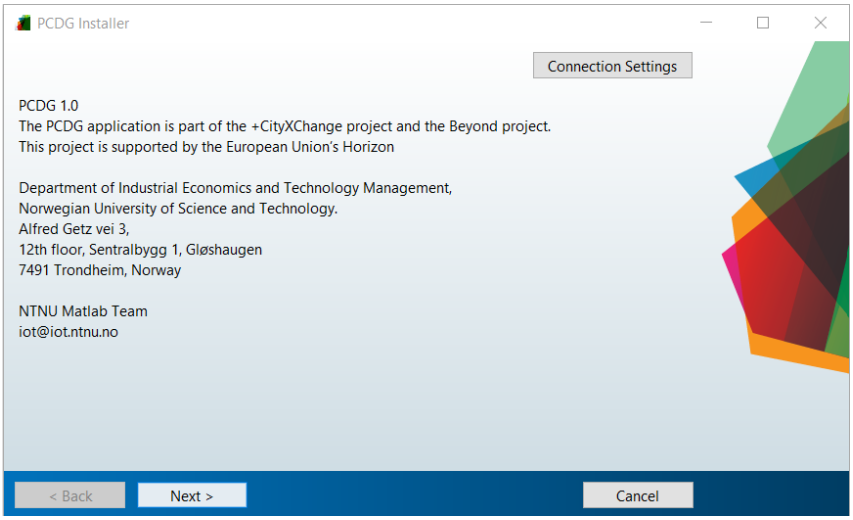


Figure 7: Snapshot: PCDG MATLAB Runtime Installer

On clicking **Next** >, the following window appears as shown in Figure 8. Choose the location where you would install MATLAB Runtime on your computer. Please make sure to change the file from the given default location and then click on next **Next** >.

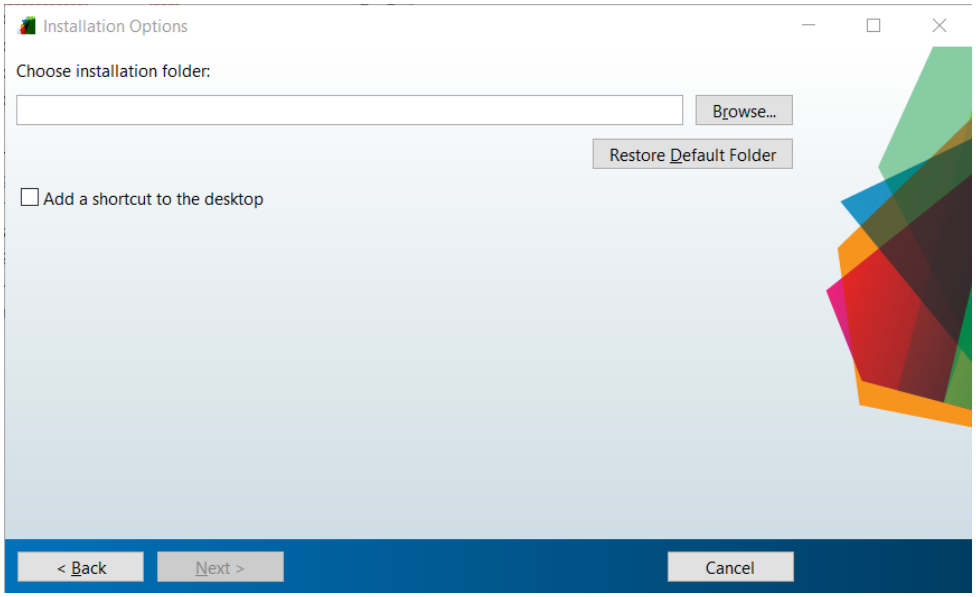


Figure 8: Snapshot: PCDG MATLAB Runtime Installer storage path

On clicking **Next** > again the installation will be carried out and whne successful, the following image as shown in 9. Click on **Finish** to conclude the pre-requirements stage for computers which do not have MATLAB installed.

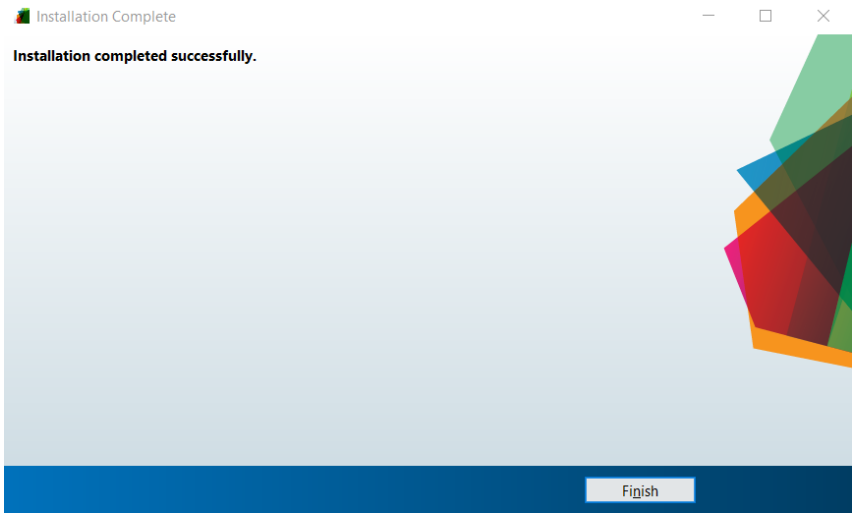


Figure 9: Snapshot: Confirmation of successful MATLAB Runtime installation

### 1.2.4 Running the PCDG application

As shown in Figure 5, the **Step-2** folder contains the PCDG application. On opening the folder following contents are seen as shown in 10.

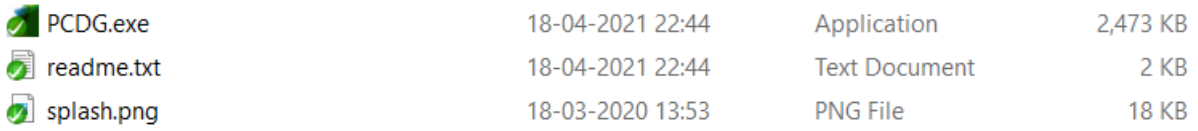


Figure 10: Snapshot: Contents of folder Step-2

Double click on **PCDG.exe** to run an instance of the PCDG application. Wait for a few seconds as the application loads and centers itself on your screen. This is the first of the PCDGv1.0.

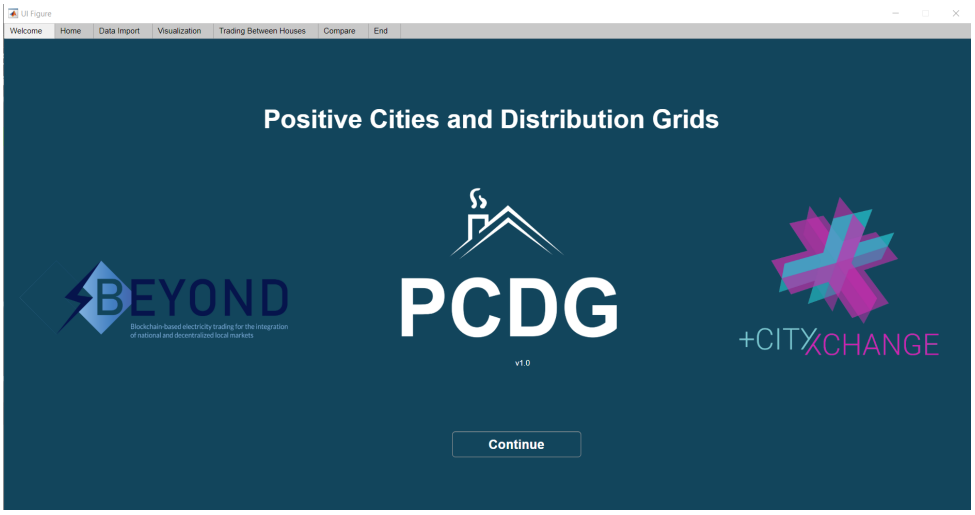


Figure 11: Snapshot: Start-up PCDGv1.0

# 2 The Welcome & Home Tab

This section describes the elements and functionality of the Welcome and Home tabs.

## 2.1 Welcome Tab

Figure 12 shows a snapshot of the Welcome Tab which provides information of the partners involved in the PCDG project. The project is a collaboration between **BEYOND - Blockchain-based ElectricitY trading for the integration of National and Decentralized local Markets** and **+CityXchange**.


Figure 12: Snapshot: Welcome Tab

### 2.1.1 BEYOND

### 2.1.2 +CityXchange

For further details regarding the partners, please click on the respective logos which will redirect you to the partner websites. You can freely navigate in the app using the tabs provided as shown in Figure 13 at the top or move to the next tab using the continue button.

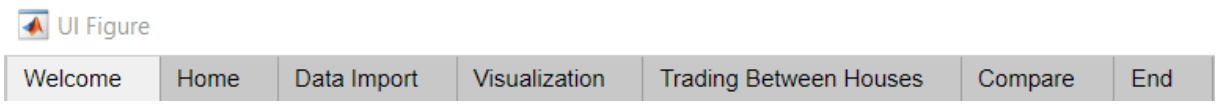


Figure 13: Snapshot: Tabs

## 2.2 Home Tab

Figure 14 shows a snapshot of the tab which contains basic information about the PCDG application which can also be found in this user guide in the Introduction of this user-guide.

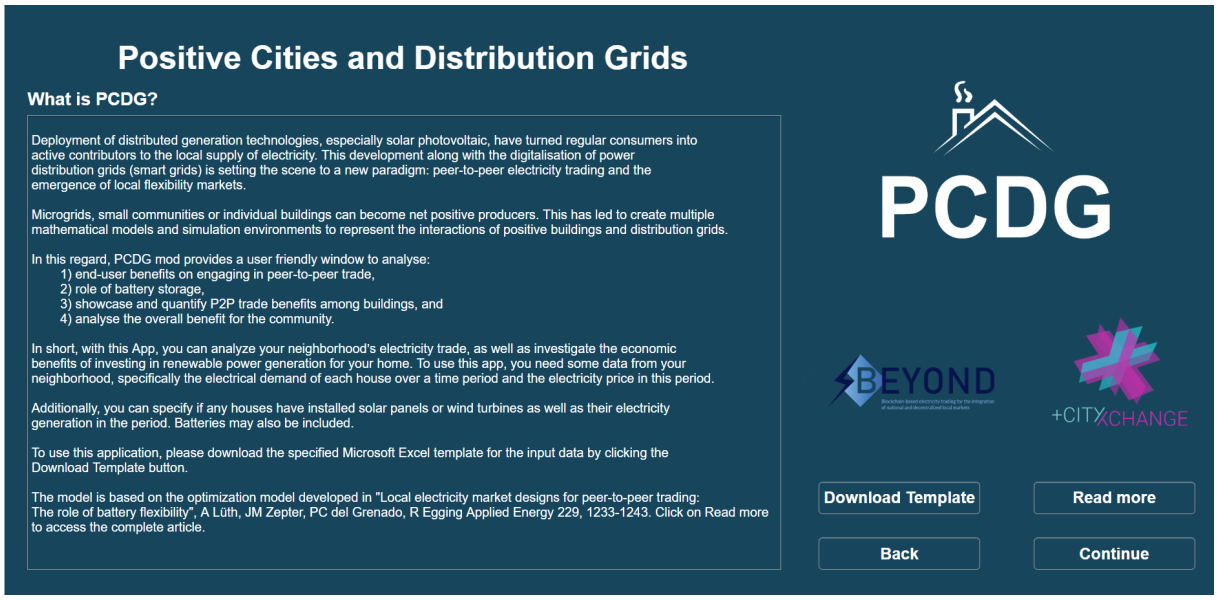


Figure 14: Snapshot: Home Tab

Additionally, there are four options provided at the bottom left corner of the PCDG application namely:

### 2.2.1 Download Template

Clicking on **Download Template** [2] downloads the required template directly and redirects you to the from the GitHub page by **LocalEnergyMarkets** [3] which is to be used as the input data for the PCDG application. The template is pre-filled with example data which is an extract from the **9 month UK Dataset for 25 Houses**. Feel free to populate the template with your own data while maintaining the format of the template or use the existing data in the template to explore the PCDG application.

### 2.2.2 Read More

Clicking on **Read more** [4]. Please feel free to also **Download** [5] the paper which is the basis of the PCDG application.

### 2.2.3 Back

Used to navigate to the previous tab in the PCDG application.

### 2.2.4 Continue

Used to navigate to the next tab in the PCDG application.

[2] Downloads the input file in the required format
[3] Clicking redirects you to the LocalEnergyMarkets git hub repository
[4] Redirects to the technical paper which is the core of the PCDG application
[5] Downloads the technical paper which is the core of the PCDG application

# 3 Data Import Tab

The data import tab in the PCDG application enables you to import the data required for the simulation in to the application. It has a simple layout where all input related parameters appear on the left hand side and the chosen system for the simulation appears on the white display space on the right hand side as shown in the Figure 15. There three buttons which are present at the bottom of the display screen which help you to navigate within the application. The **Help** button in the center would automatically download this user manual for your reference so that you can quickly scroll to the particular section in this user guide to solve your query. Clicking on the logos at the top of the display screen will automatically redirect you to the websites of the respective project partners.

On the left hand side you see two buttons namely **Get Template** and the **Import Data**. Clicking on Get Template automatically downloads the template required for the PCDG software which as described in the previous section is pre loaded with sample data. You can use the same data provided by us or populate the template with your own data keeping in mind the structure of the template. When your data is ready just click on the Import data tab and navigate to the path containing the template similar to a standard upload procedure. At the top left corner, you can also see the guide indicating you to upload the data.

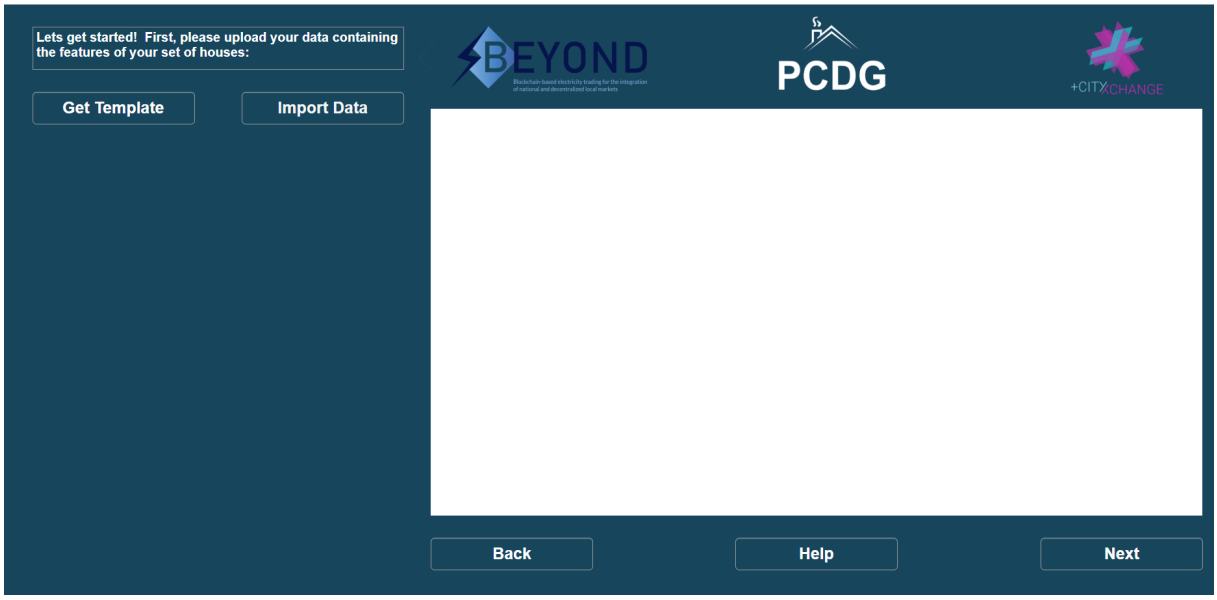


Figure 15: Snapshot: Data Import Overview

Once you upload your data, the left hand side of the screen displays more input parameters as shown in the Figure 16. Firstly, below the two buttons a **dialog box** appears which provides you with some insight of your data. The PCDG application checks your imported data to display the number of houses present in the simulation and the number of readings regarding the demand, PV, wind data etc. you have per house in your data. In the current example being used for this guide, we have used 25 houses and time series readings at 48 intervals of one day. Hence the application displays the text,

"We found Data for **25 houses** and demand data for **48 time periods**,,. It also checks whether all PV and Wind data are as per the required format and if the format has no problems "**PV** and **Wind Data** is fitting,,is displayed as shown in Figure 16.

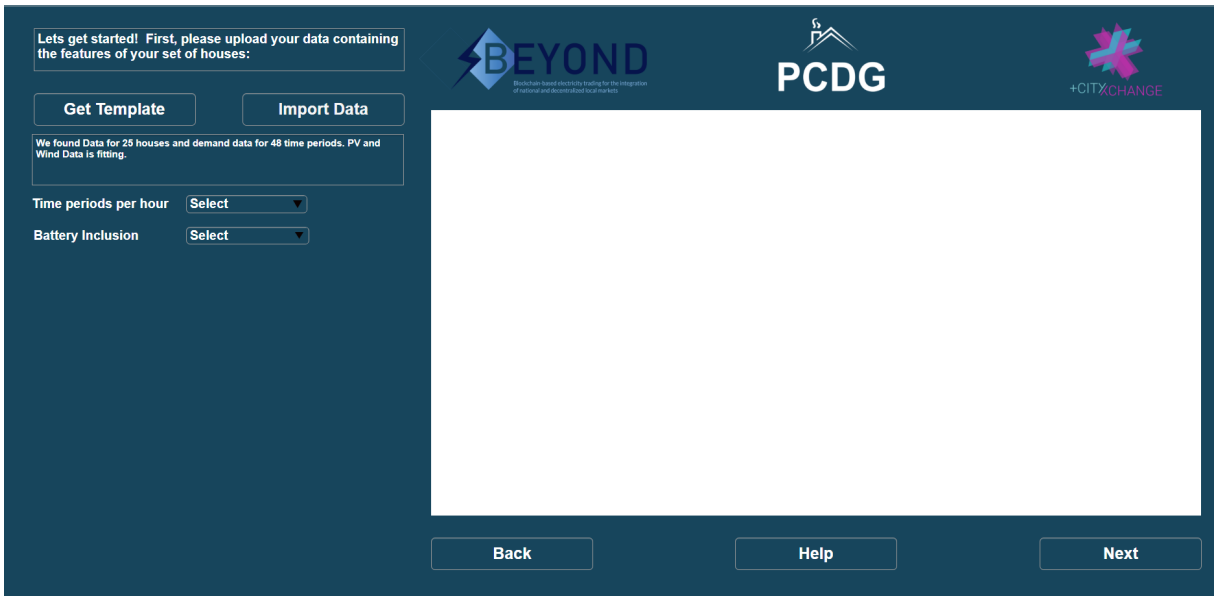


Figure 16: Snapshot: Data Import step-1

## 3.1 Option-1: Time Periods per Hour

The time period per hour option allows you to divide the hour into number of smaller intervals. The following intervals as shown in the Figure 17 are available in the drop down option. Choose the required time resolution as per your analysis.

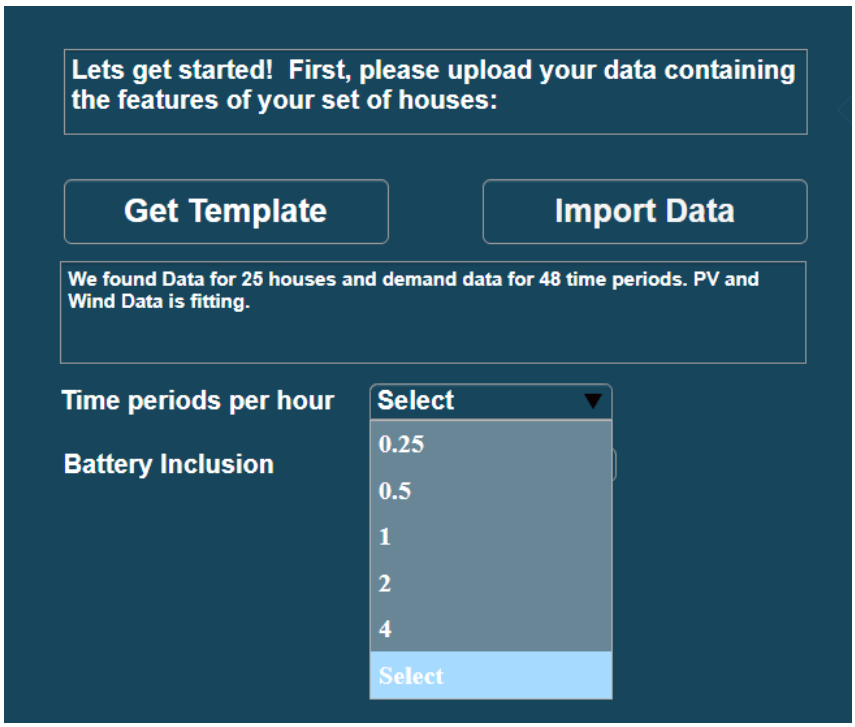


Figure 17: Snapshot: Data Import step-2

For example, in this data there are 48 entries present for the time series data. Selecting **Time periods per hour** option as 2 would result in the application reading the each data point as the value recorded every half our or in other words twice every hour. Similarly selecting **Time periods per hour** as 4 would lead to the data points being treated as data recorded every 15 minutes. A simple formula would be as follows:

$$\text{Data time interval} = \frac{\text{Number of Data points in the dataset}}{\text{Time periods per hour}} \tag{1}$$

## 3.2 Option-2: Battery Inclusion

At this point you make the first modeling choice in the application which is whether to include battery in your simulation or not. As mentioned in the article the application is based upon, this application demonstrates the potential of including batteries in P2P energy trade setup.

### 3.2.1 Battery Inclusion - Off

By excluding batteries n the first simulation you can obtain the results of the Key Performance Indicator (KPI) which can be later compared to the case including batteries to see the benefits if including batteries. A drop down option is provided to capture the input as shown in Figure 18

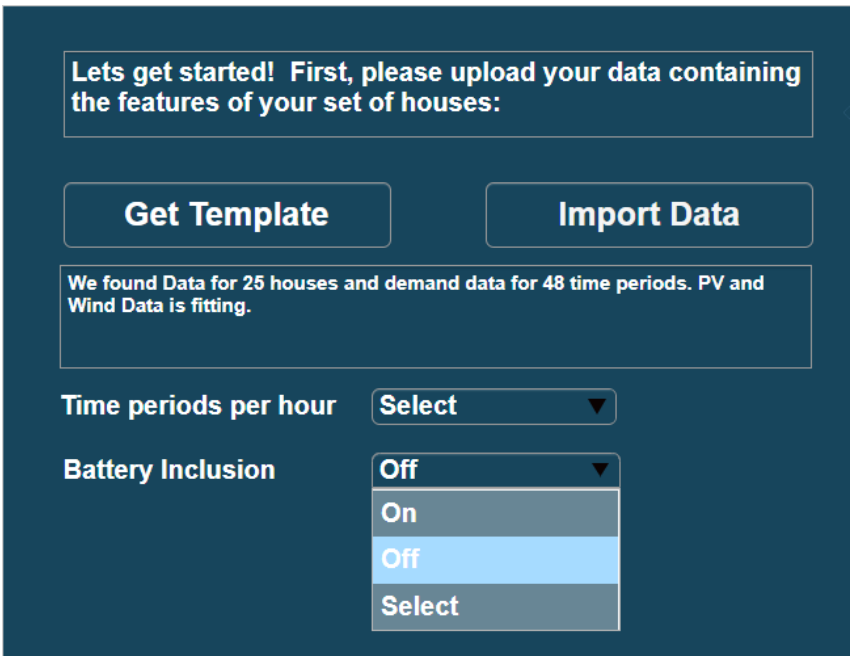


Figure 18: Snapshot: Data Import step-2

In the first simulation if the batteries are kept off the following model as shown in Figure 19 is displayed in the right hand side of the application. Each blue dot represents a house from the imported data set and is numbered as per the input order provided in the template. At this stage you can press the next button at the bottom right corner of the application to move to the next stage of the simulation.

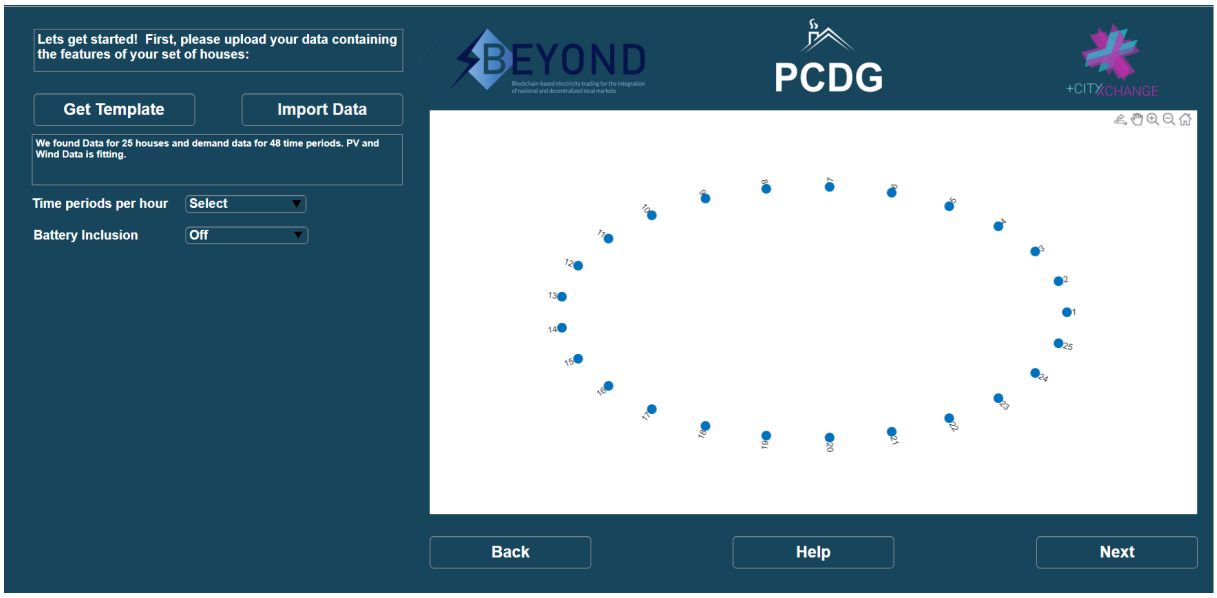


Figure 19: Snapshot: Model setup display when batteries are kept off

### 3.2.2 Battery Inclusion - On

As mentioned earlier realizing the real benefits of involving batteries is the goal of the application and this is achieved by selecting the **Battery Inclusion** option as on as shown in the Figure 20.

The left had side of the application as seen in Figure 20 has more input options. A dialog box is displayed indicating you to fill in the required input parameters for the simulation.

**Battery Parameters** Currently, the model allocates the same battery type to all houses. This means that the battery parameters being selected will be common for all houses for which batteries will be included. You are free to choose any battery parameters suiting your analysis. Be mindful about the units when you enter the values, the necessary units are displayed at the right of each parameter. For example, Efficiencies are percentage values which means this can be any number between 1-100. For this simulation we will use the battery parameters are considered in the article.

**Select House** The select house feature enables you to choose the houses to which you want to allocate the batteries to. Clicking on the number allocated to the house would be sufficient to select a particular house. If you made an error during selecting the houses, to deselect a wronglypucked house clik on the number again and it will be deselected.

After you have input all the required values to the parameters and made the selection of the houses the application view would like as shown in Figure 21. The houses to which the batteries are allocated to are highlighted with green. The houses with n battery allocation remain as blue dots. This completes teh data import to the PCDG application.

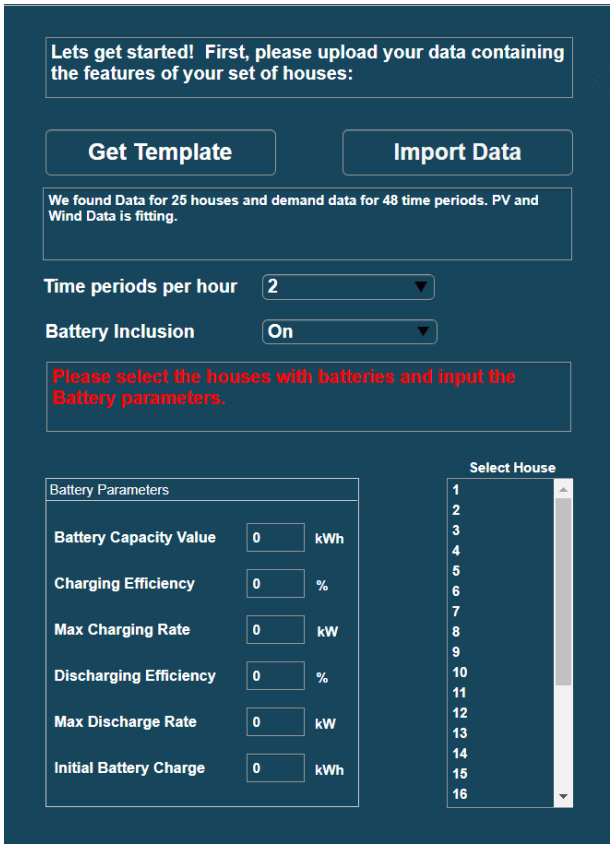


Figure 20: Snapshot: Parameters when battery inclusion is on

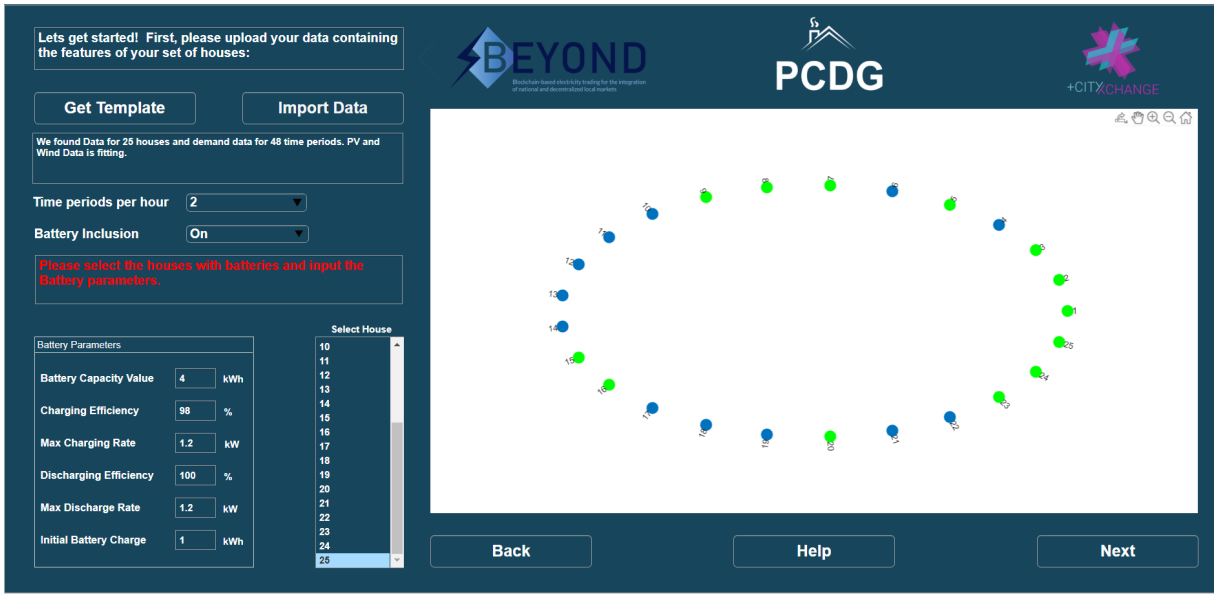


Figure 21: Snapshot: view of the application with all input parameters

# 4 Visualization Tab

The Visualization tab focuses on interpretation of the input data to identify underlying patterns and calculate the KPIs. Initially in the Visualization tab would appear as shown in Figure 22. The tab has a similar structure as the Data Import page. To the right of the screen you can see the space for visualisation and to the left is the **Run Simulation** button along with a lamp. When the lamp is red, it would mean that you have not run any instance of a simulation during this session.

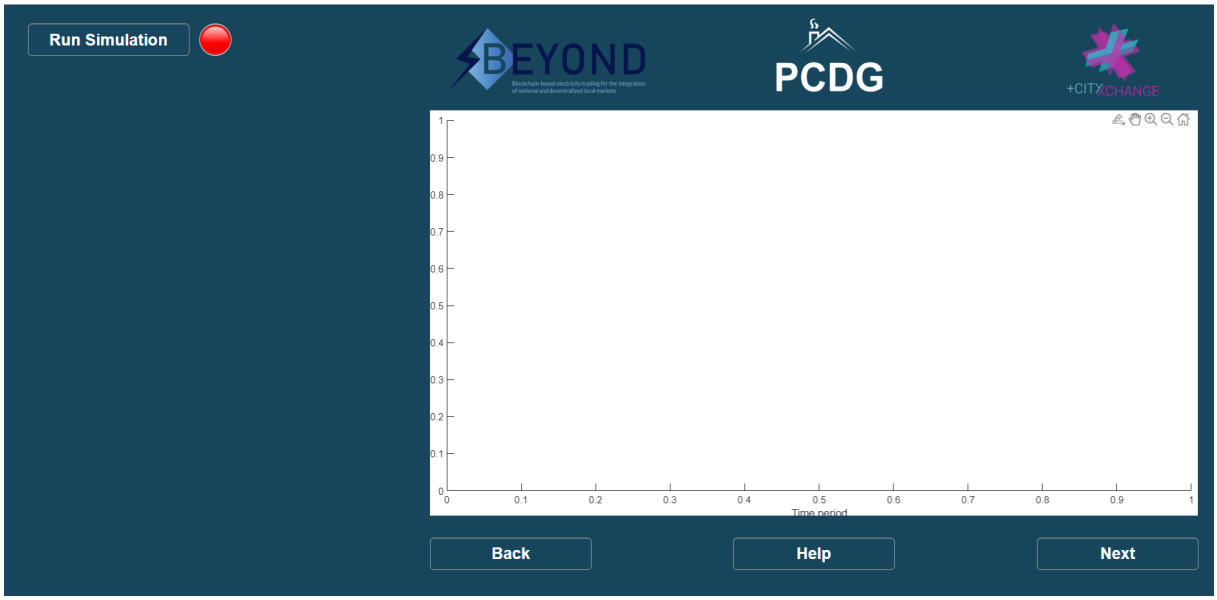


Figure 22: Snapshot: First look of the Visualisation Tab

After clicking on the **Run Simulation** button the lamp changes it's color to yellow which signifies the calculations are running and a dialog box would appear indicating the status. This is shown in Figure 23.

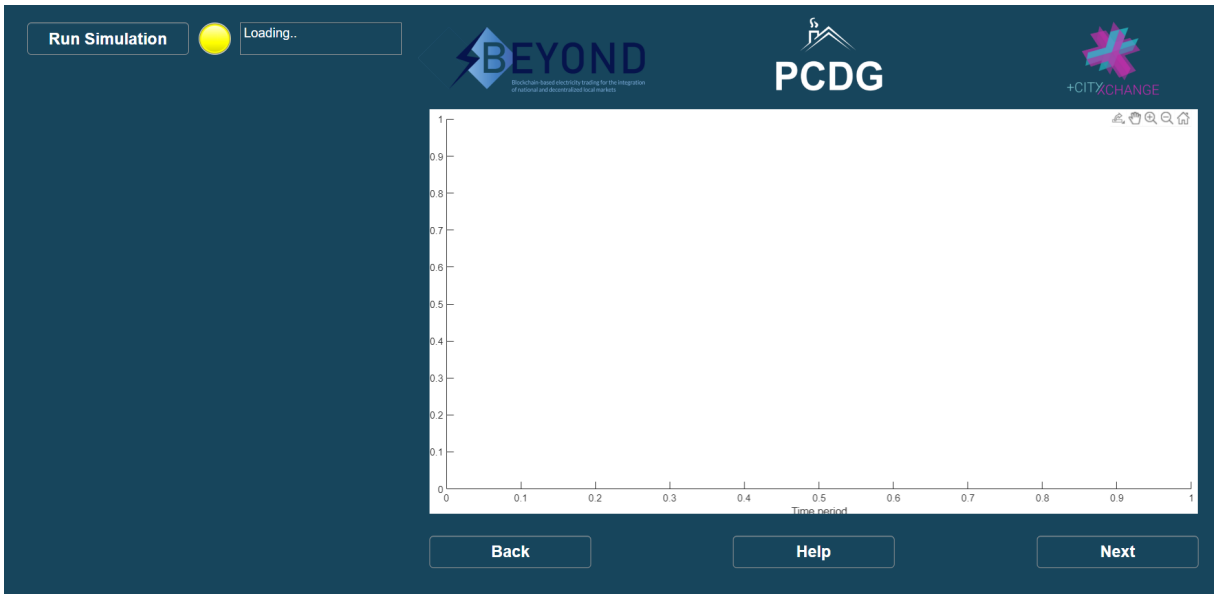


Figure 23: Snapshot: Processing the Visualisations

When the calculations are completed, the lamp turns green and the screen is populated with graphs on the right and the values of several KPIs to the left. In addition to this, several options are activated to interpret the calculations. This is shown in Figure 24

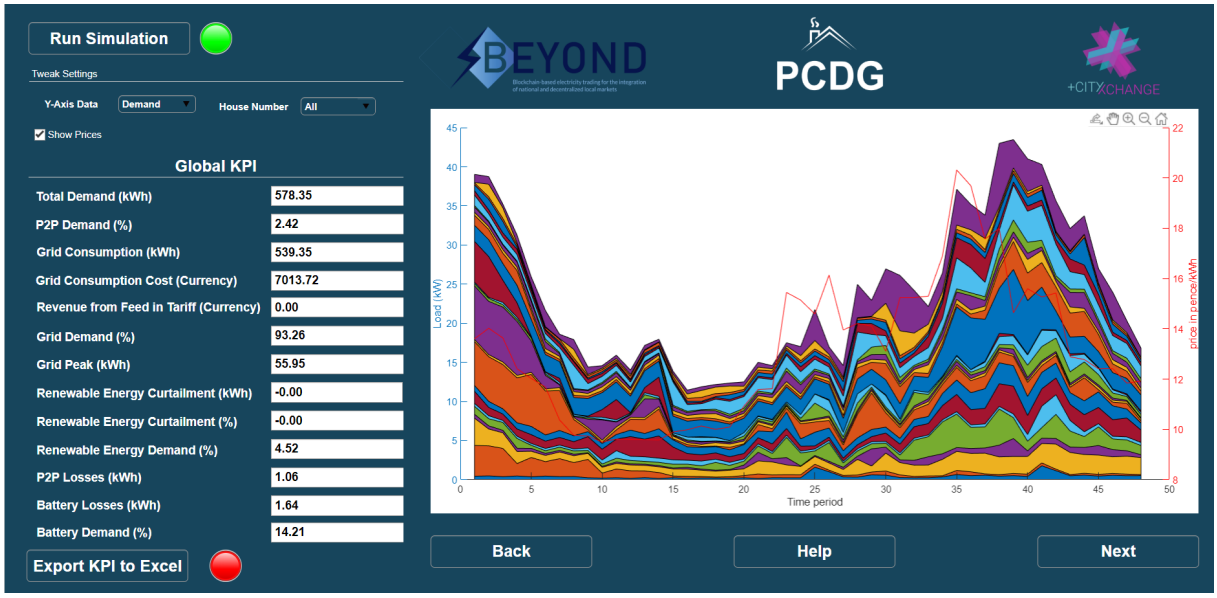


Figure 24: Snapshot: Visualisation tab with batteries included

## 4.1 Key Performance Indicators

Before we move to various graphs that we see to the right, we need to define the KPI. This will help you get a better insight to understand the values of the KPI.

- **Total Demand**

  The total demand KPI is the sum of all the load values throughout the simulation period. This value is nothing but the sum of all the values in the **Demand** tab in the input data file in kWh.

- **P2P Demand**

  The P2P demand refers to the part of the total amount of energy demand that is satisfied by P2P energy transactions. In the example the value is only around 2.5 % because the data used is from a typical day in winter with very less sunlight and wind.

- **Grid Consumption cost**

  Usage of electricity leads to consumption cost, the price for each unit of electricity is set by the utility you are subscribed to. In the template provided for importing the data, there exists a separate tab named **Price** where you can set the prices based on your per unit cost of electricity. This price can be constant at all time periods or also vary during each time interval. Hence, the grid consumption cost would be the total cost borne by all the houses present in the simulation corresponding to the total amount of electricity bought from the grid. This does not include the cost or gain from P2P transactions.

- **Revenue from Feed-in-Tariff**

  In some countries there is an option of Feed-In-Tariff. A Feed-In-Tariff refers to a fixed monetary payment per unit of electricity provided by the utility to deliver power back to the grid. This option is also present in the template under the **Grid Tariff**. In this example we have not included any tariff and set it at zero during all time intervals. Hence, the value seen is zero.

- **Grid Demand**

  Grid demand refers to the amount of total required energy in the community being supplied by the utility. A simple formula can make things more clearer for you.

$$\text{Total Demand} = \text{Grid Demand} + \text{Renewable Energy Demand} + \text{P2P Demand} \tag{2}$$

- **Grid Peak**

  Grid peak refers to the highest amount of power in kWh required during any particular time step of the input data.

- **Renewable Energy Curtailment**

  Renewable energy curtailment is the amount of energy from renewable sources which is restricted from production due to inability to use or store it at that instance of time. This is a good indicator of battery sizing. If a significant amount of energy is being curtailed, it would be an indicator that a battery with higher capacity or power rating could improve the outcome of the simulation.

- **Renewable Energy Demand**

  The amount of demand that is satisfied from renewable energy sources for self consumption is defined as the renewable energy demand.

- **P2P Losses**

  Distributing energy from one location to another in a community would lead to physical which in this cases is termed as P2P losses. Please note that these losses only occur due to the interactions of the houses within the community and are not the losses from the distribution of power by the utility. In the example we have manually set the loses due to P2P transactions to 7.6% of the total P2P demand.

- **Battery Losses**

  All batteries posess charging and discharging efficiencies. Due to these whenever a battery is charged or discharged will result in small amounts of losses. In this case we have considered the

charging efficiency to be 98% and discharging efficiency to be 100%. These parameters can be varied by the user as per requirement in the data import tab.

- **Battery Demand**

  The amount of demand that is satisfied from P2P transactions which are made possible by the batteries is defined as the battery demand.

**Please note that the KPIs depend upon the set up of the simulation in the data import tab. For example if in the Data import tab, the battery selection is switched off, then all the parameters which specifically refer to the batteries being in the system (ex. Battery Losses, Battery Demand) will not be displayed as will be equal to zero.** This is shown in the Figure 25.

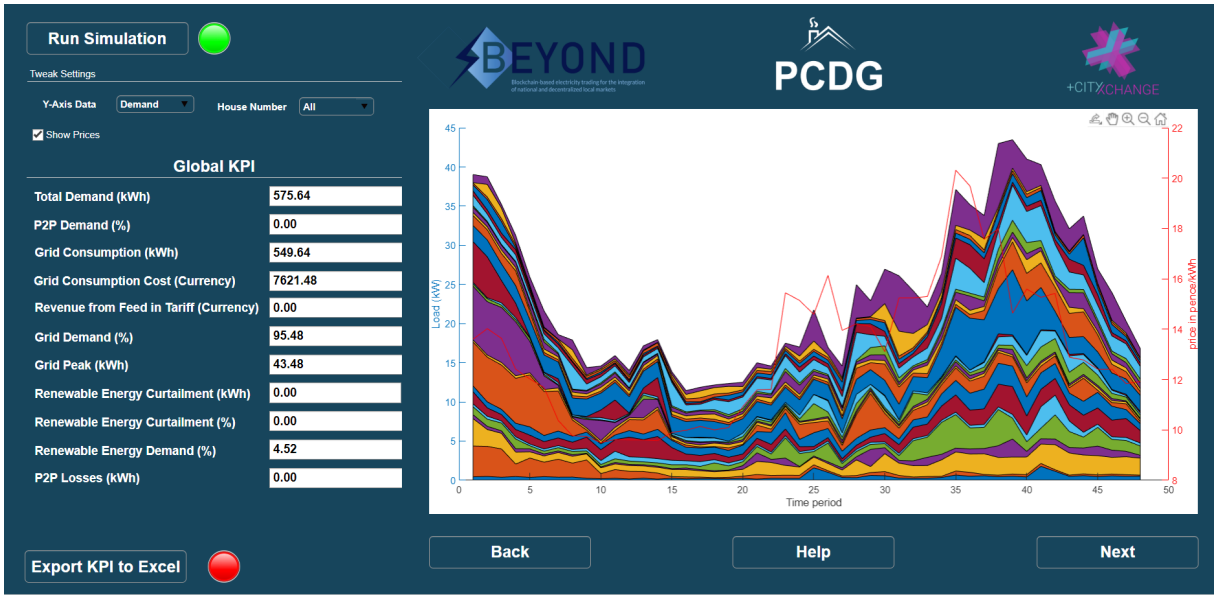


Figure 25: Snapshot: Visualization tab with batteries not included

## 4.2 Export KPI to Excel

In Figure 24 and in Figure 25, towards the bottom of the screen, there is another button which reads **Export KPI to Excel** with a lamp placed beside it. On clicking the button the KPIs that are displayed on the left will be exported to a CSV file and stored in the same location where the PCDG app launcher is present. The lamp turns green once the file is successfully stored at the location. This file is used as an input again in the **Compare** Tab which enables you to compare between two simulations.

## 4.3 Tweak Settings

With all the KPIs defined now, it would make more sense to look at the visualisations available in the PCDG application. On the top left of the screen a panel named **Tweak Settings** is visible which contains several options pertaining to the visualisations.

### 4.3.1 Y-Axis Data

### 4.3.2 House Number

Show Prices

# 5 Trading Between Houses Tab

# 6 Compare Tab

# 7 End Tab

The end tab is as shown in the Figure 26. This page provides the contact information of the project contributors and developers. If you as a user of PCDG have any comments or suggestions which could help us improve the application further, you can send us an email or also contact us through the Github platform **LocalEnergyMarkets**. Similar to the Welcome page in section 1.2.4, clicking on the logos displayed redirects you to the websites of the project partners where you can read about other new and interesting projects. In addition to this, there are four buttons present at the bottom of the screen as seen in Figure 26.

## 7.1 Downoad Template

Clicking on **Download Template** [6] downloads the required template directly and redirects you to the from the GitHub page by **LocalEnergyMarkets** [7] which is to be used as the input data for the PCDG application. The template is pre-filled with example data which is an extract from the **9 month UK Dataset for 25 Houses**. Feel free to populate the template with your own data while maintaining the format of the template or use the existing data in the template to explore the PCDG application.


Figure 26: Snapshot: End Tab

## 7.2 Read More

Clicking on **Read more** [8]. Please feel free to also **Download** [9] the paper which is the basis of the PCDG application.

[6] Downloads the input file in the required format
[7] Clicking redirects you to the LocalEnergyMarkets git hub repository
[8] Redirects to the technical paper which is the core of the PCDG application
[9] Downloads the technical paper which is the core of the PCDG application

## 7.3 New Simulation

Clicking on **New Simulation** will close the current instance of the application and will re-open the PCDG application beginning from the home page ready for a new simulation. You would be using this button to generate the second instance of output of KPIs from different simulations for comparison in the compare tab.

## 7.4 Close

The **Close** button ends the current running instance of the PCDG application.