DEFENDER : NETWORK PLANNING TOOL DEVELOPMENT (D1.3-6)

DE04 – Detailed functional/technical specification

As Built Review December 2022

V2.3

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Revision History

Name	Notes	Author	Date
1.0	Initial draft	Jane Wilson	3 August 2022
1.1	User interface additions	Joshua Cooper	14 August 2022
1.2	Review comments	Ben Robertson	23 August 2022
2.0	Final for submission	Jane Wilson	24 August 2022
As built update 2.1	Commentary on actual delivered vs original specification	Faye Schuster	21 December 2022
As built update 2.2	Updates to above	Faye Schuster	23 February 2023
As built update 2.3	Updates	Faye Schuster	8 March 2023

Authors

Name	Position	Date
Joshua Cooper	Hildebrand	5 August 2022

Approvals

Name	Position	Date
Nick Devine	NGED – Innovation Engineer	27/03/23

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Abbreviations & definitions

Term	Description
DFES	Distribution future energy scenario
DNO	Distribution Network Operator
DNOA	Distribution Network Options Assessment
EE	Energy efficiency
EHV	Extra High Voltage
ESA	Electricity Supply Area
EUI	Energy Use Intensity
HTC	Heat Transfer Coefficient
LV	Low Voltage
MDI	Maximum Demand Indicator
sFTP	Secure File Transfer Protocol
SMETS	Smart Metering Equipment Technical Specifications
SQL	Structured Query Language

1. Introduction to the As Built Update

As part of project completion, Hildebrand have performed a review of the initial Detailed Functional Technical Specification to compare original intention versus final, approved, deliverable.

Commentary is added against any element that varied from original intent. Where the final version has replaced what was in the original specification, the content of the original specification has been deleted.

To distinguish the commentary it is in dark red, prefaced by 'As built'.

2. Introduction

2.1. Purpose

Work package 1.2 of Workstream 1 of the DEFENDER project develops the capability for simulating historical and future power demands for an electricity network segment, taking into account different household archetypes created with the Household Profiler tool. The house archetypes consider the impact of energy efficiency interventions and heating technologies.

The Network Planner tool constructs scenarios, using house archetypes and weather/location as input. The user interface for the Network Planner aids in selecting a group of buildings, assigning archetypes and then showing the combined electricity consumption profile for the group. Scenarios can then be saved to compare before and after building fabric retrofit heat demand and the impact on ADMD and load profiles, including transference of gas demand to electricity demand due to heat pump take-up.

Inputs to the model include:

- Hildebrand's smart meter database of domestic gas and electricity consumption data
- Heat Transfer Coefficients (HTC) from the SMETER project which used BEIS validated algorithms to calculate building thermal performance from smart meter data
- Carbon Trust's Building Decarbonisation Options Appraisal Tool, which can determine the impact of energy efficiency and heating measures on the building's heat loss factor (U value)
- The Energy Performance of Buildings Register, which contains EPCs for homes in England and Wales, which include heating and fabric data amongst other useful information
- Local weather data from weather stations sourced from METAR feeds

2.2. Background

Document D0.1 Profiling tool specification and design document, signed off by Nick Devine of WPD on 23 May 2022, identified the data sources and flows to be used in the network planning tool and underpins this detailed functional and technical specification.

That document has been updated as part of this workstream and is re-issued at D1.1-2 Revised scoping document and high-level tool specification.

There are two end user tools that will have user interfaces:

1. Household Profiler – the tool (covered in separate detailed specification document D1.1-3_DE04_DEFENDER_HouseLevelDetailedFunctionalTechSpec_v1.2_Submitted) that creates and maintains archetypes
2. Network Planner – the tool specified in this document that applies household archetypes as a population representing the homes that are attached to a segment of the distribution network.

This document is the detailed functional and technical specification for the Network Planning tool; this activity and its outputs will inform the development of the tool itself.

2.3. Objectives

For the design of the tool the high-level objectives that are taken into consideration are:

1. To produce network level load profiles from future demand scenarios
2. Scenario comparison of load profiles based on energy efficiency measures
3. Scenario comparison of load profiles based on heating technology while considering necessary energy efficiency measures
4. Separate representation of electricity base load for the house profile that is selected
5. Save both the resulting data file and the parameters that generated the data and export to csv
6. Ability to update the scenarios in the future

2.4. Assumptions

The following are the subset of project assumptions relevant to the technical design at the present time.

Assumption status:

- Identified – The assumption has been identified but has not been validated.
- Validated – The assumption has been validated. The validation source and validation date should be stated.
- Dismissed – The assumption is not valid or is no longer relevant.

ID	Description	Status
A-1	Data coverage is good over all of the archetypes	Validated
A-2	Weather stations that are used are representative of the conditions experienced at the meter point	Validated
A-3	Time period 2019 – pre-covid; largely office working. Time period 2020 - 2021 – covid: largely home working Time period 2022 - Covid new normal: 3 days a week office working	Validated
A-4	Data coverage between EPC and smart meter properties is good	Validated. 28/04/22
A-5	Retrofit measures are those available today, there is no forecasted change in insulation or window technology	Validated
A-6	Buildings fabric will not regress once a retrofit modification is made, e.g. insulation lasts for the forecast window	Validated
A-7	Half hourly energy (kilowatt hours) accurately represents the power demand for that period (kilowatts)	Validated
A-8	Cooling is not included in this model	Validated
A-9	Retrofit measures have been installed to best practice standards	Identified

2.5. Dependencies

The following are the subset of project issues relevant to the technical design at the present time.

Assumption status:

- Open – The issue has been identified
- Resolved – A dependency has been met

ID	Description	Impact	Status
D-1	Model to be stand-alone (WPD IT environment restrictions)	No server required	Resolved

2.6. Risks and Issues

The following are the subset of project issues relevant to the technical design at the present time.

Assumption status:

- Open – The issue has been identified
- Resolved – A resolution has been accepted for the issue

ID	Description	Status
I-1	Diversity can be captured when generating load profiles or at later stages before the profile is loaded into scenario analysis. Design needs to be clear when diversity is considered.	Open

| I-2 | Parameters are stochastic and therefore multiple running of the tool will not always give the same result. | Open |
| I-3 | Weather assumptions for long term predictions may need to consider changing climate | Open |

2.7. Design Decisions

The following table lists design decisions and their rationale.

ID	Description	Impact	Rationale
DD-1	Single page interaction for web that can be run locally in a browser without an Internet connection	UI framework does not need to consider mobile interactions or browser connecting back to a server	Used in browser environment to export files locally. Local loading of saved settings so that a server is not required.
DD-2	Where possible, easy to use selection criteria with ranges are used for describing house parameters.	May lose some fine grain control of model parameters	Complicated technical input is probably difficult for most end users of the tool, assumptions will have to be used to translate from high-level combination to the reference values. As a part of UAT, the typical user will give feedback as to the suitability of the selection criteria – i.e. are they easy for those users to use
DD-3	Results downloaded to files that are stored locally	Portable; sharing must be done with the files	No server

---

3. Launching
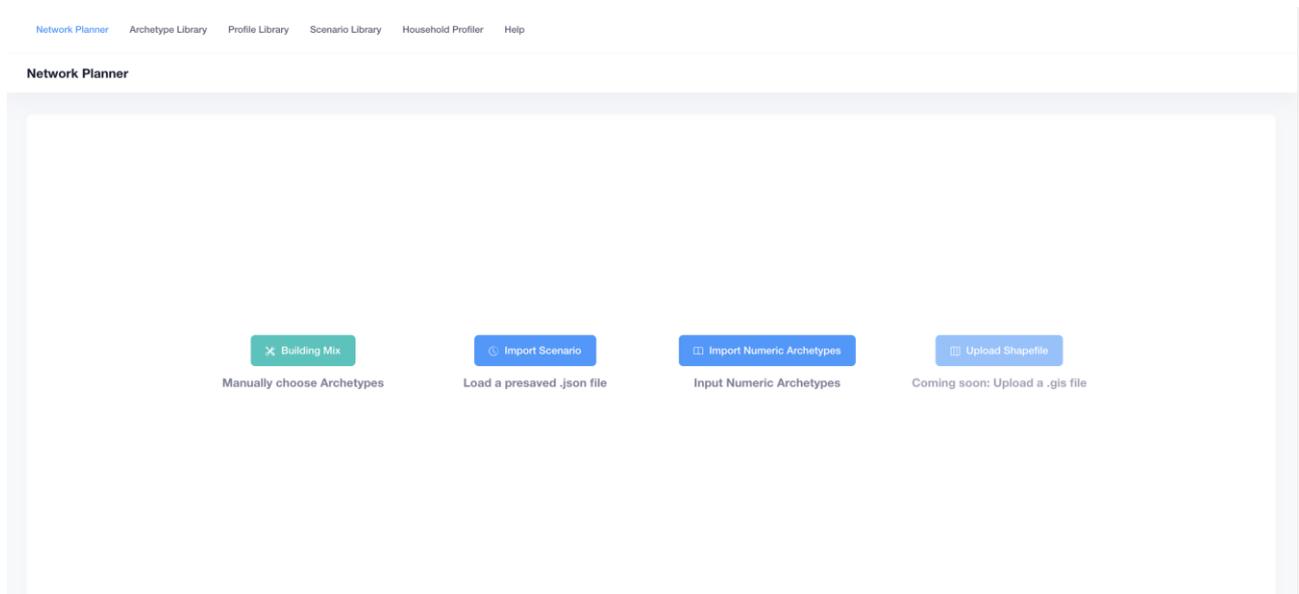
Figure 1. 'As built'. The initial launching screen and top navigation

The Network Planner launches as the first page as this is the functionality that will be required most by users. The Household Profiler can be accessed via the top navigation so the user can easily interchange between tools if needed. The Archetype, Profile and Scenario Library and Help page can also be accessed from the top navigation.

4. Scenario Inputs

This section explains the data input assumptions, the technical design of the scenario, and generation of data to be exported.

Scenarios can also be thought of as a selection of archetypes, along with temperature data that drives the generation of profile data. Mixes of archetype counts that are selected can be saved, along with the sample profile, so that different scenarios are formally defined and accessible for future re-use.

The initial screen to interact with the tool will present the options for starting a new scenario or loading an existing scenario file. The GIS based routes are being shown as an option, but may not get built because they would require the browser to be able to access the Internet (known WPD constraint).
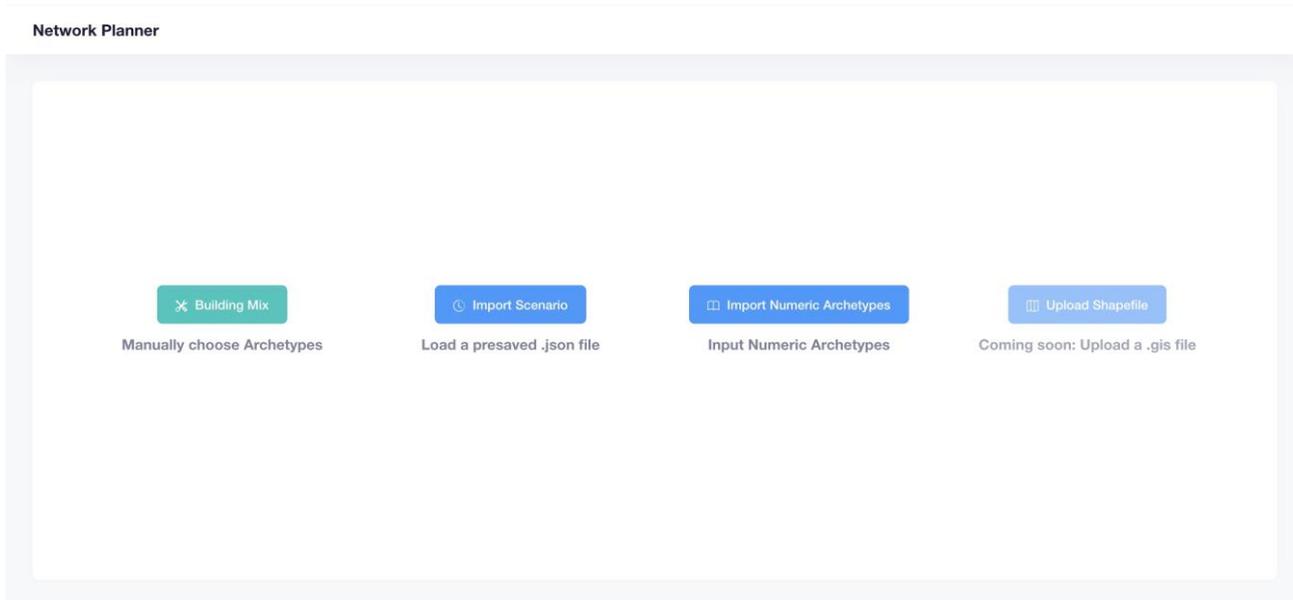
Figure 2. 'As built' Final outcome of initial 'Network Planner' screen

4.1. Network segment data

A list of homes that are serviced by a network segment is a required input. This list can be created from the following methods:

1. **Manual** - a dummy list can be created by inserting counts of archetypes into an input box. Archetypes are taken from the archetype library that has been loaded. The building mix will be manually configured.
2. **GIS [future]** – this area will be explored but possibly not fully implemented due to the requirement for an Internet connection; it will be used to determine how users may want to interact with GIS.
3. **Opening Previous Scenario** – opens a previously saved scenario file, edit and save update

'As built': Final outcome:

- 'Import Numeric Archetypes' was also added see Fig 2. This allowed Carbon Trust to create Scenarios from spreadsheets which reference Archetypes by numbers.

4.1.1. Manual input

Archetypes can be selected from the list with building counts loaded. The list is populated from the archetype library that is loaded. The user would have to know the characteristics of the archetype by its name.

For the intended minimum viable product (MVP) changes in scenarios or scenario comparison would be done by starting a new scenario and choosing a different archetype mix.

Step 1. Enter the quantities of archetypes from the archetype library (Note: heating technology and energy efficiency are embedded in Archetype name)
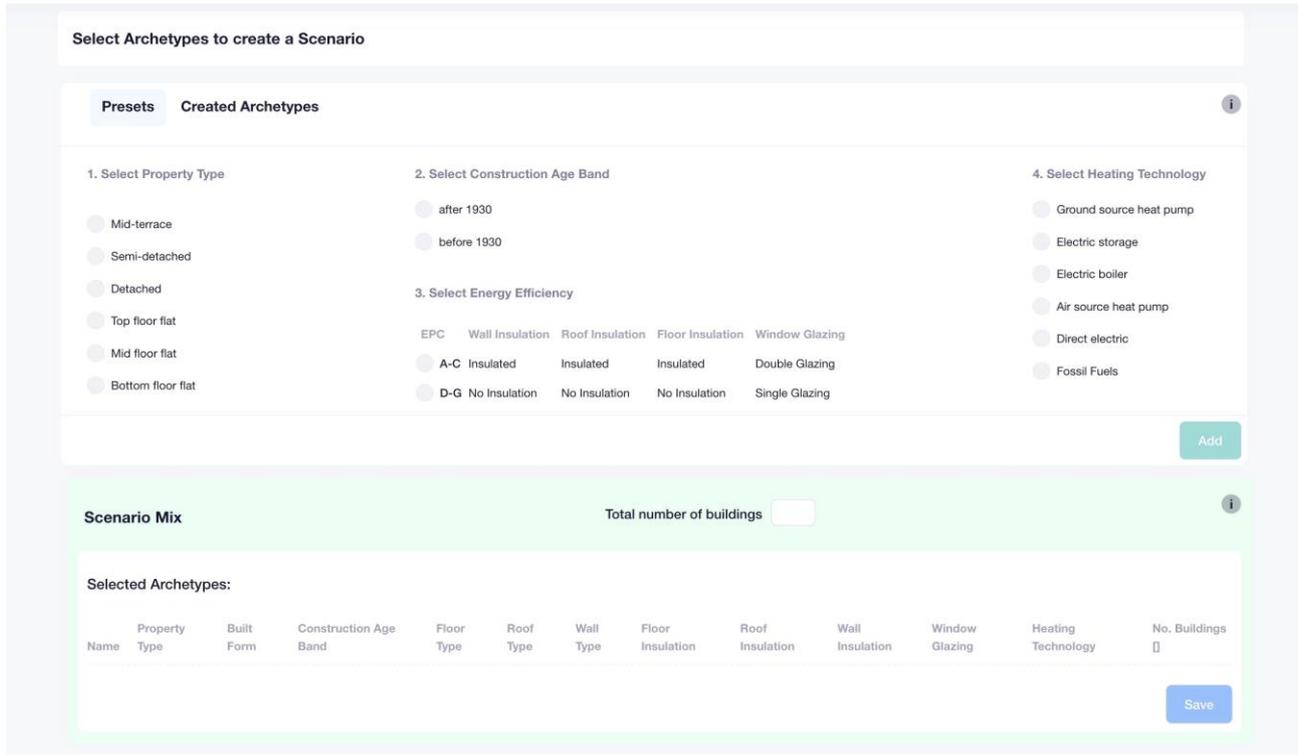
Figure 3. 'As built' Final UI outcome of manually selection Archetypes screen

- 'As built': 'Presets' - were made as an option, as requested by Carbon Trust, to create a Scenario as well as 'Created Archetypes' which are the Archetypes saved into the Archetype Library.

Step 2. Assign the weather profile, similar to the Household profiler
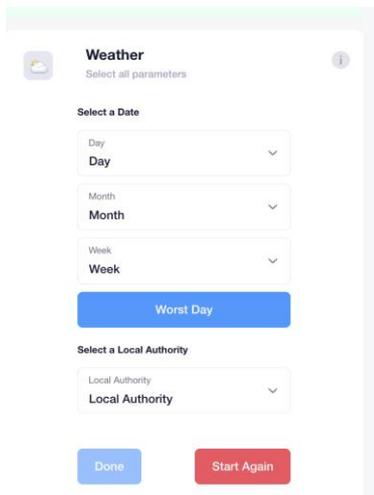
Worst Day can be selected to select the coldest day in 20 years – button added for ease

Figure 4. 'As built' Final UI of weather parameters when selecting dates.

Step 3. View the result of the scenario with the ability to save off the combined electricity profile for the archetype mix selected.
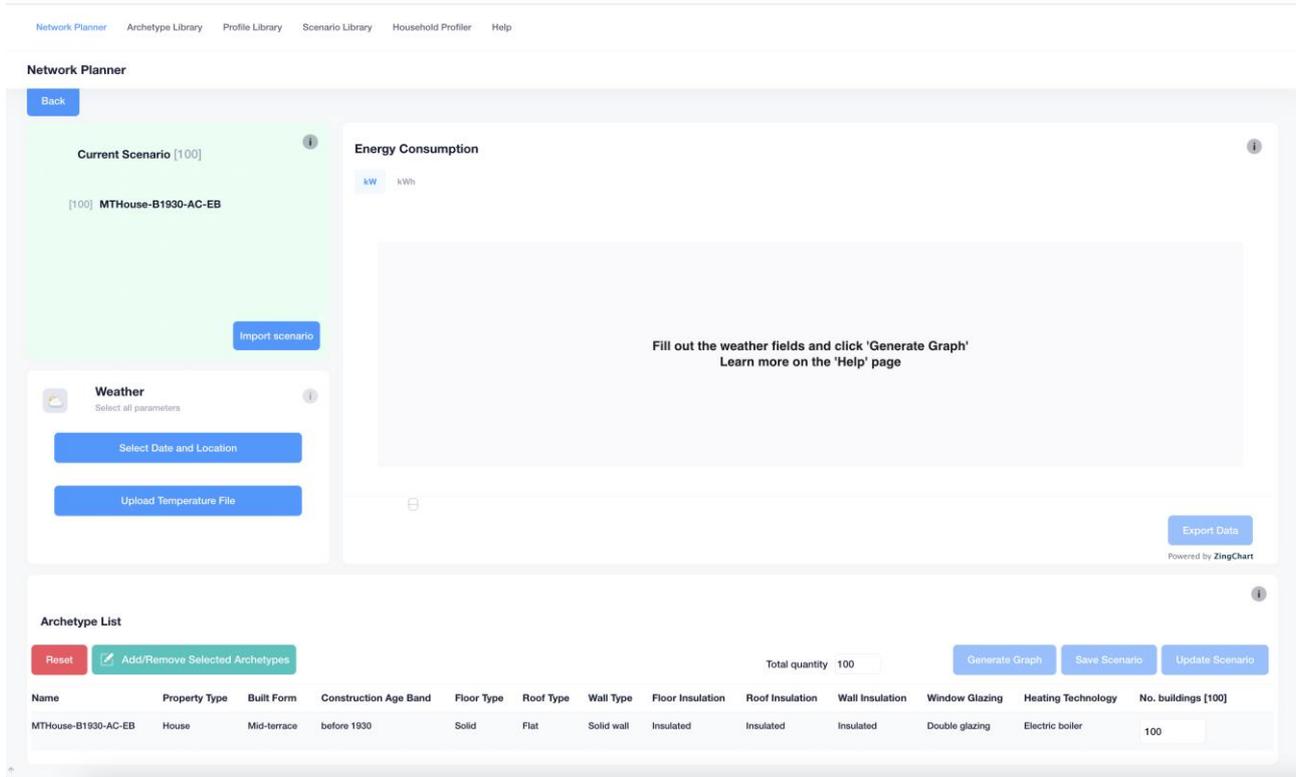
Figure 5. 'As built' : Final outcome of Archetype List UI

'As built':

- 'Add/Remove Selected Archetypes' button was added to edit/update the existing Scenario. Users can remove and add Archetypes to the existing Scenario and 'Update' the current Scenario or save it off as a new Scenario.

- The list shows each type of Archetype in the Scenario per row and the quantity of the Archetypes under the 'No. buildings' heading, allowing users to see and change the quanity of each Archetype.

- 'Reset' button added so a user can undo any changes and go back to the original loaded Scenario.

4.1.2. GIS input

'As built' - This is a proposed additional feature which has not yet been implemented in the DEFENDER project.

4.2.   Supporting data

The dataset which is distributed with the tool consists of:

1. **Archetype library**: a list of the archetype models that is used for the assignment of counts; these are created with the Household Profiler tool

2. **Weather / location data**: An hourly weather file based on data recorded from the nearest weather station to the metering point, the hourly data will be resampled to 30-minute data

4.2.1. Archetype library

The archetype library is common between the Household Profiler and the Network planner. It is a way to recall, tag and organise archetypes so they are easy to use in scenarios. It is also the only way to delete an archetype.

Sample weather data can be attached using a location assignment.

The hierarchy of the template used is also shown in the "Preset" column. It is envisaged that the hierarchy would be used to create a set of energy efficiency and heating technology possibilities for an archetype. The tagging would be used to indicate the changes made.
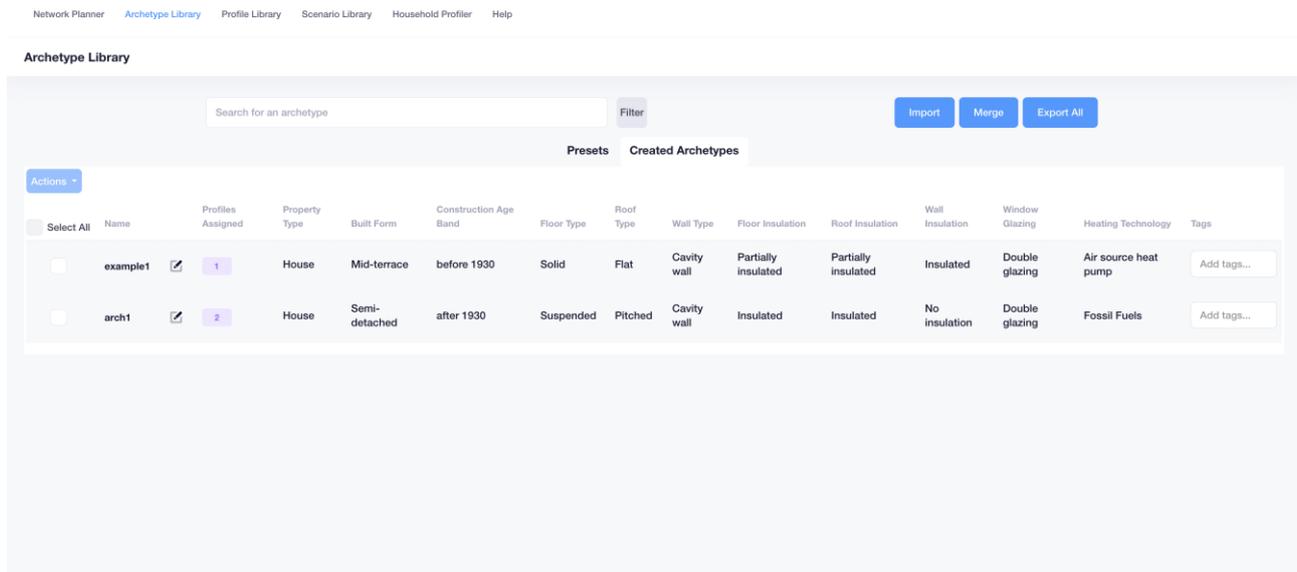
Figure 6. 'As built' Final UI of Archetype Library

'As built' Final outcome (Fig 6):

- The 'Archetype Library' and the 'Profile Library' are two separate Libraries/pages. The Archetype Library contains Archetypes which are Profiles without weather data. Presets were also added into the tool - they are pre-defined Archetypes and exist in the Archetype Library. Users can load Archetypes or Presets into the Household Profiler from the Library and create Profiles from them.

- Added functionalities of the Archetype Library:

    - Tab/section for 'Presets' which can't be deleted/edited

    - The ability to load Archetypes and Presets from the library into the Profiler tool so users have control of which Archetypes they want to create Profiles from in the Household Profiler.

    - Assign tags to multiple Archetypes at once. See Item 61, Appendix 3, D1.3-7 UAT report

    - The only way to export and import Archetypes into the tool is through the library. This is so the user can manage Archetypes in one place.
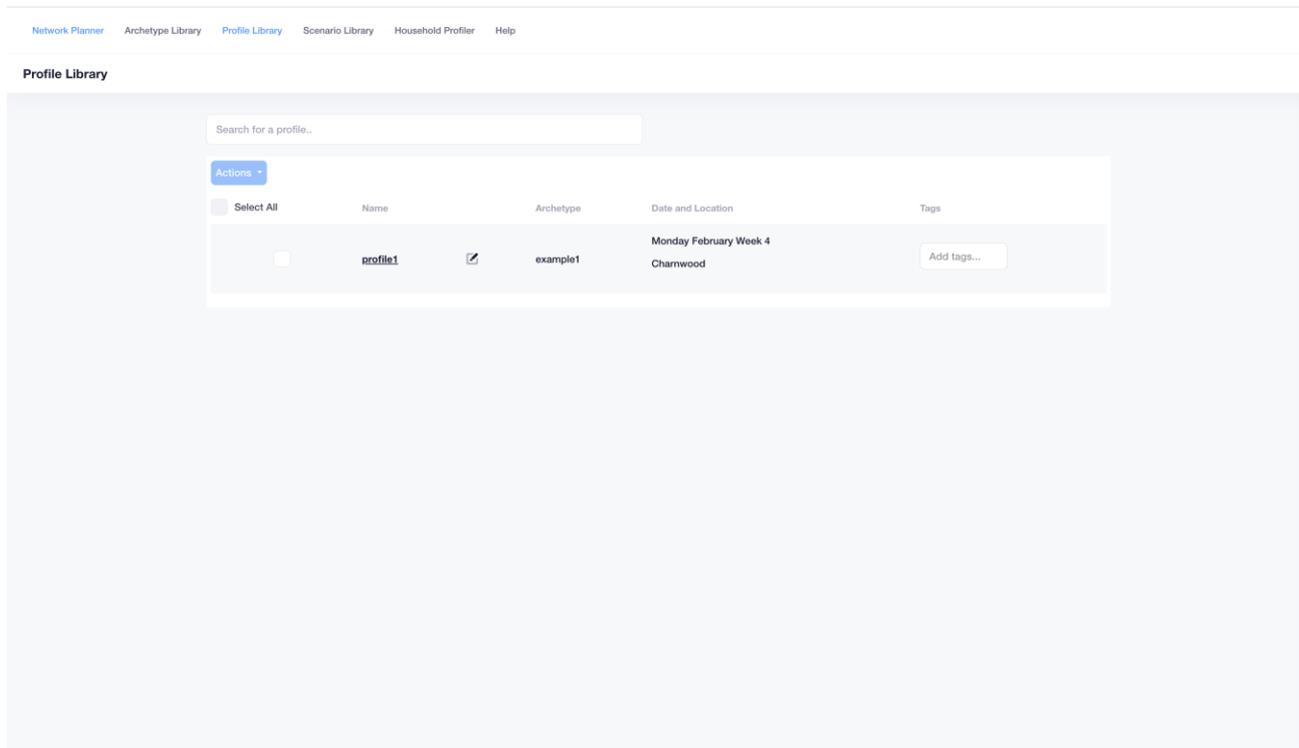
Figure 7. 'As built' : Profile Library

'As built' : Profile Library (Fig 7)

- This was added separately to manage Profiles.

- Profiles can be exported as a CSVs, renamed, loaded in the household profiler, have tags added and deleted from this library from the 'Actions' button. See Item 20, Appendix 3, D1.3-7 UAT report.

- Users can click the Profile name to open a pull-out which shows more information about the weather and the archetype associated with the profile. (Fig 8)
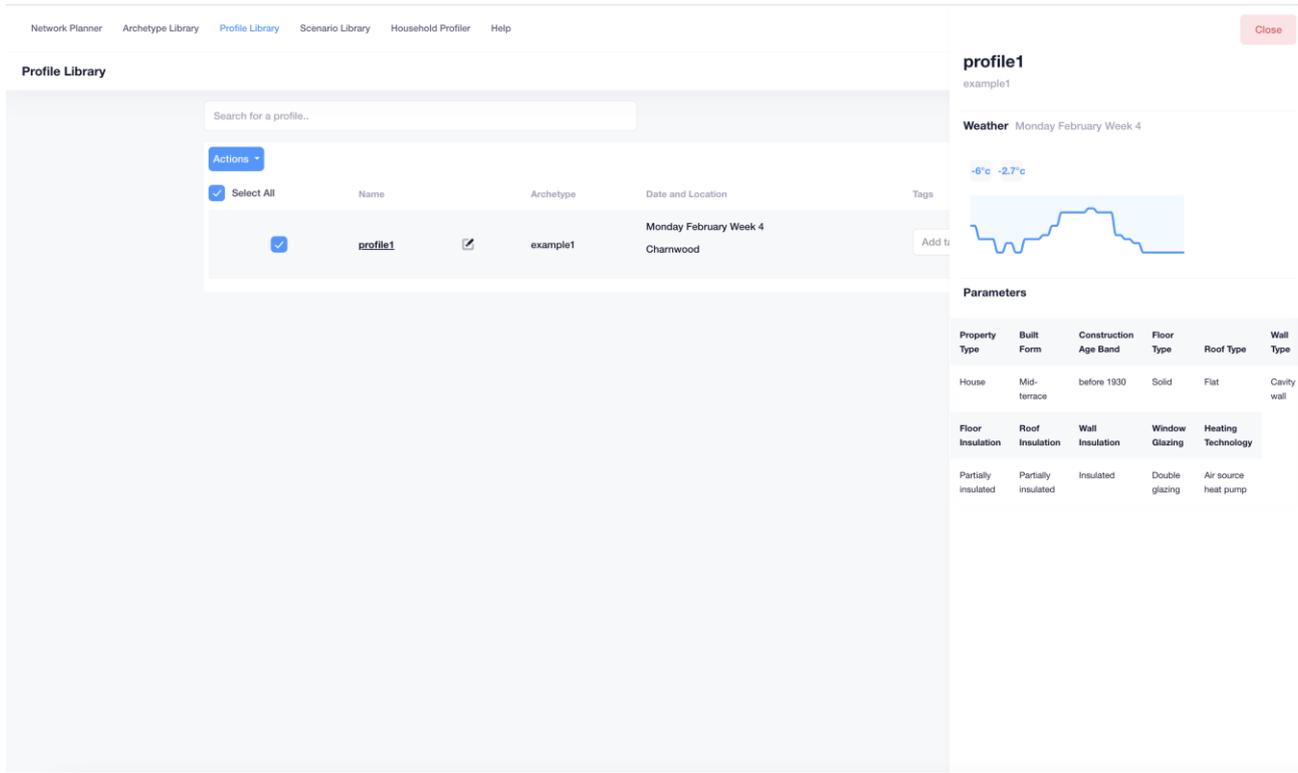
Figure 8. 'As built': Profile Library pull-out

4.2.2. Scenario Library - Saved Scenarios

Scenarios can be saved and viewed within the Scenario Library accessible from the Primary navigation. Limited editing of the scenarios, such as deleting or merging can be done to maintain a set of scenarios.

A detail pull-out is available showing the configuration parameters of the scenario, including archetype mix.
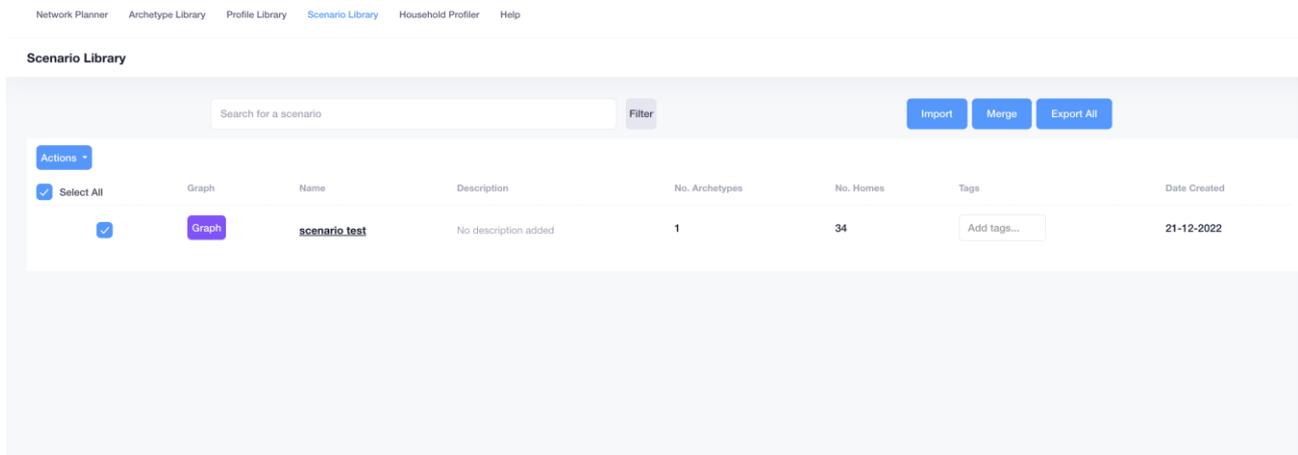
Figure 9. 'As built' Final UI: Scenario Library

'As built': Final outcome:

Added functionalities to the Scenario Library (Fig 9):

- Scenarios can be 'graphed' to the network planner from the library.
- Under the 'Actions' button, scenarios can be:
  - Exported as a JSON - see Item 46, Appendix 3, D1.3-7 UAT report

- Exported in Sincal format - see Item 35, Appendix 2, D1.3-7 UAT report

- Combined together to form one Scenario – easier to manage large Scenarios, single run instead of choosing individual Scenarios

- Mass assign tags - see Item 61, Appendix 3, D1.3-7 UAT report

- Generated to representative days – to keep the day of the week pattern between comparative years

Other additional features added to the scenario pull-out (Fig 10):

- Adding a year, author and description to a Scenario

- Rename a Scenario
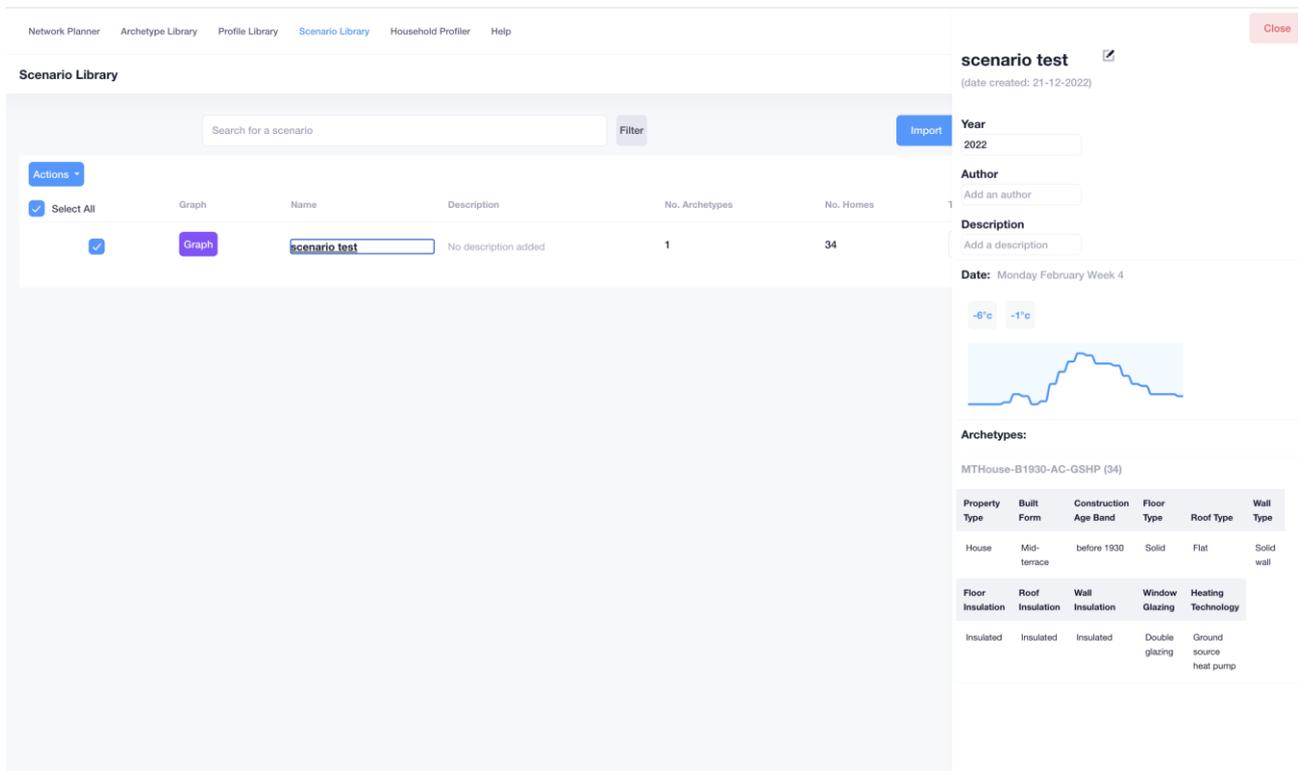
Figure 10.   **'As built' Final UI – Scenario Library pull-out**

5. Scenario outputs

An electricity consumption profile will be the main output with the ability to save a set of scenarios.

'As built'- Users can run a scenario in an extreme case of the worst weather using the Worst Case option when selecting weather.

In the simplest case the demand profile will look like:
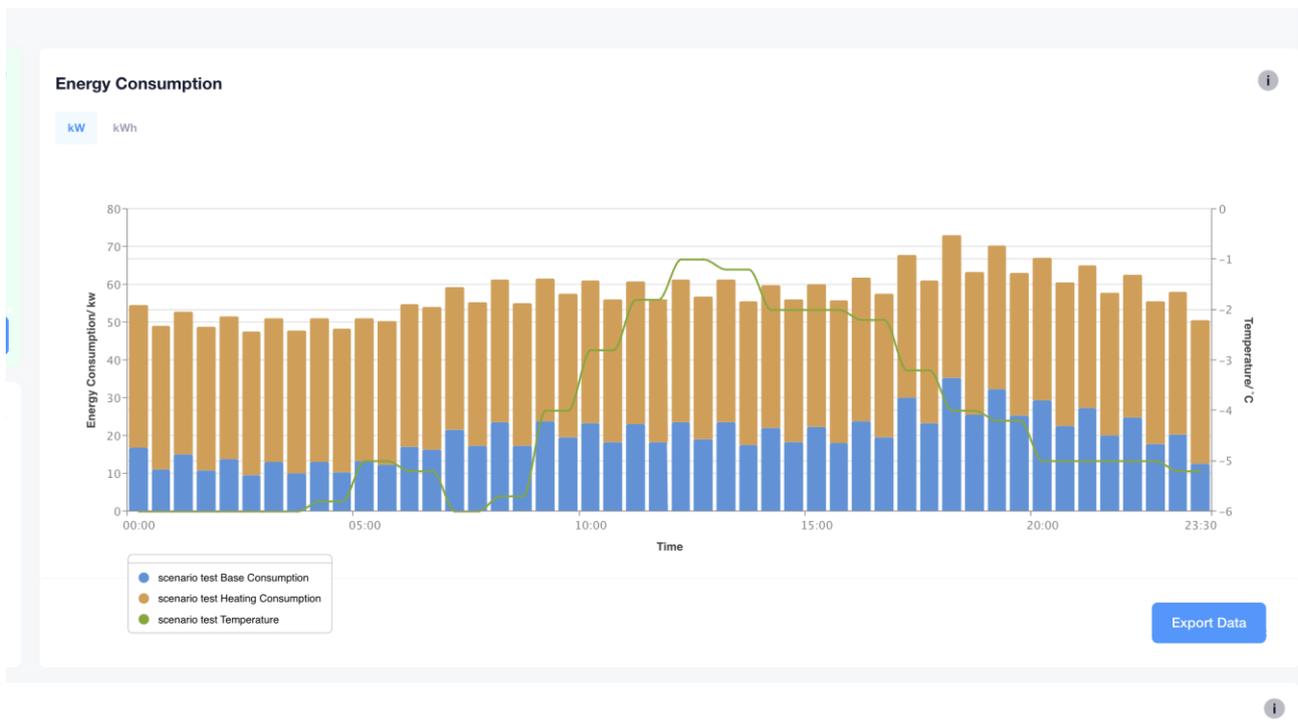
Figure 11. **'As built': Final outcome of Scenario outputs**

'As built': Final Scenario outputs (Fig 11)

- Base consumption and heating consumption is shown on the graph as well as temperature – an improvement we thought to show heating loads from the base loads.

- Hovering over the legend at the bottom allows the user to see the values of consumption.

'As built' : Final CSV output:

date,guid,name,consumption_type,units,00:00,00:30,01:00,01:30,02:00,02:30,03:00,03:30,04:00,04:30,05:00,05:30,06:00,06:30,07:00,07:30,08:00,08:30,09:00,09:30,10:00,10:30,11:00,11:30,12:00,12:30,13:00,13:30,14:00,14:30,15:00,15:30,16:00,16:30,17:00,17:30,18:00,18:30,19:00,19:30,20:00,20:30,21:00,21:30,22:00,22:30,23:00,23:30
Monday/Week 4/February, 21c001ad-9662-44ab-b574-9576f04c402f, scenario test, Base Consumption, kw,
16.580252742720255,11.474810947578563,14.782168056151637,11.065871787584626,13.603114634879006,10.021022439808853,
13.15847930733602,9.861839233239266,13.068134277001743,10.317197089092527,13.61480620739543,11.936807908619146,16.
928297624065582,16.606972029645142,21.77844625529301,17.36984939741684,23.566097997756817,17.000078242837333,23.81
595731674207,18.97244838791291,23.206176242176326,18.00062249399398,22.872275671207543,18.471927337247163,23.58798
4558570906,18.52480280489845,23.59441302696033,17.114707670850308,21.722106544065365,18.33695254775829,22.26879281
0256425,18.045309188707765,23.83631697064384,19.21168770635995,30.061206030614752,23.589140880253595,35.0278131522
25555,25.702787905532766,32.94922557235689,25.21557942560692,28.67390660733391,22.32141150156 9592,28.0777162243090
05,19.789528117099508,24.7526541055104,17.572161421890907,20.726122420618754,12.239804055825442
Monday/Week 4/February, 21c001ad-9662-44ab-b574-9576f04c402f, scenario test, Heating Consumption, kw,
37.923889335678915,37.923889335678915,37.923889335678915,37.923889335678915,37.923889335678915,37.923889335678915,
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Monday/Week 4/February, 21c001ad-9662-44ab-b574-9576f04c402f, scenario test Temperature, Temperature, C, -6,-6,-6,-6,-6,-6,-6,-6,-5.8,-5.8,-5,-5,-5.2,-5.2,-6,-6,-5.7,-5.7,-4,-4,-2.8,-2.8,-1.8,-1.8,-1,-1,-1.2,-1.2,-2,-2,-2,-2,-2.2,-2.2,-3.2,-3.2,-4,-4,-4.2,-4.2,-5,-5,-5,-5,-5,-5,-5.2,-5.2

Figure 12.   **'As built' : Sample export CSV file from a run of the network planning tool**

'As built':

- Base consumption, heating consumption and temperature on separate rows so data can be seen separately

5.1. Scenario - model mix for house archetypes

The tool will allow for the run of a scenario with the ability to name and save the archetype mix.

The detailed scenario parameters will be captured and saved. They can be loaded back into the tool as well. The file format is JSON and will have a structure that is an array of archetypes so that all the models in a "library" can be saved, shared and loaded.

```
[
        {
        "guid":"21c001ad-9662-44ab-b574-9576f04c402f",
        "description":"",
        "createdAt":"21-12-2022","
        totalHouses":34,
        "name":"scenario test",
        "weather":{
        "date":{
                "day":"Monday",
                "month":"February",
                "week":"Week 4"
        },"temperature":
                [-6,-6,-6,-6,-6,-6,-6,-6,-5.8,-5.8,-5,-5,-5.2,-5.2,-6,-6,-5.7,-5.7,-4,-4,-2.8,-2.8,-1.8,-1.8,-1,-1,-1.2,-1.2,-2,-2,-2,-2,-2.2,-
                2.2,-3.2,-3.2,-4,-4,-4.2,-4.2,-5,-5,-5,-5,-5,-5,-5.2,-5.2],
        "location":"Bath and North East Somerset"
        },
        "tags":[],
        "archetypes":
                [
                {"guid":"7f88819a-5eed-40ee-b613-3cb4d5058982",
                "name":"MTHouse-B1930-AC-GSHP",
                "house":{"propertyType":"House",
                        "builtForm":"Mid-terrace",
                        "constructionAgeBand":"before 1930",
                        "floorType":"Solid",
                        "roofType":"Flat",
                        "wallType":"Solid wall"},
                        "energyEfficiency":
                {
                        "floorInsulation":"Insulated",
                        "roofInsulation":"Insulated",
                        "wallInsulation":"Insulated",
                        "windowGlazing":"Double glazing"
                        },
                "heating":{
                        "heatingTechnology":"Ground source heat pump"},
                "models":[],
                "archetypes":[],
                "quantity":"34",
                "preset":true
                }],
        "author":"",
        "data":[],
        "year":"2022"
        }
```

]

Figure 13. **'As built' : Example scenario library file with saved archetype mix**

'As built' Final JSON output

- Extra keys added for author/date/year and whether the Archetype is a preset

6. System Interactions

The system interactions are driven from the user interface and chaining together the data flows to produce the output of energy profile data. Unlike client-server interactions the interactions will be between software modules that are implemented in application programming interfaces (APIs) between Javascript classes executing in the browser.

There is an interaction with the computer's local filesystem to save and load models and results.

Note, the Javascript classes for the model execution can be run through node.js in a server environment if a GUI is not required.

6.1. Scenarios

Scenarios can also be thought of as a collection of archetypes and a quantity representing the number of each archetype, along with the weather input that drive the generation of profile data. Options that are selected can be saved, along with the sample profile, so that different scenarios are formally defined.

The archetype area lists the archetypes and quantities that have been loaded from a senario.json file. When run, the scenario output is visualised on the profile graph.

6.1.1. Save scenarios

On saving the scenarios, a scenario.json file is created and a file dialogue is opened to save the scenario.json file on the user's local computer. The file is plain text and can be emailed, shared on a server or uploaded to a sharing platform like Github.

The last run of the data is saved as a profile object.

6.1.2. Load scenarios

After a scenario.json file has been created, it can be loaded back into the tool for the next session, or, if it has been shared, can be loaded by someone else. Once the scenario is loaded, it appears on the list in the Scenario library and in the main context.

The last run of the scenario data is loaded as well.

6.1.3. Create scenario

There are steps to create a scenario that start with the selection of an archetype library and then the assignment of quantities. A scenario can be saved with a name. The GUID would have been assigned from the "Generate" step after the archetype mix and weather assumptions were configured, but if this is the first interaction after setting the parameters.

Any changes are saved under the same GUID as updates until the user goes back to the upload archetypes step.

The name of the scenario is user definable; it does not need to be unique.

Note, changes to existing scenarios should be made in the Scenario Library.

```
Class Scenarios {
        public scenarios[] Scenario
        function add(),
        function remove(),
        function save(),
        function import(filename File)
}


Class Scenario {
        public guid GUID,
        public name String,
        public models Model,
        public weather Weather,
        function create(),
        function export()
}
```

6.2. Data

Profile data that is generated from the Scenario definition is shown in the graph user interface section. There is only one series show at any time. Changing quanities of archetype or changing weather parameters will then need a Generate button to be pressed to redraw the profile graph.

Once the "Create scenario" has occurred then the name of the scenario is taken on by the label.

To support the graph and series a set of Data objects, one Data object for each archetype, is summed in memory and bound to the graph. There is a reuse of the same data types from the Household Profiler.

```
Class Profile {
        public startdate Date,
        public demand[48] <Float>
}

Class Data {
        public model Model,
        public baselineProfile BaselineElectricity,
        public heatingProfile HeatingDemand,
        function profile() Profile, // add baseline and heating
        function export(),
        function import(filename File)
}
```

6.3. Weather

Weather class is used to hold the temperature assumptions for running the model. The location, date and stationId can be used to load data from historical sources. The populate method will get the data associated with the weather station for that day.

If using a file for populating temperatures, then the load method and a filename would be used.

The target object that will be populated is the temperature, that is a typed array of 48 values with a start date.

```
Class Weather {
    public date Date,
    public location Location,
    public temperature Profile,
    private stationId Enum, // ASOS weather station id
    function populate(), // populate the temperature from asos model
    function load(filename File), // load temperature profile from external file
}
```

7.Access and security

Since the tool will be launched from the Household Profiler menu, the Network Planner will be distributed within the same code base. Although it looks unusual, it is practically the best way to distribute the tool for use.

The tool will be open sourced and there is no restriction on use. Github will be the repository for release.

There are no security implications of the tool as there is no network element or wider system impact. The code is distributed as Javascript and will run within the browser's security.

Note: Python is not being used as there is not a way to execute Python browser side, therefore a Python source code with files would have to be supplied, with limited user interface capabilities. All libraries are self contained. The Javascript can be called from an API in addition to local execution. Javascript code will be open source and is source code by nature.

Access will be from opening an index.html within a folder. The folder will contain the following:

```
∨ 📁 householdprofiler
   > 📁 assets
     ⊙ index.html
   > 📁 js
```
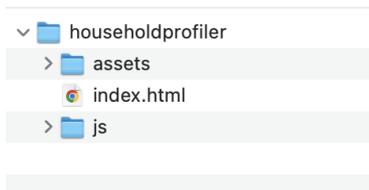
Figure 14.   **Directory structure of the files with the index.html as the launch file from the file system**

8. Software Modules

The software will run on browsers. Chrome and Edge will be the targets tested with Chrome used for development.

The following sections describe the software modules used.

8.1. Angular

A framework for coding single page applications that uses Typescript as the source language, transpiled into a distributable set of Javascript files. Metronic components will be used for page layout and selectors using metronic-ng. The compile settings in Angular will be for a single page. Tools for minification will be used. Asset and Javascript folders will contain the main code base.

8.2. Visual Components

The visual framework Metronic will be used. It has support for Angular Material, Bootstrap layout and amcharts. Line charts are the preferred visual when there are multiple series to compare.

8.3. Data Generation

Custom classes as shown above in Systems Interactions. Zebra library will be used for CSV exports. Amcharts used for visualisation.

8.4. Generative Models

WebPPL libraries will be used for sampling of the random variables. The probability distributions and parameters describing them will be done offline in PyMC3.

TensorflowJS may be used for matrix/vector manipulation with the added advantage it could be used for data generation in the future.

PyMC3 can be used to draw new samples, although the focus is on Javascript and Tensorflow is also supported within the Python.

8.5. Static Data

JSON flat files will be used for static model data such as reference values, weather, stationId lookups, etc.