User guide
for Carbon and Cost Reporting
VE Python tool

Zero Build

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Version 2.1

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Document protection

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Description	Owner	Category
Data analysis tool	Deepak Sadhwani	VE Python script package

Contents

1. Introduction

1.1 Purpose of the script

The Carbon and Cost Reporting VE Python Tool is designed to evaluate the environmental and economic performance of building energy use. It automatically calculates operational carbon emissions and energy costs across three key scenarios for one Apache Simulation file:

1. **Scenario 1**: conventional energy use without photovoltaic (PV) generation,
2. **Scenario 2:** enhanced efficiency through electricity generation with grid export,
3. **Scenario 3:** maximised self-consumption with electricity generation coupled with battery storage.

Key Features:

- Automatic calculation of operational carbon and energy costs.
- Evaluation across three scenarios: without PV, with PV and grid export, and with PV and battery storage.
- Incorporation of current UK greenhouse gas conversion factors and energy pricing.
- Intuitive interface for straightforward analysis and reporting.

1.2 Scope of this guide

This user guide covers the installation, configuration, and usage of the VE Python tool. It aims to assist sustainability leaders and their teams in efficiently utilising the tool for streamlined sense checks and quality assurance of dynamic simulation models.

2. Getting Started

2.1 Installing the script

[Follow the instructions] to install the tool by clicking on the link.

2.2 Apache simulation settings

This VE Python tool is designed to extract results from **Apace System** dynamic simulation files with hourly output. Apache HVAC is not yet supported. Verify that electricity generators are applied in the Apace Energy settings.

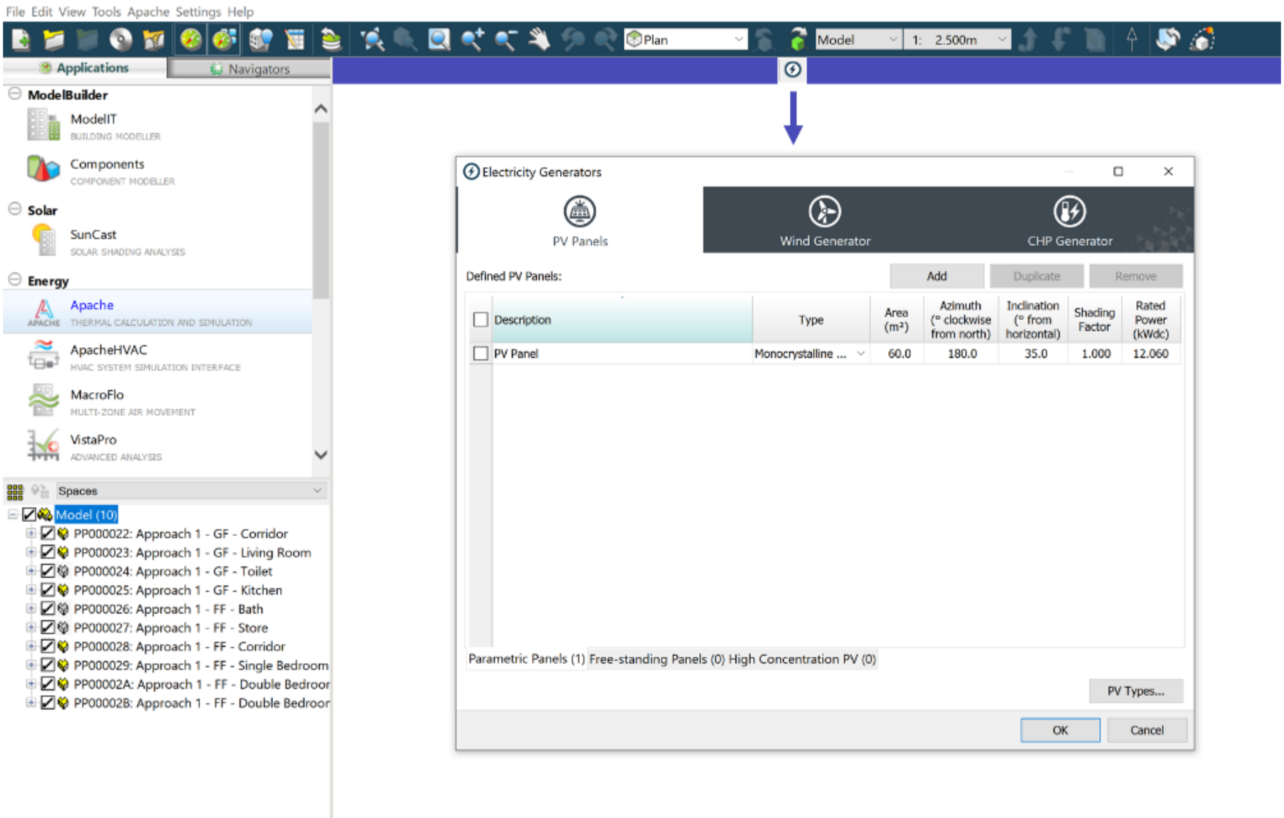

Figure 1. Energy generator settings

Refer to Figure 2 for ideal Apache Simulation settings to run the VE Python tool. Ensure that:

- **Simulation Time Step** is set to 30 minutes.
- **Reporting interval** is set to 60 minutes.
- Verify that all necessary model links are checked before running the simulation.

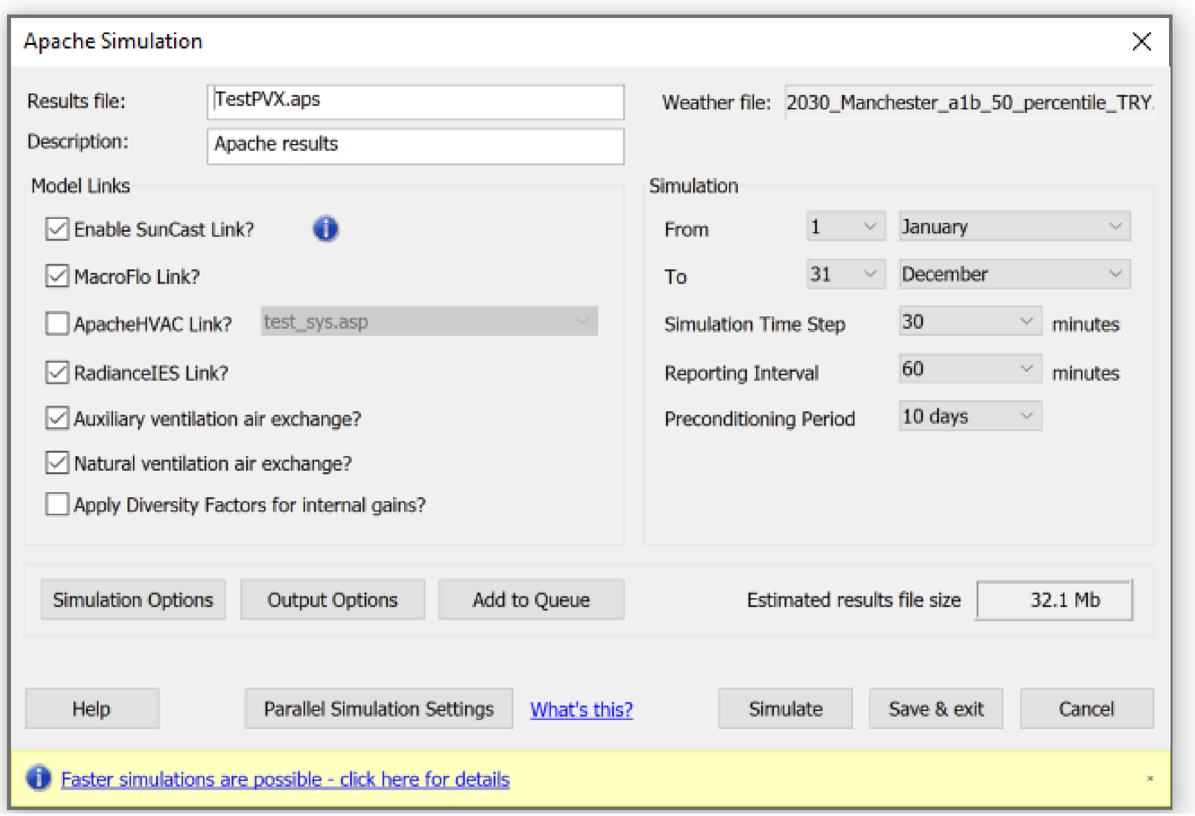

Figure 2. Ideal Apache simulation settings

2.3 Running the VE Python tool

This VE Python tool requires only the APS file from the Windows Explorer pop-up window. In some cases, you may need to navigate to the **vista** folder of your project file.

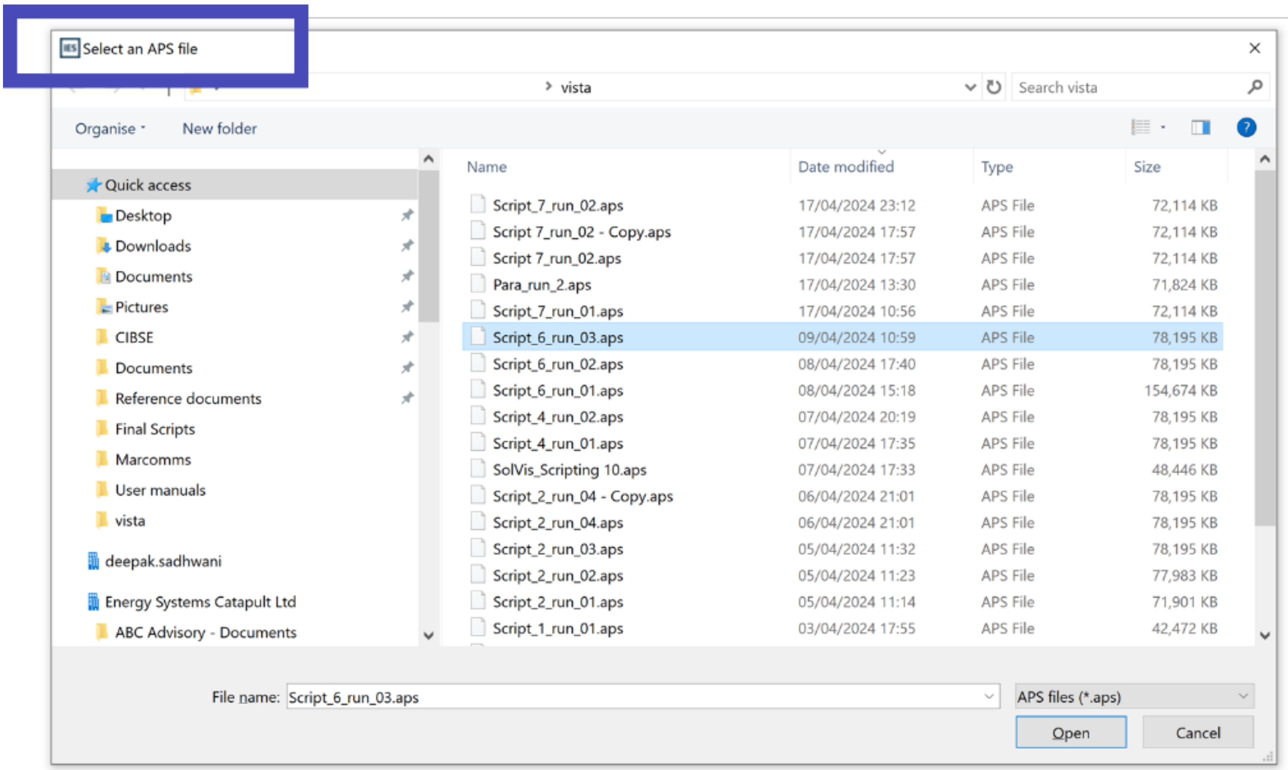

Figure 3. Select an APS file

3. Methodology

This VE Python tool exports an MS Excel worksheet to the same folder as your APS file. The tool employs a systematic approach to estimate operational carbon and cost across three scenarios, ensuring precise and reliable results.

1. **Input Data Definition:**

- Define the carbon conversion factors for gas and electricity, as well as the relevant energy prices.

2. **Data Extraction:**

- Extract total gas and electricity consumption and potential on-site PV generation from the Apache simulation file.
- Use this data to calculate daily and hourly energy balances.

3. **Scenario 1 - Conventional Energy Use:**

- Assume the building operates without any electricity generators.
- Multiply the gas and electricity consumption by the defined conversion factors and energy prices to calculate operational carbon emissions and costs.

4. **Scenario 2 - Enhanced Efficiency with PV Generation:**

- Estimate grid export when the hourly energy balance is negative (i.e., surplus energy is generated) and grid import when the energy balance is positive (i.e., energy is needed).
- Use a portion of the on-site generation to meet the building's energy needs when surplus energy is available.
- Calculate the potential for self-utilisation by subtracting the total grid import from the total electricity consumption.
- Multiply the total grid import and export by the conversion factors and energy prices. Calculate self-utilisation carbon savings by multiplying the self-utilised energy by the carbon conversion factors.

5. **Scenario 3 - Maximised Self-Consumption with Battery Storage:**

- Follow the IET Code of Practice for electrical energy storage systems.
- Calculate the daily energy balance and determine the effective battery capacity as the 75th percentile of all weekends with positive energy balance.
- Model the battery with a maximum charge rate of 5 kWh, a maximum discharge rate of 10 kWh, and a round-trip efficiency of 90%. Assume the initial battery state of charge is zero.
- For each hour, calculate the energy balance. When surplus energy is available, determine the charge energy as the minimum of:
    A. Energy balance for the hour multiplied by the round-trip efficiency.
    B. Maximum charge rate.
    C. Effective battery capacity minus the current battery state of charge.

- Update the battery state of charge by adding the charge energy of the previous hour.
- Calculate grid export using the formula:

$$\text{Grid export for the hour} = \frac{\text{Energy balance} - \text{Charge energy}}{\text{Round-trip efficiency}}$$

- When the energy balance is negative, determine the discharge energy as the minimum of:
- Energy balance for the hour divided by the round-trip efficiency.
- Maximum discharge rate.
- Current battery state of charge.
- Update the battery state of charge by subtracting the discharge energy for the hour.
- Calculate grid import using the formula:

$$\text{Grid import for the hour} = (\text{Energy balance} - \text{Discharge energy}) \times \text{Round-trip efficiency}$$

- Calculate the potential for self-utilisation by subtracting the total grid import from the total electricity consumption.
- Multiply the total grid import and export by the conversion factors and energy prices. Calculate self-utilisation carbon savings by multiplying the self-utilised energy by the carbon conversion factors.
- Determine the battery nominal capacity using the methodology from Chatzivasileiadi, Ampatzi, and Knight (2022).

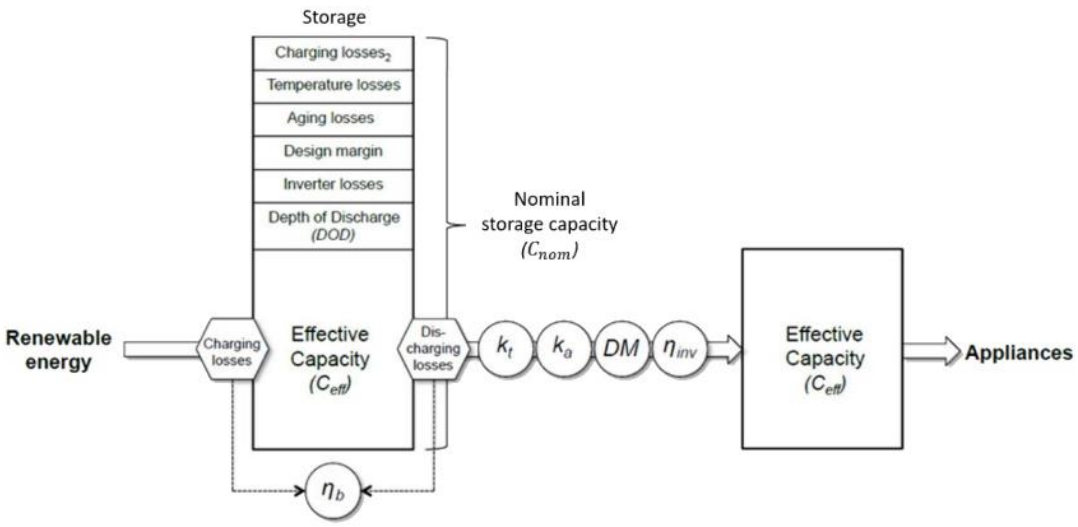

Figure 4. Nominal battery capacity calculation. Source: Chatzivasileiadi, A., Ampatzi, E. and Knight, I.P., 2022. Electrical Energy Storage Sizing and Space Requirements for Sub-Daily Autonomy in Residential Buildings. Energies, 15(3), p.1145.

6. Results Visualization:

- Generate a comparative visualisation of operational carbon emissions (measured in kgCO2e) (left axis) and operational costs (measured in GBP) (right axis) across the three scenarios.

4. Outputs

Figure 5 shows how the output excel file looks like.

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Operational carbon and cost

The tool analyses and compares the environmental and economic impacts of energy use within buildings across three scenarios.

Scenario 1: No PV generation

Calculates operational carbon and cost without considering PV generation, relying only on grid.

Scenario 2: PV with grid export

Considers PV generation and includes calculations for exported energy back to the grid.

Scenario 3: PV with battery storage

Maximising self consumption and adjusting grid import by storing surplus energy in a battery system.

APS File Script_6_run_02.aps
Weather 2030_Manchester_a1b_50_percentile_TRY.epw

Simulation results	Units	Energy
Gas consumption	kWh	0
Electricity consumption	kWh	5705
Potential on-site PV generation	kWh	-5107

Metrics	Units	Scenario 1	Scenario 2	Scenario 3
Grid import	kWh	5705	3961	2314
Generation self utilisation	kWh	0	1743	3390
Grid export	kWh	0	-3364	-1330
Operational carbon gas	kgCO2e	0	0	0
Operational carbon grid import	kgCO2e	1284	891	521
Operational carbon savings	kgCO2e	0	-392	-763
Total Operational carbon	kgCO2e	1284	499	-242
Operational cost gas	GBP	0	0	0
Operational cost electricity	GBP	1617	1190	786
Operational cost grid export	GBP	0	-505	-200
Total Operational cost	GBP	1617	685	587

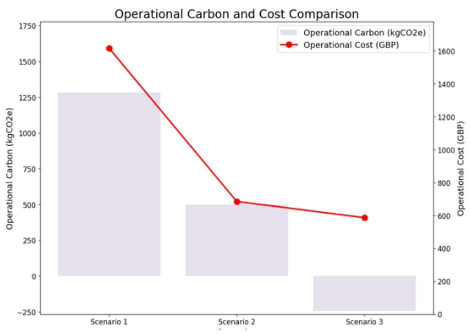

Figure 5. Example of output worksheet

Figure 6 shows the table with all the results for the three scenarios.

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Weather 2030_Manchester_a1b_50_percentile_TRY.epw

Simulation results	Units	Energy
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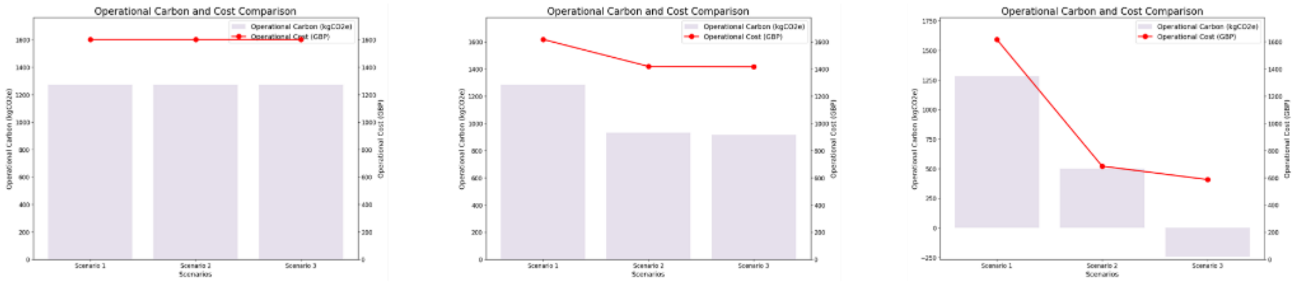
Operational cost electricity	GBP	1617	1190	786
Operational cost grid export	GBP	0	-505	-200
Total Operational cost	GBP	1617	685	587
Nominal battery capacity	kWh	24		

Figure 6. Operational carbon and cost results

It is important to model electricity generators in the model.

Figure 7(a) shows the data visualisation when no PV is modelled, (b) where a low capacity PV array is modelled and (c) where high PV capacity is modelled.



(a) Output when no PV is modelled

(b) Output when with low PV capacity

(c) Output when with high PV capacity

Figure 7. Different types of outputs based on user-input data on electricity generators.

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