Unlocking MG for sustainable development

5.2 Homer PRO

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CONTENTS

1. INTRODUCTION

Introduction to Homer Pro

Homer Pro software allows to modelize and simulate energy system with a variety of technologies and configurations. It is extremely populat in the off-grid sector and often used by consultant, developers and organization to size and optimize the system components and simulate key technical and financial parameters to use during different types of assessment.

Brief history

- Technical and economic optimisation tool for microgrids
- Originally developed in NREL by Dr. Peter Lilienthal
- Commercialised in 2009 under Homer Energy LLC

Characteristics

- On-paid basis
- Basic module and advanced modules purchased separately
- There are options for individual PC or concurrent license
- The basic support given is ~3 days or acquiring premium support gives 24-h guarantee time

- **Basic components**: controller, generator, PV, wind, storage, converter, hydrokinetic, grid
- **Advanced modules**: biomass, hydro, CHP, advanced load, advanced grid, hydrogen, advanced storage, multi-year, MATLAB Link
- **Different configurations**: autonomous such as AC/DC-coupled, diesel as backup or baseload (fuel save type), grid-connected projects
- **Library**: large build-in library of components but one can import components using a data sheet
- **Projects**: For new systems (greenfield) or retrofitting existing systems (brownfield)
- **Results**: Graphs, tables, techno-economic KPIs (COE, NPC, RE fraction, autonomy, etc)
- **Optimisation indicators**: By default Homer minimises the net present cost (NPC) of the project

2. FUNDAMENTALS OF SIZING AND OPTIMIZATION

Fundamentals of sizing and optimisation

1. Optimisation

It is essential to have the optimisation objective clear

2. Inputs

Prepare well the inputs:

- Demand profile (current and future)
- Costs
- RE resources
- Other inputs

3. Outputs

It is very important to understanding the results:

- Indicators
- Graphs

Optimisation objective

Fundamental decision, before starting:

What is the optimisation objective that mostly matters for this specific project?

Why?

To avoid under- or over-sizing the plants, resulting to mismatch between demand and generation

Examples of objectives:

1. Economic indicators
    - *Minimise LCOE*
    - *Minimise CAPEX*
    - *Minimise OPEX*
2. Technical indicators
    - *Maximise resilience,*
    - *Maximise autonomy*
    - *Maximise RE fraction*
    - *Eliminate capacity shortage or sacrifice some kWh in order to minimise CAPEX*
3. Environmental indicators
    - *Minimise emissions*

Optimisation objective

What does it depend on?

1. Financing mechanisms:
   - Grants can allow oversizing,
   - Equity/debt may require minimising CAPEX,
   - Results-based finance (RBF) may require maximum energy sold from year 1
   - Green funds may require 0 emissions
2. Tariffs:
   - Cost reflective versus uniform/regulated.
   - Some regulators may “force” developers to sell all energy immediately with modular systems and then upgrade to follow demand.
   - Are they revised periodically or are they fixed for the rest of the lifetime?
3. Other regulations:
   - Service level allowed/require.
   - Does the operator allow for diesel off?
4. Demand uncertainty:
   - A brownfield project that can have already a load profile and growth estimation
   - A greenfield project is more uncertain
5. Location:
   - Remoteness and difficulty to access

3. INPUTS

Inputs

Load Profile

1. The load in Homer is not the demand but the generation, so distribution losses should be considered: 5% for Low Voltage or transformer losses for Medium Voltage lines
2. We should consider an utilization factor for the demand (example: 85%)
3. There are "by default" profiles that can be used when no information is provided
4. Hour variations can be applied; should be minimal for residential load profiles (5% variability)
5. Homer allows different weekday and weekend load profiles
6. There is the option to consider future growth in the multi-year advanced module
7. Loads can be selected as AC or DC.

Excel for load analysis.

Inputs

Costs

1. Capital and replacement unit costs for each component
2. For hybrid mini-grids:
   - System fixed capital costs (USD)
   - PV (USD/kWp)
   - Hydro Turbine (USD/turbine)
   - Converter (USD/kW)
   - Batteries (USD/unit)
   - Controller (USD)
   - Generator (USD/kW)
3. All costs should be under the same conditions (EXW, DDP, installed costs…)
4. Diesel costs on site

Inputs

Operational expenses per component

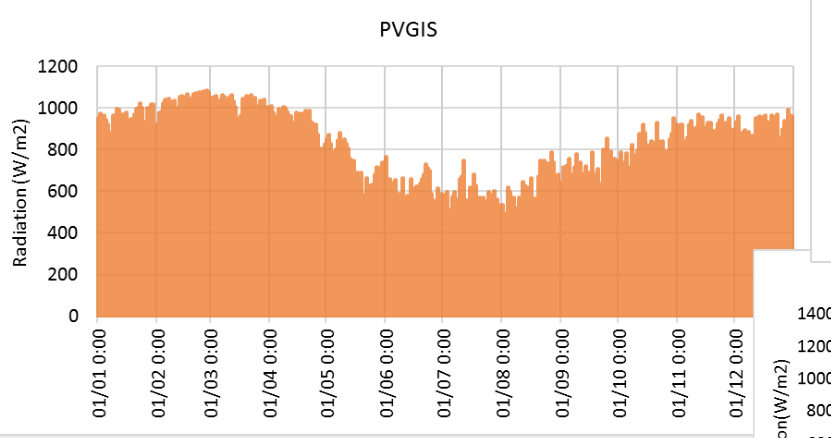
1. System fixed O&M costs (USD/year): salaries, insurances, admin costs, etc..
2. PV generator (USD/kWp/year): minimum, including module cleaning, usually done by O&M staff
3. Hydro generators (USD/yr): small, related to greasing and replacement of bearings.
4. Converter (USD/kW/year): low capacity converters do not have any important O&M costs however high-capacity ones do and are usually quoted from the manufacturer, but can be included in the battery component (example: TESLA)
5. Batteries (USD/unit/year): O&M costs depend on technology;
   - Valve-regulated Lead-acid (GEL, OPzV) = 0,
   - Open-valved Lead-acid = add distilled water
   - Lithium-ion is according to manufacturer.
6. Back-up Generator (USD/hour of operation): Cost of scheduled maintenance (oil, filters, overhauls...). It does not include fuel cost – this is computed separately

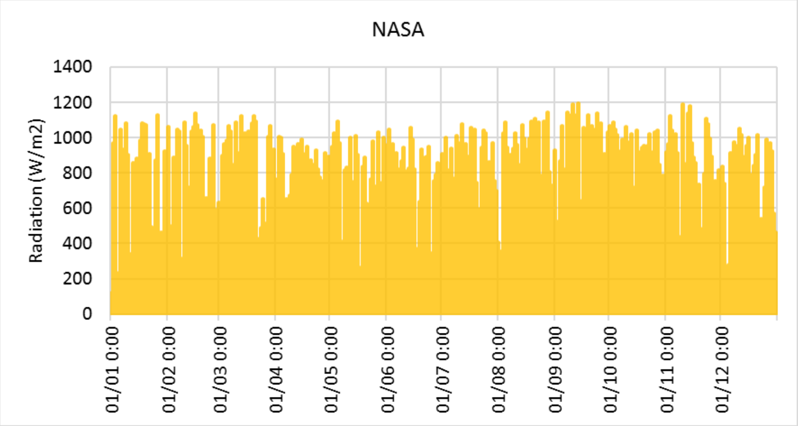
Inputs

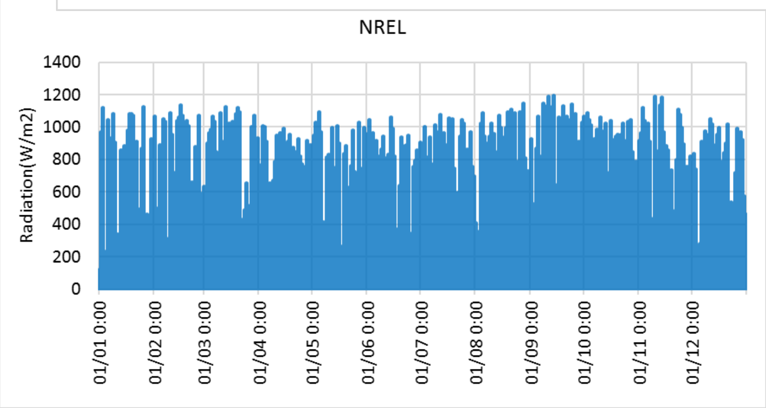
Resources - Solar radiation and renewable energy (wind, hydro, etc)

Solar Radiation

Sources: NREL, NASA, PVGIS-SARAH





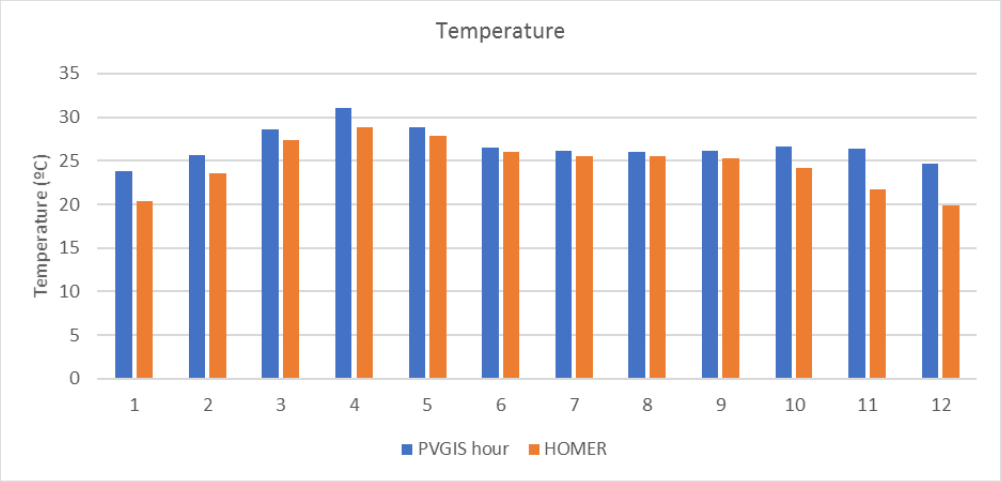


Inputs

Resources - Temperature

Why consider temperature?

- PV module performance varies depending on temperature, it can be seen in the technical specification of the modules.
- The temperature can be selected by different sources such as PVGIS or databases included in HOMER



Inputs

Financials

Input	Definition	Example
Discount rate	Discount rate used to annualize costs	12,5%
Inflation rate	Inflation rate of the country, used to estimate future costs	7%
Project lifetime	Economic lifetime of project	15 years
Capacity shortage penalty	Penalty for each kWh failed to supply	5 USD/kWh/year

Inputs

Constraints

Input	Definition	Example
Maximum anual capacity shortage	Maximum percentage of total demand allowed to not be met by the system	0% (by default)
Minimum renewable fraction	Minimum the fraction of the energy delivered to the load that originated from renewable power sources	0% (by default)
Load in current time step	The spare capacity reserved to serve a sudden increase of the load, in each time step	10% (by default) Not common in residential grids
Annual peak load	The spare capacity reserved to serve a sudden increase of the annual peak load, in each time step	0% (by default) Not common in residential grids
Solar power load	The spare capacity reserved to serve the load assuming a sudden decrease of the PV array output	80% (by default) Common where clouding effect occurs
Wind power load	The spare capacity reserved to serve the load assuming a sudden decrease of the wind output	50% (by default)

Inputs

System components

1. Select the components that characterize your desired system
2. Input technical parameters and costing for each componet
3. Configure the system

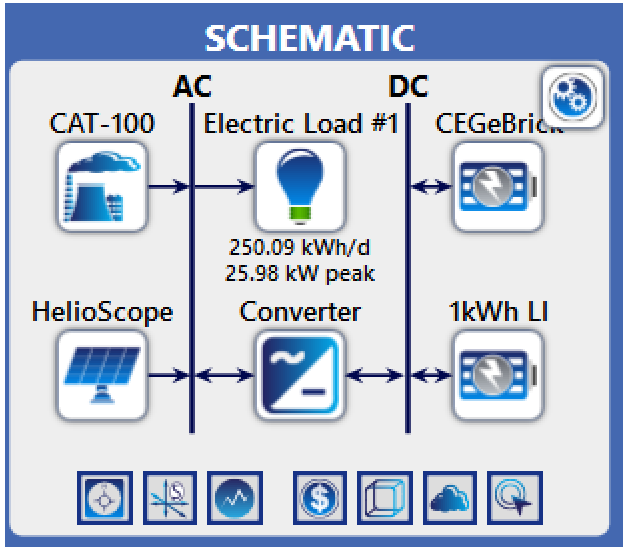
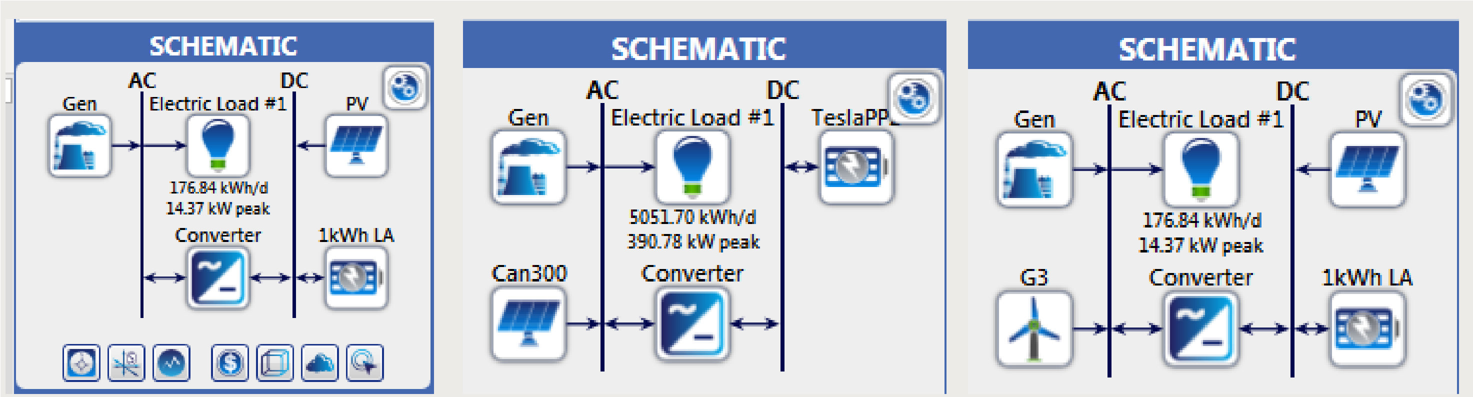


Figure. configuration schematic

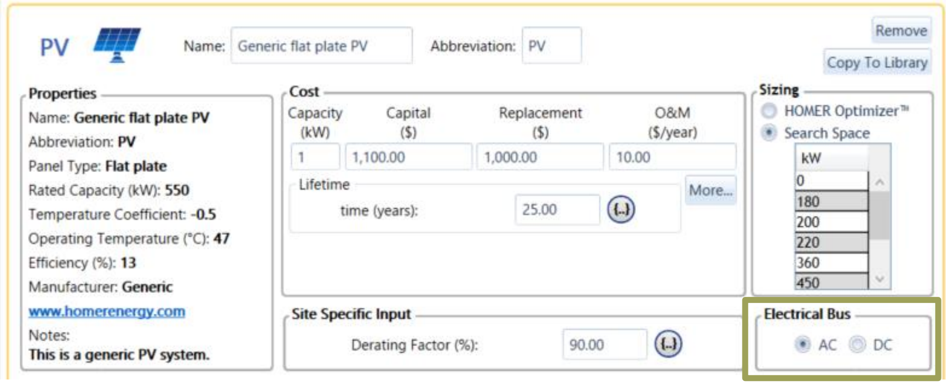
Figure. Potential components

Potential configurations



DC Coupled AC Coupled Hybrid Coupled

Example



Outputs

Optimisation is done by minimising net present cost (USD):

- Is the present value of all system costs

Levelized cost of energy (USD/kWh):

- It is the net present cost over total energy produced over the project lifetime
- It is an indicator used to compare different electrification options to supply the same amount of energy

Operating costs (USD/year):

- It is the annualised costs of operation
- It does not consider capital costs

Renewable energy fraction (%):

- Corresponds to the total renewable energy production over total load served

Autonomy (days):

- Is the days of autonomy offered by the batteries in case there is no source of generation

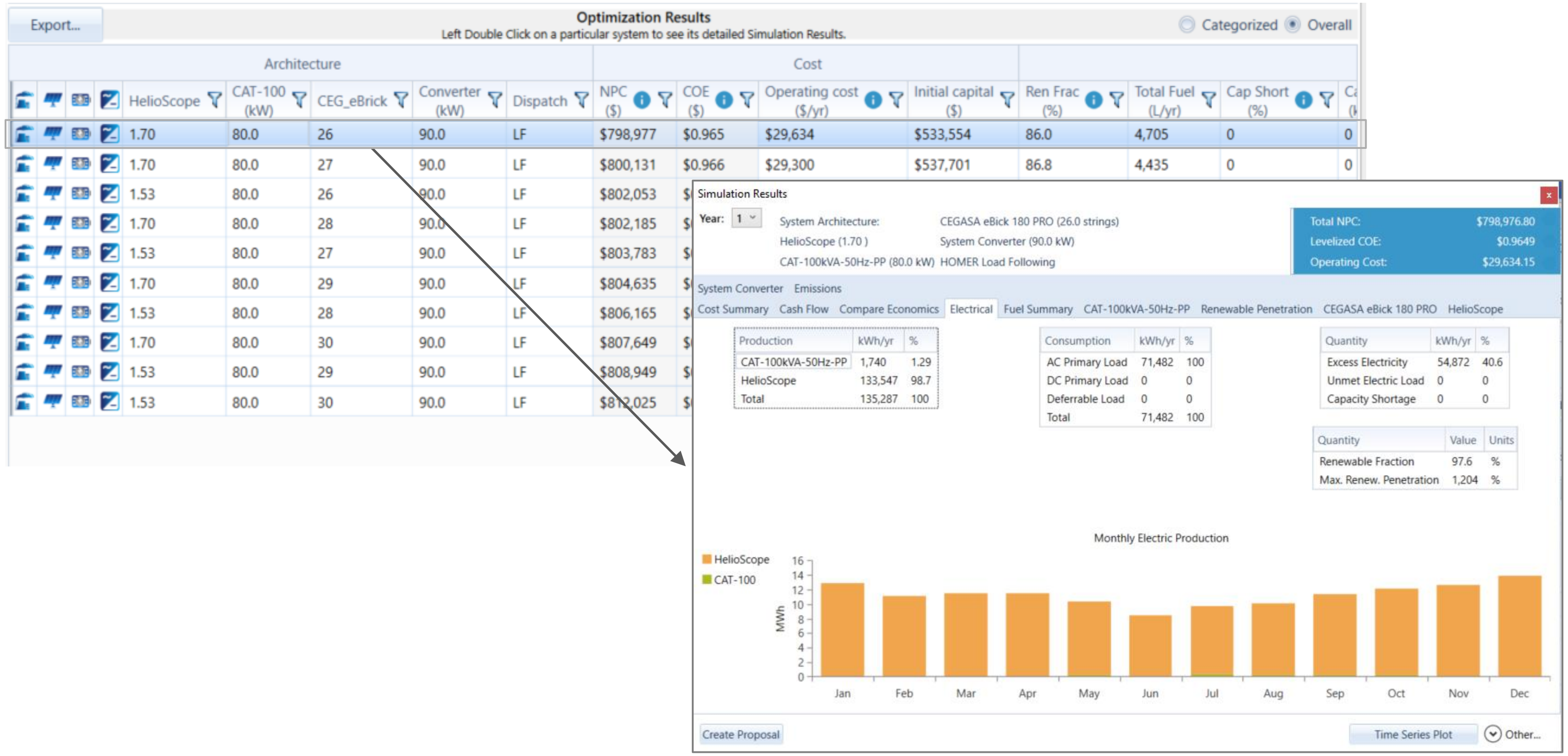
Excess Electricity (% or kWh):

- Corresponds to the energy produced but not consumed by the system. (i.e. PV curtailment)

These system parameters are complemented by the results obtained for each component.
i.e. for a diesel generator, Homer will provide Operational hours, fuel consumption, generation, etc.

4. OUTPUTS

Outputs



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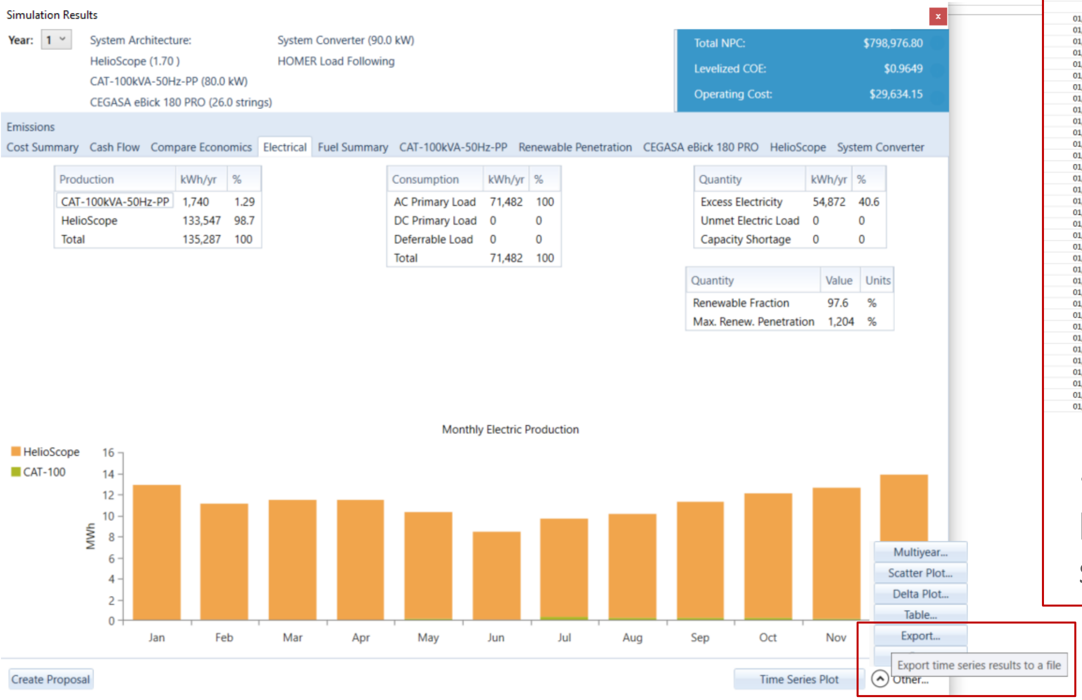
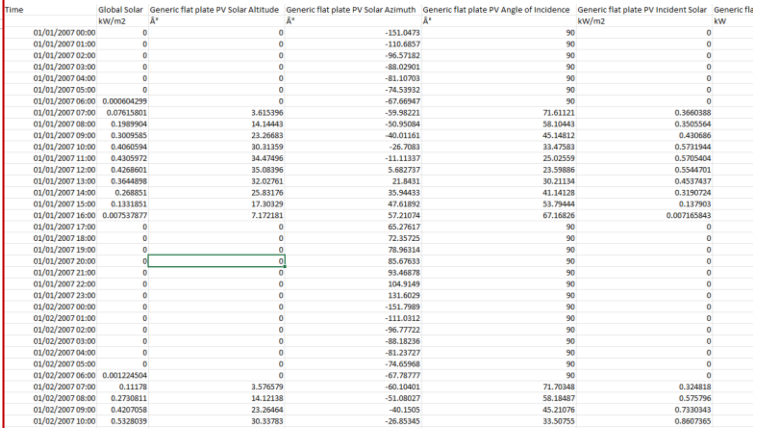
Outputs





.csv file with 8760 rows, providing hourly results of the simulation for year 1.

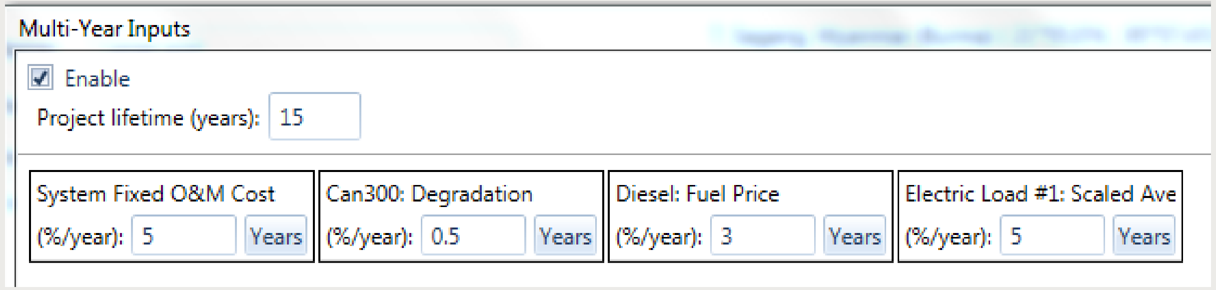
5. ADVANCED SIMULATIONS

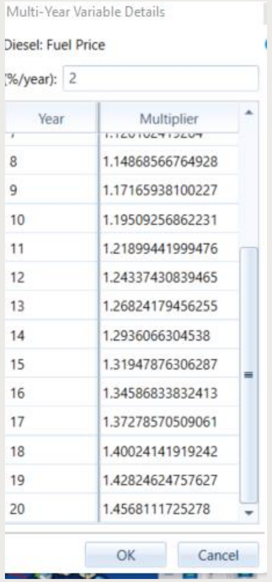
Advanced Simulations - The multi-year module

It simulates the system performance and behavior for each year of the project lifetime, taking into consideration the evolution in time of some key parameters.

The module applies a linear *multiplier* for future values on the value of year 1 corresponding to:

- System fixed O&M costs
- PV degradation
- Diesel fuel price
- Electric load





Year	Multiplier
8	1.14868566764928
9	1.17165938100227
10	1.19509256862231
11	1.21899441999476
12	1.24337430839465
13	1.26824179456255
14	1.2936066304538
15	1.31947876306287
16	1.34586833832413
17	1.37278570509061
18	1.40024141919242
19	1.42824624757627
20	1.4568111725278

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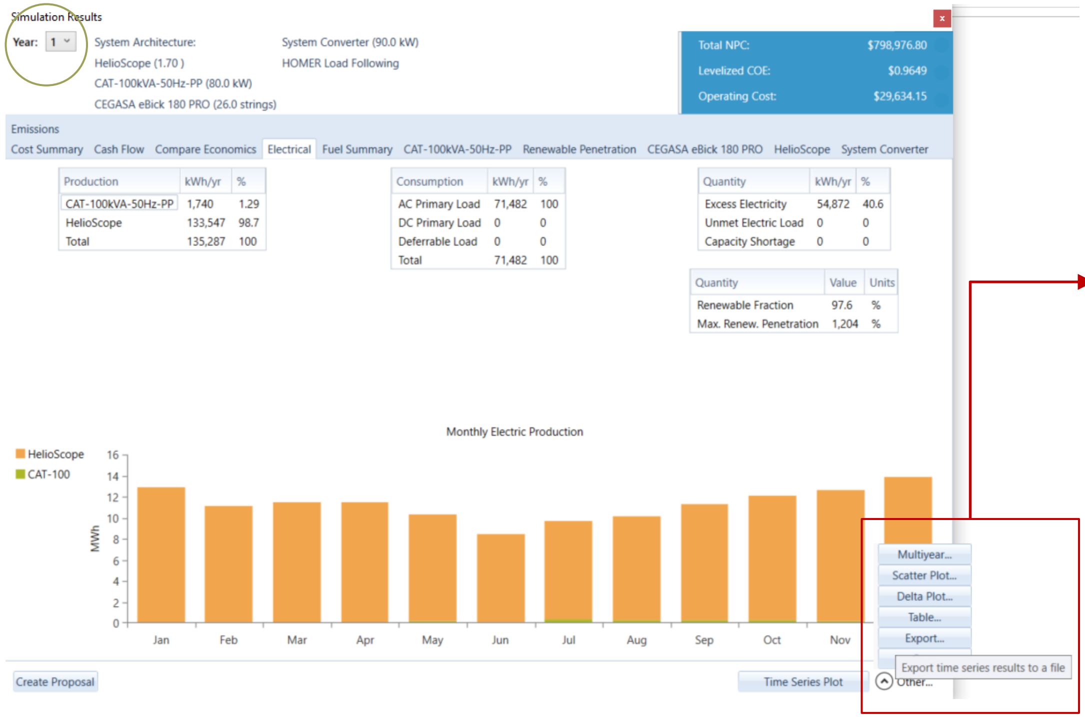
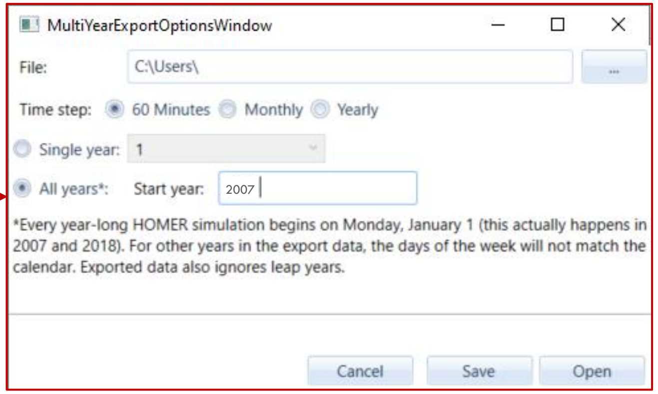
Advanced Simulations - The multi-year module

Navigate through the years of simulations





Possibility to select different formats for multi-year export:

- Hourly results
- Monthly
- Yearly

Advanced Simulations - The multi-year module

It provides yearly values for relevant system/component parameters.

Quantitative estimation throughtout the project lifetime of demand, generation sources, operational expenses, etc.

Demand for each year of operation of the project. It evolves according to multi-year multiplier

Electric Load #1: Scaled Average

(%/year):

Year	Multiplier
1	1
2	1.060
3	1.125
4	1.193
5	1.246
6	1.302
7	1.361
8	1.422
9	1.486
10	1.553
11	1.553
12	1.553
13	1.553

Year 1
Year 2
Year 3
...

Y25
End of the project

	A	B	C	D	E	F	G
1	Time	AC Primary Load Served	Total Consumption/Sales	Renewable fraction	Excess electricity	Excess electricity percent	Maximum renewable penetration
2		kWh/year	kWh/year	%	kWh/year	%	%
3	01/01/2007 00:00	63491.75	63491.75	0.993	62651.99198	0.467597	1319.768146
4	01/01/2008 00:00	67301.255	67301.255	0.99	57572.48378	0.431926	1236.348839
5	01/01/2009 00:00	71428.21875	71428.21875	0.985	52356.14481	0.394474	1156.760943
6	01/01/2010 00:00	75745.65775	75745.65775	0.976	47341.55852	0.357127	1083.190753
7	01/01/2011 00:00	79110.7205	79110.7205	0.965	43646.85934	0.329194	1029.856214
8	01/01/2012 00:00	82666.2585	82666.2585	0.954	39878.3639	0.300474	978.662394
9	01/01/2013 00:00	86412.27175	86412.27175	0.941	36178.61526	0.271743	929.683253
10	01/01/2014 00:00	90285.2685	90285.2685	0.926	32628.91086	0.243901	883.57371
11	01/01/2015 00:00	94348.7405	94348.7405	0.911	29138.16351	0.216395	839.600755
12	01/01/2016 00:00	98602.68775	98602.68775	0.892	25977.8928	0.190992	797.754794
13	01/01/2017 00:00	98602.68775	98602.68775	0.89	25307.58486	0.186984	792.170511
14	01/01/2018 00:00	98602.68775	98602.68775	0.887	24769.08918	0.183793	786.625317
15	01/01/2019 00:00	98602.68775	98602.68775	0.885	24109.06694	0.179843	781.11894
16	01/01/2020 00:00	98602.68775	98602.68775	0.884	23378.87214	0.175361	775.651107
17	01/01/2021 00:00	98602.68775	98602.68775	0.882	22762.06615	0.171521	770.22155
18	01/01/2022 00:00	98602.68775	98602.68775	0.879	22224.25355	0.168182	764.829999
19	01/01/2023 00:00	98602.68775	98602.68775	0.877	21578.80246	0.16412	759.476189
20	01/01/2024 00:00	98602.68775	98602.68775	0.876	20917.72469	0.159966	754.159855
21	01/01/2025 00:00	98602.68775	98602.68775	0.873	20324.52315	0.156152	748.880736
22	01/01/2026 00:00	98602.68775	98602.68775	0.871	19727.32482	0.152249	743.638571
23							

Advanced Simulations - The multi-year module

Homer Results

- *Estimated Demand (kWh/year)*
- *Renewable fraction (%)*
- *Diesel consumption (L/year)*
- *OPEX (USD/year)*
- *Estimated Sales (USD/year)*
- *Estimated CO2 emissions*

→ Inform Project financial assesment and Tariff Calculations

6. CASE STUDIES

Case Studies

1. Off-grid PV mini-grid
2. Off-grid Hydro + PV mini-grid

Steps:

1. Setting parameters
2. Adding components
3. Results analysis
4. Export data

Case Study 1 – Vanuatu, Malekula island, Rensarie College

Main inputs

Discount rate	12%
Inflation rate	2,5%
Project lifetime	20 years
Fixed CAPEX	261,264 USD
Fixed O&M costs	16,893.22 USD/year 2,5%/yr escalation
Demand	250,09kWh/day Y1 – increase 4.5%/yr base plus evolution of connections
Genset	85KVA, minimum part load 25%, CAPEX 450 USD/kW, Replacement 450 USD/kW, O&M 0, fuel price 1 USD/L, fuel scalation 2,5%/yr, AC Coupled, lifetime 12,000 hours
Converter	135kVA, parallel with AC generator, CAPEX 450 USD/kW, Replacement 450USD/kW O&M 0, lifetime 12 years
PV	153 kWp (Helioscope), CAPEX 1190 USD/kWp, Replacement 951,8USD/kWp, O&M 0, optimum slope and azimuth, temperature effects considered, lifetime 25 years, anual degradation 0,7%, AC coupled.
Batteries	293,76 kWh (34 Units), CAPEX 500 USD/kWh, Replacement 400USD/kWh, O&M 0, Minimum SOC 20%, Voltage 48V, lifetime 12 years,
Constrains	Mini RE fraction (60%), Maximum annual capacity shortage 0%,
Controller	Load Following, CAPEX 0 USD, O&M 0. lifetime 25 yrs, allow diesel-off operation, allow generators to simulate simultaneously, allow system with generator capacity less than peak load

Case Study 2 – Vanuatu, Pentecost Island, Loltong – Hybrid (Hydro + PV) Mini-grid

Main inputs

Discount rate	12%
Inflation rate	2,5%
Project lifetime	20 years
Fixed CAPEX	162,000 USD
Fixed O&M costs	11,000 USD/year – 2,5%/yr escalation
Demand	71,39kWh/day Y3 – increase 4,5%/yr base after Y3, considering evolution of connections
Genset	15KVA, minimum part load 25%, CAPEX 700 USD/kW, Repalcement 700 USD/kWO&M 0, fuel price 2 USD/L, fuel scalation 2,5%/yr, AC Coupled, lifetime 12,000 hours
Converter	15kVA, parallel with AC generator, CAPEX 450 USD/kW, O&M 0, lifetime 12 years
PV	2,6 kWp Generic flat plate, CAPEX 1500 USD/kWp, Replacement 1,200 USD/kWp, O&M 0, optimum slope and azimuth, temperature effects considered, lifetime 25 years, anual degradation 0,7%, AC coupled, derating factor 80%
Hydro Turbine	5 KW Generic, CAPEX 15,000 USD, Repalcement 15,000 USD, O&M 0, AC Coupled, lifetime 10 years, head 140m, Design flow rate 10 l/s, max and min flow rate 10 and 100%, Efficiency 51%.
Batteries	33 kWh Generic Li-Ion, CAPEX 650 USD/kWh, Replacement 500USD/kWh, O&M 0, Minimum SOC 10%, lifetime 12 years,
Constrains	Mini RE fraction (60%), Maximum annual capacity shortage 80%,
Controller	Load Following, CAPEX 0 USD, O&M 0. lifetime 25 yrs, allow diesel-off operation, allow generators to simulate simultaneously, allow system with generator capacity less than peak load

7. ADDITIONAL CONTENTS

Additional Contents

Links for further knowledge:

- Homer Pro User Manual:

  https://www.homerenergy.com/products/pro/docs/latest/index.html

- Homer Pro official Youtube Channel: https://www.youtube.com/channel/UCgBJKc2nEalPoZeM7qlxmFQ

- Webinar: Multi-Year Modeling Capability in HOMER Pro and HOMER Grid

  https://microgridnews.com/multi-year-modeling-capability-in-homer-pro-and-homer-grid-how-does-it-help/

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Vinaka!

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