iHOGA software

improved **H**ybrid **O**ptimization by **G**enetic **A**lgorithms

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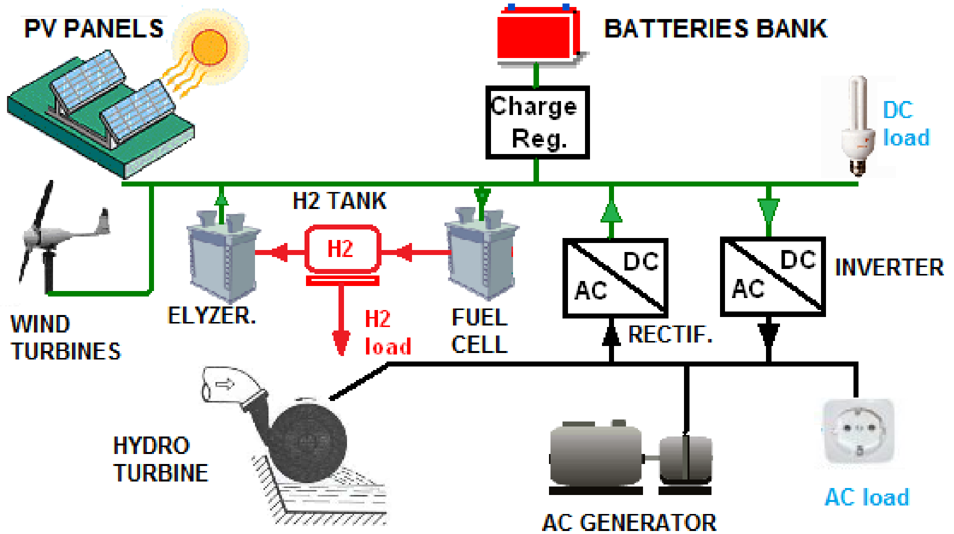
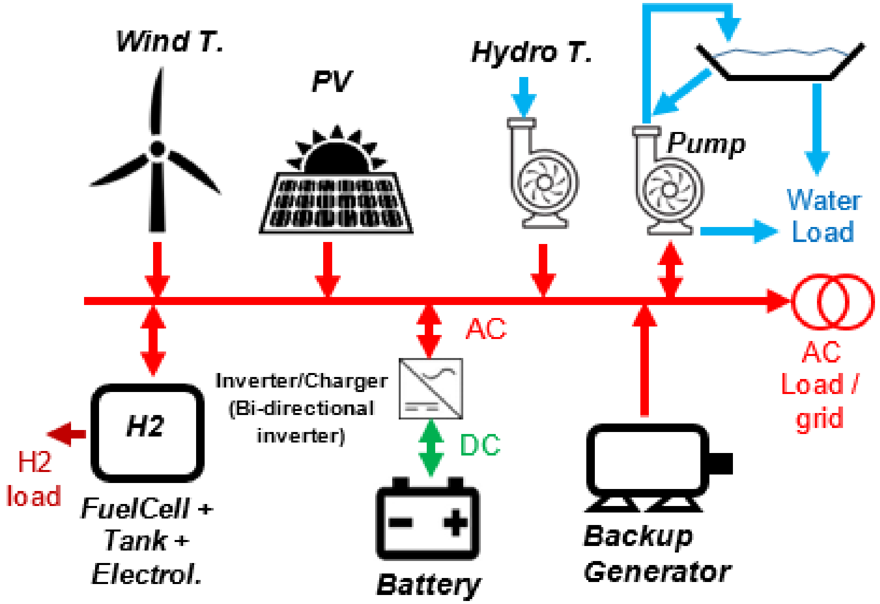
Overview

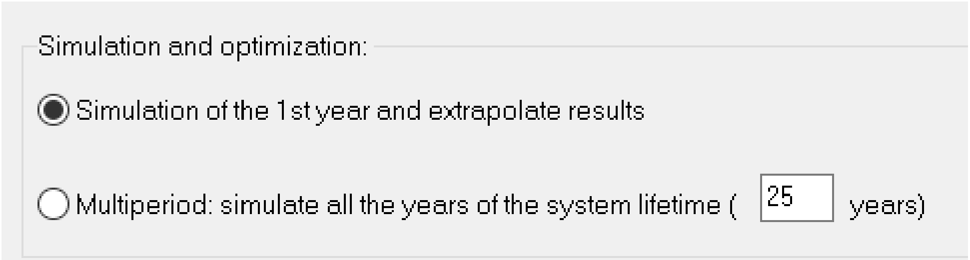
- Simulation and optimization software
- Off-grid or grid-connected generating systems
- Low load systems or high load systems
- Possible load:
  - AC
  - DC
  - H_2 for external use
  - Pumped water
- Possible components:
  - Renewable sources: PV, Wind, Hydro, TEG
  - Storage:
    - Lead-acid, Li-ion or other types of batteries
    - Pumped Hydro Storage (PHS)
    - Electrolyzer – H_2 tank – fuel cell
  - Fossil fuel generators (can be used for back-up)
- Sell / Buy electricity to the AC grid
- Sell H_2 generated by electrolyzer (Green H_2)

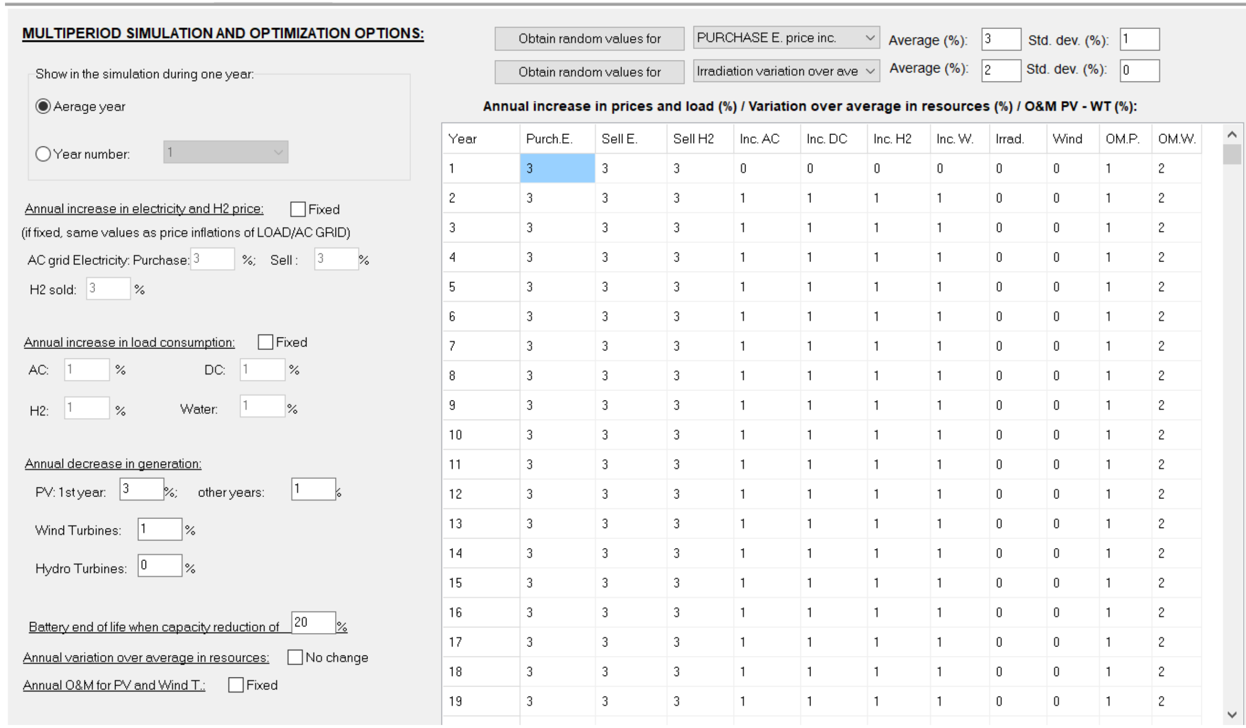




Simulation

- Each combination of components and control strategies is simulated during:
  - 1 typical year (steps from 1 min. to 1 h)
  - All the system lifetime (25 years typically), considering anual changes in:
    - Electricity price (buy / sell to the AC grid)
    - Sell generated green H_2 price
    - PV, wind resources
    - PV, wind, hydro generation
    - Battery capacity
    - O&M for PV or Wind

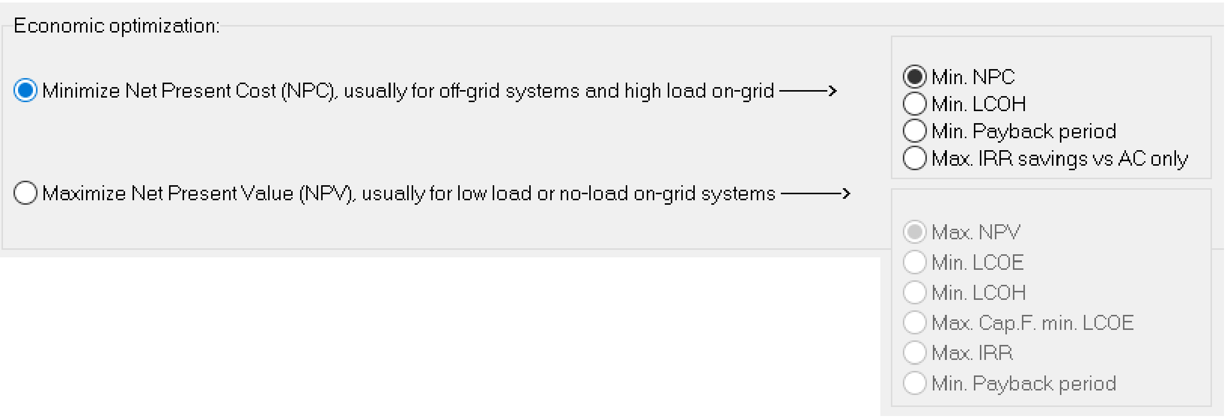




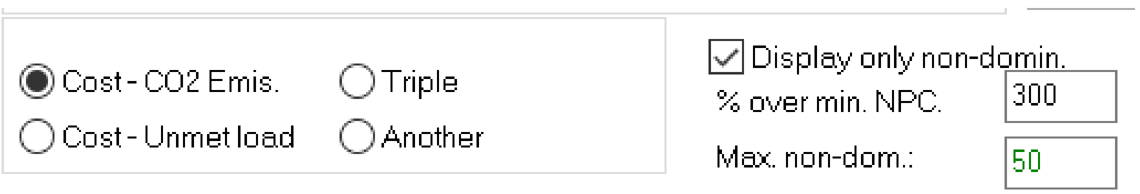
Year	Purch.E.	Sell E.	Sell H2	Inc. AC	Inc. DC	Inc. H2	Inc. W.	Irrad.	Wind	OM.P.	OM.W.
1	3	3	3	0	0	0	0	0	0	1	2
2	3	3	3	1	1	1	1	0	0	1	2
3	3	3	3	1	1	1	1	0	0	1	2
4	3	3	3	1	1	1	1	0	0	1	2
5	3	3	3	1	1	1	1	0	0	1	2
6	3	3	3	1	1	1	1	0	0	1	2
7	3	3	3	1	1	1	1	0	0	1	2
8	3	3	3	1	1	1	1	0	0	1	2
9	3	3	3	1	1	1	1	0	0	1	2
10	3	3	3	1	1	1	1	0	0	1	2
11	3	3	3	1	1	1	1	0	0	1	2
12	3	3	3	1	1	1	1	0	0	1	2
13	3	3	3	1	1	1	1	0	0	1	2
14	3	3	3	1	1	1	1	0	0	1	2
15	3	3	3	1	1	1	1	0	0	1	2
16	3	3	3	1	1	1	1	0	0	1	2
17	3	3	3	1	1	1	1	0	0	1	2
18	3	3	3	1	1	1	1	0	0	1	2
19	3	3	3	1	1	1	1	0	0	1	2

Optimization

- Mono-objective:
  - Minimize NPC (off-grid or grid-connected systems to suppply load).
    - Also option of minimization of LCOH or minimization of payback-time or maximization of IRR savings compared to system of only AC grid
  - Maximize NPV (grid-connected power generating systems)
    - Also option of minimization of LCOE or LCOH or Cap. Factor and LCOE or maximization of IRR or minimization of payback-time.



- Multi-objective:
  - NPC - CO_2 emissions
  - NPC - Unmet load
  - NPC - CO_2 emissions - Unmet load

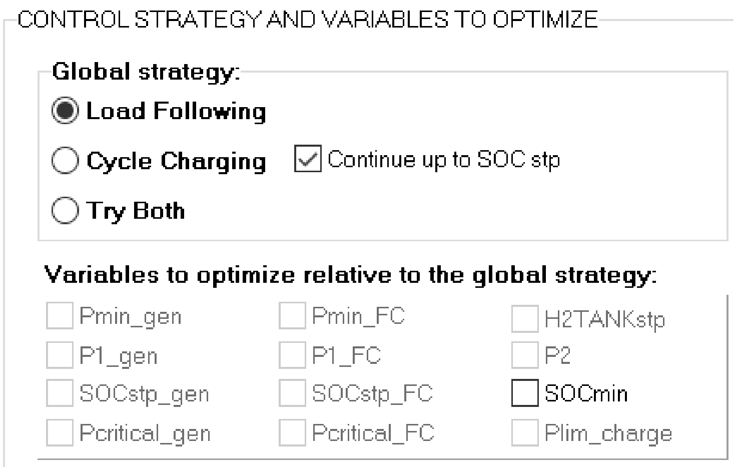


Optimization

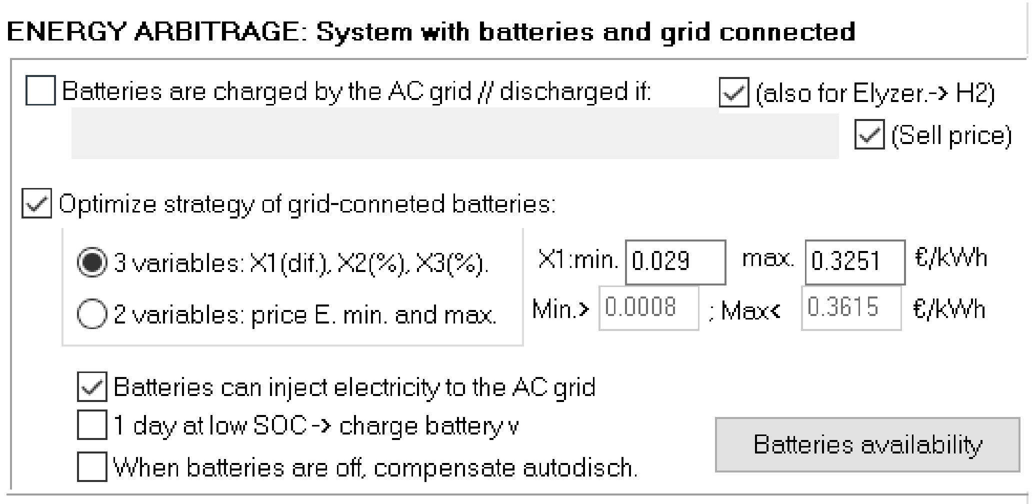
- The software simulates and evaluates all the posible combinations of components and control strategies → obtains the optimal one (lowest NPC or highest NPV or lowes LCOE or lowest LCOH or…)
- If too many combinations -> optimization time can be too high, inadmissible → Use **Genetic Algorithms** metaheuristic technique → optimize in reasonable time

Control strategies

- **For off-grid systems**:
  - Load following
  - Cycle charging
  - Control variables

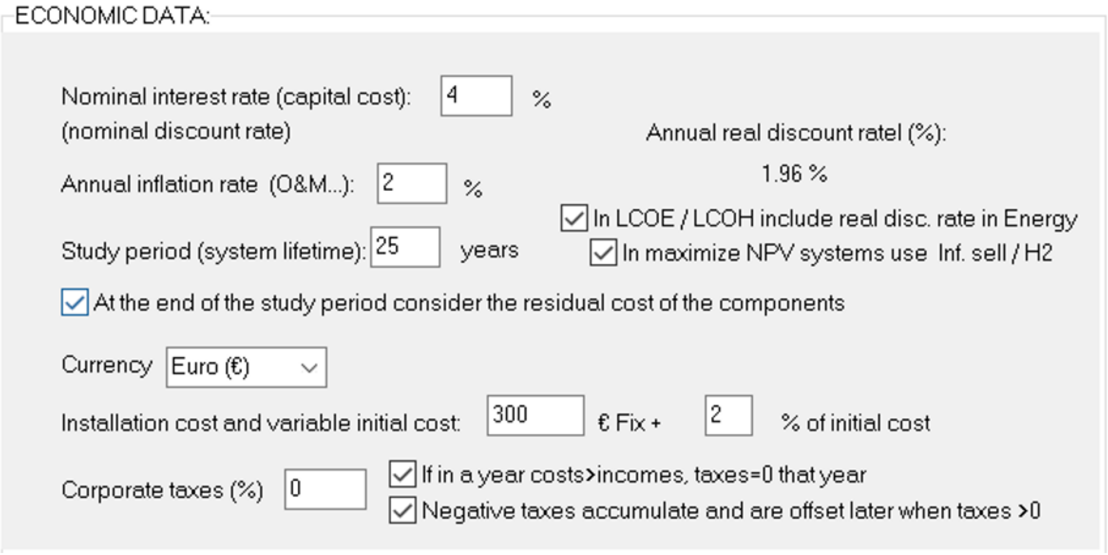


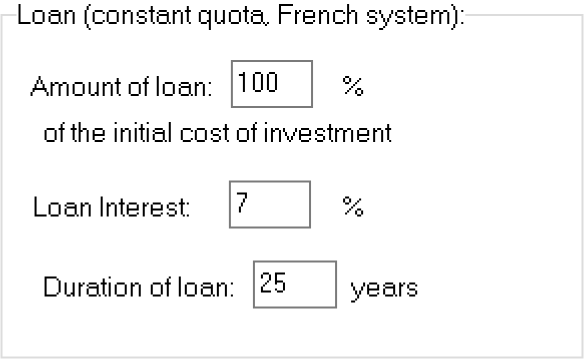
- For grid-connected power generating systems: **Energy arbitrage**
  - Fix / optimize max. electricity price to charge batteries and min. electricity price to discharge batteries -> optimal storage management
  - Also for PHS
  - Also for green H_2 generation



Economic and financial data

- Default currency (€) can be changed to $ or any other
- Nominal interest rate
- Annual general inflation rate for O&M, etc.
- Annual specific inflation rates for:
  - Electricity sell Price
  - Electricity buy Price
  - H2 sell Price
  - Backup generator fuel Price
  - Change in components prices to calculate replacing costs
- Loan
- Corporate Taxes
- After simulating → calculation of NPC/NPV, LCOE, IRR, payback time… for each combination



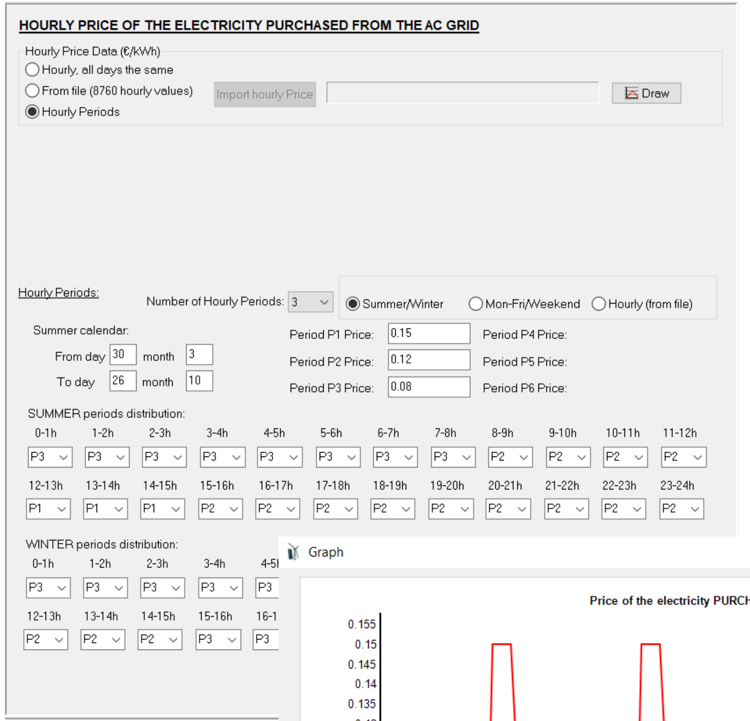


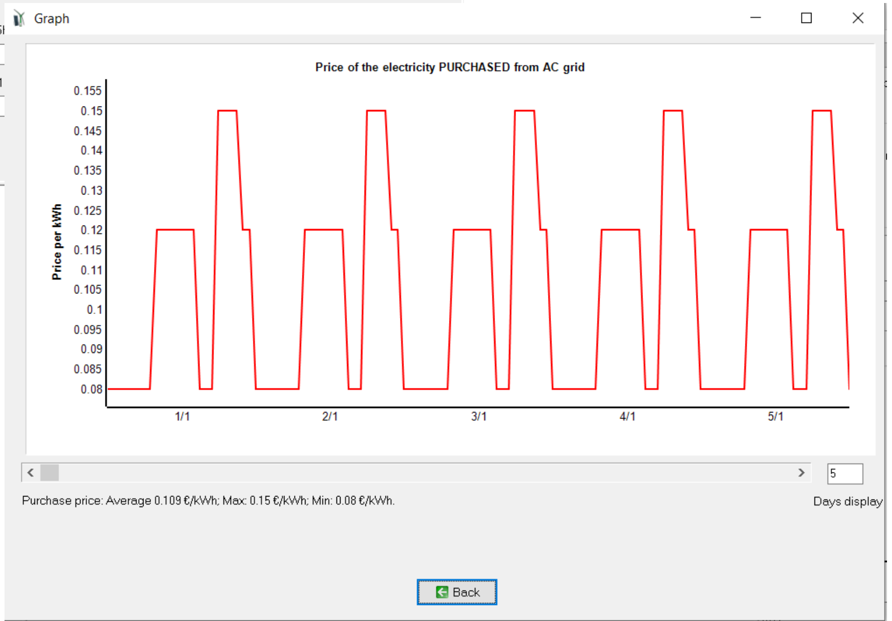
Load and Resources

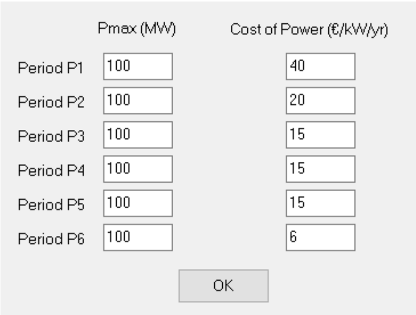
- AC, DC, H2 and water pumping load can be defined in monthly average hourly vales or it can be imported in several minutes or hourly basis.
- Irradiation, wind speed and tempertaure can be:
  - Hourly values downloaded from 3 different databases (PVGIS, NASA, RENEWABLES NINJA)
  - Obtained synthetically from monthly average data
  - Imported the whole year, in steps from 1 min. to 1 h
- Water for hydro in hourly or monthly average values
- Hourly values converted to minute values using autorregresive functions

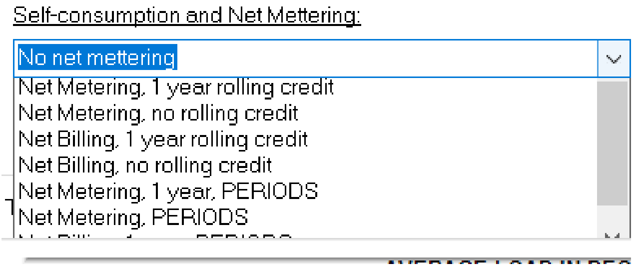
Purchase / sell electricity to AC grid

- Different prices for purchase and sell electricity
- Fixed values or hourly data, imported or by periods (TOU, RTP)
- Hourly periods also for maximum Power available from / to the AC grid
- Options for net metering / net billing



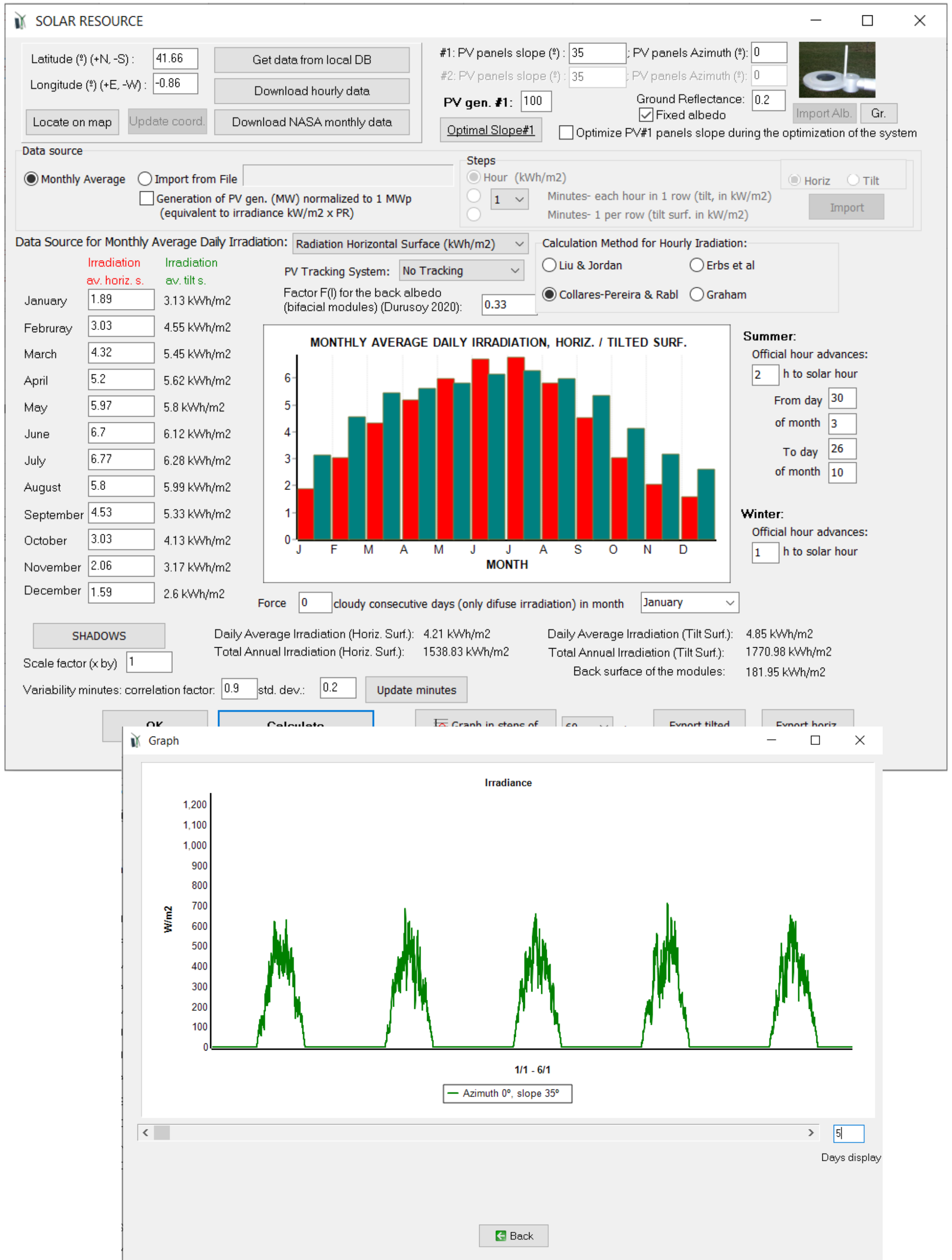






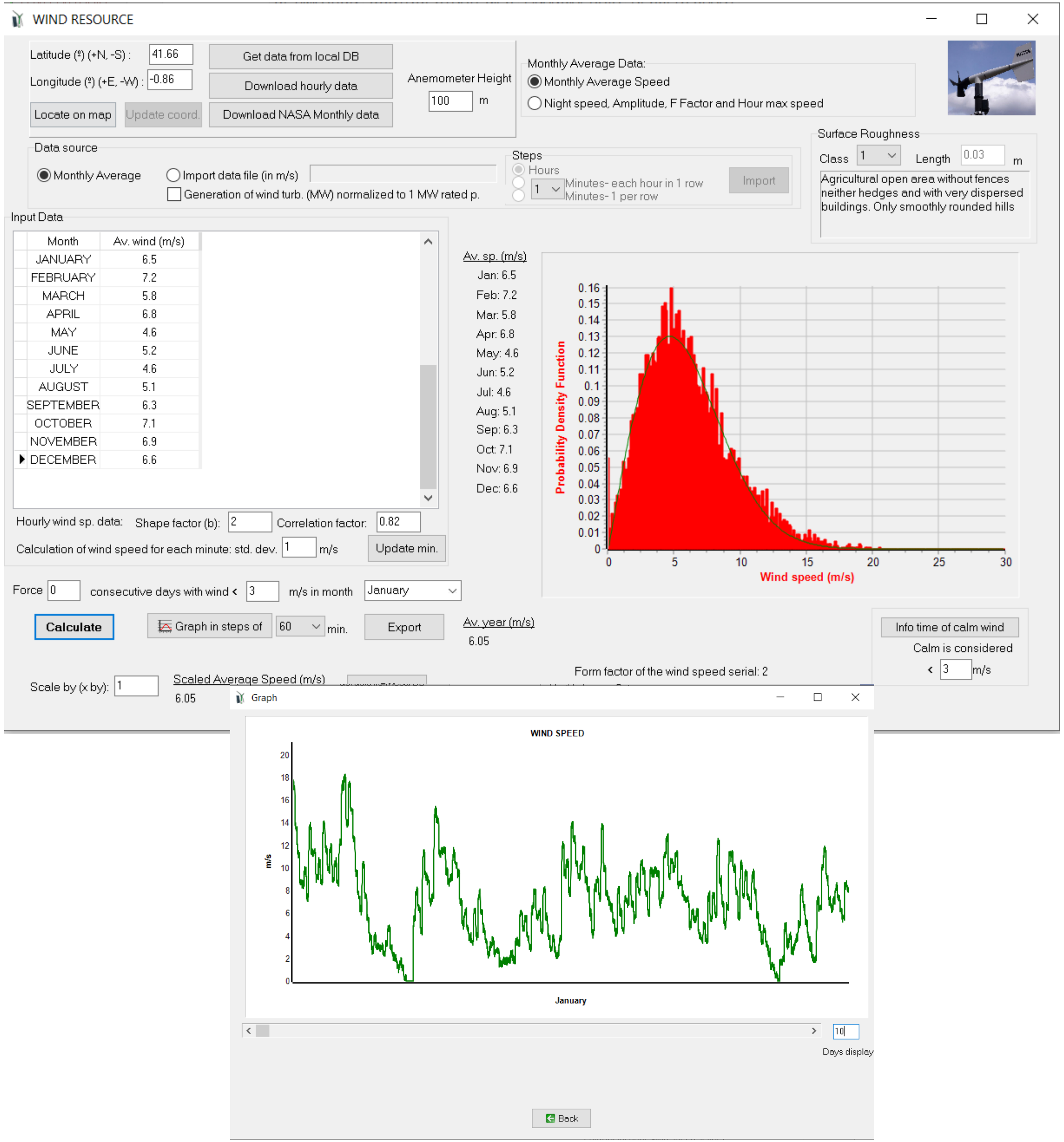
Irradiation

- Irradiation over any surface, fixed (tilt, azimuth) or 1 or 2 axis tracking
- PV generator can be divided in two zones with different tilt and azimuth.
- Irradaition over the back surface is calculated → PV bifacial modules can be considered
- Concentrating PV (CPV) can be considered (direct irradiation)



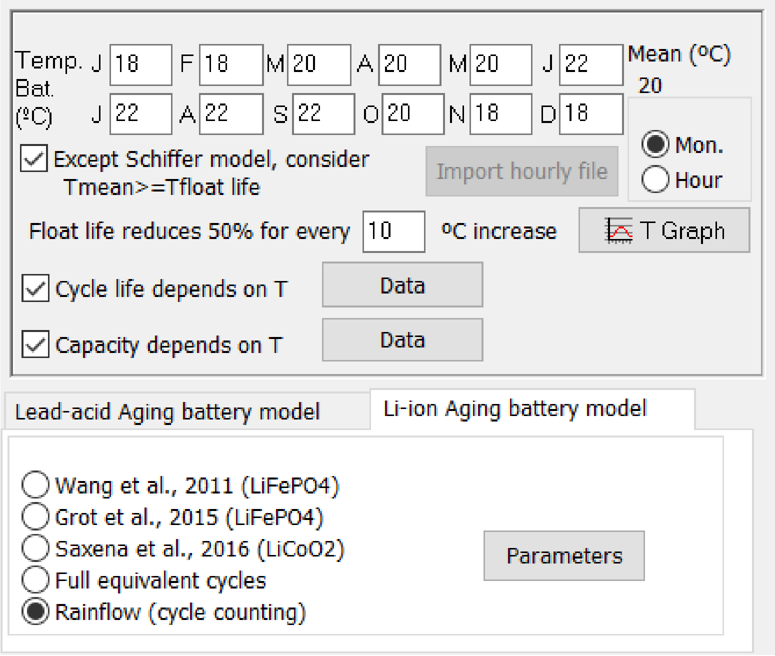
Wind speed

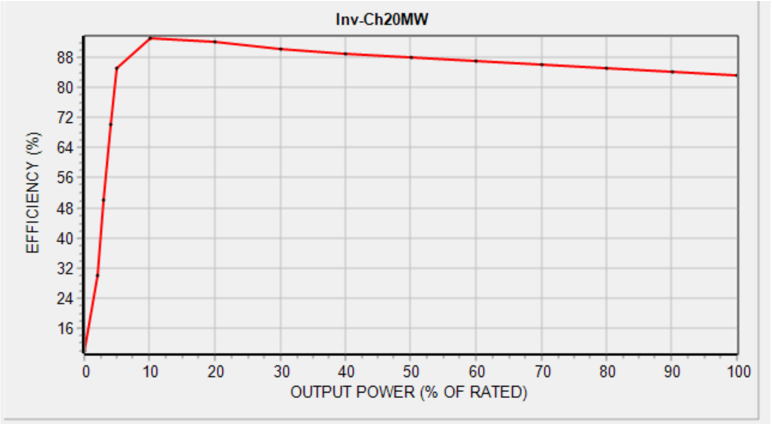
- Monthly average converted to hourly and minute basis
- Or download or import hourly or minute basis data

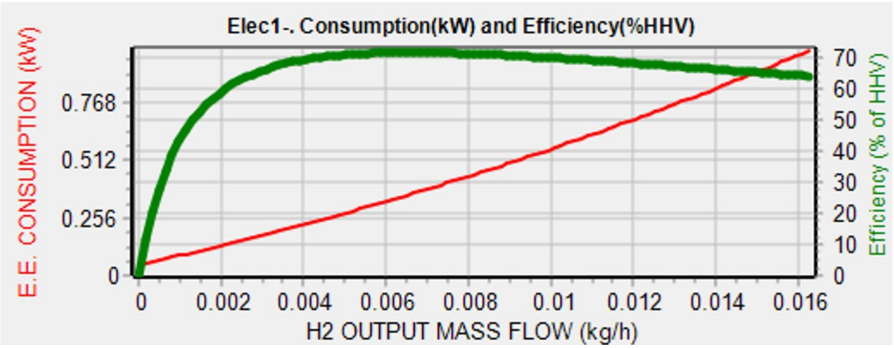


Models for components

- Accurate models for all the components
- Advanced ageing battery models, for lead-acid and for Li-ion
- Inverter and inverter-charger efficiency dependant on output power
- Variable consumption and efficiency for backup generator, electrolyzer and fuel cell

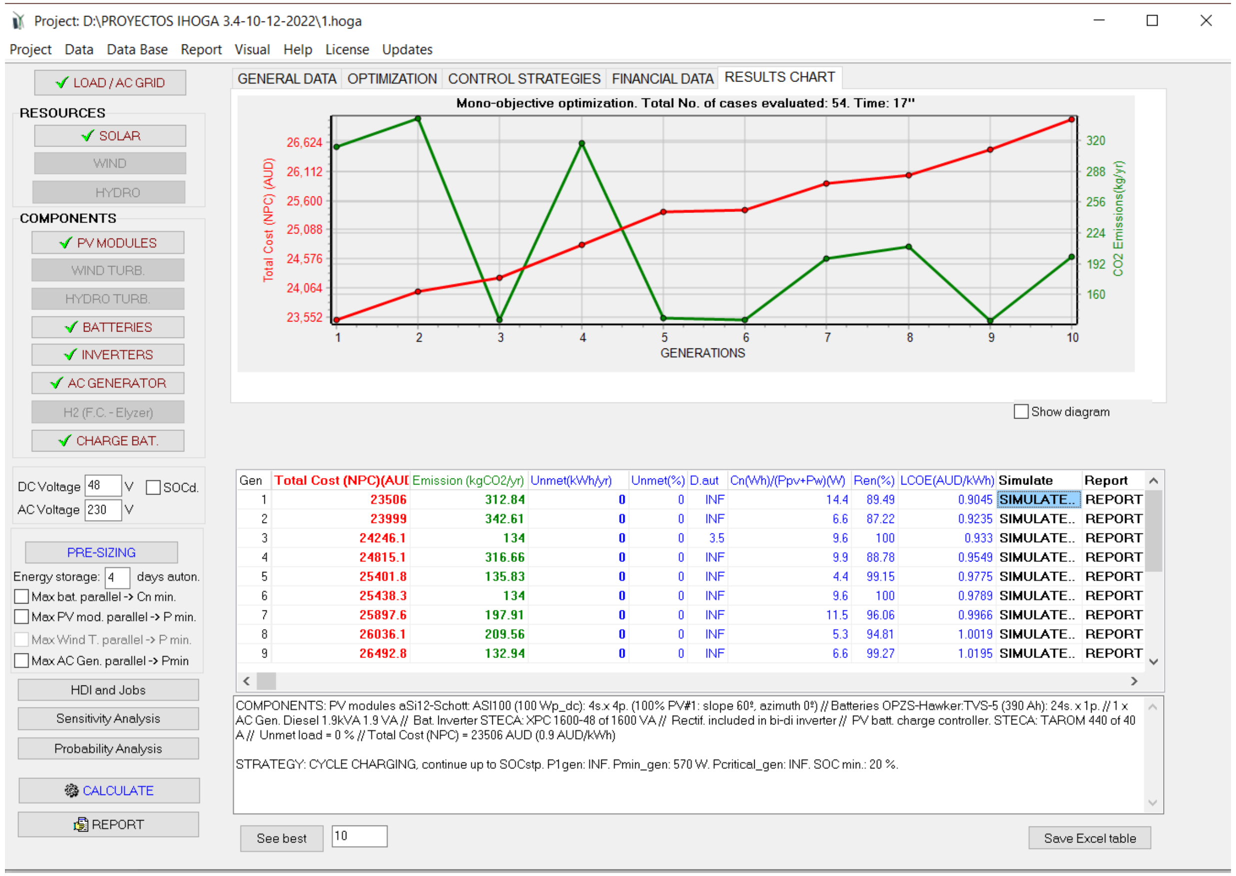




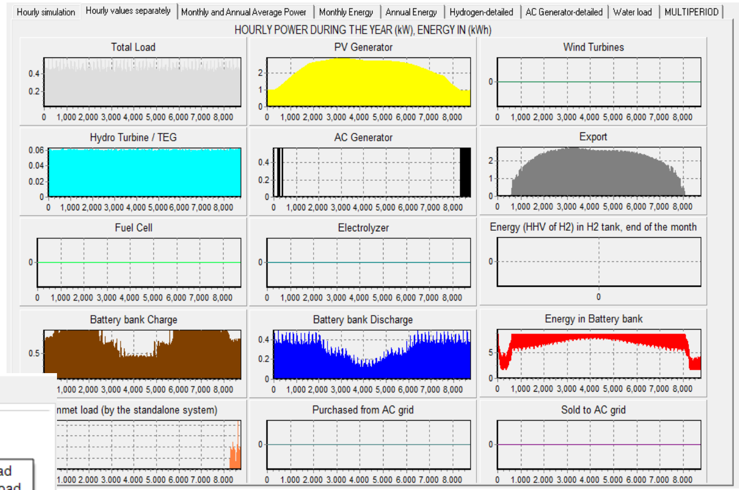


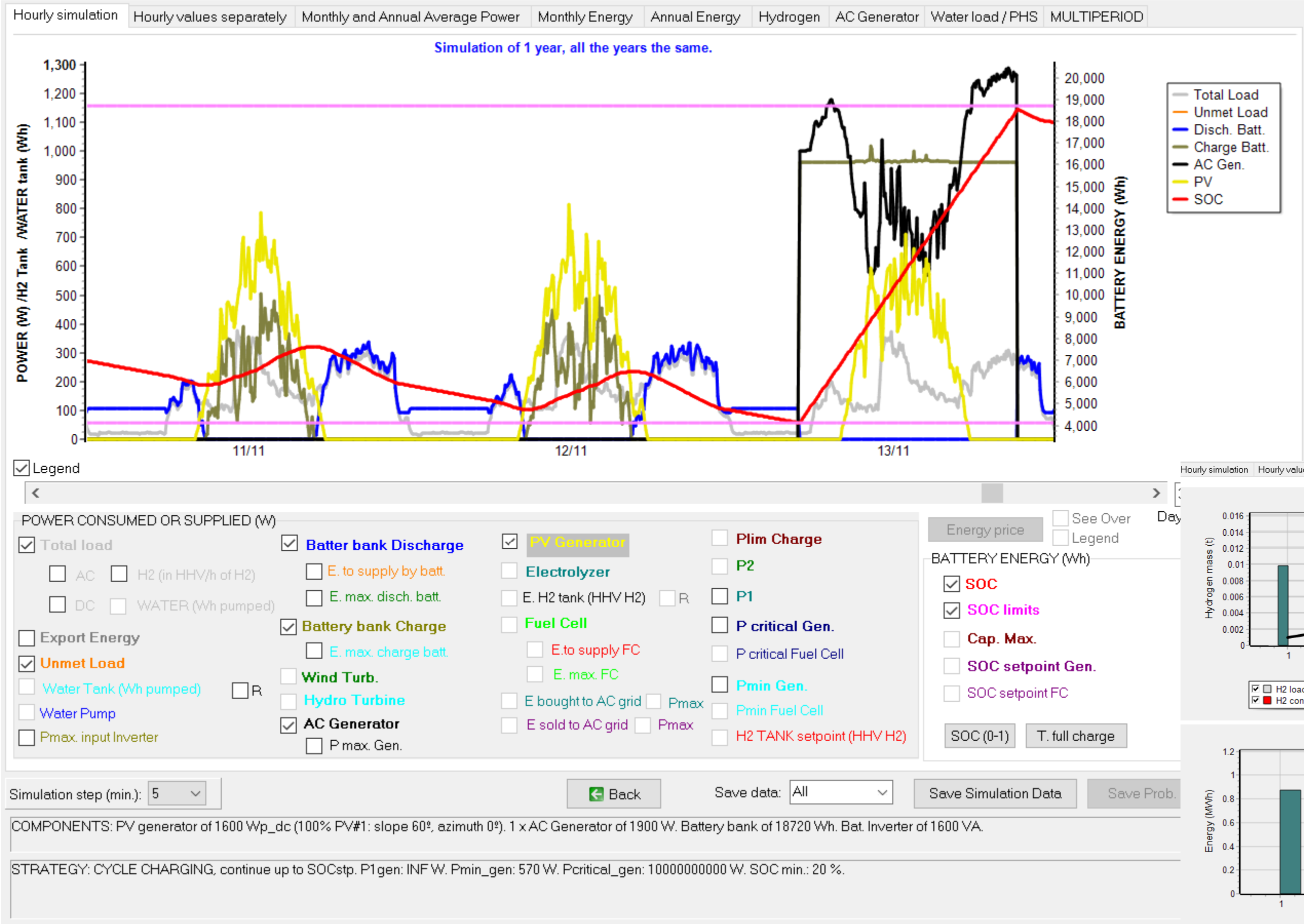
Optimization results

- Combinations sorted from best to worst (or best of each generation of the GA)
- Results table can be saved in Excel file
- Simulation of each combination (can be saved in Excel file)
- General report of each combination
- Costs report of each combination

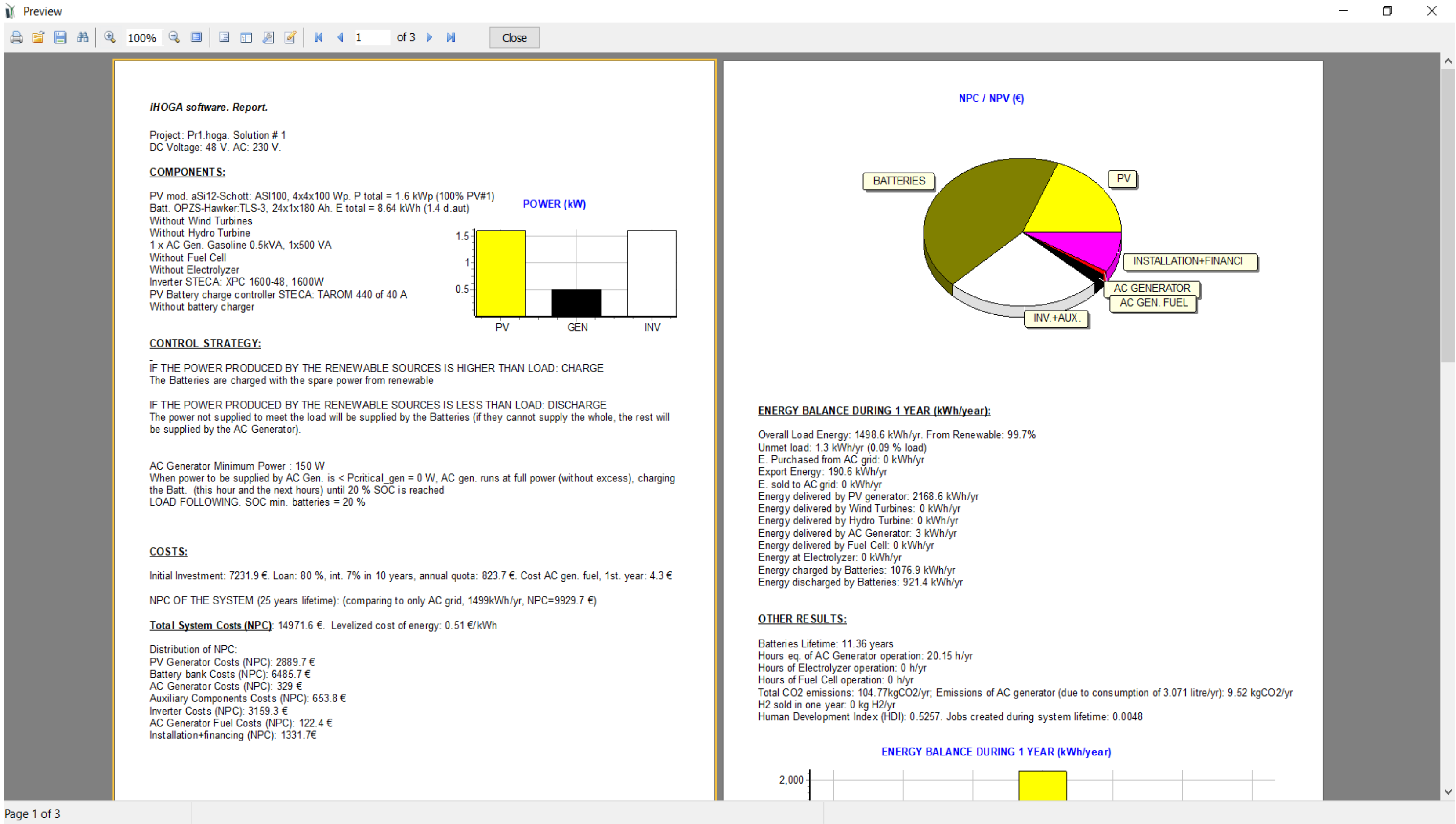


Optimization results (simulation)





Optimization results



Preview

100% 1 of 3 Close

iHOGA software. Report.

Project: Pr1.hoga. Solution # 1
DC Voltage: 48 V. AC: 230 V.

COMPONENTS:

PV mod. aSi12-Schott: ASI100, 4x4x100 Wp. P total = 1.6 kWp (100% PV#1)
Batt. OPZS-Hawker:TLS-3, 24x1x180 Ah. E total = 8.64 kWh (1.4 d.aut)
Without Wind Turbines
Without Hydro Turbine
1 x AC Gen. Gasoline 0.5kVA, 1x500 VA
Without Fuel Cell
Without Electrolyzer
Inverter STECA: XPC 1600-48, 1600W
PV Battery charge controller STECA: TAROM 440 of 40 A
Without battery charger

CONTROL STRATEGY:

IF THE POWER PRODUCED BY THE RENEWABLE SOURCES IS HIGHER THAN LOAD: CHARGE
The Batteries are charged with the spare power from renewable

IF THE POWER PRODUCED BY THE RENEWABLE SOURCES IS LESS THAN LOAD: DISCHARGE
The power not supplied to meet the load will be supplied by the Batteries (if they cannot supply the whole, the rest will be supplied by the AC Generator).

AC Generator Minimum Power : 150 W
When power to be supplied by AC Gen. is < Pcritical_gen = 0 W, AC gen. runs at full power (without excess), charging the Batt. (this hour and the next hours) until 20 % SOC is reached
LOAD FOLLOWING. SOC min. batteries = 20 %

COSTS:

Initial Investment: 7231.9 €. Loan: 80 %, int. 7% in 10 years, annual quota: 823.7 €. Cost AC gen. fuel, 1st. year: 4.3 €

NPC OF THE SYSTEM (25 years lifetime): (comparing to only AC grid, 1499kWh/yr, NPC=9929.7 €)

Total System Costs (NPC): 14971.6 €. Levelized cost of energy: 0.51 €/kWh

Distribution of NPC:
PV Generator Costs (NPC): 2889.7 €
Battery bank Costs (NPC): 6485.7 €
AC Generator Costs (NPC): 329 €
Auxiliary Components Costs (NPC): 653.8 €
Inverter Costs (NPC): 3159.3 €
AC Generator Fuel Costs (NPC): 122.4 €
Installation+financing (NPC): 1331.7€

ENERGY BALANCE DURING 1 YEAR (kWh/year):

Overall Load Energy: 1498.6 kWh/yr. From Renewable: 99.7%
Unmet load: 1.3 kWh/yr (0.09 % load)
E. Purchased from AC grid: 0 kWh/yr
Export Energy: 190.6 kWh/yr
E. sold to AC grid: 0 kWh/yr
Energy delivered by PV generator: 2168.6 kWh/yr
Energy delivered by Wind Turbines: 0 kWh/yr
Energy delivered by Hydro Turbine: 0 kWh/yr
Energy delivered by AC Generator: 3 kWh/yr
Energy delivered by Fuel Cell: 0 kWh/yr
Energy at Electrolyzer: 0 kWh/yr
Energy charged by Batteries: 1076.9 kWh/yr
Energy discharged by Batteries: 921.4 kWh/yr

OTHER RESULTS:

Batteries Lifetime: 11.36 years
Hours eq. of AC Generator operation: 20.15 h/yr
Hours of Electrolyzer operation: 0 h/yr
Hours of Fuel Cell operation: 0 h/yr
Total CO2 emissions: 104.77kgCO2/yr; Emissions of AC generator (due to consumption of 3.071 litre/yr): 9.52 kgCO2/yr
H2 sold in one year: 0 kg H2/yr
Human Development Index (HDI): 0.5257. Jobs created during system lifetime: 0.0048

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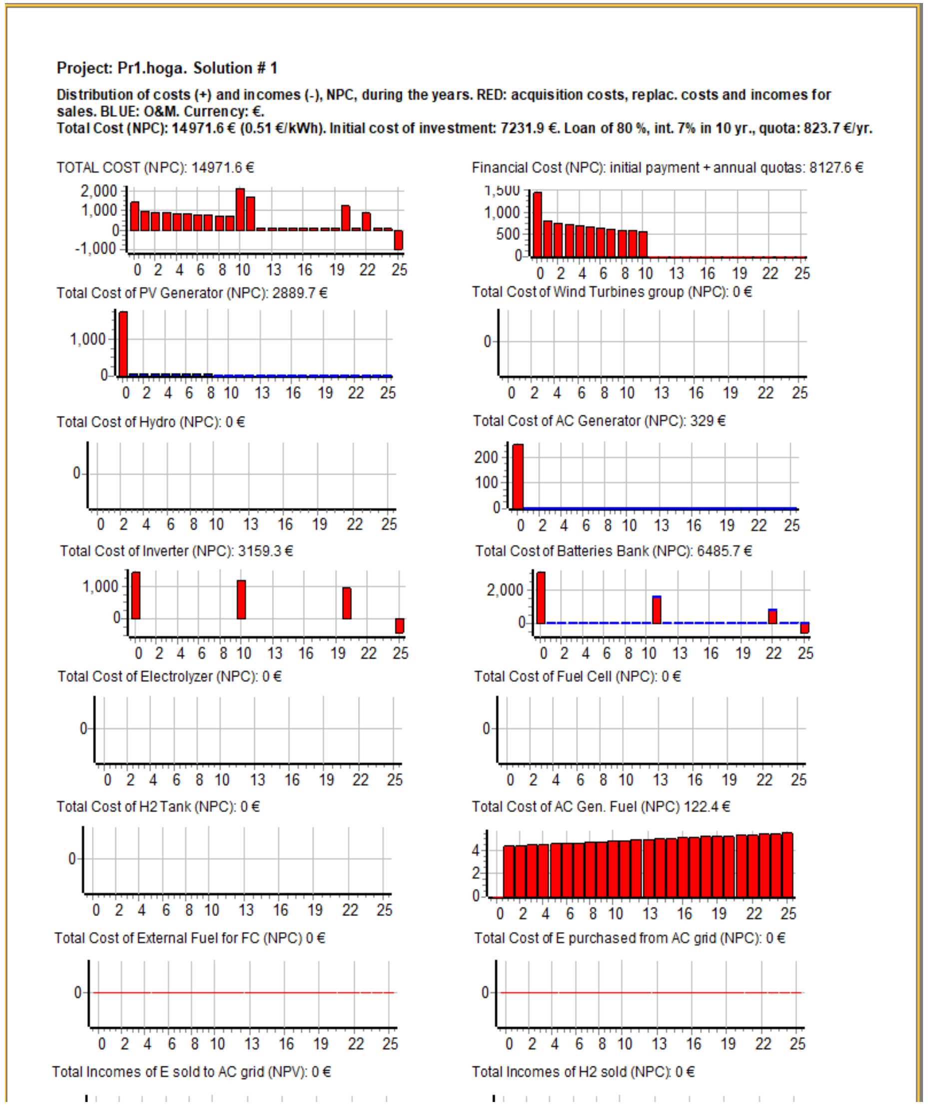
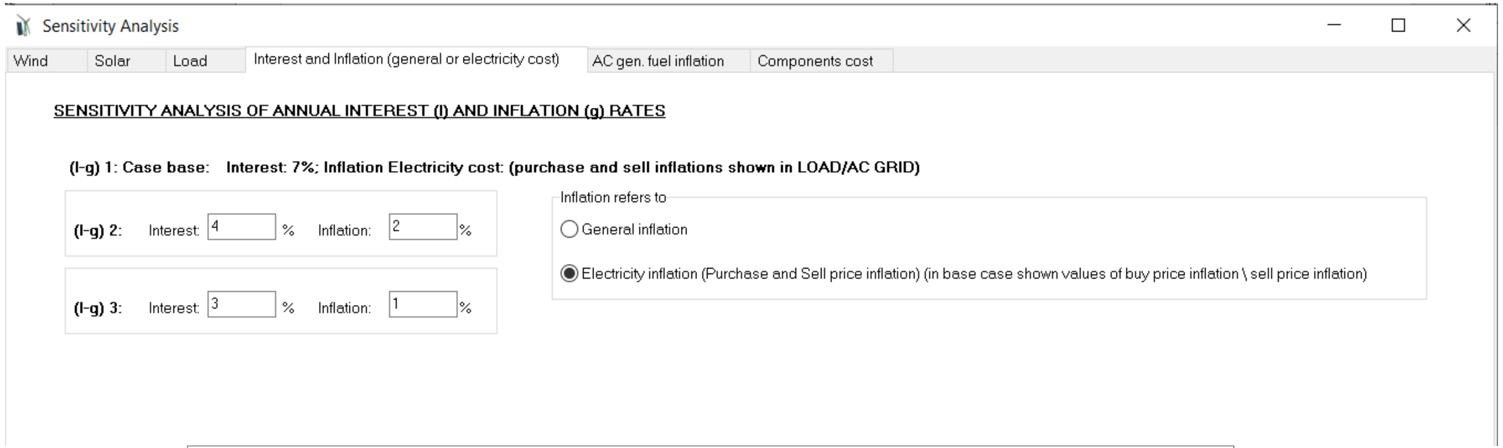
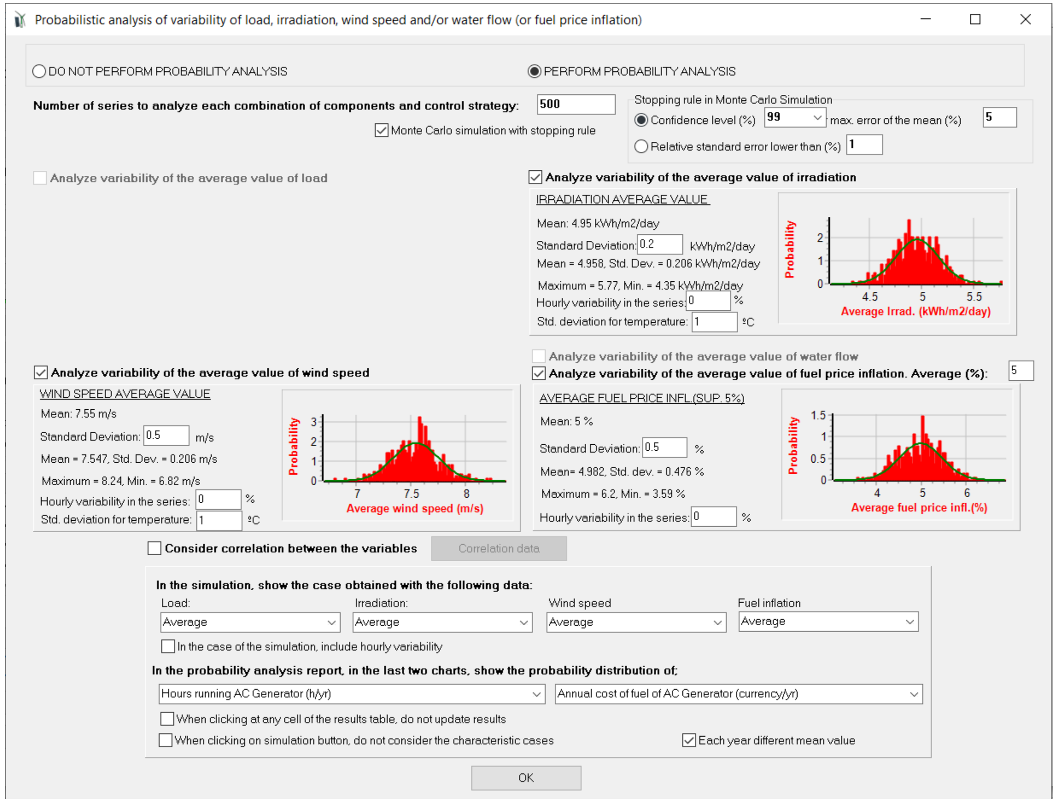
Optimization results



Other features

- Sensitivity analysis
- Probability analysis
- ….





More info

- https://ihoga.unizar.es/en/

- User manual:

https://ihoga.unizar.es/Desc/iHOGA_User_manual.pdf

- Getting started guide:

https://ihoga.unizar.es/Desc/GETTING_STARTED_iHOGA.pdf

Thank you!