



A review of tools and software for sizing and optimizing Integrated Renewable Energy Systems (IRES)

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Co-authored report by Integrate to Zero and
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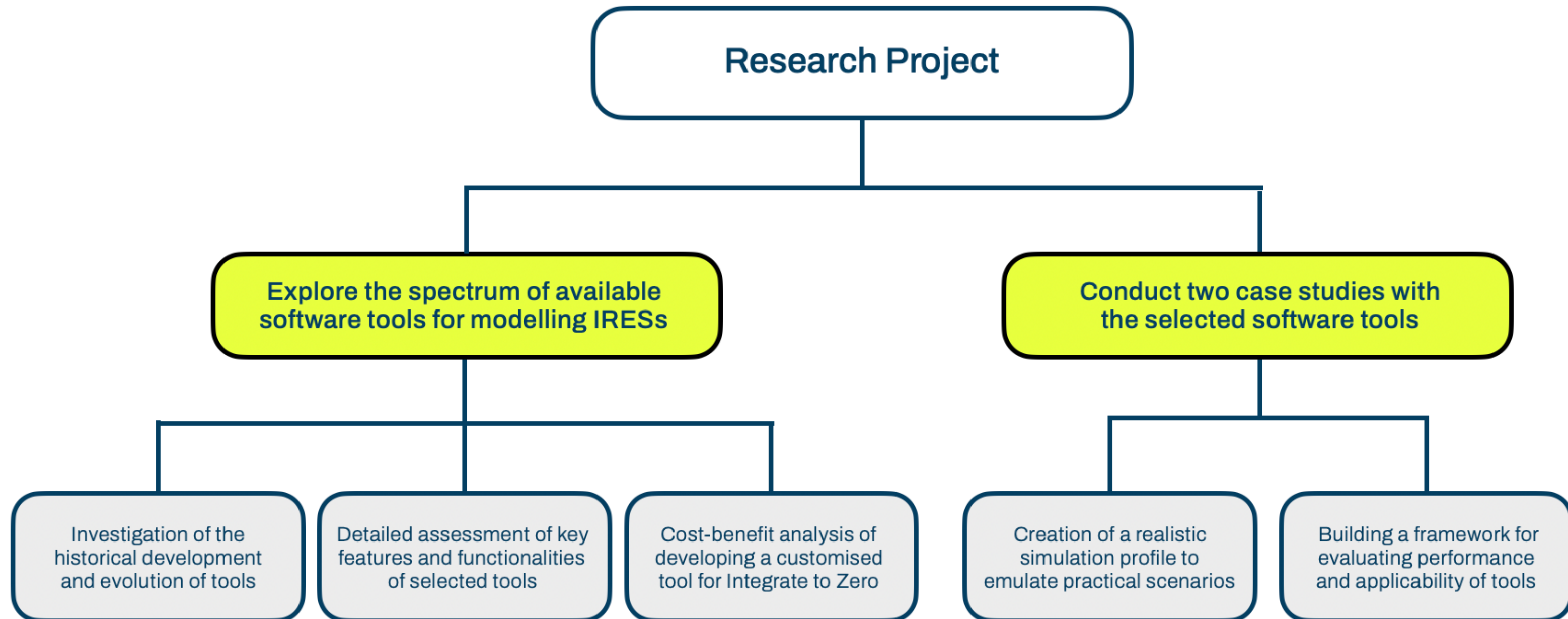
Consumers need help with sizing and identifying the benefits of integrated renewable energy sources on-site, on-road, on-grid

- Distributed energy resources are key technologies needed to decarbonise the energy sector. With only 3.8TW of renewable in the pipeline vs. 8TW needed by 2030, distributed solutions have the power to complement large-scale deployment and generate greater benefits.
- Integrating solutions on-site, on-road, on-grid can unleash greater emissions and cost reductions for consumers assembling solar PV, storage, EV and other easy to electrify energy uses whilst selling services or excess power to the grid and other energy users.
- Yet, sizing an integrated system requires a set of inputs and assumptions in order to understand the possibilities and benefits
- As part of Integrate to Zero's mission to scale the integration of renewable sources for consumers, we have identified the availability of different tools that can help consumers assess the size of an Integrated Renewable Energy Sources (IRES) that meet their needs.

Report background

- This report summarises the assessment of software tools available for energy consumers to size their integrated system on-site, on-road, on-grid (grid-connected renewable solutions: solar PV, batteries, EVs, heat pumps).
- It provides an overview of the methodology, findings and case studies from 2 of the best tools available.
- Software models are precise but sophisticated and require a level of understanding of technology features/specifics.
- Online calculators provide a simpler entry point for consumers who are less familiar with power and technology, to size systems without needing to use more complex software.
- A sample of UK calculators has been provided as an example. Other countries/regions have their own versions with similar features.
- The two case studies in the report were made with inputs from a UK energy-profile.

Motivations Behind the Study & Objectives



Key Insights

 **Diverse Tool Landscape**

Tools showcase significant diversity in terms of their functionalities and the specific areas of IRES projects that they can effectively analyse and support.

 **Limited Assessment of Transport Sector**

Tools offer limited features when it comes to assessing the economics of the transport sector, particularly in the context of electric vehicles.

 **Global Flexibility**

Tools demonstrate a high degree of flexibility, enabling robust predictions to be designed for almost any geographical location worldwide.

 **Lack of Transparency in Projections**

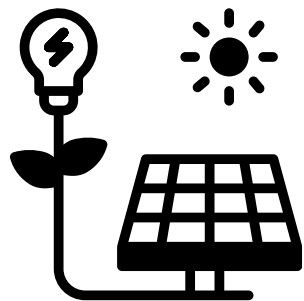
Some tools lack clear documentation on how projections are computed and the underlying models utilised.

Sample of UK Calculators

Calculator Link	Technology	Is it easy to use?	Features
Solar Energy Calculator Energy Saving Trust	Solar	Yes, asks for post code, roof slope, shading, roof direction and size with recommendations and visuals.	<ul style="list-style-type: none"> • Gives indication in kWh • Gives potential bill and CO2 saving • Gives cost breakdown
MCS Heat Pump Calculator	Heat Pump	It is a detailed and specific excel table with room for the user to input relevant values. It is complex with multiple sheets within the file	<ul style="list-style-type: none"> • Gives indication in kWh
Tiny Eco Home Life	Heat Pump	Yes, it is extremely simple however with only 2 variables: Annual Gas Usage (kWh), Desired Internal Temperature (°C)	<ul style="list-style-type: none"> • Gives indication in kWh
Great Home Solar Panel & Battery	Solar	It is straightforward and there are consumer reviews at the bottom.	<ul style="list-style-type: none"> • Gives cost savings • Shows payback period
Energy Saving Trust Solar Energy Calculator	Solar	It is simple to use and is detailed.	<ul style="list-style-type: none"> • Gives cost savings • Gives indication in kWh
Renogy Solar Sizing Calculator	Solar	Yes, it is a multi-sizing-toolkit that has simple and clear variables for users. Further to solar sizing, this also provides appliance power consumption calculation, solar cable gauge calculation and battery interconnect calculator tools.	<ul style="list-style-type: none"> • Gives indication in kWh
Unbound Solar Off-Grid Solar System Sizing Calculator	Solar	It is simple to use with the ability to add specific appliances and their daily durations of usage	<ul style="list-style-type: none"> • Gives indication in kWh
Spirit Energy Battery Storage Calculator	Solar+ Battery storage	It is simple to use and is detailed.	<ul style="list-style-type: none"> • Gives indication in kWh
@ngterry5 Battery Savings Calculator	Battery storage	It is cohesive to use, you require knowledge of your electricity consumption and some data. It is targeted at households and has a quick and easy to use structure if you have the data/	<ul style="list-style-type: none"> • Gives indication in kWh • Gives cost savings by time period • Shows minimum payback period

- Due to complex nature of calculating exact technology size, many suppliers recommend contacting them in the first instance to advise on requirements, and be able to provide an accurate quote : [Cinergi Air Source Heat Pump Calculator UK](#), [All Seasons Energy Heat Pump Calculator UK](#) , [Ovo Energy](#)
- There are more solar sizing calculators than other technologies

Spectrum of Available Tools



*There is a wealth of tools available for designing energy systems, with the literature identifying nearly 60 software options *.*

Several studies have categorised and assessed these tools based on their features and capabilities. Here are some prominent recent examples:

[!\[\]\(642aa997563f9a325b310230bb5078b7_img.jpg\) A review of computer tools for analysing the integration of renewable energy into various energy systems — 2010](#)

[!\[\]\(2b376d1a92330ab09dad2665d2f89bf5_img.jpg\) Review of software tools for hybrid renewable energy systems — 2014](#)

[!\[\]\(3cb60d42b10e53f9522bb0b392c1c4cd_img.jpg\) A review of AI-based optimisation techniques for the sizing of IRESs in smart cities — 2020](#)

*Full list in the
appendix

Analysis & Feature Assessment Table

Tools	Economics Analysis	Technical Analysis	PV System	Wind System	Generator Set	Storage device	Bio-energy	Hydro Energy	Thermal System	EVs & Chargers
HOMER	X	X	X	X	X	X	X	X	X	—
RETScreen	X	X	X	X	—	X	—	X	—	—
TRNSYS	X	X	X	X	X	X	—	—	X	—
iHOGA	X	X	X	X	X	X	—	X	—	—
EnergyPLAN	X	X	X	X	X	X	—	X	X	X
ORCED	X	X	X	X	X	X	X	X	X	X
BALMOREL	X	X	X	X	—	X	—	—	X	—
COMPOSE	X	—	X	X	X	—	—	—	X	—
INSEL	—	X	X	X	X	X	—	—	—	—
HYBRID2	—	X	X	X	X	X	—	—	X	—
BCHP Screening	—	X	X	X	X	—	—	—	X	—
LEAP	—	X	X	X	X	—	—	X	X	—
ARES-I & II *	—	X	X	X	X	X	X	—	—	—
SOLSTOR *	X	X	X	X	X	—	—	—	—	—
HySim *	X	X	X	—	X	X	X	—	—	—
Hybrid Designer *	X	—	X	X	X	X	—	—	—	—
SOMES *	X	X	X	X	—	X	—	—	—	—

While there is an abundance of available tools, only 17 have demonstrated a measurable influence on the design of renewable energy systems, based on their frequency and prominence in previous literature.

Criteria for Selection

In order to shortlist the two tools for the case studies, the following criteria were employed:

Availability

The tool must have remained active since its launch. This not only ensured that it could be used but also indicated constant improvement.

Accessibility

The tool needed to be freely downloadable and usable, or at least offer a demo version for capabilities assessment.

100% Renewable Systems

The tool must have a proven track record of effectively modelling 100% renewable energy systems in prior works.

User Base

The tool has a considerable number of users, with a minimum threshold of approximately 1000 users.

Homer and iHOGA were used as case studies

Tools	Developed by (year)	Computer Platform / Programming Language	Analysis Type	Users / Downloads	Freely Available	Offers Demo	100% Renewable Systems
👑 HOMER	NREL, USA (1993)	Visual Studio, C++	Technical, economical, emission analysis	> 30,000	No	Yes	Yes
RETScreen	Ministry of Natural Resources, CA (1998)	Visual Studio, Excel, C	Financial, environmental analysis	> 200,000	No	Yes	Yes
TRNSYS	University of Wisconsin & Colorado, USA (1975)	Fortran	Simulation of transient system behavior	> 1,000	No	Yes	Yes
👑 iHOGA	University of Zaragoza, ESP (2015)	C++	Multi or mono objective optimisation using genetic algorithm	> 1,000	No	Yes	Yes
EnergyPLAN	Aalborg University, DNK (1999)	Delphi Pascal	Technical, economical, emission analysis	> 1,000	Yes	Yes	Yes

HOMER and iHOGA were selected for trial because they featured as the most user- friendly platforms and offered free trial.

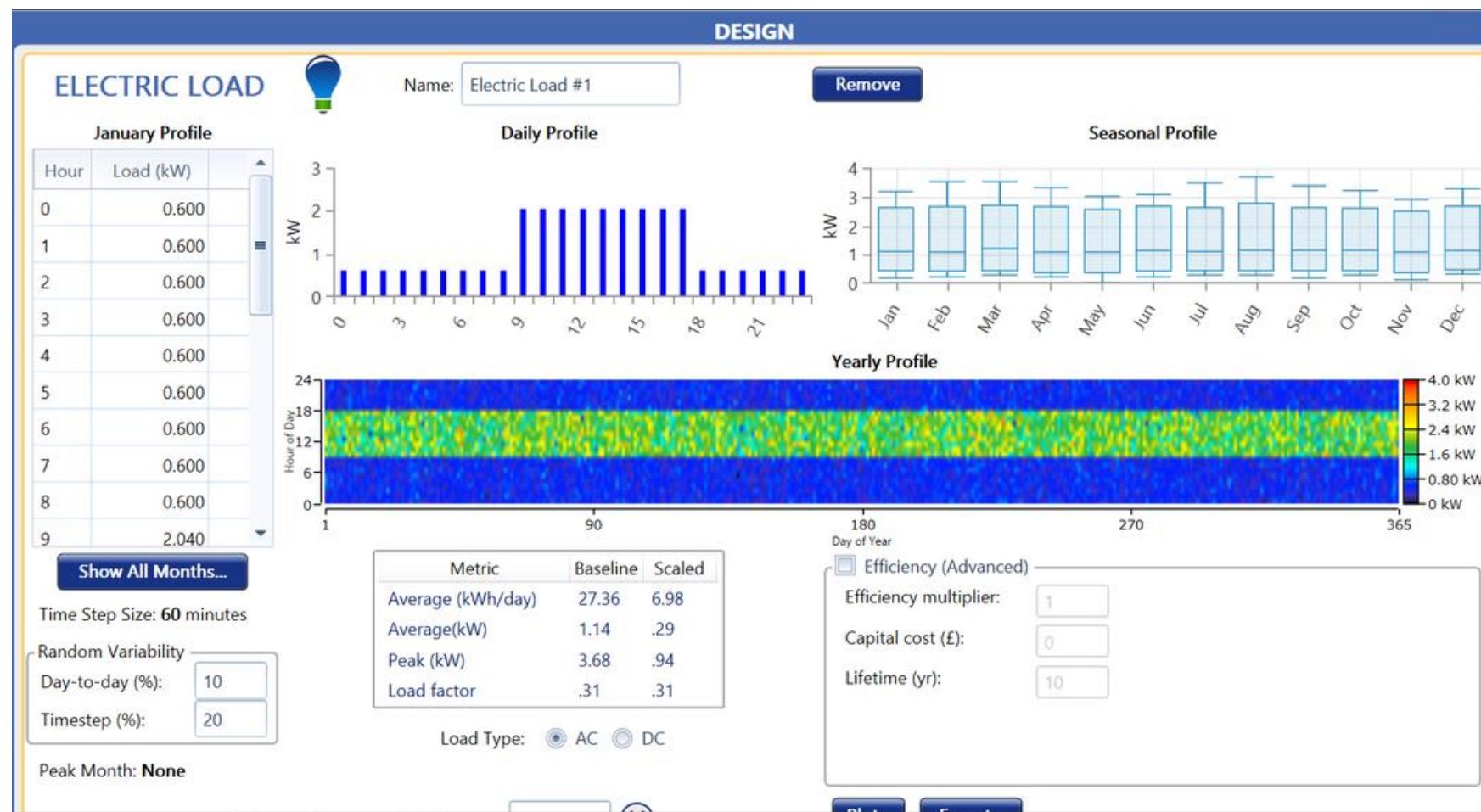
Foundational Inputs

Location	Office Building in London
Load	~7 kW (daily)
Type of Renewable	Solar Energy / Photovoltaic (PV)
Minimum Renewable Fraction	75%
Economics	Nominal Discount Rate: 8% Expected Inflation Rate: 5% Real Discount Rate: 2.86% Annual O&M: 1%

Although achieving identical inputs for a direct comparison was ideal, the differences in the software architectures occasionally necessitated variations in input parameters.

Despite this, foundational inputs were kept constant.

Case Study I: HOMER



A snapshot of HOMER user-interface.

Main Advantages

- User friendly interface;
- Accurate graphical representation of results;
- Auto-generates proposal document;

Main Disadvantages

- Missing features around EVs and chargers;
- Limited selection of pre-set energy profiles;
- Missing in-app tutorials and learning material;

Case Study I: HOMER

Calculation Report	
1,094 solutions were simulated:	
946 were feasible.	
148 were infeasible due to the minimum renewable fraction.	
119 were omitted:	
0 due to infeasibility.	
90 for lacking a converter.	
7 for having an unnecessary converter.	

Cost Summary

Economic Metrics

IRR ?	8.0%
ROI ?	5.4%
Simple Payback ?	8.8 yr

	Base Case	Lowest Cost System
NPC ?	£9,310	£7,814
Initial Capital	£4,887	£7,699
O&M ?	£293.44/yr	£7.61/yr
LCOE ?	£0.102/kWh	£0.0741/kWh

Key Figures

NPC	£7,814
LCOE	£0.0741
O&M	£7.61 / year
Energy Produced	6416 kW
Renewable Fraction	94%
Simple Payback	8.8 years
ROI	5.4%
IRR	8%

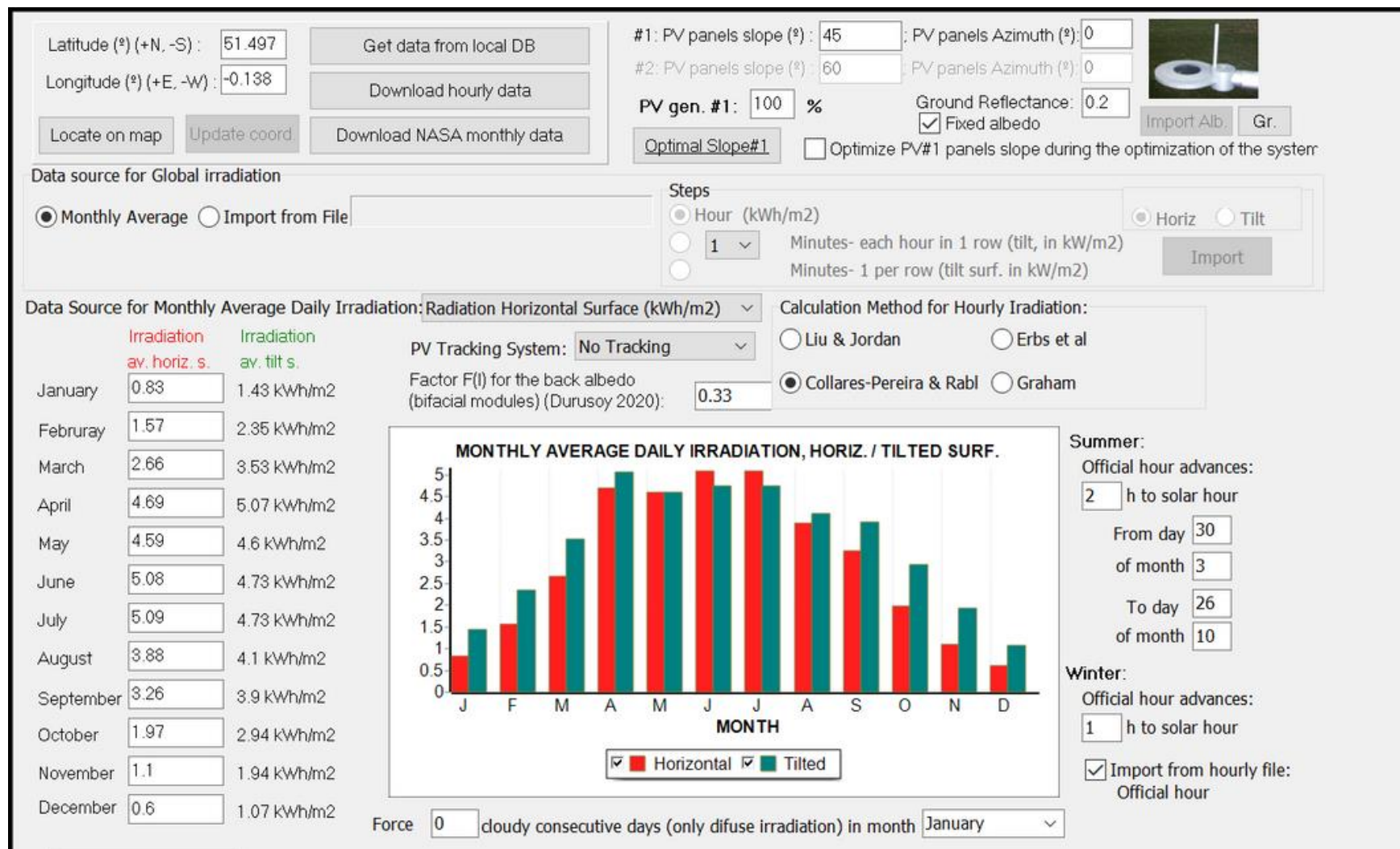
Case Study II: iHOGA

Main Advantages

- Multi-objective optimisation with NPC & NPV;
- Hourly and minute data handling capacity;
- Product catalogs are vast and with prices;

Main Disadvantages

- Missing features around EVs and chargers;
- Longer simulations due to genetic algorithm;
- Simulations capped at 7 kW for EDU version;

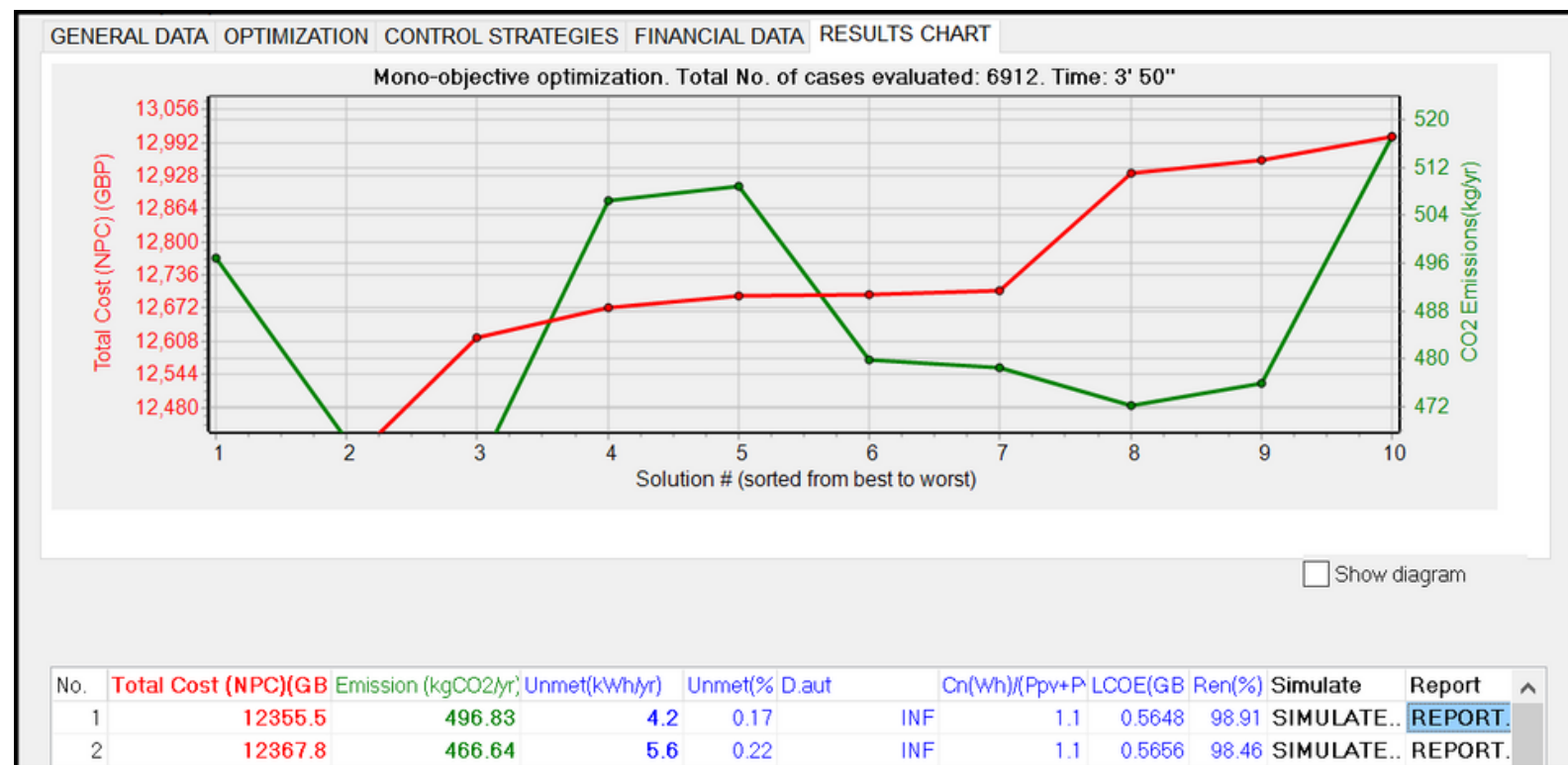


A snapshot of iHOGA user-interface.

Case Study II: iHOGA

Key Figures

NPC	£12,355
LCOE	£0.5648
O&M	Not available
Energy Produced	6540 kW
Renewable Fraction	99%
Simple Payback	Not available
ROI	Not available
IRR	Not available



The final results page of the simulation with iHOGA

HOMER appears to be the most user-friendly interface which provides financial analysis

HOMER

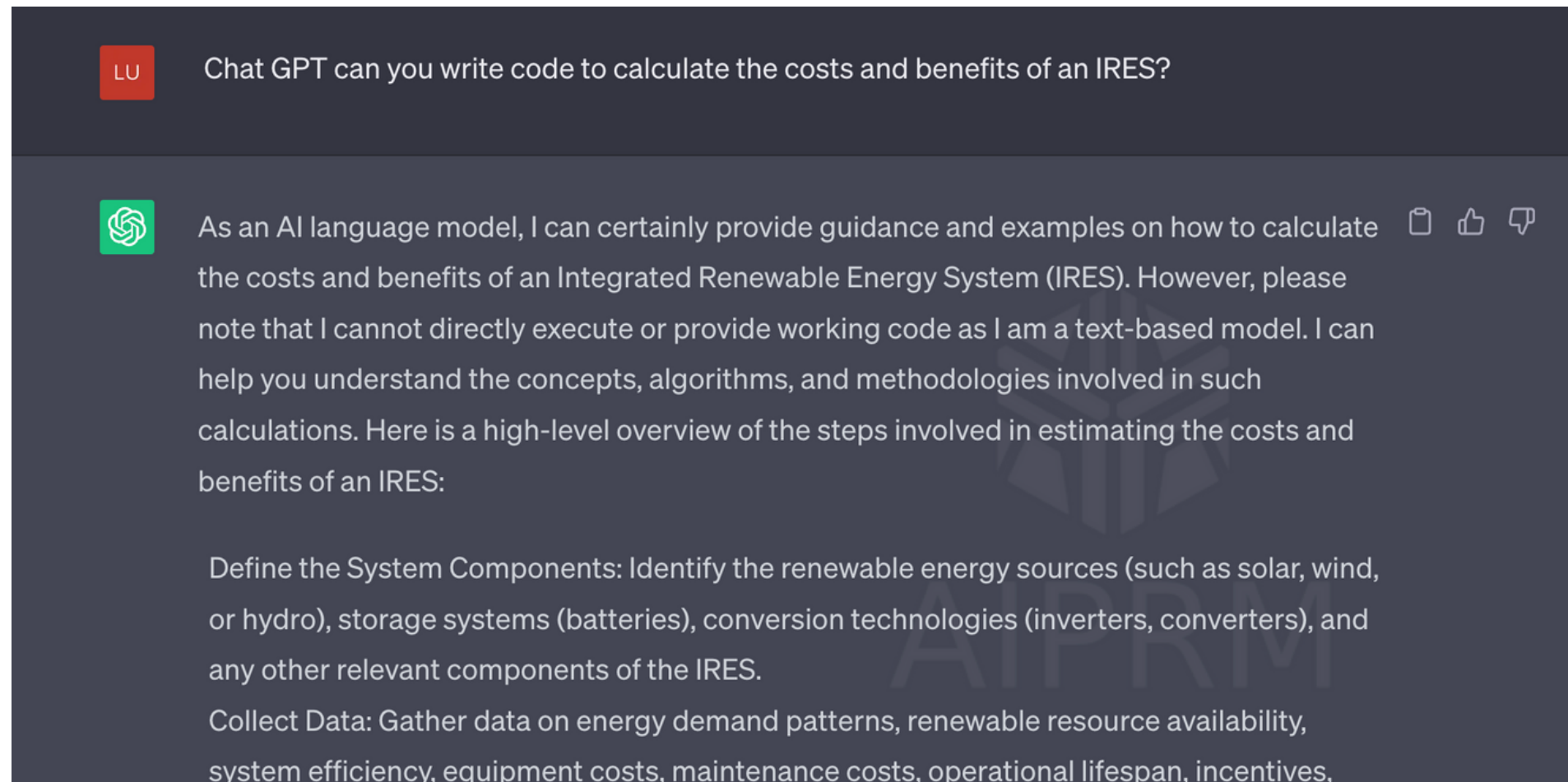
Stands out with its user-friendly interface, making it the ideal choice for business use and non-experts who require efficient and intuitive software. It also is able to provide Payback, Return on Investment, Internal Rate of Return.

iHOGA

iHOGA is a hybrid system optimization software tool for planning and monitoring electrical and thermal energy systems. It has been tailored mostly to meet the needs of academics, researchers and energy planners but does not dive into financial results. However the PRO version is designed for businesses.

The Potential of AI

AI has the potential to support with formula making to calculate the size of a system and its financial benefits by browsing the latest tools and formula available online.



Chat GPT can you write code to calculate the costs and benefits of an IRES?

As an AI language model, I can certainly provide guidance and examples on how to calculate the costs and benefits of an Integrated Renewable Energy System (IRES). However, please note that I cannot directly execute or provide working code as I am a text-based model. I can help you understand the concepts, algorithms, and methodologies involved in such calculations. Here is a high-level overview of the steps involved in estimating the costs and benefits of an IRES:

Define the System Components: Identify the renewable energy sources (such as solar, wind, or hydro), storage systems (batteries), conversion technologies (inverters, converters), and any other relevant components of the IRES.

Collect Data: Gather data on energy demand patterns, renewable resource availability, system efficiency, equipment costs, maintenance costs, operational lifespan, incentives,

Chat GPT can you write code to calculate the costs and benefits of an IRES?

As an AI language model, I can certainly provide guidance and examples on how to calculate the costs and benefits of a system [...]

If I gave you data inputs, would you be able to assess the benefits of a system?

Yes, I can certainly help you assess the benefits of an Integrated Renewable Energy System (IRES) if you provide the necessary data inputs [...]

Greater support is needed to estimate a dynamic system size and benefits

1.

Developers of calculators and tools need to evolve their offerings so that they help consumers to estimate systems that integrate the site road and grid. Most tools only focus on one of these however increasingly consumers are joining them up. Developers should consider how AI can help in this endeavour

2.

Consumers who have limited time and knowledge should use the simple tools available as an entry point to decide whether to get quotes and or help with more sophisticated estimates

3.

One Stop Shops (consumer advisory) should point consumers towards the existence of different calculators and tools to help them understand the options and benefits of adopting renewable energy systems.



Appendix

Bibliography

List of tools

Disclaimer - Whilst reasonable steps have been taken to ensure that the information contained within this publication is correct, the authors, Integrate to Zero, its agents, contractors and sub-contractors give no warranty and make no representation as to its accuracy and accept no liability for any errors or omissions

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Bibliography

- Aalborg University (1999) “EnergyPLAN.” Aalborg University. Available at: <https://www.energyplan.eu/>.
- Al-Karaghoul, A. and Kazmerski, L.L. (2010) “Optimization and life-cycle cost of health clinic PV system for a rural area in southern Iraq using HOMER software,” *Solar Energy*, 84(4), pp. 710–714. Available at: <https://doi.org/10.1016/j.solener.2010.01.024>.
- Canada, N.R. (1998) RETScreen. Available at: <https://natural-resources.canada.ca/maps-tools-and-publications/tools/modelling-tools/retscreen/7465> (Accessed: June 7, 2023).
- Connolly, D. et al. (2010) “A review of computer tools for analysing the integration of renewable energy into various energy systems,” *Applied Energy*, 87(4), pp. 1059–1082. Available at: <https://doi.org/10.1016/j.apenergy.2009.09.026>.
- Ekren, O., Canbaz, C.H. and Güvel, Ç.B. (2021) “Sizing of a solar-wind hybrid electric vehicle charging station by using HOMER software,” *Journal of Cleaner Production*, 279, p. 123615. Available at: <https://doi.org/10.1016/j.jclepro.2020.123615>.
- Estimating Hydropower’s Contribution to the Control of Greenhouse Gas Emissions (2002). Oak Ridge National Laboratory. Available at: http://www.ornl.gov/sci/engineering_science_technology/cooling_heating_power/orced/reports/WPXIIIGHG.PDF (Accessed: July 2, 2023).
- Kanase-Patil, A.B. et al. (2020) “A review of artificial intelligence-based optimization techniques for the sizing of integrated renewable energy systems in smart cities,” *Environmental Technology Reviews*, 9(1), pp. 111–136. Available at: <https://doi.org/10.1080/21622515.2020.1836035>.
- Rao, A.N. et al. (2020) “Computer Tools for Energy Systems,” in *Lecture notes in electrical engineering*. Springer Science+Business Media, pp. 475–484. Available at: https://doi.org/10.1007/978-981-15-2612-1_46.

Bibliography

- Rehman, S. et al. (2007) “Feasibility study of hybrid retrofits to an isolated off-grid diesel power plant,” *Renewable & Sustainable Energy Reviews*, 11(4), pp. 635–653. Available at: <https://doi.org/10.1016/j.rser.2005.05.003>.
- Rehman, S. and Al-Hadhrami, L.M. (2010) “Study of a solar PV–diesel–battery hybrid power system for a remotely located population near Rafha, Saudi Arabia,” *Energy*, 35(12), pp. 4986–4995. Available at: <https://doi.org/10.1016/j.energy.2010.08.025>.
- Saha, H. (1981) “Design of a photovoltaic electric power system for an indian village,” *Solar Energy*, 27(2), pp. 103–107. Available at: [https://doi.org/10.1016/0038-092x\(81\)90030-x](https://doi.org/10.1016/0038-092x(81)90030-x).
- University of Zaragoza (2015) “iHOGA.” University of Zaragoza. Available at: <https://ihoga.unizar.es/en/>.

This bibliography only includes the most relevant sources used in the analysis of the tools presented. A comprehensive bibliography will be made available upon the conclusion of the research.

List of tools included

Not Included	1. AEOLIUS	14. PSR	27. WASP
	2. E ₄ cast	15. Ready Reckoner	28. PSAT ORCED
	3. EMINENT	16. PRIMES	29. PERSEUS
	4. ENPEP-Balance	17. ProdRisk	30. TRNSYS16
	5. HYDROGEMS	18. Samplan	31. UniSyD3.0
	6. INFORSE	19. SEDS	32. CHPSizer
	7. MESAP PlaNet	20. RAMSES	33. CO2BD
	8. MESSAGE	21. SGM	34. EMPS
	9. MENSA	22. TESOM	35. DER-CAM
	10. MOREHyS	23. SimREN	36. DIMES
	11. MiniCAM	24. SIVAEI	37. DREAM
	12. NEMS	25. UREM	38. E3database
	13. NESSIE	26. STREAM	39. Endur
Included	1. BChP Screening Tool	6. ORCED	11. Hybrid Designer
	2. LEAP	7. Ares-I&II	12. HYSYS
	3. TRNSYS	8. HySim	13. SOMES
	4. INSEL	9. SOLSTOR	
	5. HYBRID2	10. HybSim	
Analysed in-depth	1. HOMER	3. RETScreen	
	2. EnergyPLAN	4. iHOGA	