MicroGridsPy: An Open-Source Modelling Ecosystem for Mini-Grid Planning

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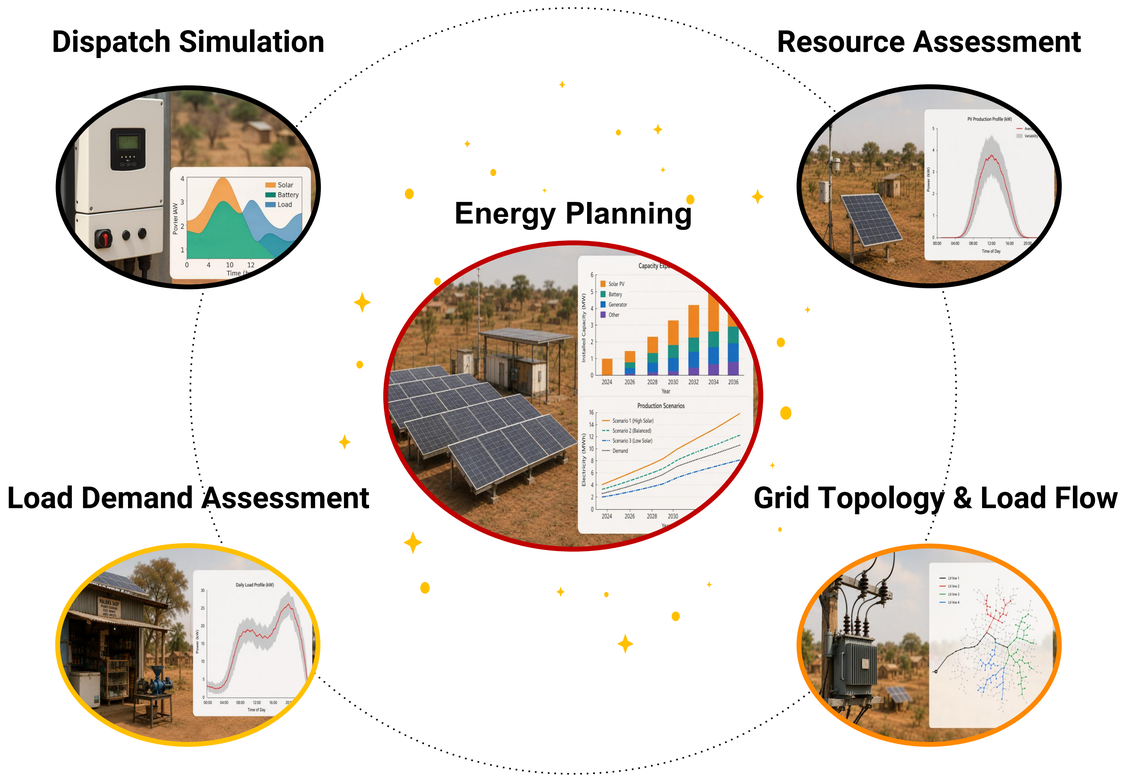
Key Message

Keywords:
Open-source modelling · Mini-grid· Stochastic demand · Capacity expansion · LV/MV topology · Load-flow · Energy access

MicroGridsPy provides an **open-source**, **modular workflow** for **planning mini-grids under uncertainty**. The ecosystem links **stochastic demand generation**, renewable resource assessment, **multi-year techno-economic optimization**, and **LV/MV topology design with load-flow validation**, supporting transparent and field-informed decisions from early feasibility to detailed planning.

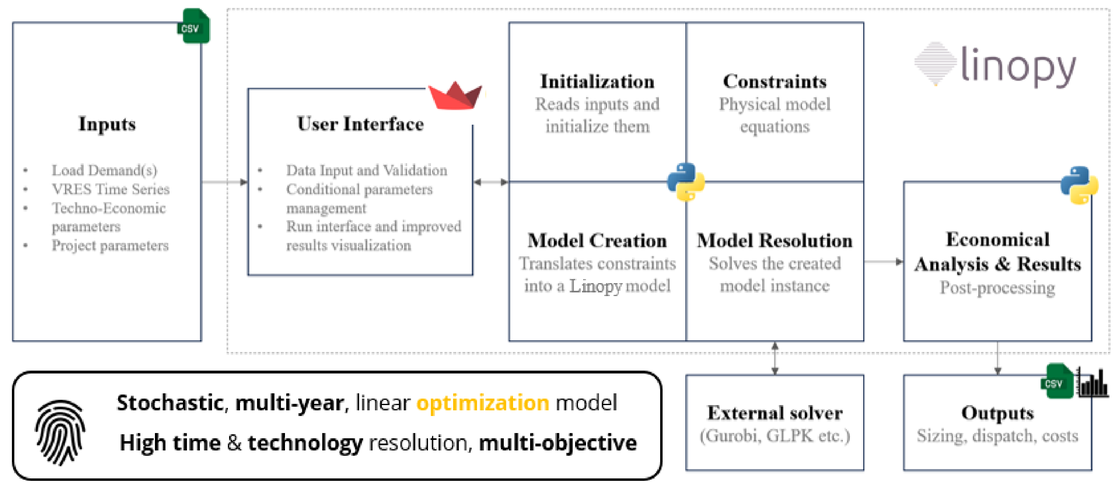
A Modelling Ecosystem

Integrated yet modular: each tool addresses a specific planning step, while together they form a **reproducible pipeline** from load to optimized sizing and network design.



Energy Planning

At the core of the ecosystem, MicroGridsPy **optimizes the sizing and dispatch of renewables**, batteries, generators, and power-conversion components. The model supports **hourly LP/MILP formulations**, **multi-year capacity expansion**, **stochastic scenarios**, **grid-connection options**, and **cost–emission trade-offs** through Pareto analysis.

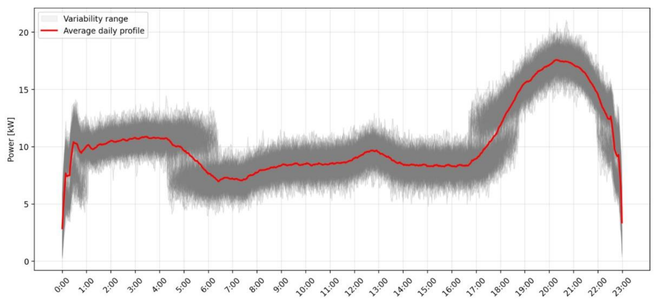


Planning outputs
Optimal Installed capacity · Capacity expansion pathway · Scenario-specific dispatch · NPC/LCOE · CO_2 emissions · Pareto cost–emission curve · Cash flows · Payback and bankability indicators · Curtailment · Lost load · Fuel use

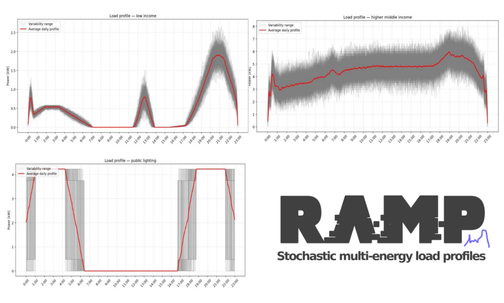
Stochastic Load Demand Estimation

The RAMP-based module generates **appliance-level Monte Carlo load profiles** and assembles daily **realizations by season and user segment** into **yearly demand scenarios**. These profiles reveal **peak coincidence**, **productive-use shocks**, and **variability bands** that strongly affect battery, inverter, and generator sizing.

Average Daily Profile with variability



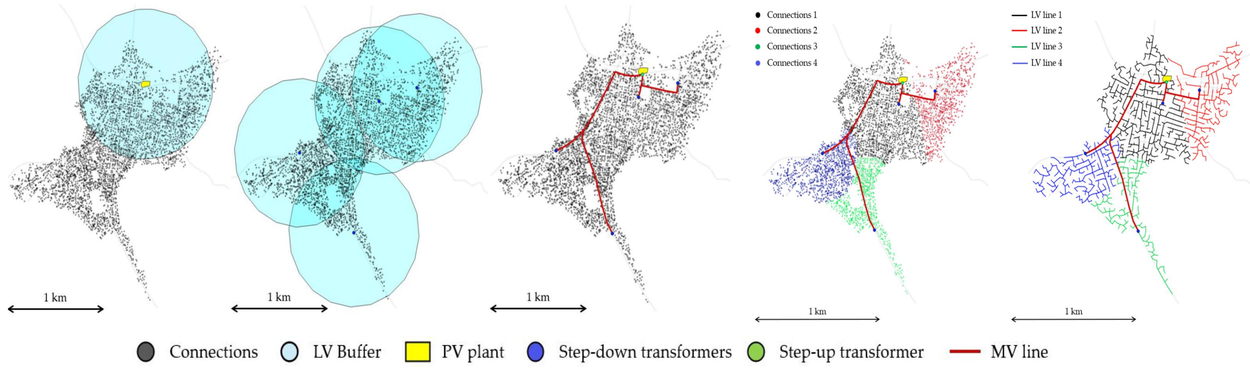
Segmentation by user and seasons



RAMP
Stochastic multi-energy load profiles

LV/MV Grid Topology & Load Flow

The distribution module converts **georeferenced customers** and **road layouts** into realistic **LV/MV mini-grid networks**. A **pole-first heuristic** places poses under distance and capacity constraints, while **Minimum Spanning Tree** optimization minimizes conductor length and preserves radial structure. The resulting topology is then tested through **AC load-flow analysis** to detect voltage and thermal violations and guide **targeted reinforcement**.



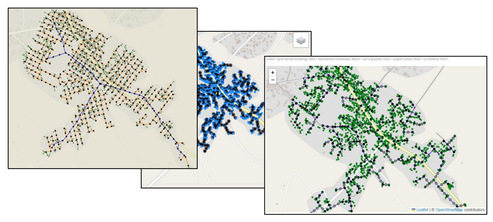
Open Source Tools Comparison

Open-source mini-grid tools are complementary rather than interchangeable. They serve **different purposes**: choosing the right one depends on project stage and required level of detail.

MicroGridsPy

+ Full techno-economic optimization
+ Supports uncertainty and multi-year expansion
+ High model flexibility and customization
- Requires more input data
- Higher computational cost

Detailed feasibility studies
Investment planning
Long-term system design



offgridplanner

+ Web-based *(no installation required)*
+ Automatic building detection *(OpenStreetMap)*
+ Integrated workflow from layout to sizing
- Simplified network representation
- Limited customization compared to other tools

Early-stage feasibility
Fast site preparation
Projects with limited data

OnSSET for MiniGrids

+ Designed to evaluate many locations
+ Fast capacity screening
+ Suitable for regional or national analysis
- Simplified operational modelling
- Requires GIS pre-processing

Regional planning
Pipeline development
Pre-feasibility screening

Feature	OnSSET for Mini-Grids	offgridplanner	MicroGridsPy
User interface	Jupyter Notebook	Web-based	Streamlit-based
Multi-site optimization	✅	❌	❌
Multi-year capacity expansion	❌	❌	✅
PV, Batteries, Generator, Inverters and AC loads	✅	✅	✅
Wind	❌	(✅)**	✅
Other technologies	❌	❌	(✅)***
DC loads	❌	(✅)*	✅
Topology approach	Trunk-first + Partition	Delaunay Triangulation + Selection	Pole-first heuristics + MST
Road following	❌	❌	✅
Powerhouse placement	✅	✅	❌
Automatic building extraction	❌	✅	❌
SHS option for remote customers	❌	✅	✅
Load-Flow analysis	❌	❌	✅

*Can be included in the underlying OffGridders tool
** WindDieselBattery version available, but not in combination with PV
*** The tool can include any generation technology, but this requires additional pre-processing compared to the built-in technologies

Let's Start!

Scan the QR code and **start exploring the tools!** The full workflow is accessible through a **user-friendly Streamlit interface**, and supported by:

- **example cases**,
- **data validation**,
- **dynamic result visualizations**.

Dedicated **GitHub folders** are available for each planning step, making it easy to test, adapt, and **contribute to the ecosystem**.

SCAN ME

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References:

Sergio Balderrama, Francesco Lombardi, Fabio Riva, Walter Canedo, Emanuela Colombo, Sylvain Quoilin, "A two-stage linear programming optimization framework for isolated hybrid microgrids in a rural context: The case study of the "El Espino" community", Energy 2019, 188, 116073

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