Sizing and Optimization of Hybrid Mini-Grids with *micrOgridS*

— *an Open-Source Modelling Tool.*

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3rd International Hybrid Power Systems Workshop

8.5.2018

Reiner Lemoine Institut (RLI)

Applied research to target 100% RE in the mix

- Not-for-profit research institute
- 100 % subsidiary of Reiner Lemoine Foundation (RLS)
- Established 2010 in Berlin
- Managing Director: Dr. Kathrin Goldammer
- Approximately 25 researchers + students
- Member of: ARE, eurosolar, SDSN, dena

Alliance for Rural Electrification

EUROSOLAR Europäische Vereinigung für Erneuerbare Energien e.V.

SUSTAINABLE DEVELOPMENT SOLUTIONS NETWORK A GLOBAL INITIATIVE FOR THE UNITED NATIONS

dena Deutsche Energie-Agentur

Reiner Lemoine
Founder of Reiner Lemoine-Foundation

Agenda

1) Motivation
2) Methods & Modelling Approach
3) Case Study
4) Conclusions

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1) **Motivation**
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Motivation: Hybridization Potential

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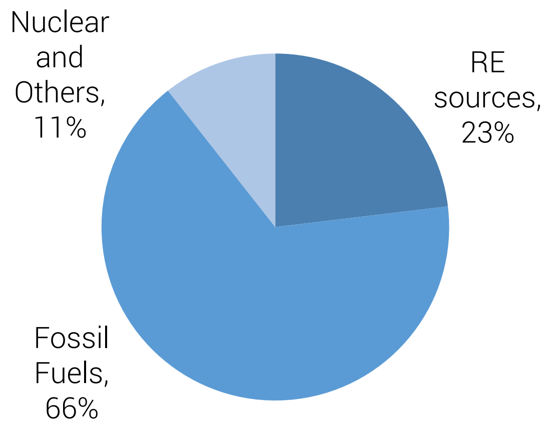
SDG # 7	World	Island States/ SIDS

1)



Electricity generation in 2015

Total = 24255 TWh

2)

- Strong dependency on petroleum goods
- Highest electricity rates worldwide
- Vulnerability to effects of climate change

3)

Motivation: Software Tools for Hybrid Mini-Grids

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Software tools are crucial to …

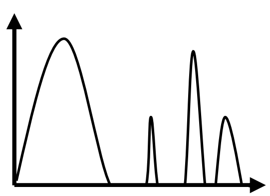
- map the complexity of interactions of system components
- provide optimized sizing of system components
- identify optimized operational strategies
- provide guidance for political decision making and identify investment cases

Motivation: Software Tools for Hybrid Mini-Grids

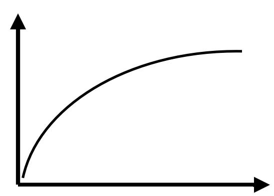
Software tools are crucial to …

- map the **complexity** of interactions of system components

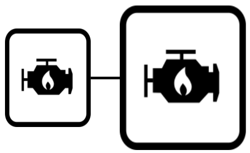
increases by:



natural intermittency of RE sources



non-linear DG efficiency



parallel operation of different DGs

Motivation: Software Tools for Hybrid Mini-Grids

Software tools are crucial to …

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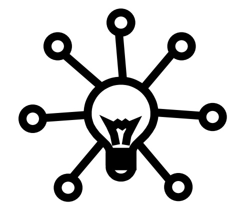
Motivation: Software Tools for Hybrid Mini-Grids

REINER LEMOINE INSTITUT

Open source software is crucial to …

- meet scientific standards in software based research
- foster bottom-up approaches by reducing barriers associated with high license cost of proprietary software tools
- improve research quality & completeness & knowledge pooling due to collaborative modelling

open source



collaborative

openmod open energy modelling initiative

„(…) models need to meet scientific standards as public acceptance becomes increasingly important“

Hilpert et. al[3)]

Agenda

1) Motivation
2) **Methods & Modelling Approach**
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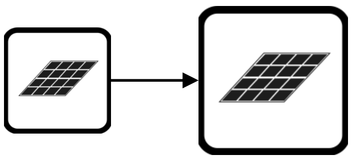
Requirements for a comprehensive software tool

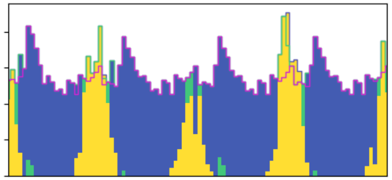
sizing of system components

+

optimized operational strategies



	priority high	medium	low
RE	• PV • generic	• wind • biomass • micro-hyrdro	• geothermal • tidal sources
Storage	• lead-acid BESS • Li-ion BESS • generic	• thermal • fuel cell	• Redox-Flow BESS • high temperature BESS • pumped hydro
Other	• grid controller • diesel gensets • inverters • AC- and DC Bus	• grid	



- **adjustable time resolution** (15 mins – hourly)
- **multi-objective** optimization
- include **stability criteria** (rotating mass and spinning reserve)

micrOgridS – Overview

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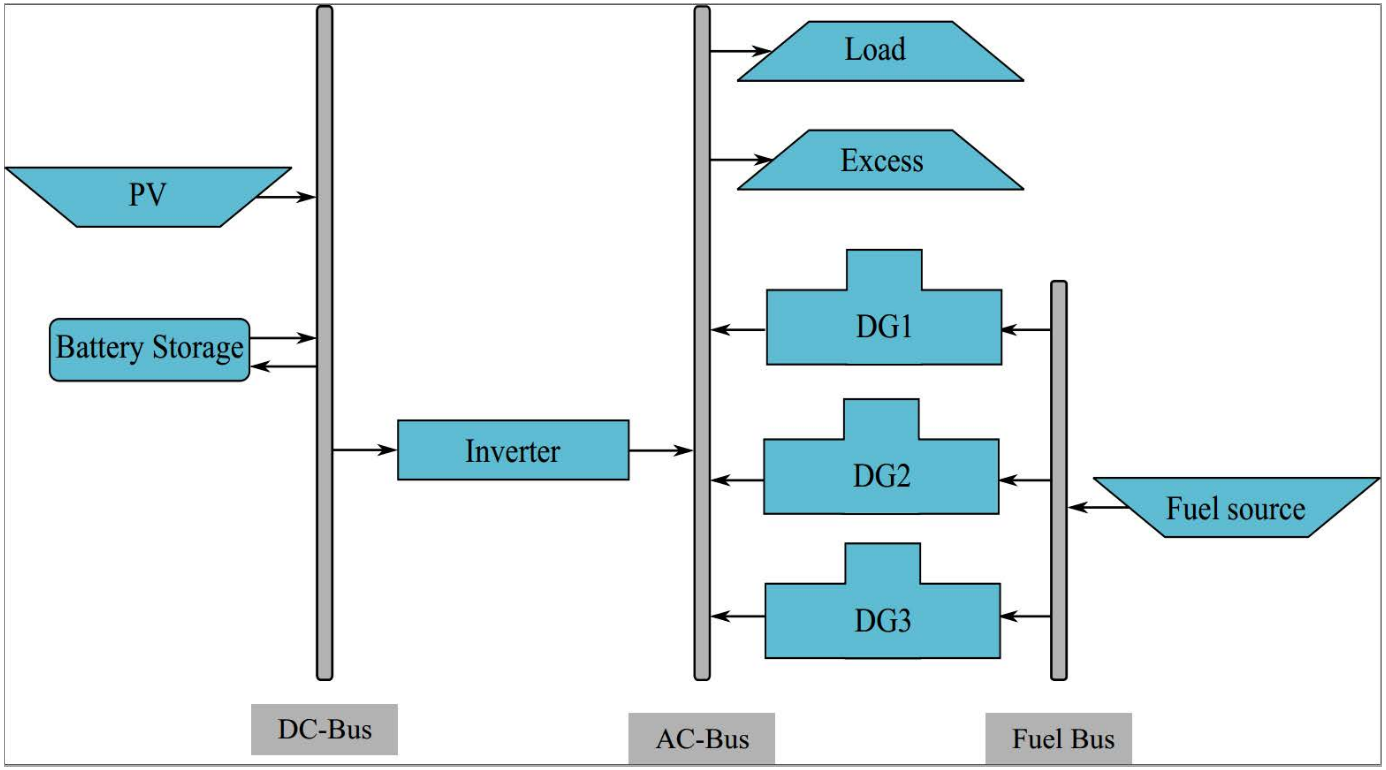
The micrOgridS tool as an open-source optimization tool adopted for the purpose of HMG design.



micrOgridS – Main functions

- generates sizing of PV and BESS
- calculates optimized hourly dispatch
- allows to modify the scheduling horizon by utilizing the Rolling Horizon Approach
- formulated as a Mixed Integer Linear Problem
- based on the Open Energy Modelling Framework (Oemof) that is programmed in Python

micrOgridS – Tool Design

oemof ['ø:mɔf]
open energy modelling framework

- open-source framework for energy system modelling
- hosted by RLI and ZNES Flensburg
- modular and generic
- developed in a community project
- embedded in Open Energy Modelling Initiative
- well-documented

Website:

https://oemof.org/

Github:

https://github.com/oemof/oemof

Documentation:

https://oemof.readthedocs.io/en/stable/

Latest release : oemof v 0.2.1

micrOgridS – Objective and Constraints

Objective Function

A single objective function describing the total annualized system cost TC of the HMG

$$\min TC = \sum_j (CC_j + OPEX_j) + AWC + \sum_{dg} FC_{dg} \qquad \forall j, \forall dg$$

TC	total annualized system cost
CC_j	capital cost of component j
$OPEX_j$	operation cost of component j
AWC	average wear cost of battery
FC_{dg}	fuel cost of diesel genset dg

Stability Constraints:

- Spinning reserve
- Rotating mass
- simplified (N-1)-constraint
- generator order

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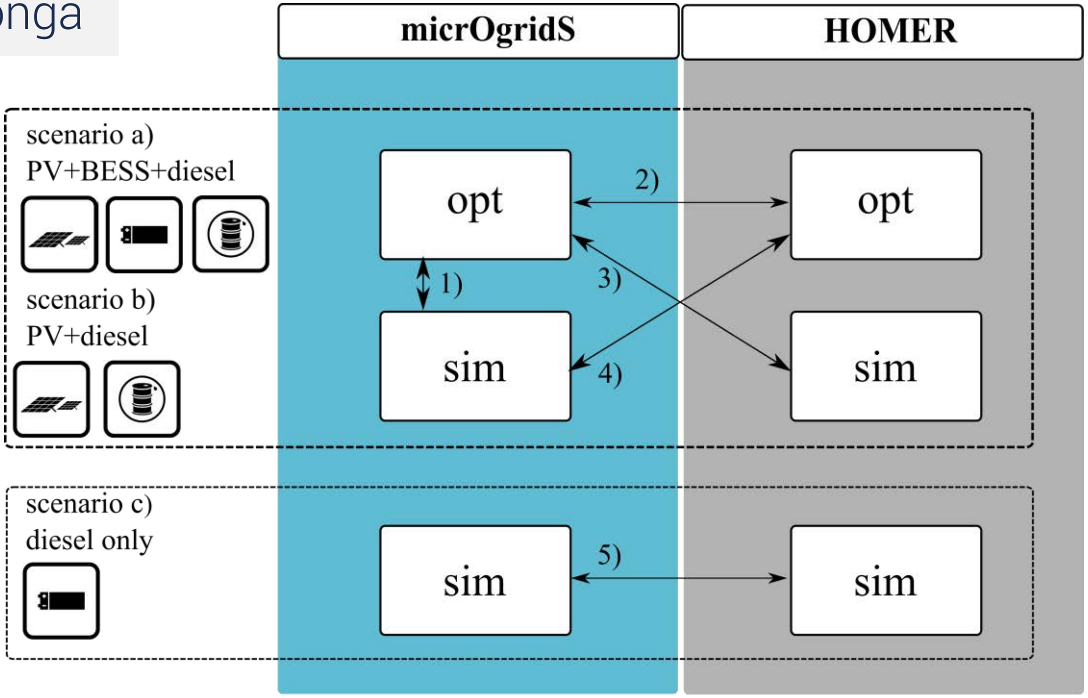
Application of micrOgridS – Case Study

Case Study: Lifuka Island, Tonga

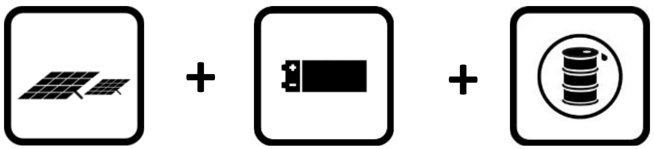


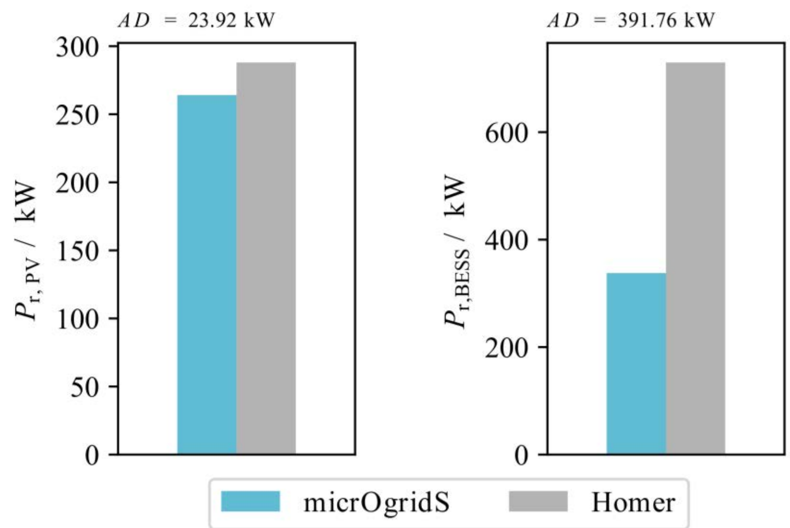
- Project lifetime: 20 years
- *WACC* = 0.094

		PV	BESS	DG1=DG2	DG3
installed capacity	[kW]	free	free	186	320
CAPEX	[$/kW]	2500	300	500	
OPEX	[$/kW], [$/kW/h_{on}]	2.5	3.88	0.02	
lifetime	[yrs]	20	10	20	

Application of micrOgridS – Case Study

Case Study: Comparison with Homer



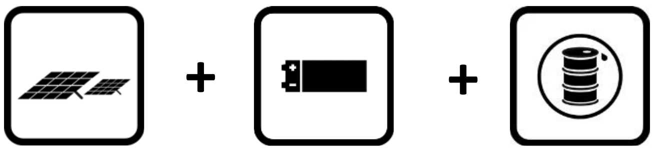


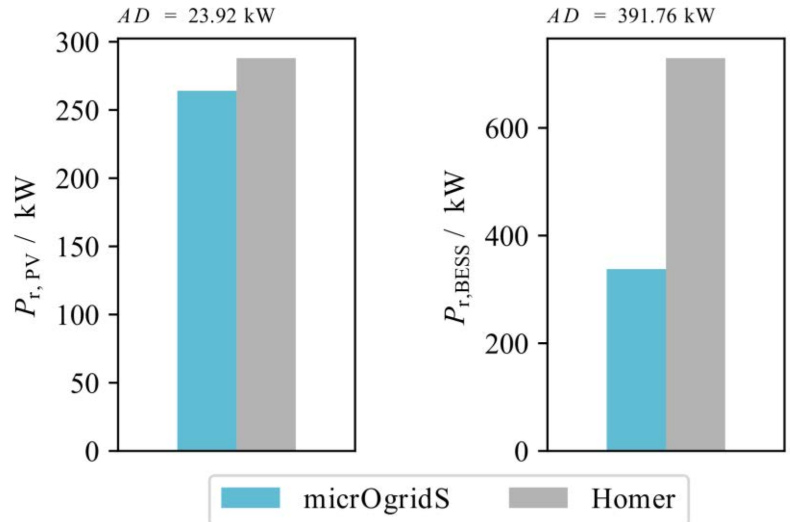
micrOgridS		Homer		%RD			
PV [kW]	BESS [kWh]	PV [kW]	BESS [kWh]	LCOE	RE share	fuel consumption	excess energy
264	338	288	730				

micrOgridS/Homer						
PV [kW]	BESS [kWh]					
264	338					
288	730					

Application of micrOgridS – Case Study

Case Study: Comparison with Homer



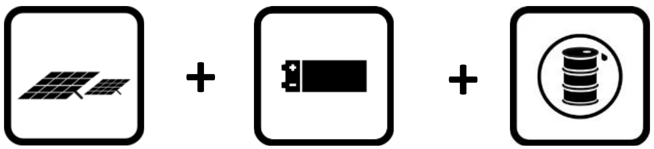


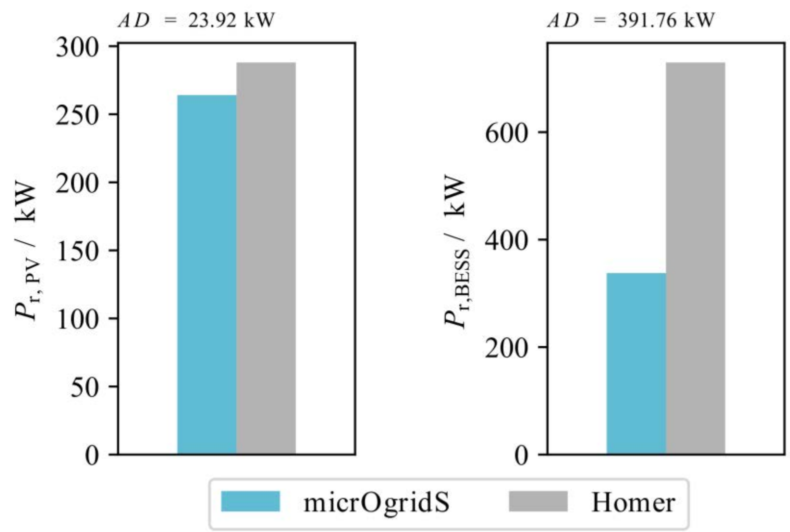
micrOgridS		Homer		%RD			
PV [kW]	BESS [kWh]	PV [kW]	BESS [kWh]	LCOE	RE share	fuel consumption	excess energy
264	338	288	730	-10%			

micrOgridS/Homer					
PV [kW]	BESS [kWh]	LCOE	RE share	fuel consumption	excess energy
264	338	-12.1%			
288	730	-6.4%			

Application of micrOgridS – Case Study

Case Study: Comparison with Homer



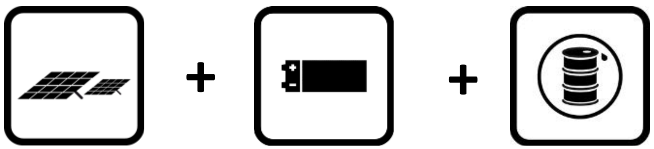


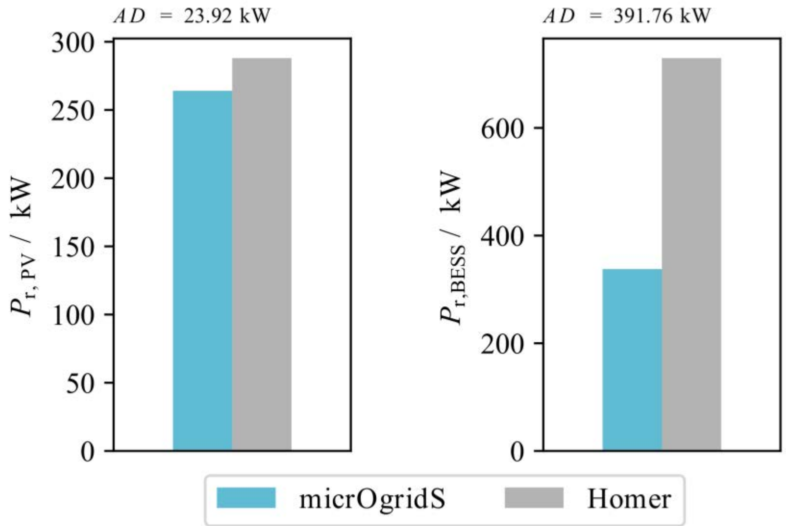
micrOgridS		Homer		%RD			
PV [kW]	BESS [kWh]	PV [kW]	BESS [kWh]	LCOE	RE share	fuel consumption	excess energy
264	338	288	730	-10%	-3.9%		

micrOgridS/Homer					
PV [kW]	BESS [kWh]	LCOE	RE share	fuel consumption	excess energy
264	338	-12.1%	24.7%		
288	730	-6.4%	7.6%		

Application of micrOgridS – Case Study

Case Study: Comparison with Homer



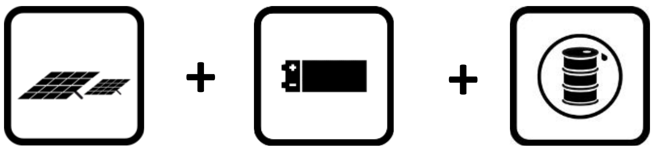


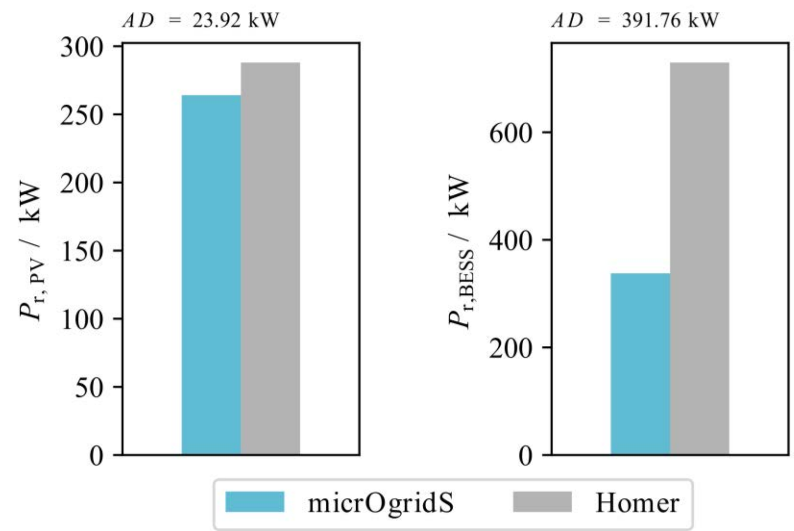
micrOgridS		Homer		%RD			
PV [kW]	BESS [kWh]	PV [kW]	BESS [kWh]	LCOE	RE share	fuel consumption	excess energy
264	338	288	730	-10%	-3.9%	-4.3%	

micrOgridS/Homer					
PV [kW]	BESS [kWh]	LCOE	RE share	fuel consumption	excess energy
264	338	-12.1%	24.7%	-15.7%	
288	730	-6.4%	7.6%	-10.8%	

Application of micrOgridS – Case Study

Case Study: Comparison with Homer





micrOgridS		Homer		%RD			
PV [kW]	BESS [kWh]	PV [kW]	BESS [kWh]	LCOE	RE share	fuel consumption	excess energy
264	338	288	730	-10%	-3.9%	-4.3%	-35.7%

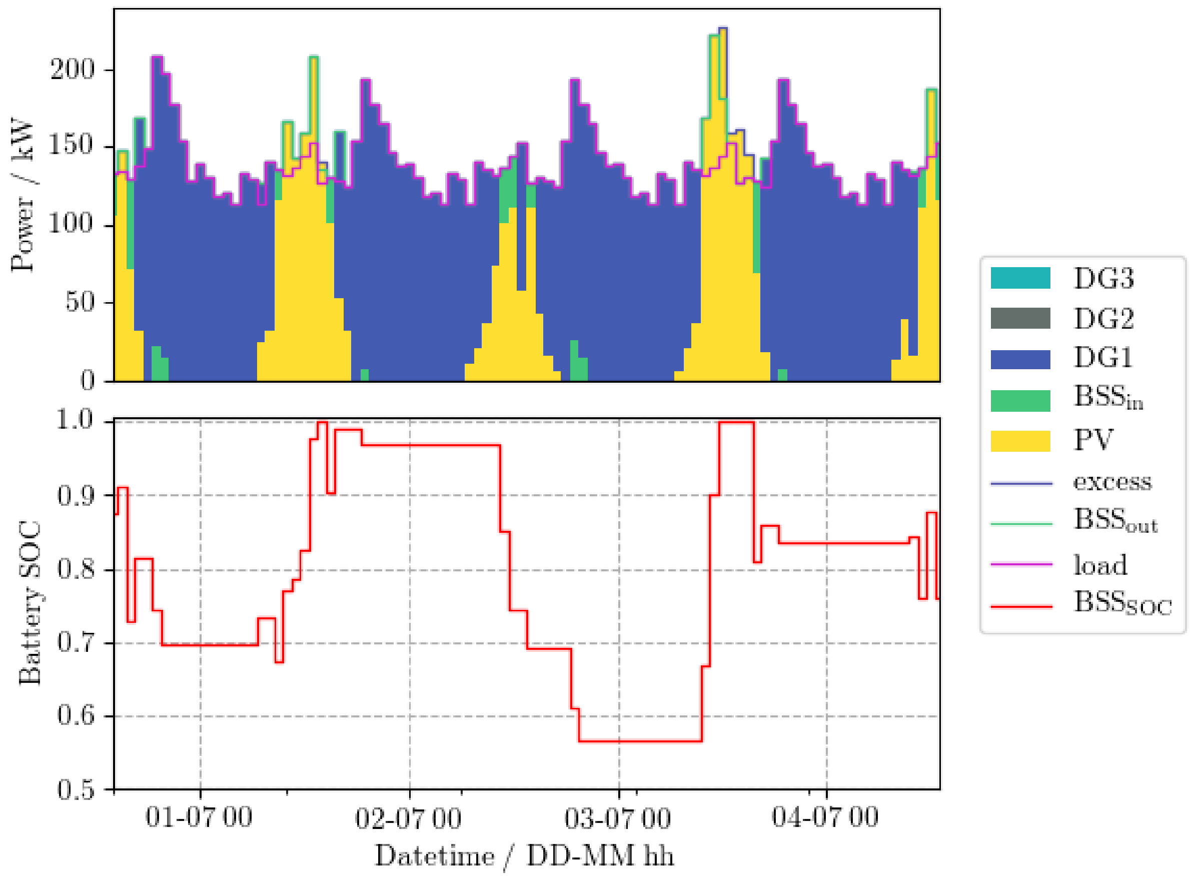
micrOgridS/Homer					
PV [kW]	BESS [kWh]	LCOE	RE share	fuel consumption	excess energy
264	338	-12.1%	24.7%	-15.7%	-70.5%
288	730	-6.4%	7.6%	-10.8%	-61.9%

Application of micrOgridS – Case Study

micrOgridS results in

↓ LCOE,
fuel
excess energy

↑ computational
time



due to

- optimized dispatch strategy
- simplified BESS component model
- comparability issues through lack of transparency

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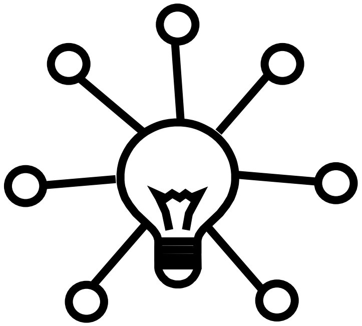
Conclusions & Further Development

mircOgridS represents a valid base for HMG related modelling tasks.

Oemof is a useful toolbox to model the elaborated requirements for a comprehensive software tool.

All high priority components are integrated.

There are deviations compared to Homer.



Further development targets e.g. :

- integrate missing requirements
- reduce computational time (time series aggregation approaches, solver algorithm)
- GUI development (web-based interface, reduced in complexity)

Thank you!

Join the open source modelling community!

Thanks to the Photovoltaik Institut AG Berlin

for funding and collaboration in this project.

Comments & Ideas?

... Partnerships

... Research Collaboration

... Joint Project Proposals

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Sources

1) United Nations (2015). Web source: https://www.un.org/sustainabledevelopment/wp-content/uploads/2016/10/UN-Guidelines-for-Use-of-SDG-logo-and-17-icons.October-2016.pdf
2) International Energy Agency. World Energy Outlook 2017
3) Lucas, H., et al. (2017). „Critical challenges and capacity building needs for renewable energy deployment in Pacific Small Island Developing States (Pacific SIDS). ", Renewable Energy vol 107, pp. 42-52
4) Hilpert, S et al (2017, February). Addressing energy system modelling challenges: The contribution of the open energy modelling framework (oemof). doi: 10.20944/preprints201702.0055.v1
5) P. Peerapong and B. Limmeechokchai, "Optimal electricity development by increasing solar resources in diesel-based micro grid of island society in thailand," Energy Reports, vol. 3, pp. 1–13, Nov. 2017.
6) J. Y. Tao and A. Finenko, "Moving beyond LCOE: impact of various financing methods on PV profitability for SIDS," Energy Policy, vol. 98, pp. 749–758, Nov. 2016.

Back-Up

Reiner Lemoine Institut (RLI) - Fields of Research

Transformation of Energy Systems	Mobility with Renewable Energy	Off-Grid Systems
" We analyze and optimize future scenarios with an energy supply largely based on renewable energy sources. "	"We study sustainable mobility concepts through sophisticated implementation and optimization of renewable energy systems. "	"We support the development of sustainable energy supply for remote regions."

Reiner Lemoine Institut (RLI) – Fields of Research

Off-Grid Systems

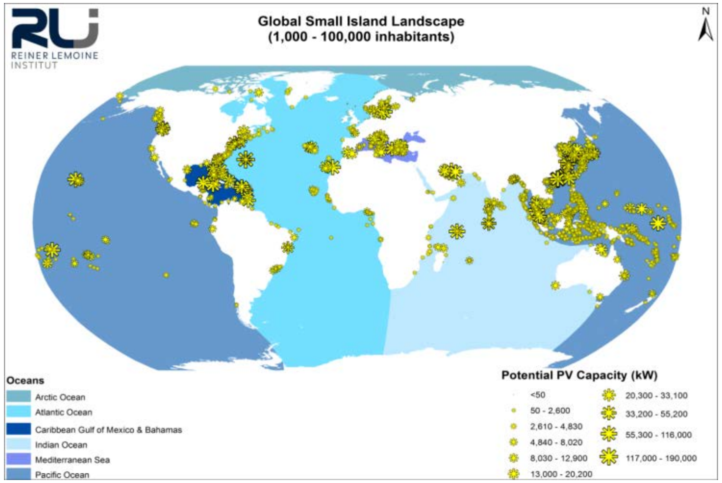
“We support the development of sustainable energy supply for remote regions.“

OUR MOTIVATION

Economic Decentralized energy supply systems represent an attractive market for RE and battery storage

Ecological Fossil fuel substitution by RE reduces harmful emissions locally and globally in off-grid systems

Social Electricity is a prerequisite for improved local development, health care and education.



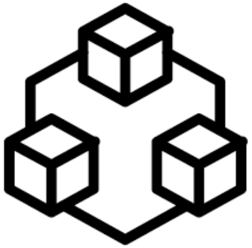
OUR EXPERTISE

- Geographic Information System
- Energy System Modelling
- Market Potential Analysis
- Financial Assessment
- Strategic Planning

Requirements for a comprehensive software tool

General

- **Modular**, **extensible**, **open** for external modules
- Generate **robust** results
- Integrate **easy-to-use capabilities**

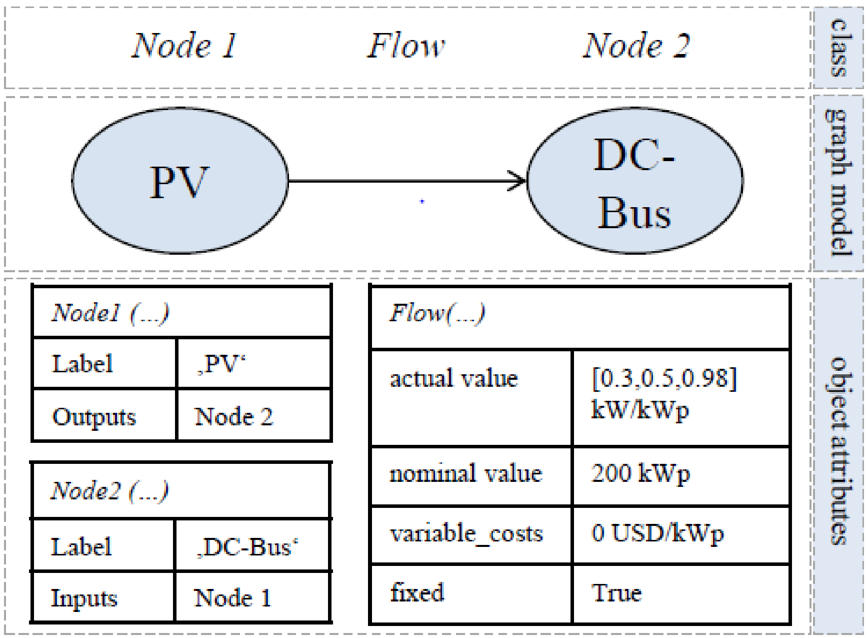


Further functionality criteria

- Include possibility to **update uncertain parameters**
- **direct download of resource data**

micrOgridS – Modelling of System Components

The Hybrid Micro Grid is modelled via graph-based modelling approach.



- System components are described as *Nodes*
- *Nodes* are connected with *Flows*
- Parameterization mainly attributed to *Flows*

→ „generic" component models