

Diesel-PV-Battery Hybrid System Study for Kaledupa Island



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Peter-Philipp Schierhorn, M.Sc.



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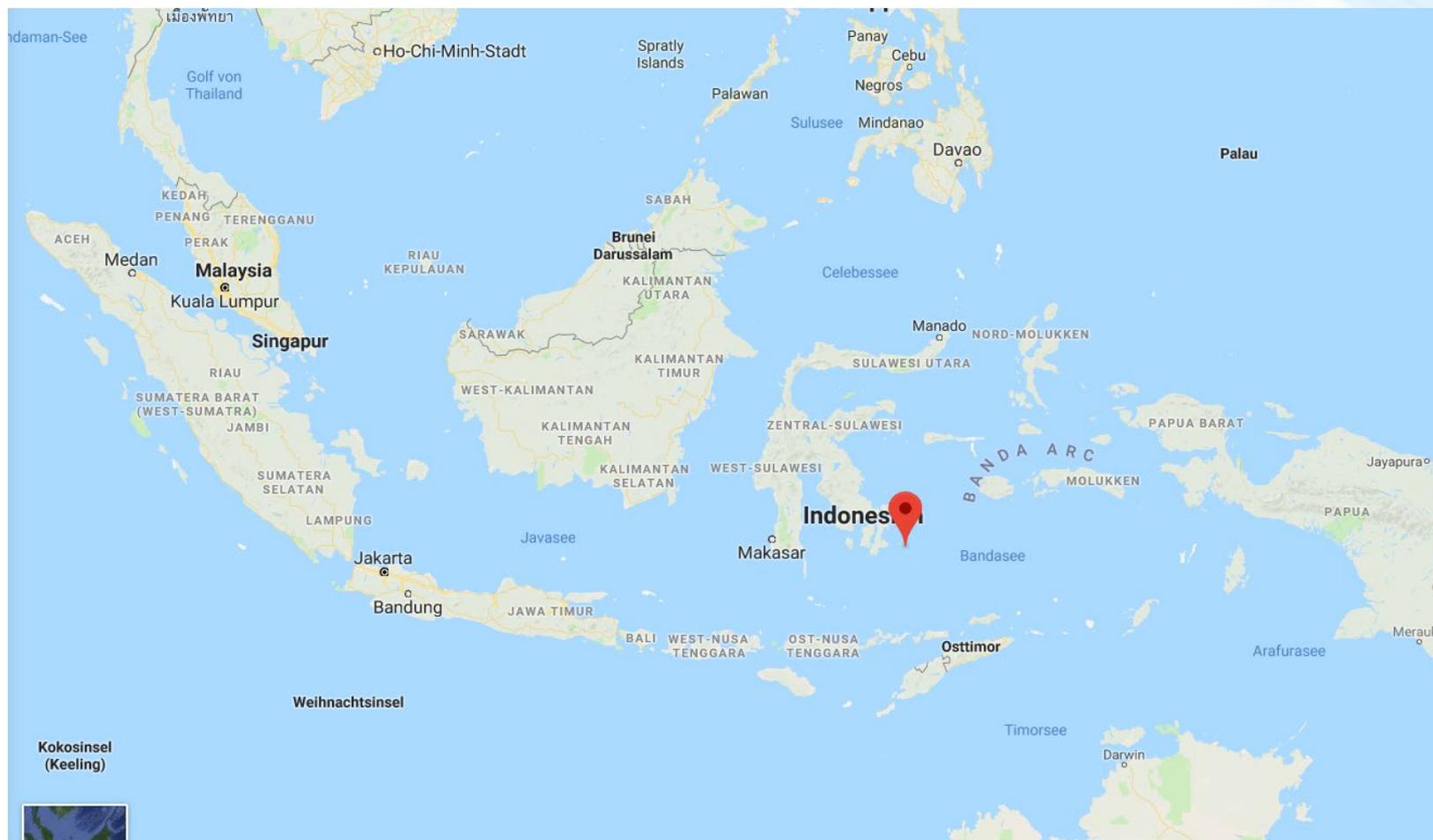




1. INTRODUCTION



PULAU KALEDUPA: LOCATION





PULAU KALEDUPA: DEMAND AND SUPPLY

12 h/d electricity supply

Additional hours on Friday and Sunday

Peak load > 800 kW

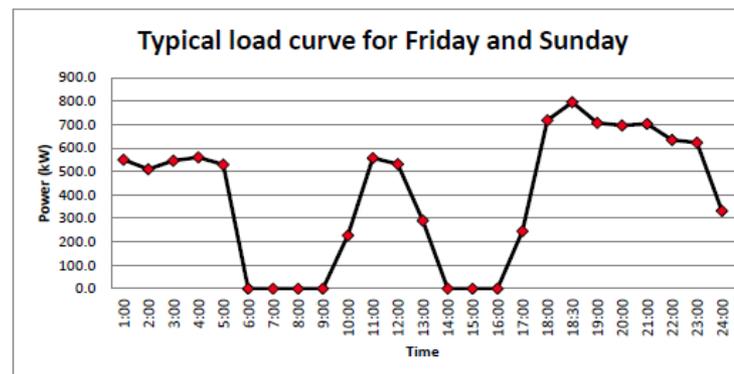
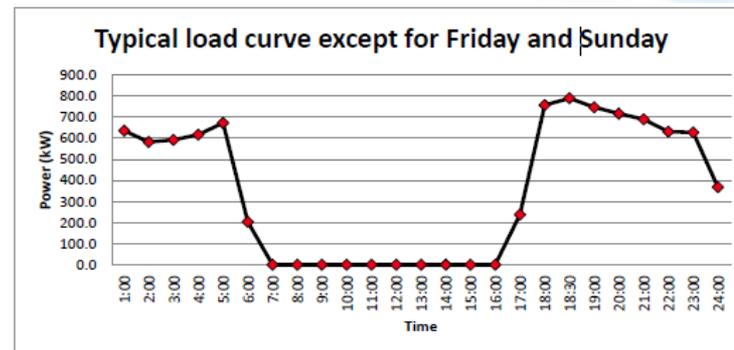
Annual production 2700 MWh

Annual fuel cost ca. 740.000 € (11400 Mio Rp)

-> cost of electricity by fuel alone: **27 ct/kWh (4200 Rp/kWh)**

System has recently been updated with new, more efficient diesel generators, which will likely result in a fuel cost of **around 21 ct/kWh (ca. 3000 Rp/kWh)**

PV today can generate at a lower cost, under 10 ct/kWh (ca. 1500 Rp/kWh)



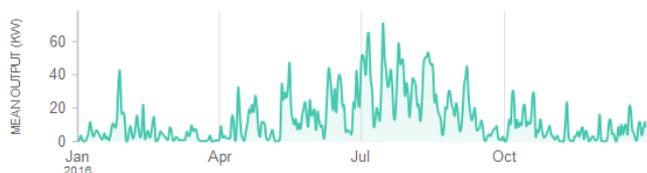


PULAU KALEDUPA: RENEWABLE RESOURCES

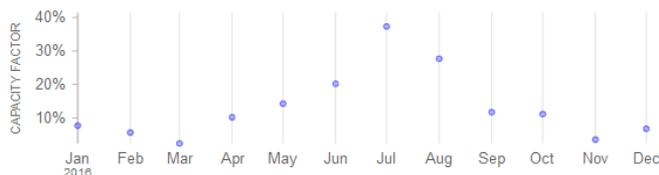
WIND



Daily mean output



Monthly capacity factor



Total mean capacity factor: 13.3%

Save hourly output as CSV

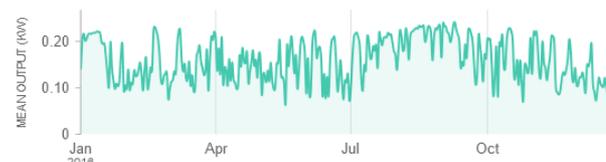
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Citation: Staffell and Pfenninger (2016)

Wind with small 100 kW XANT turbine: Very low capacity factor, probably not economically feasible (large turbines perform worse)

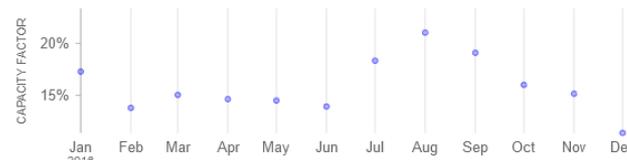
PV



Daily mean output



Monthly capacity factor



Total mean capacity factor: 15.9%

Save hourly output as CSV

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Citation: Pfenninger and Staffell (2016)

PV installation, almost flat: Good potential
PV is the primary resource on Kaledupa



MOTIVATION OF THE STUDY

- National target for **Indonesia: 23 % renewable energy** in the power sector by 2025
- Scope of the study: Develop strategies for **23 % renewables by 2025 on Kaledupa**
- Available resource: **Photovoltaics**
- Problem: **Currently only 12h of power supply (night time)** for cost reasons, incompatible with PV.
- PLN: **Supply will be extended to 24h if PV can contribute significantly** and reduce cost. Incurs the following necessary scenario assumptions/constraints:
 - 24 h supply implemented
 - High PV shares from the beginning, not only in 2025.

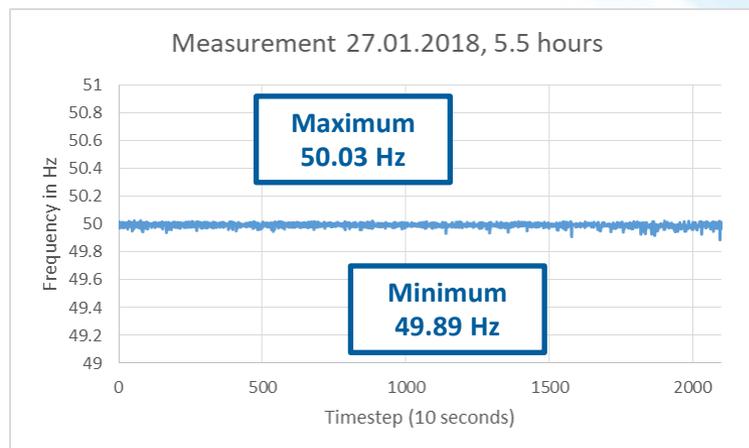


DIESEL AND FREQUENCY CONTROL



Results of site visit at diesel power plant:

- New 2x 656 kW Cummins generators
- Minimum stable output: 20 kW per genset
- Demonstrated ramp rate: 150 kW/s (!)
- Automatic isochronous load sharing
- Modern and capable generators should have no problem balancing out PV fluctuations

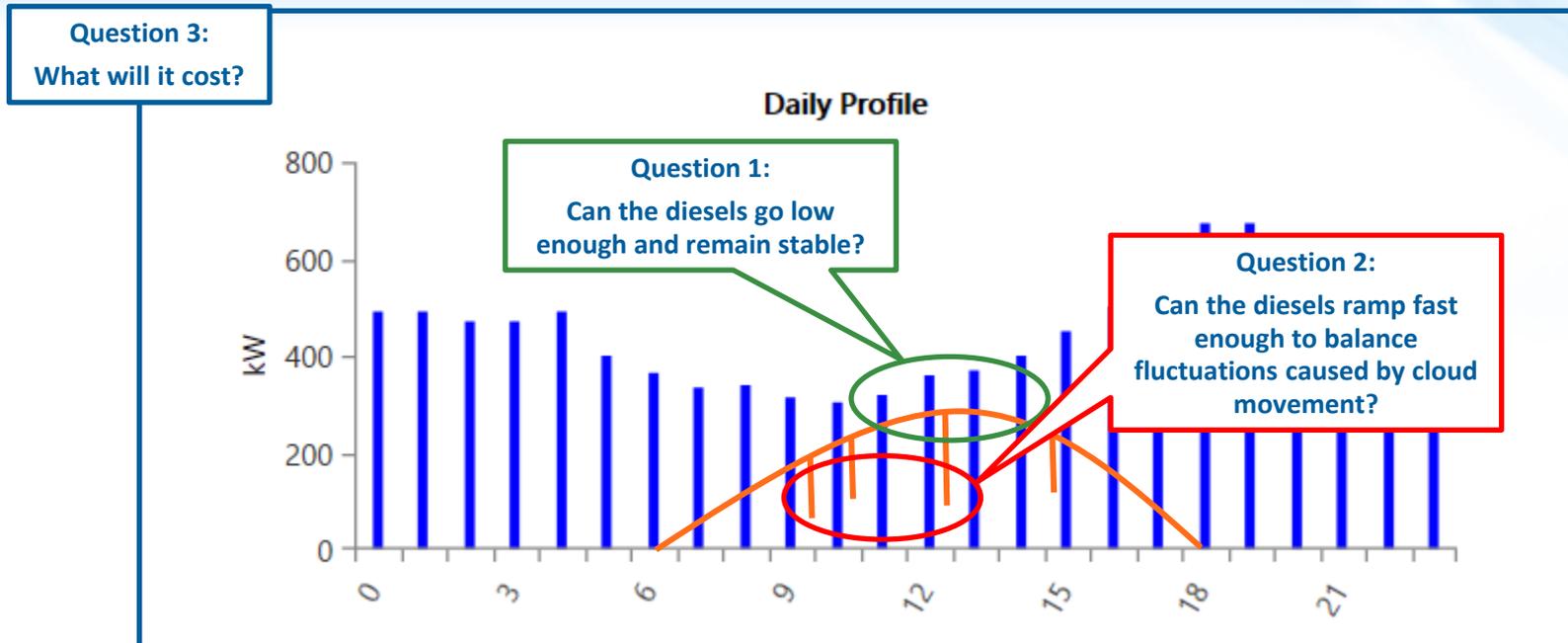


Frequency measurement

- PQA installed at generator
- First data has been transmitted to server
- Frequency quality is currently exceptionally good for a small island
- Frequency control is working properly



DIESEL-PV HYBRID SYSTEM



Load data from 24 h supply trial runs in January 2018: Low day time load

PV will supply power only during daytime – so a high instantaneous penetration will be reached quickly!

Can the diesel generators on Kaledupa deal with that?

Load profile obtained from PLN log books at PLTD Ambeua, Kaledupa.

What needs to be done to compile a plan for 23 % renewable energy on Kaledupa

- Cost of diesel and PV needs to be assessed in detail
- Load development until 2025 / 2027 needs to be taken into account
- Potential for demand side management needs to be assessed

- Objective of HOMER optimization: Find economically optimal system setup
- HOMER side result: Generation dispatch for each hour of the year
- DIgSILENT load flows and stability calculations with HOMER results

- In case of technical issues (stability, reserves, voltage): Develop economically feasible solution
- HOMER optimization including cost of enabling technologies
- Check technical feasibility with DIgSILENT

Final result: Roadmap for an economically optimal and technically feasible 23 % RE system



2. SCENARIO AND ASSUMPTIONS



EXPECTED LOAD DEVELOPMENT

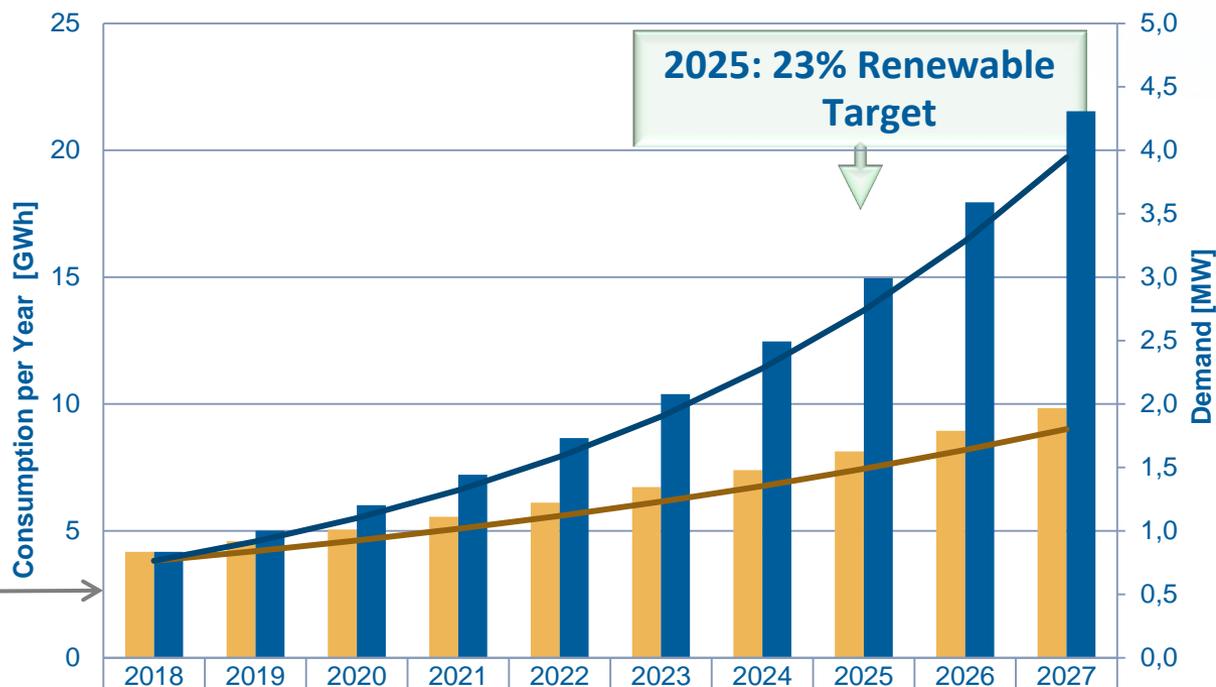
24 h supply, two Load Projection Scenarios: 10% and 20% demand increase/year.

Current usage per capita: 103 kWh/year, 1/8 of national average.

20% scenario is more realistic.

Measured load from 24h supply period

Consumption and Demand Projection

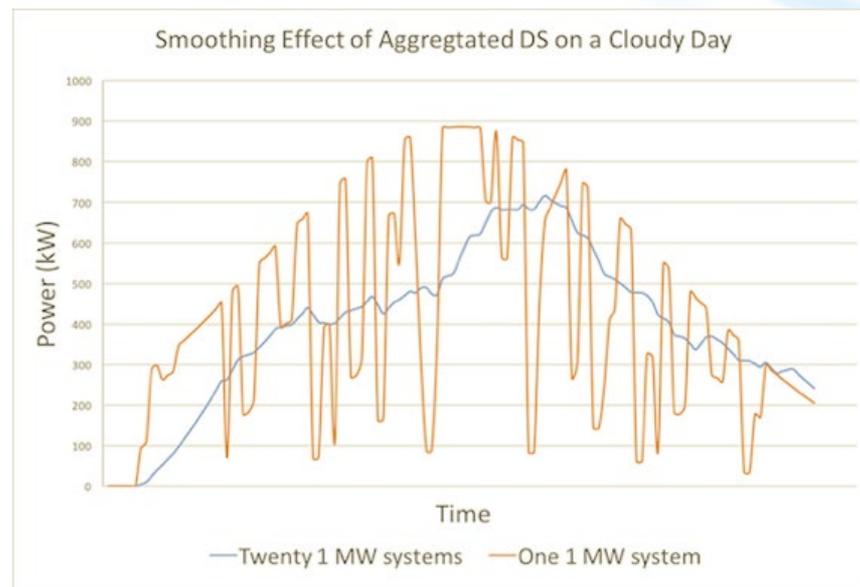
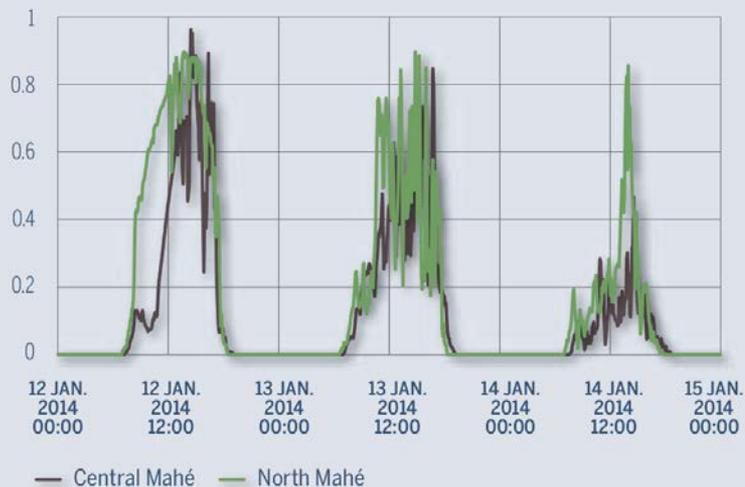




SPATIAL SMOOTHING EFFECTS

Note that the profiles do not appear to be synchronous (the green profile leads by around ten minutes)

PV production
[per unit nominal power]



Sites on the Seychelles (Mahé), ca. 12 km apart.

(Source: Energynautics journal paper, peer reviewed, on island grid integration in the Seychelles, accessible at <http://journals.openedition.org/factsreports/4148>)

Typical smoothing effect

(Source: Generic data from Renewable Energy World)



DISTRIBUTION OF PV

Scenario assumption: PV is distributed across the island.



PVs are distributed evenly to 8 sites across the island, close to larger villages, located on piers and free space outside villages.

The size of the installations will depend on the projected load scenario (10% and 20% load increase/year).

New lines to Sombano and Lentea/ Darawa are included in the system. PV there is only installed later on when the lines are definitely there.



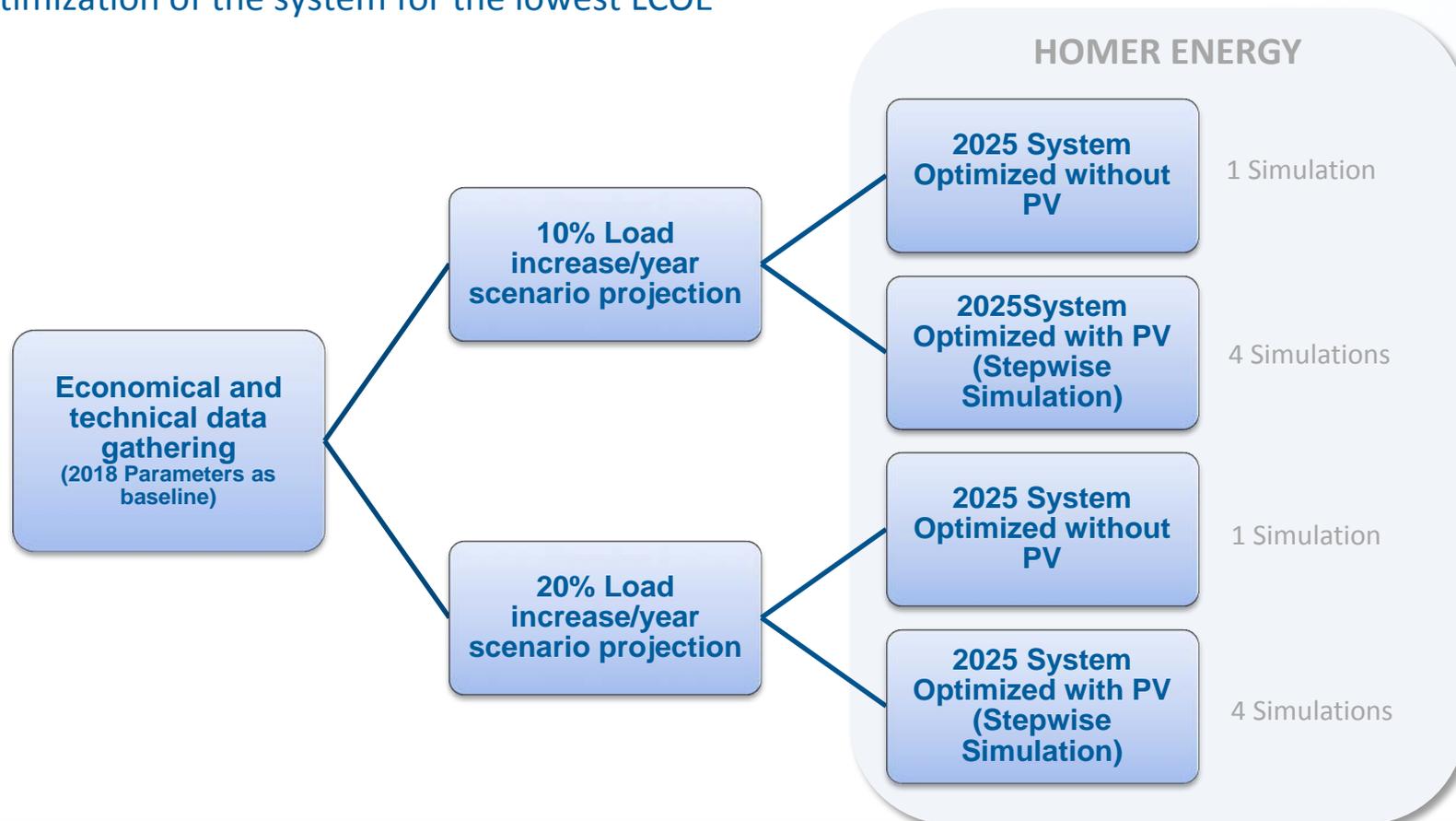
3. ECONOMIC OPTIMIZATION



ECONOMIC SYSTEM OPTIMIZATION (1)

System Optimization Approach

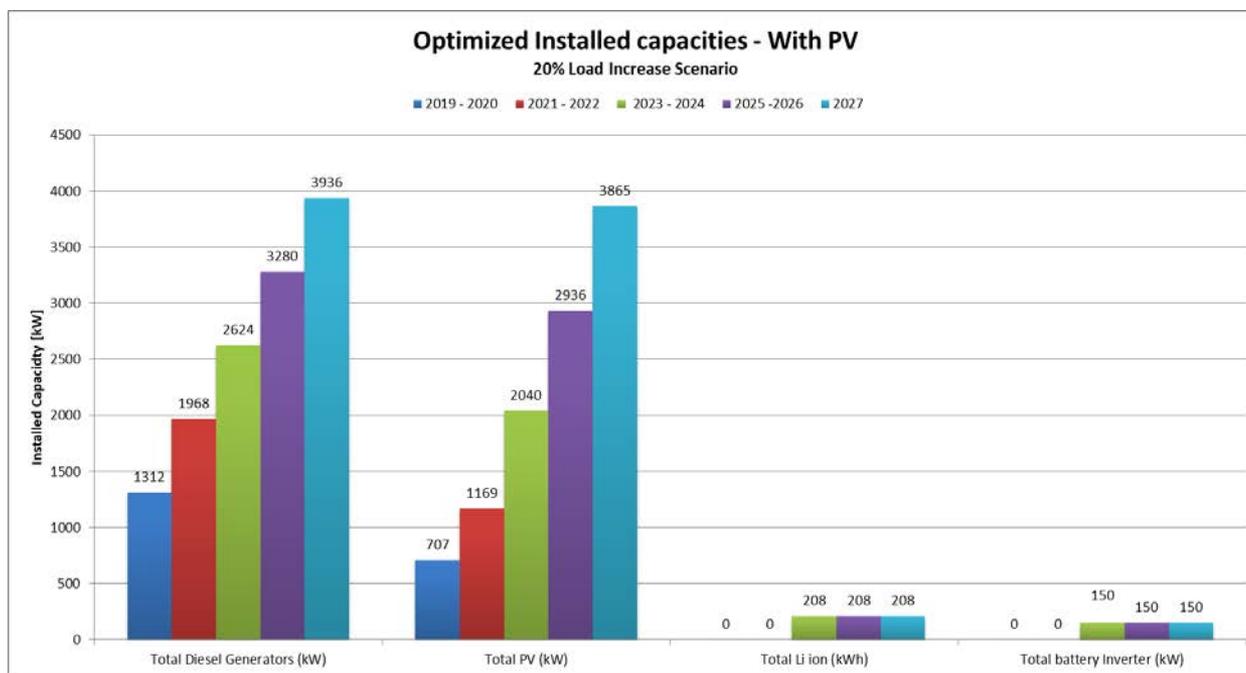
- 10 simulation cases performed using HOMER ENERGY
- Optimization of the system for the lowest LCOE





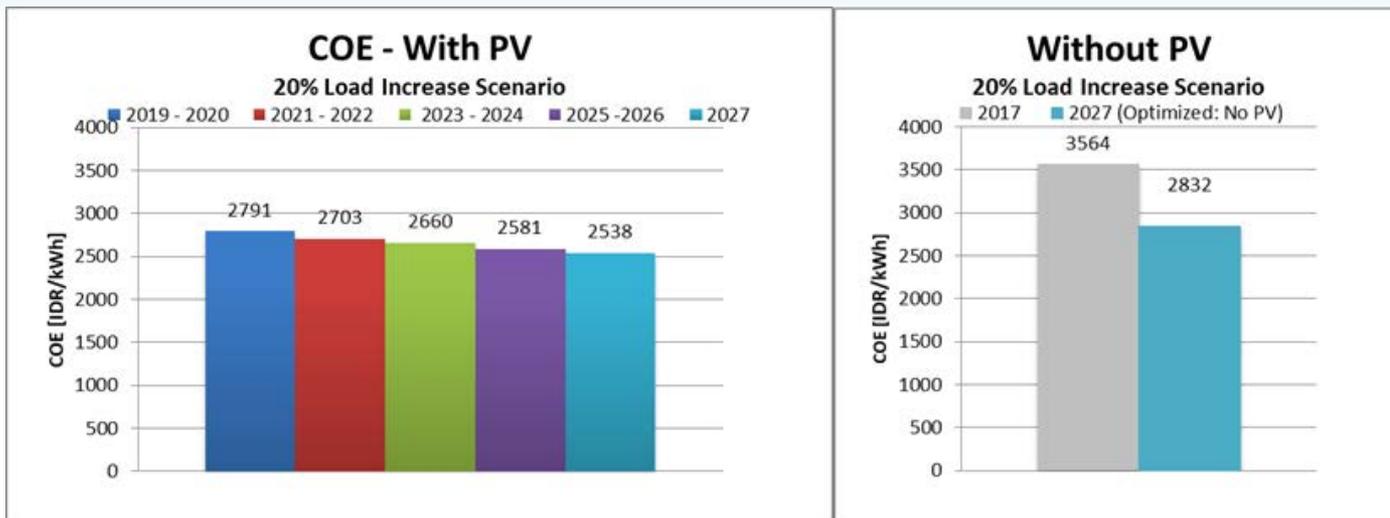
RESULTS: INSTALLED CAPACITIES (1)

20% Load Increase Scenario

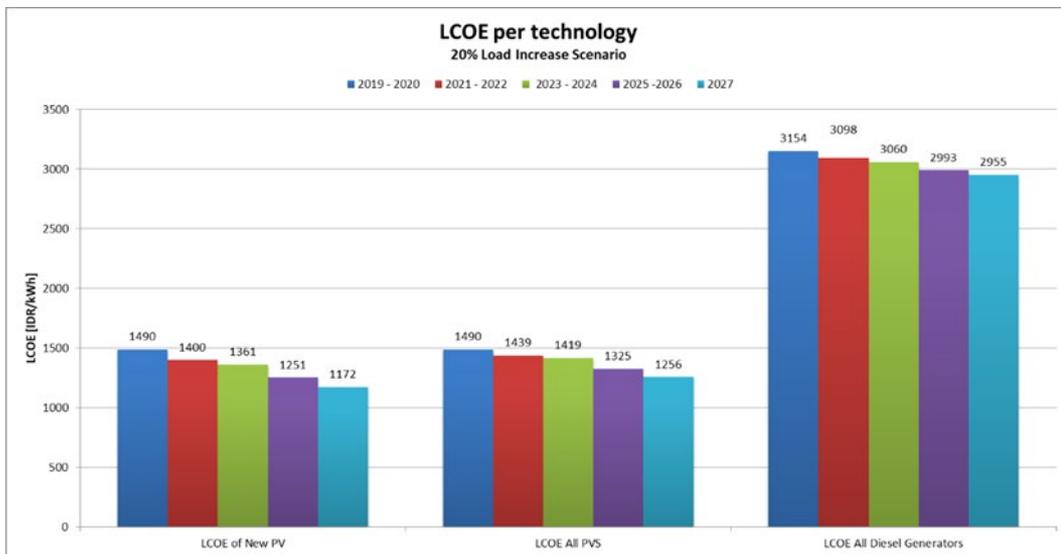




RESULTS: COST OF ELECTRICITY (1)



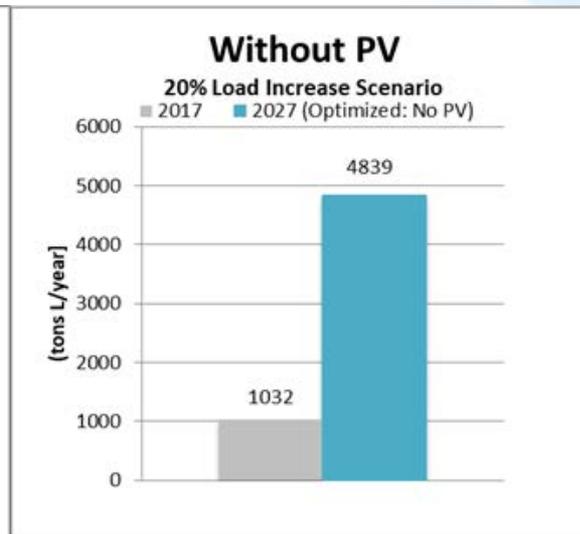
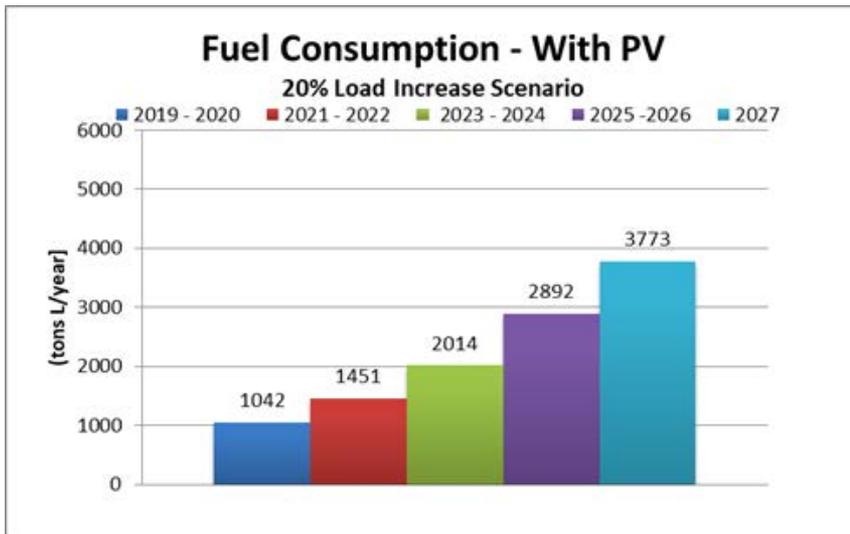
2017 values (with the old generators) based on fuel cost only – excluding O&M etc., solely for comparison!





RESULTS: CONSUMPTION OF DIESEL FUEL

20% Load Increase Scenario

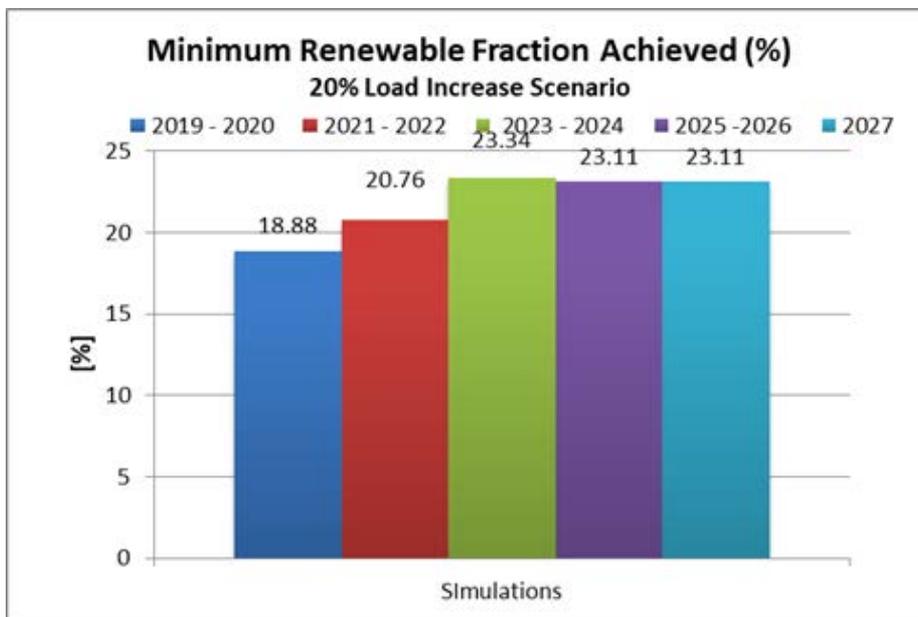


More efficient generators and PV leads to a similar fuel consumption in 2019 as in 2017, even with 24h supply and a >30 % increase in total generation



RESULTS: RENEWABLE FRACTION

20% Load Increase Scenario



HOMER optimization reaches above 23% of renewable participation by 2025 based on the economical parameters (without a renewable constraint).

Including PVs in the system is economically optimal and meets the 23% target of 2025!

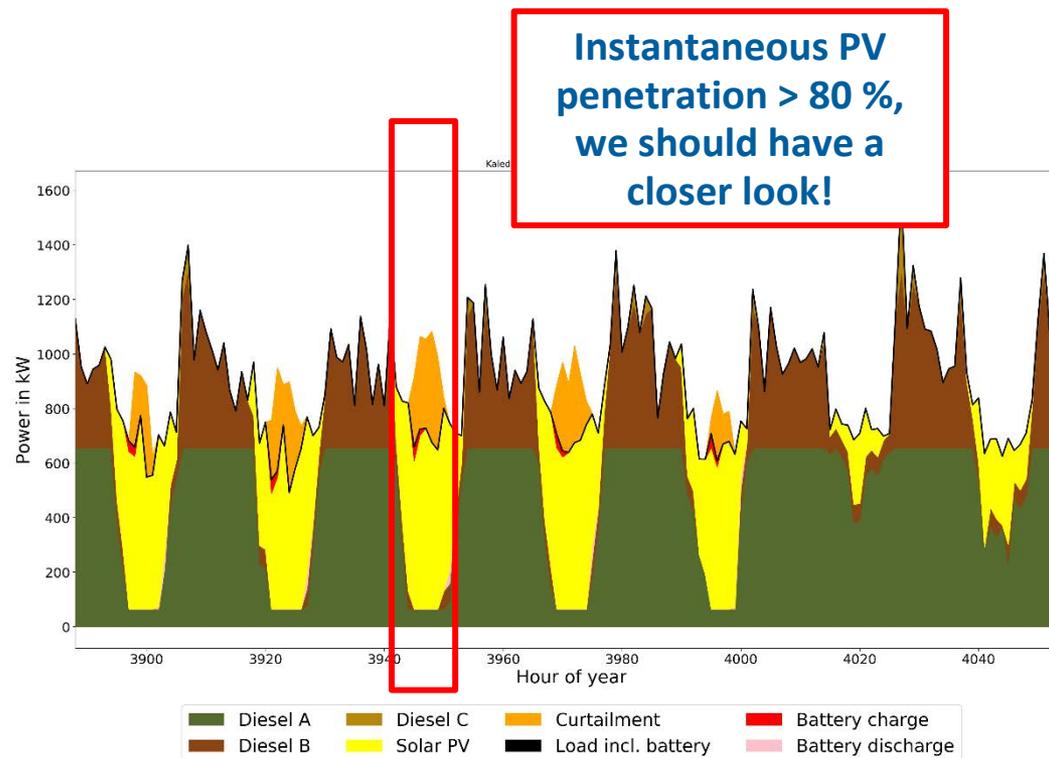
TECHNICAL FEASIBILITY



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System is now economically optimal and has >23% renewables – but will it work?

PV penetration is extremely high at times, will the system remain stable?



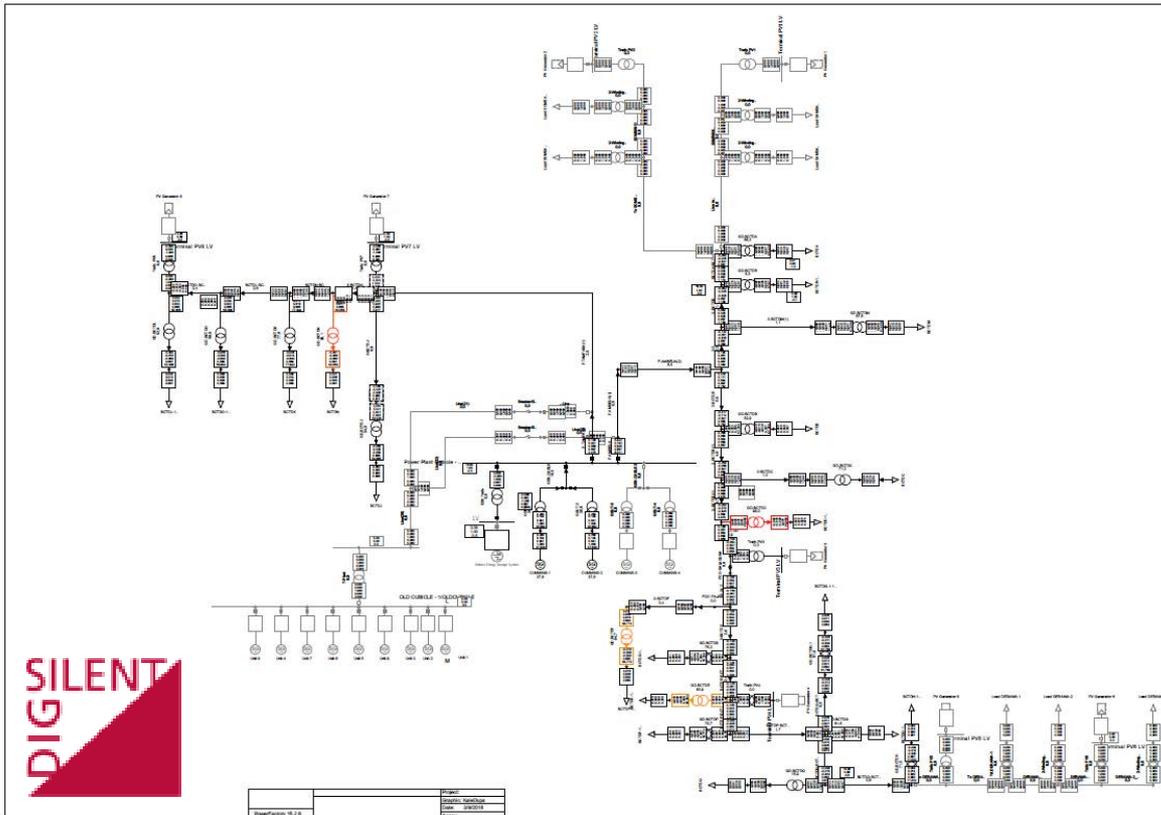


4. GRID SIMULATIONS

GRID MODEL



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Basic model set up by STT-PLN based on data obtained from PLN Wakatobi

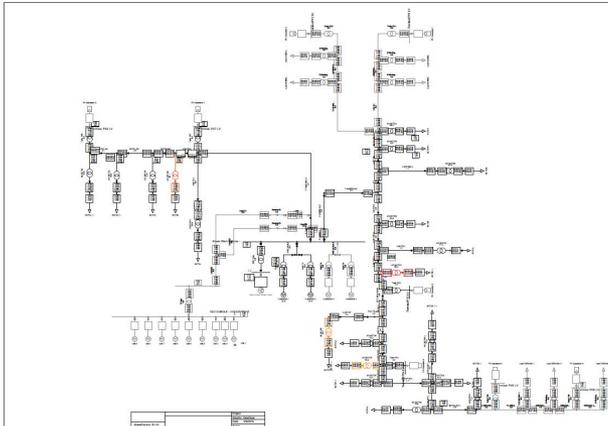
New feeders Darawa/Lentea and Sombano added

PV distributed to 8 locations

New diesels are installed at PLTD Ambeua

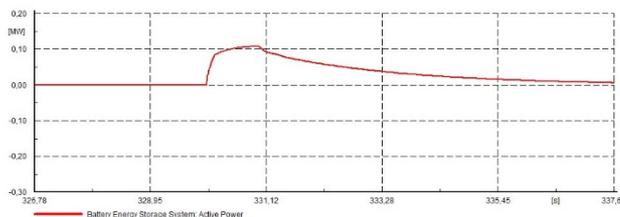
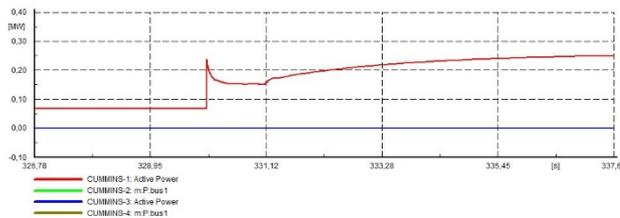
Battery located at PLTD Ambeua

Dynamic data for diesels based on (rough) manufacturer data



Steady state (power flow)

- Undisturbed normal operation
- Analysis of most critical situations
- Result 1: Grid elements are not overloaded
- Result 2: PV need to provide reactive power
- Maximum penetration > 80% of PV



Dynamic stability (RMS)

- System reaction to disturbances
- Analysis of grid faults and element losses
- Frequency and voltage stay stable
- PV and battery need to provide frequency response
- Grid controller (EMS) is necessary



CONCLUSION: REQUIREMENTS FOR PV

System stays stable in all critical cases, but PV and battery need to contribute ancillary services

- PV needs to contribute to reactive power demand and to provide LVRT
- Frequency sensitivity of battery is helpful to stabilize frequency
- Overfrequency sensitivity PV is necessary to retain frequency in the allowed range at losses of load
- PV needs to be able to receive setpoints per remote, as PV capacity exceeds daytime load -> **Energy Management System / Grid Controller necessary**

All these functions are commercially available and required in several countries!



5. DEVELOPMENT PLAN



DEVELOPMENT PLAN 20% SCENARIO



Sombano, Lentea/Darawa and Sampela are the latest installations, as these areas need to be connected to the grid first.

Locations are tentative and need to be scouted on site eventually.



THANK YOU FOR YOUR ATTENTION!