OPTIMIZATION OF GREEN MICROGRIDS/MINIGRIDS WITH SOLAR AND WIND POWER PRODUCTION

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Long-Term Joint EU-AU Research and Innovation Partnership on Renewable Energy

The LEAP-RE project has received funding from the European Union's Horizon 2020 Research and Innovation Program under Grant Agreement 963530.

Introduction

WHY MINI-GRIDS ARE RELEVANT:

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- 60% of Africans live in rural areas and only 5% have access to modern electricity services:
  - Dispersed populations;
  - Distance to the main power grid;
  - Low population density.

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    - Dispersed populations;
    - Distance to the main power grid;
    - Low population density.

- Effective and economical way of providing access to energy to disperse or remote costumers or areas:
    - “Easier” installation;
    - Flexible and modular / adaptable to varying electricity needs;
    - Can be integrated in the main power grid in the future;
    - Can use different generation systems (conventional and/or renewable based);
    - Can include energy storage systems.

Source: State of the global mini-grids market report 2020, BloombergNEF, 2020

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RENEWABLES USE IN MINI-GRIDS:

- Interesting for the electrification of rural and peri-urban areas:
  - Significant cost reductions in the last decade;
  - Modularity (e.g.: PV) suitable for small-scale electricity generation systems (10 KW to 10 MW range is typical for mini-grids).

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- Integration of vRES (e.g. solar PV and wind) in a safe and reliable power system present challenges:
    - High temporal variability (e.g.: weather dependency, day-night cycles, seasonal variations).

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- Integration of vRES (e.g. solar PV and wind) in a safe and reliable power system presents challenges:
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- **Explore all the capabilities of vRES through the synergetic combination of the different vRES generation profiles:**
  - Reduces requirements for storage / conventional generators.

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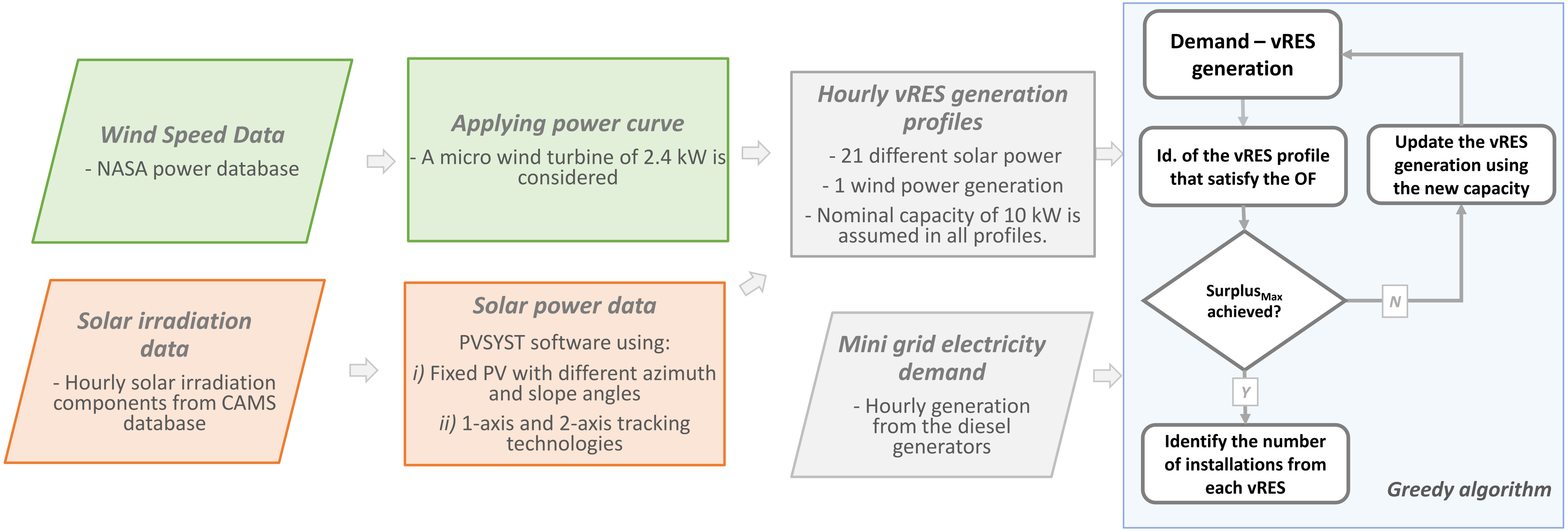
Objectives of this work:

- Present a methodology designed to strategically identify wind and solar PV capacity to meet more effectively the power demand in mini-grids:
    - Exploring the wind production profile and different solar PV production profiles, considering various azimuth / slope angles for the solar panels and tracking systems.

- Demonstrate the methodology by applying it to a real mini-grid located in Kenya.

Methodology

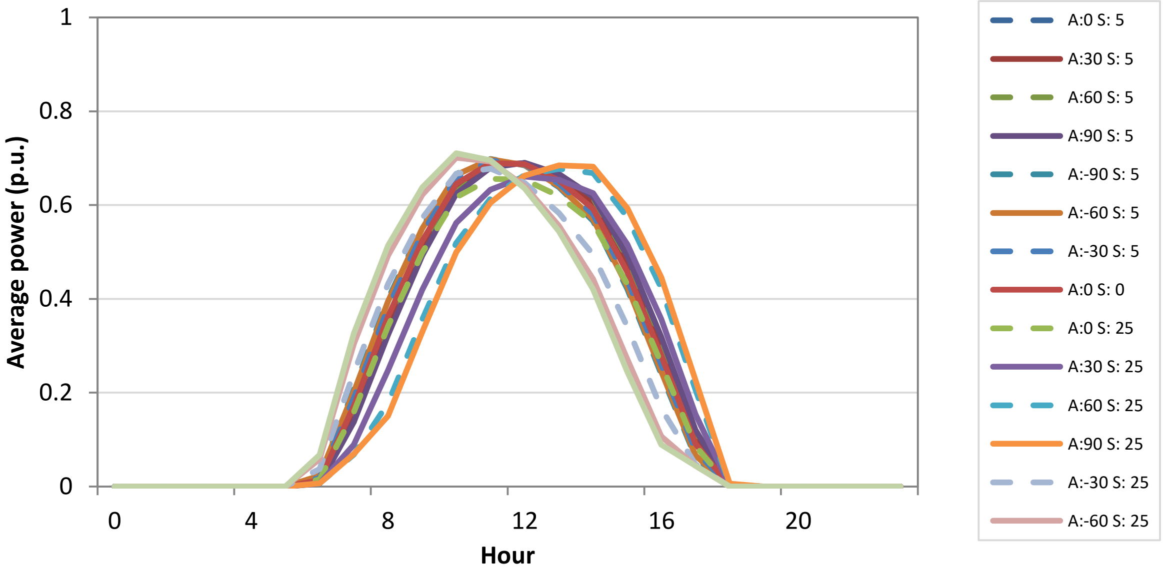


- At each iteration, the greedy algorithm selects the vRES generation profiles that minimise/maximise an objective function (OF) subject to the maximum of energy surplus (Surplus$_{Max}$).

Case study

Solar power – Fixed azimuth (A) and slope (S) angles

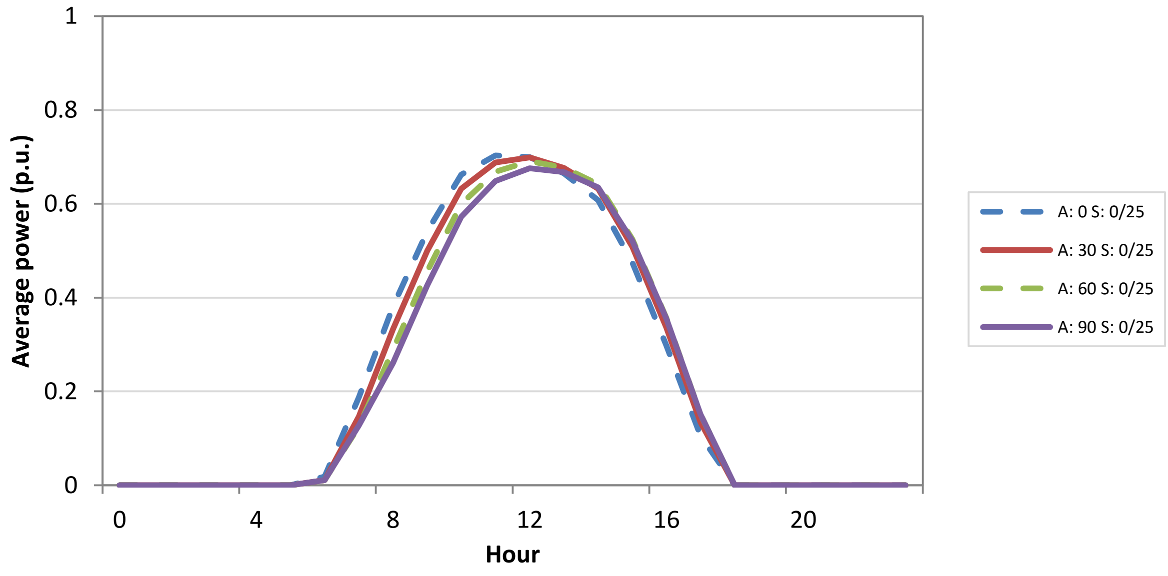
Fixed	
Azimuth (A)	Slope (S)
0	5
30	5
60	5
90	5
-90	5
-60	5
-30	5
0	0
0	25
30	25
60	25
90	25
-30	25
-60	25
-90	25



Case study

Solar power – Fixed with seasonal adjustment in the slope (S) angle

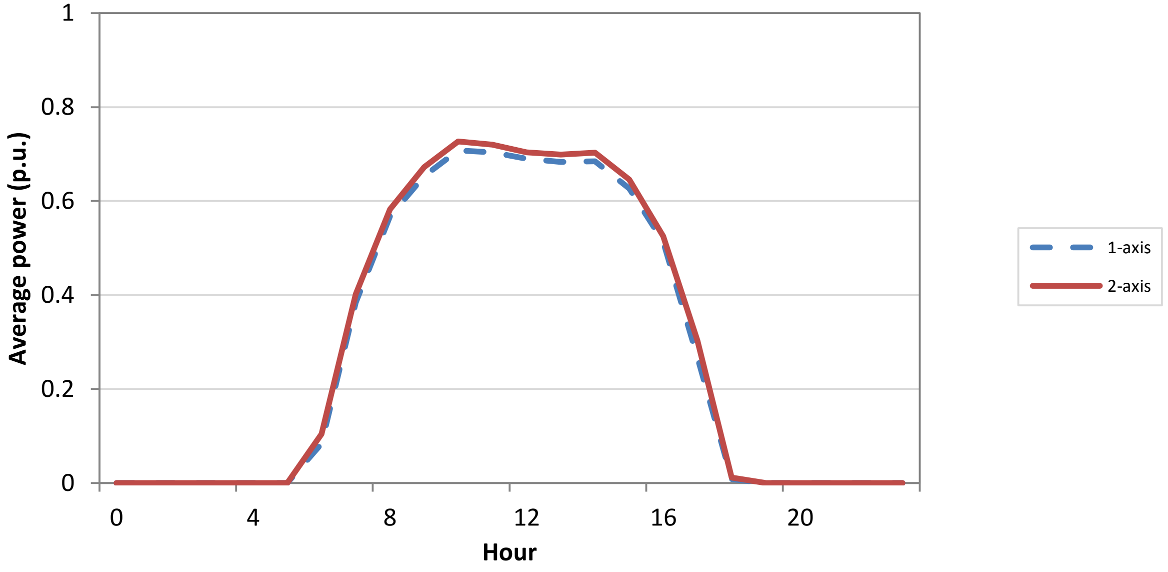
Fixed	
Azimuth (A)	**Slope (S)**
0 30 60 90	25º (Apr. – Sep.) 0º (Oct. – Mar.)



Case study

Solar power – tracking system

Tracking		
Type	**Azimuth (A)**	**Slope (S)**
1-axis	0	-50 to 50
2-axis	100 to 100	0 to 85



Case study

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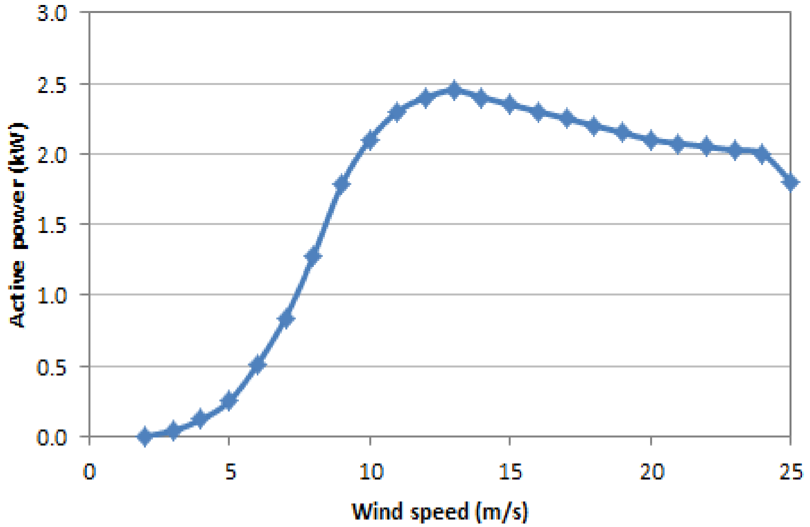
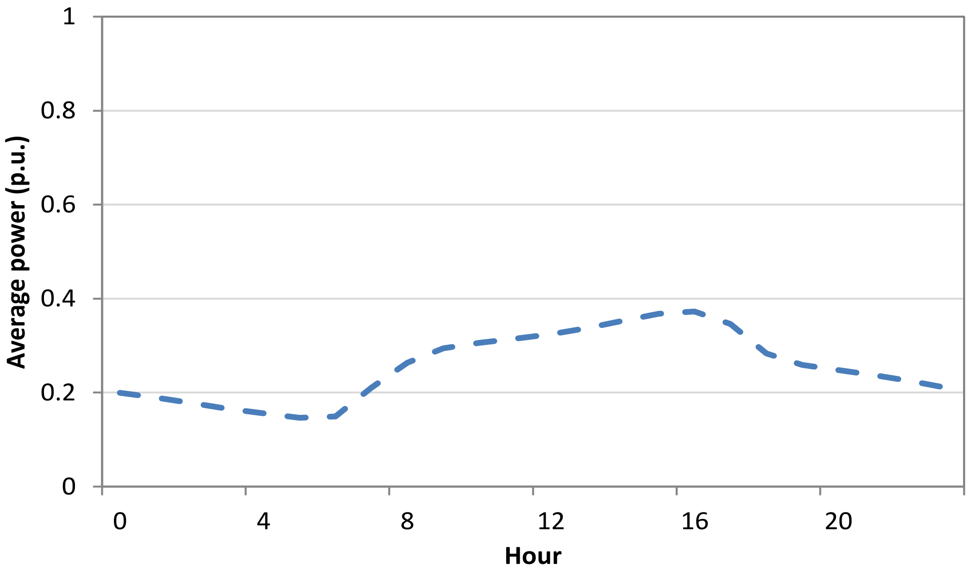
Wind power

- A wind turbine (SKYSTREAM 3.7) with 2.45 kW nominal capacity was used.
- Wind speed was retrieved from the Nasa power database.





Case study

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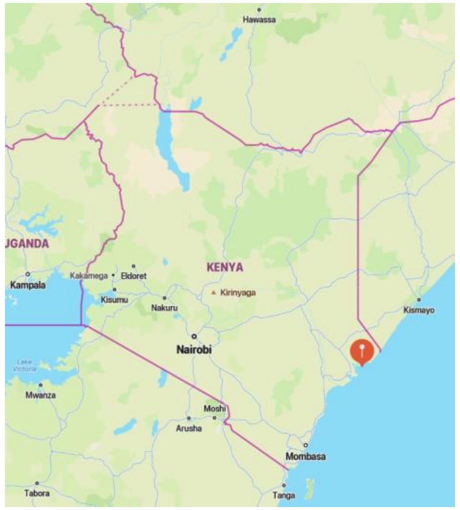
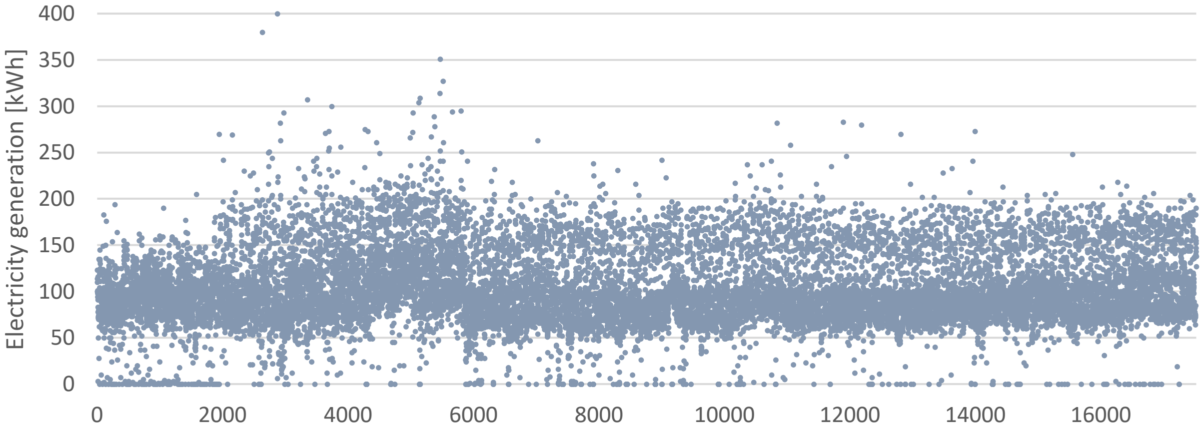
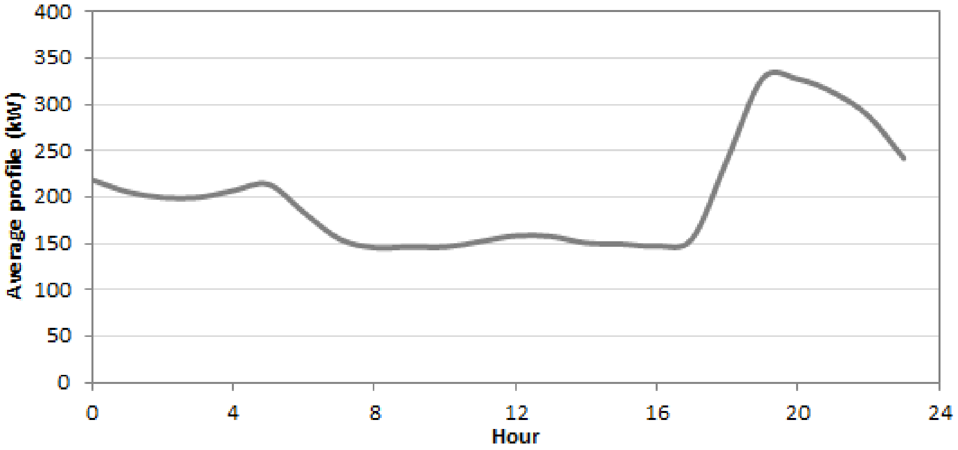
Faza mini-grid

- Located at Faza – Pate Island, Lamu County, Kenya
- Diesel-based mini-grid with 6 000 users
    - Power demand: 900 kVA
    - 4 diesel generators: 650 kVA + 500 kVA operational
- Available data:
    - electric energy generation data for 2022
    - Temporal resolution: 30 min

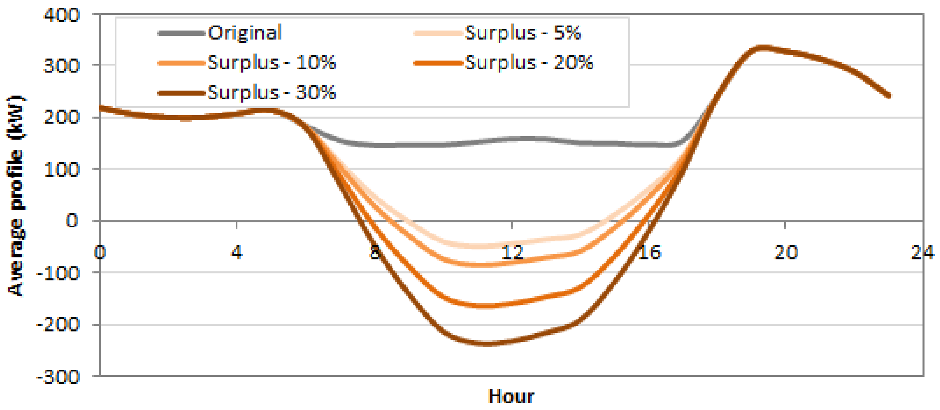






Results

- ***Traditional approach** using the azimuth and slope angles that **maximise the solar power annual production**:*



- Surplus of 5% is reached with 280 kW of solar PV capacity.
- As expected, a reduction in the fossil fuel generator only in a few number of hours of the day → strong power ramp-rates are expected.

Results

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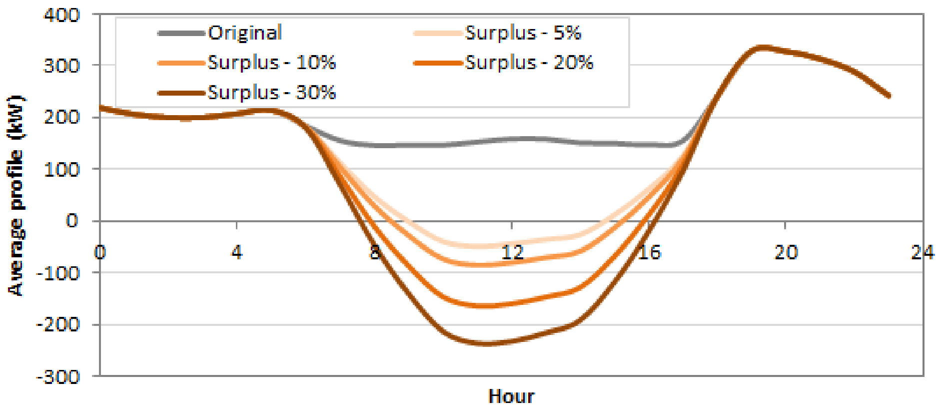
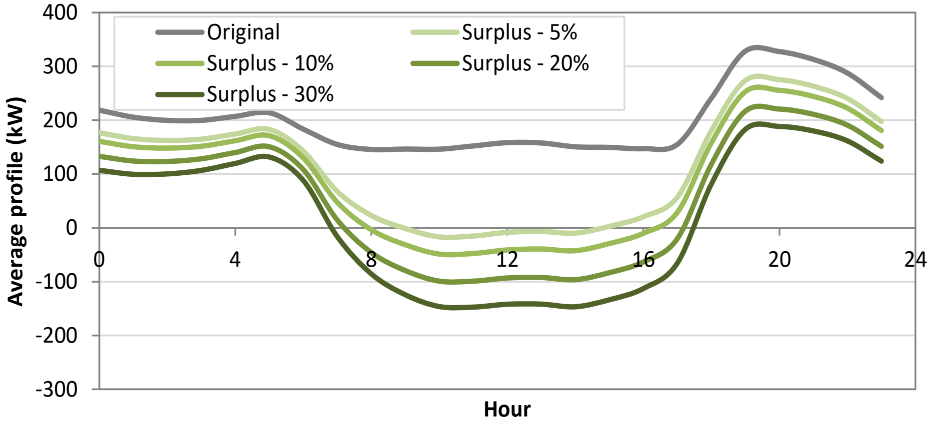


- Surplus of 5% is reached with 280 kW of solar PV capacity.
- As expected, a reduction in the fossil fuel generator only in a few number of hours of the day → strong power ramp-rates are expected.

- *Using the* ***proposed methodology*** *to* ***minimise the annual use of diesel conventional generator:***



- **Strategic deployment** of wind and solar PV presents **several benefits**, *e.g.*, **reduction in the**:
  - i) **periods with surplus of energy**,
  - ii) **the power ramp-rates**.

Results

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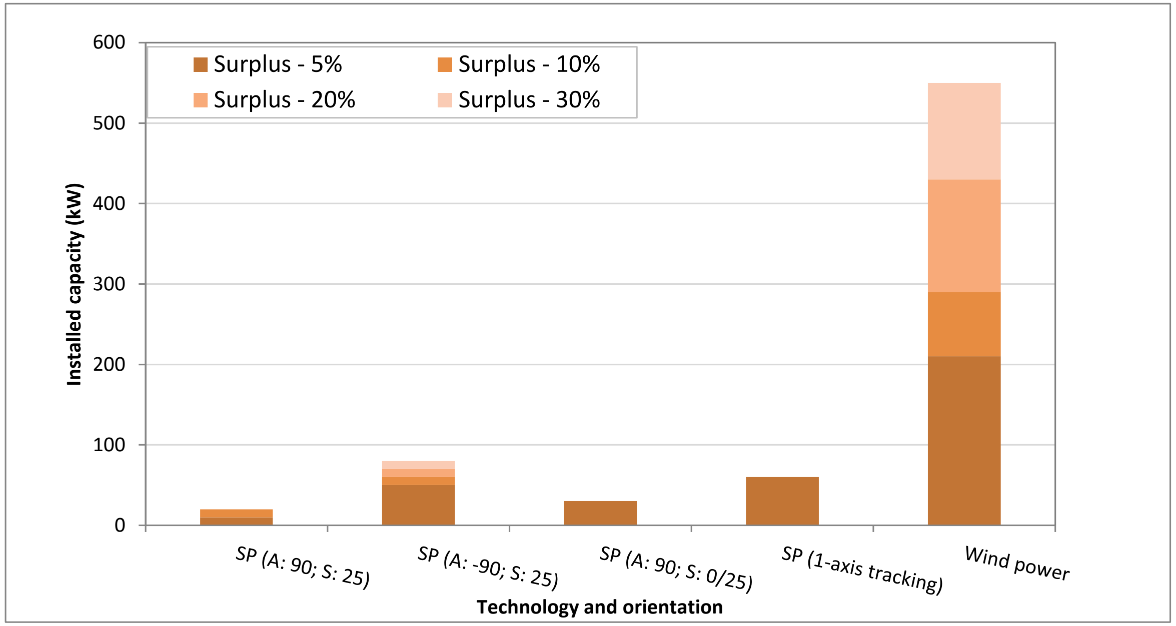
- Capacity installed per technology and orientation for different level of energy surplus:



- For this case study, **methodology highlights the need to install**:

  i) a **high capacity of wind power**;

  ii) **solar PV capacity using different azimuth and slope angles**.

Results

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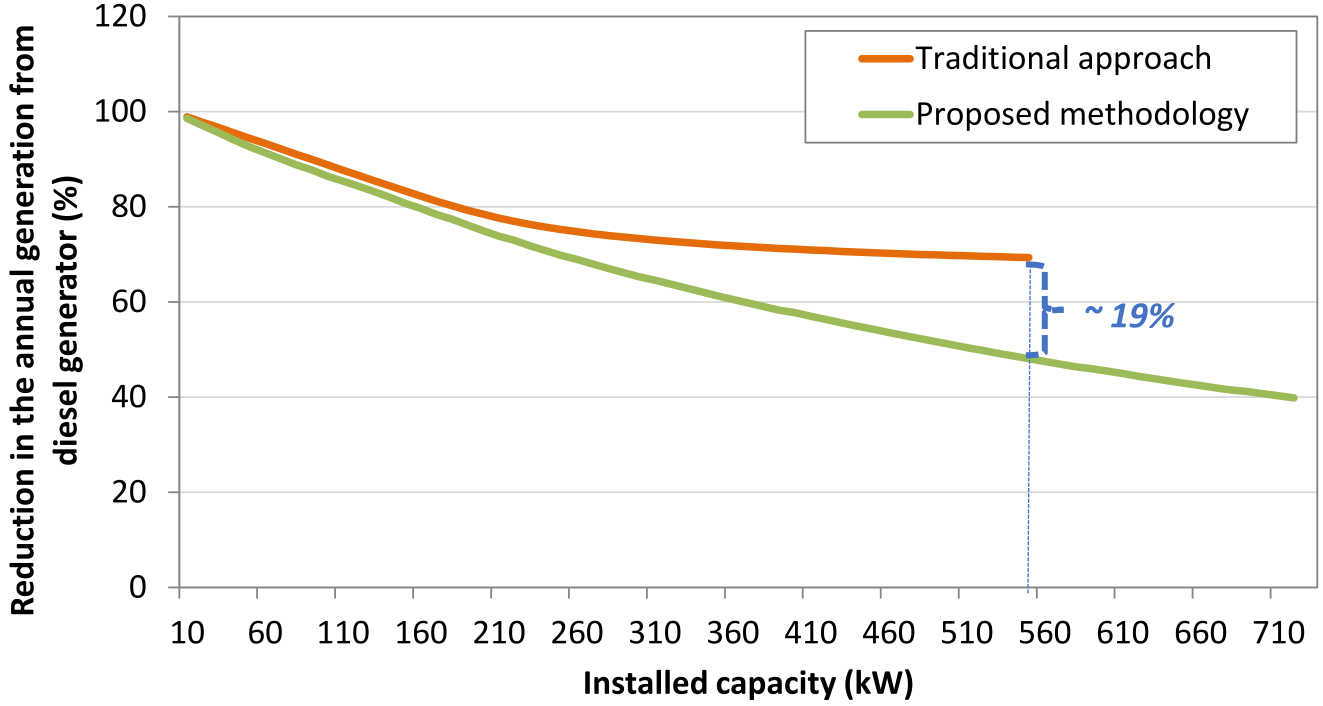
- Reduction in the annual generation of the diesel generators:



- The reduction in the use of diesel generators reaches a saturation point after installing aprox. 250 kW;

- The exploitation of strategic deployment of vRES enables a reduction in the need to use diesel generators;

- For a surplus of 10%, **the reduction of yearly energy from the diesel generator is**:

  i) 28 % in the traditional approach;

  ii) **38% in the proposed methodology.**

Conclusions

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- A methodology to identify the most suitable mix of wind and solar photovoltaic capacity to satisfy in a complementary way the energy demand in a mini-grid in Kenya was presented;
- Different PV plant configurations were explored;
- Part of the demand can be satisfied by wind and solar PV, but significant levels of energy curtailment are expected;
- It is necessary to diversify the orientation of solar panels and explore wind power to avoid several periods of generation curtailment;
- To fully decarbonise the mini-grid storage solutions (e.g., batteries) are needed to deal with periods of surplus/deficit of energy;
- Further studies should expand the methodology to consider other relevant factors:
    - Costs;
    - Available land;
    - Storage technologies;
    - Social acceptance.

Acknowledgments

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