Model for optimization of renewable isolated microgrids (MG) configuration for rural electrification in Africa

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Nicolas Plain – PhD presentation (Mar. 2017 -> Feb. 2020)

RENEWABLE ISOLATED MICROGRIDS (MG) FOR RURAL ELECTRIFICATION IN SUB-SAHARAN AFRICA
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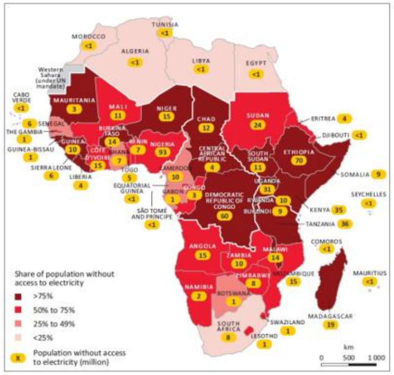
TODAY 1.2 BILLION PEOPLE DO NOT HAVE ACCESS TO ELECTRICITY, 87% OF THEM ARE LIVING IN RURAL AREAS; 600 MILLION IN AFRICA (645 MILLION IN 2030)

UN global goals for 2030

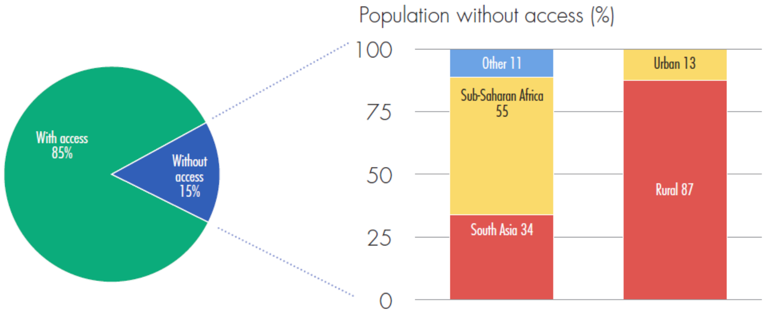
- N ° 7: Ensuring access for all to reliable, sustainable and modern energy services at an affordable cost by 2030

% of people having electricity

Africa: the only continent where the percentage will increase (2030)



87% of people without electricity are living in rural areas



Data 2012 - World Bank, Global Electrification database

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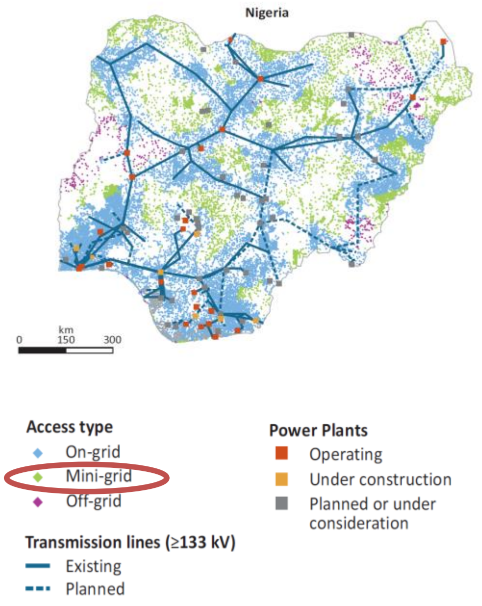
THE QUESTIONS WE ARE INTERESTED IN AS PART OF THE RESEARCH WORK

MR: one of the solutions for access to electricity



World Energy Outlook 2014

How to develop high quality and cost effective MG ?

1. How better:

- Standardize MG projects to reduce costs and accelerate the rate of electrification?
- Integrate the productive uses of electricity (high load factor and in time adequacy with solar production)?

2. Method:

- Define several typical configurations of rural villages in sub-Saharan Africa with associated domestic and productive uses
- Create typical MG configurations [solar panels / batteries / diesel generators] suitable for these villages

How to optimize these typical MG configurations ?

- For each typical MG configuration, what is the optimization of the kWh cost and the ideal quality of service with
  - Number of solar panels
  - Battery capacity
  - Power of the diesel generator
- Depending on the solar resource available, can we consider 100% solar / batteries MG while having a good quality of service and a low cost per kWh?

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THE 3 MAIN STEPS OF THE PHD TO ANSWER EACH QUESTION

1. . A better estimate of the solar resource on the continent (details in annex 1)

- Study of the temporal variability of the solar resource adapted to the case of MG
- Africa mapping with relevant Indicators

2. Characterization of electricity uses and their temporal variability (details next page)

- Obtaining daily load curves for different days and months of the year associated with different MG configurations
- Disaggregation of the load curve to get the consumption of different productive uses and households

3. Model to optimize the configurations with supply / demand adequacy (details in appendix 2)

- Optimization according to
  - Cost of kWh
  - Quality of service

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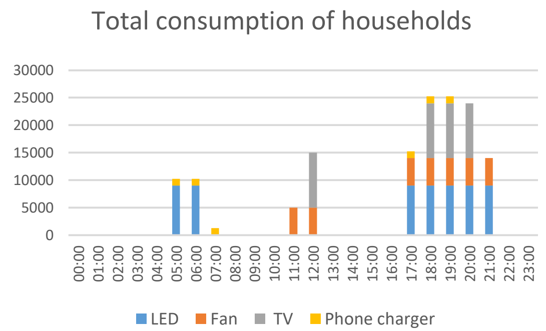
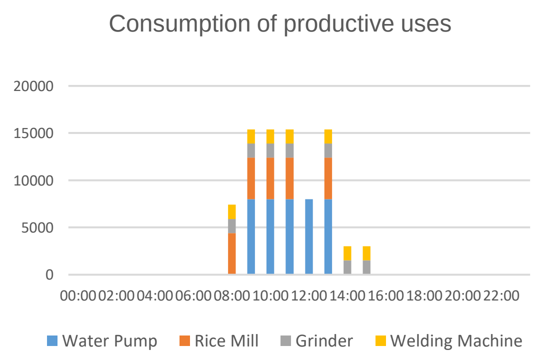
PART 2: TEMPORAL VARIABILITY OF ELECTRICITY USES

1. Obtaining load curves measured at different sites

- Results of typical configurations are significant if the study is based on a large number of load curves
- Analysis of the temporal variability of the different uses associated with these load curves (intraday, daily, seasonal)
- Need to have measurements of the load curve with
  - A time step of 30 min to 1 hour
  - Over a whole year (to obtain the seasonality)
- Need to know the details of the different uses of electricity (domestic and productive) associated

2. Analyzes of the different uses of electricity

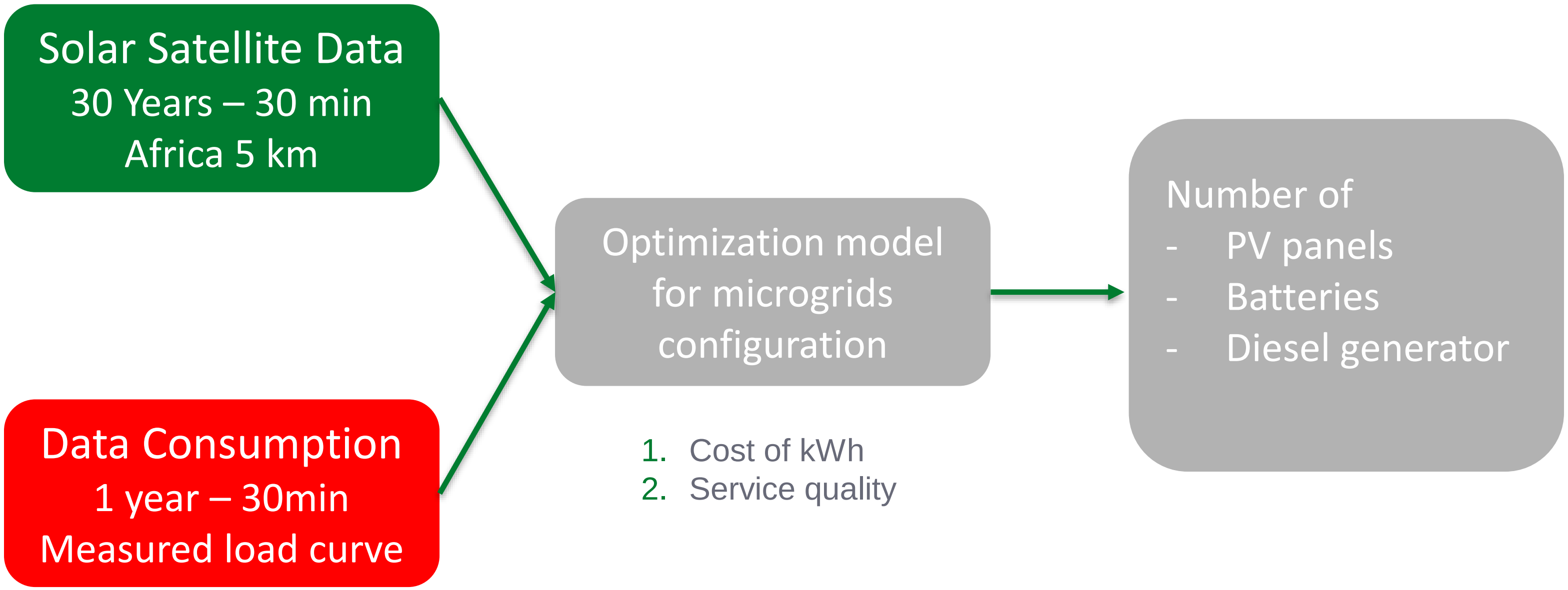




Load curve of Kanti village in Myanmar

3. Creating typical load curve profiles

- Getting about ten typical configurations of rural villages in Africa with domestic and productive uses of electricity
- Associate these configurations with daily load curves with their seasonality according to the different locations (1 typical load curve per month and per configuration)
- Creation of a dozen standard MG configurations adapted to each type of village


Solar Satellite Data
30 Years – 30 min
Africa 5 km
Data Consumption
1 year – 30min
Measured load curve
Optimization model for microgrids configuration
1. Cost of kWh
2. Service quality
Number of
- PV panels
- Batteries
- Diesel generator

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THE DATA NEEDED FOR OUR STUDY AND THE BENEFITS FOR THE PARTNER

1. The type of data needed

- MG consumption data installed with, ideally, the following characteristics:
    - Time step of 30 minutes to 1 hour
    - Period over a whole year
    - Distinction between household consumption, productive uses (small businesses or industries) and community uses (schools, churches, hospitals, etc.)
- Nevertheless, data, even very simple, can be very useful and bring interesting complements to our study

2. The benefits for our partner

- Optimization of the installed MG architecture in relation to consumption analysis (number of solar panels, batteries, diesel generator), useful for
    - Installation of future MG
    - Increased production capacity
- Reflection on the incentive mechanisms for deferring demand to valorize the use of electricity during periods of high solar production
- Sharing the overall results of our study
- Citation of the partner in scientific articles and publications with the prior agreement of the latter

3. Our commitments

- Data confidentiality
- Possibility of establishing a research partnership agreement

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THE ORGANIZATIONS ATTACHED TO THE PHD

- PhD director : Benoit Hingray
- The Institute for Geosciences and Environmental research (IGE) is a public research laboratory in Earth and Environmental Sciences
- The IGE is a joint research unit supervised by CNRS / INSU, IRD, Université Grenoble Alpes (UGA) and Grenoble-INP

- PhD director : Sandrine Mathy
- The Grenoble Applied Economy Laboratory (GAEL) is a public research laboratory in microeconomics of sustainable innovation and consumption, with results mainly applied to the fields of energy and the agro-industry
- GAEL is a joint research unit of CNRS, INRA, University Grenoble Alpes (UGA) and Grenoble INP

- PhD Supervisors :
  - David Gualino
  - Thomas André
- Schneider Electric SE is a French industrial group with an international dimension, which manufactures and offers electricity management products, automation and solutions adapted to these trades.
- Schneider Electric has an "access to energy" program to allow the greatest number of people, especially in rural and peri-urban areas, to have access to electricity

QUESTIONS & DISCUSSIONS

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nicolas.plain@univ-grenoble-alpes.fr

Thanks !

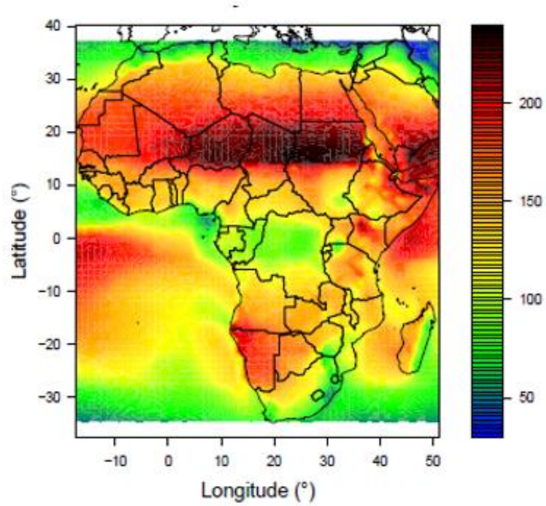
APPENDIX 1: BETTER ESTIMATE OF THE SOLAR RESOURCE ON THE CONTINENT

1. Scalar Indicators Relevant to Our Study

- Study of the temporal variability of global solar radiation received at ground level (SIS)
    - Intraday
    - Daily
    - Seasonal
    - Inter-annual
- Using very high resolution satellite data over 21 years:
    - 1995-2015
    - Time step: 30 minutes
    - Space step: 0.05 ° x 0.05 °
- Definition of relevant scalar indicators adapted for isolated MG to better estimate the available solar resource

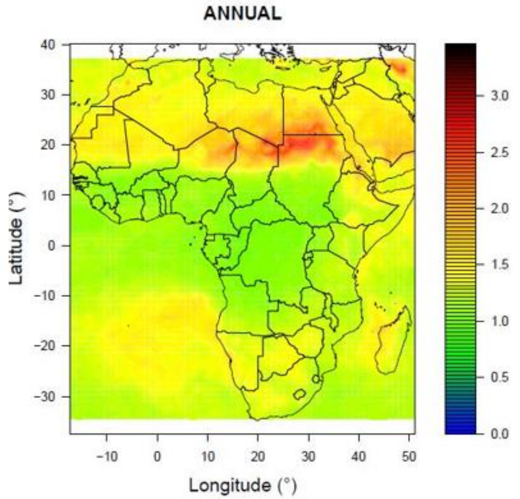
2. Africa mapping of these different indicators

- Obtaining the value of indicators throughout the African continent
- Example below for the Quantile 5 values of SIS received at ground level



3. Periods of low solar resource for MG

- Average duration period (in days) of consecutive days inferior to the percentile 5 of the total daily GHI period 1995-2015



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APPENDIX 2: OPTIMIZATION OF CONFIGURATIONS WITH SUPPLY / DEMAND ADEQUACY

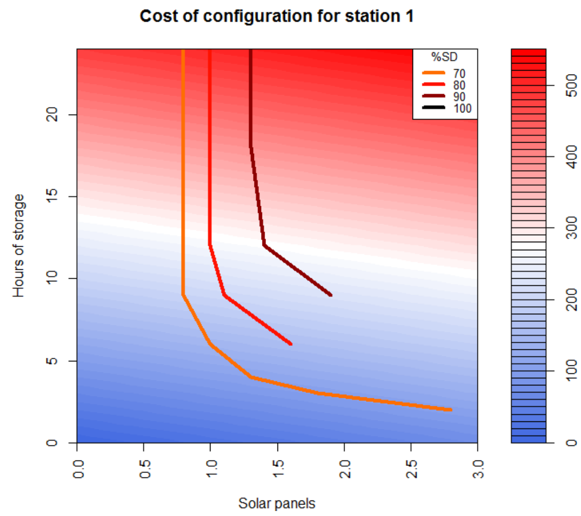
1. Association of load and production curves

- For each typical configuration, calculation of the quality of service and the cost of the kWh with supply / demand balance over several years with a time step of 30 minutes and a production

1. Only solar
2. Solar + battery
3. Solar + battery + diesel generators

2. Optimization of configurations

- For each typical village configuration, find the MG configuration that is optimal for kWh cost (right scale) and quality of service (%SD = percentage of demand satisfied)



3. Different mechanisms to reduce the price of kWh

- Innovative incentive pricing systems to consume during periods of high solar production
- Prioritization of different uses with different costs of the associated kWh
- Mix between
  - Main MG
  - Off-grid systems for nighttime consumption (lighting, other?)
- Integration of other type of storage
- Other?