LEOPARD PROJECT

March 2023

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LEAP-RE

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

LEOPARD

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

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

LEAP-RE | LEOPARD

2021/2025 – 33 million Euros - 50% par l'UE - 33 countries - 83 organisations (39 Africa / 44 Europe)

8 projects R+D+I on renewable energy (REN)

Developed jointly by Europe-Africa consortia

Collaborations between public and private partners

50% co-financed by partners

L'ambition

Create sustainable research and development cooperation through peer-to-peer cooperation, trust and long-term lessons learned.

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

LEOPARD

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1 - Geothermal Atlas for Africa
Assessment, social needs

2 - Geothermal Village
Assessment, needs-based technology

3 - Renewable Energy for African Agriculture
Water – Energy – Agriculture nexus, productive uses

4 - Sustainable Energy Transition and Digitalization of Smart Mini-Grids for Africa
Mini-grid for local development

5 - Productive Use in Rural African Markets using Standalone Solar Cooking
TRL 4-6 – End uses, jobs, health.

6 - Energy Village Concept
TRL 5-7 – Village energy communities

7 - E. & A. cooperation, from grid digitization to sustainable energy for all
TRL 6-7 – Nano-mini grid, local needs

8 - LEOPARD REs plug in solutions in West Africa
TRL 7-8 – Solar containers for local needs

The LEOPARD Project

1 530 000 €

2021 - 2024

50%

7 partners

UPJV (FR), EIFER(DE), MEDEE(FR), ARESS(BJ), CT2S(SN), SONGHAI(BJ), UAC-EPAC(BJ).

Nos objectifs

- Deploy two containerized solar energy production demonstrators in urban and peri-urban areas in Benin

- Analyze the conditions for interconnecting the off-grid solution to a larger network

- Optimize the technical and economic benefits of the solution

- Define replicability conditions in Benin and Senegal

LEOPARD - Methodology

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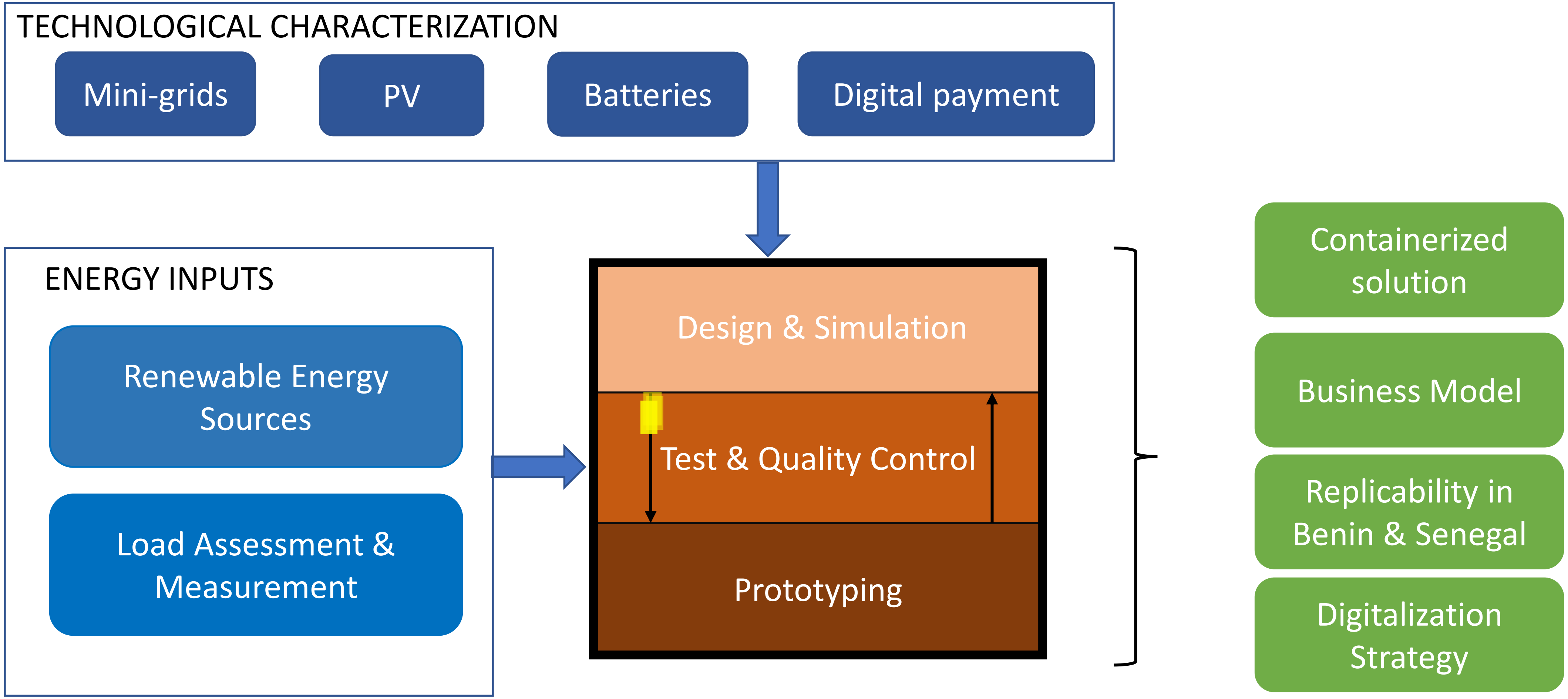

LEOPARD Consortium

- University: expertise on isolated and connected electrical systems
- Coordinator

- Energy research institute founded by EDF and the Karlsruher Institut fürTechnologie
- Develops two modeling and dimensioning tools: LENI and MemoGrid

- Company specializing in solar installations for domestic and professional use
- Provide detailed specification and assemble prototypes

- Agro-ecological center
- Living Lab to test the first container and develop it

- Electrical Engineering Cluster
- In charge of communication and dissemination

- Solar Systems Test Center
- Defines the quality control protocol & participates in the replicability study in Senegal

- Public training establishment
- Evaluates potential for replicability while ensuring local acceptance

LEOPARD Progress

Measurement campaign on the Songhai Center site.

Dimensioning of the first prototype based in particular on the results of the EIFER simulation tool, "Memogrid“.

Drafting of the control protocol.

Completed installation of the first demonstrator at Songhai Center.

Selection of the second pilote site in progress.

PROJET LEOPARD
15 MARS 2023

PROJET DE CONSTRUCTION D'UNE MICRO CENTRALE CONTEUNERISÉE D'UNE CAPACITÉ DE 36,4 KWC AVEC UN STOCKAGE DE 46,2 KWH

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MAITRE D'OUVRAGE	CONSORTIUM LEOPARD
NATURE DES TRAVAUX	CENTRALE SOLAIRE HYBRIDE CONTEUNERISÉE - BRANCHEMENT DU CENTRE SONGHAI
CENTRALE PV	36KWC - 30 KVA - 46.2KWH EN TRIPHASÉ

UNIVERSITÉ de Picardie Jules Verne · ARESS · Songhaï · EPAC · MEDEE · eifer · CT2S

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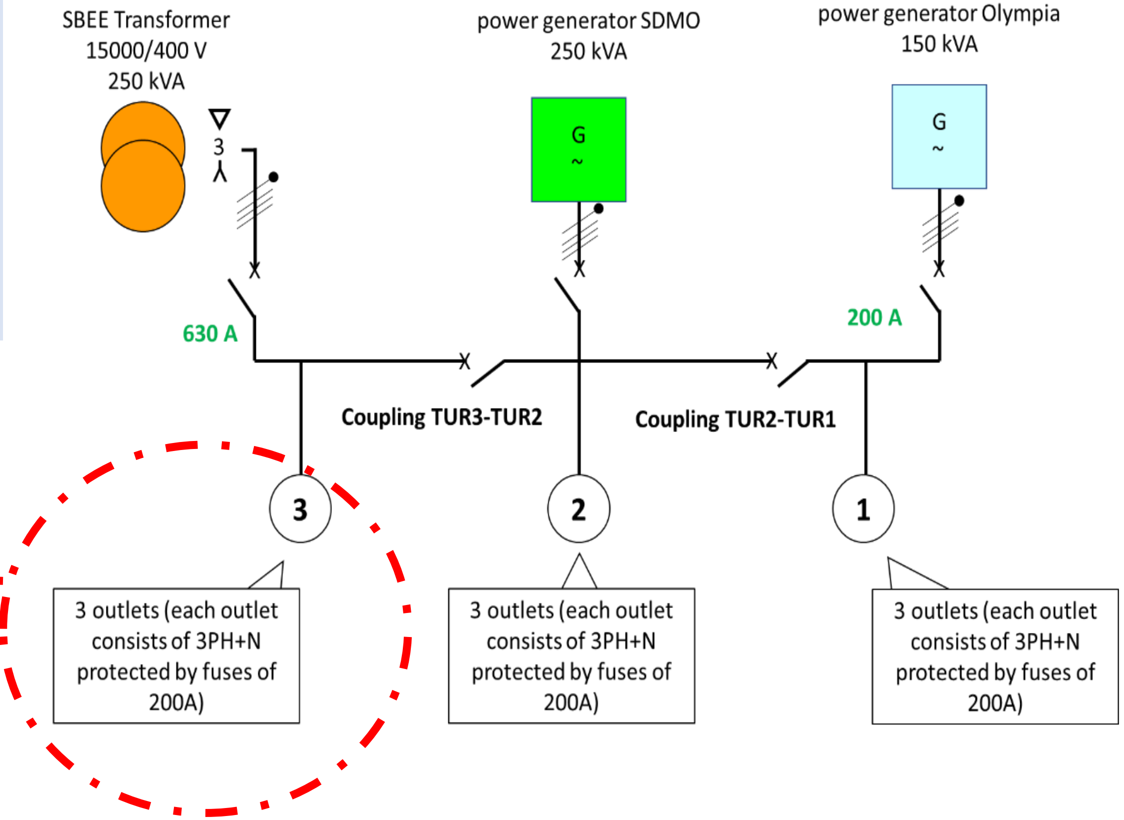
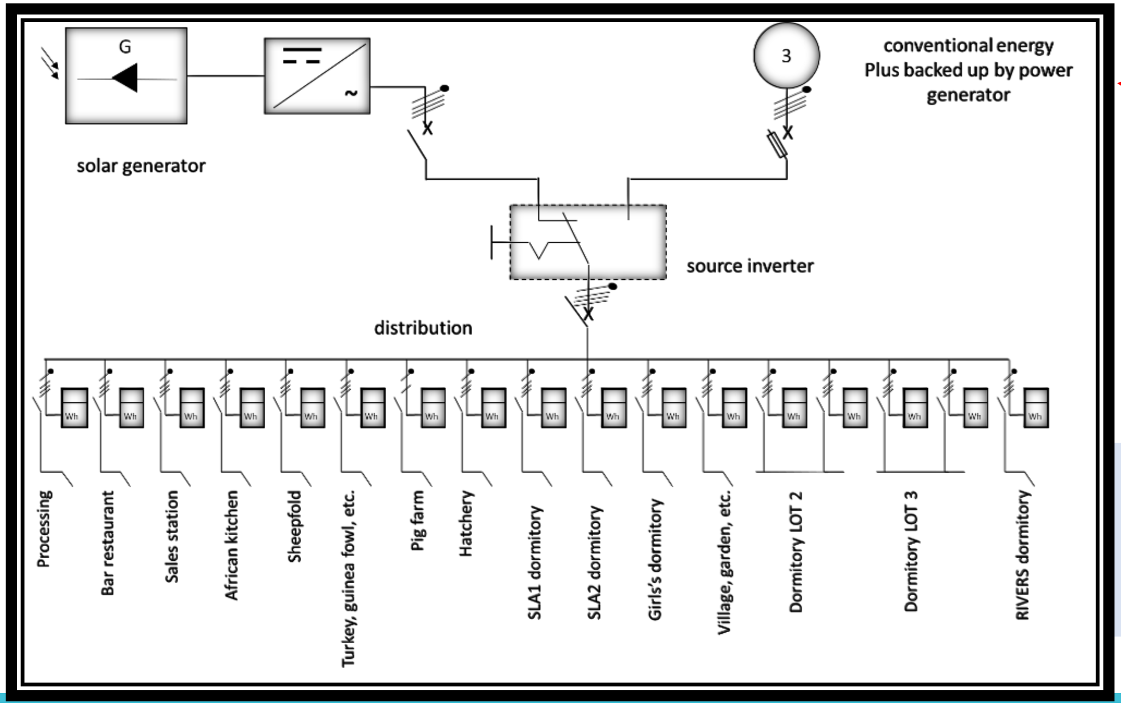
Characteristics of Songhaï site electrical grid

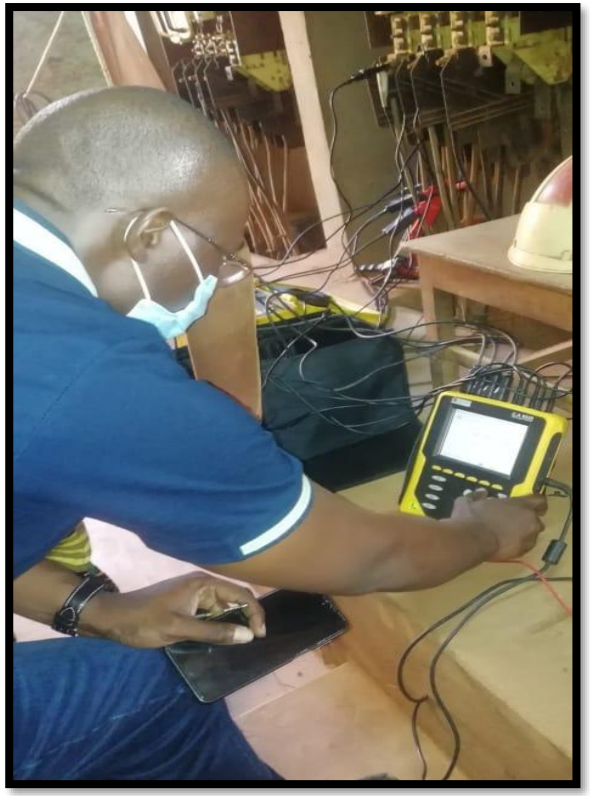
- 250 kVA subscription with SBEE.
- Two emergency generators: 150 kVA and 250 kVA (used during off-peak hours, weekends and holidays)
- Leopard solar village is set up on outlet 3 serving several uses (bar restaurant, shops, sheepfolds, dormitories etc.)

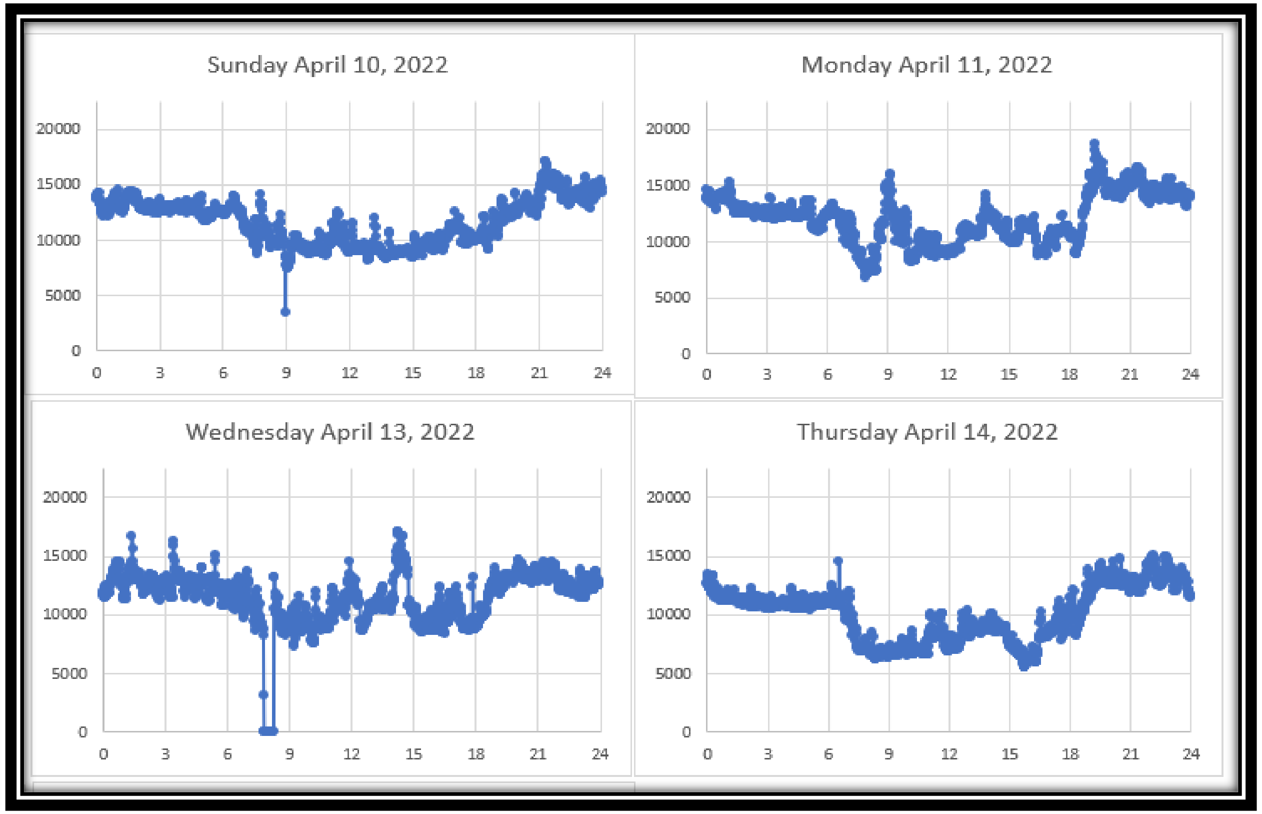




- To obtain daily consumption profile of outlet 3, four measurement campaigns were carried out over the period from July 2021 to August, 2022.

Recording of the consumption profile of the Leopard village on the Songhai site





	Value
Power Variation (kW)	0.013 to 32.48 kW
Daily energy consumption (kWh/day)	100.64 to 377.61 kWh/day
Ratio of diurnal use	45% to 50%

- ❑ Peak power demand is around 32 kW
- ❑ Daily consumption can reach 378 kWh/day
- ❑ Daily share of consumption is around 50%
- ❑ Electrical system resumes after power outages without a particular call for power

Characteristics of the selected system

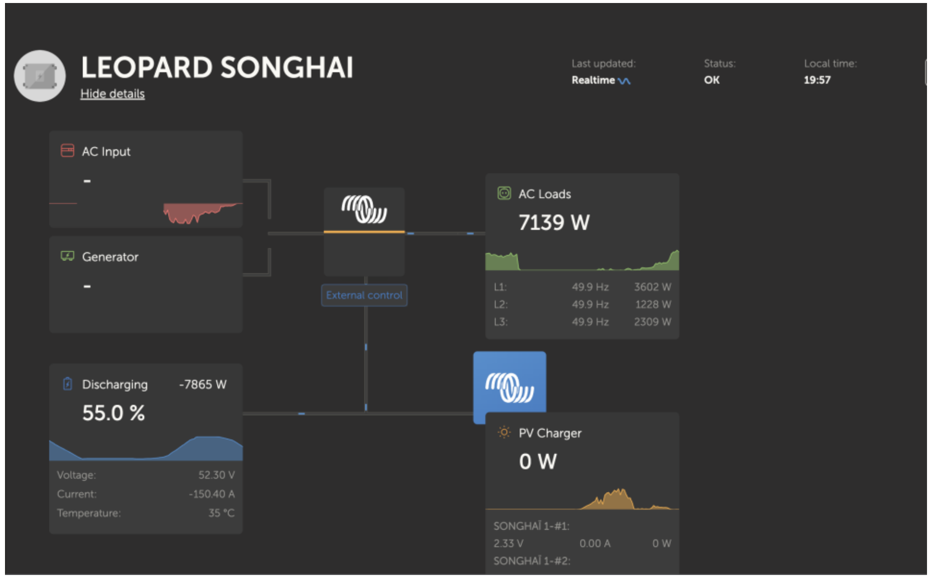
- Following previous analysis, we validate the Model IV: 90 kWh average consumption profil to size the solar unit
- A three-phase system of 36.2 kWp capable of supplying about 90-120 kWh guaranteed per day, with a storage of 50% autonomy for evening needs
- Acquisition of a sea container that has been refurbished to meet thermal constraints
- Installation of an A+ air conditioning system to maintain the entire infrastructure at room temperature

Technical proposal installed

PV JA Solar	455 Wp	78	
Fronius	8 kWc + 6 kWc	1 + 1	
MPPT Victro	450/100	3	
Quatrro Victron	48v10kVA/100	3	
Storage BYD	15.4 LVD	3	
Monitoring	Cerbo + GX	1	
Electrical Protection (AC & DC)	Electric Boxes	2	
Misc. & Grounding	-	-	

Provisional reception of the installation

Remote Monitoring



- Connected system to monitor and managed remotely
- Data record analysis to check if unit profil fits with theorical loard curve
- 24/7 after sale services
- After +150 days after commissioninig:
  - Around 13 MWh consumption
  - 10.16 T CO2 avoided

Lessons learnt

- Unique opportunity to compare data simulation VS realtime data recorded : ARESS#EIFER
- Challenge to use sea freight container to refurbish for solar tehnical room ==> high energy management constraint : ARESS#EPAC
- Load optimization to fit with the initial load profil load : ARESS#SONGHAI
- Enhance CT2S recommendations as standards for any solar mini grids deployment : ARESS#CT2S
- Estimate CAPEX and OPEX for evaluation of the LCOE : ARESS#UPJV
  - Based on the performance of the unit , around 23cts USD on a 10y.o life without re-investment

THANK YOU FOR YOUR KIND ATTENTION

LEOPARD PROJECT
QUALITY CONTROL

LEAP-RE

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and Innovation Partnership on Renewable Energy

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Background

This presentation focuses on the quality control of the minigrid (container) within the framework of the LEOPARD project. This control relates to action 2 of task 16.3 of work package 16.

It presents the objectives, the methodology, the various tests proposed for determining the quality and reference state of the minigrid.

General objective

- Check the conformity of the installation Measure production performance
- Evaluate the quality of the installation
- Determine the reference state of the system

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Specific objectives

- ❑Measure production performance
- ❑Evaluate the quality of differents components
- ❑Locate heat dissipation points
- ❑Determine the load profile
- ❑Verify the compliance with installation standards
- ❑Determine the reference state of the system

Methodology

- ❑General system inspection
- ❑Delimitation and identification of the different parts of the subsystems
- ❑Production subsystem performance testing
- ❑Performance measure of regulators
- ❑Efficiency measurement of charger inverters
- ❑Storage Subsystem Performance Measurement
- ❑System Thermographic Inspection

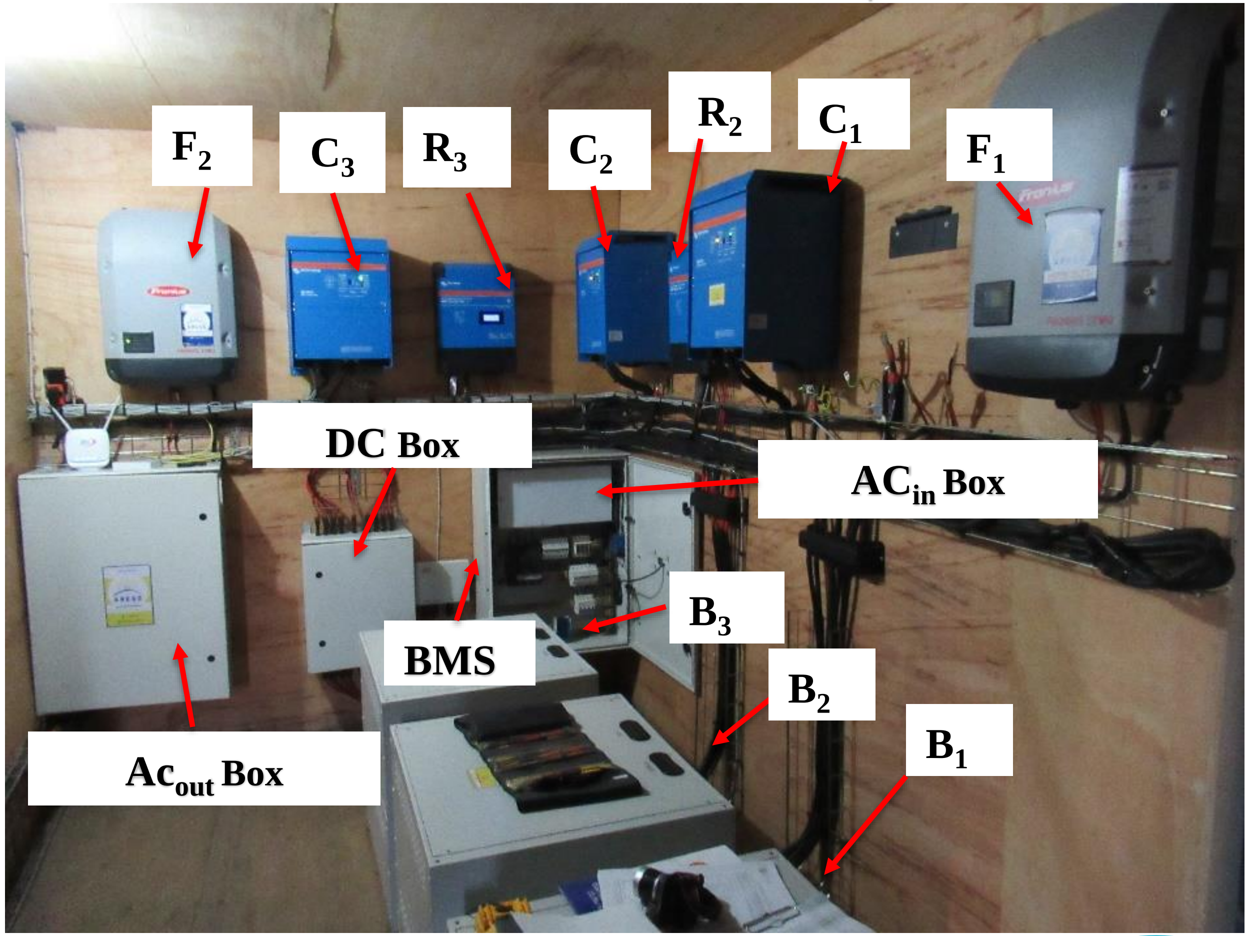
Different types of testing

- ❑Visual inspection (PV Field, batteries, regulators, inverters, cables, boxes, protections)
- ❑PV modules characterization (Pmax, Voc, Impp, Vmpp, Isc, FF)
- ❑IR Test of PV modules
- ❑Batteries test (SOH, Capacity, Energy efficiency, Nominal voltage, …)
- ❑Performance Test of regulators and inverters (Efficiency, characteristics, …)
- ❑Determine load profil

Quality control

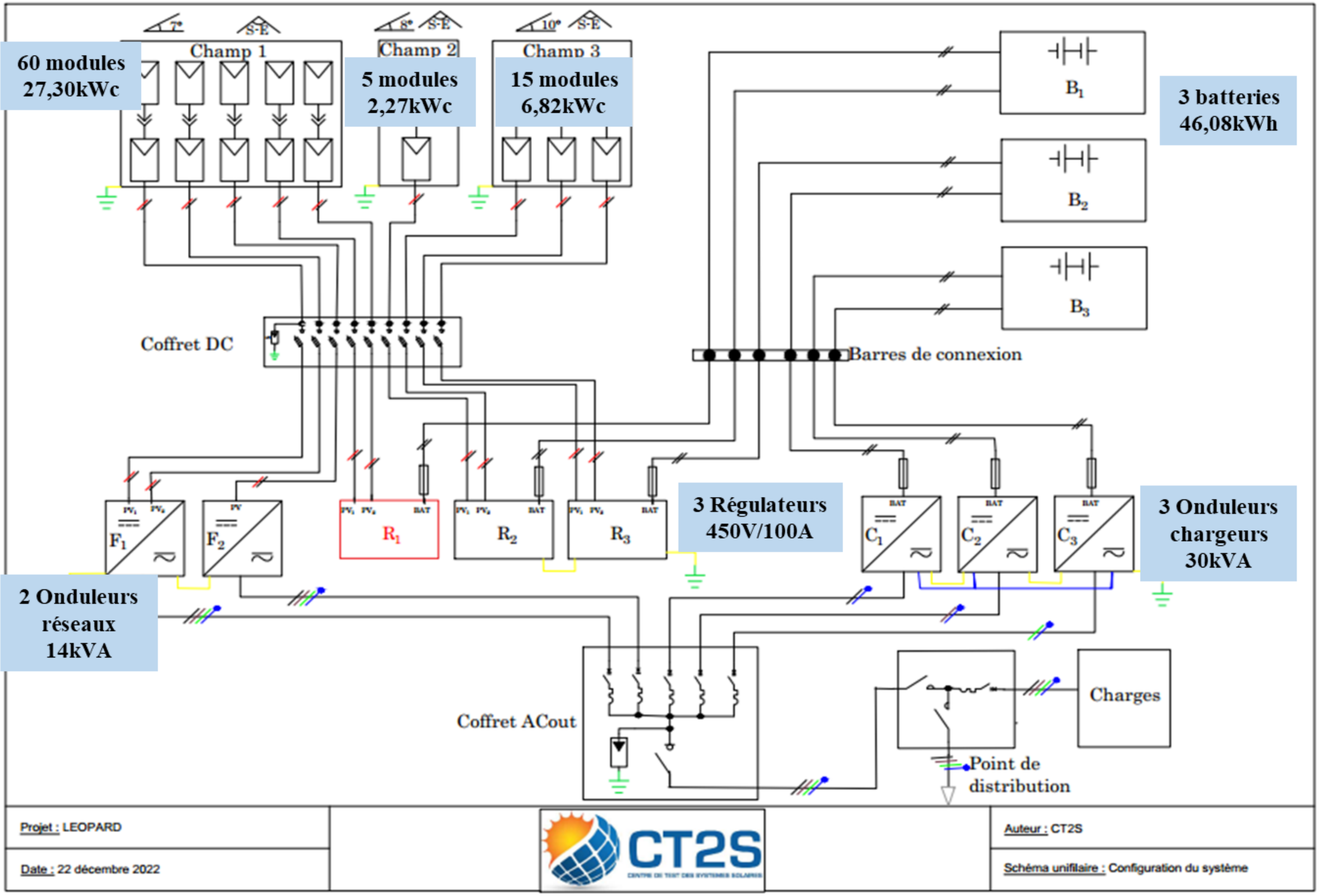
System global view

System overview



The technical room

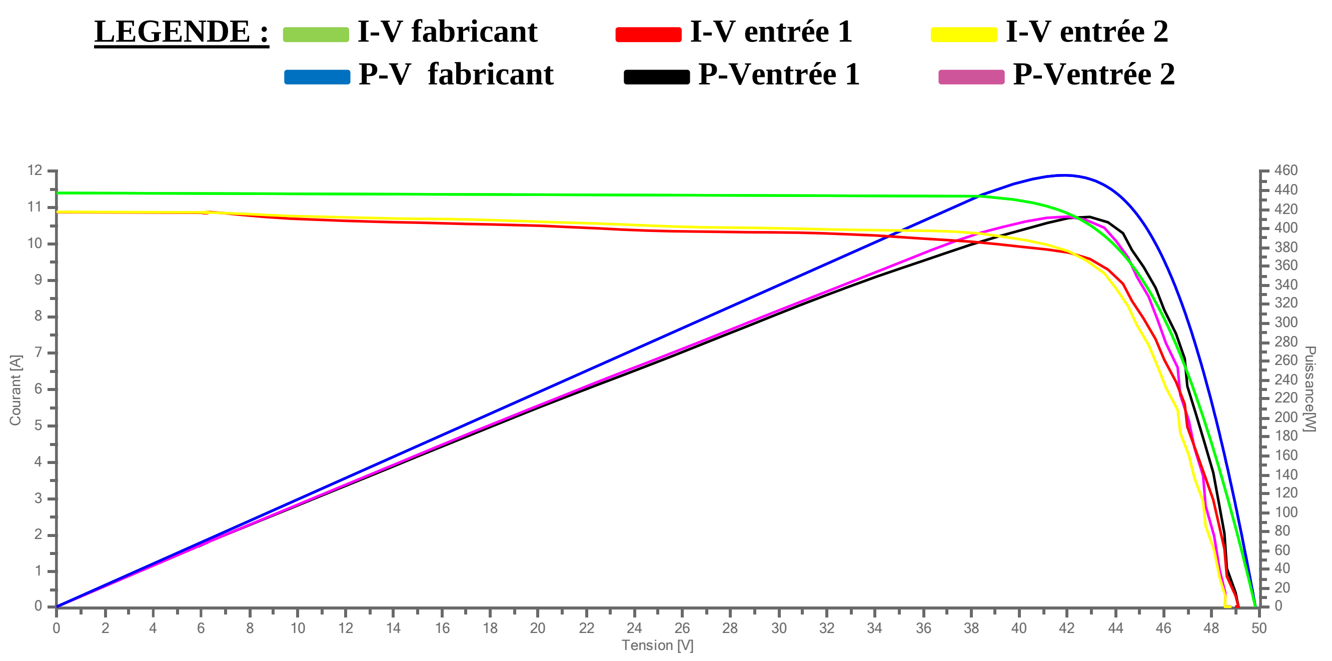
Quality control - System global view



System configuration

Quality control : PV field

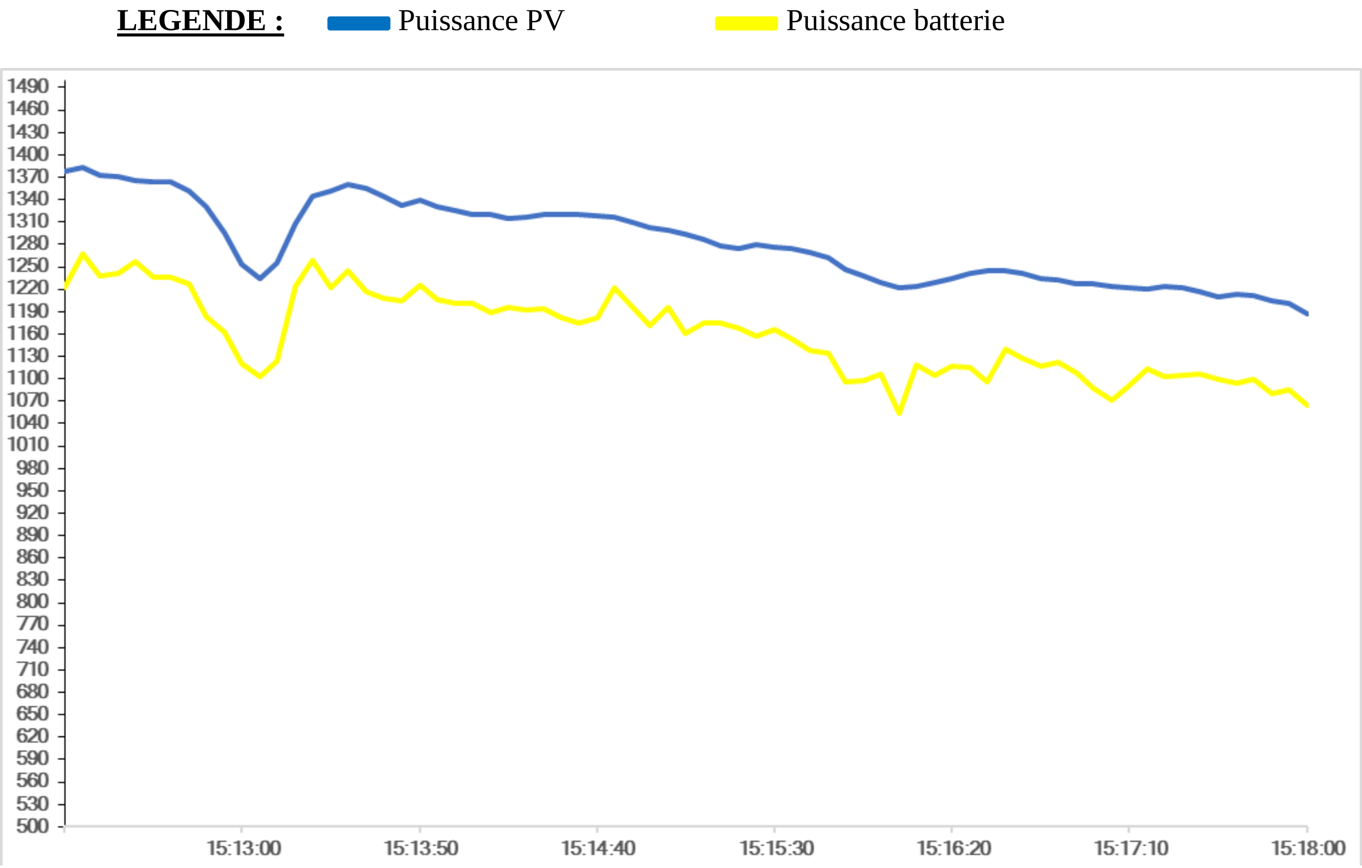
Groupes PV	Conditions	P_{max} [W]	V_{oc} [V]	V_{mpp} [V]	I_{mpp} [A]	I_{sc} [A]	F.F [%]	Irr. [W/m2]	Temp [°C]
-	Fabricant	455	49,8	41,8	10,88	11,41	80	1000	25
Groupe 1-1 6 modules	OPC	1874	265,8	225,6	8,31	9,32	76	858	59,4
	OPC_{moy}	312	44,3	37,6	8,31	9,32	76	858	59,4
	STC	404	48,8	42,4	9,53	10,69	77	1000	25,0
	Écarts[%]	*-11,2*	*-2,1*	*1,3*	*-12,4*	*-6,2*	*-4*	*0,0*	*0,0*
Groupe 1-2 6 modules	OPC	1888	267,3	227,1	8,31	9,85	72	874	58,9
	OPC_{moy}	315	44,6	37,9	8,31	9,85	72	874	58,9
	STC	399	49,0	42,6	9,37	11,10	73	1000	25,0
	Écarts[%]	*-12,4*	*-1,8*	*1,8*	*-13,9*	*-2,6*	*-8,8*	*0,0*	*0,0*



I-V and P-V characteristics of the group connected to the regulatorR3

The powers measured are lower than that announced by the manufacturer with average deviations of -11.8% for group 1, -14.6% for group 2, -9.4% for group 3, -11.6 % for group 4 and -12.2% for group 5.

Quality control : MPPT charger



Variations of the input and output powers of R2

Performance of regulators 1 and 2

Regulators	**PV input** [W]		**Storage output** [W]	**Efficiency** [%]
	Groupe *n*-1	Groupe *n*-2		
R$_2$	91,42	343,6	363,94	84
	179,92	851,5	708,70	69
	178,77	802,3	695,81	71
R$_3$	216,19	1092	1 223,73	94
	217,42	1005,1	1 054,50	86
	211,82	1165,6	1 221,49	89

Yields measured in real conditions are acceptable given the level of charge of the batteries

Quality control : Charger inverter

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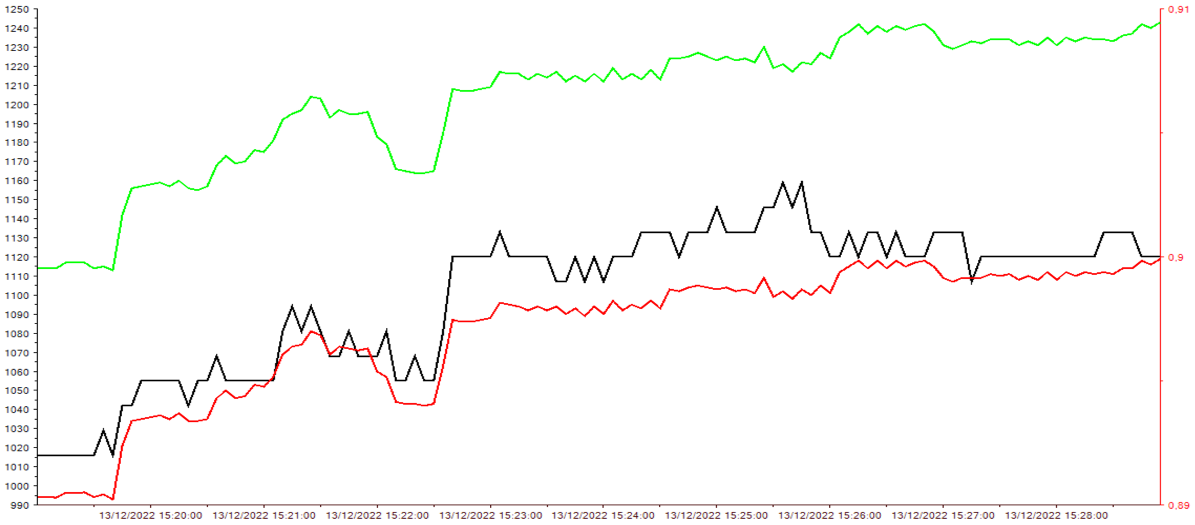
Performance of charger inverters

Charger inverter	Power DC [W]	Power AC [W]	Load [%]	Efficiency [%]
C_1	2238	2019	20	90,2
	3339	3045	30	91,2
	3840	3548	35	92,4
C_2	1114	994	9,9	89,2
	1173	1050	10,5	89,5
	1217	1096	11,0	90,1
C_3	3942	3571	36	90,6
	4938	4632	46	93,8
	5095	4794	48	94,1

LEGENDE : Puissance DC Puissance AC Rendement

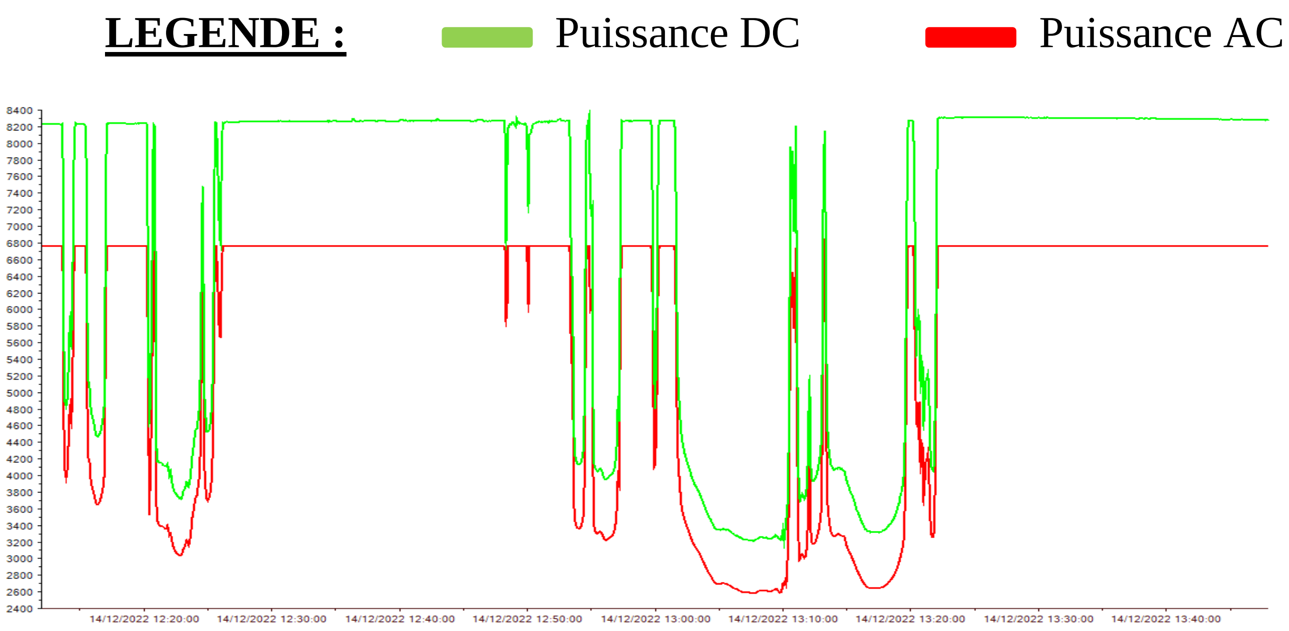


Variations of the powers of C2

Quality control : Grid inverter

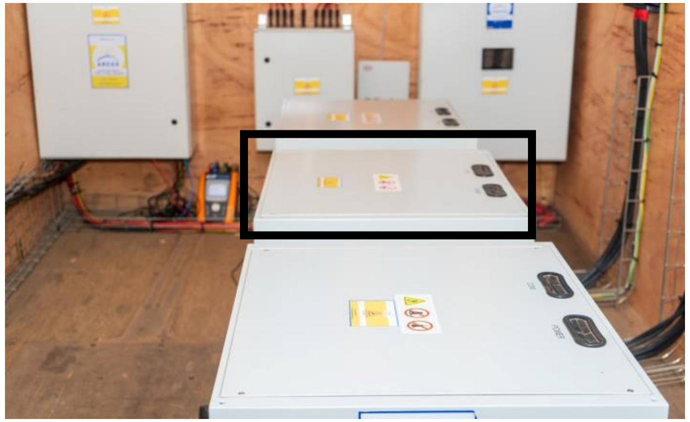
F1 Grid Inverter Performance

DC PART		AC PART	
Nominal power	13,65 kWc	Average power	6,77 kW
Average power	8,27 kW	Power factor	0,97
Voltage	637,1 V	Efficiency	82%
Current	12,98 A	Phase-to-phase voltage 1-2	395,7 V
Efficiency	88%	Phase 1 current	8,48 A
ENVIRONNEMENT		Phase-to-phase voltage 2-3	396,7 V
Irradiance	690 W/m²	Phase 2 current	12,32 A
Cell temperature	43°C	Phase-to-phase voltage 3-1	395,3 V
Ambient temperature	33°C	Phase 3 current	12,36 A
Average performance ratio = 72,6%			



Variations of the DC and AC powers of F1

- The average power injected into the system is **6.7kW**
- The efficiency of the panels (group 4) is **88%>85%,**
- The overall performance ratio is **72.6% >70%,**



Battery performance

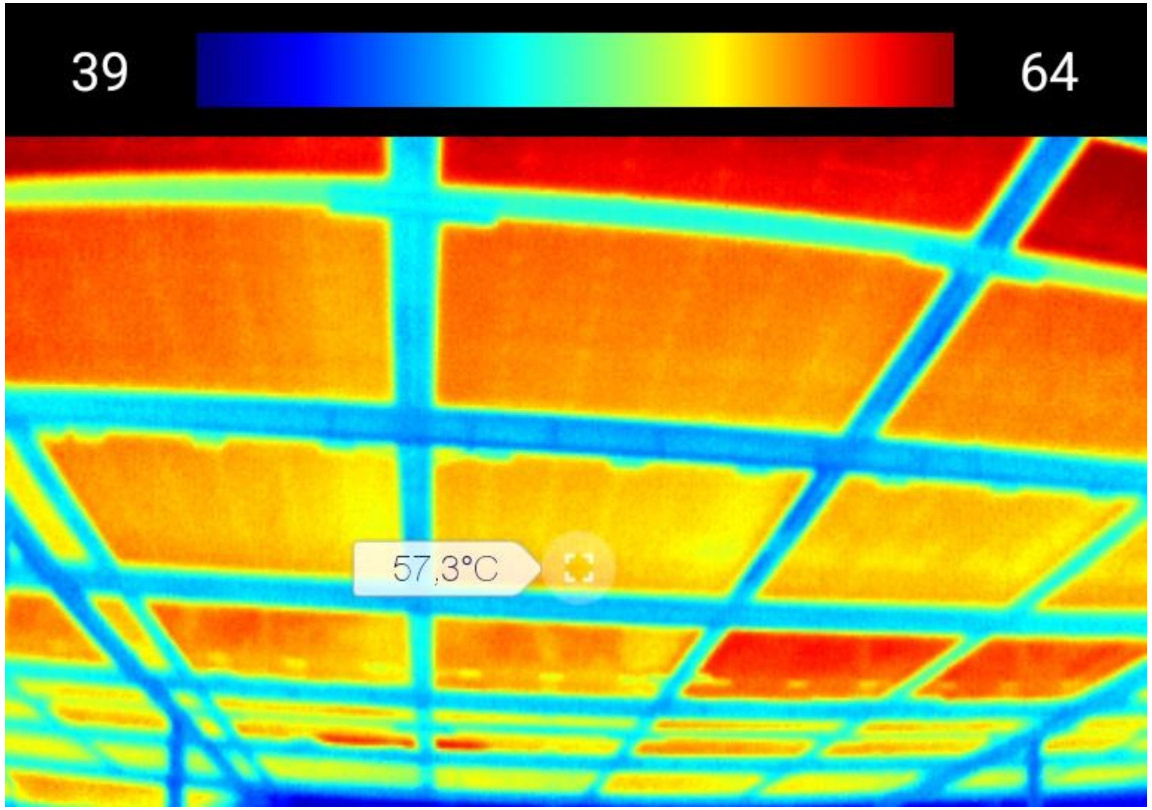
	Battery 1		Battery 2		Battery 3	
	V (V)	Internal resistance (mΩ)	V (V)	Internal resistance (mΩ)	V (V)	Internal resistance (mΩ)
Charged : SOC=93%	53,45	4,64	53,43	3,60	53,44	4,01
Discharged : DOD=90%	52,22	5,38	52,19	3,69	52,17	4,15

The performance of the bench was studied during a complete cycle for a **state of charge** (Stat Of Charge: SOC) ranging from **10% to 93%.** The results showed that the batteries have good performance in a dynamic and real operating regime with good yields. In addition, the internal resistances are compliant for the charged and discharged states of the battery.

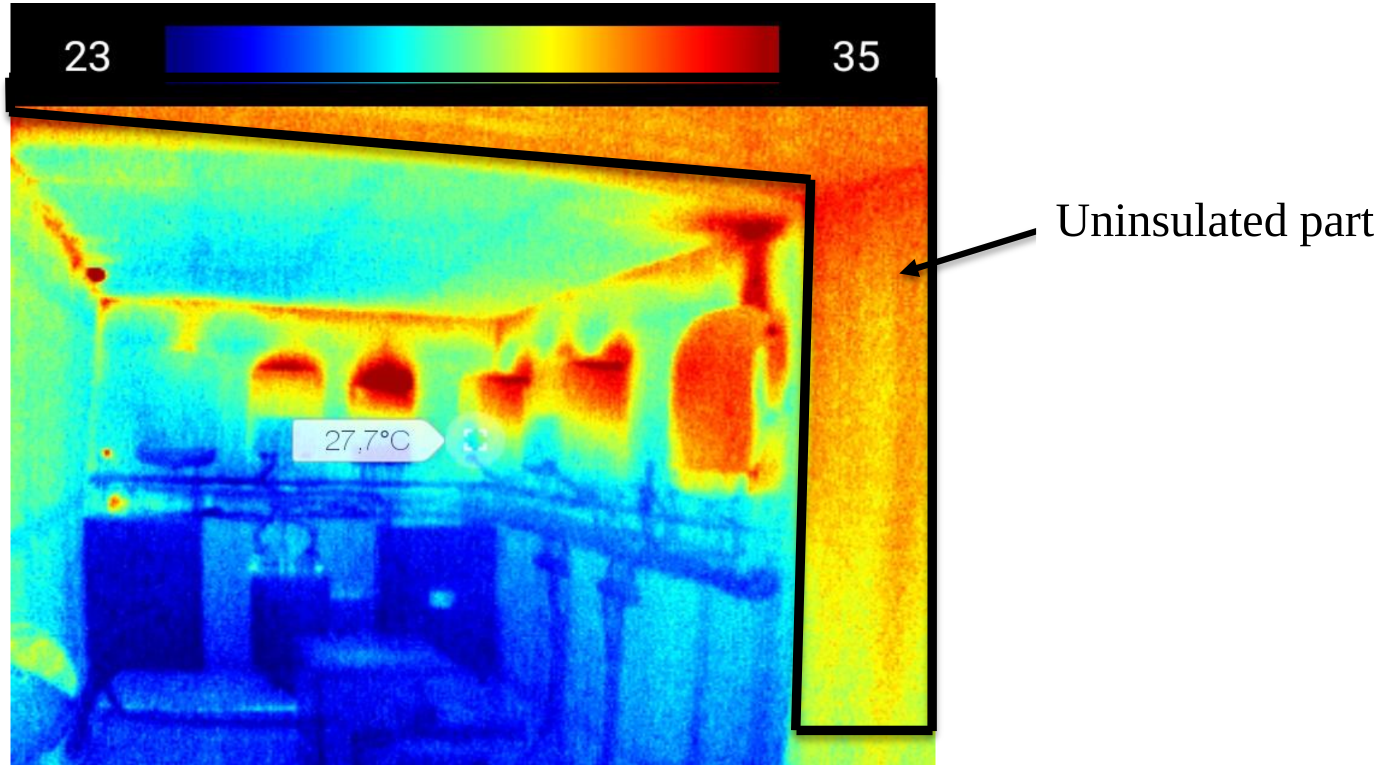
Coulombic efficiency = **88.18%**

Energy efficiency = **87.90%**

Quality control : Imagery



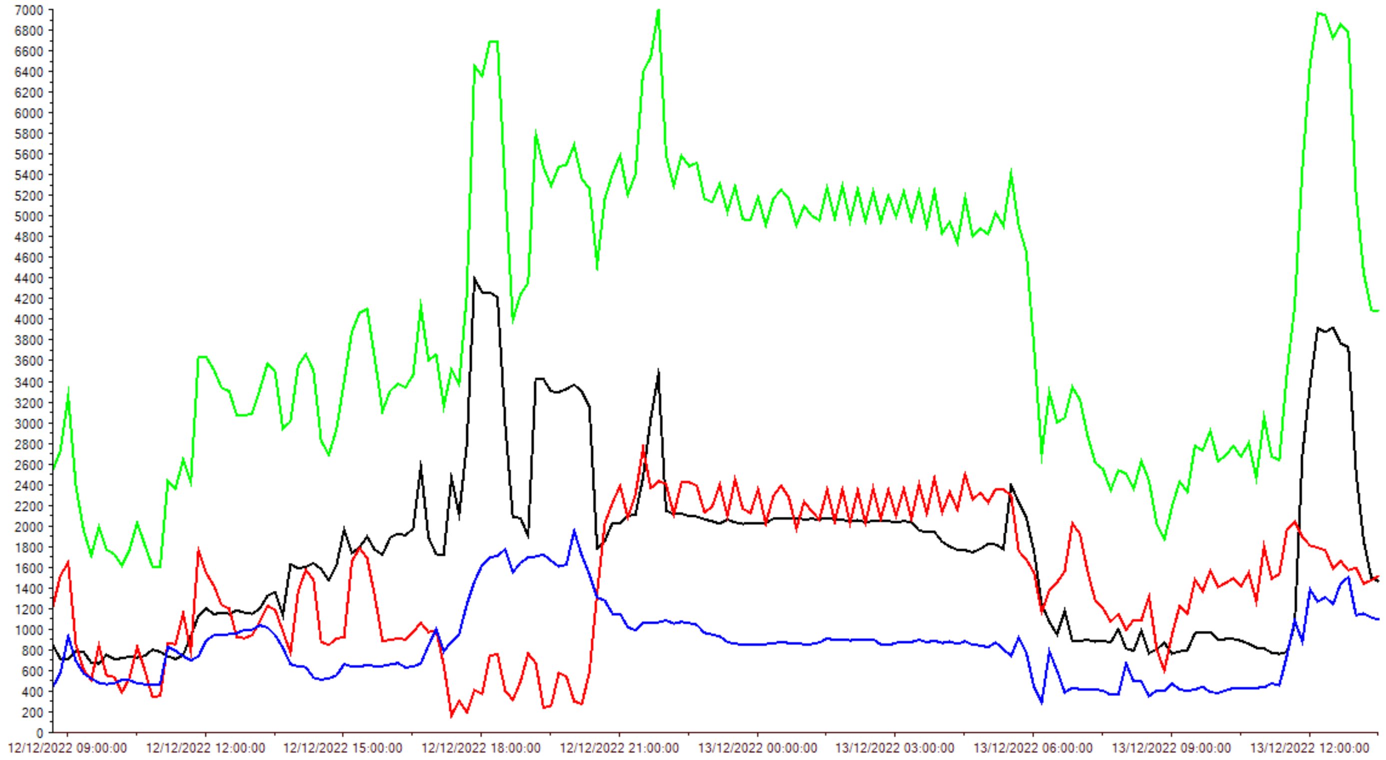
Thermographic image of field 1



Thermographic image of the technical room

Quality control : System

LEGENDE : Puissance totale | Phase 1 | Phase 2 | Phase 3



System load profile

Limit powers

	Average power	Maximal power	Minimal power
Phase 1	1775	4373 à 17h50	668W à 9h40
Phase 2	1463	2754 à 21h30	167W à 17h20
Phase 3	855	1952W à 20h	294W à 6h11
Total	4070	7000W à 21h51	1607W à 10h51

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Conclusion

Quality control for Minigrids and test of Initial service are very important.

This allows confirming :
-The quality of Material installed regarding the announcement of the Company
-The respect of the standard for the Installation

At Least it will be necessary for the sustainability of the system to have a periodical test during the lifetime of the Minigrid (each 6 months)

LEAP-RE : LEOPARD PROGRESS
Quality control

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Thank you for your attention

CT2S
CENTRE DE TEST DES SYSTEMES SOLAIRES

LEOPARD PROJECT
LENI & MEMOGRID

LEAP-RE

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Toolbox for electrification projects: LENI and MemoGrid

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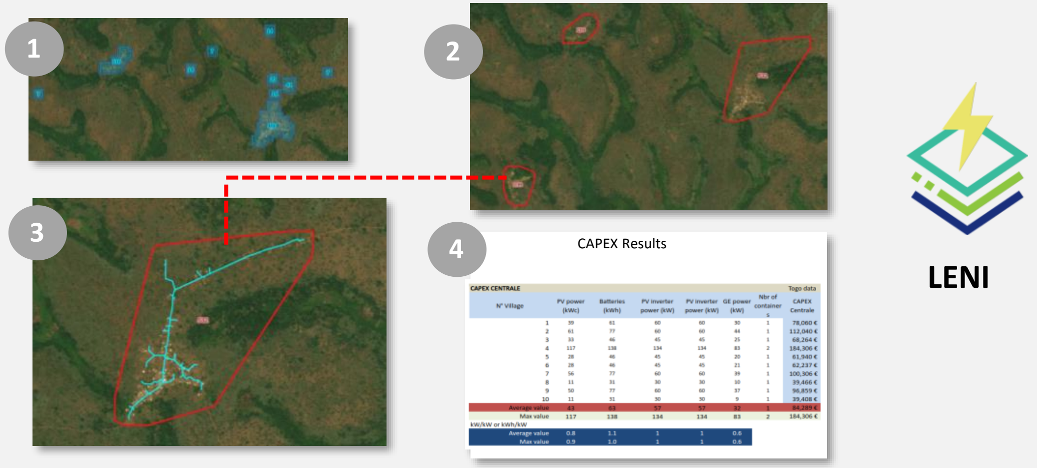
Solutions for identification & implementation of rural electrification systems

OBJECTIVES

- Provide a means of rapidly identifying candidate sites for electrification solution implementation
- Determine the most appropriate solution (solar home system, microgrid, grid extension) at the identified candidate sites
- Simulate and optimize the selected system
- Quick optimization of large number of microgrids for given areas
- Continuously improve these methods with new data, more refined methodology and use cases for evolving client needs

METHODS

1. Constructed database of most accurate & recent population data & topography (roads, land cover, etc.)
2. Apply clustering algorithm designed to build clusters of desired size (in terms of geographic extent and population)
3. Estimate required network length using “Pathfinder” algorithm
4. Perform initial rough cost ranking based on minimizing levelized cost of electrification (LCOE)



MemoGrid

5. Simulate the real time behavior of an energy system based on the user inputs
6. Visualize the KPI in a customized interface depending on the needs of the user and to save them in files (ex. Excel/CSV)
7. Optimize and find the best design of the microgrid to ensure the minimum LCOE given some restrictions. This approach can be applied automatically to large number of microgrids in the same simulation.

Authors: Isaac Boates, Stefano Sanfilippo

Replicability Study: LENI tool

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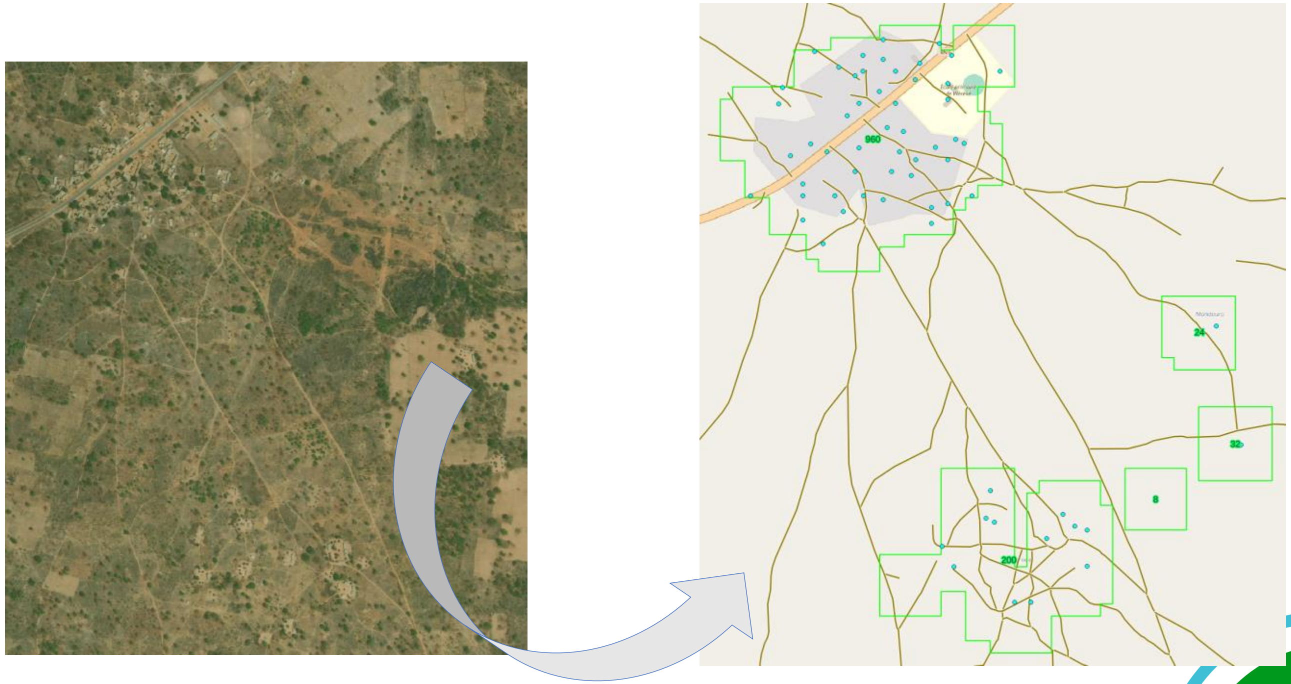
DELIVERABLES

GIS Study on replicability/adaptability of the LEOPARD microgrid solution to Beninese and Senegalese rural environment and context

LENI

DATABASE

- ✓ Tool developed over the last few years for use in identifying microgrid (+ other electrification method) candidates
- ✓ Uses a geographic database containing several open-source datasets
  - ✓ Population estimates
  - ✓ Localization of demand points
  - ✓ Place names
  - ✓ Roads which may be missing from official maps
  - ✓ Lights visible from space at night
  - ✓ Health care facilities
  - ✓ Telecommunication towers



- ✓ The various data sources are passed through an automatic processing pipeline developed at EIFER to put them into one standardized database

15.03.2023

Replicability Study: LENI tool

CLUSTERING ALGORITHM

- ✓ A clustering algorithm has been developed which uses this standardized database + a study area as an input
- ✓ It produces **a list of candidate sites inside the study area, with all known information about the candidate associated to it**
- ✓ Various parameters can be tweaked to make the clusters more or less dense, to allow them to grow to be larger or smaller, etc.

Outputs

- Excel file with all candidate information in rows
- Geographic data file (shapefile, KML, GPKG, whatever)
- Interactive map

Replicability Study: LENI tool

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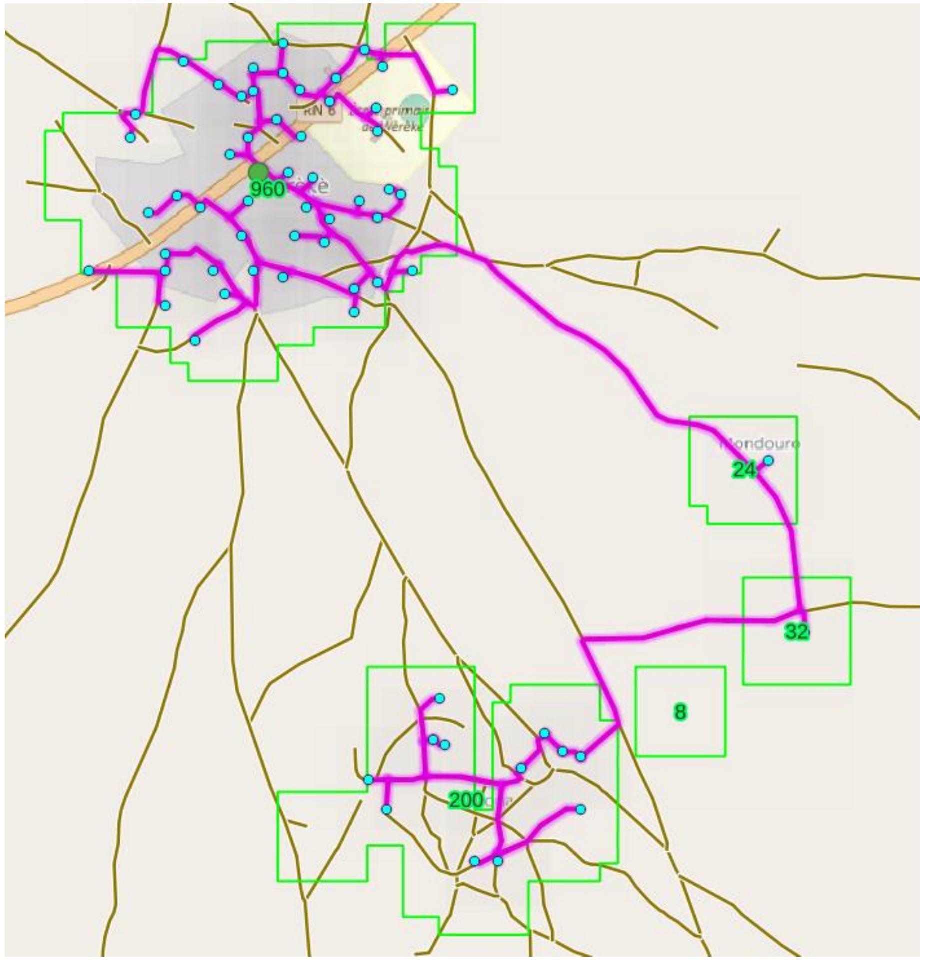
PATHFINDER

- ✓ Algorithm that has been in general use in the Microgrids by EDF topic for quite a while now
- ✓ Automatically draws **networks that are geographically optimized to follow the surrounding infrastructure layout** (e.g. roads)
- ✓ The candidates identified by the clustering algorithm can be fed directly to the Pathfinder as an input
- ✓ This **allows a rough pre-assessment of the required network structure**



Replicability Study: LENI tool

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USE IN REPLICATION STUDY

- ✓ We intend to use this work to identify sites in Benin and Senegal, which are comparable to the demonstrator site, in terms of approximate size, population
- ✓ Also to identify sites that are high priority due to the presence of health care facilities, telecom towers, etc.
- ✓ A list of specific sites can then be generated, which can then be filtered and analyzed by experts more efficiently and precisely
- ✓ This should greatly expedite the site selection process when replicating the demonstrator site
- ✓ This process is itself **highly replicable** and can be applied to almost any other country in Africa + beyond

Stay tuned for a live demo of the results

EIFER contribution in LEOPARD

DELIVERABLES

Development of a specialized tool for the design of microgrids to design the solution i.e. PV panels, storage and associated power electronics in relation with load curves

TOOLS

MemoGrid : **M**ulti-**E**nergy **MO**delling for micro**Grid**

MemoGrid is used for the evaluation of project potential (**Prefeasibility study**) and for technical-economical validation (**Feasibility study**). It can work using different technologies, such as photovoltaic, battery, diesel engine, H2 technologies, biomass and others.

It is a **Decision Helping tool** for **LMES** design and it can be used in the following ways:

- **Simulation**: quick technical-economic evaluation for the micro-grid energy system with possibility of the detail of the real time behavior
- **Multi Simulation**: quick technical-economic evaluation for several microgrids in parallel or for different years of the time life of a microgrid
- **Optimization**: possibility to find the best design of all the technologies of the microgrid which ensure the minimum LCOE
- **Multi Optimization**: possibility to optimize several microgrids in parallel (replicability approach)

MemoGrid can be used in stand alone mode. In the frame of LEOPARD, the use through a secure web platform (AnyLogic Cloud) is developed and will allow partners access to the simulation.

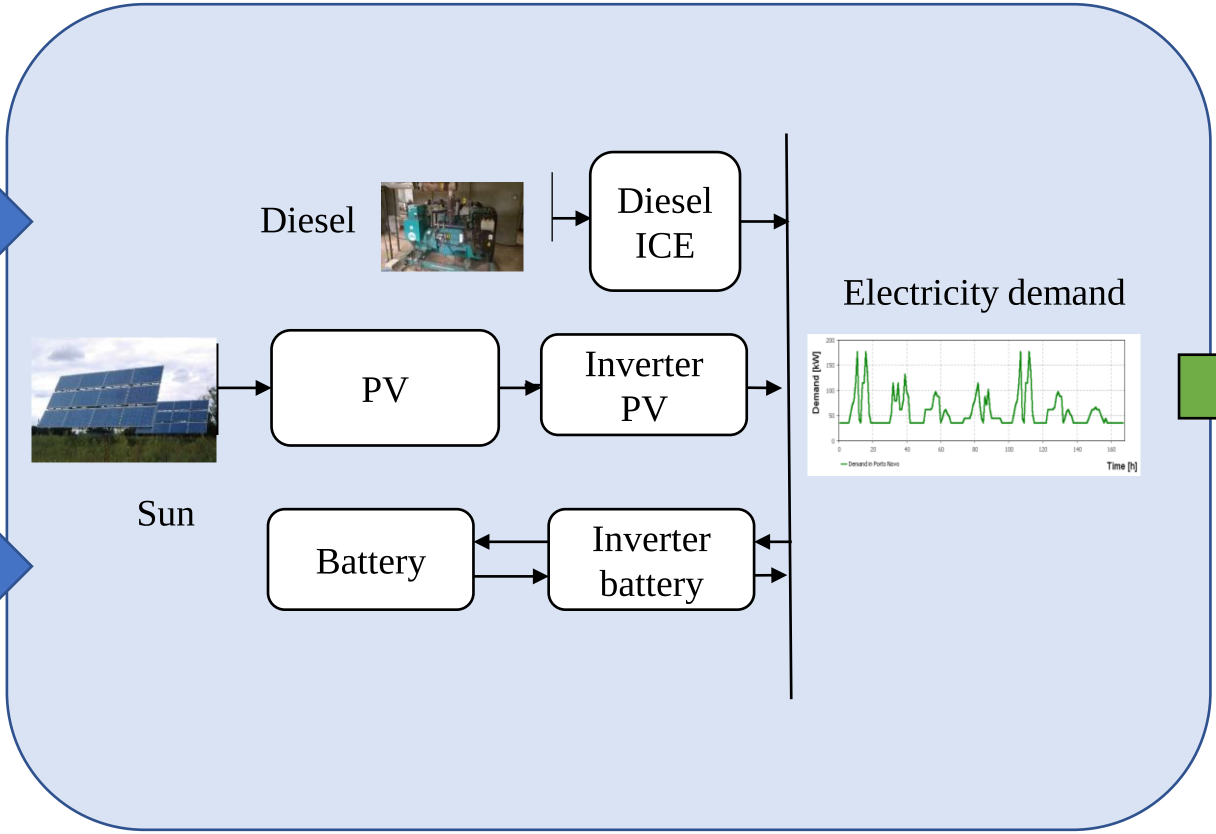
EIFER contribution in LEOPARD: Simulat

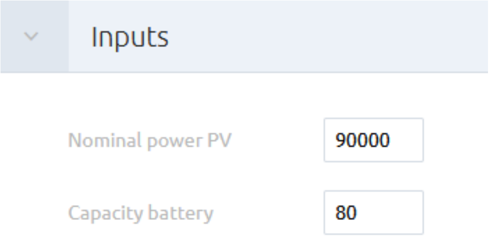
MemoGrid will allow to simulate the microgrid of the villages through a web interface

Inputs

- Environmental characteristics (irradiation, temperature)
- **Load curve**
- Technologies types and specifications
- Economic data (capex, opex)
- EnergyLogic EIFER/EDF components library to develop Dynamic Energy Systems Simulation, using latest simulation approaches such as agent-based modelling

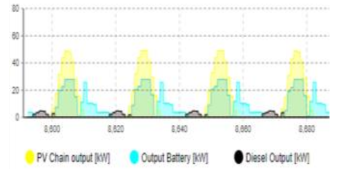
MemoGrid Model





Outputs

- Global share of production of the technologies
- Lost energy
- LCOE
- Real time behavior (share of production at hourly level)



EIFER contribution in LEOPARD: Optimiz

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MemoGrid will allow to optimize the design of each microgrid.

MemoGrid Model

Inputs

- **Villages coordinates** in order to evaluate the boundary conditions such as irradiation and temperature.
- **Load curve** of each village (households types, nb commercial client, nb public client, nb productive client, nb public lighting, evolution over the years of the load curve)
- **Technologies types and specifications** (kind of panel/battery,materials, efficiencies, minimum level of battery, nb hours for discharge of battery, nb for charge of battery, etc..)
- **Economic data**: investment costs, maintenance cost, life time, discount rate, inflation rate, etc..

MemoGrid

Outputs

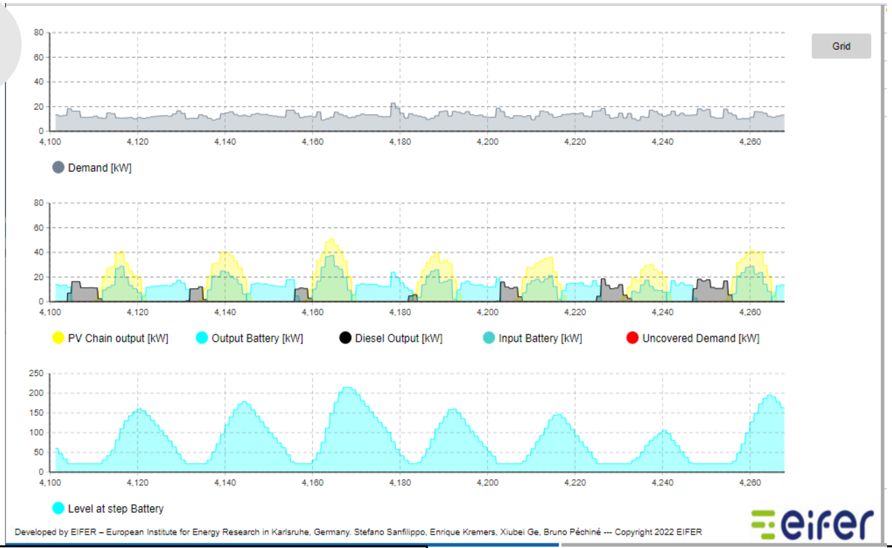
- Best design (PV size and Battery capacity)
- Diesel percentage
- Lost energy
- Yearly diesel input
- LCOE

Optimization requirements

- Maximum uncovered demand
- Maximum acceptable percentage of diesel

Results : KPI

1



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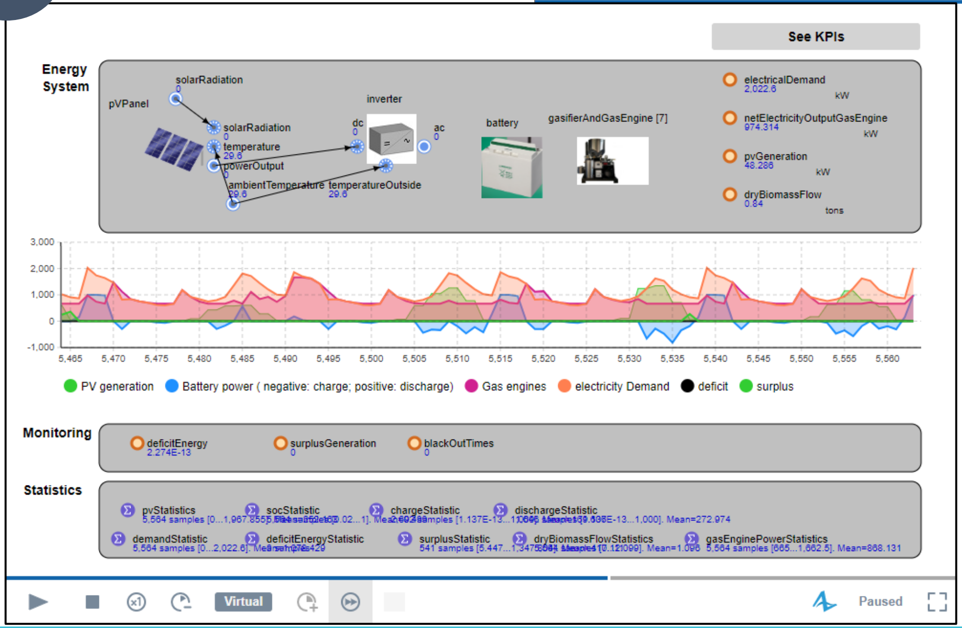

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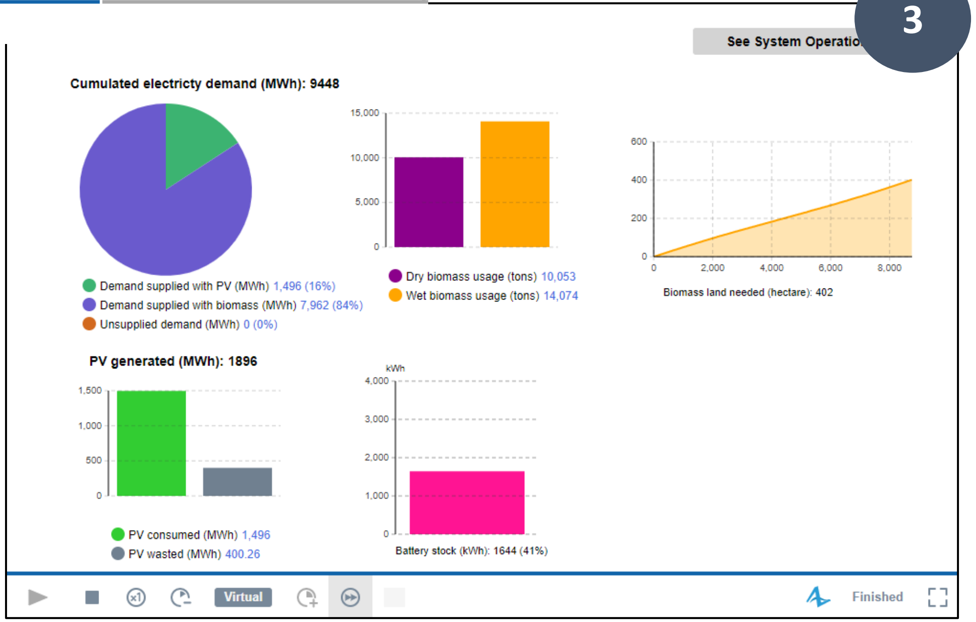

LEOPARD PROJECT

CAPACITY BUILDING

PROGRAM

LEAP-RE

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

LEOPARD

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

LEAP-RE LEOPARD

Background:

The objective of this module is to train the technical personnel required for the design, sizing, and implementation of Clean Energy Micro Grids (CEMGS)

This module will initially introduce the issue of universal access to electricity in the ECOWAS area and Mauritania by highlighting the place of CEMGS

The main points targeted by the Module are the sizing of the various equipment and subsystems, the installation process in the standards, monitoring and maintenance (preventive and curative) of the CEMGs

LEAP-RE LEOPARD

General objective of the training sessions

Train staff capable of Designing, sizing, implementing and maintaining Clean Energy Micro Grids (CEMGs)

LEAP-RE LEOPARD

Target skills

At the end of the training sessions the participants will be able to:

-Have an overview of the interest and place occupied by CEMGs in energy access in the ECOWAS region

-Identify the different typologies of CEMGS(characteristics, classes, etc...);

- Identify the components and subsystems of a CEMG;

-Assess the energy demand of a community and be able to achieve an optimized load profile;

- Choose the appropriate configuration for a CEMGS in a given context;

- Carry out the complete technical designing of a CEMG in a given context;

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Target skills

At the end of the modules the participants will be able to:

-Correctly carry out the procedures for checking and putting into service a MCEN;

-Properly carry out the tasks of managing/managing a CEMG;

- Correctly perform the different maintenance tasks (preventive and curative)

Training organized on sequences

Sequence 1	**1. The challenges of rural electrification in West Africa**
	1.1 Energy policies and projects 1.2 Renewable energy potential and resources (ECOWAS region)
Sequence 2	**2. General information on CEMGs**
	2.1. Architectures of renewable energy systems 2.2. Mini Clean Energy Networks: Configuration and Operation 2.3. Energy transport and storage in CEMGs 2.4 Life Cycle Analysis of CMEGs Projects

Training organized on sequences

Sequence 3	3. **Sizing of CEMGs**
	3.1. Methodology for the Evaluation of RENEWABLE RESOURCES (potential) 3.2. Study of needs and development of the load profile 3.3. Sizing of the components of an CEMG 3.4. Technical sizing of an MCEN with Homer software 3.5. Case Studies and Mini Projects on the sizing of CEMGs
Sequence 4	4. **Implementation of CEMGS**
	4.1. Supply procedures in MCENs facilities 4.2. Quality control of CEMGs equipment 4.3. Procedures for installing an CEMGs according to the standards and safety
Sequence 5	5. **Exploitation and maintenance of CEMGs**
	5.1. Operation and management of CEMGs 5.2. Maintenance of CEMGs

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Organisation of the training sessions

- The training sessions will be organized on sequences
- The Webinars concept is proposed
- The duration of webinars will 2 hours Maximum

Proposition of Organisation to be validated

Webinar1: Sequence 1and 2

Webinar 2: Sequence 3 part1

Webinar 3 : Sequence 3 part 2

Webinar 4: Sequence 4

Webinar 5: Sequence 5

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MANY THANKS FOR YOUR ATTENTION.

Lead of

Capacity building

CT2S
CENTRE DE TEST DES SYSTEMES SOLAIRES