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Techno-economic analysis of energy storage integration for solar PV in Burkina Faso

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OUTLINE

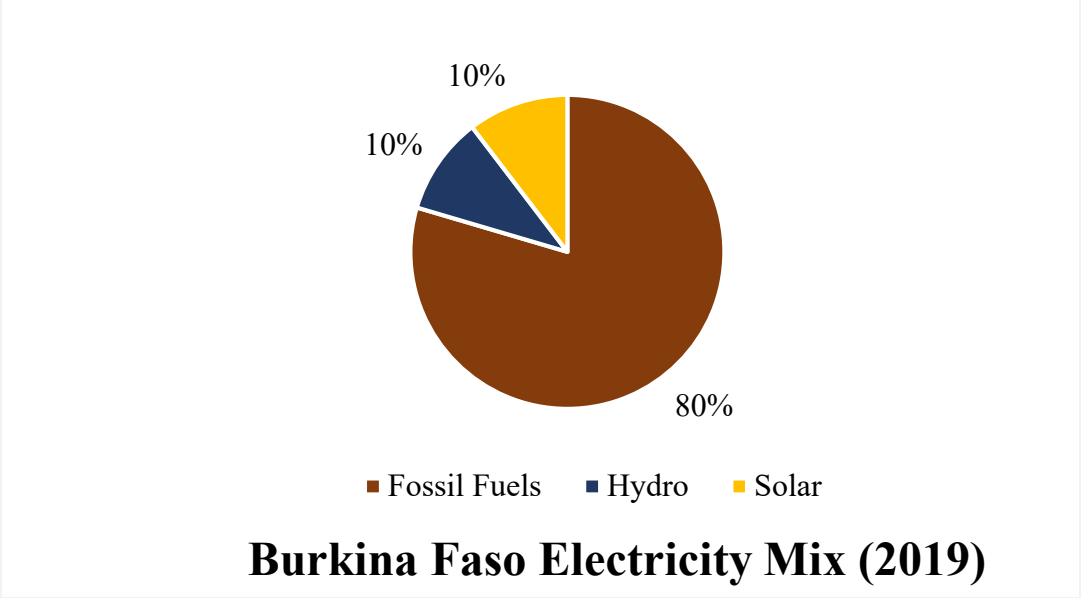
- **Introduction**
- Methodology
- System Analysis
- Results: Off Grid
- Results: Grid Connected
- Conclusion: Policy Suggestions

Introduction: Burkina Faso

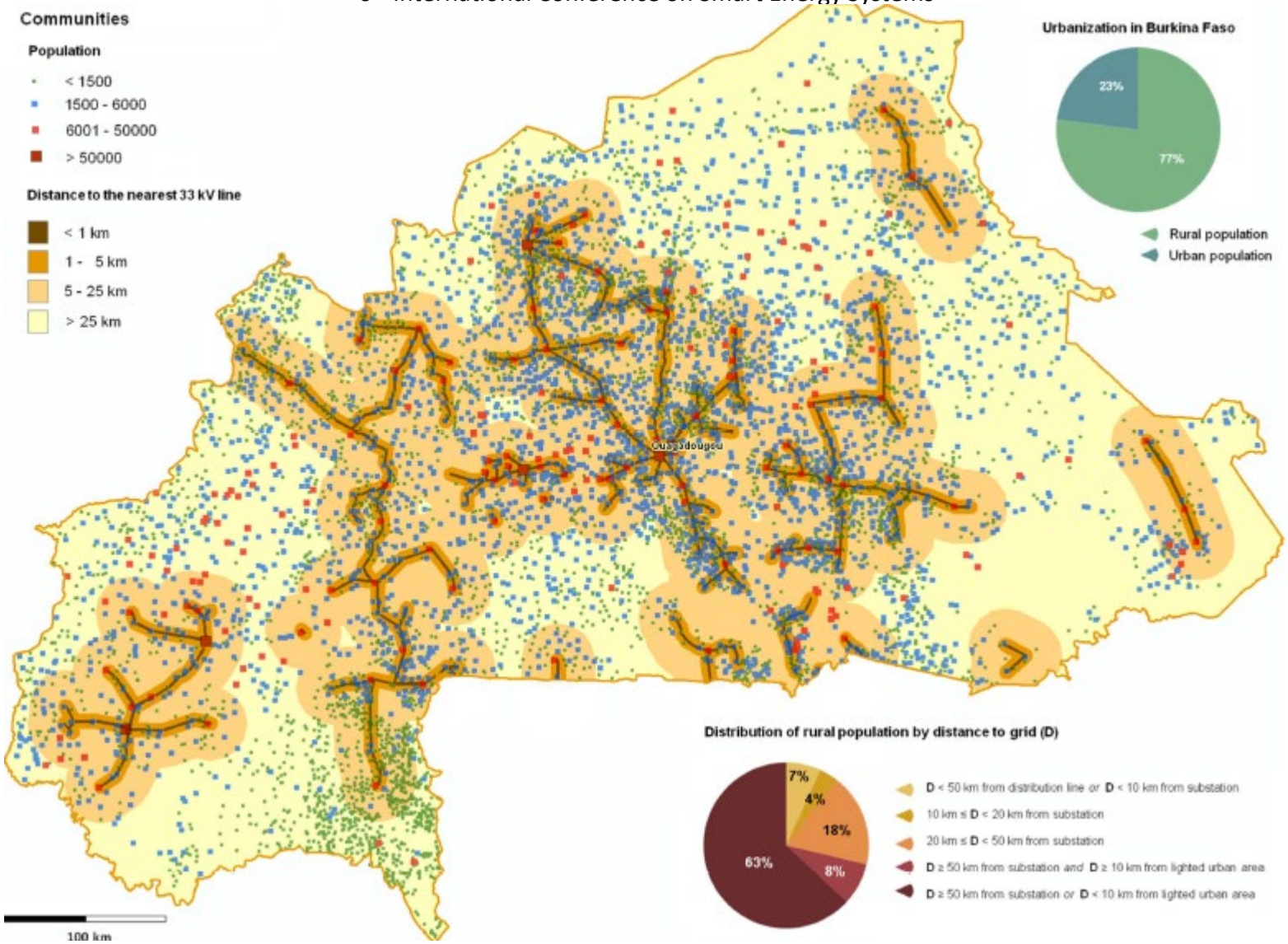
- Landlocked country in West Africa
- Population 19 million (2017)
- Urban electrification (60 %)
- Rural electrification (9 %)

Burkina Faso: Energy Sector

- Dependent on fossil and biomass
- No oil reserves or refineries
- Solar production: 35 MW
- 3000 hours direct sunshine per year

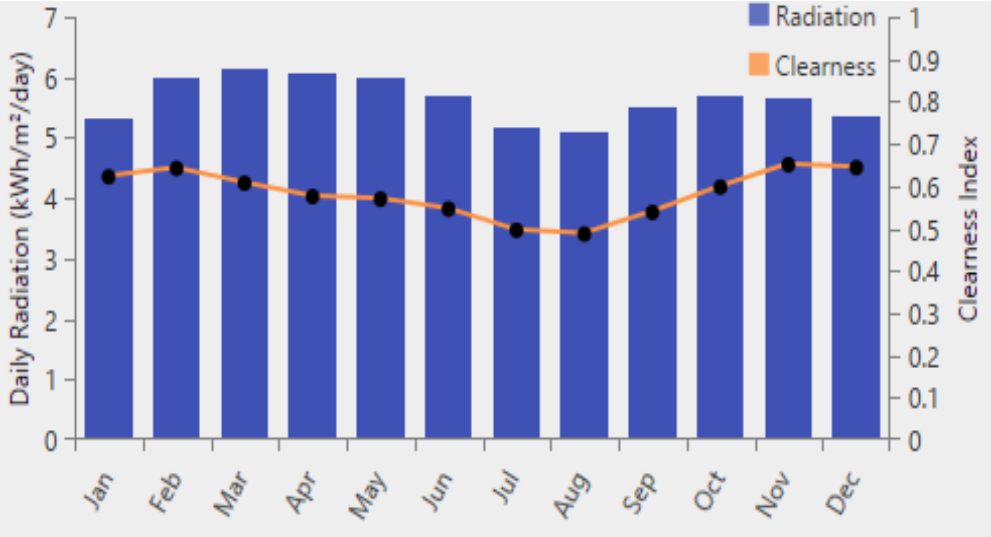


Burkina Faso Electricity Mix (2019)

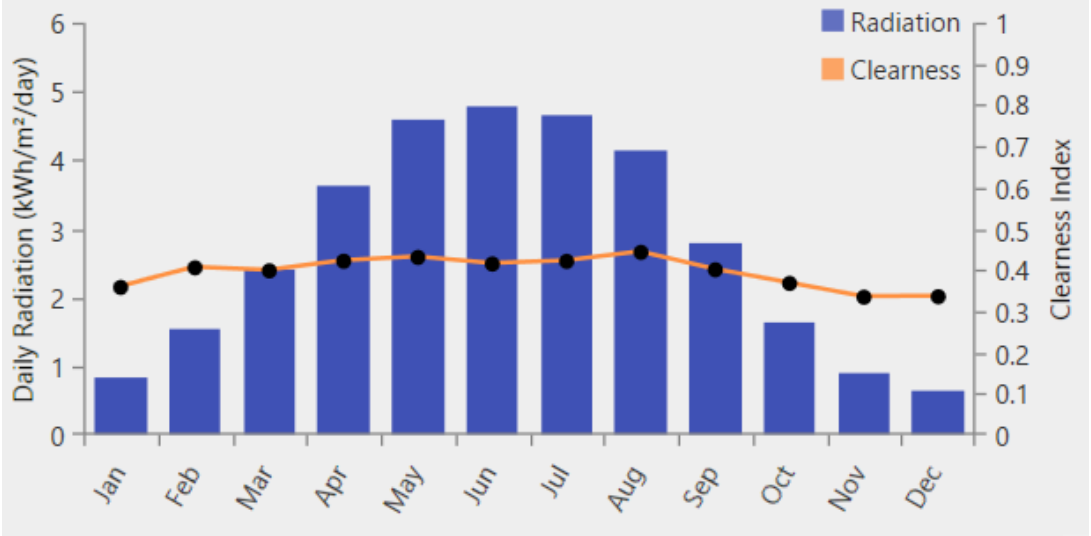


Distribution of Rural Communities according to size and distance from the grid (Source: Moner-Girona et. Al 2016)

Solar Potential Burkina Faso



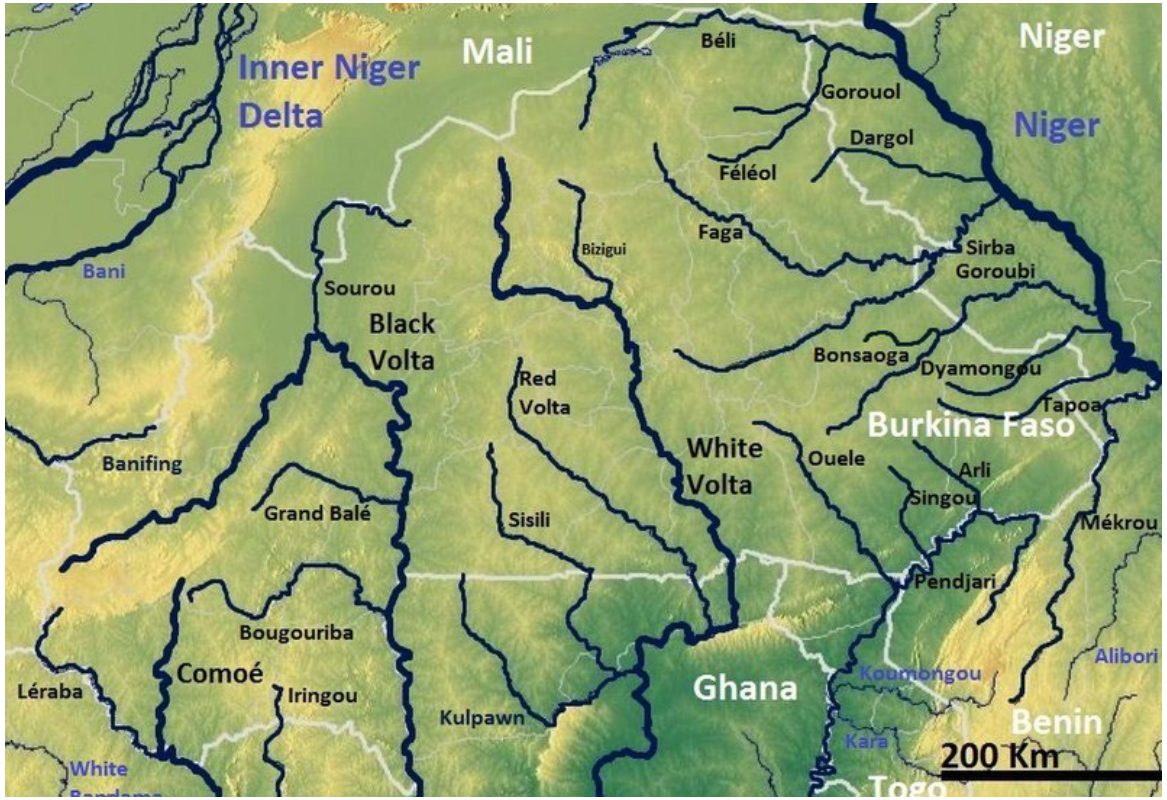
Monthly Daily Average Solar Radiation and Clearness Index for Ouagadougou



Monthly Daily Average Solar Radiation and Clearness Index for Berlin

Hydro Potential

- Existing large hydro capacity: 32 MW
- Hydro potential in the country :138 MW (Source: UN WSHPDR 2016)

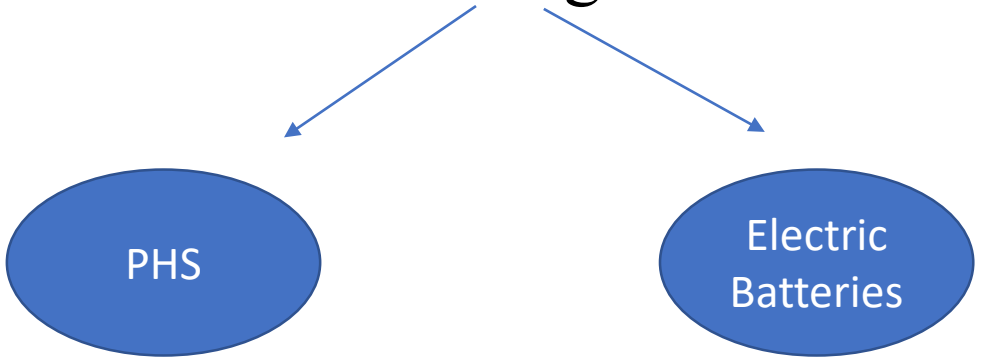


Rivers in Burkina Faso (Source: maps-for-free.com)

Research Objective

Asses the techno-economic feasibility of solar PV with storage in Burkina Faso for:

- Off grid rural system
- Grid connected urban system



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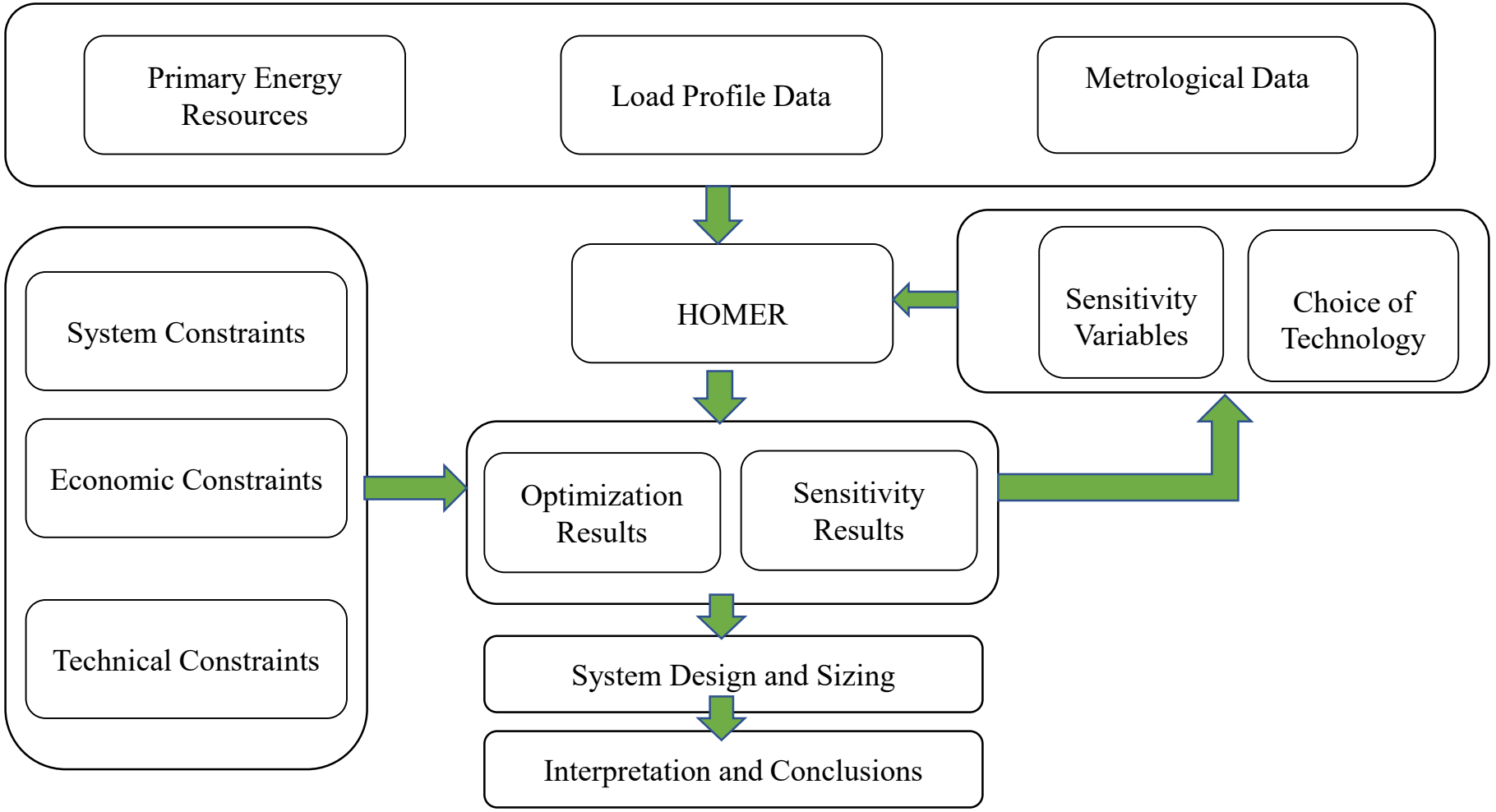
Methodology



Load Profile Assessment

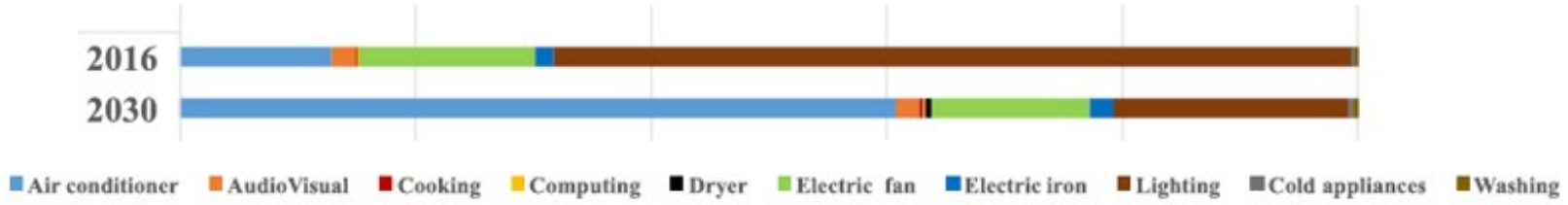
Rural Load Profile

- Residential Load
- Non-Residential Load

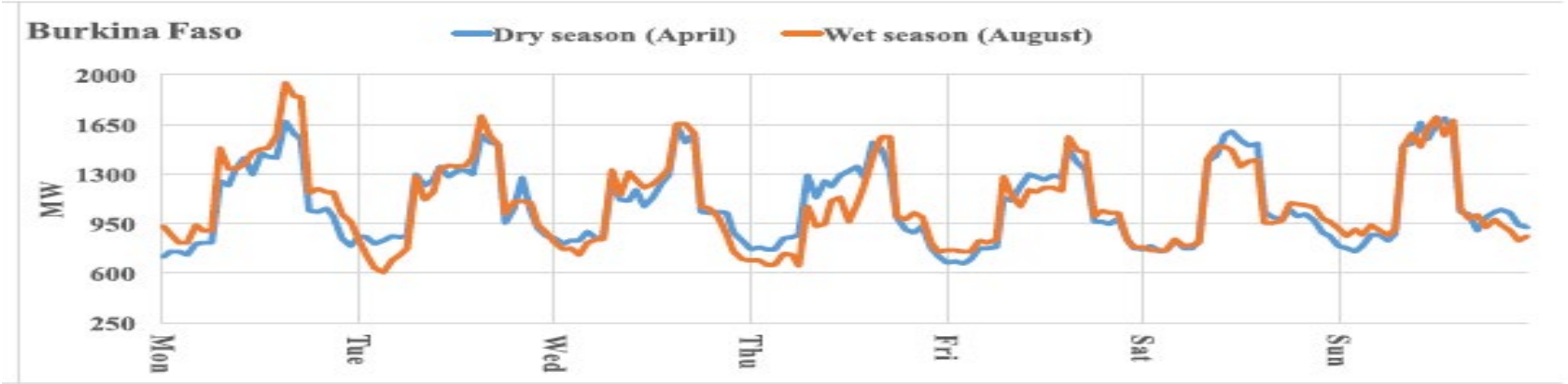
Urban Load Profile

- Residential Load
- Non-Residential Load

Load Assessment: Key Assumptions



Residential Electricity Consumption in Burkina Faso (Source: Adeoye et al)

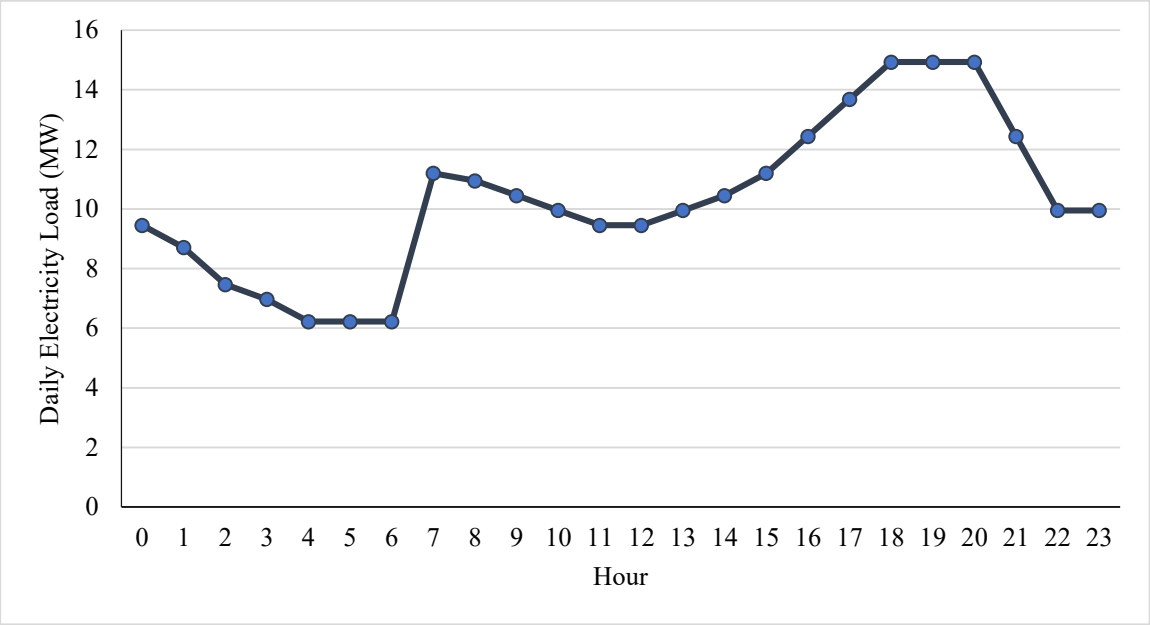


Seasonal Variation of Electricity Consumption in Burkina Faso (Source: Adeoye et al)

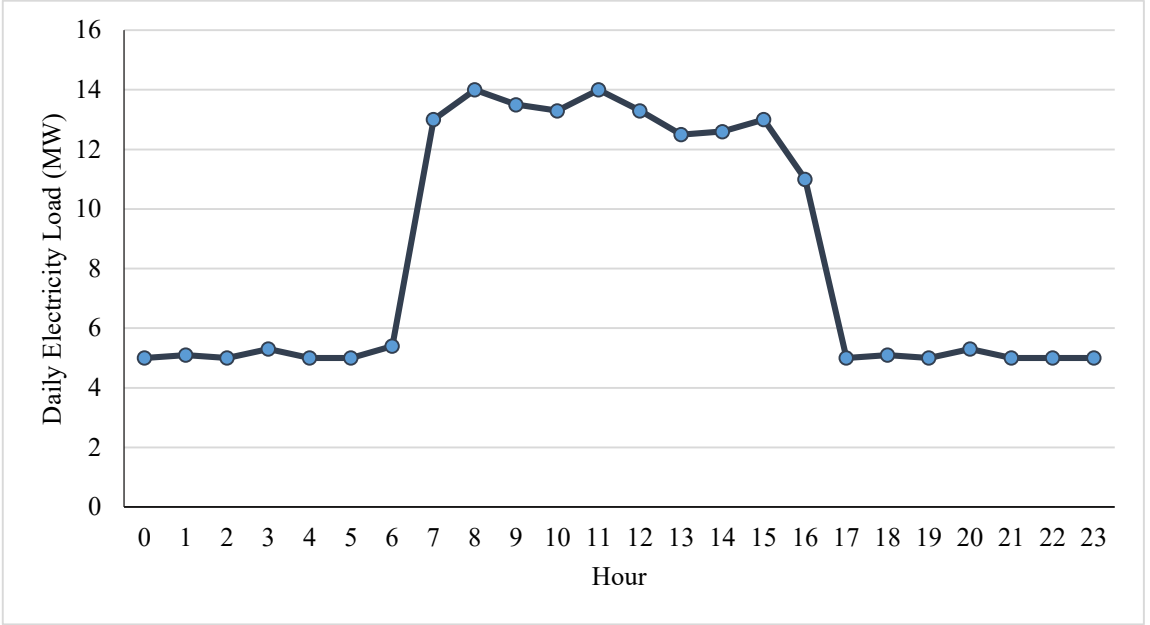
Load Assessment: Key Assumptions

General Parameters	Values-Assumptions
Urban Population (Ouagadougou)	2.2 million
Rural Population (Sabou)	45,000
Number of inhabitants (per household)	5 in urban areas 7 in rural areas
Daily energy consumption pattern for households	1/3 energy consumed during daytime and 2/3 during evening and night
Daily energy consumption pattern for non-residential	1/3 energy consumed during evenings and 2/3 during the day
Electricity consumption per capita (residential)	40-45 kWh per year

Load Assessment: Urban Profile

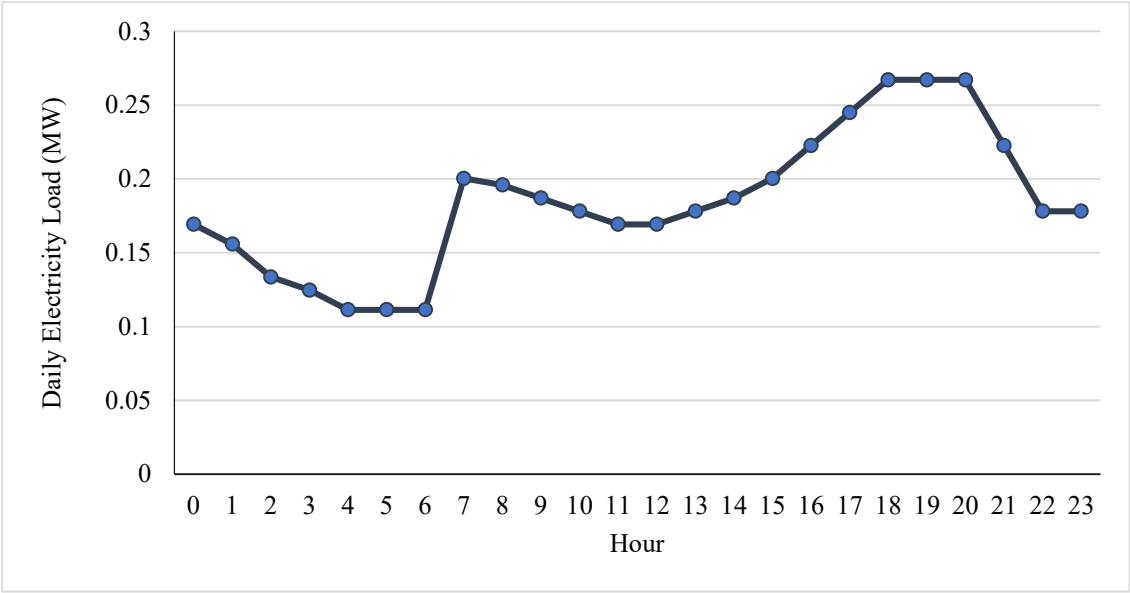


Burkina Faso: Residential Urban Profile

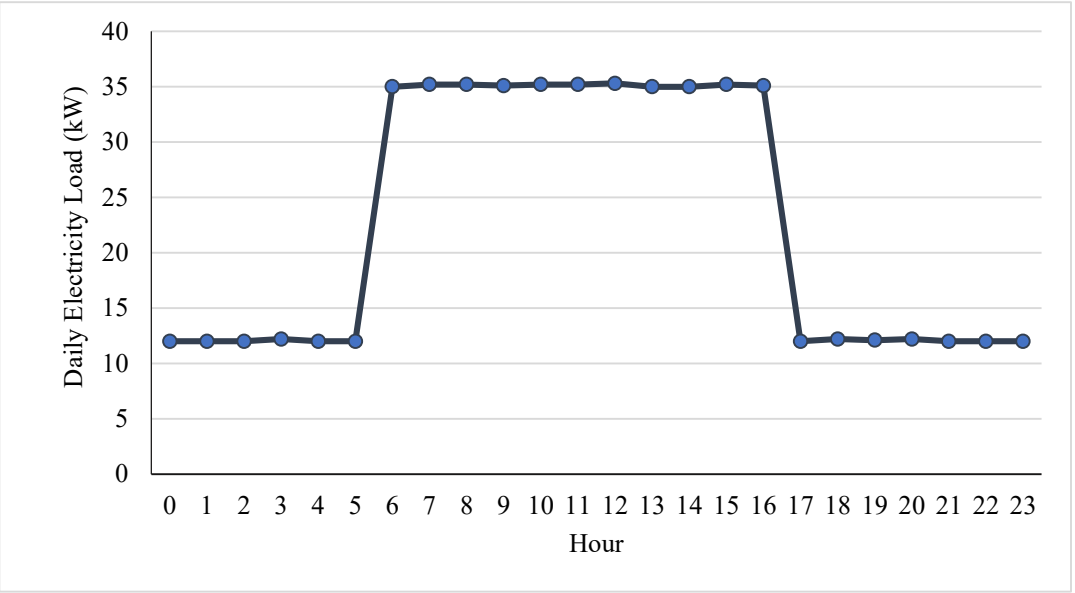


Burkina Faso: Non-Residential Urban Profile

Load Assessment: Rural Profile



Burkina Faso: Residential Rural Profile



Burkina Faso: Non Residential Rural Profile

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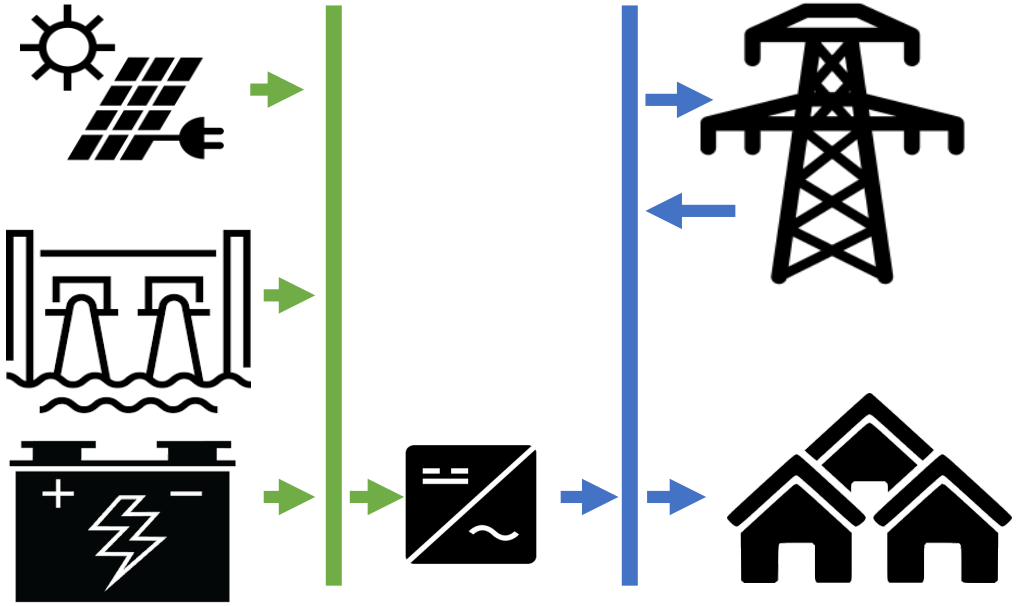
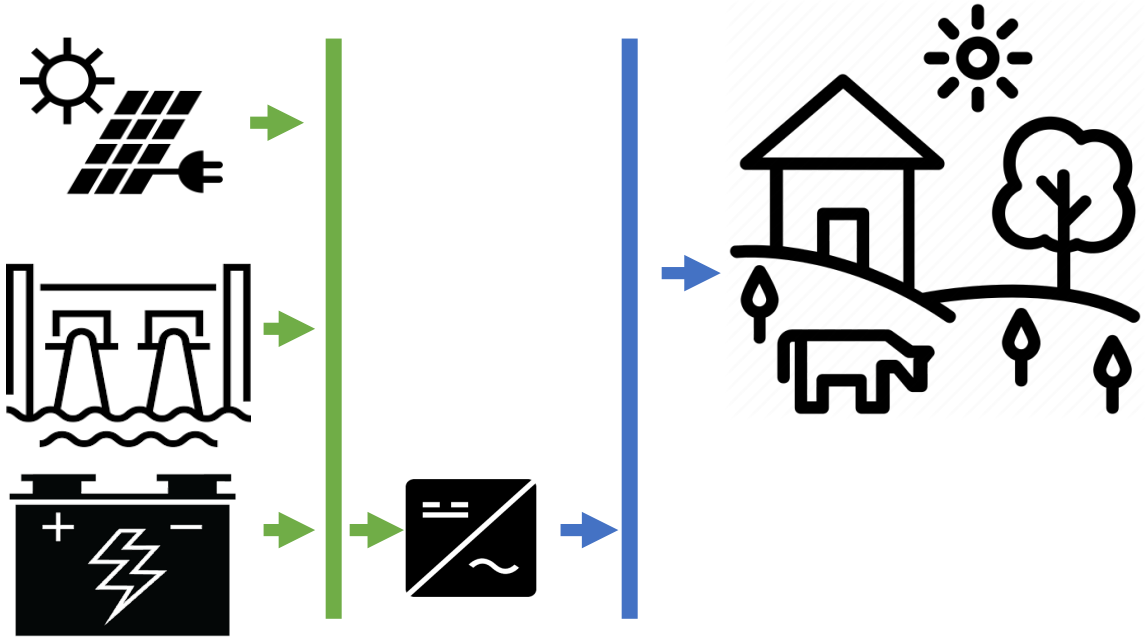
System Architecture

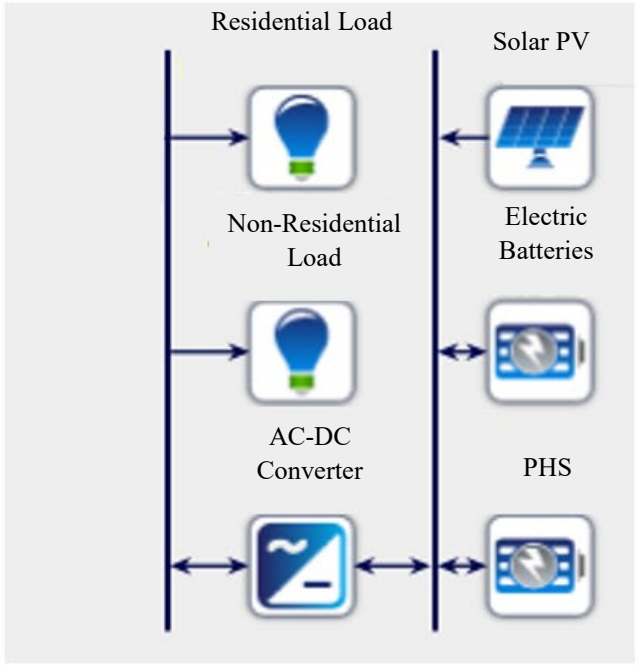


Grid Connected Urban System Architecture

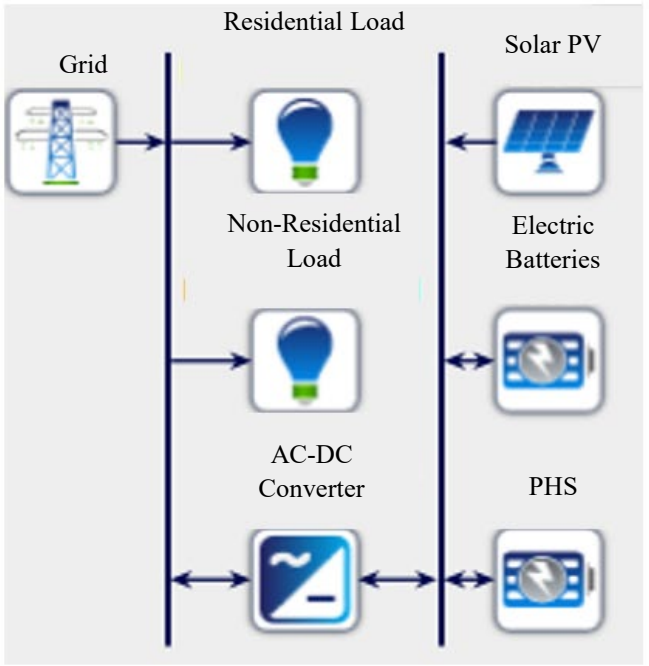


Off Grid Rural System Architecture

System Architecture



Off- Grid System (HOMER)



Grid Connected System (HOMER)

Solar PV

Parameter	Value	Unit
Capex	850-2000	€/kW
Replacement Cost	850-1500	€/kW
Lifetime	25	years
Operation and Maintenance Cost	10	€/kW/year

Economic Parameters for Monocrystalline PV System: Source Lazard's LCOE, 2018

Electric Batteries

Parameter	Value	Unit
Capex – Generic Li Ion	200	€/kWh
Replacement Cost	200	€/kWh
O & M Cost	50	€/kW/year
Lifetime	10	years
Efficiency	90	%

Economic Parameters for 100 kWh Li Ion Electric Storage: Source Lazard's LCOE, 2018

Pumped Hydro Storage

Parameter	Value	Unit
Capex	800-1200	€/kW
Replacement Cost	600-800	€/kW
O and M Cost	40	€/kW/year
Lifetime	25	years
Efficiency	81	%

Economic Parameters for Generic 245 kWh PHS System: Source ESA, 2015

Effective head: 100 m

Discharge time: 12 hours

Time to fill reservoir : 14 hours

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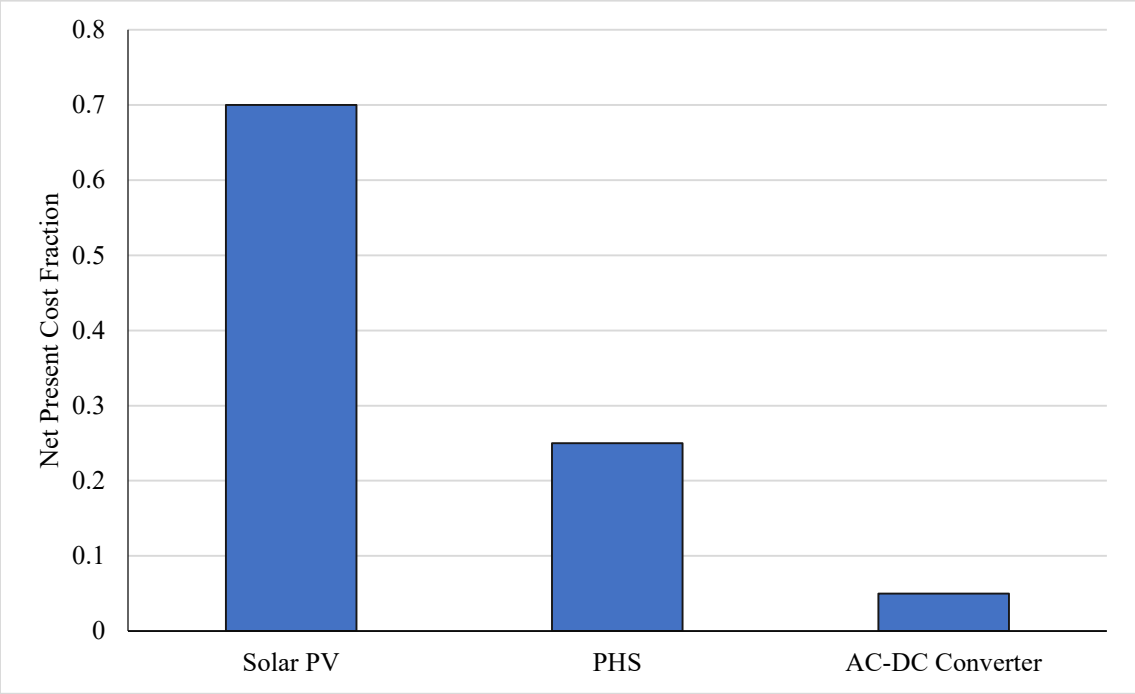
Results: Off grid

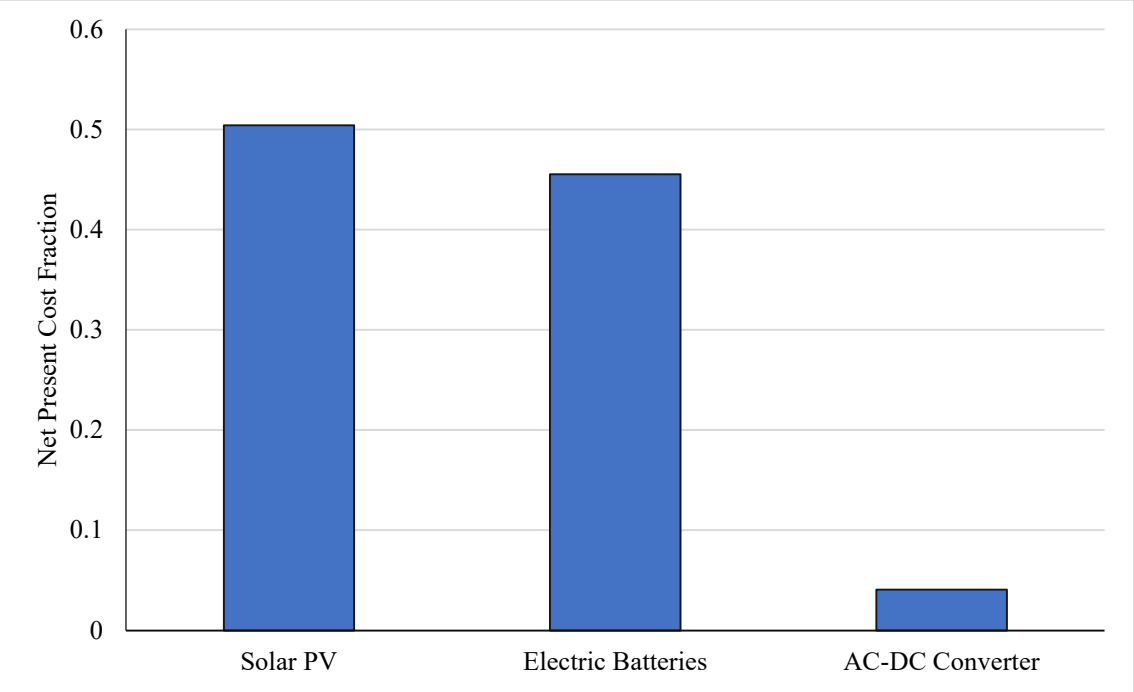
Result Specification	Parameter	Unit	Category 1 (PV+PHS)	Category 2 (PV+ Electric Batteries)
System Architecture	PV	MW	1.6	2.2
	PHS	MW	1.4	0
	Electric Batteries	MWh	0	14.9
	AC-DC Converter	kW	523	906
Economic Specifications	NPC	€	6.15 Million	12.3 Million
	Capital Cost	€	5.54 Million	9.29 Million
	COE	€/kWh	0.25	0.4

Results off grid considering availability of reservoirs

Results: Off grid



*NPC Breakdown of Category 1 (PV plus PHS) **



*NPC Breakdown of Category 2 (PV plus Electric Batteries) **

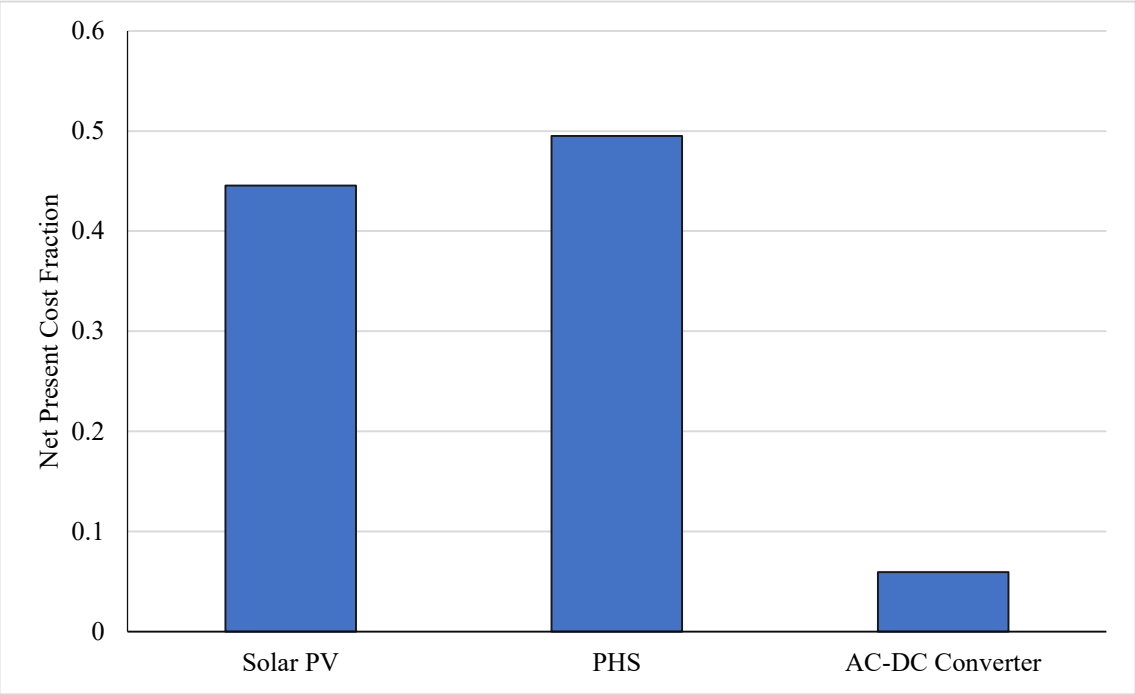
**Considering availability of reservoirs*

Results: Off grid

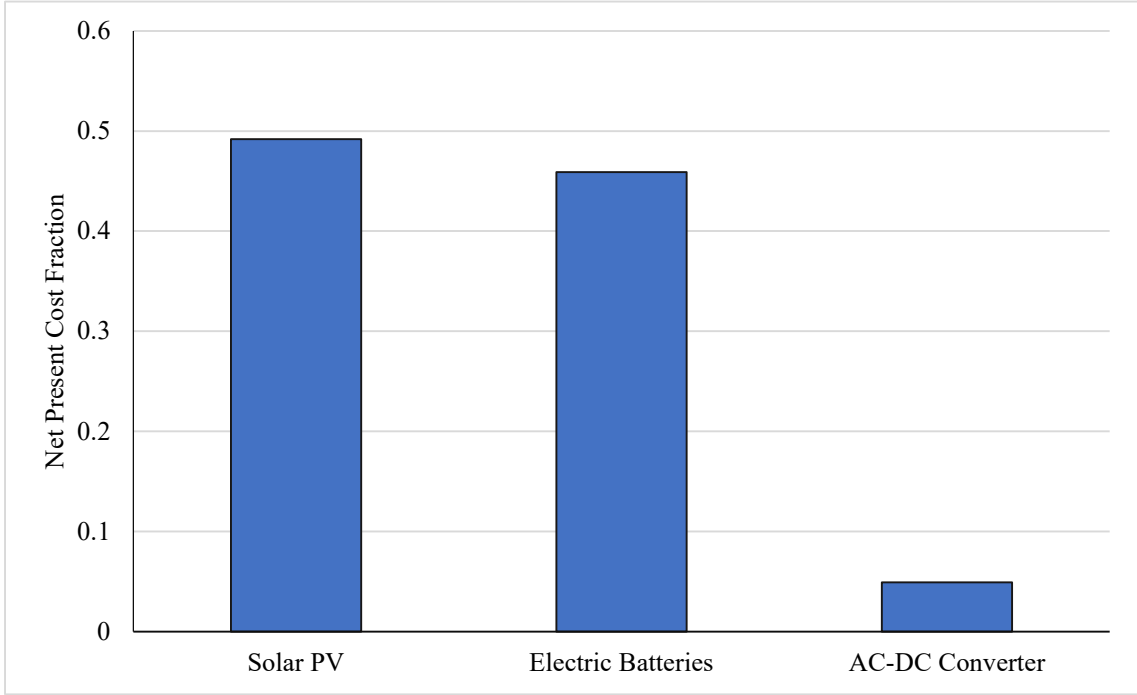
Result Specification	Parameter	Unit	Category 1 (PV+PHS)	Category 2 (PV+ Electric Batteries)
System Architecture	PV	MW	1.6	2.2
	PHS	MW	1.4	0
	Electric Batteries	MWh	0	14.9
	AC-DC Converter	kW	665	906
Economic Specifications	NPC	€	10.1 Million	12.3 Million
	Capital Cost	€	9.53 Million	9.29 Million
	COE	€/kWh	0.4	0.4

Results off grid Including Ádditional Costs of Excavation for Pumped Hydro Reservoirs

Results: Off grid



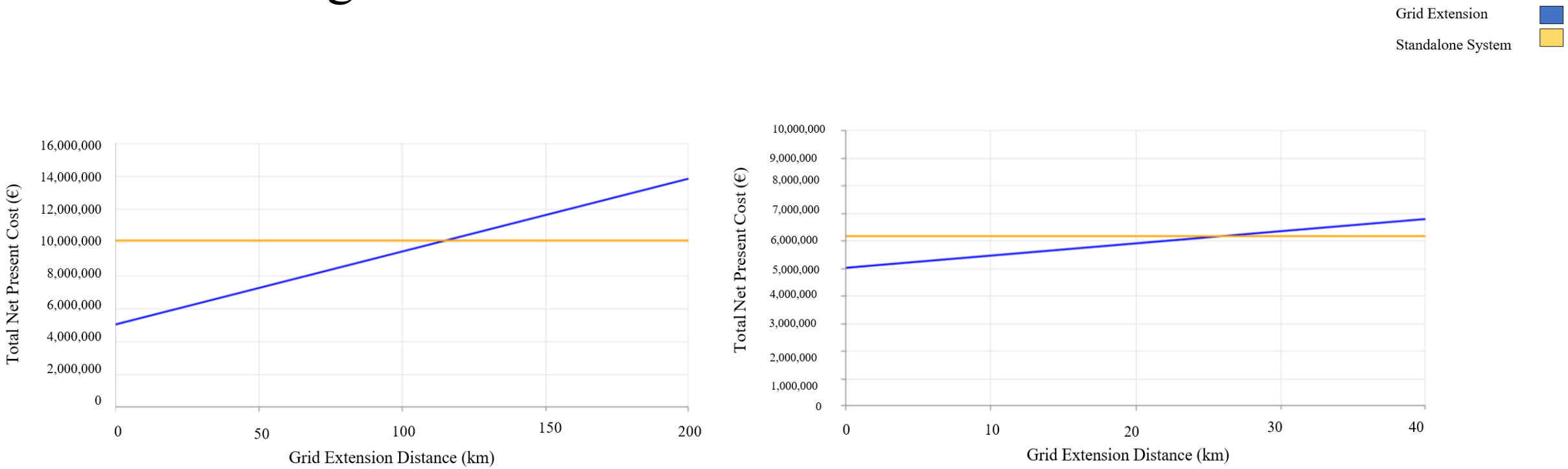
*NPC Breakdown of Category 1 (PV plus PHS)**



*NPC Breakdown of Category 2 (PV plus Electric Batteries)**

**Considering non-availability of reservoirs*

Results: Off grid

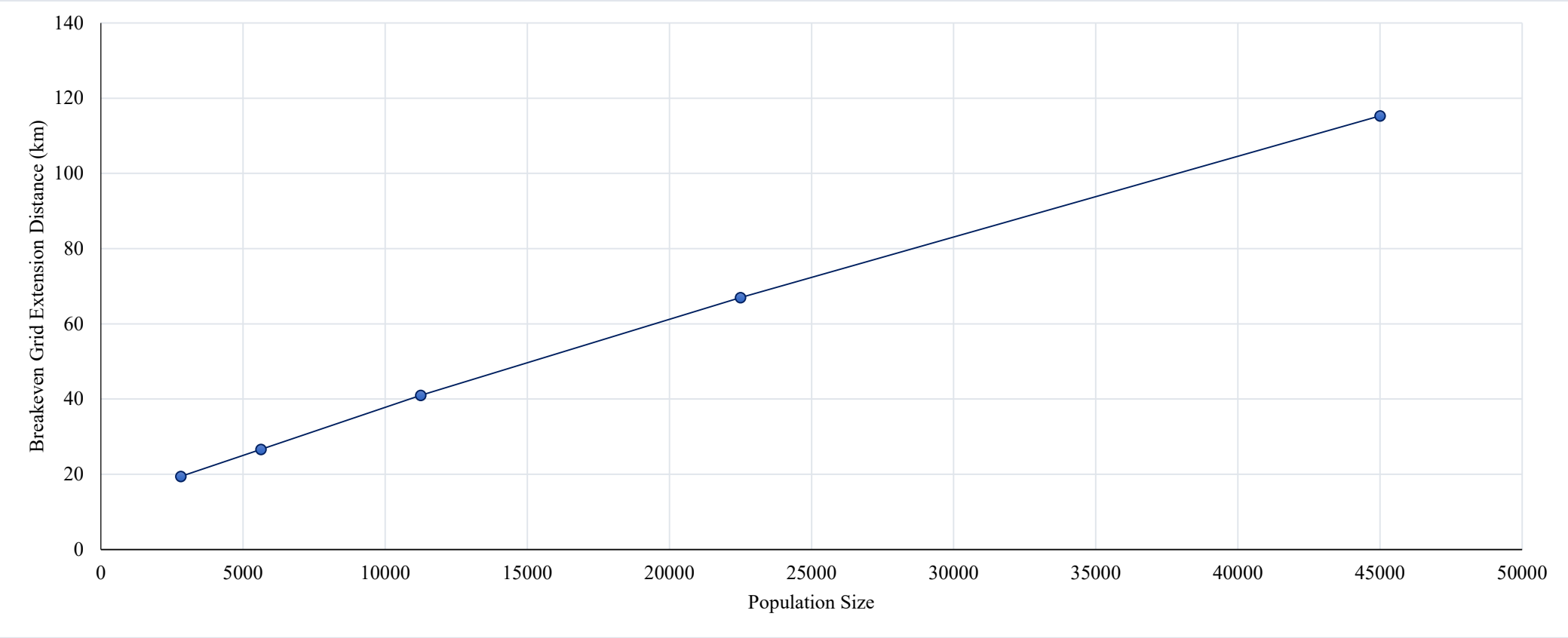


BGED for Solar PV plus PHS with Additional Costs of Excavation: 115 km *

BGED for Solar PV plus PHS without Additional Costs of Excavation: 26 km *

****Calculated for a population of 45000 people (Sabou village in Burkina Faso)***

Results: Off grid



Sensitivity Analysis of BGED with Population Size for PV plus PHS Considering Availability of Reservoirs

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Results: Grid Connected

Result Specifications	Parameter	Unit	Category 1 (PV+PHS + Grid)	Category 2 (PV + Grid)	Category 3 (Grid Only)
System Architecture	PV	MW	136	71	0
	PHS	MW	26.9	0	0
	Batteries Li-Ion	MWh	0	0	0
	AC-DC Converter	MW	29	29.4	0
Economic Specifications	NPC	€	323 Million	352 Million	471 Million
	Capital Cost	€	236 Million	80 Million	0
	COE	€/kWh	0.129	0.1	0.2
	Renewable Fraction	%	88.3	48.6	0
	Grid Purchases	GWh	20	92	167

Results Grid Connected System Architecture

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Conclusion

- PV + storage (PHS) better suited for rural electrification than grid connected systems
- Batteries remain an expensive option for utility scale systems as compared to PHS
- Driving down capital cost of PVs could have a significant impact on NPC and could accelerate electrification in the region
- Following suggestions may help achieve universal electrification:
    - In house PV production
    - Subsidies for solar PV
    - Rapid effective unbundling of energy sector

Thank You

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