ASIA CLEAN ENERGY FORUM 2017
THE FUTURE IS HERE: ACHIEVING UNIVERSAL ACCESS AND CLIMATE TARGETS
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HIGH RENEWABLE ENERGY PENETRATION IN AN ISLAND

FEASIBILITY STUDY OF HURRA ISLAND IN MALDIVES

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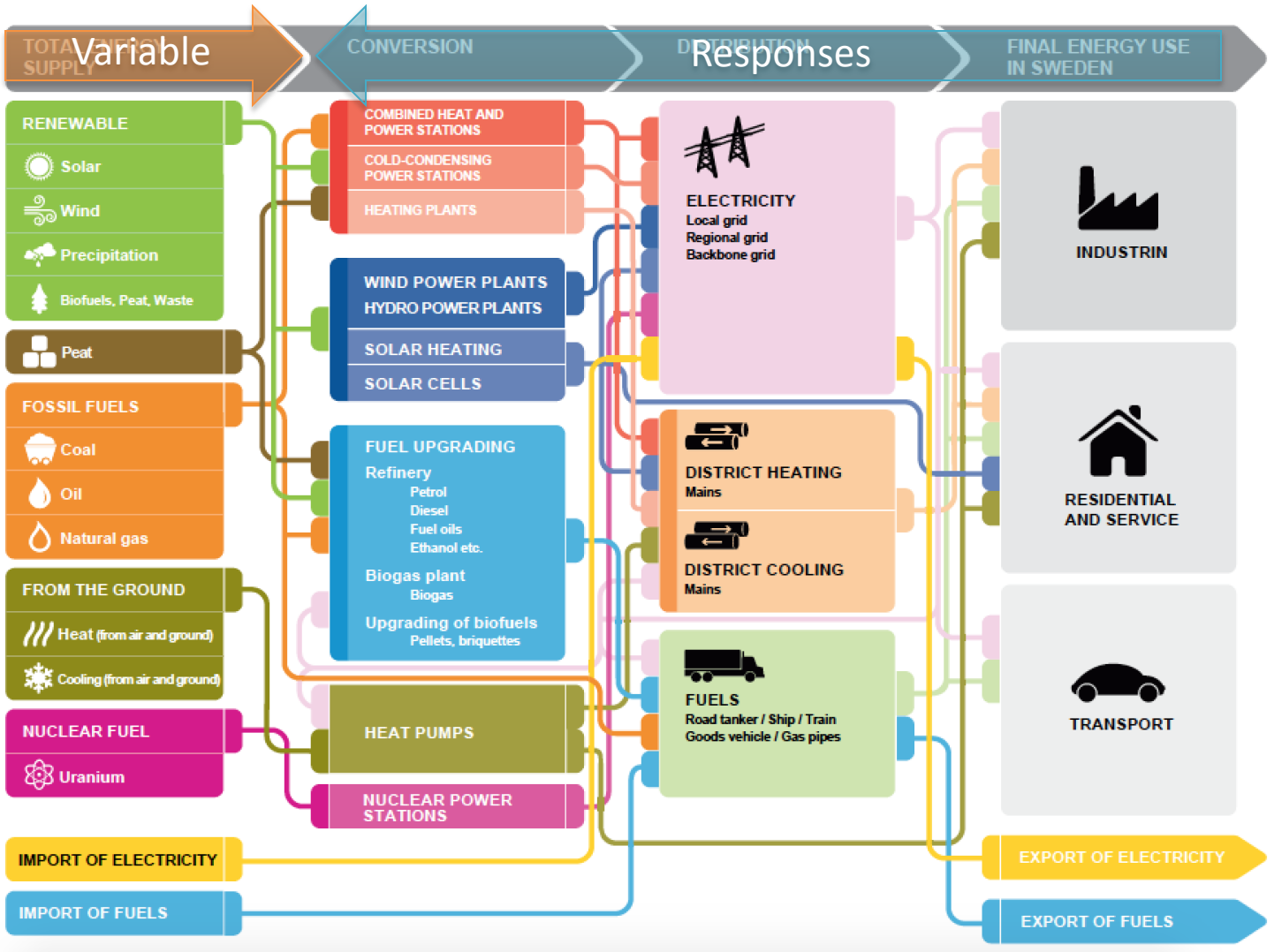
International Conference on Applied Energy

Clean Energy Systems: 3D+?

Resources ➔ Generation ➔ Distribution ➔ End uses

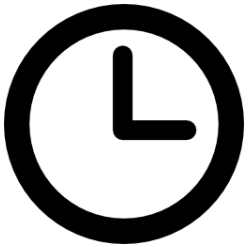
International Conference on Applied Energy

Transitions of energy systems



Energy Systems: 3D+

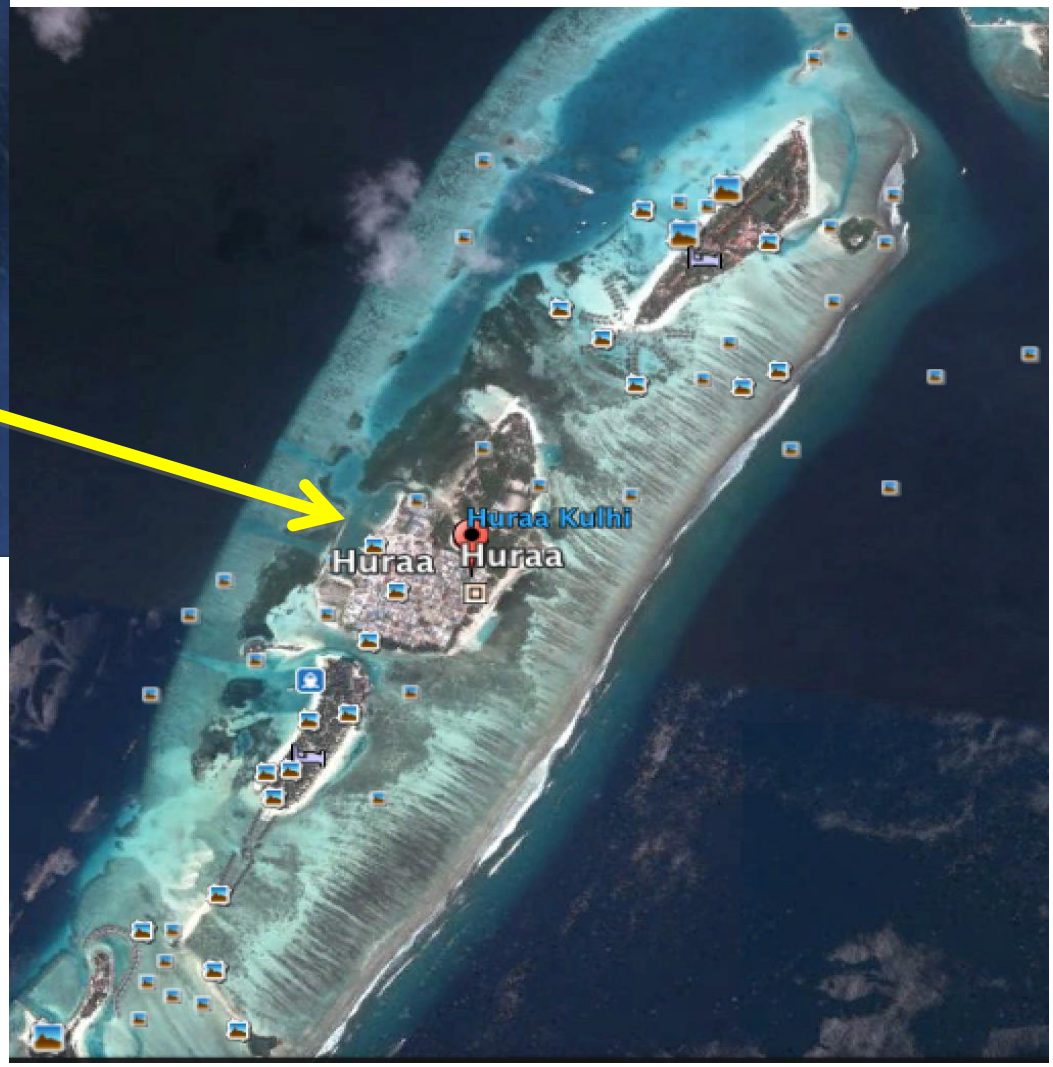
Space

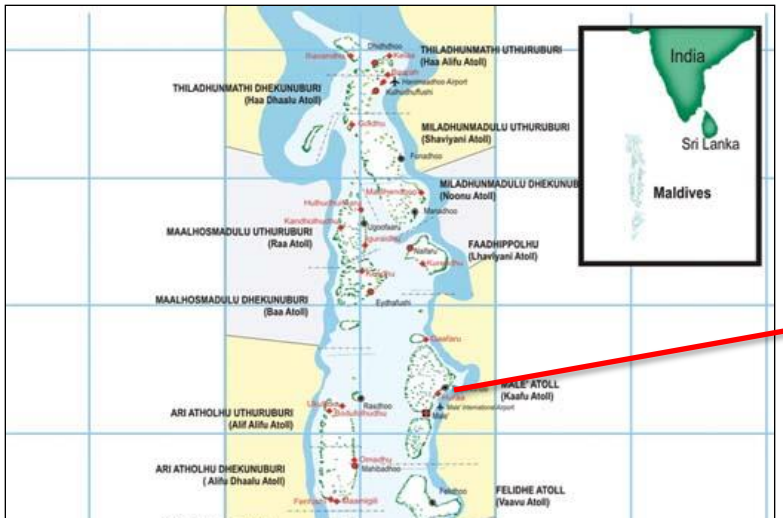


Time

Human

Island System: Maldives

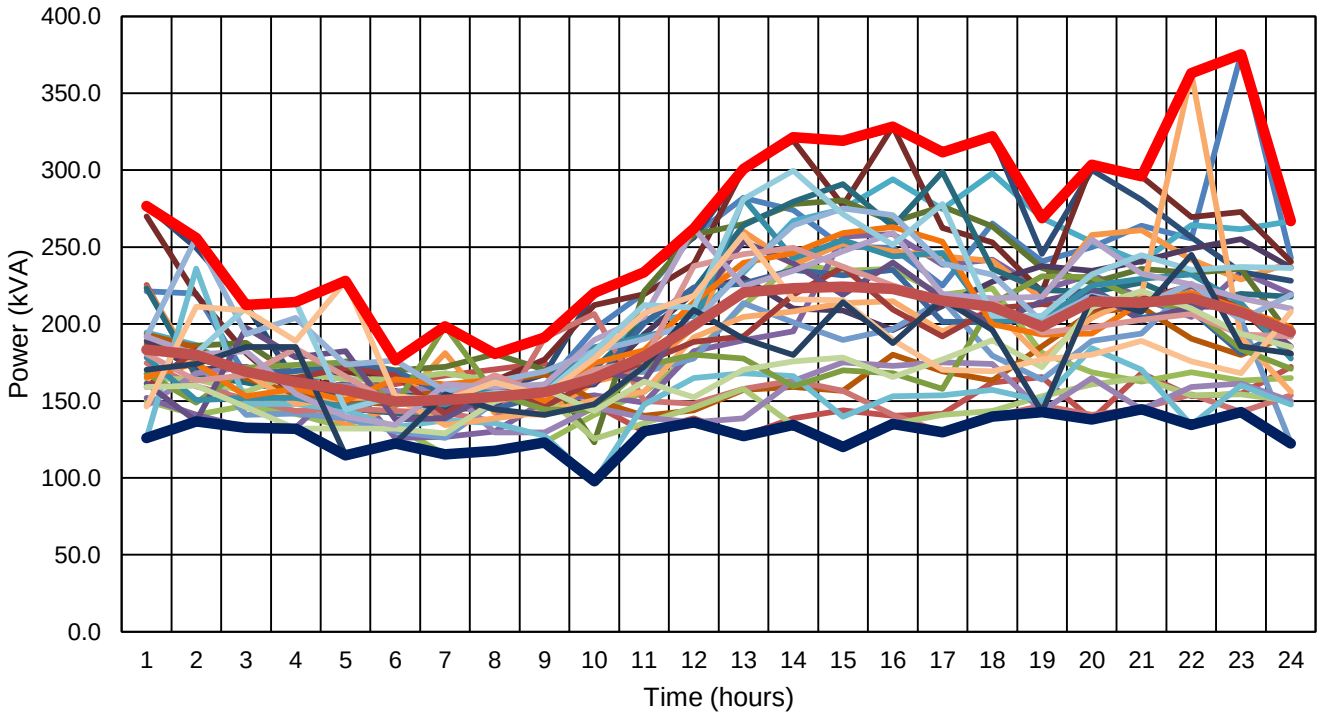




Summary of Existing Features on Huraa Island

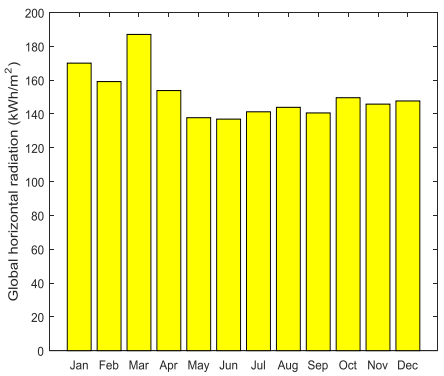
Parameter	Details
Atoll /Locality	Kaafu Atoll – North Male Atoll
Island	Huraa
Geographical Location	4°20'19" N; 73°36'63" E
Total Land Area (km^2)	0.3
Population	1142 (registered) *This figure does not include 2000-2500 resort workers.*
Number of Households	200
Distance from Male (km)	19.1
Distance from nearest Airport (Km)	17.9
Electricity Provide	Local community

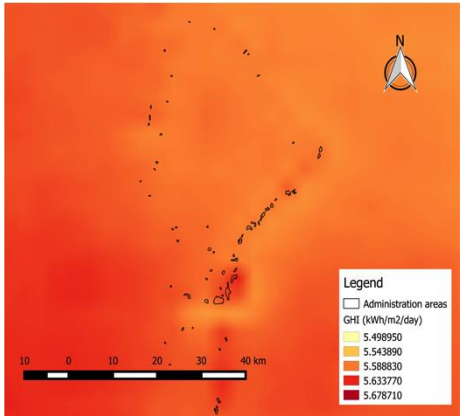
Electricity Profile based on the Power House data



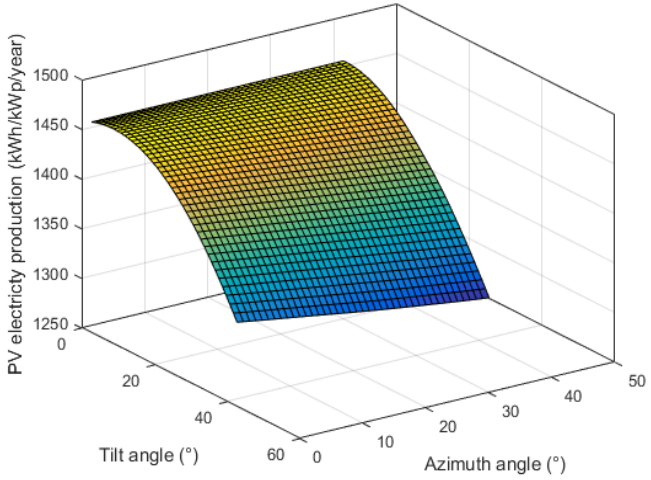
Production (Load) profiles gathered during the field survey and referring to July 2016 (red tick line: highest hourly production profile; blue tick line: lowest hourly production profile; orange tick line: average hourly production profile).

Annual photovoltaic potential from Meteonorm



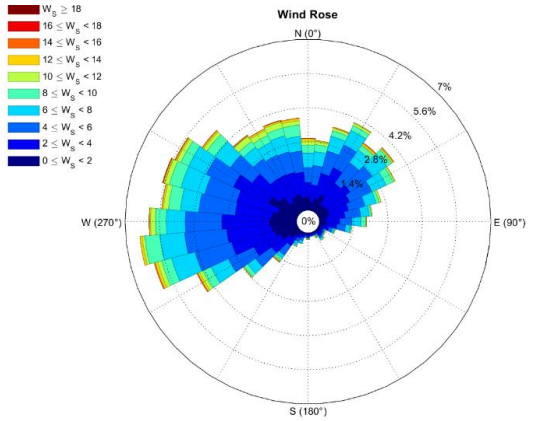


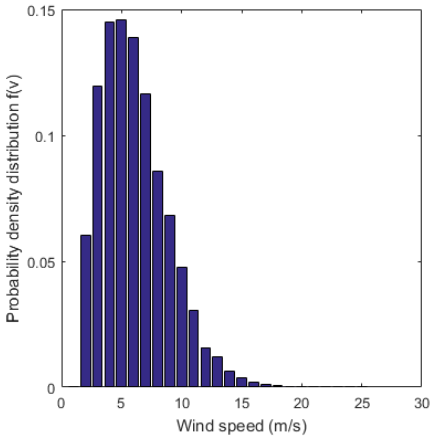
The pattern of solar irradiation is stable at about 140 kWh/m^2

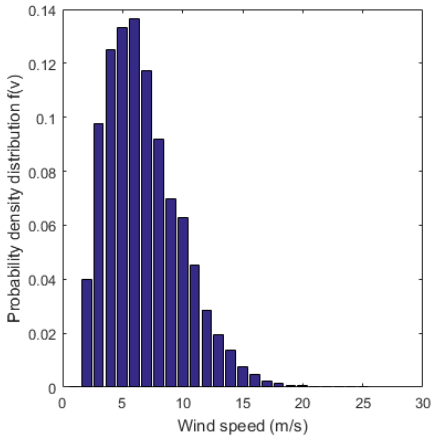


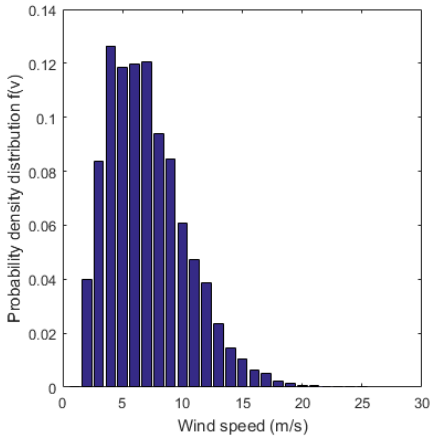
PV electricity production is in the range of 1.45-1.30 kWh/kWp.

Wind potential from Meteonorm



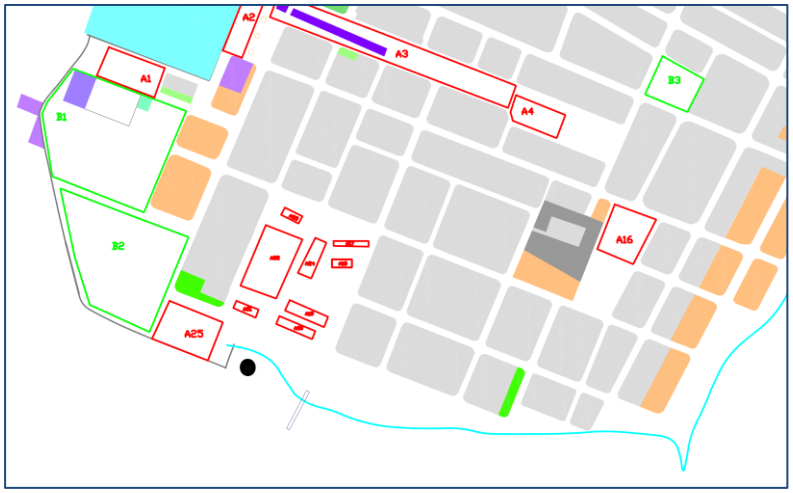






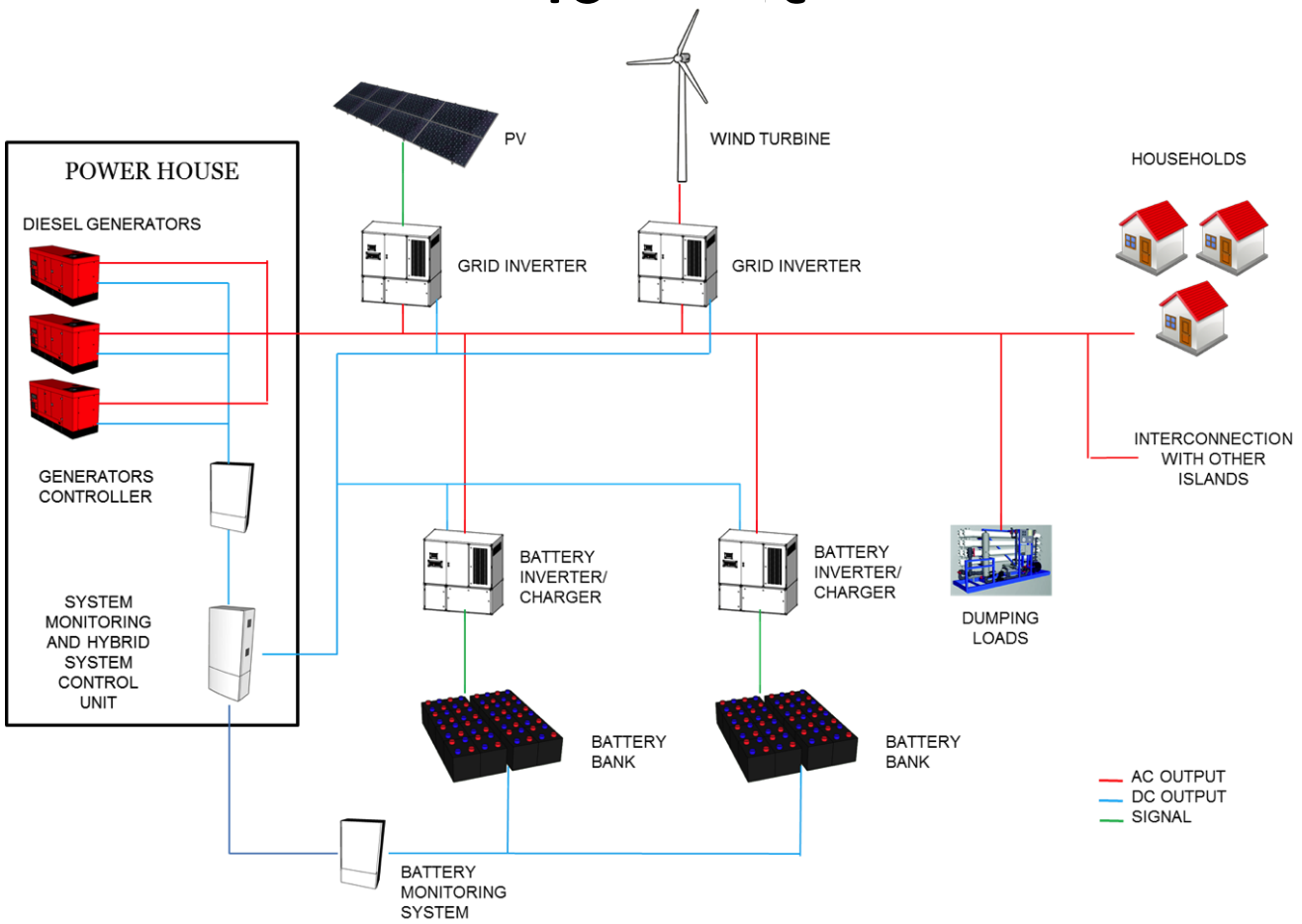
The theoretical wind energy content is 1180 kWh/m^2 swept area/year at 10 m, 1755 kWh/m^2 swept area/year at 30 m, and 2070 kWh/m^2 swept area/year at 50 m above the ground.

Location for the installation of renewable energy



- Category “A”: potential sites already available:
  1.3 ha that corresponds to ca 1.9 MW_p of PV installation considering PV modules with rated efficiency of 15%.
- Category “B”: potential sites that need to be highly modified or there are potential pending projects:
  1.3 MW_p
- Category “C”: future potential sites that can be exploited using solar floating PV technology or after land reclamation

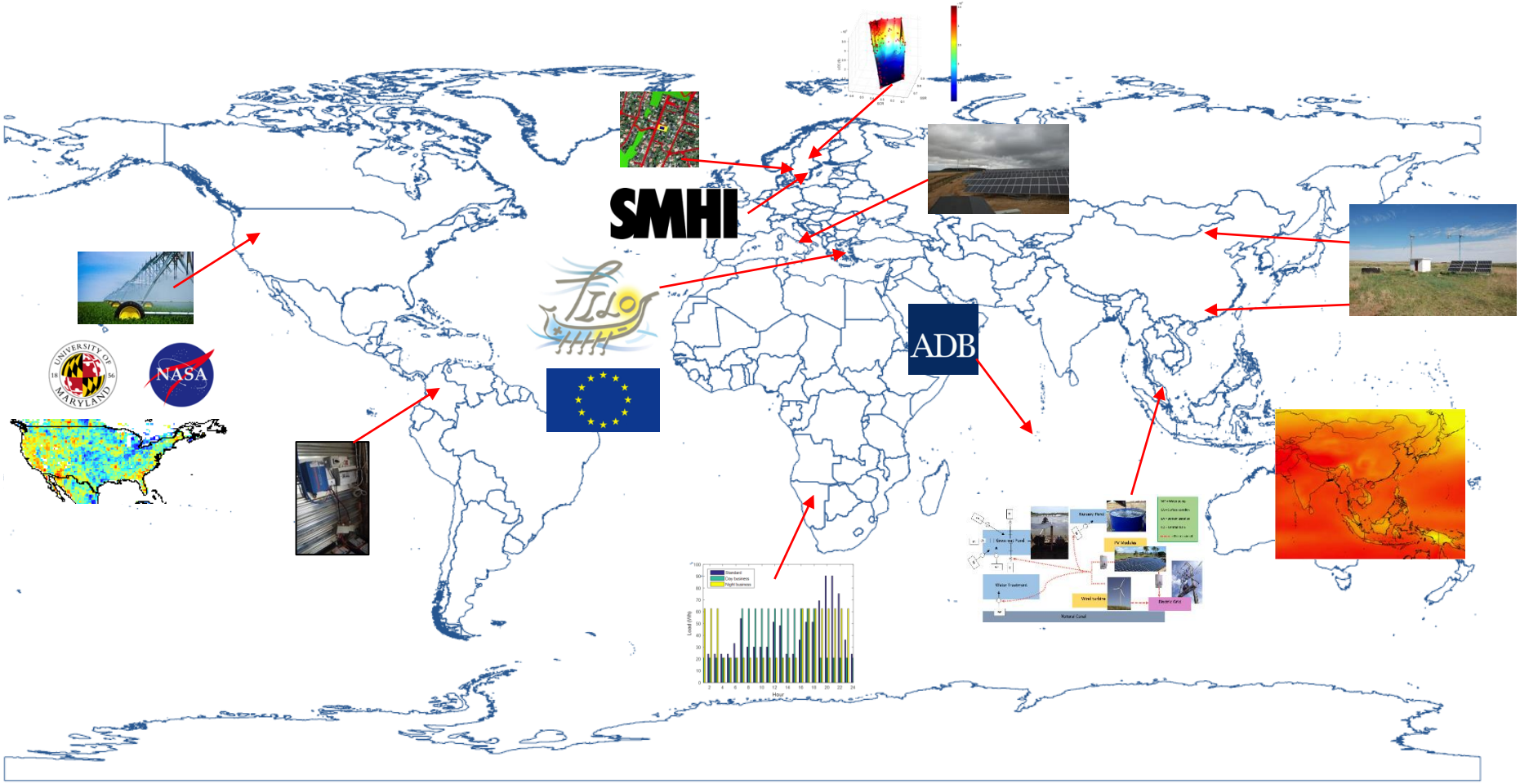
Schematic diagram of the PV/wind/battery/diesel generator layout



Optimization tool OptiCE

PTI•CE

Open-source code for modelling and optimization of clean energy technologies



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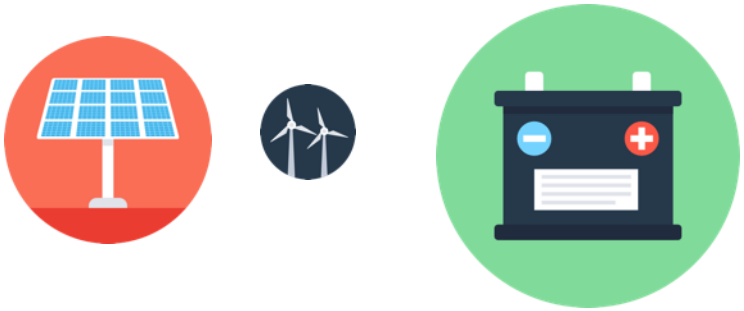
System integration

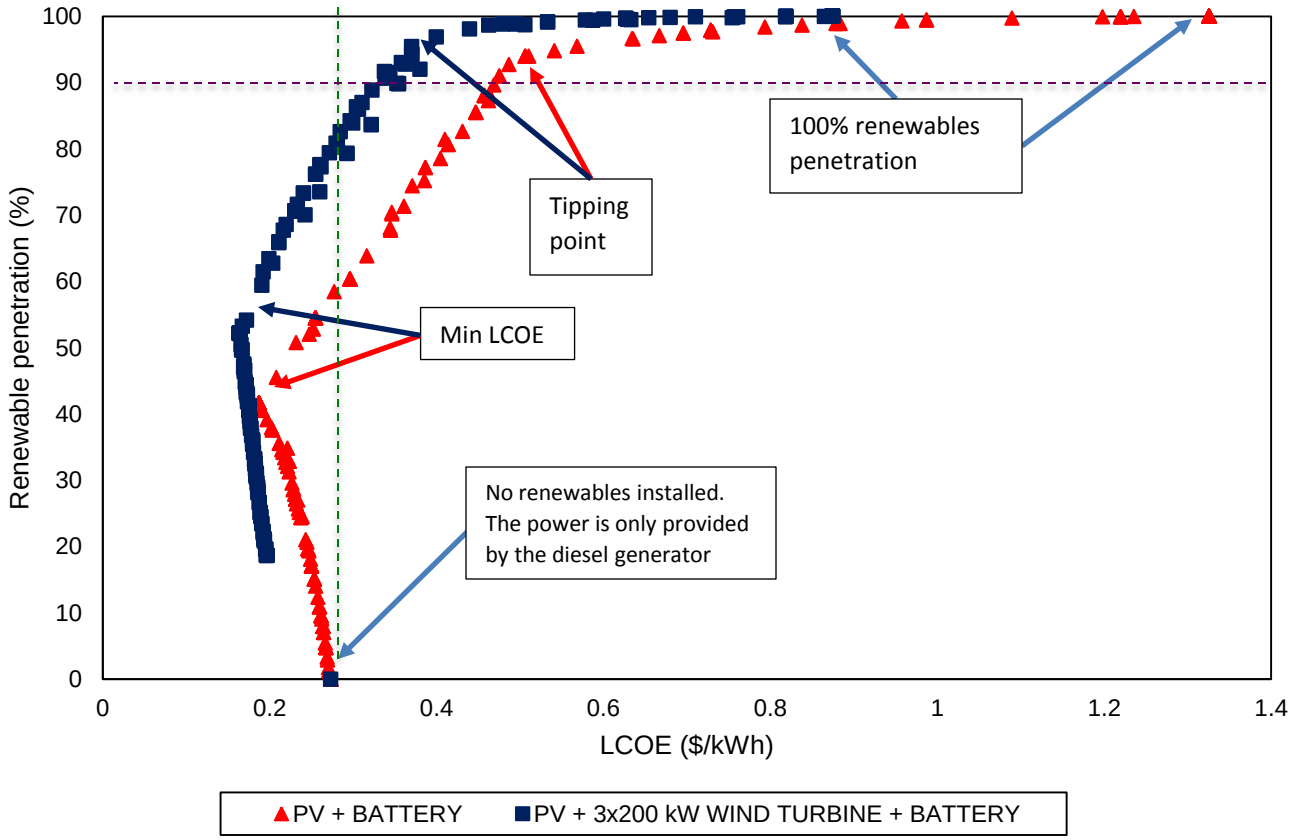
1. Cost-effective: Solar alone: 30-40%

2. Moderate: Solar + wind + storage: 30-70%

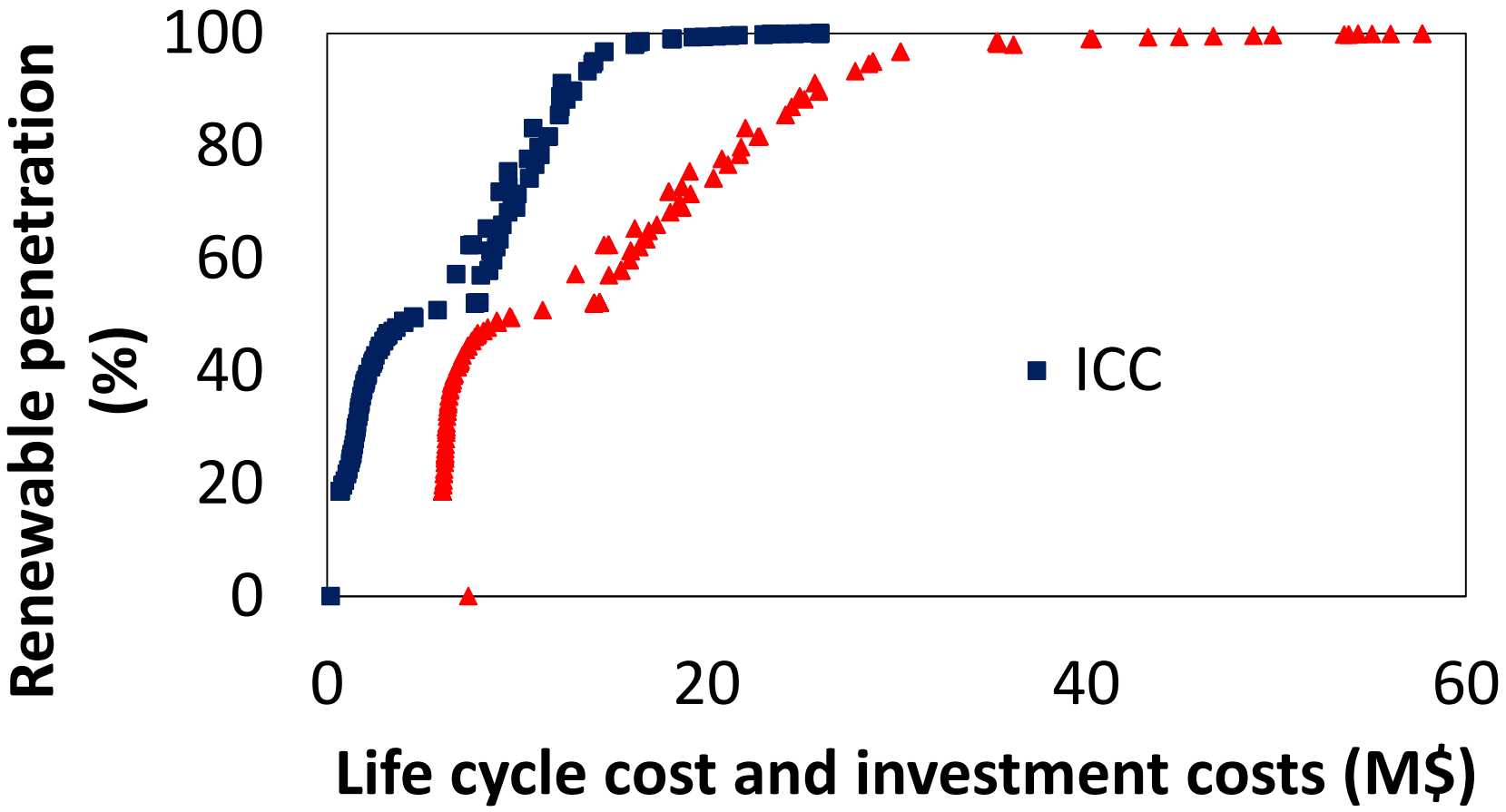
3. High RE penetration >90%



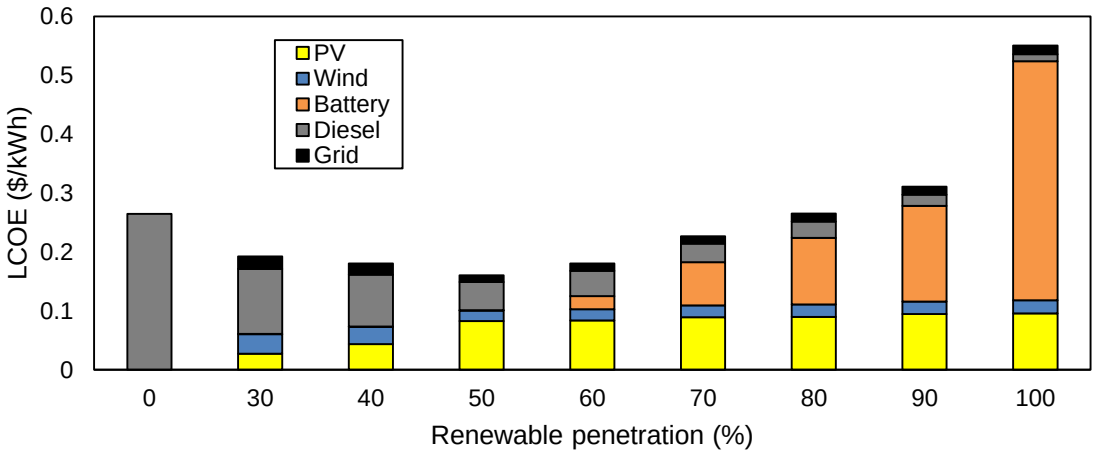
LCOE vs RE Penetration



LCC vs RE penetration



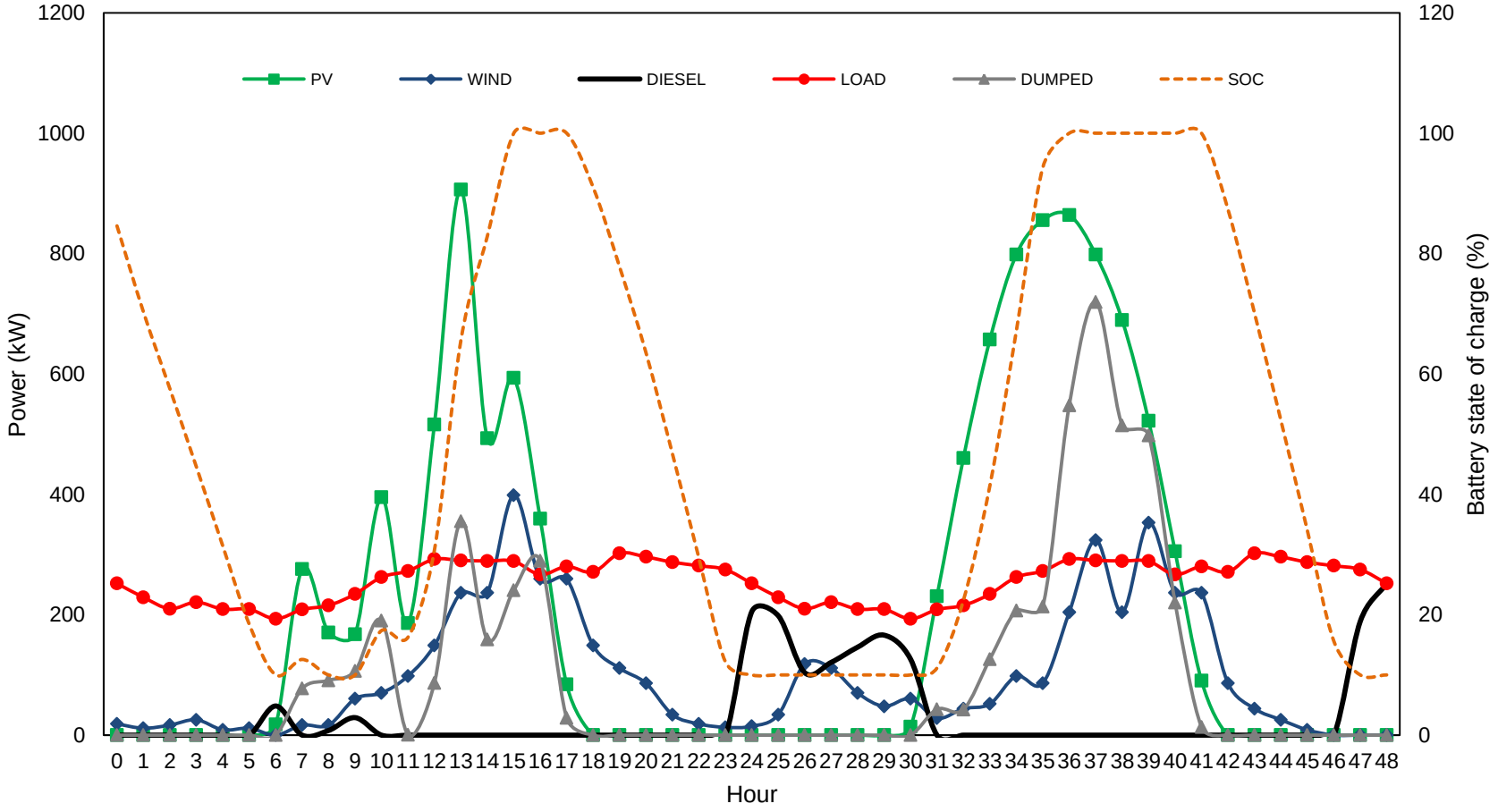
LCOE breakdown of components



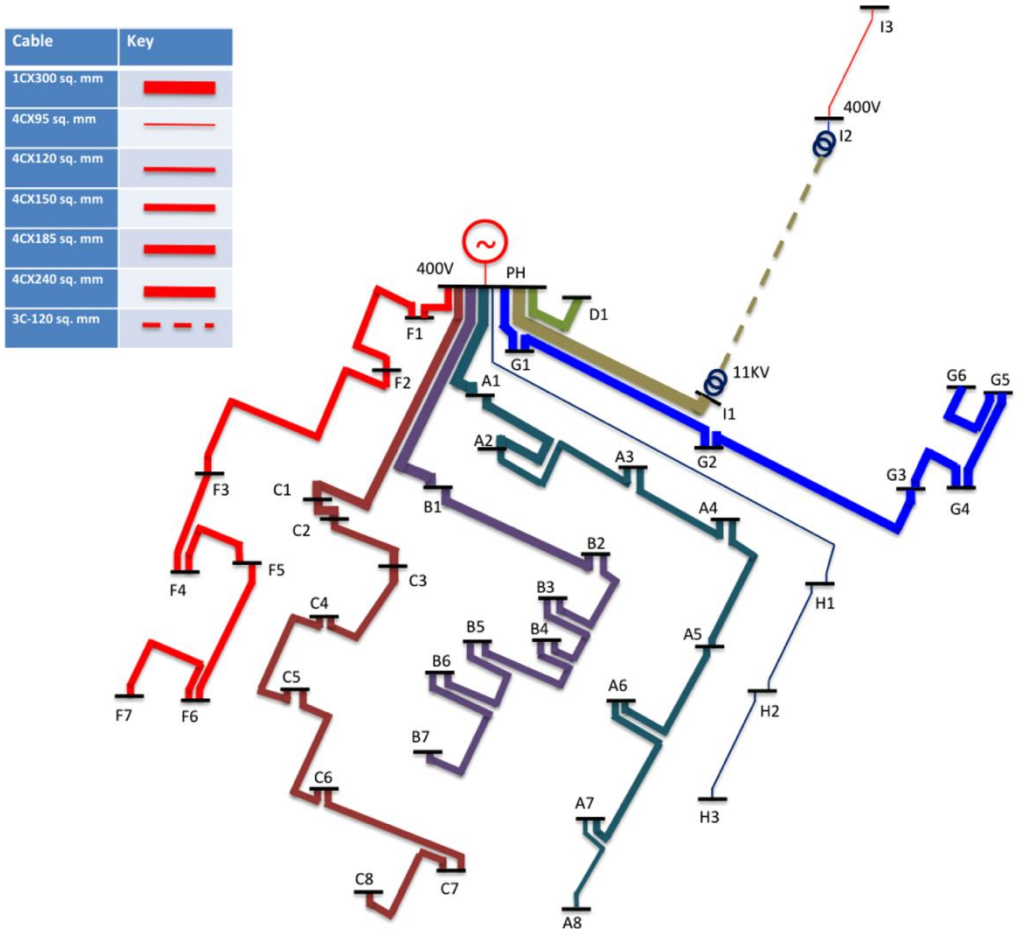
Scenario S1: PV/wind turbine/battery

Renewables penetration (%)	30	40	50	60	70	80	90	100
Diesel (kW)	400	400	400	400	400	400	400	400
PV (kW_p)	350	610	1700	1700	1800	1800	1800	1800
Battery (kWh)	-	-	-	950	1800	2600	3800	8500
CO_2 emission (tonne/year)	1129	993	853	706	452	325	164	0
Dumped energy (MWh)	642	915	2670	2380	2150	1780	1720	1440
ICC (M$)	2.18	2.71	5.28	5.60	6.80	7.20	8.35	12.45
LCC (M$)	6.10	6.40	9.26	9.90	12.10	13.13	15.41	25.81
LCOE ($/kWh)	0.192	0.180	0.160	0.180	0.226	0.264	0.310	0.550

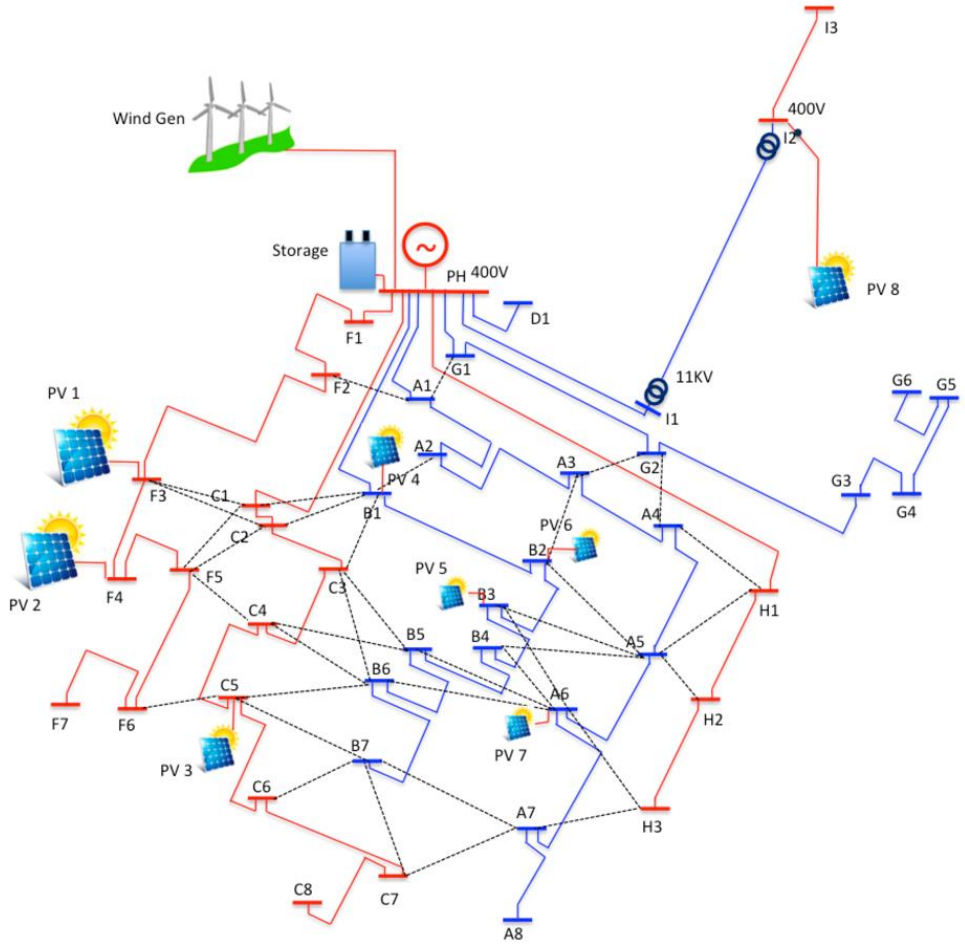
Dumping load?



CURRENT ELECTRICITY NETWORK



The potential locations of renewable generation sites and the possible new cables links between busbars



Smart multi-energy system

- A smart multi-energy is a group of interconnected loads and distributed energy resources in a defined geographic area that can connect and disconnect from the grid.
- This complexity of multi-energy system is characterized by their sophisticated use of advanced system controllers.
- The controller orchestrates the energy supply, which may come from several on-site energy sources, such as solar, wind, combined heat and power (CHP), energy storage and reciprocating engines, as well as from the central grid.
- It also integrates the end-users load control with different energy saving approaches.
- It is location specific and highly tailored to serve its customers' needs.

Issues

- Optimized market allocation – identification of markets where certain bids can have higher revenues
- Market price forecasts
- Flexibility forecast from technical units – novel forecasting techniques will be developed to cope with uncertainties of flexibility availability
- Management of uncertainties – reduce risks in the bidding process
- Energy storage flexibility assessment – defined developments to be able to assess the flexibility provision of storage facilities

Conclusions

- High penetration of renewable energy for an island is technical feasible
- 90% is better than 100%: Optimal solution is hybrid system of PV, wind and energy storage with renewable penetration between 50-90%
- Load management is important for handling dumping load: energy efficiency and increasing flexible industrial load.
- Tailor-made system with careful considerations of local conditions is critical.

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