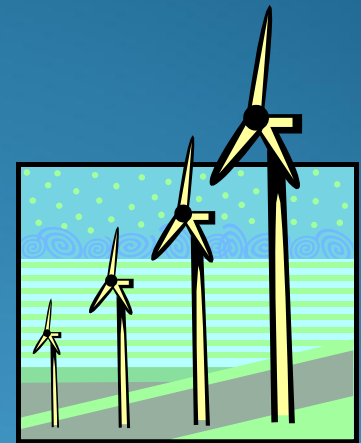


Sustainable Renewable Electricity for Small Islands: A Methodology for Essential Load Matching



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AEMS Lab
Advanced Energy and Material Systems

Engineering a Sustainable Energy System



Engineering Requirements



- Reliable Electricity Supply
- Environmentally Sensitive
- Manage Fossil Fuel Shortage and Reduction
- Remote Island Power System: **Maldives**

Particular Concerns

- Current reliance on diesel generators
- Diesel price spikes
- Diesel shortages
- Power system shut-downs

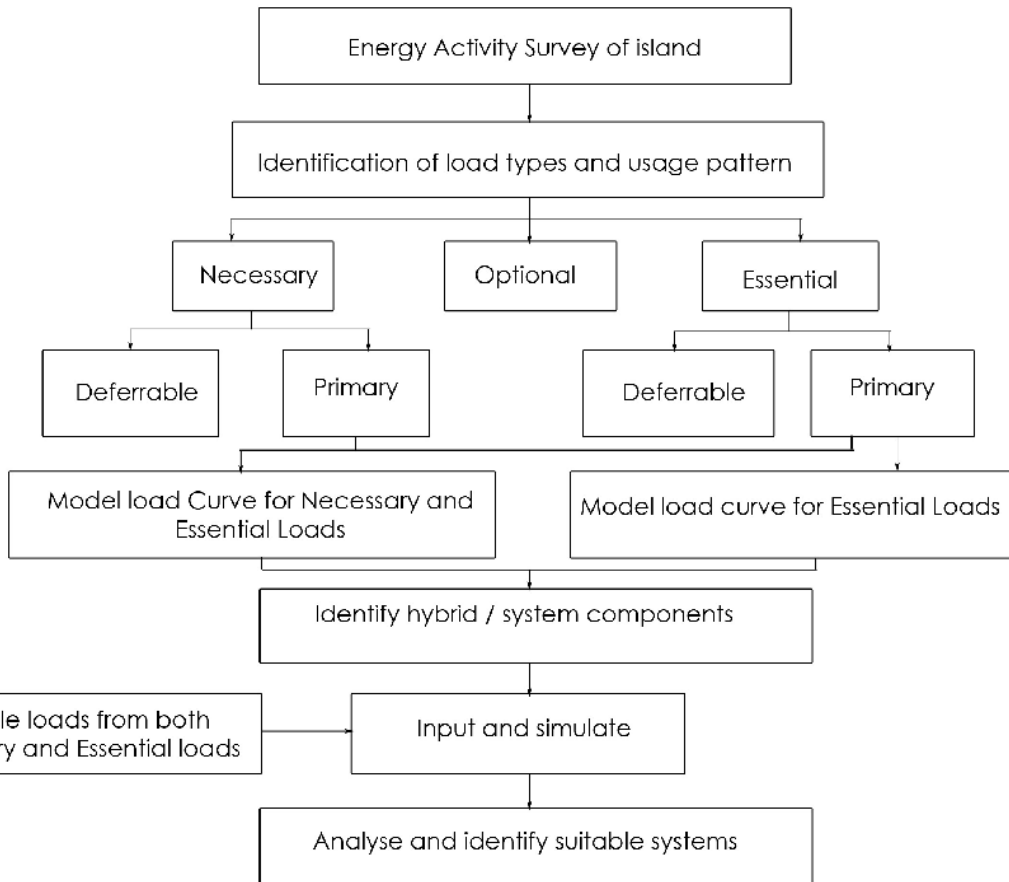


Research Objectives

- Whole Island Energy Audit
 - Method for village-scale audit
 - Method for assessing essential load
- Hybrid System
 - Wind and/or Solar
- Generation and Power Control System
 - Design for Essential Load Security
 - Robust design for Diesel fuel disruption and decline



Essential Load Matching Methodology



Energy Audit

Needs Analysis

Load Modelling

Hybrid System Modelling

Essential Load Design

Managed Load Control

Essential-Load Design

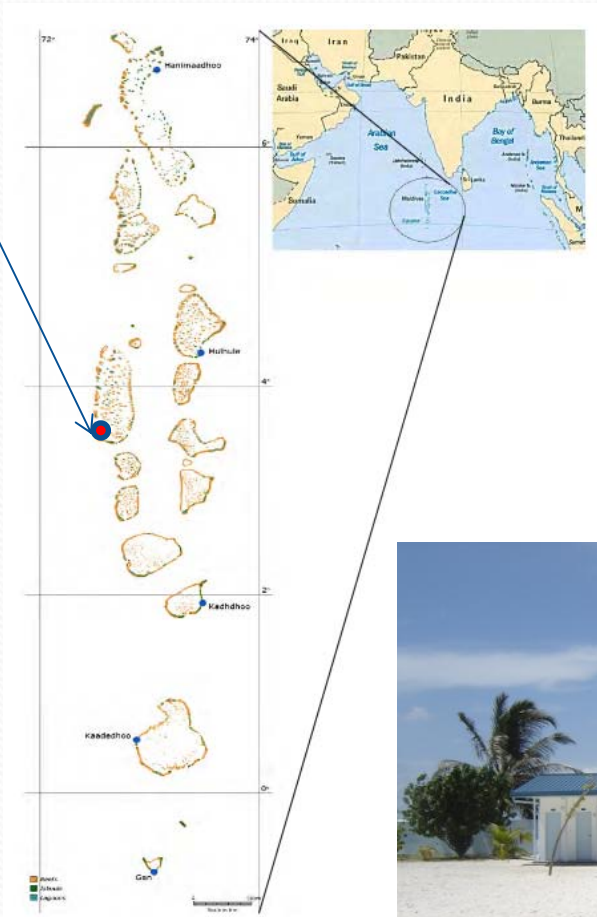


Community can get by
without Fossil Fuel

- Design a renewable-only system that meets Essential Loads
- Communication with Community
- New Design and Operation Concept

Case Study: Fenfushi Maldives

Fenfushi



Energy Audit: Facilities

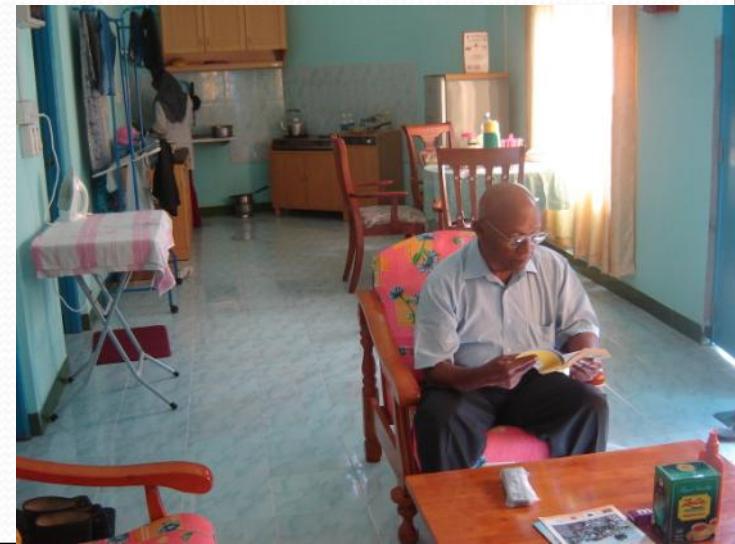
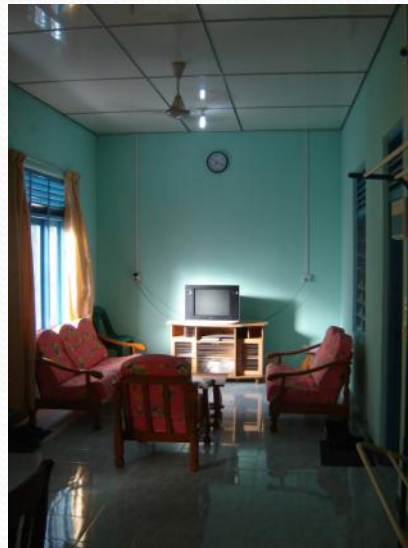


600 Residents
78 Households
Government Office
School
Medical Clinic
8 Shops

Equatorial Climate
1000m x 300m
0.3 km² land area
Muslim Community



Fenfushi Residential Loads



Commercial Loads



Government Office



Medical Clinic



Food and Small Goods Shops



School

Industrial Loads

Ship Building
Construction of New Homes



Cultural Loads

Friday Prayers - Washing
Ramadan - Electric Ovens



Energy Audit: Electricity Supply System

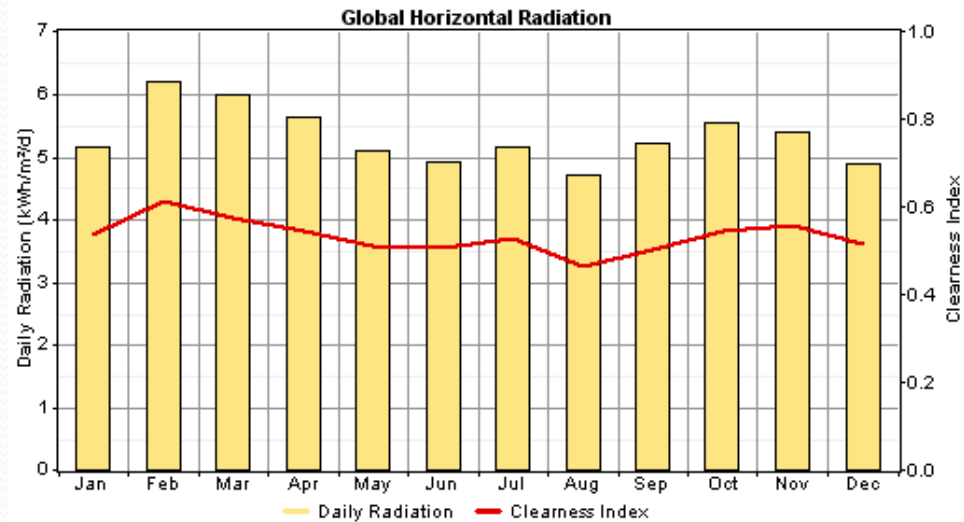
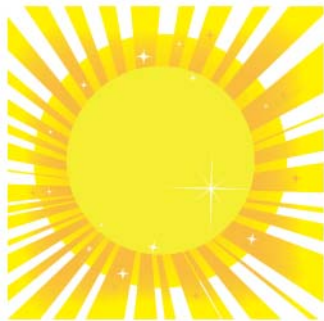
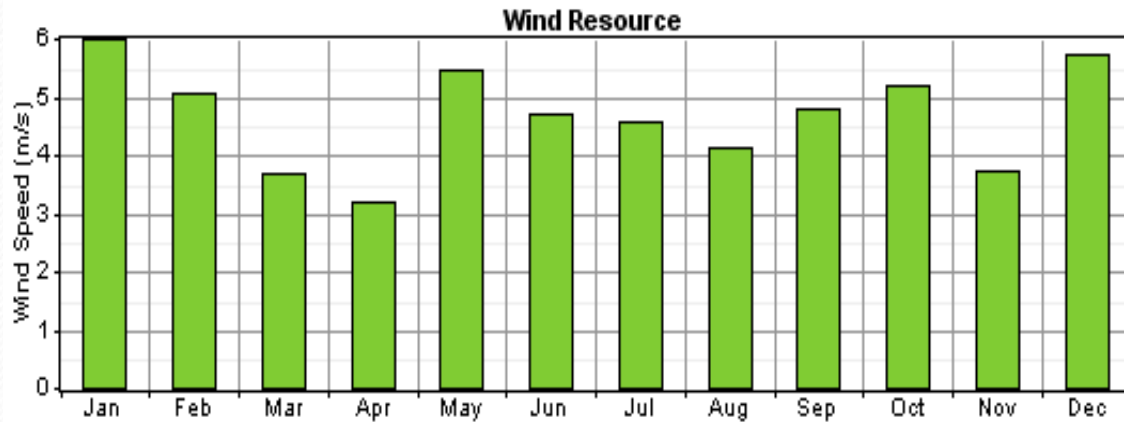
- Electrical generation capacity consists of one 40 kW, two 60kW and one 160kW diesel generators.
- No synchronisation mechanism to run the generator sets simultaneously.
- Maintenance issues



Energy Audit: Energy Sources

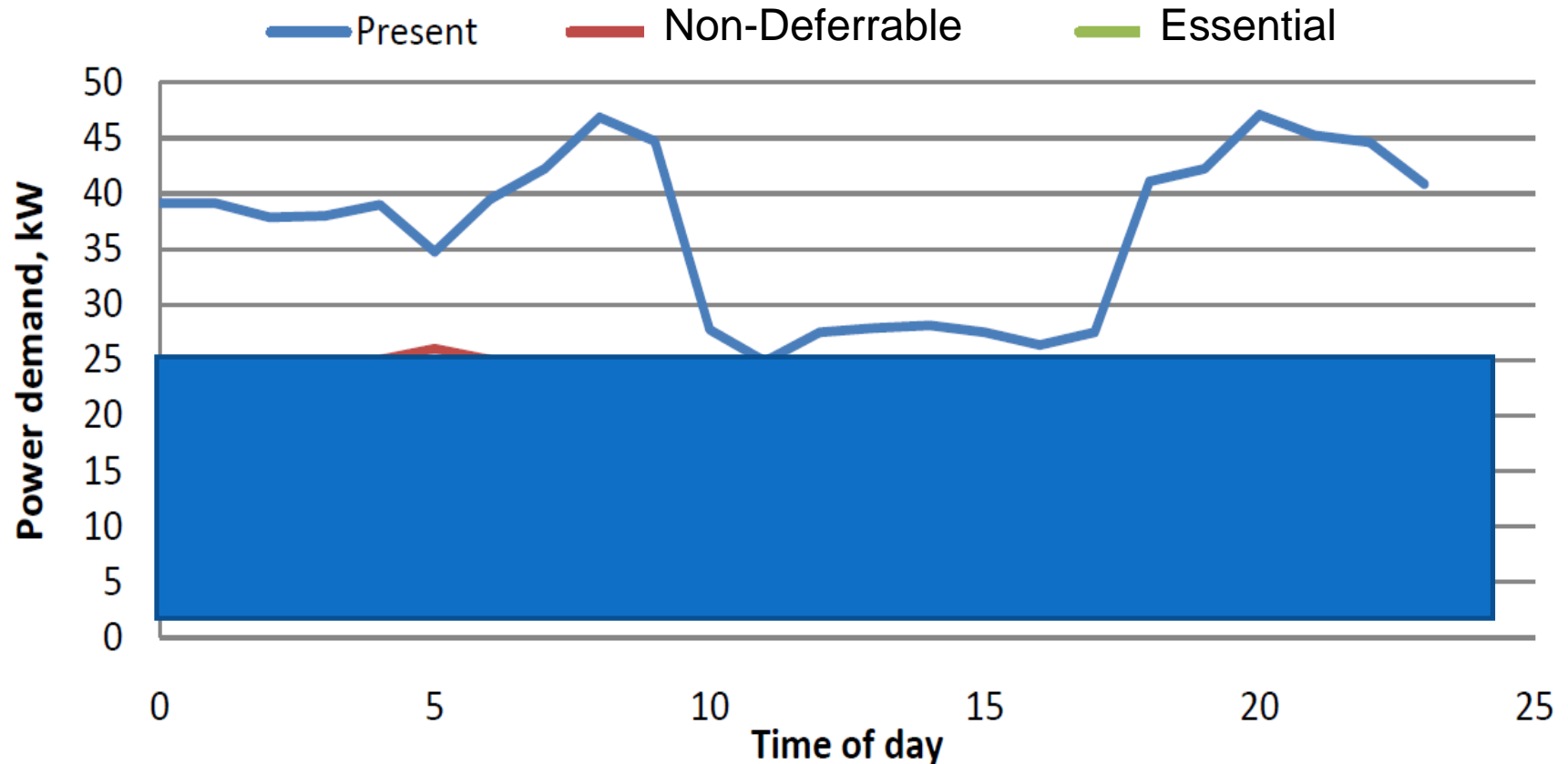
- The generators consume approximately 112,000 litres of diesel fuel per year (2007/2008)
 - Energy Intensity: 0.5 litre per person per day
 - Levelised Cost of Generation = US\$0.5 per kWh
- The island has a flat selling rate of US\$0.4 per kWh
- Average Solar Irradiance = 5.31 kWh/m²/day
- Average Wind Speed = 4.7 m/s

Renewable Resources



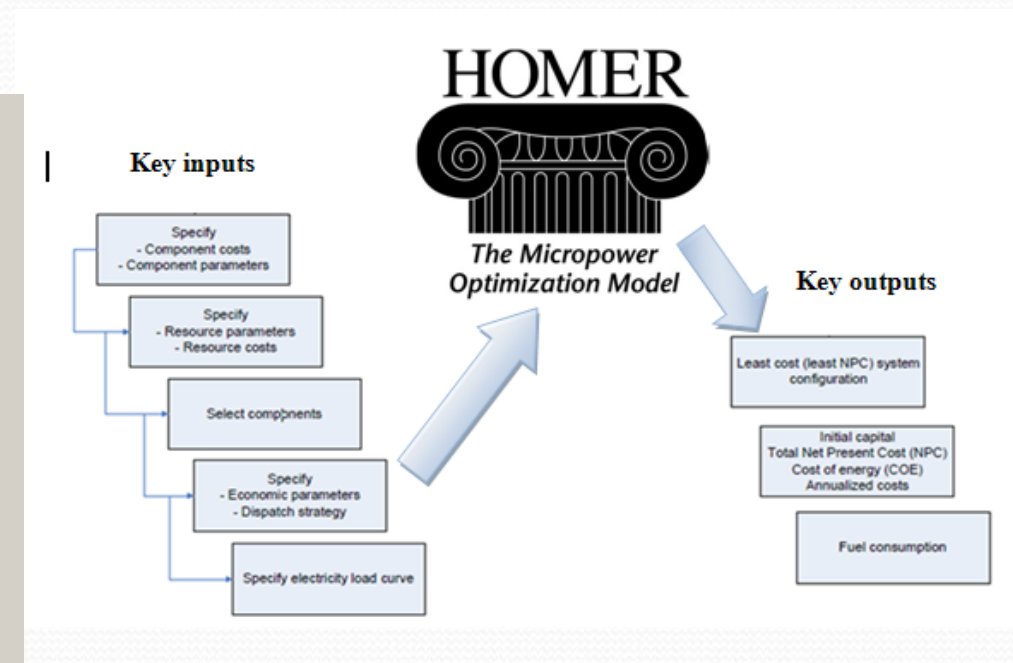
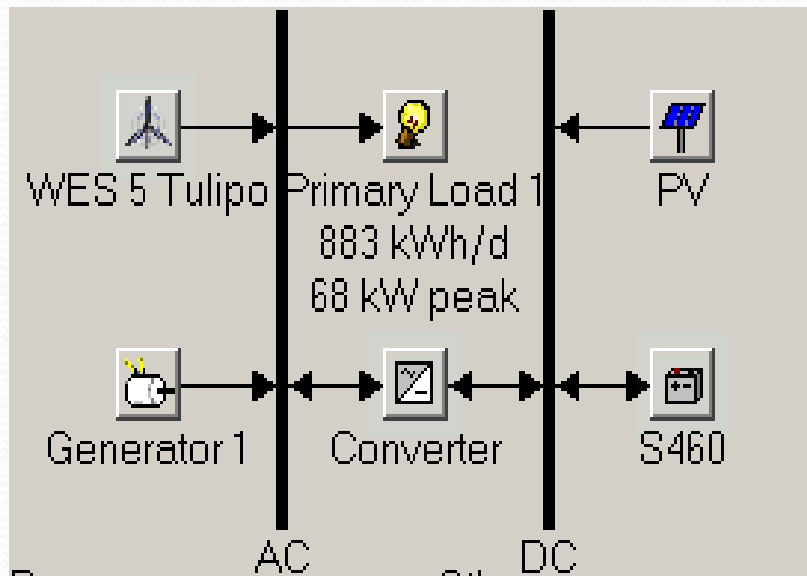
Load Modelling: Energy Services

Night Time Peak Loads: Fans, Lights, TV
Essential Load = 38% of Normal Load



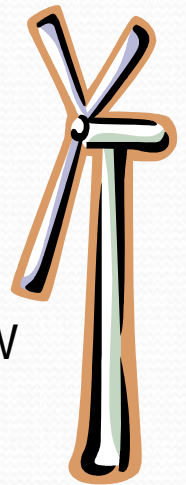
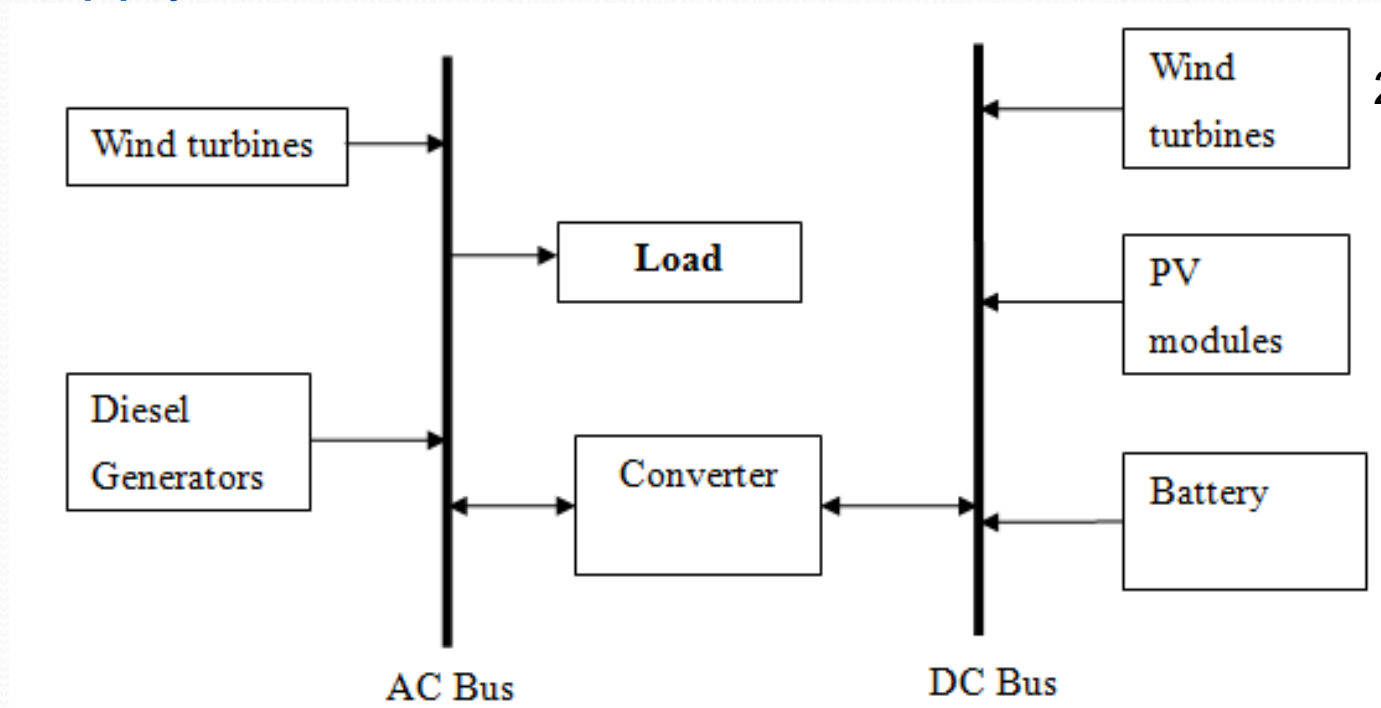
Hybrid System Modelling

Renewable Sources and Battery Storage
sized to meet Essential Load



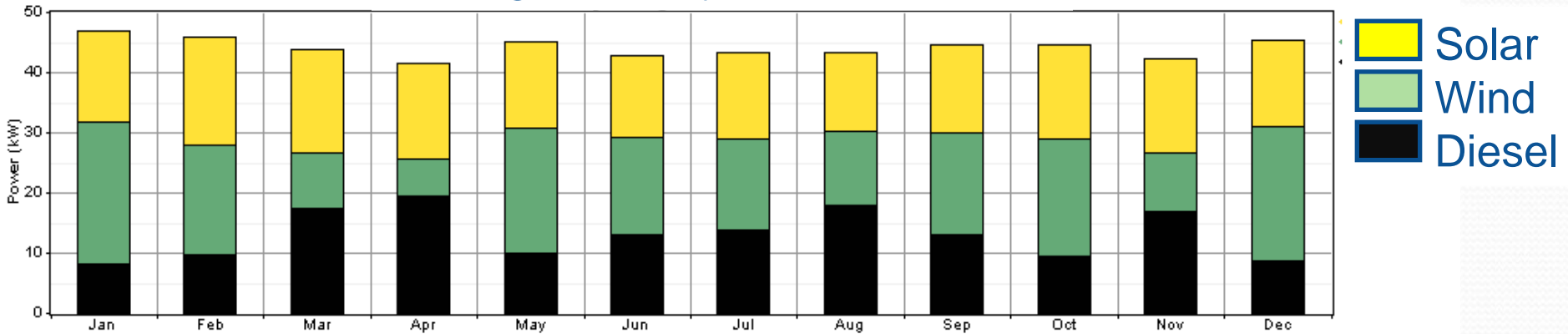
Hybrid System Configurations

Parallel configurations allow synchronous bi-directional power flow between battery bank and AC generators, reducing the risk of power supply failure



Hybrid System Performance & Cost

Average Monthly Production (kW)



Net Present Cost

Solar PV	\$400,000
Wind	\$200,000
Diesel	\$600,000
Batteries	\$300,000

Hybrid System Performance & Cost

Lowest cost systems chosen from 27 configurations

100% Renewable Energy 100% Essential Load Met

85 kW Solar PV
18 Wind Turbines

Battery Energy Storage
COE = \$0.51 /kWh
NPC = \$884,194
112,684 kWh excess energy

Hybrid Renewable-Diesel 100% Total Load Met

0.6 kW Solar PV
30 Wind Turbines
40 kW Diesel Generator
Battery Energy Storage
COE = \$0.33 /kWh
NPC = \$1,346,943
61,660 kWh excess energy

The Essential Load Matched Design

- Renewable Energy sufficient for Essential Load
- Diesel to meet 100% of current Total Load
- 66.5% Diesel fuel reduction over current system

Energy Supply

85 kW Solar PV
18 Wind Turbines
40 kW Diesel Generator
Battery Energy Storage

Economics

COE = \$0.37 /kWh
NPC = \$1,532,340
37,140 kWh excess energy
70% RE Penetration

The Final Selection- Economics

Essential Load Matched RE-Hybrid system better than current 100% Diesel system

Metric	Value
Present worth	\$ 432,761
Annual worth	\$ 33,853/yr
Return on investment	13.1 %
Internal rate of return	13.0 %
Simple payback	6.89 yrs
Discounted payback	9.47 yrs

Conclusions

- The simulation results and analysis show that there were no 100% renewable systems that can meet present demand at a realistic cost
- Either the system was too expensive or there were too many generation components for the available land area (often available land is constrained in these islands)
- The minimum renewable system components identified to serve the essential load with diesel generators results in a solution for these islands with lower NPC and COE values compared to diesel only generation.

Acknowledgements

I would like to thank my supervisors Associate Professor Susan Krumdieck and Dr. Larry Brackney for their help and support in accomplishing this project:

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Thank you for listening ...