Design and Analysis of Hybrid Power System Options for Off Grid Rural Electrification in Northern Kenya

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Motivation

- Electricity consumers in remote villages in Northern Kenya are serviced by stand-alone diesel power stations.
- Servicing these villages purely on diesel generation is accompanied by:

1. Significant CO_2 emissions from electricity and heat production (See Figure 1).
2. Escalating diesel prices (See Figure 2).

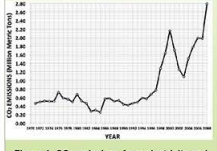


Figure 1: CO_2 emissions from electricity and heat production in Kenya, 1971-2008

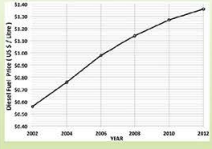


Figure 2: Diesel fuel prices in Kenya, 2002-2012

What Can Be Done To Address This?

- Six different options of hybrid power systems incorporating wind energy, solar energy and battery storage have been proposed to replace the stand-alone diesel power systems.
- The best hybrid system option **jointly minimises the CO_2 emissions and the total net present cost (NPC) of the system.**
- This is determined using the Multi-Attribute Trade-Off Analysis. The different system options are presented on a Pareto Curve (See Figure 3)

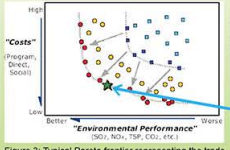


Figure 3: Typical Pareto frontier representing the trade off between environmental performance and cost.

- The system design alternatives that lie on the curve are considered dominant or Pareto superior

Dominant system design that jointly minimizes cost and improves environmental peformance

What is a Hybid Power System?

- A hybrid power is a small, often stand-alone system that uses more than one generating technology, usually consisting of one or more renewable energy sources to produce electricity.
- The hybrid system options proposed, modeled and analyzed are:

Design Option 1. Wind-diesel hybrid power system

Design Option 2: Wind-diesel-battery hybrid power system

Design Option 3: PV-diesel hybrid power system

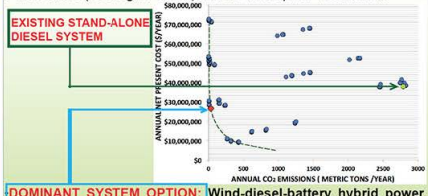
Design Option 4: PV-diesel-battery hybrid power system

Design Option 5: Wind-PV-diesel hybrid power system

Design Option 6: Wind-PV-diesel-battery hybrid power system

Best Hybid Power System Option for N.Kenya

All configurations of the six hybrid design options were represented on a Pareto curve (See Figure below) and the best option determined.



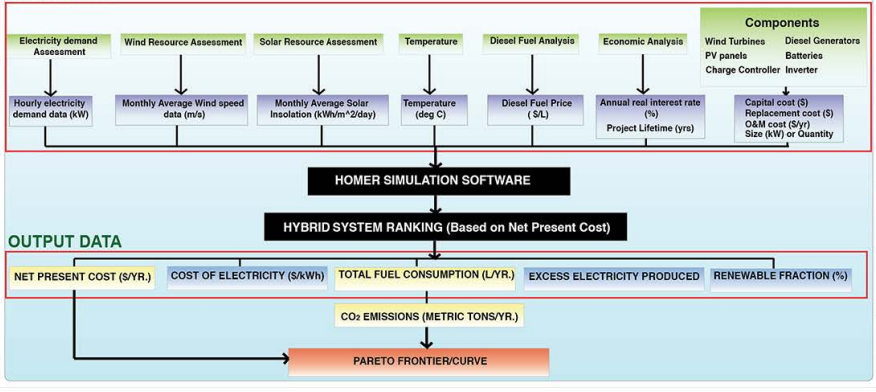
DOMINANT SYSTEM OPTION: Wind-diesel-battery hybrid power system with a configuration of one 1056 kW diesel generator, two 500 kW wind turbines, and 660 12V batteries (Represented by diamond shape)

- **Net Present Cost of System: $ 26.5 Million (30 % decrease from existing system)**
- **CO_2 emissions from System: 34.3 metric tons per year (98.8 % decrease from existing system)**

Hybrid Power System Design and Analysis Process

Calculating power output of a hybrid system requires knowledge of electricity consumption patterns in the location, data concerning the resources available and that of the different components of the system.

INPUT DATA



Future Work

1. Simulating proposed hybrid system dynamic performance in order to analyze system voltage and frequency stability so as to develop guidelines for the optimal operation of the system

2. Incorporating a water-pumping unit to the system, which can make use of the excess electricity produced to provide water for household use and also for agriculture.

Acknowledgements

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