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Techno-Economic Feasibility of a Hybrid Power Generation System

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Sheffield Hallam University

Background

- Connecting communities with continuous electrical supply has always been challenging in developing economies, especially in isolated areas.

- According to International Energy Agency, 17% of global population, predominantly living in rural areas, did not have access to electricity in the year 2016.

- Converting chemical energy of fossil fuels into electricity releases greenhouse gas (GHG), primarily carbon dioxide (CO_2), into the atmosphere.

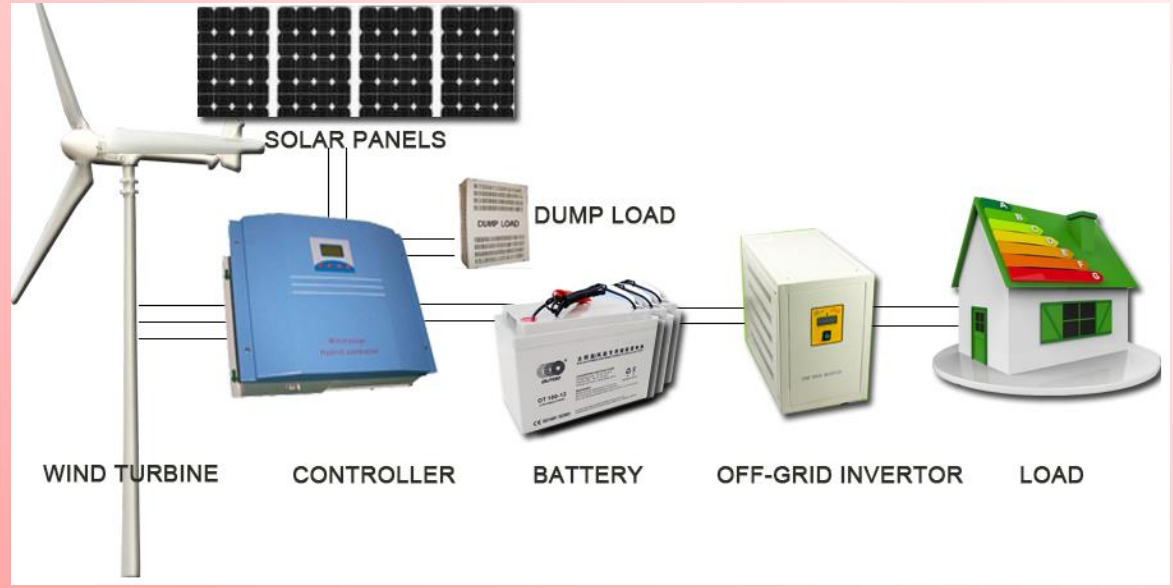
- The cost of conventional energy resources will increase in future, as the availability and the fetching of these resources becomes more challenging.

Renewable Energy

Challenges:

- Large area requirements for solar photovoltaic power plants.
- The fluctuations in wind speed and solar radiation with seasons and day-night cycles can cause interruption in continuous power supply.
- Requires huge energy storage capacity to ensure continuous power supply.
- High capital cost due to larger number of batteries.

Hybrid Power Generation

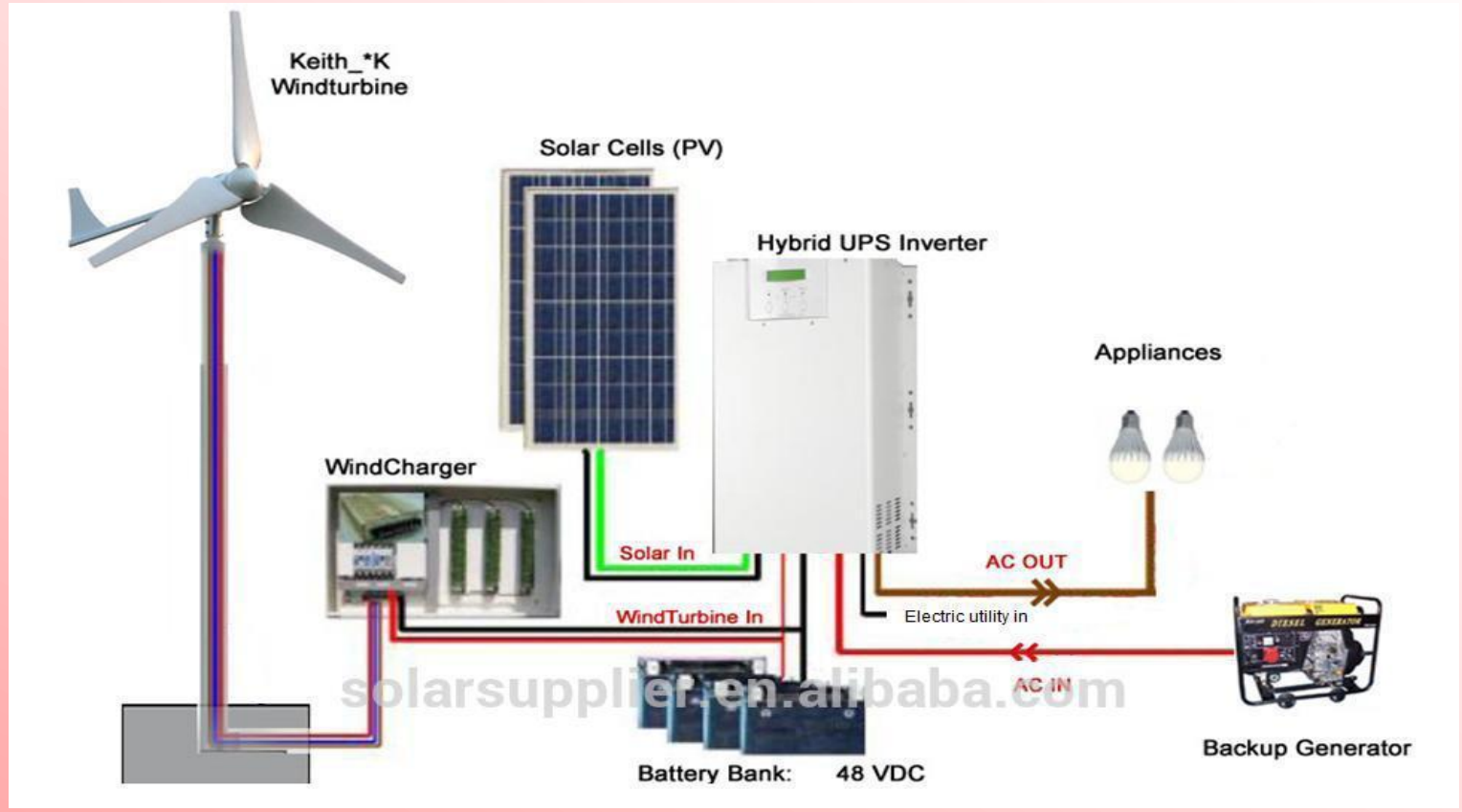


- Mixture of more than one energy source.
- The high intensity availability of one source could subdue the weakness or unavailability of the other.
- Reduce fluctuations in power generation.
- Cut down the large area required for PV system.

Challenges:

- Batteries still required.
- Produce excess energy (unused and not stored) during high wind speeds and solar radiations.
- Require more batteries to store this excess energy.
- Sizing of individual energy system increases design complexity.

Hybrid Power Generation with Backup System



Diesel Generator unit for backup

- Reduces the amount of excess energy by carefully optimising the size of individual systems.
- Requires less batteries.
- Produces GHG from diesel generator.

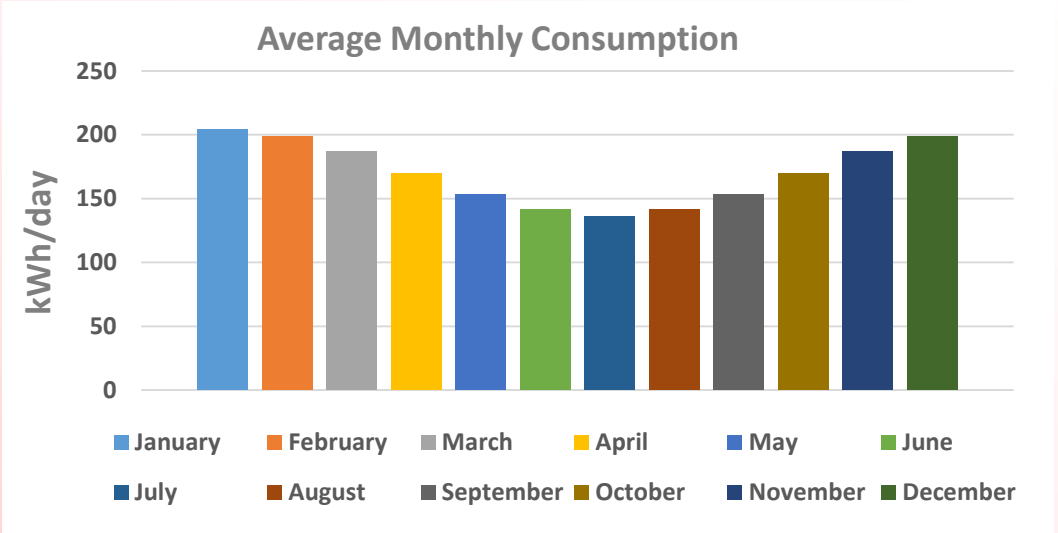
Hybrid Power Generation with Backup System

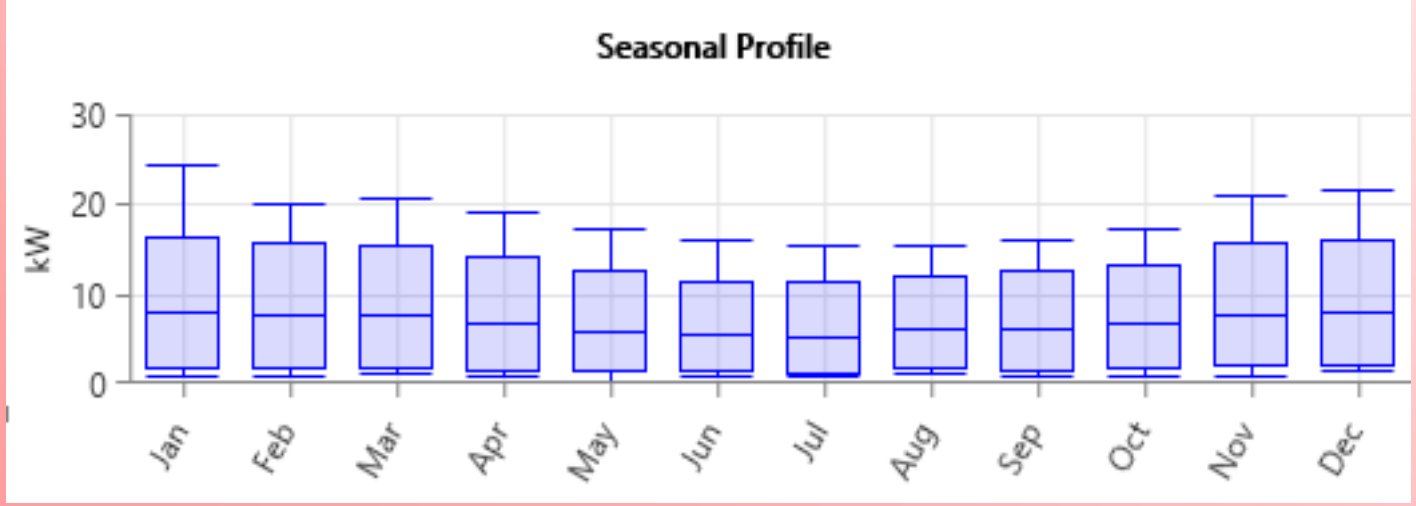
Grid supply for backup

- Excess energy is not wasted and sold to grid.
- No batteries required.
- Negative emissions.

Project Site

- Site type : **Community**
- Site location : **Latitude: 31.10; Longitude: 77.17**.
- Annual Average electricity consumption : **165.29** kWh/day.
- Peak load : **24.57** kW.
- Annual solar radiation range: **4.76 - 7.16** kWh/m^2/day.
- Monthly average wind speed range in an year: **4.7** - **7.16** m/s





Hybrid Plant Model

- Modelling and optimisation tool for energy systems involving renewable and non-renewable energy sources.
- Developed at the National Renewable Energy Laboratory (NREL), and enhanced and distributed by HOMER Energy.

Model 1: Wind and Solar with grid backup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Model 2: Wind and Solar with diesel generator backup (Standalone system)


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Model 1: Wind and Solar with grid backup

Wind Turbine System
Size: 10 kW

Solar PV System
Size: 46 kW

Grid Supply
COE : £0.055 / kWh

Model 2: Standalone System

Wind Turbine System
Size: 20 kW

Diesel Generator
Size: 28 kWh

Inverter
Size: 8.26 kW

Solar PV System
Size: 21.6 kW

Battery
Size: 51 kWh

Simulation Results : Model 1

Electricity generation and COE

Quantity	Units	Value
Production by PV	kWh/year	81,633
Production by wind turbine	kWh/year	17,626
Energy purchased from Grid	kWh	24,554
Total electricity production	kWh/year	123,814
Renewable fraction	%	80.1
Total electricity consumption	kWh/year	60,330
Excess electricity	kWh	63,483
Levelised COE	£/kWh	0.0297
Payback	years	< 13.8

Emissions from a hybrid system and a grid supply system

Quantity	Units	Model 1	Grid
Carbon Dioxide	kg/year	-24,603	38,129
Carbon Monoxide	kg/year	0	0
Unburned Hydrocarbons	kg/year	0	0
Particulate Matter	kg/year	0	0
Sulfur Dioxide	kg/year	-107	165
Nitrogen Oxides	kg/year	-52.2	80.8

Cost summary (all costs are in £)

Component	Initial Capital	Replacement	O&M	Fuel	Salvage	Total
One 10 kW Wind Turbine	16,000	0	1,278	0	0	17,278
Lead Acid Battery	300	208	127	0	-28	608
Flat plate PV	46,509	0	5,945	0	0	52,455
Inverter	10	4	0	0	-0.85	14
Grid	0	0	-23,312	0	0	-23,312
Overall system	62,820	213	-15,961	0	-28	47,044

Simulation Results : Model 2

Electricity generation and COE

Quantity	Units	Value
Production from PV	kWh/year	37,922
Production by wind turbine	kWh/year	35,253
Production by diesel generator	kWh/year	18,292
Fuel consumption by diesel generator	L/year	6,892
Total electricity production	kWh/year	91,466
Renewable fraction	%	69.7
Total electricity consumption	kWh/year	60,330
Excess electricity	kWh	27,928
Levelised COE	£/kWh	0.255

Emissions from a hybrid system and a grid supply system

Quantity	Units	Model 2	Grid
Carbon Dioxide	kg/year	18,041	38,129
Carbon Monoxide	kg/year	114	0
Unburned Hydrocarbons	kg/year	4.96	0
Particulate Matter	kg/year	0.689	0
Sulfur Dioxide	kg/year	44.2	165
Nitrogen Oxides	kg/year	107	80.8

Cost summary (all costs are in £)

Component	Initial Capital	Replacement	O&M	Fuel	Salvage	Total
Diesel Genset	8,456	11,111	10,539	59,030	1,434	87,702
Two 10 kW Wind Turbine	32,000	0	2,556	0	0	34,556
51 Lead Acid Battery	15,300	27,850	6,519	0	-2,783	46,886
Flat plate PV	21,605	0	2,761	0	0	24,367
Inverter	2,477	1,033	0	0	-192.40	3,318
Overall system	79,839	39,996	22,377	59,030	-4,411	196,831

Summary

Quantity	Units	Model 1	Model 2	Grid
Production from PV	kWh/year	**81,633**	**37,922**	-
Production by wind turbine	kWh/year	**17,626**	**35,253**	-
Production by diesel generator	kWh/year	-	**18,292**	-
Energy purchased from Grid	kWh	**24,554**	**-**	**60,330**
Total electricity production	kWh/year	**123,814**	**91,466**	-
Renewable fraction	%	**80.1**	**69.7**	**0**
Total electricity consumption	kWh/year	**60,330**	**60,330**	**60,330**
Excess electricity	kWh	**63,483**	**27,928**	-
Overall system cost (NPC)	£	**47,044**	**196,831**	-
Levelised COE	£/kWh	**0.0297**	**0.255**	**0.055**
CO_2 emissions	kg/year	**-24,603**	**18,041**	**38,129**

- The COE for Model 1 is ~47% lower than the grid price, whereas Model 2 has 5 times higher COE than grid price.
- The net present cost (NPC) of Model 1 is 4 times less than Model 2.
- The share of electricity from renewables in Model 1 is 15% higher than Model 2.
- Both Model 1 and 2 cuts CO_2 emissions.

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Thank you

Any questions ?

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A full reference list can be provided on request.