Clean Electricity- Hybrid Power Generation

Avijit Sharma (*Author*)
Tolani Maritime Institute
Pune, India
avijitsharma94@gmail.com

Kamal Yadav (*Author*)
Tolani Maritime Institute

Himanshu Sharma (*Author*)
Tolani Maritime Institute

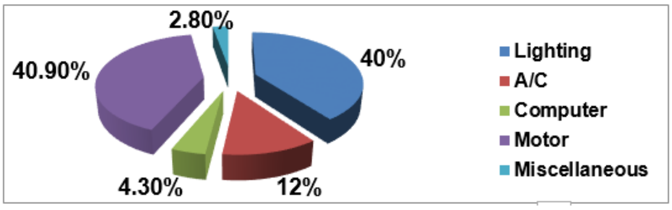
***Abstract*— Energy is critical in the entire process of evolution, growth and survival and it plays a vital role in the socio-economic development of a country. Energy is a `strategic commodity' and any uncertainty about its supply can threaten the functioning of the economy. India is on the threshold of a growth trajectory. In order to sustain economic growth there is an enormous demand of energy resources. India faces a peculiar challenge of increasing output while minimizing the production cost .At the present rate of growth the energy demand is set to increase by nearly two folds by 2020. Nearly 54 % of the total installed electricity generation capacity is coal based. Renewables energy such as wind, geothermal, solar, and hydroelectricity represent a 2 percent share of the India's electricity generation capacity. Also nuclear holds a one percent of this share. The total potential for renewable power generation in the country by 2013 was estimated as 89774 MW. This has motivated research, development, demonstration, innovation and dissemination of knowledge to contribute in minimizing pollution and providing clean energy. The hybrid energy system has received much attention over the past decade. It is a viable alternative solution as compared to a system which relies entirely on hydrocarbon fuel. It will not only overcome hydrocarbon fuel consumption but also give clean and eco-friendly electricity. This paper aims at analysing the feasibility of the above and gives a conceptual design of a hybrid micro power grid which will serve the port facilities. Port loads considered here are office buildings, residential buildings, water pump house, air conditioning, tower lamps etc. The pattern of electrical load of Tolani Maritime Institute (TMI) campus has been studied and suitably modelled for optimization of the hybrid energy system and implemented to a port having a similar load distribution in order to reap the benefits of hybrid energy. National Renewable Energy Laboratory (NREL)'s, Hybrid Optimization Model for Electric Renewable (HOMER v2.68 beta) has been used as the sizing and optimization software tool.**

The action plan has been formed on the basis of cost effective modelling, that is minimization of energy production cost in the long run along with minimizing the pollution. Also a comparative study has been carried out in order to study feasibility of various combinations of sources of energy generation that include wind, solar and conventional fuel.

Keywords—Micro grid, Hybrid, Renewable energy, Port, Sustinable.

I. Introduction –Case and Scope

Tolani Maritime Institute (TMI) is located 19.1336° N, 72.9154° E. The infrastructure at the campus includes the network of wide tree-lined roads, architectural design with the landscape and waterscape of cooling ponds and a lake. The engineering systems of the campus are a 0.8 MW coal fired power plant, modern vapor absorption chiller, water treatment plant and effluent treatment plant. The academic facilities includes air conditioned classrooms (50), workshops (2), laboratories (20), a library (7,000 sq. ft.), an auditorium (300 seated), a functional ship-in-campus, simulators and faculty offices for over 100 faculties. The residential facilities include 3 hostels accommodating over 1500 students, town styled apartments over 125 for families of faculty and an executive residence for the persons enrolled in advanced courses. In addition to these, different sports facilities, 24X7 medical facilities, canteens, shopping complex and a laundry.The pattern of load consumption of campus are studied and suitably modelled for optimization of the hybrid energy system using Homer Software.



II. LOAD DISTRIBUTION

In order to derive the load profile of the drink water treatment plant, two key questions need to be addressed: 1) What is the total electricity demand over the course of the year, and 2) How is the demand distributed over a year, week, day, and on an hourly level. The load variation of the campus on a 24 hour basis was measured using a Power Analyzer YOKOGAWA CW240. We have considered the load variation of a day with maximum average load in order to show the feasibility of the micro grid.

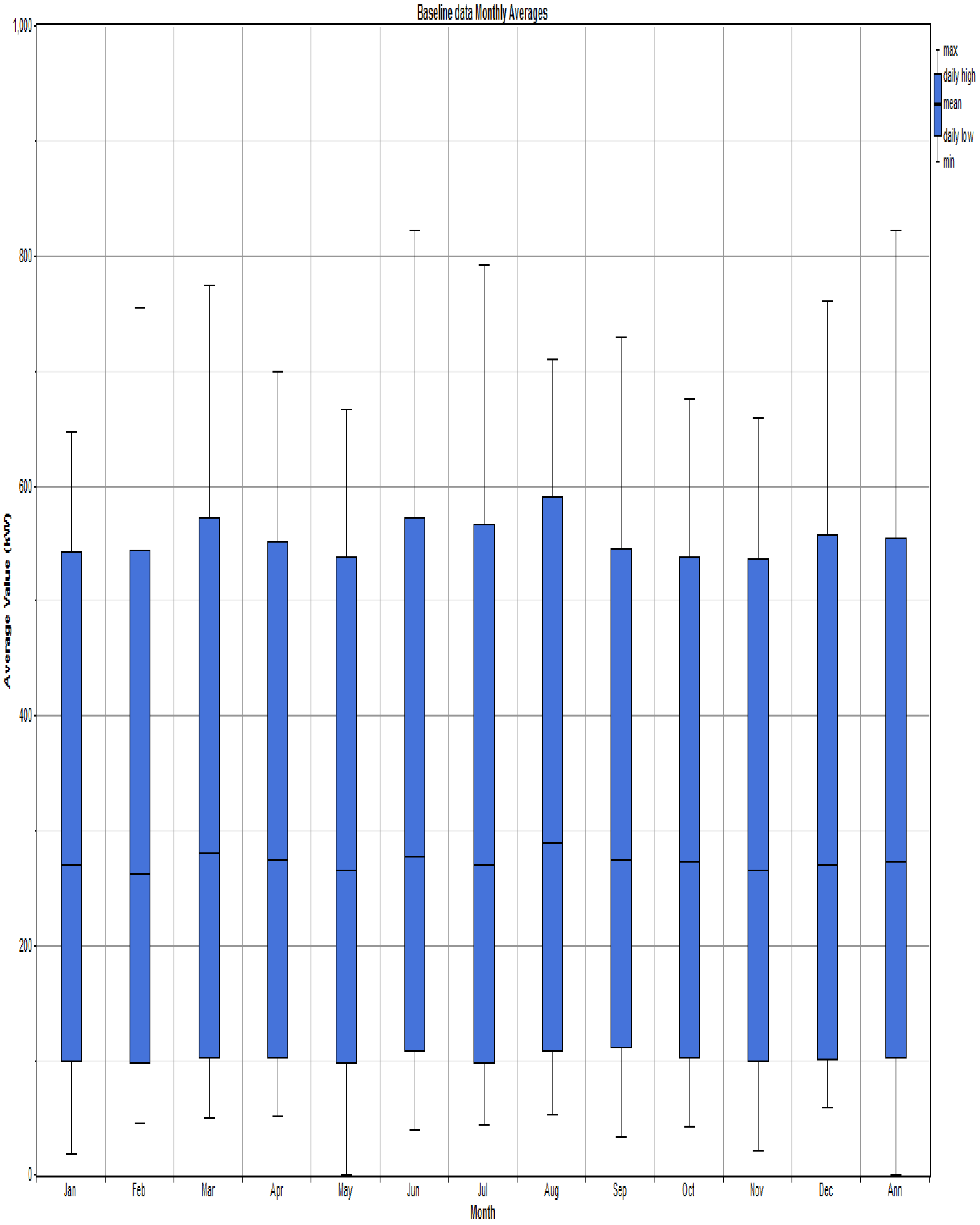


Fig1: Baseline Data Monthly Average Load Variation of TMI Campus

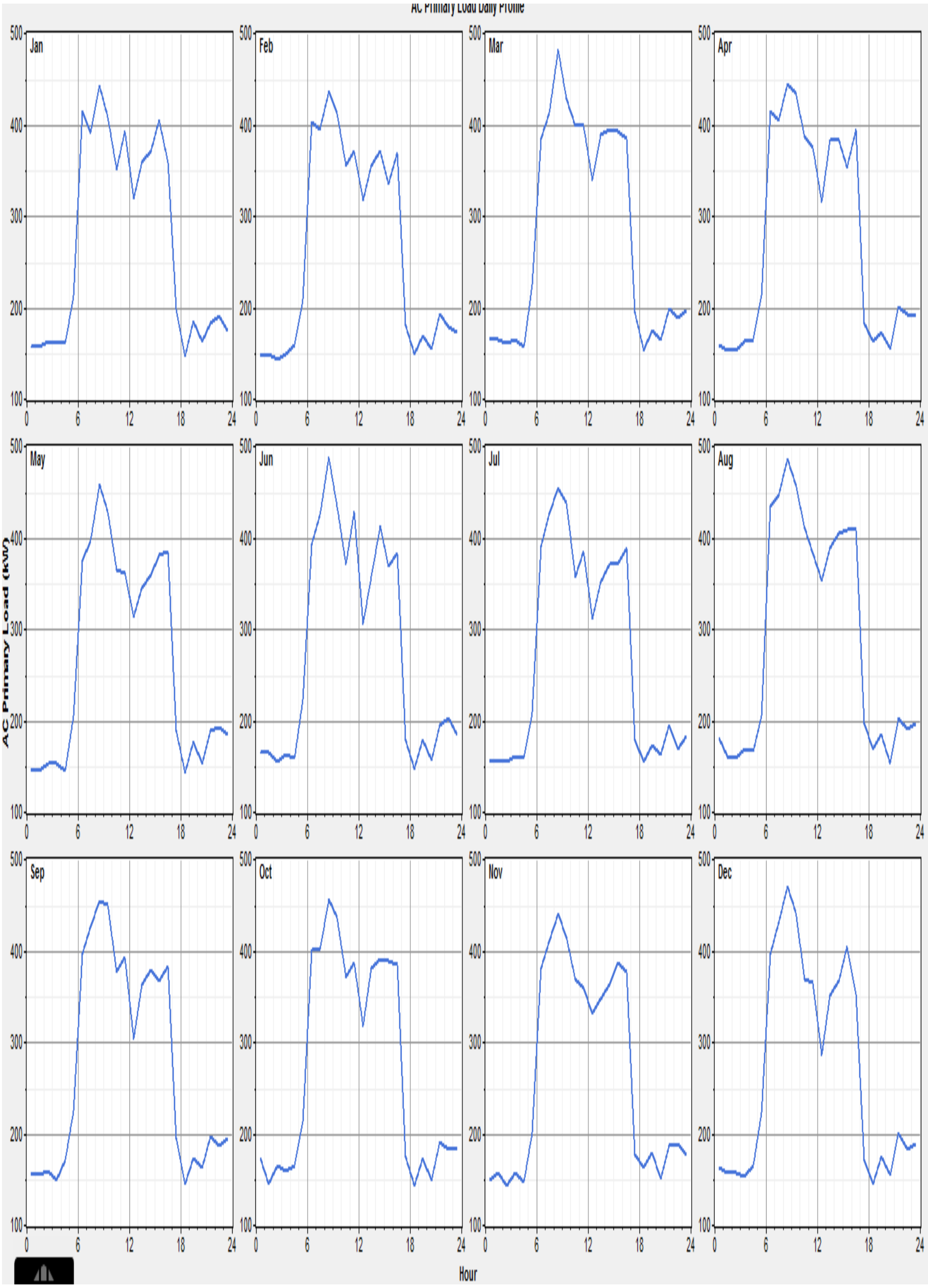


Fig 2: Campus Load Variation Over a year

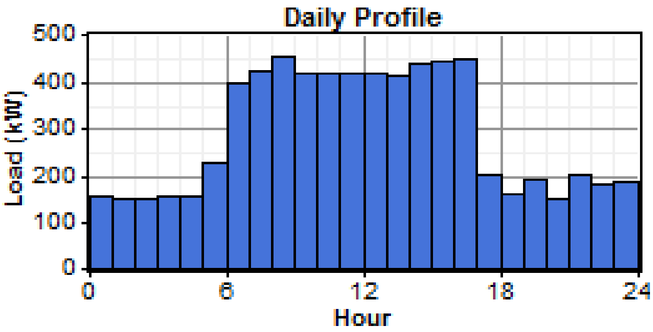


Fig 3: Daily load profile for weekday

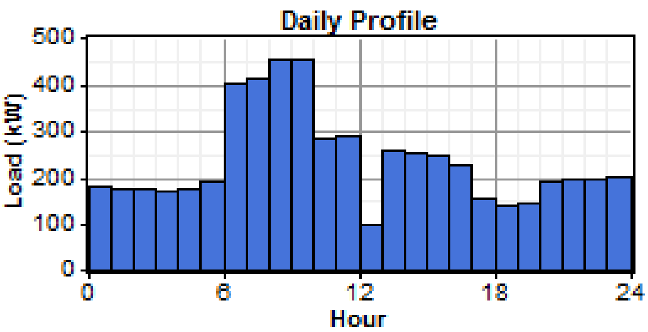
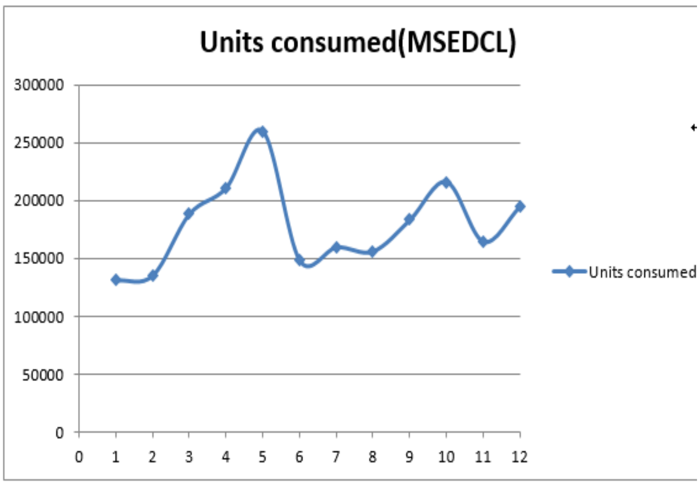


Fig 4: Daily load profile for weekend

III. SUPPLY GRID CHARACTERISTICS

The TMI campus is a High Tension (HT) Consumer and is fed by a 22 kV line from Maharashtra State Electricity Distribution Company Limited (MAHADISCOM). It has connected and sanctioned load of 1193 kW, the contract and the sanctioned demand of 750 kVA, and the average of monthly units consumption is 172000. The details of the sub-station are number of incoming feeder/s 1, the outdoor plinth mounted type, 1000 kVA, 22 / 0.415 kV, Delta/Star connected. The campus has a backup supply of two diesel generator sets of 500 kVA each.



MONTH	Cost/KWh
Jan	7.80
Feb	8.23
Mar	8.83
Apr	8.42
May	8.65
Jun	9.14
Jul	7.00
Aug	8.57
Sept	8.59
Oct	8.09
Nov	7.68
Dec	8.00

Fig 5: Cost/KWh of MSEDCL supply

IV. HYBRID MODEL

A variety of terms are used to describe advanced power networks that incorporate traditional and renewable energy: smart grid, VPP, micro grid, and hybrid energy systems.

A micro grid, on the other hand, focuses on the internal structure of the energy system from the consumer-perspective to be autonomous from the main grid by matching supply and demand internally. Self-sufficient energy systems already have been set up in a number of developing countries in order to help with the implementation of rural off-grid electrification in countries such as China, Mexico, Kenya and Bangladesh. The energy systems often consist of PV with battery packs or even backup diesel generators. It is normally grid-connected to help deal with the intermittency of its renewable energy generation. Hybrid systems are usually built for design of systems with lowest possible cost and also with maximum reliability. Once all chosen technical and economic parameters are input, HOMER simulates one year of system production for all combinations of input technology sizes to supply the input electricity demand based on the indicated control/dispatch strategy and by cost optimization using a minimum time-step of 1 minute. This means that at each time step, HOMER chooses to use the cheapest power supply option within the system dispatch and control constraints based on the input fuel costs ($/kWh) to supply the electricity demand. The annual costs for the one year simulation of each feasible system are then extrapolated over the project lifetime and discounted, based on the input discount rate, in order to calculate the net present costs for each system for the project lifetime.

The resulting feasible micro grid configurations are then listed based on the lowest net present cost for the project lifetime. The main optimization output results list the size and combination of components simulated (kW or number of wind turbines), grid-connection capacity (kW), initial capital ($), operating cost ($/yr), total net present cost ($), COE ($/kWh), renewable fraction of load (%), capacity shortage (%), diesel fuel used (L), and generator hours. However, more in depth technical production and economic are also produced and analyzed. The final goal is to maximize energy output and reduce COE from distributed energy resources (DERs) by Optimization using HOMER.

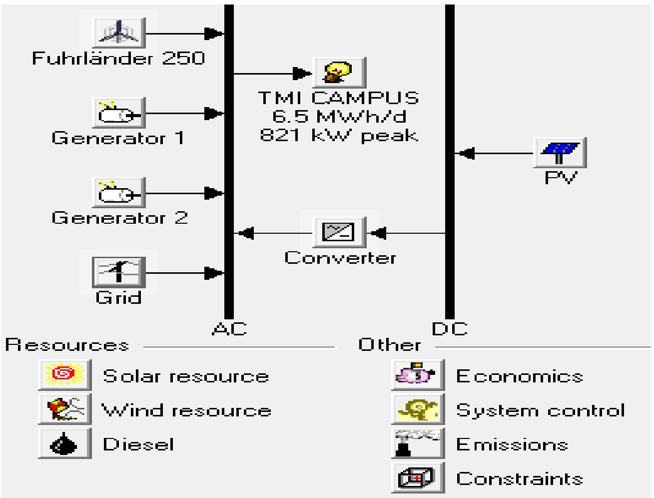


Fig 6: Proposed Hybrid Model

V. CLEAN ELECTRICITY

If the campus produces green electricity onsite and consumes it directly, it can avoid paying these high electricity costs. In this case, solar and wind technologies are chosen due to the aforementioned reasons in the case description.

VI. WIND POWER

The total wind power potential of the country is about 49130 MW. The site-specific potential for wind energy depends on the wind speeds at the location. Figure illustrates the measured average wind speeds at the site location.

The wind generator units convert wind power into electrical power. The wind passes through the propeller and producing the circumferential force and axial thrust. This circumferential force is also known as torque, which drives the generator to produce the electrical power. The wind velocity is a variable quantity, both in magnitude and in direction. This variable feature of wind turbine power generation is different from conventional fossil fuel, nuclear or hydroelectric power systems. Wind energy has become the least expensive renewable energy technology in existence. The greatest advantages of electricity generation from wind are that, it is renewable, eco-friendly and needs less maintenance. The most commonly used type of wind turbine is a horizontal axis turbine with a three blade rotor spinning in a vertical plane attached to a nacelle. The Fehrlander 250 wind turbine is considered and is specially designed for low to medium wind speeds.

The capital and replacement cost of the turbine is approximately 308 lakhs. The total onsite potential for wind depends on the space requirement per turbine and space available onsite. The amount of space required for a wind turbine depends primarily on the height and diameter of the turbine both in relation to other turbines and the built environment. Normally a spacing of about 5 to 10 rotor diameters between turbines is necessary in order to maintain optimal wind speeds and production for each turbine. Taking into account the distance to nearby houses, shadow cast by the turbines, and noise effects on the surrounding environment. Other parameters included in the analysis are weibull k, diurnal pattern strength, hours of peak wind speed, etc.

VII. SOLAR POWER

Solar photovoltaic (PV) technology converts the sun’s radiating energy into electricity. However, the sun’s energy that reaches the earth varies over time. Since the Earth has an elliptical orbit and changes its axis relative to the sun, the amount of radiating energy that reaches a specific latitude varies within a year and from year to year. The solar irradiance is also affected by the “clearness index” which is based on the cloud cover and atmospheric haze since these scatter, absorb, and reflect the sun’s radiation. These factors result in varying solar irradiance at a specific latitude, which is one of the main factors in electricity production from the sun.

Besides the solar irradiance, the total amount of electricity produced by solar PV also heavily depends on the specific characteristics of the PV cells, like the conversion efficiency, the placement of the PV panels in relation to the sun, and de-rating factors which cause the PV cells to perform below the rated efficiency.

VIII. PV PANEL CHARACTERISTICS

At current levels, PV technology used for commercial purposes ranges from 12-16% in conversion efficiency, which differs depending on cell type and manufacturer. The PV model chosen for this research is the monocrystalline silicon cell 40A 24V PWM CC model from BlazePower, whose specifications are shown in the table.

Power output of the PV panels is also highly dependent on how and where the PV modules are placed, since the following variables influence electricity yield:

- Tilt angle of the array (slope depending on the location latitude)
- Azimuth (the direction towards which the panels face)
- Ground Reflectance (aka albedo, which is the fraction of solar radiation incident on the ground that is reflected)
- De-rating factors (internal & external) that hinder maximum power production

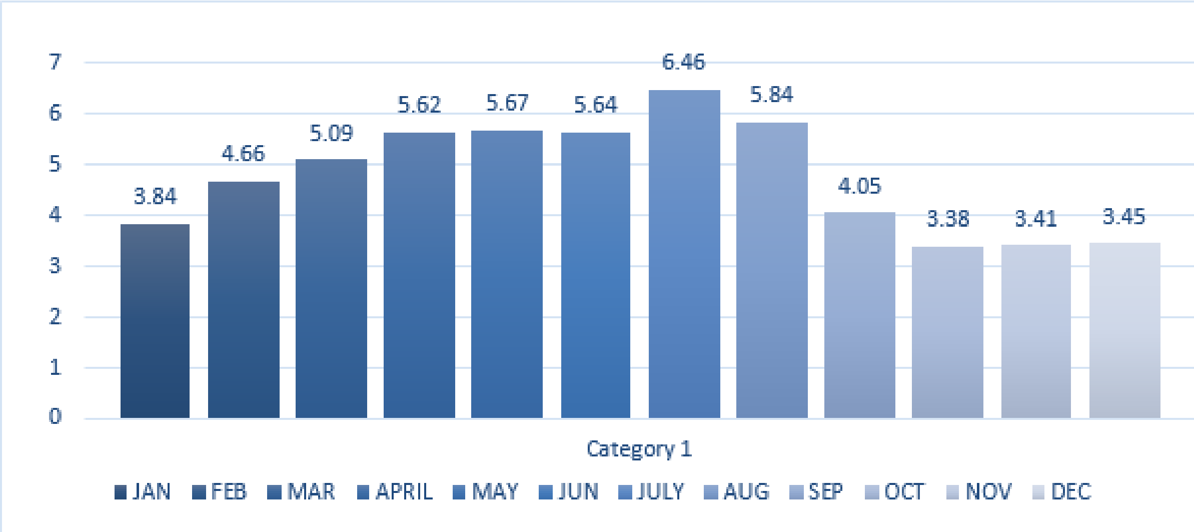


Fig 7: Yearly wind speed profile at the campus site

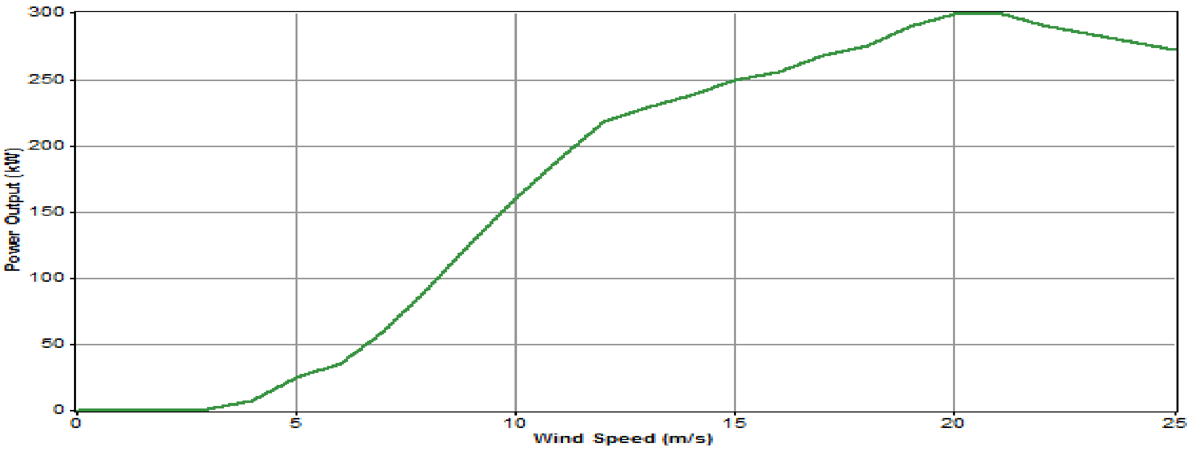


Fig 8: FL250 Wind Turbine power curve

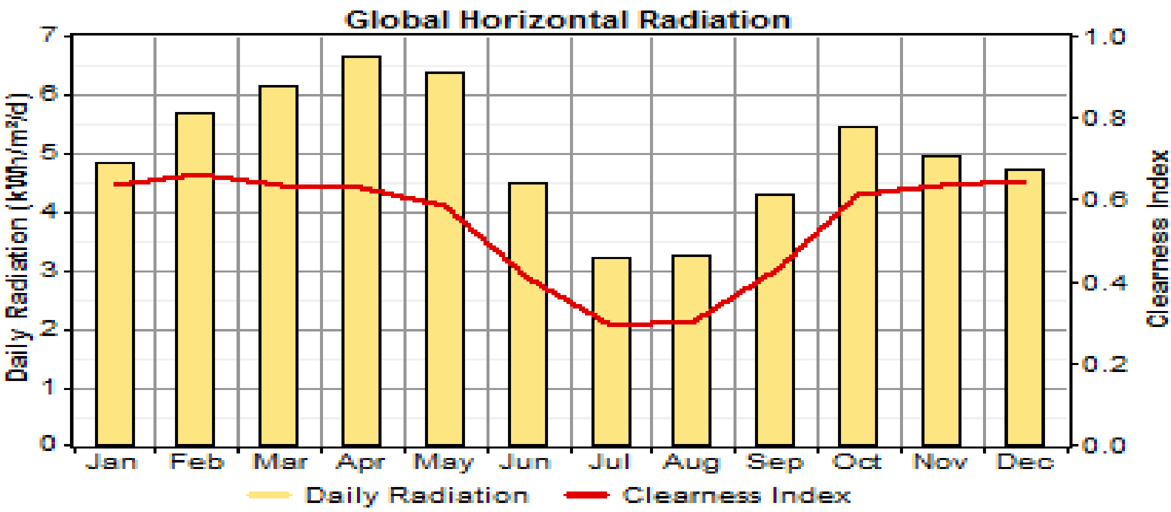


Fig 9: Yearly solar radiation at the campus site

1 Kilo Watt
250*4 Poly PV Panels
40A 24V PWM CC
Mounting Structure
10m of 4&16sqmm Wire
Combiner Box
DC Fuse Protection
Inverter: No
Battery: No
MRP: 69500

IX. INVERTER

Since PV technology produces DC electricity, inverters are required to convert the DC power to AC power in order to be used by the system and injected into the grid. Since it has proven compatibility with the chosen PV modules, the modelled inverter is the ABB central PVS800 inverter. The installation and replacement cost per kilowatt capacity of inverter is Rs. 18550.

The maximum AC power output is 98.7% and inverter efficiency is 98.5% at full load, which is well above the required 95%. It has a wide DC input range with a maximum of 1100 V and offers a 20 year replacement and repair warranty on these inverters. However, normal inverter lifetimes are 15 years, so this will be assumed in this analysis.

X. DIESEL GENERATORS

Two Cummins 500 kva silent diesel generators are used as backup/standby at the campus. Taking into consideration the present cost of diesel, the average cost of diesel generated electric power is 17.8 Rs/KWh.

XI. RESULTS: MICRO-GRID TECHNO-ECONOMIC POTENTIAL

A) CASE 1

In the first case having the lowest cost of energy as optimized by HOMER is 8.1 Rs/KWh.

The total renewable energy fraction stands at 45% of the total energy requirement. Energy produced by PV array is 1,247,820 Kwh/yr, whereas the grid purchase is of 1,502,133KWh/yr. Total capital cost of installation of PV array is 504 lakhs, giving a total payback period of 4.55 years. Excess electricity produced contributes 9.71% of total power generation which can be sold back to the grid or the grid consumption can be reduced. Above system gives a cost saving of Rs 138,000 per year on the grid purchase.

Quantity	kWh/yr	%
Excess electricity	266,948	9.71
Unmet electric load	0.00	0.00
Capacity shortage	0.00	0.00

Fig 10: Case 1-Excess electricity

B) CASE 2

When a sensitivity analysis is carried out with the same system applied to a port(in this case Mumbai port) with an annual average wind speed of 5.6m/s, cost of energy is reduced to 7.8 Rs/yr. With grid purchases contributing to about 49% of the total energy generation and excess electricity production of 6.51%, thus making the system more feasible.

This change in wind speed also reduces the operating cost by Rs 13,90,500 lakhs. The system includes one FL250 wind turbine, 500kw PV array and 1000Kw grid supply which is capable of giving a 14.66% reduction in cost of energy over a period of a month. With these high RE potentials onsite, grid-connected micro grid system can sell excess electricity beyond the demand, which are very profitable.

Production	kWh/yr	%
PV array	779,887	30
Wind turbine	566,296	22
Generator 1	0	0
Generator 2	0	0
Grid purchases	1,273,147	49
Total	2,619,331	100

Fig 11: Case 2-Sensitivity optimization for a port

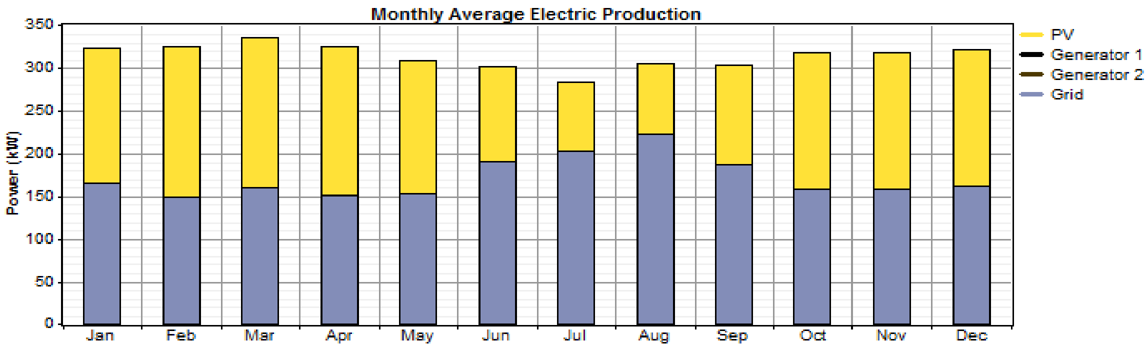


Fig 12: Case 1- Monthly average electricity production

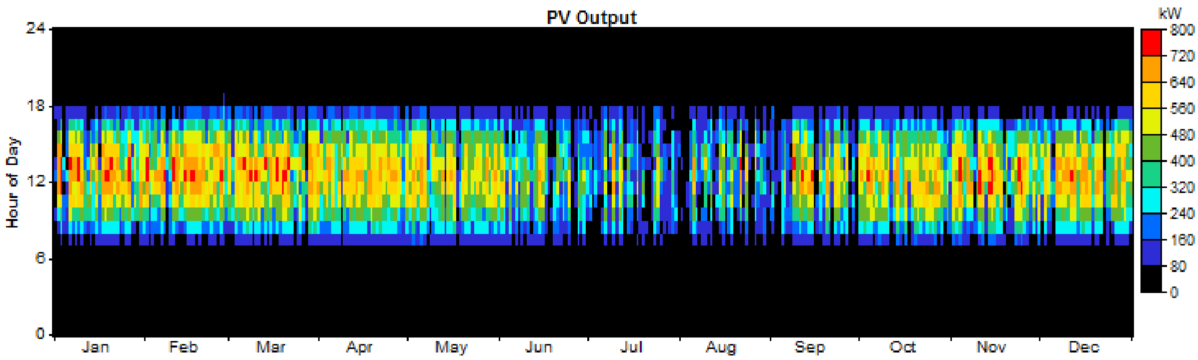


Fig 13: Case 1-PV output

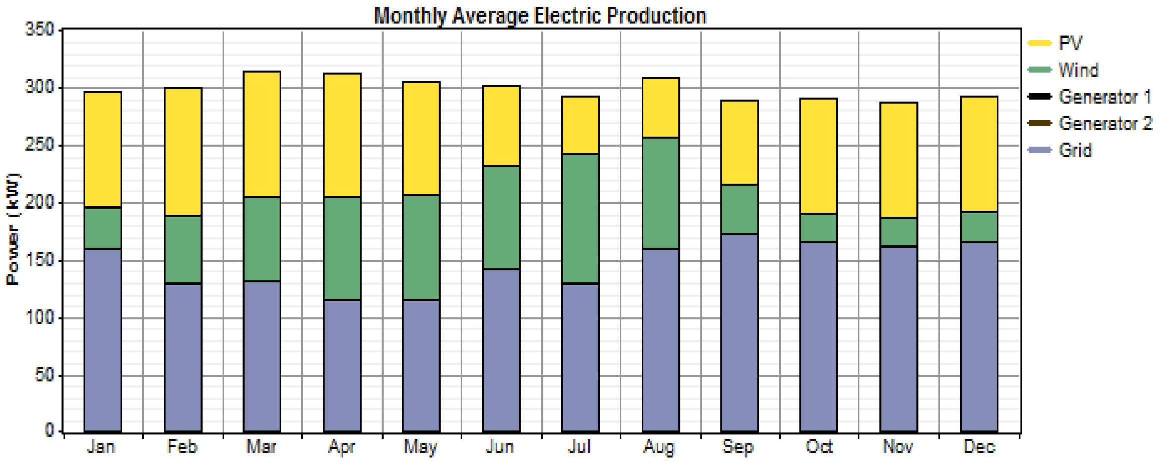


Fig 14: Case 2- Monthly average electricity production

	PV (kW)	FL250	Label (kW)	Label (kW)	Conv. (kW)	Grid (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Diesel (L)	Label (hrs)	Label (hrs)
	500	1	400	400	400	1000	$ 1,296,695	207,511	$ 3,949,379	0.130	0.51		0	0
	800		400	400	400	1000	$ 1,106,400	229,995	$ 4,046,510	0.133	0.45		0	0
		2	400	400		1000	$ 1,158,590	247,300	$ 4,319,917	0.142	0.43		0	0
			400	400		1000	$ 148,000	355,107	$ 4,687,463	0.154	0.00		0	0

Fig 15: Case 2- Optimized Hybrid model for port

Sensitivity Results | Optimization Results

Double click on a system below for simulation results. Categorized Overall Export... Details...

PV (kW)	FL250	Label (kW)	Label (kW)	Conv. (kW)	Grid (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Diesel (L)	Label (hrs)	Label (hrs)
800		400	400	400	1000	$ 1,106,400	229,995	$ 4,046,510	0.133	0.45		0	0
800	1	400	400	400	1000	$ 1,611,695	199,768	$ 4,165,399	0.137	0.58		0	0
	1	400	400		1000	$ 653,295	311,512	$ 4,635,463	0.152	0.16		0	0
		400	400		1000	$ 148,000	355,107	$ 4,687,463	0.154	0.00		0	0

Fig 16:Case 1- Optimized hybrid model for campus

XII. Government Policies

Even the government has taken certain measures which promote the use of renewable energy. Accelerated Depreciation is one such policy. This tax benefit allows projects to deduct up to 80% of value of wind power equipment during first year of project operation. Investors are given a tax benefit of up to 10 years. Moreover, the government offers indirect tax benefits, which includes concession on excise duty and reduction in customs duty for wind power equipment. In addition to the above the government also offers Central-level Generation –based incentives. Under this the GBI for wind is available for independent power producers with a minimum installed capacity of 5 MW for projects commissioned on or before 31/03/2012.

XIII. FUTURE OF RENEWABLE ENERGY

Human Beings are consuming their non-renewable resources at such a rapid rate that it has been predicted that within the next hundred years all the energy provided by Mother Nature in this form will be over. Thus, there is an ever increasing need for mankind to research upon other alternate sources of energy. Renewable Energy becomes an important aspect of study on which one must concentrate so that the future generations of this planet will not have to suffer and will have something to bank upon, to live their lives as comfortably if not more than the present generation. Sustainable development is the need of the hour and this can be only be attained through further research in renewable energy.

Hybrid Energy Systems holds the key to the future of renewable energy. Some ideas that have been proposed include the "Night and Day" concept. In this concept it seen that the wind blows more strongly at night in some regions and solar energy can be tapped only during the day. By making more sophisticated use of this basic concept in a connected grid, and combining it with a more advanced form of energy storage, the door could be opened for a much wider use of renewable energy systems. Another concept that is being looked at is the concept of Advanced Energy Storage. In this Electricity is being produced by efficient wind farms. This is then transmitted to a different place where it is being stored via compressed air in certain rock formations; and ultimately used to help power a completely different third location.

Wind energy may be one of the more sustainable sources of power available, but the spinning blades of conventional wind turbines require regular maintenance and have attracted criticism from bird lovers. Researchers in the Netherlands set out to eliminate the need for a mechanical component entirely and created the EWICON, a bladeless wind turbine with no moving parts that produces electricity using charged water droplets.

Where most wind turbines generate electricity through mechanical energy, the EWICON (short for Electrostatic WInd energy CONvertor) creates potential energy with charged particles – in this case, water droplets. The current design consists of a steel frame holding a series of insulated tubes arranged horizontally. Each tube contains several electrodes and nozzles, which continually release positively-charged water particles into the air. As the particles are blown away, the voltage of the device changes and creates an electric field, which can be transferred to the grid for everyday use.

Energy output would be dependent not only on the wind speed, but also the number of droplets, the amount of charge placed on the droplets, and the strength of the electric field.

Taking the concept of windmills one step further, or higher, scientists want to create power stations in the sky by floating windmills 15,000-feet in the air. The strange crafts will be kept afloat by four propellers that double as turbines, and feed electricity back to earth through a cable.

XIV. CONCLUSION

The result from simulation of distributed energy resources by HOMER shows that solar PV modules, wind turbine, diesel generator and inverter connected to the supply grid is the most economical solution to design integrated system with minimum total net present cost and cost of electricity for a port. Though the different distributed energy resources are technically suitable and available in market, but not necessarily be financially viable. Economic viability should be in top priority over the technical feasibility exclusively for port load electrification in the country.

Utilizing measured wind speed and solar irradiation data for the campus, real time manufacturer data for technology components and a bottom-up approach to model a flexible demand from demand response, the modelled results prove that there is a very high potential for renewable electricity at the campus site which improves further when transferred to a port location, which can make the electricity consumption more than 50% self-sufficient with renewable electricity from solar PV and wind power production. The results show that wind production potential is very high at a port location and can meet 22% of onsite demand with solar PV. However, the results indicate that PV production potential is also substantial and provides a more balanced supply which can supply electricity at times when wind production is insufficient. Due to the supplemental supply over different parts of the day, adding solar PV also increases the benefits gained from the demand response strategy. Therefore, a solar-wind system combination is recommended over a wind or solar only system for installation at port sites.

ACKNOWLEDGMENT

We express our sincere gratitude and admiration for Mr. Pradeep Zunke for his extraordinary contribution towards this project and for guiding us throughout our work. We would like to thank Mr. Prasad Mehendale for the key inputs provided which have been instrumental for our project. We admire and respect Mr. Arun Mahajan for encouraging us to work on this topic. Finally we thank all the Cdt. Ashutosh Patel for helping us prepare our project.

REFERENCES

[1] NASA Surface meterology and Solar energy, eosweb.larc.nasa.gov/sse.

[2] Roger Taylor, Hybrid Power Systems.

[3] National Renewable Energy Laboratory, HOMER guide.

[4] National Statistical Organisation, Govt. of India, Energy Statistics 2013.

[5] Coastal Climate Change Vol 22. No.1 2013.

[6] Journal of Clean Energy Technologies, Vol 1, No. 1, January 2013, Arjun A.K.

[7] Dr. Peter Lilienthal, Remote Microgrid Business Models.

[8] Massachusetts Clean Energy Center, Port and Infrastructure Analysis for Offshore Wind Energy Development, 2010.