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Feasibility study of Standalone Hybrid Power system modeled with Photovoltaic modules and Ethanol generator for Victoria State, Australia

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ABSTRACT : *The electricity generated in Victoria state is majorly with fossil fuels, consequently the resources are diminishing and enormous amount of emission is released in to atmosphere and thereby creating threat to the environment. Furthermore, the electricity supplied through grid to the end users is expensive; this is because various extra charges are added in to feed in tariff, especially carbon taxes. Since with these concerns, alternatively this paper aims to design an off- grid-stand alone hybrid power systems (HPS), to determine the economic and environmental performance majorly with Renewable energy (RE), to supply electricity to Victoria State-Australia. To investigate the RE sources-Solar and Wind, the data is collected from Bureau of Metrology (BOM) and NASA, using the collected data of nine different location in Victoria state, the average availability of solar energy and Wind energy were compared and it was determined that Mildura has abundant solar energy, whereas Warrnambool has abundant wind energy. However, in this study only solar data was used for modeled Photovoltaic (PV) cells while modeling HPS, battery is used for storage purpose to supply extra demand as well as to be able to supply the unpredictable load in future. The study performed in HOMER (Hybrid Optimization Model for Electric Renewable) NREL (National Renewable Energy Laboratory) tool.*

KEYWORDS : *Renewable Energy (RE), Green house Gas emission (GHG), Solar data, Wind data.*

I. INTRODUCTION

In the last decade, Victoria's annual electricity demand has grown significantly. Victoria has traditionally produced more electricity than it consumes and has been a net exporter of electricity to other states. Typically, Victoria exports electricity during off-peak times and imports during peak hours. Victoria's electricity generation has historically been dominated by coal-fired, and gas fired generation and whilst RE generation has made important inroads over the last few years, it accounted only 5 % of Victoria's generation in 2009, the same share of generation as in 2000 [1]. The majority of powers supplied in houses by state or local power authority throughout Victoria are with 240-volt alternating current (AC) [2]. Firstly, electricity generated in Victoria is majorly dominated with coal-fired generation, and its emission released in Victoria State is high as shown in the Figure.1 (left). Secondly, the gas fired energy generation and it emission represents the next highest and is as shown in the Figure.1(right).

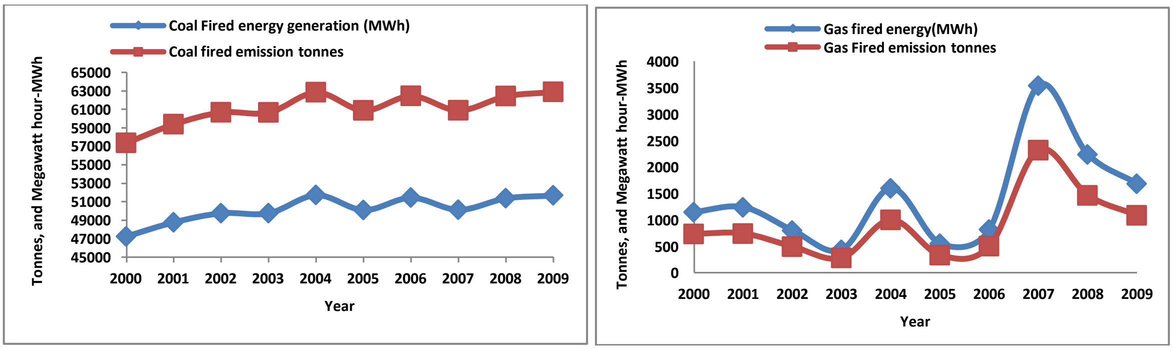


Figure. 1. Coal fired energy generation and its emission released (left), and Gas fired energy generation and its emission released (right)

Furthermore, the RE energy contributes the least while compared to other power generation, as shown in the Figure. 2. (Left), and the emission released is 0%. The total power generated and the total emission emitted by all the power generation technology in Victoria is as shown in the Figure. 2.(Right). By comparing the entire resources share utilized to generate energy is as shown in the Figure.3 [1]; Coal is contributing more than 87%, and less than 96 % between years 2000 to 2010, closely the emission released maintained no less than 95% and to a maximum of 99.5 %.

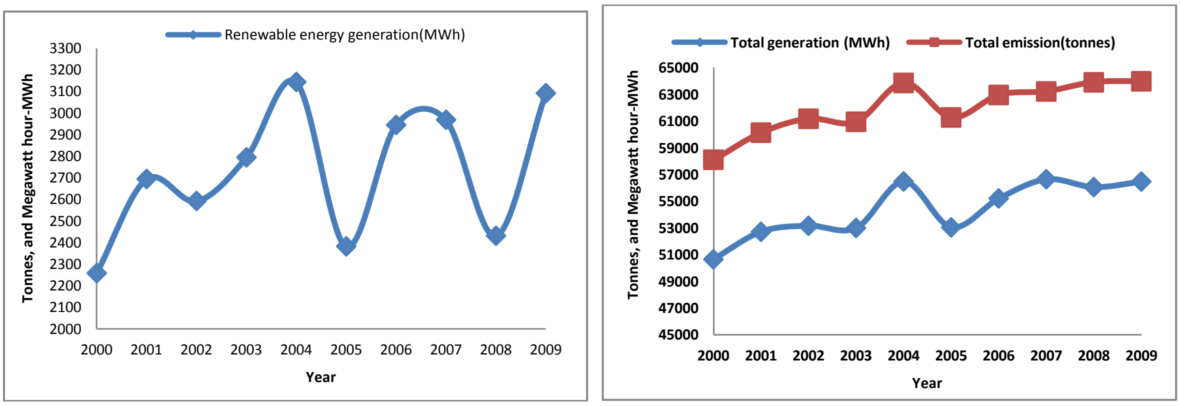


Figure.2 . RE generation and its emission released is zero (left), and Total energy generation and its emission released (right)

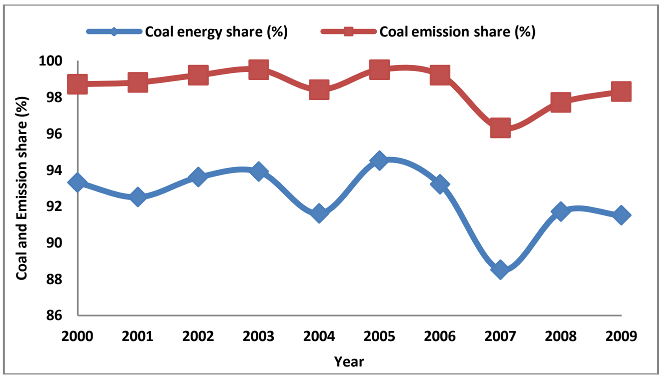


Figure. 3. Proportion of Coal fired energy generation among other methodologies [*1*]

Due to the usage of coal to generate energy, it leads to significant green house emission (GHG) release in the atmosphere, as a result this adds up a portion to Global warming. To reduce GHG and due to the rising electricity, Australian government has taken Clean Energy Initiation (CEI) for deploying wide range of RE and clean energy technologies. The CEI program consists of [*3*]

1) Carbon Capture and Storage (CCS) initiatives: This program aims to accelerate the deployment of CCS projects- in order to minimize the emission released from coal usage

2) Solar flagships: This program aims to support the demonstration and construction of solar panels connected to grid in a large-scale sector in order to play a key role in power generation.

3) Australian Solar Institute (ASI): ASI aims to facilitate developments for solar researchers, and ensure strong bonding between universities, institutes, and industries. Australian Centre for RE (ACRE); aims to propagate RE development, deployment, and commercialization

4) RE Future Fund (REFF): This program facilitates the development

The major RE technologies installed capacity and its output in Victoria State are as shown in the Figure. 4. [*4*]

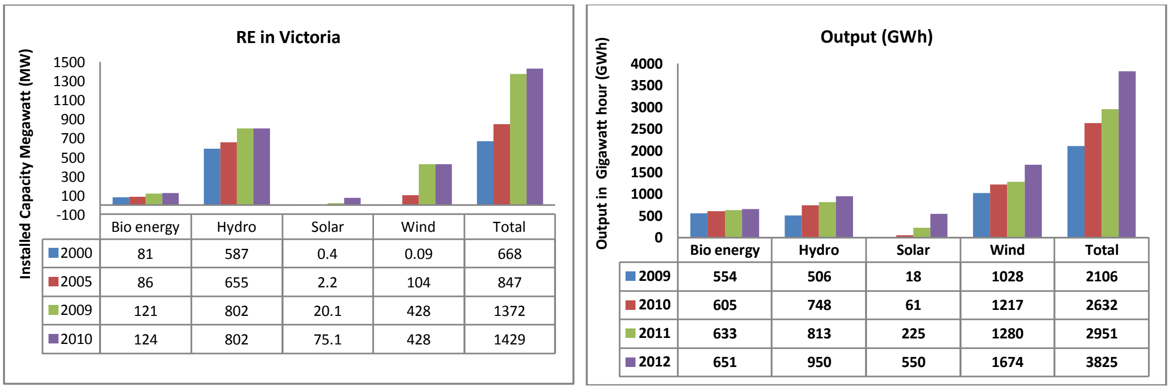
The various technologies used are

[1] Hydro power- The statistics in the year 2012 showed that in Victoria State; hydro generators generated 950 gigawatt-hours (GWh) through 803 megawatts (MW) hydro plant. The source of the generated energy through Hydro generation is all located within the Victorian border except the Hume Dam hydro power plant; represents 50% within Victoria. The collected data was monitored at various locations where Australian Energy Market Operator (AEMO) had a possibility and at the plant where it is not a scheduled generator; direct communication with the owner. This methodology reported that Victoria has 32 operating hydro plants.

[2] Bio energy- In 2012, bio-energy sources supplied 651 GWh; represents about 17 % of Victoria's total RE generation. Among the installed capacity, a single black liquor plant with a capacity of 54.5 MW represents 42%. Victoria has lot of methane landfill capacity, which further represents 38 % of capacity.

[3] Solar- In 2012, the 550 GWh of solar energy was produced to supply electricity in Victoria (14% of all RE). There was a massive gap of electricity while compared to the past; due to the huge growth of rooftop PV systems steered by declining solar prices, as well as state and federal government incentives. In 2012, the installed capacity varied from 270 MW to 418 MW. Solar panel generation for Victoria calculated using a capacity factor of 15 %.

[4] Wind- Among all the Wind RE contributed the highest to Victoria's renewable electricity supply for the last four years-from 2012. In 2012, Victorian wind energy provided 1674 GWh. In 2012, the energy supplied electricity to over 230,000 average Australian homes. The aggregated capacity factor of Victorian wind farms in 2012 (comparing total generation to total installed capacity) is 34%.



RE in Victoria

	Bio energy	Hydro	Solar	Wind	Total
🟦 2000	81	587	0.4	0.09	668
🟥 2005	86	655	2.2	104	847
🟩 2009	121	802	20.1	428	1372
🟪 2010	124	802	75.1	428	1429

Output (GWh)

	Bio energy	Hydro	Solar	Wind	Total
🟦 2009	554	506	18	1028	2106
🟥 2010	605	748	61	1217	2632
🟩 2011	633	813	225	1280	2951
🟪 2012	651	950	550	1674	3825

Figure. 4.RE Installed capacity in Victoria state- Australia (MW), and RE output generated form Installed sources in Victoria (GWh)

Despite of having numerous installed EPS (electricity power systems), still few house owners find that the prices of the power connected through grid are expensive [5] [2]. Therefore, a need of alternative solution is essential, and alternatively using RE technologies will mitigate the current problems, and will escalate the driving improvement in clean technologies, which is essential component of the clean energy plan for Victoria.

II. LITERATURE REVIEW

The first and foremost purpose of the literature review presented here is to identify the alternative solution to find the facts of knowledge gap that justifies the requirements for the increasing emission release, escalating COE, and also finding sustainability of current resource in Victoria state. Secondly, it provides support for the methodology that has been proposed in the study and is the foundation of information.

A. Bahadori et al proposed that according to Australia's future energy supply an affordable, reliable, environmentally sustainable energy is necessary to Australia's future economic growth and prosperity. It also needs a lower GHG emission release EPS in order to meet the challenges posed by climatic changes driven by rising level of carbon dioxide in the Earth's atmosphere [6]. **T. Yusaf et al** In Australia, 50% of GHG emissions released due to electricity generation with a large part of the remaining emissions represent the transport and vehicular sectors. Australia's population continues to grow; consequently, the dependency of energy supply will also grow. Alternatively by raising the usage of RE sources will assist in reduction to GHG emission from national contribution to the world; thereby it not only increases the sustainability of energy generating resources but also reduces the dependency on foreign countries [*7*]**.**

Shaheen Hasan Chowdhury.et.al, the purpose of any EPS is to accommodate sufficient electricity to everyone through clean technology anywhere and anytime in the country. Through a modern EPS by integrating electrical energy from clean RE, sources into the nation’s electric grid to enhance the reliability, efficiency, and security of the power system can be accomplished. For optimal electricity generation from RE sources, the prospective electricity generation from wind turbines and PV cells are proposed to increase electrical energy in to the power grid of Australia. RE is a vital for EPS because it not only generates electricity but also reduce thousands of tons of carbon dioxide emissions [8].

K. S. V. Swarna et al. investigated the prospects of RE in Semi-arid region, North East region of Victoria - Australia, and designed a Hybrid model for RE generation. The study compared NPC (Net present cost), COE and Renewable energy factor (RF) in six different locations. The study reported that a location that is suitable for wind energy generation is also feasible for wind-PV-grid system and the integration of RE, especially solar energy and wind into the grid will reduce the energy crisis worldwide and reduces the COE and emission spread in to the atmosphere. [9].

Liu et. al. carried out economic and environmental performance parameters of a PV-wind-grid HPS in hot arid Australia through a computer based modeling system. The study used the local meteorological data of wind and solar of Alice Spring region, a typical hot arid region-Australia. The study concluded that the region is capable to reduce not only COE but also decreases the emissions of carbon dioxide, sulphur dioxide and nitrogen oxides by less than 40% as compared to the standard grid power system [*10*].

Harish Kumar R. N performed a study by comparing five different proposed methodologies for a residential load at Geelong area Victoria State, Australia. The study compared the change of COE ($), Emission (Kilogram/year-kg/yr), and (RF), the study determined that system with PV-grid-converter-and with optimum battery size optimizes the COE, and contributes considerably less emission to the atmosphere, by achieving high RF [11]

Harish Kumar R. N. proposed a HPS system with a desire of 100 percent RE to supply electricity to North Island-New Zealand. The study reported that a HPS with PV-Biogas Generator- Converter-Battery; Auckland based showed a cost effective and environmentally friendly results [12].

Harish Kumar R. N conducted a feasibility Study; PV- Biomass Based HPS integrated to Grid- South Australia- Australia. The study concluded that for yearly unstable electricity load-a grid connected HPS system is cost effective, environmental friendly and a feasible solution [13].Liu et. al aimed to investigate the economic, technical, and environmental performance of residential PV system based on the Queensland (Australia) climatic conditions. The study collected the solar irradiation data of four typical climate zones of Queensland, including tropical, sub-tropical, hot arid and warm temperature zone. The study observed that under specific climatic conditions of eleven major cities belonged to Queensland-PV system effectively decreases COE and mitigates carbon dioxide emission. The study concluded that a 6-kilowatt (kW) PV system in Townsville is able to supply 61% of the total electricity load; it not only saves approximately over 90% of payments paid for electricity bills, but also reduces approximately 95% of carbon dioxide emission [14]

Sonali Goel et al. considered the load profile of a village by analyzing configuration of equipments through HOMER, for carbon dioxide reduction and future load demand, solar-wind-hydro-diesel generator system was recommended to install. HPS are successfully functional in areas wherever grid extension is almost impossible or uneconomical [*15*]. **K.H. Solangi et al** solar energy is one of the most promising RE. It is very consistent and is not significantly vulnerable to changes in seasonal weather patterns. Solar energy can be exploited through the solar thermal and solar panels for various applications. Power generated by solar energy is not just relatively simpler, it is also environmental friendly compared to power generation using Non-RE sources. Considering the increasing usage of energy worldwide throughout the years, alternatively switching to solar energy can be a viable move. Globally, policy analyses have increasingly focused on the effects of negative externalities on environmental quality, human health, economic development, or institutional objectives such as emissions growth management [*16*]. HOMER, developed by NREL (National Renewable Energy Laboratory) has been repeatedly used as a preferred tool to design HPS in order to supply electricity, through RE, Non-RE connected to grid/off grid/standalone system, and with or without a storage. The computer model assists in estimating the COE, NPC, RF, and emission with the designed EPS. The modeling of HPS by various researchers and the obtained results are as shown in the Table.1.

Table. 1. Modelled power system to supply electricity in various places by determining RF, NPC, and COE

Study	Place	Hybrid Model	Electricity Load	RF%	NPC($)	COE/kWh($)
Harish Kumar R.N [11]	Residential load-Geelong, Victoria, Australia	PV-C-B	16 kwh/day-4.2 kW peak	100	21,091	0.283
		G-PV-C-B	16 kwh/day-4.2 kW peak	86	22,450	0.30
		G- PV-C-B	16 kwh/day-4.2 kW peak	89	10,979	0.147
		G-PV-C-G	16 kwh/day-4.2 kW peak	80	13, 4760	0.184
		G	16 kwh/day-143 kW peak	0	19,624	0 .263
Harish Kumar R.N [13]	South Australia, Australia	PV-C-B-B.G	1617 kwh/day-4.2 kW peak	79	91377	0.129
Harish Kumar R.N [12]	North Island Context-New Zealand	PV-C-B-B.G	1675 kWh/day- 185 kW peak	100	1452058	0.186
Deepak Kumar Lal, et al. [17]	Sundargarh district of Orissa state,India.	PV-W-H-D.G	3MWh/d-307kW	93	2687272	0.194
Liu et. al [10].	Alice Spring based, Hot Arid Australia	PV-W-G	100 kWh/day-14kW peak	58	119337	0.256
K. S. V. Swarna et al. [9]	Mount Hotham	W-G	1621kWh/day-178kW peak	87	1,649,920	0.218
	Falls Creek	W-G	1621kWh/day-178kW peak	79	1,878,971	0.248
	Mount Buller	W-G	1621kWh/day-178kW peak	71	2,208,844	0.292
	Wangaratta	PV-G	1621 kWh/day-178kW peak	45	2,479,722	0.343
	Edi Upper	PV-G	1621kWh/day-178kW peak	43	2,694,285	0.356
	Benalla	PV-G	17kWh/day-18kW peak	42	2,722,924	0.360
	Langkawi small load	W-D.G-B-C	17kWh/day-18kW peak	-	118,660	1.217
	Socotra Islands small load	PV-D,G-B-C	17kWh/day-18kW peak	-	138,499	1.420
Ahmed M. A. Haidar, [18]	Langkawi different loads	PV-D.G-B-C	17kWh/day-18kW peak	-	397,646	1.109
	Socotra Islands different loads	PV-D.G-B-C	17kWh/day-18kW peak	-	138,499	1.420
S. Rehman [19]	village in Saudi Arabia	PV-W-D.G	47 MWh/day-14.4MW peak	0.36	41389628	0.212
H.Rezzouk , M.Hatti, A.Mellit [20]	Bou-Ismail wilaya of Tipaza -Algeria	PV-D.G-B	501 kWh/day-111 kW peak	0.28	649360	0.275
Shaheen Hasan Chowdhury [8]	Australia	W-G-PV	1000 kWh/day- 135 kW peak	73	1,152,635	0.247
Gerry, and Sonia [21]	Latitude- 30° 32’ N and longitude- 76°39’ E	PV-H-W-B.G-C	291 kWh/day- 53 kW peak	100	1,46,987	0.123
V.Arangarajan [22]	Victoria, Australia	W-PV-G	1621 kWh/day- 178 kW peak	71	1463352	0.193
				77	1232388	0.163
R. Sen, S.C. Bhattacharyya [23]	Chhattisgarh, India	PV-W-H-BioDiesel-C	3 Loads- 493 kWh/day-159kW Peak (together	90	673,147	0.420
A. Asrari et al. [24]	Binalood region,Iran	PV-W-G	145 kWh/d and 13.4 kW,	45	102,637	0.214
A. Ghasemi et al. [25]	Rural electrification-Eastern Iran	PV-D.G-C-B	200 kWh/day 18 Kw peak	24	264,544	0.397
S. Bhattacharjee, A. Dey [26]	Ranirbajar, Agartala, India	PV-B.G-G	92 kWh/day 25 Kw peak	91	78980	0.143
G. Liu et al. [14]	Queensland-Australia	PV-G-C-B	23 kWh/day 3.1 kW peak	61	6682	0.071
					$ 8819	0.092
G.M. Shafiullah et al. [3]	Australia Context	PV-G--C	100 kWh/day 14 kW peak	42	171565	0.368

*Abbreviations- W- Wind, PV- Photovoltaic, D.G- Diesel generator, C-Converter, B.G- Biogas Generator, H-Hydro, G-generator.

Storage devices including batteries, super capacitors, and flywheels can be used to match generation with demand in micro grids. Storage can supply generation deficiencies, reduce load surges by providing ride-through capability for short periods, reduce network losses, and improve the protection system by contributing to fault currents [27].

Mohammad Taufiqul Arif. proposed that it is vital to investigate the effective utilization of solar and wind energy by determining the effective storage size according to the load demand in various potential locations in Australia. Besides the storage not only minimizes GHG emission but also reduces overall COE by escalating the usage of solar and wind energies. However, to manage total energy generated by the RE sources and to manage the daily load demand, storage is essential even where solar radiation and wind speed are strong and duration is greater. Storage significantly adds flexibility in RE by minimizing intermittent nature of RE, and improves energy management [28].

R. Huva et al presented the estimated potential power output for wind and solar farms, and its combinations across a great domain of more than few hundred kilometers. The estimated back-up power capacity is necessary to meet the demand from a sample RE network optimization model, which is steered with output from a high resolution mesoscale weather model of Victoria climate, as shown in the Figure.5 [29].

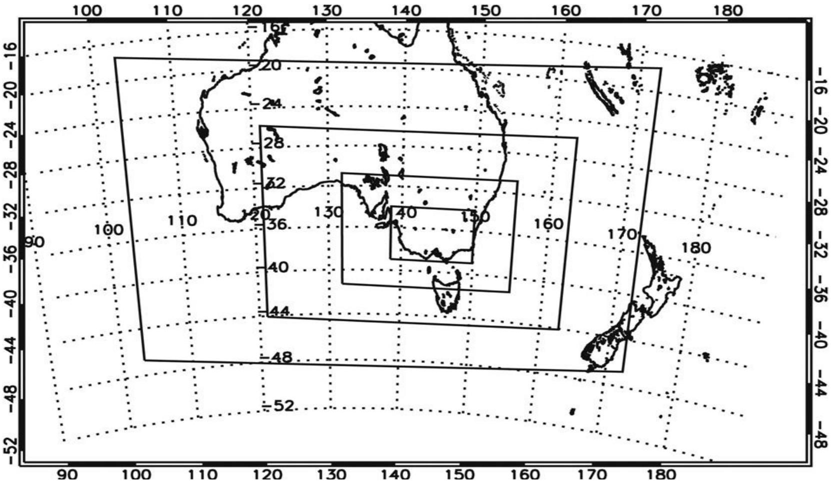


Figure. 5. WRF domains to determine the solar and Wind data to estimate the potential of power generation

The model finds the network configuration that minimizes the price of the system, and showed that considerably less installed capacity of both renewable and back up is essential if the preference of locations for wind and solar farms takes into consideration. Selection of sites from within the inner grid of WRF was experimented with and the level of backup electricity generation varied to show potential combinations of energy sources for Victoria in the future. The study revealed that no matter the site selection technique, there were inevitable periods of low renewable output. Undoubtedly, a better choice of locations would assist in reducing variability, while longer simulations would provide exposure to a greater range of meteorological conditions that affect RE output whereas the study further need a focus on the economical factors for Victoria state [29].

From literature review, it was noticed that there is a need to focus on economical factors for Victoria State. By considering RE sources such as PV, Wind, and fuel, generators can mitigate the emission release, reduces the COE, more reliable, and assists with resource sustainability. It is seen that HOMER tool assists in modeling a HPS to understand the outcomes that will likely result after real implementation.

III. HOMER ECONOMICAL, AND ENVIRONMENTAL ANALYSIS

To compare various distributed generation; both conventional and RE energy sources with a battery was considered. HOMER NREL software tool used to identify the feasibility study, and economical analysis of modeled Hybrid power systems; it defines the GHG emission spread in the atmosphere.

1) NPC: The NPC of a system is the subtraction of total present price of all the costs that it incurs over its lifetime and the present value of all the income earned over its lifetime. HOMER calculates the total net present cost using (1) [26].

$$C_{NPC} = \frac{C_{ann,total}}{CRF(i, R_{proj})} \qquad (1)$$

Where:

$C_{ann,tot}$ =total annualized cost [$/yr]

CRF() = capital recovery factor

i = interest rate [%]

R_{proj} = project lifetime [yr]

The total net present cost is HOMER's main economic output. HOMER ranks all systems according to total net present cost.

2)) CRF- The capital recovery factor (CRF) is a ratio used to calculate the present value of an annuity (a series of equal annual cash flows). The equation to determine capital recovery factor is (2) [26]:
Where:
i=real interest rate
N=number of years

3) COE-HOMER defines the levelized COE as the cost per kWh of useful electricity produced by the system. To calculate the COE, HOMER divides the annualized cost of producing electricity the total useful electric energy production. The equation to determine COE is (3) [30]

$$COE = \frac{C_{ann,tot}}{E_{prim,AC} + E_{prim,DC}} \qquad (3)$$

WHERE:
$C_{ann,tot}$ = total annualized cost of the system [$/yr]
c_{boiler} = boiler marginal cost [$/kWh]
$E_{thermal}$ = total thermal load served [kWh/yr]
$E_{prim,AC}$ = AC primary load served [kWh/yr]
$E_{prim,DC}$ = DC primary load served [kWh/yr]
E_{def} = deferrable load served [kWh/yr]
$E_{grid,sales}$ = total grid sales [kWh/yr]

4) RF RF-The RF is the portion of the system's total energy generated from RE sources. HOMER calculates the RF by dividing the total annual RE production by the total energy production. The equation to estimate renewable fraction is (4):

$$f_{ren} = \frac{E_{ren} + H_{ren}}{E_{TOT} + H_{tot}} \qquad (4)$$

Where: E_{ren}=renewable electrical production [kHz]
H_{ren}=renewable thermal production [kHz]
E_{tot}=total electrical production [kHz]
H_{tot}=total thermal production [kWh]

IV. RESOURCE ASSESSMENT AND ELECTRICITY LOAD

The availability of solar energy in Victoria State from 1st July 2013 to 31st may 2014 is shown in Figure.6. *[31]*.It can be noticed that a significant energy can be generated using with the available potential solar energy.

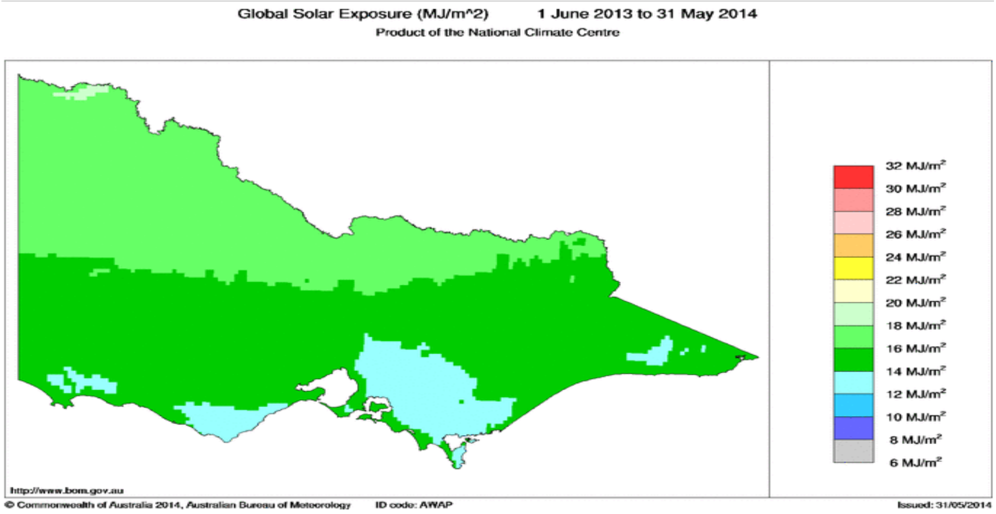


Figure. 6. Availability of solar energy in Victoria State Australia

The ranking system performed by collecting the average annual Solar and Wind data from BOM and NASA is listed in Table.2. The location which receives maximum Solar energy is Mildura, followed by Bendigo, Shepparton, Warragul, Ballarat, Geelong, Warrnambool, Melbourne, and Traralgon. Whereas for Wind, the location that receives highest wind speed is Warrnambool and followed by Geelong, Traralgon, Warragul, Mildura, Melbourne, Bendigo, Shepparton, and Ballarat.

Table.2: Ranking of solar radiation and wind speed in Victoria

Place	**Latitude (South) (°)**	**Longitude (East)(°)**	**Elevation (Meters)**	**Solar Ranking**	**Wind Ranking**
Mildura	34.19	142.16	78	1	5
Bendigo	36.76	144.30	199	2	7
Shepparton	36.38	145.40	264	2	7
Warragul	38.16	145.93	120	4	4
Ballarat	37.56	143.85	196	5	9
Geelong	38.16	114.36	101	6	2
Warrnambool	38.38	142.48	80	6	1
Melbourne	37.84	114.98	207	8	6
Traralgon	38.38	142.48	150	9	2

Solar energy is one of the cleanest energy sources that do not contribute to the global warming. Besides, the Sun radiates more energy in one second than as compared to the people who has used since from the beginning of time. The availability of economical and plentiful energy with lowest environmental and ecological hazards associated with its production is the first and foremost important factor for preferred enhancement in the quality of human's life. In remote regions of the earth, PV's are considered as today's best answer for decentralized energy supply as per 2010 BP Statistical Energy Survey [16]. Therefore, by considering the simplicity, easier approach, PV is selected as the best RE resource and Mildura was selected for the PV solar resource. The selected locations solar elevation and Azimuth angle are retrieved from University of Oregano sun chart program, as shown in the Figure. 7 [32]. The scaled annual average solar radiation in Mildura region is 5.17 kWh/m^2/day and the average clearness index is 0.548.

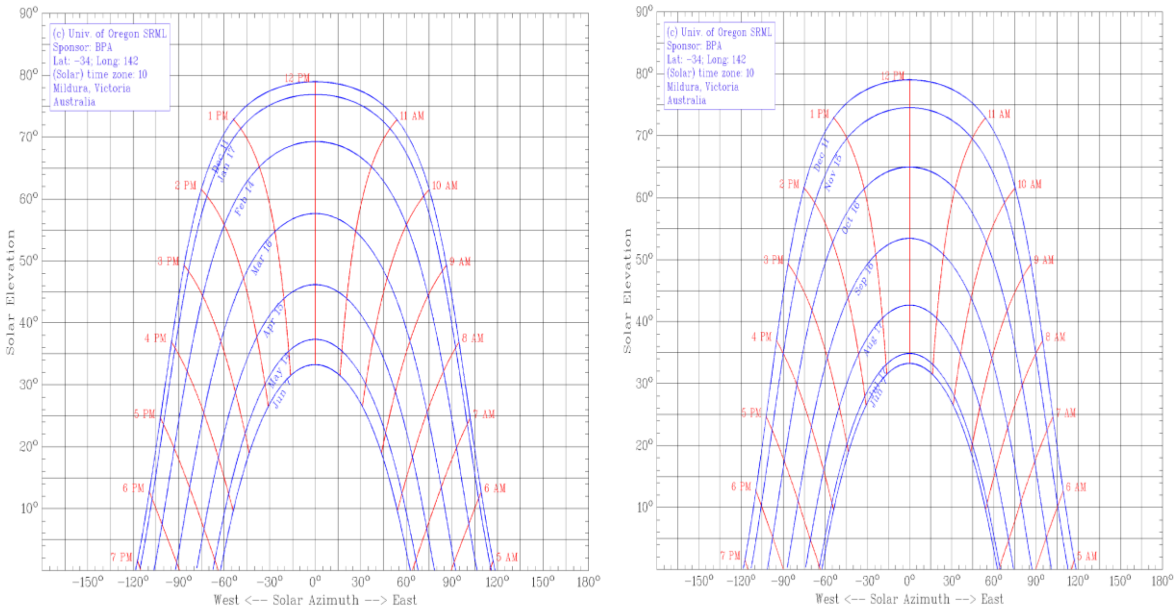
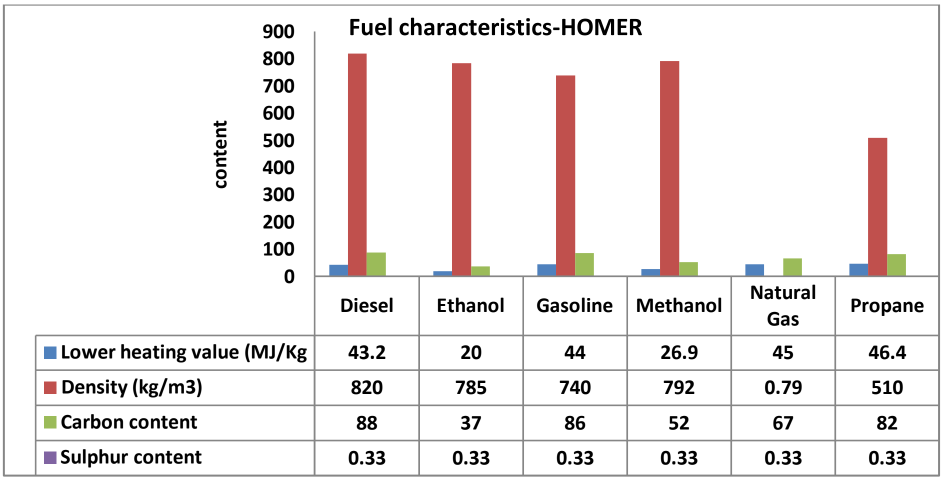


Figure. 7. Solar elevation, and solar azimuth for Mildura-January-June (left), and from June- December (right)

A consideration of Non-RE resource was accounted; comparison was performed among the Non-RE power generators based on HOMER tool as shown in the Figure. 8.; the details of the generators such as diesel, ethanol, gasoline, methanol, propone were considered for study, and their lower heating value, density, carbon content, and sulphur content is compared, and it was determined that ethanol fuel has least carbon content. Since with the concern of carbon content and its emission; ethanol based fuel generator was opted for modeling HPS in order to supply electricity.



	Diesel	Ethanol	Gasoline	Methanol	Natural Gas	Propane
🟦 Lower heating value (MJ/Kg	43.2	20	44	26.9	45	46.4
🟥 Density (kg/m3)	820	785	740	792	0.79	510
🟩 Carbon content	88	37	86	52	67	82
🟪 Sulphur content	0.33	0.33	0.33	0.33	0.33	0.33

Figure. 8. Fuel based power generators

The electricity load is as shown in the Figure. 9. The retrieved load is between 2011 June to May 2012. From the figure it can be noticed that the load is fluctuating at each time and at each particular month. The demand is peak during the month of Jan, Dec, and November, while low during the month of May, June, and July.

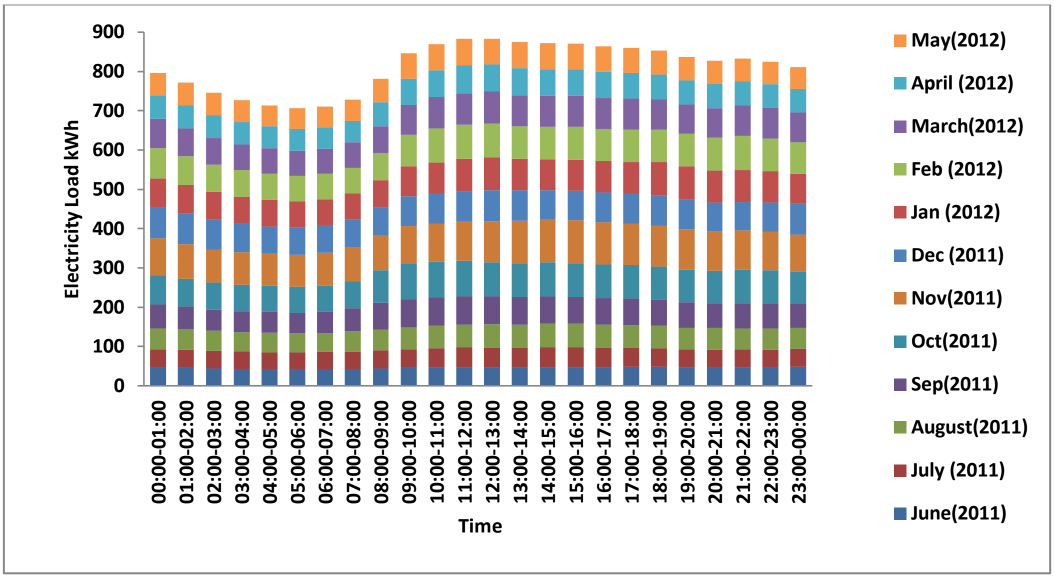


Figure. 9. Electricity load from June 2011 to May 2012

A typical daily load profile of the electricity load is as shown in the Figure. 10; the load demand is above 65 kW at all time.

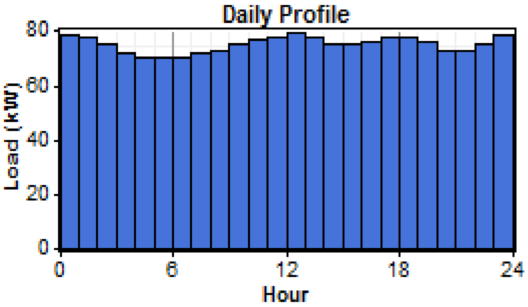


Figure. 10. Daily profile of electricity load

V. PROPOSED HYBRID POWER SYSTEM

The proposed Hybrid power system is as shown in the figure. 11; in this system a primary load, PV cell, converter, Ethanol generator, Battery were considered.

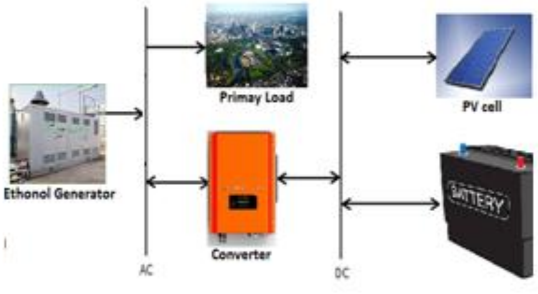


Figure. 11. System components for smart grid design

VI. RESULTS AND DISCUSSION

1. PV MODULE

PV majorly depends on the solar radiation available in a particular location [*12*]; PV converts the received solar energy in to electric current [*13*]. The generated output from PV cells can be calculated using (5) [*11*]. In this study, the temperature effects are not considered.

$$P_{PV} = Y_{PV} f_{PV} \left(\frac{G_T}{G_{T,STC}} \right) \quad (5)$$

Where Y_{PV}—rated capacity of PV array, meaning power
Output, considering standard conditions in Kilo Watt (kW)
f_{PV} —PV de-rating [%]
G_T —Solar radiation exposure on PV module [kW/m^2]
$G_{T,STC}$ —incident radiation, considering standard test conditions (1 kW/m^2)

The electricity generated from PV in HOMER is direct current (DC), to convert to AC a converter is hooked to supply electricity to the end users [*13*]. The PV was tilted 38.78 ° to the horizontal throughout the year in the same angle to the horizontal surface (earth), with an azimuth angle of 180 ° (West-South). The derating factor, ground reflectance, and lifetime years are considered as 80%, 20%, and 20 years respectively. A capital cost of 1000$, with a replacement cost of 800$ were considered during the study. The obtained cost curve for overall installed capacity is as shown in the Figure. 12. The rated capacity of modeled PV is 600 kW. The mean output, and capacity factor are 2,598 kWh/d, and 18 %. As an overall, the minimum output generated from PV is 0; when there is no solar radiation, and the maximum output obtained was 593 kW when maximum solar radiation was available. PV annually operated for 4,382 hours, by generating 948,327 kWh/year electricity, and thereby resulted with a penetration of 162%. The determined levelized cost of PV is 0.0549$/kWh. The working and the obtained PV output is shown in the Figure. 12; in detailed with change of color.

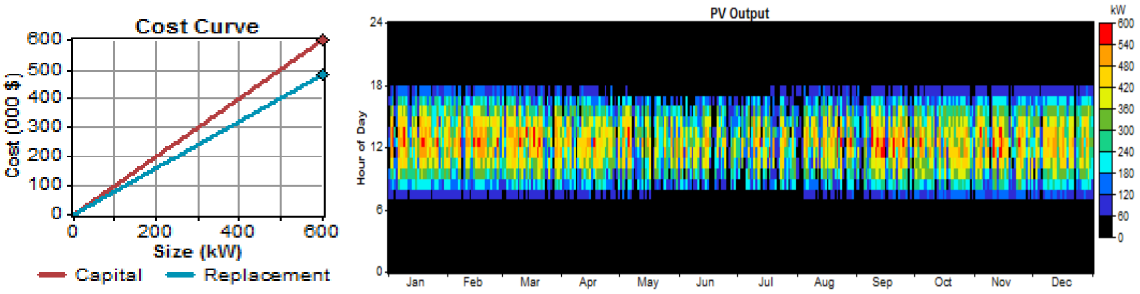


Figure.12. Cost curve and output of PV cell

2. CONVERTER

The converter is hooked to the PV for converting AC to DC to readily use the generated electricity from PV's. The cost of the converter is considered as 200 $, the replacement cost is considered as 180$, and the overall cost curve for the rated inverter is shown in the Figure. 13. The annual converter output is as shown in the Figure. 13. The rated capacity is similar to PV; 600 kW, the mean output is 62 kW. In an overall, the minimum output was 0 kW, whereas the maximum output is 178 kW, and the capacity factor is 10.3%. Energy of 599,525 kWh/yr from PV is supplied to the converter- DC, and after conversion, energy out of AC 539,573 kWk/yr is obtained. In order to convert the electricity, the converter operated for 8,256 hr/yr, and the overall loss occurred was 59952 kWh/yr.

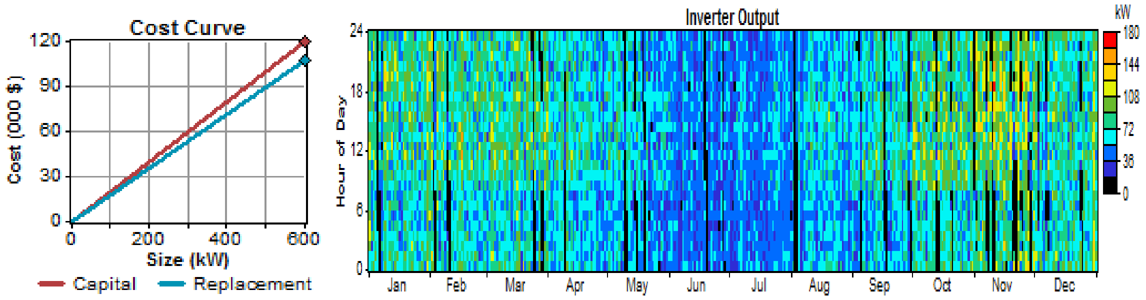


Figure. 13. Cost curve and Inverter output

3. BATTERY

The cost curve, monthly statistics of state of charge and battery bank state of charge are as shown in the Figure. 14. Battery is used to store electricity generated form PV and ethanol generator; it is majorly used because the power generation produced from PV is only when solar radiation is available. The obtained results from the simulation of battery nominal capacity is 4,560 kWh, usable nominal capacity is 2,736 kWh, autonomy is 40.9 hr, lifetime throughput is 6,341,160 kWh, battery wear cost is 0.037 $/kWh, average energy cost is 0.014 $/kWh, energy in is 401,588 kWh/yr, energy out 322,956 kWh/yr, storage depletion 1,882 kWh/yr, losses 76,750 kWh/yr, annual throughput 361,076 kWh/yr, and expected life is 12 yr. The state of charge (SOC) can be estimated using (6).

$$\text{SOC}(i+1)=\text{SOC}(i)-\text{SOC}\,(i).\sigma_{SDR} \pm I_B(i).\Delta t.\eta_{BCE} \quad (6)\ [13]$$

Where SOC (t)-state of charge,
σ_{SDR-} self discharge rate,
$\pm I_B(t)$-battery charge (+) and discharge (-) current,
Δt- time in hours,
η_{BCE}- battery charging efficiency.
During discharge, η_{BCE} is assumed as 1.
During charging, η_{BCE}-0.65 to 0.85, changes, and depends upon charge of current

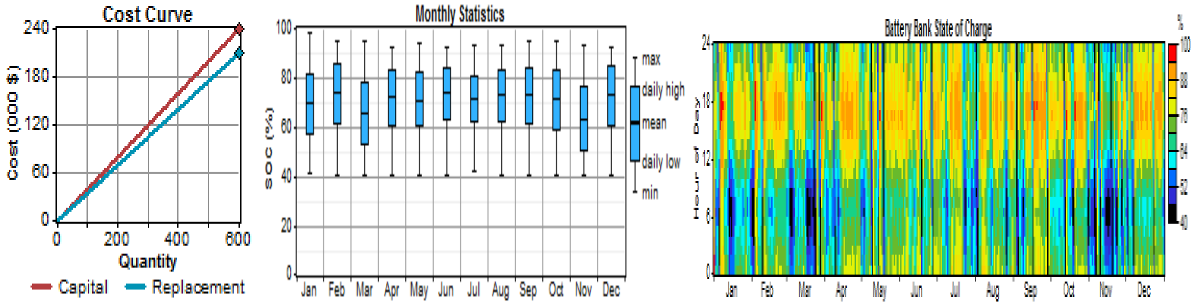


Figure.14. Cost curve, monthly statistics of state of charge, and battery bank state of charge

4. FUEL GENERATOR

Ethanol (ethyl alcohol) fuel is similar as alcohol found in alcoholic beverage. Ethanol is produced by fermentation process of plant sugar, with wide variety of feedstock such as bagasse, sugarcane, sugar beet, miscanthus, grain sorghum, sorghum, barley, switch grass, hemp, barley, potatoes, sweet potatoes, kenaf, sunflower, cassava, molasses, corn, fruit, wheat, gains, Stover, cotton, straw, other biomass, and also many other types of cellulose waste and harvesting. Ethanol is one of the promising fuels to fight air pollution [*33*]. The cost curve, and generator output of Ethnol generator is as shown in the Figure. 15. The generator was operated for 791 hr/yr, number of starts is 26 starts/yr, operational life is 19.0 yr, capacity factor is 7.13 %, fixed generation cost is 7.73 $/hr, marginal generation cost is 0.200 $/kWh, electrical production is 62,447 kWh/yr, mean electrical output is 78.9 kW, minimum electrical output is 30.0 kW, maximum electrical output is 100 kW, fuel consumption is 21,940 Liter/yr, specific fuel consumption is 0.351 liter/kWh, fuel energy input is 95,682 kWh/yr, and mean electrical efficiency is 65.3%.

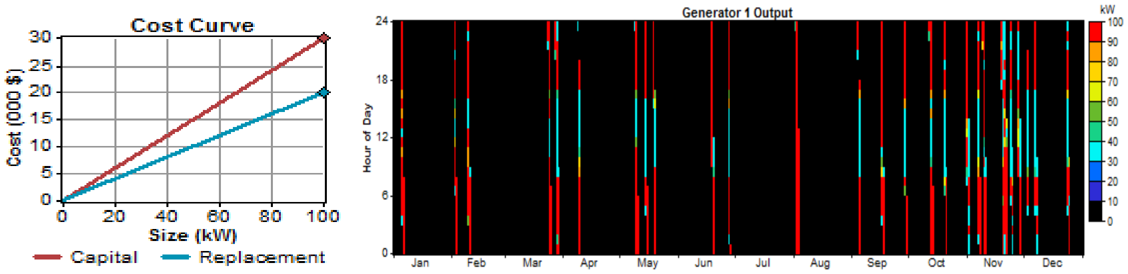


Figure. 15. Cost curve, and generator output of Ethnol generator

5. COE

A comparison of electricity household prices among developed countries- Australia, United States (US), European Union (EU), Canada and Japan revealed that US, EU, Canada, and Japan had a competitive and stable electricity prices between 2002-2010/11 years. In contrast, Australian electricity were stable only between 2002 and 2007, but afterwards a significant electricity house hold price hike was seen- 40% hike in real terms, and it has been also noted that there will be 30% projected price hike over next two years after march 2012. As per year 2011 four states belonging to Australia-South Australia, New South Wales, Victoria, and Western Australia fall under highest house hold electricity prices from top after Denmark and Germany. On the other hand the remaining states- Tasmania (eleventh highest), Queensland (sixteenth), the Northern Territory (twenty-first) and the ACT (twenty-ninth) respectively, and lie outside of the top eleven out of 91 comparator countries. The household electricity prices of Australia are now considered as higher than that of in Japan, EU, US, and Canada. In the year 2012, with the exchange rates the household electricity prices in Australia will be about 30% higher than in Japan, 60% higher than in the EU, 160% than in the US. and 250% higher than in Canada by 2013/14 [*34*].In the past, Australia had a stable and competitive electricity prices, but in the recent years due to the developed world standards, and due to the age factor of the power lines, the transmission lines and distributions lines which supply electricity to the electricity load have become old and had to be replaced with new ones, and unfortunately this led to increase of electricity prices, which reflect on the electricity bill at regular intervals of time when it turns up [*11*]. The electricity prices imposed in Australia on small business and households are highly regulated. National Electricity Market (NEM) decides electricity prices of most states in Australia to the end users. The states that are connected to NEM are New South Wales, Victoria, Queensland, South Australia and Tasmania, this service is attained through state and federal regulation together, the only state- Western Australia is not part of NEM, and formed its own system of regulation. While determining the COE there are various charges which are included prior to the final payment, the charges broadly fall into three categories [*35*]; the maximum extra charges which are included in the bill are network costs, whole sale costs, and remaining charges are added due to retail operation cost. However, the percentage of each charge varies time to time, and year to year.

- Retail operation costs, includes meter reading, billing, and marketing.
- Network costs, includes transmission and distribution cost.
- Wholesale electricity costs.

The in detail tariff structuring is broadly classified below [*35*].

Tariff- tariff is a pricing structure that is imposed on the end users for energy consumption. The charges are classified into two parts.

- Fixed charge- The charged added due to supply of energy to premises.
- Variable charge- The charge added for energy used, and the charges computed are directly proportional to the energy consumption.

There are totally three types of tariffs based on different offers

- Standard offer– set by the retailer and offers are published.
- Market retail offer– set by the retailer and offers are not published.
- Government regulated offer– set by the government with input from the retailer.

Types of tariff structure for electricity

- Single rate– The electricity rate is constant throughout the day.
- Block rate– The usage rate computed based on blocks of energy usage.
- Off-peak– The rates will be applicable during low usage periods, such as overnight.

Time of use– The electricity rates vary at different times in a day and at different times of year.
Feed-in tariff– The rates paid to the customer with regards to the amount of energy 'feed in' to the grid, from the customer for generating through one of the RE energy.

Note- Tariffs vary depending on your energy distributor, and is as shown in the Table.3 [*36*].

Table. 3.Retail Feed in tariff Electricity in Victoria Note: As per 19 June 2012

Retailers	Distribution Zone	Standard Fit cents/kWh	Transition cents/kWh	Premium fit cents/kWh
AGL	Jemena- Domestic General	25.1	33	68
	Jemena- Small General	26.3		
	United Energy- Domestic General	24.2		
	United Energy- Small General	28.3		
	Citipower- Domestic General	22.7		
	Citipower- Small Business	25.1		
	Citipower- Domestic General	26.0		
	Citipower- Small Business	25.1		
	Powercor- Domestic General	26.0		
	Powercor- small General	28.9		
	Sp Ausnet- Domestic General	26.3		
	Sp Ausnet- Small General	30.3		
Australia Power and Gas	All	1-for-1	25	60
Click Energy	All	1-for-1	29	64
Country Energy	All	1-for-1	31	60
Diamond Energy	All	1-for-1	33	68
Dodo	All	Peak Electricity Rate	25	60
Energy Australia	All	1-for-1	25	60
Lumo	All	1-for-1	31	66
Momentum	All	1-for-1	25	60
Neighbourhood Energy	All	1-for-1	25	66
Origin	All	Not less than 1-for-1	31	66
Power direct	Jemena-Domestic General	25.1	31	68
	Jemena-small business	26.3		
	United energy- Domestic business	24.2		
	United energy- small business	28.3		
	Citi power-domestic general	22.7		
	Citi power small business	25.1		
	Powercor domestic general	26.0		
	Powercor- small business	28.8		
	SP Ausnet-Domestic general	26.3		
	SP Ausnet- small business	30.3		
Red Energy	All	1-for-1	33	68.2
Simply Energy	All	1-for-1	25	60
TRUenergy	All	1-for-1	31	60

From the simulated results after designing the HPS an optimum COE of 0.191 $/kWh was determined. By comparing the electricity cost in Victoria by various energy providers- from Table.3, the obtained COE is cost effective.

6. NET PRESENT COST

The PV Capital cost is $600,000, replacement cost is $ 149,666, fuel ($) 0, O&M 0, salvage cost is $ -83,880, total 665,787. The generator 1 capital cost is $ 30,000, replacement cost is $ 6,624, O&M cost is ($) 0, fuel cost is $ 224,371, salvage cost is $-3,177, and total is $ 257,819. The Surrette 4KS25P capital cost is $240,000, replacement cost is $156,229, O&M 0, fuel ($) 0, salvage cost is $ -44,852, and total cost is $351,377. The Converter capital cost is $120,000, replacement cost is $45,065, fuel ($) 0, O&M 0 salvage cost is $-8,388, and total cost is $156,677. Therefore the overall capital of the system is $990,000, replacement cost is $357,585, O&M 0, fuel cost is $224,371 salvage cost is $-140,296, and total cost is $1,431,660- obtained from the simulated results, and is as shown in the Figure. 16.

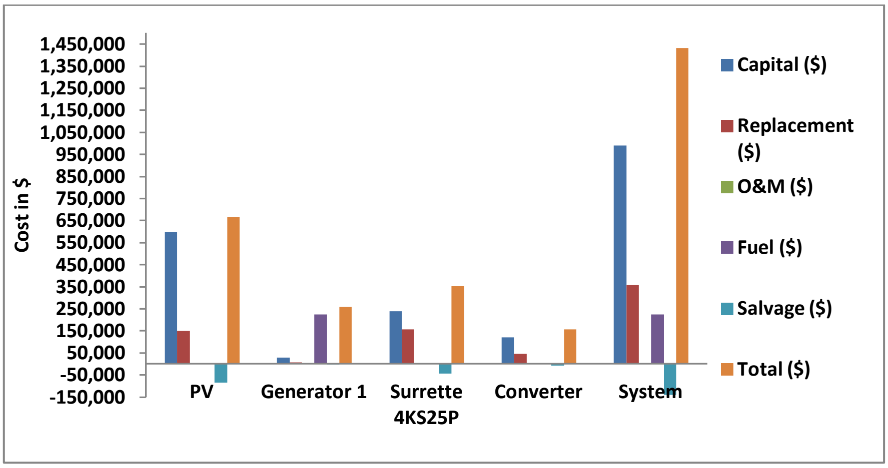


Figure.16. Net present cost of the systems used to design HPS

7. EMISSION

The emissions (kg/yr) released in the atmosphere is as shown in the Figure. 17; the obtained emission are carbon dioxide 23,120, carbon monoxide 143, unburned hydrocarbons 15.8, particulate matter 10.8, sulfur dioxide 111, and nitrogen oxides 1,273. The emission released form PV cells are zero, where as the resulted emission is released due to the usage of ethanol generator.

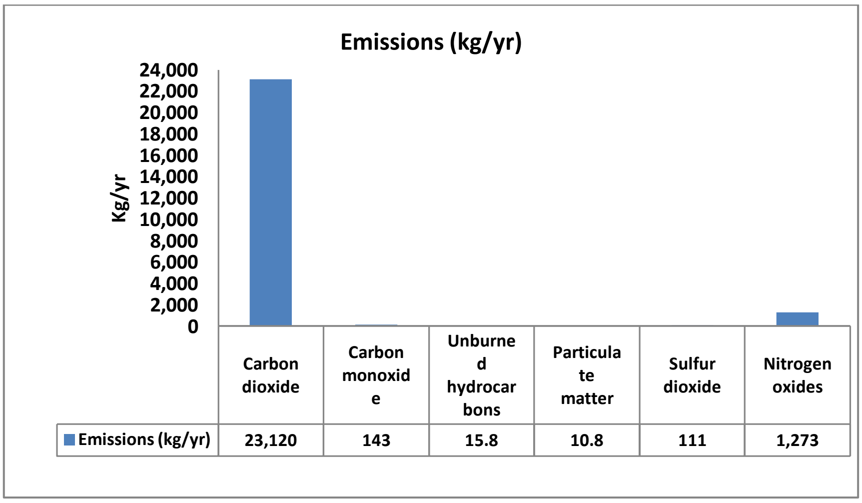


Figure.17. Emission released with the designed HPS

VII. CONCLUSION

The Feasibility study of standalone HPS-with PV, converter, battery, and ethanol generator in Victoria State, Australia was studies. The study determined that the initial cost of the PV modules and its supporting devices-converter are accounting the major cost. Although it accounts major cost, the GHG emitted from the PV modules is zero, which will reduce the emission penalties, reduces the release of harmful, escalates the usage of RE, leads to resource sustainability, and optimizes the COE. From the modeled HPS system, the obtained NPC, COE, RF are 1431,659 &, 0.191$/kWh, and 94%. Therefore, from the obtained results it is concluded that PV cells and ethanol generator will together make economical, environment friendly and viable system. Therefore, this performed feasibility study can be used further to implement the idea to facilitate in large-scale RE integration.

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