HYBRID ENERGY GENERATION FOR HIGH RAISED BUILDINGS: A CASE STUDY

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Abstract: Energy has become essential part of everybody's life and one of the basic infrastructure for economic development of a country. High consumption of conventional energy sources (e.g. coal, petroleum, wood) have made us to use renewable energy resources. As we know solar, hydro and wind are the three major basic sources of renewable energy. Researchers also have been working to invest high efficient techniques to harness this energy. Many tall buildings in different cities have been constructed in our country. At present, energy requirements of these building are mainly fulfilled by coal based power plants or by some other conventional power source, which has higher cost as well as greater GHG emission within a building in comparison to renewable sources of energy.

In this paper we explore the possibility of generating one third of the total energy consumption of a high rise building. For this, we have considered a standard high-raised building with 70 meter height for the case study. We have proposed a hybrid system, which produces electricity by combined effort of solar, wind and hydro. As we know generally rooftop of high building is of no use, so by installing solar panel, we can tap solar energy from building. Calculation regarding possible energy generation from different power sources viz. solar, wind, rainwater, R.O waste water & grey water. Detailed design of rooftop is given for how panel are installed and where wind turbine is located to harness maximum wind power. We also purpose concept of PAT in place of turbine to reduce cost of system and calculation have also proved its economic feasibility. Important aspect of this study is to utilize RO waste water, generally a huge amount of water gets wasted by RO purifier during purification of water and is utilized effectively.

Calculation showed that the proposed system is commercially viable for most of major as well as small cities in India. Cost benefit analysis of the system as well carbon emission by power generation have also been discussed. Pay Back period of the proposed hybrid system is also short as compared to individual PBP of different systems, therefore suitability increases from cost side also.

Key words **– Grey Water, HSWH, hybrid energy, PAT, RO water**.

I. INTRODUCTION

Energy is primary and most universal measure of all kind of work by human beings and nature. World's energy requirements are increasing day by day with increase in population rate and high growth rate. Recent assessments suggest that as many as 1.3 billion people still do not have access to electricity, and more than 2.6 billion people rely on traditional biomass for cooking and heating [1]. India is one of the largest and fastest growing economies in the world, as well as an expansive population of above 1.2 billion people. The energy consumption of India is the fourth biggest after China, USA and Russia. There is a very high demand for energy, which is currently satisfied mainly by coal, foreign oil and petroleum, which apart from being a non-renewable, and therefore non-permanent solution to the energy crisis, it is also detrimental to the environment.

A building represents about 32% of the total final energy consumption in the world. In terms of primary energy consumption buildings represent around 40% in most IEA countries [10]. In USA, residential buildings and commercial buildings use almost 70% of the total electricity generated [8]. India is experiencing an unprecedented construction boom. The country developed its floor space between 2001 and 2005 and is expected to add 35 billion m2 of new building by 2050. Building accounts for 35% of total final energy consumption in India today [7]. Thus, due to increase in energy demands, we have to think of new possible energy saving techniques. These new techniques may include use of Renewable Sources of Energy for generation of electricity. Renewable sources contributed 19 percent to our energy consumption and 22 percent to our electricity generation in 2012 and 2013, respectively [9]. Smart buildings with advanced energy efficiency and security technology play an important role in sustainable infrastructure development. Around 40% energy savings can be realized through Intelligent Building Automation [14]. The new Leela Hotel in New Delhi is a prime example for green and smart buildings in India, contributing to sustainable urban development. We can also further think of zero energy buildings[8] which not only produces their own electricity but also consume almost negligible energy from grid and green buildings[11], which uses less water, optimizes energy efficiency, conserves natural resources and provides healthier space for occupants. There are many major initiatives taken by GOI like subsidized solar cell, solar cooker, solar air heaters [12], use of roof top solar energy systems and passive building design techniques used in buildings.

II. Scope and availability in India

Renewable Energy has vast potential in India. RE comes under the purview of The Ministry of New and Renewable Energy. India was the first country in the world to set-up a Ministry of Non-Conventional Energy Resources in early 1980's. India's Cumulative grid interactive renewable capacity (excluding large hydro) has reached 34.35 GW[12]. Renewable energy contribution in total installed capacity is 30% (including large hydro)[13]. India has the world's fifth largest wind power market and plans to add about 100GW of solar power capacity by 2022.

Unlike many other solar markets, India is fundamentally an energy deficient country. The average peak power deficit is more than 10% over the last seven years ending in 2013. Although the per capita consumption is very low but the demand for energy will continue to rise owing to economic growth and a changing lifestyle. Conventional power sources are unable to cope with the rising demand as plants and projects stall due to unavailability of fuels or environment and social concerns. India's planning commission projects that dependency on energy imports is expected to exceed 53% of the country's total energy consumption by 2030.The government is only too aware that increasing imports of oil, gas or coal reduces its energy security and puts significant stress on the budget and country's balance of trade. Thus it is therefore imperative for India to invest more in renewable energy sources. Among these, solar is the only one that has the potential to become the backbone of the country's energy.

Based on the strong fundamentals, the International Energy Agency (IEA) predicts that India will overtake both the US and Chinese market in terms of yearly installations to become world's leading solar market by 2030.

Under the guidance of the MNRE, an Energy Development Agency has been set up with the sole purpose of financing renewable energy projects across India. The most proactive measure taken by India to increase the share of renewable energy is the enactment of the Renewable Purchase Obligation Programme, which compels distribution companies, open access consumers and captive consumers to purchase a certain proportion of their power from renewable energy sources[15]. Urbanization and economic development are leading to a rapid rise in energy demand in urban areas in our country leading to enhanced Green House Gas (GHG) emissions. Increasing population density has led to construction of high raised buildings and skyscrapers in India. For instance top 10 tallest buildings in India are listed in Table 1 along with their heights.

Energy consumption in commercial and residential buildings is very high and so need to reduce energy consumption from conventional sources (coal, diesel) in order to reduce CO2 emissions arises. We have to thus rethink of environment friendly techniques like green building concept. Green building functions by using an optimum amount of energy, consume less water, conserve natural resources, generate less waste and create spaces for healthy and comfortable living, as compared to conventional buildings. Many cities around the world are setting targets and introducing polices for promoting renewable energy and reducing GHG emissions and the countries like Australia and USA are developing the solar cities.

Rank	Name	City	Height	Floors	Year	Building Type
1	Imperial Tower 1	Mumbai	254 m	61	2010	Residential
1	Imperial Tower 2	Mumbai	254 m	61	2010	Residential
3	Ahuja Towers	Mumbai	249 m	55	2014	Residential
4	World Crest	Mumbai	223 m	57	2014	Residential
5	DB Enclave	Mumbai	210 m	52	2014	Residential
6	Kohinoor Square	Mumbai	203 m	52	2014	Mixed use
7	Ashok Towers	Mumbai	193 m	49	2009	Residential
8	Ruby Mills Tower	Mumbai	191 m	40	2013	Commercial
9	Orchid Woods 1	Mumbai	190 m	55	2013	Residential
10	Orchid Woods 2	Mumbai	190 m	55	2012	Residential

Table 1. Top 10 tallest buildings in India[16]

III. AIM AND METHODOLOGY:

An economically feasible combination of various Renewable Sources of Energy which would meet all the energy requirements of a building was the major area of our concern. As Sun is the major source of solar energy on Earth therefore it is important to harness its power. For this purpose Solar PV panels are installed over the roofs of a high raised buildings. Wind power could also be harnessed by installing wind turbines along with solar panels over the roof top. Since the wind speed increases with height therefore turbines would be more effective and generate more power as compared to ground level.

To add up to the cause of generation of electricity RO Waste Water and Rainwater Harvesting can also be utilized effectively. This would meet the demand for electricity of the building to some extent. The only difference between the two will be that RO waste water will be present throughout the year but rainwater will be available mainly during the rainy season. This will not only help in increasing the underground water table level but will also supply water for drinking purposes especially during the summers when there is scarcity of water.

In Metropolitan cities like Delhi and Mumbai a large amount of water is consumed and a major part of this is directly wasted or is discharged into the drainage systems. Since there are buildings in such cities with considerable heights so this waste water or grey water can be utilized for generation of electricity too. It is to be noted that solar will cope for major part of the demand throughout the year but would not be efficient for rainy and thus rainwater harvesting concept would now come into effect.

3.1.Case Study: We have considered a twenty-storied building in two metropolitan cities Mumbai and Delhi for the case study.

1. Delhi 28.533ºN, 77.2ºE, 293 m above mean sea level
2. Mumbai 18.9ºN, 72.817ºE, 10-15 m above mean sea level.

The potential of high raised buildings in these cities is explored towards generation of the electricity through renewable sources. The corresponding data related to the buildings is listed in Table 2 with total residents being nearly about 600. Solar, wind, small-hydro through Ro waste water and Rain-water could be our major energy sources under consideration. Factors viz. location, building topography, solar Intensity, wind- speed, rainfall intensity, water consumption rate etc. will play an important role in designing and setting up of panels, turbines etc. and thus effecting the net power generation. These potentials can then be further compared to determine the best suited means for generation in the concerned city. Energy required by the building was also analyzed and effectiveness of these sources in fulfilling the requirement is considered. A major part of energy requirement will be met by the generated power. This would not only decrease the net load on the grid system but also less pressure over the conventional power fuels like coal, oil etc. as it uses completely renewable sources of energy.

Table 2. Standard Building Specifications for calculation purpose:

Number of floors	20
Height of building	70 m
Number of flats per floor	6
Area of each flat	250 m^2
Total Available roof-top area	1500 m^2
Residents per flat	5

IV. METHODOLOGY AND PROCEDURE OF WORK:

4.1. Solar PV Cell:

Two metropolitan cities Delhi and Mumbai have been considered for the case study. Monthly solar incident radiation from NASA Surface And Solar Energy's data have been considered for Delhi[27] and Mumbai[28] .Tilt of solar panels is provided to face up maximum solar radiation during the day thus increasing the net power output. The tilt comes out to be 18º for Mumbai and 28º for Delhi. Gap should also be provided between two corresponding arrays of panels to overcome for shades which would otherwise fall on the next array thus decreasing the effectiveness of panels.

4.1.1. Specification of Solar Panel:

Solar cell data and specification are taken from SRM Manufacturer China.
Efficiency η = 19-20% [30]
We take 19% (minimum)
Capacity of 1 panel = 250 Watt
Total pieces to be used = 320
Capacity of Solar panel PV System = 250 Watt * 320 = 80 kW
Size of one piece = 1.650* 0.992 * 0.045
A_{eff} = 320 * 1.650 * 0.922 = 523.776 m
Performance Ratio = Usually 0.75 for mono-crystalline cell
Solar Panel tilt = 18° (Fixed for cost optimization)
Total Roof Top Area covered by Solar Panel = $A_{roof} = 1.90 \times A_{eff}$
Due to panel arrangement , shades and tilt more area is required.
So A_{roof} = 1000 m^2 (66.67 % of roof area)

4.1.2. Calculations for power generation from PV cells:

Month	Mean hours		Power generated kWh/day		Total Power (kWh)	
	Mumbai	Delhi	Mumbai	Delhi	Mumbai	Delhi
Jan	269.5	214.6	487.3867	384.3861	10855.43	6803.238
Feb	257.6	216.1	541.8725	440.3647	11536.06	7848.479
Mar	274.3	239.1	556.0537	482.9084	12605.42	9522.754
Apr	283.7	261	533.6623	462.7561	12512.4	9961.183
May	296.2	263.1	498.5824	438.8719	12204.97	9523.068
Jun	148.6	196.5	423.9443	403.792	5206.456	6543.928
Jul	73.4	165.9	376.9223	355.2773	2286.454	4861.072
Aug	75.9	177	373.1904	343.3352	2340.922	5011.986
Sep	165.1	219	422.4515	393.3427	5764.194	7104.499
Oct	240.2	269.3	463.5025	432.9009	9201.099	9614.862
Nov	245.8	247.2	478.4301	414.2413	9718.853	8445.399
Dec	253.2	215.8	464.9952	368.7121	9730.314	6562.315
Annual Average	2583.5	2684.6	467.9808	409.7631	103962.57	91802.783

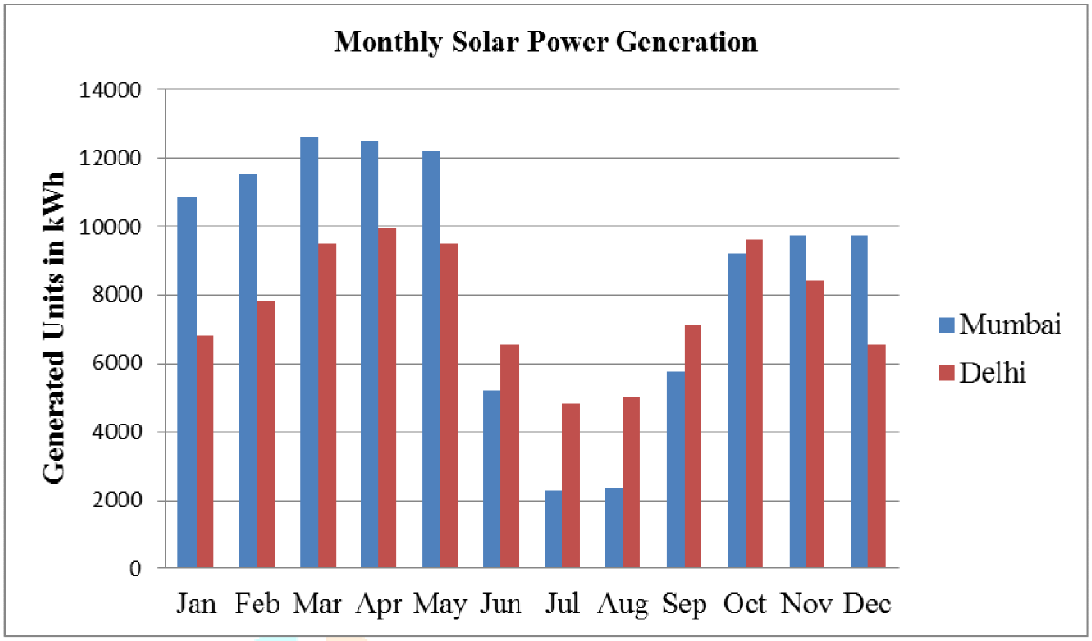

Fig.1. Comparison of expected solar power in the two cities.

4.2. Wind Energy and selection of Wind Turbines:

Data related to wind speed and other parameters related to wind are observed from records of NASA surface metrology and solar energy[43]. The percentage of wind that is available during the months and its variations in Mumbai and Delhi are studied which are then used to calculate energy generation by different turbines. This is done to check out for the most effective wind turbine in the respective cities. The number of wind turbines depends on the available roof area. A total of 10 wind turbines are to be installed effectively. Wind speed and its direction plays an important role in arrangement and setting of wind turbines on the roof.

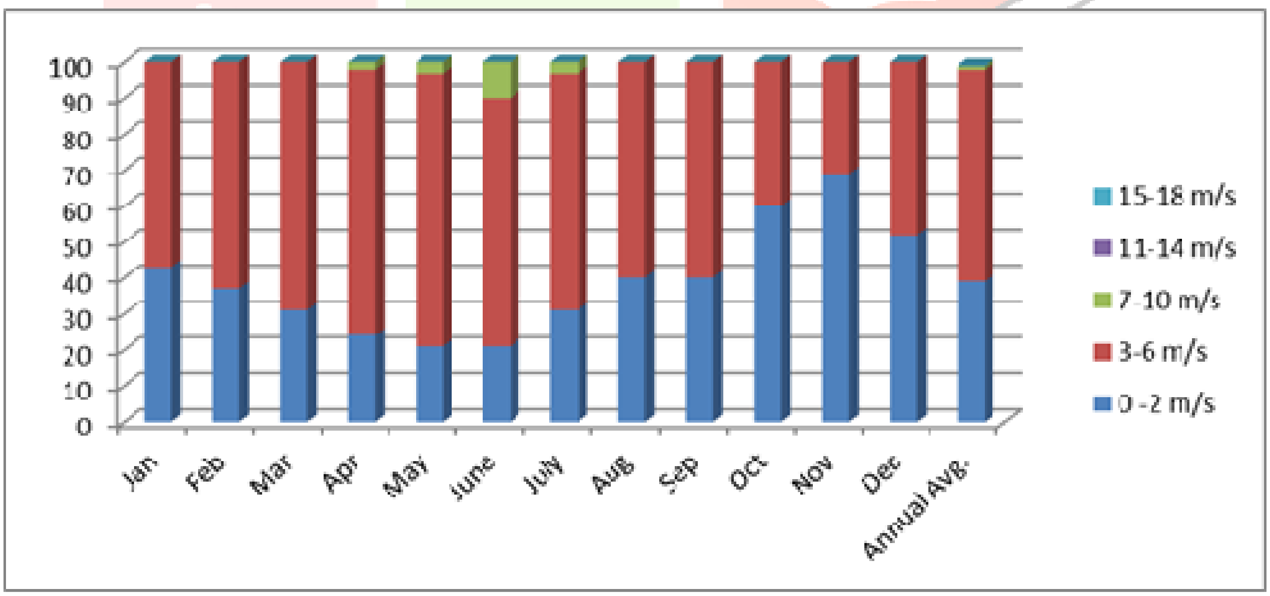

Fig.2. Monthly averaged percentage of time the wind speed at 50 m above the surface of the earth is within the indicated Range (%) in Delhi[48].

VAWT 1000W @150rpm for Mumbai		**HI-VAWT 700W @ 405 rpm for Delhi**	
Rated Power	1000w	Rated Power	700w
Max Power	1200w	Cut-In Speed	< 3 m/s
Rotor Diameter	1.5m (4.9 ft)	Rated Wind Speed	12 m/s

Blade Number	5pcs	Cut-Out Speed	15 m/s
Cut In Speed	1.8m/s (4 mph)	Rotor Diameter	1.93 m
Rated Speed	10m/s (22.3 mph)	Total Height	1.60 m
Swept Area	1.5m^2	Tower Height	3 m (min recommended)
Voltage Output	48vdc-110/220vac at 50/60hz	Turbine Weight	60 kg
Tower-Up Height	75kg (137lb)	External Darrieus	3 blades
Tower	6m(19.7ft), guy wire tower	Internal Savonius	2 layer

Table.3. Specifications of the selected wind turbines.

Pgen = % of time wind speed * Turbine Power$_{power\ curve}$*Hours$_{monthly}$

Month	Mumbai	Delhi	Month	Mumbai	Delhi
Jan	84.24	46.17	Jul	412.83	65.07
Feb	185.985	51.03	Aug	365.94	48.6
Mar	263.88	55.89	Sep	162	48.6
Apr	308.7	67.68	Oct	93.33	32.4
May	299.61	73.17	Nov	101.79	25.11
Jun	317.97	94.59	Dec	72	38.88
			Annual Avg	225.27	51.66
Annual Power generated by single Turbine (kWh)				2668.275	647.19
Annual Power generated by 10 turbines (kWh)				26682.75	6471.9

Table 4. Comparison of estimated wind power in the two cities month-wise (kWh)

4.3. RO & Grey water power generation:

Water is important to the mechanics of the human body. In fact, all the cell and organ functions made up in our entire anatomy and physiology depend on water for their functioning. Water makes up more than two thirds of the weight of the human body, and without it, humans would die in a few days. The human brain is made up of 95% water, blood is 82% and lungs 90%. A mere 2% drop in our body's water supply can trigger signs of dehydration: fuzzy short-term memory, trouble with basic math, and difficulty focusing on smaller print, such as a computer screen[49]. The Institute of Medicine determined that an adequate intake (AI) for men is roughly about 13 cups (3 litres) of total beverages a day. The AI for women is about 9 cups (2.2 litres) of total beverages a day.[50]

The RO water filter does its job of purifying drinking water by getting rid of all the salts in the water. This includes all toxic chemicals like Arsenic, Mercury, Heavy metals, Nitrates, etc. which can cause great health damage. In this process of removing the poison chemicals from water, it also removes essential minerals. This loss of essential minerals in water is insignificant when you compare it with the benefits of being sure that your water is free from all poison chemicals. so some RO water purifiers have a Cartridge called a re-mineraliser cartridge, filled with purified alkali essential mineral salts of Calcium and Magnesium, through which the pure RO water passes through. Thus the pure RO water dissolves some of the essential minerals from this remineralisation cartridge or an alkalizer to give alkaline RO water. The alkaline RO water is good for health. Osmosis is a natural process. When two liquids with different concentrations of a solute are separated by a semi-permeable membrane, the fluid has a tendency to move from low to high solute concentrations for chemical potential equilibrium.

Formally, reverse osmosis is the process of forcing a solvent from a region of high solute concentration through a semi-permeable membrane to a region of low solute concentration by applying a pressure in excess of the osmotic pressure. The largest and most important application of reverse osmosis is the separation of pure water from seawater and brackish waters; seawater or brackish water is pressurized against one surface of the membrane, causing transport of salt-depleted water across the membrane and emergence of potable drinking water from the low-pressure side.

The quantity of water wasted by an RO water purifier is about the same as the amount of pure water it produces. We say the RO has 50% recovery when it gives half the incoming water as pure water and the other half is wasted. The most inefficient RO would only have about 25% recovery, in which case it wastes 75% of the incoming water and only produces 25% pure water.[51] Conventional RO purification technology, while purifying, rejects a very high percentage of water (around 80%) and only 20% purified water is recovered.[52]

On the basis of wastewater availability there is a need to select a suitable pump, which can be works as a turbine (PAT). We have selected a 7.5 kW capacity centrifugal pump which act as turbine for generating power from all possible water sources viz. RO waste water, Grey water and rain water. First two water collections tank are to be constructed at 10th floor, one for waste RO water collection and other for grey water collection. The radius of tank say is 2 m and height is 3 m. The RO waste-water as well as grey water will be collected from upper 10 floors in the respective tanks. And the head available for power generation will be from the remaining half of the building i.e. from bottom 10 floors. The water after power generation can either be stored in an underground water tank or can be allowed to settle deep down to the ground thus raising the underground water level. This water may be directly lifted up by a hand pump or by a hydraulic pump for purposes like washing cars or as the need arises.

Now net power generated by the PAT is to be calculated. But first available RO waste water is to be calculated as follows.
Persons per flat = 5
Total number of persons in the building = Total flats $\times$ Persons per flat = 120 $\times$ 5 = 600
Water required for only drinking = 3 litres
Water required for only cooking purpose per person per day= 12 litres
Water to be purified by RO system for one person per day = 15 litres
Total water purified by RO system for a family=15 ltrs $\times$ 5 persons per family =75ltrs
Let water wastage by RO be 80% [52]
Total RO waste water per family per day = 75 $\times$ 0.8/0.2 = 300 litres
Total RO waste water in the building per day = 300 litres $\times$ 60 flats = 18000 litres
Total volume of RO water collection tank = $3.14*2^2*3=37.7\ m^3$

4.3.1.Calculations for RO water:
Pump efficiency of 7.5kW pump, η_p = wQH/P = 9.81*1000*0.014*50/7500 = 0.9156
Considering all the losses let the η_p be around 70%.
H.Nautiyal [67] have compiled various methods for PAT in his study. Considering the Sharma's performance prediction method for PAT from the same for which BEP is the criteria, turbine parameters like effective head or discharge under which the pump will work in turbine mode can be determined.
Head ratio $H_t/H_p = 1/\eta_p^{1.2}$
$H_t = H_p/\eta_p^{1.2} = 50/0.70^{1.2} = 76.7$ m
Discharge ratio $Q_t/Q_p = 1/\eta_p^{0.8}$
$Q_t = Q_p/\eta_p^{0.8} = 0.014/0.7^{0.8} = 0.0186\ m^3/s$
It is to be noticed that working head and discharge will always be lower than these.
Therefore discharge (Q) is taken to be .015 m^3/s
Volume of collected water/day, V= 18 m^3
Time taken to empty the tank = V/Q = 18/0.015=1200 s
Available head for RO power generation = 35 m (since RO collection tank is on th 11th floor)
Generated Power, P_t = wQH = 9.81*1000*0.015*35 = 5.1503 kW
Assuming spur gear efficiency in gearbox, ($\eta_{g.b.}$) = .94, generator efficiency($\eta_{g.}$) =.97
Thus $P_o = \eta_{g.b.}*\eta_g$ =.97*.94*P_t = 5.03kVA
Total Energy generated = 5.03*1200/3600 = 1.68 kWh/day

4.3.2.Similarly for grey water: In the same way power can be harnessed from grey water. A separate tank has to be constructed for grey-water collection. Tank dimensions may vary but here they are taken to be same i.e. radius is 2m and height is 3m. For communities with a population of over 100,000,150 to 200 litres per head per day. Break-up of this demand per person per day is as-Bathing(55 L), Washing clothes(20 L), Washing utensils(10 L) [62]**.** According to an estimated water consumption about 76% of grey water can be utilized for hydroelectricity[63]. Also same pump is used as PAT that was used for RO power generation therefore same discharge (Q=0.015 m/s) of the PAT can be taken.
Available head (H) = No. of floors * Height of a floor = 10 * 3.5 =35 m
Generated Power, P_t = wQH = 9.81*1000*0.015*35 = 5.1503 kW
Total grey water collected for a family = 0.76 $\times$85$\times$ 5 persons per family = 323 litres
Total grey water collected in the building per day = 323 litres $\times$ 60 flats = 19380 litres
Time taken to empty the tank = V/Q = 19.38/0.015=1292 s
Assuming spur gear efficiency in gearbox, ($\eta_{g.b.}$) = .94, generator efficiency($\eta_{g.}$) =.97
Thus $P_o = \eta_{g.b.}*\eta_g$ =.97*.94*P_t = 5.03kVA
Total Energy generated = 5.03*1292/3600 = 1.81 kWh/day

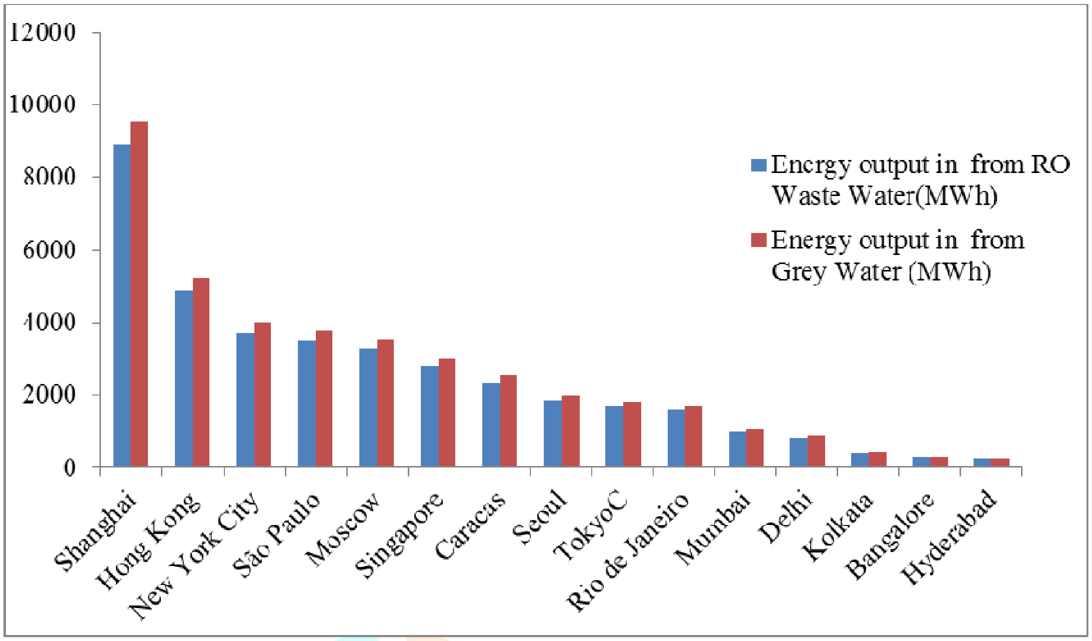

Fig 3. Estimated Energy output in cities with most high raised by RO water and Grey Water

4.4 Rainwater power generation:

India's primary energy consumption more than doubled between 1990 and 2011 to nearly 25,000 PJ. India's dependence on imported energy resources and the inconsistent reform of the energy sector are challenges to satisfying rising demand. The 2015 edition of BP's Energy Outlook projected India's energy production rising by 117% to 2035, while consumption grows by 128% [56].

Rainwater harvesting is the accumulation and deposition of rainwater for reuse on-site, rather than allowing it to run off. Its uses include water for garden, water for livestock, water for irrigation, water for domestic use with proper treatment, and indoor heating for houses etc. In many places the water collected is just redirected to a deep pit with percolation. The harvested water can be used as drinking water as well as for storage and other purpose like irrigation.

This water collected on the roof of a high raised building can then be effectively utilized for generating electricity by making a use turbine provided at the ground floor or an underground arrangement as the case may be. The efficiency of this Micro Hydro Electric plant can then be calculated based on the discharge or total available water and the net effective head. A schematic diagram of the proposed system is shown in fig 4. Since the same PAT is used therefore it becomes cost effective too, to use PAT for generation. Also there are two possible cases that includes either to generate power along with rainfall or to store the rainwater in the overhead tank and then generated power later on. The first one being the more effective from our observations. Apart from generation of electricity this water can also be utilized in other useful applications like recharging of groundwater table, flood control or providing water for emergencies like fire fighting or for secondary purposes like cleaning or washing cars etc.

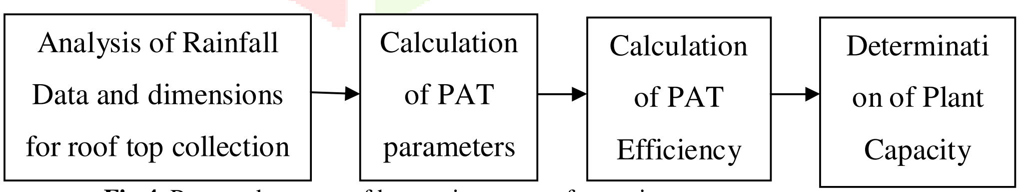

Fig.4. Proposed process of harnessing energy from rainwater.

4.4.1. Calculations for rainwater power:

Volume of available water = Area*rainfall intensity= 1500*237/1000 = 355.5 m^3
Since PAT is used for power generation therefore same discharge as before, i.e. Q=0.015 m^3/s
Time for which turbine works = volume/ discharge=V/q =355.5/0.015=23700 sec
Generated Power, P_t = wQH = 9.81*1000*0.015*70 =10.3 kW
Assuming spur gear efficiency in gearbox, ($\eta_{g.b.}$) = .94, generator efficiency($\eta_{g.}$) =.97
Thus $P_o = \eta_{g.b.*}\eta_g$ =.97*.94*P_t = 9.4 kVA
Total Energy generated, E= Po*t/3600= 9.4*23700/3600 = 61.88 kWh
Since 83% rainfall occurs in 4 months between June to Sept, therefore maximum power is generated in these months.

	Rainfall (mm)	Avg rainy days	Volume (m^3)	Time (sec)	Generated Power (kWh)

Jun	70	14.5	105	7000	18.3
Jul	237	23.2	355.5	23700	61.9
Aug	235	21.4	352.5	23500	61.4
Sep	113	14.4	169.5	11300	29.6
Rest months	135	3	202.5	13500	35.3
Total	790	78.9	1185	79000	206.5

Table 5. Estimated Energy Generation from Rainwater in Delhi

V. RESULTS AND DISCUSSION

The purposed hybrid system taps the maximum renewable potential available within a building. These systems normally consist of two or more energy resources. The study confirms the utility and cost effectiveness of solar, wind and hydro energy systems by analysing various data of two major cities of India viz. Delhi and Mumbai. Available power generation from various renewable sources are compared in fig.5. It is to be noticed that since a single PAT is being used for combined power generation from RO waste water, grey water and rainwater, therefore they have been considered under a single hydropower unit.

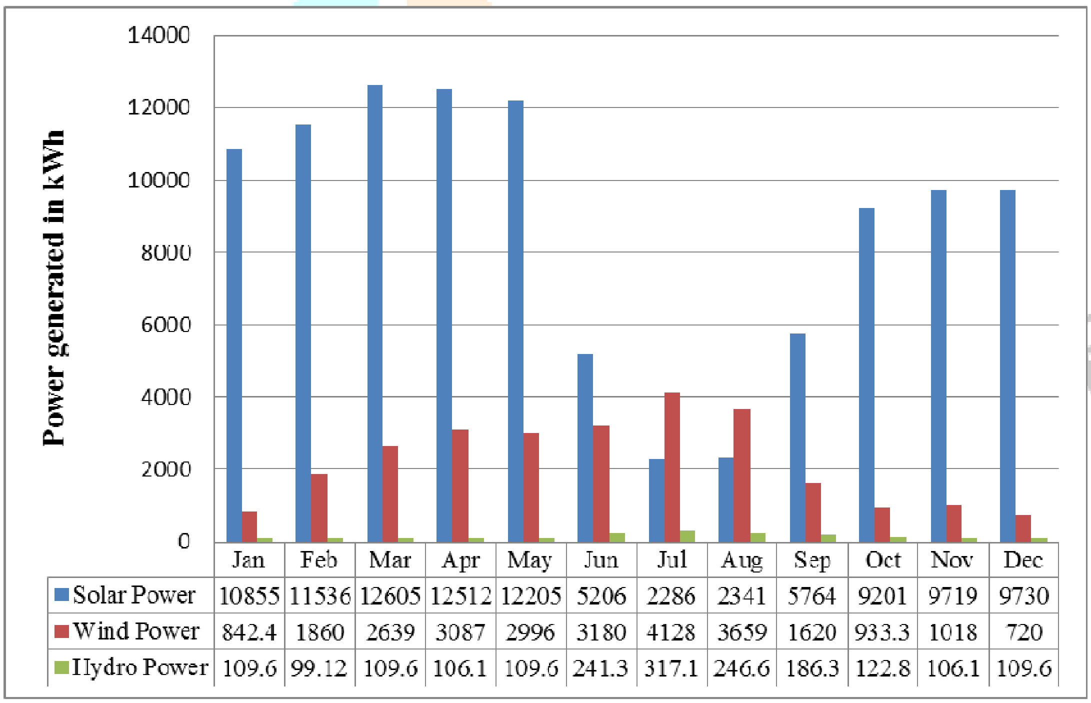

Fig. 5. Comparison of estimated power generation by various sources (Mumbai)

Hybrid solar-wind-hydro (HSWH) system finds usefulness in the sense that this system generates energy throughout the year. Due to variation in climate, solar energy varies but at same time reduction in solar energy is compensated by wind energy for as on a cloudy or a windy day, we get more wind power than the normal days. During rainy season when there is considerable decrease in solar as well as wind power, it can be compensated by generating electricity from rainy water, for which collection tank is made on the rooftop. It can be seen that 79% of power is produced from solar (Mumbai) in a 20 storied high raised building as shown in fig.6. Thus current research work purposes a novel approach, which is validated by the theoretical formulation by considering various geographical conditions efficiently. We suggest utilizing the waste produced from R.O water apart from grey water. In urban areas use of water purifier is necessary and purified water is used for drinking and cooking purposes. So by utilizing the R.O waste water, additional small amount of power by R.O waste throughout the year constantly. It is also to be noticed that a single PAT is used with change in input water source depending upon its availability. Also since a pump in turbine mode is used there will be no difficulty in its mass production as it is already available in the market. The proposed hybrid system also aims to increase cost effectiveness.

Kumaravel and Ashok[65] designed a hybrid system with solar, hydroelectric and biomass energy sources with 20.44 MWh/year load for a remote area in Kerala, India. Cost of energy (COE) was found to be $0.164/kWh for 2 KW solar-PV, 15 kW pico-hydroelectric and 5 kW biomass generated hybrid system.

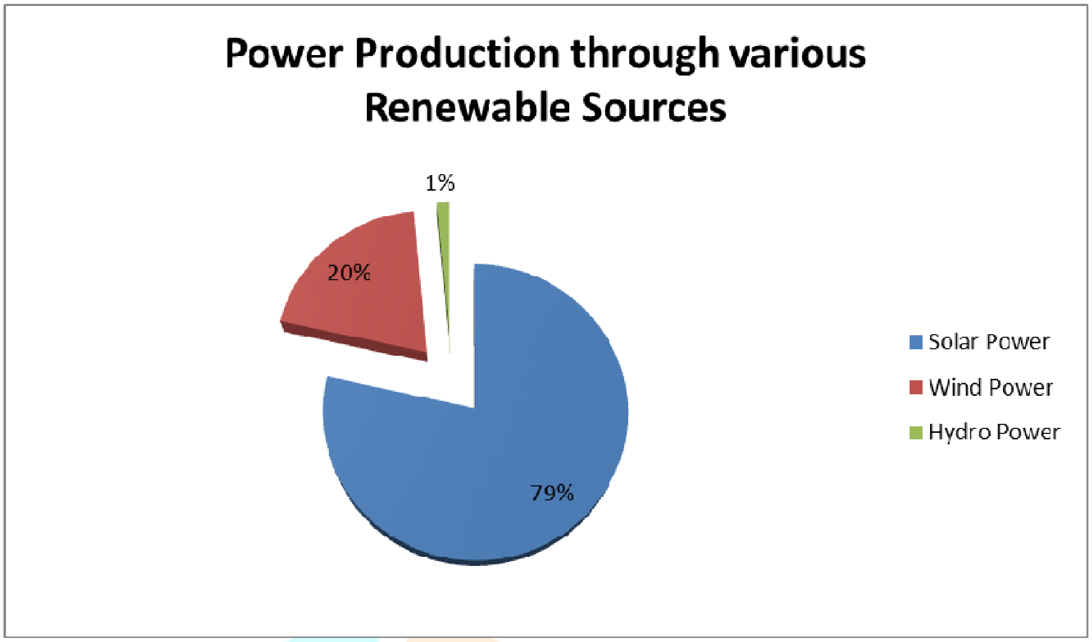

Fig 6. Power production through various renewable sources

VI. CONCLUSION:

From the case study of two metro cities in India (Delhi and Mumbai) we came to the conclusion that Mumbai has vast potential in wind energy compared to Delhi. Solar-PV and hydro (R.O waste and grey water) are suitable for both locations but since rainfall is available only for two or three months and Mumbai has more rain than Delhi, therefore Mumbai is more favourable site for installing Hybrid energy system because of abundant potential present in terms of solar, hydro and wind, while in Delhi solar-PV is most suitable.

This proposed system is able to fulfil 30.67% electricity requirement of all residents within a building. Following table shows this estimate [Table 6].

Power Generated by hybrid system(annually)	Power consumption of building(annually)
132507 kWh	120*300*12 =432000 kWh Where 120= no. of flats, 300=units consumed by a flat in one month
% of power generated by hybrid system = 132507*100/432000 = 30.67%	

Table 6. Efficiency of HSWH

So the proposed system is more cost effective than others. Building (which is taken for case study) also satisfies the major objective of a green building by generating electricity by water, solar and wind. The system tries to achieve zero net energy consumption principle by reducing GHG emission by introducing clean sources of energy. Carbon emission produced for generating 132507 unit electricity is 91.4 Metric tons which is equivalent to 8.3 homes energy use for one year[68]

REFERENCES:

[1] http://www.ren21.net/portals/0/documents/resources/gsr/2014/gsr2014_full%20report_low%20res.pdf
[2] http://en.wikipedia.org/wiki/World_energy_consumption
[3] http://www.world-nuclear.org
[4] http://www.indiacore.com/coal.html
[5] http://en.wikipedia.org/wiki/Electricity_sector_in_India
[6]http://www.ruralelec.org/fileadmin/DATA/Documents/06_Publications/Position_papers/ARE-WG_Technological_Solutions_-_Brochure_Hybrid_Systems.pdf
[7] www.pnn.gov/main/pnnl/23217.pdf
[8] Annual Energy Review, Energy Information Agency 2005
[9]http://www.ren21.net/portals/0/documents/resources/gsr/2014/gsr2014_full%20report_low%20res.pdf
[10] http://www.iea.org
[11] http://en.m.wikipedia.org/wiki/Green_building_in_India

[12] Vijay Singh Bisht, Anil Kumar Patil, Anirudh Gupta,Review and performance evaluation of roughened solar air heaters, Renewable and Sustainable Energy Reviews, Volume 81, Part 1,2018
[13] http://www.cea.nic.in/reports/planning/dmlf/growth.pdf
[14] http://www.siemens.co.in/sustainable-development-in-india/infrastructure.html
[15] http://www.worldenergy.org/data/resources/country/india/solar/
[16] http://en.wikipedia.org/wiki/List_of_tallest_buildings_in_India
[17] http://en.wikipedia.org/wiki/Solar_energy
[18] Non- Conventional Energy Resources, 2nd Edition B.H. Khan
[19] Smil (2006), Pg 12
[20] Perlin(1999), Pg147
[21] "Magic Plates, Top Sun for Power", June 1931 Popular Science
[22] Antonio Luque, "Will we exceed 50%efficiency in photovoltaics?"aip.org
[23] www.mnre.gov.in
[24] http://en.wikipedia.org/wiki/Photovoltaics
[25] "Software TM 318 Solar Panel Data Sheet", February 2010. Retrieved 30 march 2011
[26] "Market Report 2013 (02)", EPIA publications March 2014
[27]https://eosweb.larc.nasa.gov/cgi-
[28]https://eosweb.larc.nasa.gov/cgi-bin/sse/grid.cgi?&num=253109&lat=18.9&submit=Submit&hgt=100&veg=17&sitelev=&email=&p=grid_id&p=swv_dwn&p=exp_dif&p=avg_dnr&p=clr_sky&p=sol_noon&p=daylight&p=ret_tlt0&p=ret_esh0&p=ret_psh0&step=2&lon=72.817
[29] https://energypedia.info/wiki/Solar_Cells_and_Modules
[30] http://www.windgenerators.cn/
[31] http://en.wikipedia.org/wiki/Climate_of_Mumbai
[32] http://en.wikipedia.org/wiki/Climate_of_Delhi
[33] Fthenakis, V.; Kim, H. C. (2009). "Land use and electricity generation: A life-cycle analysis". Renewable and Sustainable Energy Reviews 13 (6–7): 1465. doi:10.1016/j.rser.2008.09.017
[34] non conventional energy resourses, 2nd edition, B H Khan.
[35] http://online.wsj.com/articles/denmarks-wind-power-output-rises-to-record-in-first-half-1409750563
[36] REN21 (2011). "Renewables 2011: Global Status Report". p. 11.
[37] The World Wind Energy Association (2014). 2014 Half-year Report. WWEA. pp. 1–8.
[38] http://www.inwea.org/ indian wind energy association
[39]http://www.gwec.net/wp-content/uploads/2015/02/2_global_annual_installed_wind_capacity_1997-2014.jpg
[40] http://newwindturbine.com/wind-turbines/wind-turbines-for-high-rise-buildings/
[41] "What is wind?". Renewable UK: Education and careers. Renewable UK. 2010. Archived from the original on 4 March 2011. Retrieved 9 April 2012
[42] http://dx.doi.org/10.1016%2Fj.renene.2014.12.045
[43] https://eosweb.larc.nasa.gov/cgi-bin/sse/grid.cgi?email=
[44] http://www.windgenerators.cn/500w_vawt.html
[45] http://www.hi-vawt.com.tw/en/ds700w.html
[46] http://www.windgenerators.cn/1kw_vawt.html
[47]https://eosweb.larc.nasa.gov/cgi-
[48]https://eosweb.larc.nasa.gov/cgi-bin/sse/grid.cgi?&num=258119&lat=28.533&submit=Submit&hgt=100&veg=17&sitelev=&email=&p=grid_id&p=ws50_0_2&step=2&lon=77.2
[49] http://www.freshlysqueezedwater.org.uk/waterarticle1.php
[50]http://www.mayoclinic.org/healthy-living/nutrition-and-healthy-eating/in-depth/water/art-20044256?pg=1
[51]http://www.achawater.com/RO-disadvantages-minerals-wastage.html#.VRqyheGTzCo
[52] http://www.kent.co.in
[53] http://en.wikipedia.org/wiki/Water_resources
[54]http://timesofindia.indiatimes.com/city/allahabad/Rainwater-harvesting-future-of-water-conservation/articleshow/7763690.cms
[55]http://www.yourarticlelibrary.com/essay/essay-on-water-scarcity-in-india-1113-words/20871/
[56] http://www.world-nuclear.org/info/Country-Profiles/Countries-G-N/India/
[57] http://timesofindia.indiatimes.com/city/allahabad/Rainwater-harvesting-future-of-water-conservation/articleshow/7763690.cms
[58]http://www.yourarticlelibrary.com/essay/essay-on-water-scarcity-in-india-1113-words/20871/
[59]http://timesofindia.indiatimes.com/india/Depleting-ground-water-levels-cause-of-worry/articleshow/39079749.cms
[60] Prabir Sarkar, Bhaanuj Sharma, Uran Malik; Energy generation from grey water in high raised buildings: The case of India,2014
[61] Shahram Derakhshan, Ahmad Nourbakshsh, Experimental study of characteristic curves of centrifugal pumps working as turbines in different specific speed,2007
[62] http://www.thehindu.com/features/homes-and-gardens/how-much-water-does-an-urban-citizen-need/article4393634.ece
[63] Maher P, Smith N, Williams A. Assessment of pico hydro as an option for offgrid electrification in Kenya. Renew Energy 2003;28:1357e69
[64]https://www.bijlibachao.com/news/domestic-electricity-lt-tariff-slabs-and-rates-for-all-states-in-india-in-2015.html

[65] KumaravelS,AshokS.Anoptimalstand-alonebiomass/solar-PV/Pico-hydel hybridenergysystemforremoteruralareaelectrification ofisolatedvillage in western-ghatsregionofIndia.InternationalJournalofGreenEnergy 2012;9(5):398–408
[66] http://www.pumpkart.com/shakti-three-phase-open-well-pump-shos-40-200-10hp
[67] Himanshu Nautiyal, Varun, Anoop Kumar; Reverse running pumps analytical, experimental and computational study, 2010
[68] http://www.carbonfootprint.com/calculator.aspx
[69] http://en.wikipedia.org/wiki/Energy_policy_of_India
[70] http://www.bridgetoindia.com
[71] Rawal S, Kshirsagar JT. Numerical simulation on a pump operating in a turbine mode, Kirloskar Brothers India Limited. In: Proceedings of the twenty-third international pump users symposium; 2007.
[72] Gulich JF. A book on centrifugal pumps. Springer Publications; 2007
[73] http://www.thethirdpole.net/groundwater-levels-dip-alarmingly-in-north-india/

LIST OF ABBREVIATIONS

NSM	National Solar Mission
MNRE	Ministry of New and Renewable Energy
Fit	feed-in tariff
NABARD	National Bank for Agricultural and Rural Development
IREDA	Indian Renewable Energy Development Agency
IEA	International Energy Agency
RES	Renewable Energy Systems
GOI	Government of India
GSR	Global Solar Radiation
P.R	Performance Ratio
HAWT	Horizontal Axis Wind Turbine
VAWT	Vertical Axis Wind Turbine
RO	Reverse Osmosis
PAT	Pump As Turbine
BEP	Best Efficiency Point
COE	Cost Of Effectiveness
GW	Giga Watt

LIST OF SYMBOLS

Aeff	Effective area where panel are installed
Aroof	Rooftop Area
Pt	Total power
Q	Discharge(m3/s)
N	rpm
Np	pump efficiency
V	volume of collection tank
Ng.b	gear box efficiency
Po	output electrical power