Sustainable Technologies for Residential Townships in India: A Review

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Abstract - *Integration of sustainable technologies in residential buildings aims to conserve natural resources like water, fossil fuels and soil demonstrating less damage to the environment. Present manuscript aims at identifying technically efficient, economically viable, locally available and environmentally suitable sustainable technologies. An extensive literature survey, web survey and market survey carried out enables to identify sustainable technologies which can be integrated into residential buildings of India. The Material, water and energy are identified as key resources for conservation. The costs and specifications of components enable, to find out technically efficient, economically viable, locally available technologies along with the components. It is revealed that among the building materials of AAC blocks, stabilized mud blocks, fly ash bricks and clay burnt bricks, use of fly ash bricks requires less capital cost with less amount of CO_2 emission. Recycling of rooftop rainwater using underground R.C.C. tank, PVC pipes and Rainy filter, is most feasible. Saving in fresh water using LFDs like showerheads, faucets, and dual flush toilets is found the best technique of water conservation. Grey water treatment technology developed by National Environmental Engineering Research Institute, Nagpur, India, was found techno-efficient, cost effective and does not require energy for the treatment. Polycrystalline photovoltaic panels and passive type of thermosyphon solar water heater with evacuated tube collector were found technically efficient and economically viable for Indian climatic condition. Horizontal axis wind turbine (HAWT) was found a matured and technically updated technology used for rooftop application where wind speed is more than 4.0 m/sec.*

Key Words: Sustainable technology; technically efficient; economically viable

1. INTRODUCTION

Developing cities in India are experiencing remarkable population growth and in turn exerting excess pressure on natural resources like materials, water, energy, demand and affecting the environment adversely. Integration of sustainable technologies in residential buildings aims to conserve natural resources like water, fossil fuels and soil demonstrating less damage to the environment. Sustainable technology emphasizes on practicing the principles of the 3Rs. Reduce, recycle and reuse.

Reduced consumption of natural materials can be achieved using sustainable materials in building construction. Reduced use of natural resource like water is possible by practicing water conservation techniques, which in turn can reduce groundwater, drinking water consumption and reduce wastewater discharges contributing to net energy savings. Reduced conventional energy consumption of a building is possible by using energy conservation techniques. The annual electricity use per apartment in residential buildings is predicted to increase from 650 kWh in 2012 to 2750 kWh by 2050. They therefore represent the largest opportunity to reduce buildings' energy consumption, improve energy security and reduce CO_2 emissions [1].

Reuse and recycle of waste material, rainwater and grey water after proper treatment can reduce pressure on potable water.

For the integration of sustainable technologies in residential buildings, there is a need to identify technically efficient, economically viable, locally available and environmentally suitable technologies for residential buildings. There is a lack of literature and research on cost saving possibilities related economic dimension of sustainability.

2. METHODOLOGY

A detailed literature review and market survey was carried out to find out technically efficient, economically viable, commercially and locally available sustainable technology models along with their components suitable for residential buildings of India.

2.1 LITERATURE REVIEW AND MARKET SURVEY

2.1.1 WATER CONSERVATION TECHNOLOGIES

Nzewi E (2010) showed that scarcity of potable water can be controlled by the implementation of reduce, reuse and recycle strategy for use of water [2]. Different researchers have reported that the reuse of greywater promotes potable water savings in buildings [3]. Friedler E and Hadari M (2006) reported that the residential built environment is a major untapped resource that could be exploited for water conservation [4].

Reduced use of natural resource like water is possible by rainwater harvesting, which reduces use of groundwater, drinking water consumption and reduces wastewater discharges contributing to net energy savings. Recycling of wastewater or grey water after proper treatment can reduce pressure on potable water. Nzewi E (2011) also mentioned that around 75% of total consumed water can be recycled and reused [5-8]. Nazer D et al. (2010) showed that the annual environmental impact of the in-house water uses can be reduced by 8 % when using low-flow shower heads, and up to 38 % when using a rainwater harvesting system. Use of low flow devices like dual flush toilets, faucets and shower heads using aerators are economically viable in long term [9].

There are few reports on the saving of water using a combination of rainwater harvesting, greywater recycling to promote potable water savings [10].

2.1.1.1 RAINWATER HARVESTING

Rainwater has been acknowledged to promote potable water savings in different types of buildings and in different countries.

Bharti R (2016) showed that practicing the technique of rainwater harvesting; a considerable amount of potable water can be saved [9]. Li Z et al. (2010) recommended harvested rainwater from rooftops for watering, gardening, car washing and toilet flushing after ensuring the quality of water after giving treatment using any of the techniques [10]. Tam VWY et al. (2010) suggested that the biggest consideration in the decision whether to install a RWH system lies in terms of financial costs and benefits, remaining the issues about public acceptability and water quality in the background [11]. For this reason, it is particularly important to determine the economic feasibility of RWH systems. It was found essential to identify technically efficient, economically viable and locally available components of rainwater harvesting system before integrating in residential buildings.

The rooftop RWH system consists of components of catchment, delivery system and a storage tank. Farreny R et al. (2011) suggested that flat cement roofs are most suitable and clean for residential apartments which form a major part of residential townships [12].

According to the Manual on Rainwater Harvesting, Texas Water Development Board (2005), Polyvinyl chloride rainwater pipes are easy to install, have long life and are more economical compared to other options of Aluminium, Plastic, Vinyl and Galvalume. Box washer costs INR20,400 – INR40,800. Post filtering washer is susceptible to freezing and costs INR7, 650 – INR25,500 and automatic smart valve costs INR 2,550 per kit [13]. The diameter of pipe selected for draining out rainwater is based on rainfall intensity and roof area [14]. Devas and Varun filters are mentioned in literature and costs INR2,500 and INR3,300 respectively. Varun filter developed by S. Vishwanath can handle 50 mm per hour intensity of rainfall from a roof area of 50 square meter. It consists of three layers of sponge and 150 mm thick layer of coarse sand. Ferrocement tanks cost INR2.5/liter. Aboveground eco-friendly bamboo tank having a 1500 lit capacity, costs INR1,000, is eco-friendly but requires pre-treatment. Bamboo tanks cannot be used below ground and occupy land space, poor in impact resistance and requires skilled labour. Polypropylene tanks are durable and lightweight. But black tanks result in warmer water and clear/translucent tanks foster algae growth. Metal tanks are light weight, can be easily transported, but show rusting and leaching of zinc, costs INR.6.73 - INR20 per litre. Welded steel tanks cost INR10.8 - INR53.83 per liter. Aesthetically pleasing, durable tanks madeout of red wood, Fir, Cypress are comparatively costlier costing INR27/litre. Disinfection using cartridge filter and R.O. filter costs INR 1, 020 - INR3, 060. Ultraviolet light disinfection costs INR 17,850. Ozone disinfection requires INR35,700 - INR1,32,600. Chlorination disinfection, manual dose requires INR55 per month [13]. Pasteurisation though is low cost method it is effective only when it reaches temperature of 50^0 C. Rainwater harvesting system with underground storage tank of size 1,500 lit to 10,000 lit are provided in Ireland for domestic application. Chlorination should meet the level of 0.2 - 0.3 mg/l free chlorine [17].

2.1.1.2 USE OF LOW FLOW DEVICES

toilets (saving 16 lit/flush). Use of dual flush toilet having the maximum water saving capability includes separate water fill tanks in a toilet tank, selectively pivoted to deposit different quantities of water for flushing. Shower heads, faucets with aerators (saving 50% water) can be installed in residences for conservation of water. Aerators generally provide a low-cost and effective alternative which saves the direct energy due to water conservation. It also saves energy demand at the supplier level. M/S of Parryware, Hindware and ESS-ESS Gurgaon, in India, has brought out aerators for faucets and showerheads. These aerators use aeration technology, mixes water droplets with air to cover the desired surface area which helps to deliver a strong spray, saving the consumption of water]. Nagaraj U (2014) showed that the aerators of M/S Parryware, having two dissimilar mesh combination can save comparatively more water [18]. Wills R et al. (2010) showed that an electronic shower monitor saved 3% of water and 2.4 % of energy with a payback period of 1.65 years [19].

2.1.1.3 Greywater recycling

Greywater (GW) is generally defined as low strength polluted wastewater originating from bathtubs, showers, hand washing basins and washing machines, but excluding wastewater from the kitchen and the toilet flushing system. GW contains an easily bio-degradable organic content and a relatively low pathogen content, making it much easier to treat and safer to recycle for water uses that do not need potable water quality, such as toilet flushing which accounts for around 20–30% of the total household water usage and urban landscaping or floor cleaning which comprises about 34% of the total household water budget [20]. It has been reported by different researchers that the reuse of greywater also promotes potable water savings in buildings [21]. Greywater represents the most profitable source in terms of its reliability, availability and raw water quality [22]. Highly efficient and reliable conveyance, storage and treatment systems are required to avoid health risks and negative aesthetics (i.e., offensive odour and colour) [23]. If the practice of on-site greywater reuse becomes widespread, the costs of the systems will obviously decrease, making them more appealing to individual consumers. In addition, under typical conditions, on-site greywater reuse is a feasible solution for decreasing overall urban water demand, not only from an environmental standpoint, but also in economic terms [24]. Several greywater treatment (GWT) technologies have been developed since 1970 which are classified based on physical unit processes, chemical unit processes, physico-chemical processes and biological unit processes. Treatment of grey water can range from simple coarse filtration to advanced biological treatment [25]. Previous studies by Jefferson B et al. (2000), Nolde E (1999) and Dalas et al. (2004) have suggested that biological processes should be preferred due to the high levels of organics in the water. Biological greywater treatment technology options for greywater reuse include membrane bioreactor, rotating biological contactor or constructed wetland[26-28]. The major difference between technologies has been the level of suspended solids and micro- organism removal. In comparison, direct physical processes are common at very small scale and have been shown to remove solids, but are less effective for organics removal [29, 30]. Grey water treatment systems target suspended solids removal to ensure removal of particles associated Coliforms prior to disinfection.

Lin J et al. (2005) established a compact and inexpensive electro - coagulation process with a capacity of 28m³/day to reclaim domestic greywater for human noncontact usage , after studying various GW treatment systems like biological oxidation, ultra -filtration costing \$1.8/m3 , Biological oxidation, microfiltration, UV, costing \$1.05/m^3 , Biological oxidation, sand filtration, ozonation, costing \$3.05/m^3 The total unit cost of on-site domestic greywater reuse using electro-coagulation was \$0.27/m^3 with the area requirement of 8 m^2 [31].

Kim J et al. (2009) showed that anaerobic - anoxic - oxic - membrane filtration - oxidation process system is effective in removing COD, turbidity, colour, and suspended solids, E. coli, total coliform, Salmonella and Staphylococcus [32].

Gual M (2008) used GW treatment of sand filtration followed by chlorination using hypochlorite in hotels required INR77/m^3 [33].

Li Z (2010) mentioned about use of simpler methods of two- stage system with underground storage tank, having coarse filtration along with disinfection and physical process system comprising of mainly depth filtration, invariably based on sand, and/or membranes. Li Z (2010) also reported the payback period of (GWT) system used in Ireland as 20 to 35 years if GW is used only for toilet flushing [34].

Maheshwari A (2010) analysed a case study of GWT system consisting of secondary treatment, tertiary treatment, use of MBBR, settler , clarifier, pump, sand filter and UV disinfection units, used in Sriperam-buthur in Chennai having 10 residential, 13 storied towers, saved 78 Lacs per annum [35].

Menon F et al. (2005) mentioned use of GW for toilet flushing, firefighting, car washing, explained economic assessment tool for GWT system consisting of a balancing tank, screens, roughening filter (up flow filter), anaerobic tank and biological treatment unit and estimated an amount of INR22,5,988 for 40 residences [36]. Muttukumaru S (2011) evaluated various GWT technologies based on cost effectiveness, application of renewable energy, simplicity in operation and maintenance, water reuse guideline adaption and less chemical consumption and reported solar vacuum membrane distillation, solar electro-coagulation-ultra filtration, solar membrane bioreactors as most suitable methods of GWR [37].

Shaikh S and Younus SK (2015) studied greywater recycling system designed for 100 lit/hr capacity restricted to five components such as storage tank with 100 liters capacity, sedimentation tank with 40 liters capacity, filter-I (gravel + sand) with 40 liters capacity, filter-II (coconut shell coal + charcoal) unit of 40 liters capacity and disinfection tank with 40 liters capacity and reported that this system requires low energy demand, less operating and maintenance cost, lower load on fresh water, less strain on septic tank, highly effective purification, and ground water recharge [38].

Pidou M (2007) stated that the information on Life cycle cost and total energy requirements for greywater treatment options is sparse. He concluded in his research that the value of the contribution which the greywater recycling technologies can make to sustainable water management will vary as a function of local circumstances and regional preferences [39].

National Environmental Engineering Research Institute (2007) developed a GWR system consisting of screens, junction chamber, equalization tank, horizontal roughening filter and a disinfection unit. Recycled water use is reported for toilet flushing. Installation cost of treatment unit for GW generated at the rate of 500 lit/day to 2000 lit/day is INR13, 785 with maintenance cost of INR674 per annum [40].

ReWater's (2010) outdoor irrigation system consisted of surge tanks, sand media filtration tank and piping. These systems costed \$1000 to \$5000 for a single-family home and are land-intensive. Burnat J and Eshtayah

I (2010) explained use of physical greywater treatment system used in Qubia village of Palestine. Nubian Oasis (2010), a company based in Australia, developed a modular greywater treatment system that can treat from 1,000 to 50,000 liters of greywater per day (the average per capita water use is around 200 liters per day in Australia). The treatment technologies include membrane filters to remove contaminants, bacteria, and viruses along with aerobic biological treatment. Aerobic biological treatment involves aeration to increase dissolved oxygen and activate bacteria present in the greywater to consume the oxygen and digest the organic contaminants. Some aerobic treatment systems include corrugated plastic sheets or other media for bacteria to attach to and grow on. One common method of aerobic biological treatment uses a rotating biological contactor (RBC) that cycles discs in and out of greywater tanks [41].

Pontos, a grewater system manufacturer based in Germany created Aqua Cycle. This system filters out coarse particles, gets aerated in holding tanks, undergoes biological treatment and then is disinfected using ultraviolet radiation. These types of systems tend to be most expensive, costing as much as $10,000 for a single-family home and also require space for multiple treatment tanks [42].

Pidou M et al. (2007) evaluated and showed that membrane bioreactor, electro-coagulation, rotating biological contactor and submerged membrane bioreactor are high energy required techniques and hence concern with carbon footprint precludes the use of high energy requirement technologies [39]. Gander M et al. (2000), Kader M (2013) stated that energy consumed using a membrane bioreactor; electro coagulation is 1.7 kWh/m^3 and 0.3 kWh/m^3 respectively. Kader M (2013) also mentioned that energy consumed using rotating biological contactor, submerged membrane bioreactor is 1.2 kWh/m^3 and 3.6 kWh/m3 respectively [43,44]. Kuntal A (2014) stated that the energy required for electro-coagulation is 0.3 kWh/m^3 [45]. There are few reports on the saving of water using a combination of rainwater harvesting, greywater recycling to promote potable water savings [46].

Ghisi E (2007) concluded in his economic analysis of combined use of rainwater and greywater in houses in Southern Brazil that there need to be Government incentives in order to promote the use of rainwater or greywater in houses in Southern Brazil [47].

2.1.2 CONSERVATION OF ENERGY

World energy consumption is projected to rise by 30% by 2020. According to Enerdata's latest predictions from May 2007 energy consumption will increase at a rate of 1.4% per year till 2035. Coal consumption of India's power sector has increased from the 285 MMT/year to 450 MMT/year by 2012. By 2030 India's GHG emissions could reach between 5.0 billion and 6.5 billion tones [48].

Strategies to reduce the environmental impact of coal-based generation on atmosphere, water and land would need urgent consideration. Solar energy has the greatest potential of all resources of renewable energy. It is an environmentally clean source of energy. The power from the Sun intercepted by the Earth is approximately $1.8*10^{11}$ MW which is 20,000 times the world's demand. Energy radiated by the sun on a bright sunny day is approximately 1 kW/m�[49].

Khare V (2013) mentioned about availability of adequate sunshine and balanced wind speed in India. Hence there is greater opportunity for extension of solar and wind energy system in the Indian scenario along with enough future scope for these renewable sources through "Grid Parity" [50].

Hagoes D et al. (2014) concluded that solar energy use for water heating is competitive and viable even in low solar potential areas [51].

Chang K et al. (2015) stated that for sustaining the solar thermal industry in Taiwan, the dominant factor for disseminating SWHs in metropolitan areas involves developing building-integrated solar thermal systems [52].

India is located in the equatorial sun belt of the earth, thereby receiving abundant radiant energy from the sun. The annual global radiation varies from 1600 to 2200 kWh/sq. m. [53].

Wind Resource Assessment Unit, Centre for Wind Energy Technology, Chennai (2005) showed a great potential of wind energy in all states of India except in Orissa and West Bengal. Currently, wind power accounts for about 8 % of India's total installed capacity but it generates only 2 % of country's power [53].

India has set up a Ministry of Non-conventional Energy Sources (MNES). India's cumulative Grid interactive or Grid Tied Renewable Energy Capacity (excluding large hydro) has reached 26.9 GW, of which 68.9% comes from Wind, while SPV contributed nearly 4.59% of the renewable energy installed capacity in India of total generation capacity of India. Use of renewable sources of energy has to be increased urgently [54,55].

2.1.2.1 SOLAR PHOTOVOLTAIC FOR LIGHTING

The competitiveness of renewable energy systems as alternatives to the diesel generator was evaluated by Agarwal A (2007) [57]. The impact of small-scale PV systems installed in homes, schools and public buildings was assessed by Schmid A & Hoffman CA (2004) and it was found that financial subsidies enabled remote rural communities to receive an electricity supply replacing traditional energy sources [58].

An integration of solar photovoltaic of 25kWp capacity was developed in an existing building of the cafeteria on the campus of the Indian Institute of Technology, Delhi by creating a solar roof covering with the photovoltaic array inclined at an angle of 15° from the horizontal and faces due south [59].

Feasibility of the stand-alone hybrid systems was studied by Bansal NK, Sandeep G (2000), Elhadidy MA, (2002) and Elhadidy MA & Shaahid SM (2005) [60-63]. It was found that the renewable energy system is competitive and feasible for off-grid application, but single source renewable usually leads to component over sizing, which increases the operating and life cycle costs [64].

Razykov T et al. (2011) reviewed the technical progress made in the past several years in the area of mono- and polycrystalline, thin-film photovoltaic (PV) technologies based on Si, III–V, II–VI, and I–III–VI2 semiconductors, as well as nano-PV and showed that Monocrystalline and Polycrystalline wafer Si solar cells remain the predominant PV technology with module production cost around $1.50 per peak watt. Thin-film technologies require much more surface area [65].

Table 2.1 shows the comparison of characteristics of different photovoltaic technologies [66]. Kolhe M et al. (2002) showed that PV-powered systems are the lowest cost option at a daily energy demand of up to 15 kWh [67].

Nouni M (2006) estimated levelized unit cost of electricity (LUCE) using photovoltaics for eighteen select locations situated in different geographical regions of the country. The LUCE found to vary in the range of Rs. 28.31–59.16/kWh (US$ 0.65–1.35/kWh) for PV projects in the capacity range 1- 25kWp [68].

Table -1: Characteristics of the different PV technologies

Particulars	**Monocry -stalline**	**Polycryst- alline**	**Thin Film**	**Hybrid**
Cell efficiency at STC	16 - 17 %	14 - 15 %	8 - 12%	18 - 19 %
Module efficiency	13 - 15 %	12 - 14 %	5 - 7 %	16 - 17 %
Area needed for modules	7 m^2	8 m^2	~ 16 m^2	~ 6 m^2
Annual energy generated / m^2 (South facing, 30^0 tilt)	107 kWh/m^2	100 kWh/m^2	~51 kWh/m^2	~146 kWh/m^2
Annual energy generated / kWp (South facing, 30^0 tilt)	750 kWh	750 kWh	800 kWh	900 kWh
Annual CO_2 saving Kg / m^2	46 Kg / m^2	40 Kg / m^2	22 Kg / m^2	60-65 Kg / m^2
Annual CO_2 saving Kg / kWp	323 Kg / kWp	323 Kg / kWp	344 kg/kWp	387 Kg / kWp

According to Lazou A (2000), PV-battery systems without a back-up generator can economically meet the electricity demands of a residential household located in remote areas where insolation is plentiful [69].

Charabi Y (2011) concluded from research study on solar resource assessment considering different photovoltaics (c-Si, a-Si,CdTe, CIGS,CPV) in Oman that crystalline photovoltaic technology (CPV) provides great potential in producing electricity [71].

Makride G et al. (2009) showed that the performance of photovoltaic systems depends to a great extent on the operating temperature which is a factor that influences their daily and seasonal performance. The best performing technologies based on the annual yield have been mono c-Si, CIS and CdTe (the latter two being thin film technologies [72].

Yoo S and Lee E (2002) proposed a building design to have the PV modules shade the building in summer, so as to reduce cooling loads, while at the same time allowing solar energy to enter the building during the heating season to provide daylight and conducted an analysis of the system performance, evaluation of the system efficiency and the power output [73].

Chow T et al. (2008) presented a photovoltaic thermosyphon collector for residential applications with rectangular flow channels and discussed the energy performance [74].

A widely used method of storing electricity is electrochemical battery storage. Hua S et al. discussed the behaviour of GFMU valve-regulated lead-acid (VRLA) batteries during three cycling test procedures, and that of batteries in practical stand-alone PV systems and the cycling test results showed that GFMU VRLA batteries display good cycle life and could be successfully used for standalone photovoltaic application in northwest areas of China [75].

Posorski R et al. proposed Solar Home Systems (SHS) that are commercially disseminated and used them cost efficiently to substitute kerosene and dry cell batteries to reduce GHG emissions and thus make a significant contribution to climate protection [76]

Levelised cost of solar power is between $0.28 and $0.46 per kWh for residential solar systems [77]. CdTe and Cu (In,Ga)Se2 thin-film solar cells demonstrated record efficiencies of 16.5% and almost 20%, respectively. These values are the highest achieved for thin-film solar cells. Production cost of CdTe thin-film modules are presently around $0.76 per peak watt [78].

A combination of one or more resources of renewable energy, called hybrid, improves load factors and help in saving on maintenance and replacement costs as the renewables can complement each other [79]. High initial capital of the hybrid is a barrier to adopt the system thus needs for long lasting, reliable and cost-effective system [80].

Designing a hybrid system would require correct component selection and sizing with appropriate operation strategy [81,82].

It was presented that due to high diesel cost only diesel-based power generation is not economically feasible [70]. The global solar radiation potential of Balikesir in Turkey was investigated, and an analysis was performed to assess the techno-economic viability and environmental performance of a hybrid PV-diesel-battery system to meet the load requirements of a typical rural farmhouse. The Cost of Energy (CoE) for this kind of hybrid system was found to be 1.245 US$/kWh [71].

2.1.2.2 SOLAR WATER HEATING

Demand for hot water for bathing shows significant variations across regions. The survey tried to capture this by collecting information from households on the number of months in a year when they use hot water for bathing. The survey found that apart from cold and moderate climatic regions, which show a high demand for hot water (> 8 months/year) for bathing. There are certain areas in the country which do not fall under cold and moderate climate regions but exhibit high use of hot water e.g. parts of Maharashtra, Kerala, and Tamil Nadu where surveyed households responded that hot water is used for more than 8 months in a year [72].

Fatidis J (2012) investigated the effect of the incentive program on the payback time of a typical glazed solar hot water system in Greece [73]. Kalokirou S and Tripanagnostopoulos Y (2006) showed that application of the PVs have better chances of success especially when both electricity and hot water is required in domestic block of flats [74,75]. Hang Y (2012) Evaluated the solar water heating systems for the U.S. typical residential buildings, from the energetic, economic and environmental perspectives, and included two different types of solar collectors, flat-plate and evacuated-tube solar collectors. The study revealed that the life cycle cost payback for solar water heating systems vary from 4 to 13 years for different cities and different configurations when using the conventional electrical water heating system in each city as the benchmark [76].

For small applications, upto 3000 litres capacity, users may prefer thermosyphon system for its simplicity and ease of operation. In such cases, the source of water must be placed at least 7 feet above the terrace level for size upto 500 litres and for larger tank sizes, the height requirement goes upto 10 feet or higher. Forced circulation system is required for systems of size larger than 3000 litres per day. Solar water heater (SWH) with heat exchanger is used for places where quality water is not suitable for direct use in solar collector or in cold regions where water in the collector may freeze in the night, solar water heating system with indirect heating is required. Users located in low temperature zones (minimum night temperature below 2 ^{0} C and below) have to use heat exchangers. For thermosiphon system, heat exchangers shall be always in the hot water storage tank.

Depending on the nature of heat transfer through the working fluid, SWH systems can be broadly classified into: direct systems and indirect systems. In the direct system, water is heated directly in the collector which is then passed through a condenser or a heat exchanging device to heat water. Similarly, depending on the circulation of working fluids, SWH systems can also be grouped into either: passive circulation system or active circulation system. Passive circulation systems refer to thermosyphonic method in which density difference induces the circulation of the fluid, naturally. On the other hand, active circulation employs a pump to effect forced circulation of the working fluid, during adverse weather conditions. Different techniques have been employed such as recirculation or drain-down technique and drain-back technique for direct and indirect SWH systems, respectively. Usually differential thermostats are used to control the system in accordance to the hot water demand with an exception to thermosyphon and integrated collector storage systems [75].

There are three common types of stationary collectors used in SWH systems. These are flat plate collectors (FPCs), evacuated tube collectors (ETCs) and compound parabolic collectors (CPCs). FPCs and ETCs are the most widely deployed collectors for small-scale water heating applications [77]. Different authors have investigated the performance of SWH systems with heat pump FPCs [86-91]. Zambolin E and Del D carried out a side by side testing of FPC and ETC in Padova, Italy [92]. Typical domestic installations for families of 4-6 persons in temperate climates consist of 4-6m^2 FPCs and 3-4m^2 ETCs [86].

Huang J et al. investigated the thermal performance of thermosiphon flat plate solar water heaters with a mantle heat exchanger in China while Al-Nimr MA and Akam MK studied the thermal performance improvements of a conventional tubeless collector [93,94].

Peppias F et al. (2014) compared the process production of ETC and FPC. The cost of acquisition of evacuated tube solar collectors is 104.04% therefore concluded that the choice for a specific kind of collector depends on the desired advantages, and a complement is required for decision-making based on the availability of economic resources. Economically, therefore, the choice for a specific kind of collector depends on the desired advantages, and a complement is required for decision-making based on the availability of economic resources [95]. ETC is strong and long lasting. If any tube is broken, it is just replaced which is considered as a cheaper option compared to flat plate collector (FPC) which require the replacement of the whole collector [96,97]. The predicted performance at various Indian stations revealed that hot water is required at most places for domestic use only during winter season and it can provide 100 litres of hot water at an average temperature of 50-70 ^{0}C that can be retained 40-60 ^{0}C till next day [98].

As per study conducted by the Beijing Solar Energy Institute, it is clear that FPC shall perform better in hot climatic conditions whereas ETC shall perform better in cold climatic conditions. In tropical country like India where seasonal variations are quite wide, solar water heater should be selected considering the winter climatic conditions. For low temperature application from 40^0 C up to 80^0 C FPC or ETC can be used. ETC is used for lower maintenance in hard water area or to prevent collector tubes breakage by ice freeze in tubes. Quality of water plays an important role in selecting collector technology. ETC are more reliable for regions having hard water. If water is saline both FPC and ETC can be used. In acidic water conditions ETC shall be used whereas in alkaline water conditions both FPC and ETC can be used. Avoid use of ETC in hailstorm prone regions [99]. The optimum tilt angle of collector is an angle equal to the latitude of the place plus or minus 15 ^{0} plus sign to be used for winter and minus sign for summer [100]. ETCs have been the core attraction of modern development in the solar water heater market as the manufacturing cost is comparatively lower and ETCs have better performance than FPCs particularly for high temperature operations. Sabiha MA (2015) et al. reported significant developments of solar water heaters using ETCs which eventually include 65% of 6.5 million m^2 /year in China [101].

Latest solar thermal technology in China and its status shows that Evacuated tube SWH systems are commercialized for mass market and are having cost-effective prices [102].

2.1.2.3 WIND TURBINES

Estimates of Purohit P and Michaelowa A (2007) indicated vast theoretical potential of CO_2 mitigation by the use of wind energy in India [103]. As is well known wind energy can be used not only in large systems but also in small installations. These power generation systems are showing a real growth opportunity. Antonio M and Simona C (2012) evaluated the performances of small wind turbines available in market in South Italy and showed that the choice of turbine is closely related to the wind conditions and to the type of terrain. The opportunity offered by the Italian legislative framework allow to pay more attention to a new potential market of the urban areas [104].

Rooftop – mounted or wall – mounted micro wind turbines are new emerging type of turbine. Vertical axis wind turbines are less common than horizontal axis wind turbines [105].

The study of geographical distribution of wind speeds, characteristic parameters of the wind, topography and local wind flow and measurement of the wind speed are very essential in wind resource assessment for successful application of wind turbines. Kocak K (2002) was concerned with speed persistence, which is an important factor in maintaining wind energy production [111]. Wood A (2001) determined the optimum tower height using power law and by a lgorithmic law. The site with annual mean wind speed of 20km/h with a hub height of 30m and power density of 150W/m^2 is economically viable annual wind speed for power generations [112]. The Weibull density function had been used by Weisser D (2003) for the analysis of wind energy potential of Grenada (West Indies) based on historic recordings of mean hourly wind velocity [113].

Weibull, Rayleigh distribution and Markov chain model were found suitable to predict wind speed data for the site. Grant A et al. (2008) concluded that ducted turbines have significant potential for retrofitting of existing buildings but visual impact and safety are the matters of concern [114]. Karothia K et al. (2014) carried out feasibility analysis of rooftop wind turbines in India and showed that in several areas of India where the wind speed is more than 4.83 m/s, use of rooftop wind turbine is feasible [115]. Li Z et al. (2012) investigated economic viability of six sample micro wind turbines (Ampair 600-230, Swift1.5kW, Siliken 3.4, Siliken 4.1, Skystream 3.7, Proven 11) available in Irish market, for use in Ireland, using HOMER software and concluded that micro wind turbines are not economically viable if installed in the locations with low average wind speed (< 5 m/s), they are more promising when installed in locations with relative high wind speed (> 6 m/s). Providing lower loan rates and /or substantial capital grants are best incentive approaches to encourage maximum penetration of micro wind turbines [116]. Nibir S et al. (2012) concluded in his analysis of rooftop micro wind turbines (Ampair 600, Flex 400, Gdcraft WG600, Whisper 200, Windmax HY 600) on Bangladesh perspective that at low wind speeds, difference in performance of the analysed models is not much significant and the turbine which has best performance might not be best economically [117].

Most vertical axis wind turbines (VAWTs) have an average decreased efficiency from a common horizontal axis wind turbines (HAWTs), mainly because of the additional drag that they have as their blades rotate into the wind. Versions that reduce drag produce more energy, especially those that funnel wind into the collector area. It is less cost effective [118]. Generally, average annual wind speeds of atleast 4.0- 4.5 m/s are needed for a small wind turbine to produce enough electricity to be cost effective [119]. Vertical axis wind turbine is an immature technology whereas horizontal axis technology is proven, tested and constantly refined technology. Vertical axis wind turbines require twice the swept area and four times the material compared to HAWT, to generate the same electricity [106]. Messineo A (2012) evaluated performances of small wind turbines in Itly and showed that horizontal axis wind turbines produce more energy than the vertical axis [116]. Full Department of Engineering for Innovation – University of Salento, Lecce Itly (2013) identified guidelines for micro sitting of building integrated micro wind turbines, based on simulations using Taguchi method and analysis of variance (ANOVA) methods for horizontal axis wind turbines. It was found that the most relevant parameter is the wind turbine height which has the percentage contribution equal to 62.0% and 64.7% for turbulence intensity and speed-up factor, respectively. Tiwari A and Harinarayana T (2014) developed wind turbine along with accessories which can generate a constant electricity supply even at locations having wind speed between 2 m /s to 4 m/s. The only disadvantage of this system is that it will be commercially beneficial only when wind speed ranges from 3m/s to 6 m/s [118].

2.1.3 MATERIAL CONSERVATION

Utilization of fly ash can result not only in reducing the magnitude of the environmental problems, but also in exploiting fly ash as a raw material for value added products while conserving traditional materials and for the extraction of valuable materials. Amongst the many uses of fly ash, its use as a building material is particularly suitable because it is anticipated, that there would be a considerable shortage in production of various building materials. According to a study, there is a huge shortfall in the production of bricks, to the tune of 25 billion bricks on an estimated demand of 100 billion bricks per year in India as of today. To tackle the problem and encourage the use of fly ash for making building materials, the Government of India has imposed restriction on brick manufacturers to use at least 25% of fly ash on weight–to–weight basis if the brick kiln is located within a radius of 50 km from a coal or lignite based thermal power plant [119,120].

Steel, cement and bricks as construction materials are used in a very large quantity during building construction and they are most significant in terms of environmental impact. In India, it is estimated that the brick industry produces 22% of the CO_2 emissions of the construction sector and requires about 27% of the energy used in building materials production [121,122]. The consumption of coal in brickmaking contributes to the greenhouse gases. In addition to air pollution, it also contributes to water pollution and degradation of soil quality due to top- soil erosion [123].

Use of recycled or waste material as a principle raw material can conserve the natural resources. The waste material may include fly ash, cotton waste, paper processing residues, granulated blast furnace slag, rubber, limestone dust, agro waste. Ralegaonkar RV et al. (2014) used recycled paper pulp waste (RPPW) as a principle raw material in development of bricks. These bricks (90 % RPPW and 10% cement) have 10 % less embodied energy compared to fly ash bricks [124]. In a similar study sugarcane baggase (SBA) ash was used as the principle raw material in developing bricks. Bricks were developed with quarry dust and lime with SBA (50%), quarry dust (30%) and lime (20%) composition. Developed SBA bricks showed 3% reduction in embodied energy and hence reduction in carbon footprint [125]. Reddy BV (2010) investigated the potential of stabilized mud blocks (SMB) as an alternative to burnt clay bricks. The blocks were manufactured compacting manually a mixture of soil, sand, stabilizer (cement/lime) and water. SMBs were found to be energy efficient with approximately 60-70% saving when compared with burnt clay bricks [126].

The main objective of using fly ash in most of the cement concrete applications is to get durable concrete at reduced cost, which can be achieved by using fly ash based Portland Pozzolana Cement (PPC) conforming to IS:1489 Part-1 in place of Ordinary Portland Cement and using fly ash as an ingredient in cement concrete [127].

Apart from being added at the clinkering/grinding stage to make the PPC, up to 25% of cement can be replaced with fly ash by blending it at the concrete mixing stage at project sites [128]. Autoclaved Aerated Concrete (AAC) Block is manufactured using fly ash mixed with cement, lime, water and an aerating agent. The Blocks are an eco friendly and sustainable construction building material made using non polluting manufacturing process. It makes productive use of recycled industrial waste (fly ash). These Blocks are 3-4 times lighter than traditional bricks and are available in custom sizes. The use of AAC block also reduces the requirement of materials such as cement and sand up to 50% [129].

Stabilized Mud blocks perform considerably better, in environmental terms, than fired bricks. They have significantly less embodied energy, contribute fewer CO_2 emissions and help to promote the local economy and local labour [130].

2.2 MARKET / WEB SURVEY

2.2.1 WATER CONSERVATION TECHNIQUES

2.2.1.1 RAINWATER FILTERS

Sieve filters like Rainy filters, Pop-up filter, Aqua filters and Varun filters are commercially available in India.

Table 2 shows the specifications, costs and parameters of commercially available models of Rainy filter [145].

Varun filter is available for INR5,000, manufactured by Bangalore based company. Varun filter is constructed on principal of slow sand filter and can handle 50 mm per hour intensity of rainfall from area of 50 square meters.

Table-2: Technical specifications, costs and parameters of various models of Rainy FL series dual intensity RWH filter

	Rainy FL - 100	Rainy FL - 200	Rainy FL - 300	Rainy FL - 500
Suitable upto roof area	110 m²	225 m²	350 m²	500 m²
Cost (INR)	8, 500	12,250	16,750	25,750
Max. intensity of rainfall	75 mm/ hr	75 mm/ hr	75 mm/ hr	75 mm/ hr
Working principle: cohesive force , centrifugal force				
Operating pressure	Less than 0.060 kg/cm²			
Capacity	105 LPM	225 LPM	340 LPM	480 LPM
Filter element	SS- 304	SS- 304	SS- 304	SS- 304
Mesh size	250 Microns	250 Microns	250 Microns	250 Microns
Inlet	90 mm	110 mm	110 mm	110 mm
Clean water outlet	63 mm	75 mm	90 mm	90 mm
Drain outlet	90 mm	90 mm	90 mm	90 mm
Housing	High density polyethylene	High density polyethylene	High density polyethylene	High density polyethylene
Efficiency of filter	Above 90 %	Above 90 %	Above 90 %	Above 90 %
Source of power	Gravity	Gravity	Gravity	Gravity

Source: http://www.rainyfilters.com/fl-500.html

It consists of three layers of sponge and 150 mm thick layer of coarse sand. It has been developed by S. Vishwanath, a Bangalore based water harvesting expert [146].

Popup filter is made of Polyethylene. Rain tap popup does not have drain outlet so users have to open and remove debris manually. Rain tap popup filter uses plastic mesh. One Raintap Popup filter can handle water from only 92.9 m^2 of rooftop, so users need to use multiple units for bigger rooftops and only one size of model is available. Pop up filter costs INR7,000 [145].

Devas filters are used in Madhya Pradesh, India. The filter consists of a polyvinyl chloride (PVC) pipe 140 mm in diameter and 1.2 m long. There are three chambers. The first purification chamber has pebbles varying between 2-6 mm, the second chamber has slightly larger pebbles, between 6 and 12 mm and the third chamber has the largest 12-20 mm pebbles. There is a mesh at the outflow side through which clean water flows out after passing through the three chambers. The cost of this filter unit is INR 7,000 [146].

2.2.1.2 LOW FLOW DEVICES

Ultra-low flush toilet saves 6.822 liters/flush costs INR13, 260. Shower head with aerator costs INR1,200 and saves 50 % of water [147]. Low flow faucets with aerators also save 50% of water costing INR225-

INR510. Dual flush toilets save 16 liters/person/day costing INR15, 300 [148]. As per the manufacturer of the renouned Parryware Company, cost of a Universal Combination European Water closet (dual flush) and a PVC cistern in the year 2015 was INR3, 999 and INR897 respectively. Unit cost of bib cock, pillar cock, health faucet, and shower head of the same company in the year 2015 was found INR899, INR1,175, INR1, 200, and INR829 respectively.

Hindware company quotes INR4,000 for a dual flush water closet (catalogue number 20095), INR835 for a PVC cistern. Same company quotes INR1,600 for pillar cock with honeycomb aerator, INR879 for bib cock (Model No: F280002), INR1, 516 for health faucet (Model No.: F160013), INR970 for showerhead (Model No.: F160008).

Aerator consists of 3 major components, housing, insert and rubber washer. Faucet aerator is classified on basis of its flow rate and type of water stream i.e. aerated, non-aerated and spray. Faucet aerators are available in standard sizes- M22x1 (female) threading or M24x1 (male threading) [139]. There are the different streams available in faucet aerators.

Spray Stream is used to produce a miniature shower pattern and provides full coverage of hands during washing. Similar to the laminar stream, it is non-aerated and restricts the flow of water is suggested for use in public lavatories.

Laminar Stream produces a non-aerated water stream ideal for high flow applications or health care facilities with a beautiful crystal clear, non-splashing stream.

Aerated/Bubble Stream mixes air into the water. It produces a larger, whiter stream that is soft to the touch and non-splashing. This stream is usually the choice for residential faucets [139]. Female faucet aerator thread diameter 19mm costs INR180. Aerators of shower head of cost INR300 per piece [142].

2.2.1.3 GREYWATER TREATMENT SYSTEM

Readily available GW treatment system OASIS (GT 600) enclosing membrane filters, aerobic biological treatment unit, and membrane biological reactor costs INR 33, 0840. The treated GW using this system can be used for fruit & vegetable gardens [152]. GW treatment units like Siemens Membrane Biological Reactor costs INR 386-1,100 per gallon of treated GW and can be used for non-potable purposes [153].

PONTOS AquaCycle 1500 a Germany based company having sequencing batch reactor (SBR) of capacity1000 lit/day performs a twostep biological treatment, with bacteria growing on fixed bed of foam cubes and a ultraviolet lamp for disinfection costs €10.900 (INR 736.40, 2005 rate)[153].

Flotender GWT system (GS-40-2SP) having total surge capacity of 40 Gallons costs INR1,91,887, Flotender GWT system (GS-80-2SP)having capacity of 80 Gallons costs INR2,18,023, Flotender GWT system(GXL-390-2SP) costs INR4,71,943.These systems are used for recycling of treated water for non-potable purposes [154].

Wavebrite greywater recycling system shown in figure 2.4 is from United Kingdom for domestic purposes require electricity for operation [155].

2.2.2 ENERGY CONSERVATION TECHNIQUES

2.2.2.1 MODULES OF SOLAR PVS

The wholesale price of multicrystalline modules is INR35/watt [156]. The retail price of polycrystalline photovoltaic panels is around Rs 50-60 per Wp . Table 3 shows the prices multicrystalline solar panels [157]. Table 4 shows price list for multicrystalline Modules of sizes ranging in power from 3Wp to 210Wp in 12V/24V, in India . Table 5 shows the price list from various manufacturers of solar panels in India [158]. The cost of polycrystalline solar panels INR 45/Wp. The cost of monocrystalline solar panels INR 60/Wp [154,155] As per market survey, Table 6 shows the cost break-up of assembly of solar panels set-up, for lighting in India in the year 2013 [159,160].

Table- 3: Tata Solar Panels Price List

Model (Watt)	MRP INR	Selling Price
10W 12V	1069	1015
40W 12V	3071	2918
80W 12V	6142	5835
100W 12V	7678	7294
150W 12V	11516	10940
200W 24V	13920	13224
250W 24V	17400	16530
300W 24V	20880	19836

Table-4: Solar panels price list

Wattage	Price (INR/Wp)
3Wp(12V/24V)	80
125 Wp (12V/24V)	48
5Wp	70
150Wp,10Wp (12V, 24V)	55
180Wp, 20Wp	47
200Wp (24V)	45
30Wp	45
210 Wp, 37Wp (12V)	50

Table-5: Price of Solar Panels in India

Manufacturer	Model	Wattage (Wp)	Efficie-ncy (%)	Price (INR)	Price Per Wp (INR)
Solar Universe	SUI-250P-60	250	15.00	8,514.00	34.00
Solar Universe	SUI-300P-72	300	15.00	10,238	34.00
Shan Solar	Ruby 60 250	250	15.00	8,790.00	35.00
Solar Universe	SUI-250P-60	250	15.00	8,844.00	35.00
Solar Universe	SUI-300P-72	300	15.00	10,608	35.00
Navitas Green Solutions	NS300	300	16.00	10,837	36.00
Navitas Green Solutions	NS240	240	15.00	8,698.00	36.00
PV Power Tech.	ECO 250	250	15.00	9,031.00	36.00
Shan Solar	3PSS60 245	245	15.00	8,718.00	36.00
Universal Solar	USP P6-40/36-G	40	----	1,452.00	36.00

Table-6: Cost break-up of solar panel assembly

Cost break-up
Module - 68%
Inverter - 11%
Support structure - 7%
Mechanical work - 6%
Electrical work - 5%
Quality control - 3%

2.2.2.2 Solar Water Heater

Both solar water heaters with flat plate collector (FPC) and evacuated tube collector (ETC) are available in India. ETC systems with heat pipes are also available, but are not used commonly in India. Table 7a shows the approximate cost of ETC and FPC systems with different capacities for providing hot water of 60^o to 70^o C in a day. The normal temperature of the hot water requirement is between 30^o to 40^o C in residences [163]. Table 7b shows the costs and specifications of SWHs of different companies obtained from web survey accessed on September 2015.

2.2.2.3 Wind turbines

Small wind turbines with capacity ranging from 300 W to 25 kW are now available in Indian market and gaining popularity [164]. Table 8a, Table 8b show various wind turbine models along with start up, cut in and design wind velocity and costs obtained from the manufacturers, available in India.

3. CONCLUSION

An extensive literature survey was carried out in order to find out different types of sustainable technologies for natural resource conservation. The survey enabled to identify sustainable technologies which can be integrated into residential buildings. Material, water and energy were identified as key resources for conservation. Cost of sustainable technologies and technical efficiency of sustainable technologies was the focus of the literature survey.

Table-7a: Cost of SWH systems

System capacity (lpd)	ETC based systems with glass tubes		FPC based systems with metallic collectors	
	Cost (INR)	Maximum solar collector area (m^2)	Cost (INR)	Maximum solar collector area (m^2)
100	15000	1.5	22000	2
200	28000	3.0	42000	4
250	34000	3.75	50000	5
300	40000	4.5	58000	6
500	62000	7.5	85000	10

For the identified sustainable technologies and the components of sustainable technologies, market survey and web survey was carried out for finding out the latest technologies and their components locally available in the market.

The costs and specifications of components enabled, to find out technically efficient, economically viable technologies along with the components.

It was revealed that among the building materials of AAC blocks, Stabilized mud blocks, fly ash bricks and clay burnt bricks, use of fly ash bricks requires less capital cost with less amount of CO_2 emission. Comparison of costs of Ordinary Portland Cement and Pozzolana Portland Cement showed that Pozzolana Portland Cement is cheaper without any compromise on strength. Fly ash waste management can also be accomplished by use of fly ash bricks and Pozzolana Portland cement in building the residential apartment buildings on a very large scale.

The rooftop RWH system having underground storage in the R.C.C. tank with on-site utilization of recycled water was found most suitable, preventing light penetration, keeping stored water constantly cool and saving the valuable land area in the residential apartment buildings. It was found that ready underground PVC storage tanks are available in Indian market, but these tanks show bursting when the ground water level is above the base of the PVC tank, in empty condition.

Table-7b: Costs of SWH systems obtained from Companies

Name of Company	Capacity of SWH	Type of collector	Cost (INR)
Focusun energy	100	ETC	17000
Bipin Engineers Private Ltd.	100	ETC Specifications: Suitable for Indian hard water conditions. International Certified SUS 304-2 B Stainless Steel Inner Tank, 0.376 mm or 0.426 mm painted steel, aluminium alloy stands 6063: Wind Proof and anti-corrosion, foaming density of 45 Kg/ m^3 and high cell closing rate for better insulation.	22350
Supreme solar	100	ETC	14799
Supreme solar	200	ETC Specifications: Tube Dimensions: 47 – 1800 mm or 58 – 1800 mm, Inner Tank Materials: High grade stainless steel, outer tank Materials: Stainless Steel / powder coated (both options available)	18459

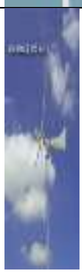
Sunbeam	100	ETC Specifications: Weight (Kg): 50 Kg, vaccum tube size (mm):(102x50x52 mm)	22113
Tata Power Solar	100	ETC Material: Stainless Steel Colour: Orange Insulation: PUF Tube Material: Triple coated glass tube Tube Length (mm):1500 Absorber Coating:CU, AL, N/ SS (Three Layer) Warranty: 5 Temperature: 65	17500
Racold	200	ETC Number of tubes: 24 Collector area (sq m): 3.93 Absorber material/coating: Selective Three layer coating (A1N/SS/Cu) Tube material: Borosilicate glass Tube length: 1800 mm Outer tube diameter: 58 mm	26299
Rayon Energy	100	ETC Material: stainless Steel Colour: Sliver Insulation: PUF Tube Material: Glass Tubes Tube Length (mm):1800	22000

Table- 8a: Specifications of rooftop wind turbines

Picture	Wind Turbine	Output power per day	Wind velocity	Rate (INR)
	SunChip Wind 1000	960 Wh	Start Up, Cut in & design wind velocity (0.9 m/s, 1.2 m/s & 3.9 m/s)	29, 00
	SunChip Wind 2000	1800 Wh	Start Up, Cut in & design wind velocity 0.9 m/s , 1.2 m/s & 3.9 m/s	37, 00
	SunChip 3000	3350 Wh	Start Up, Cut in & design wind velocity 0.9 m/s , 1.2 m/s & 3.9 m/s	47, 00
	SunChip 12000	12000 Wh	Start Up, Cut in & design wind velocity 0.9 m/s , 1.2 m/s & 3.9 m/s	87, 000
	SunChip 24000	24000 Wh	Start Up, Cut in & design wind velocity 0.9 m/s , 1.2 m/s & 3.9 m/s	1, 09, 000
	Whisper 100	21600 Wh	Cut in , design , cut out wind velocity 3.4m/s, 12.5m/s ,55 m/s	1,70,00 0
	Whisper 200	24000 Wh		2,10,00 0
	Sikco Wind 1000	1000 Wh	1.6 m/s , 4.9m/s cut in , rated wind velocity	25,000

Table- 8b: Specifications of rooftop wind turbines

Picture	Wind Turbine	Output power per day	Wind velocity	Rate (INR)
	Sikco Wind 2000	2000 Wh	1.6 m/s , 4.9m/s cut in , rated wind velocity	39,790
	Sicko Wind 3000	3000 Wh		57,790
	Sicko Wind 5000	5000 Wh		65,650
	Sicko Wind 12000	12000 Wh		116500
	Sicko wind 24000	24000 Wh		158500
	Sicko Wind 48000	48000 Wh		

	Windistar 400	9600 Wh	3.1 m/s , 10.5 m/s, 49 m/s cut in, rated, cut out wind velocity	77,000
	650 Watt smallwind turbine	550 Watts	10, 2.7, 24 rated, cut-in, cut-out wind velocity in m/s	
	1 KW small wind turbine	1 KW	2.5 m/s,3.9 m/s, 18 m/s cut-in, rated, cut-out wind speeds	1,65000

Rainy filter based on the principle of cohesion and centrifugal force, was found commercially available in Indian market, which is dual intensity, self- cleaning and maintenance free. Filter inlet and outlet connections suit the pipeline direction and has a bypass valve to divert the sudden summer rains. They are made from high density ultraviolet treated polyethylene material. Rainy filters were thus found most efficient and maintenance free. Rainwater reuse after simple and easy treatment of chlorination was found most suitable for residential buildings.

Saving in fresh water by using LFDs like showerheads, faucets, and dual flush toilets was found the best technique of water conservation, but the economic feasibility of implementing this technique was found the basic hurdle. There is no literature available for life cycle costing of LFDs.

Hence actual calculations for life cycle cost and saving in water in the life of LFDs was found essential for comparison with the other techniques.

Evaluation of various GWT technologies showed that membrane bioreactor, electro-coagulation, rotating biological contactor and submerged membrane bioreactor are high energy required techniques. GWT technology developed by National Environmental Engineering Research Institute, Nagpur, India, was found techno-efficient, cost effective and does not require energy for the treatment. The quality of treated water was found suitable for toilet flushing without any problem of causing diseases. It was found that sparce work is done in finding out life cycle cost analysis of the GWR hence scope was found in calculating life cycle cost of GWR system.

For energy conservation techniques for lighting, crystalline solar panels were found most efficient. Mono crystalline photovoltaic panels are found efficient in very high temperature areas and were the costliest. Polycrystalline photovoltaic panels were found technically efficient and economically viable for Indian climatic condition.

For domestic water heating in apartment buildings, passive type of thermosyphon solar water heaters were found suitable since these solar water heaters do not require energy for pumping. In thermocyphon solar water heater the circulation of water [during the heating process was found purely due to the difference of density of cold water and hot water. It was also found that in this system, there is no other mechanical moving part, hence the system reliability is very high. In India Racold is the time tested, reputed company for solar water heaters. Choice of collector for SWH depends upon climatic conditions and the quality of water. Evacuated tube collectors were found suitable for hard water where bore well is the source of water and mostly used in India.

It was also found that potential of wind energy can also be explored for lighting in residential apartment buildings using rooftop wind turbines. HAWT was found a matured and technically updated technology cheaper than VAWT technology can be used for rooftop application where wind speed is more than 4.0 m/sec. For wind speeds less than 4.0 m/sec use of wind turbine was found infeasible.

REFERENCES

1) Global buildings performance network (2014) Residential buildings in india: energy use projections and savings potentials, India – Technical report.
2) Nzewi, E. (2010) Effective rainwater harvesting schemes for Sub-Saharan West Africa. ASCE Conference Proceedings. p.1-10.
3) March, J. Gual, M. and Orozco, F. (2004) Experience on greywater re-use for toilet flushing in a hotel (Mallorca Island, Spain). Desalination. 164. p.241-247.
4) Friedler, E. and Hadari, M. (2006) Economic feasibility of onsite greywater reuse in multi-storey buildings. Desalination. 190. p.221- 234.
5) Nzewi, E. (2010) Effective rainwater harvesting schemes for Sub-Saharan West Africa', ASCE Conference Proceedings, pp. 1-10.
6) Nazer, D. Siebel, M. Zaag P, Mimi Z, Gijzen, H. (2010) A financial, environmental and social evaluation of domestic water mnagement options in the West Bank, Palestine. Water Resources Management. 24(15). p.4445-4467.
7) Dixon, A. Butler, D. and Fewkes, A. (1999) Water saving potential of domestic water recycling systems using greywater and rainwater in combination. Water Science & Technology. 39(5). p.25-32.
8) Villarreal, EL. and Dixon, A. (2005) Analysis of a rainwater collection system for domestic water supply in Ringdansen, Norrkoping, Sweden. Building and Environment. 40(9). p.1174 -1184.
9) Bharti, R. (2016) Domestic rainwater harvesting (RWH)- A review. International Journal of Engineering Technology Science and Research. 3(5). p.193-199.
10) Li, Z. Boyle, F. and Reynolds, A. (2010) Rainwater harvesting and greywater treatment systems for domestic application in Ireland. Desalination. 260. p.1- 8.
11) Tam, VWY. Tam, L. Zeng, SX. (2010) Cost effectiveness and tradeoff on the use of rainwater tank: an empirical study in Australian residential decision- making. Resource Conservation. 54. p.178-186.
12) Farreny, R. Morales-Pinzo, T. Guisasola, A. Taya, C. Rieradevall J. Farreny, XG. (2011) Roof selection for rainwater harvesting: Quantity and quality assessments in Spain. Water Resources. 45(10). p.3245-3254.
13) Texas water development board (2005) Manual of rainwater harvesting.
14) Indian National Building Code (1996).
15) http://www.rainwaterharvesting.org/Urban/Components.htm[Accessed Dec 2012].
16) Helmreich, B. and Horn, H. (2009) Opportunities in rainwater harvesting. Desalination, 248. p.118-124.
17) Taleb, H. and Sharples, M. (2011) Developing sustainable residential buildings in Saudi Arabia, a case study. Applied Energy. 88. p.383-391.
18) Umesh, V. Nagaraj S. (2014) Hydraulic peroformnace of faucet aerator as water saving device and suggestions for its improvements. International Journal of Research in Engineering and Technology. 3(7). p.243-247.
19) Wills, R. Stewart, K. Panuwatwanich, J. Kyriakides, S. (2010) Alarming visual display monitors affecting shower end use water and energy conservation in Australian residential households. Resource, Conservation & recycling. 54. p.117-1127.
20) Li, F. Wichmann, K. and Otterpohl, R. (2009) Review of the technological approaches for grey water treatment and Reuse. Science of the Total Environment. 407(11). p. 3439-3449.
21) Al-Jayyousi, O. (2003) Greywater reuse: towards sustainable water management. Desalination. 56(1-3). p.181-192.
22) Kujawa-Roellveld, K. and Zeeman, G. (2006). Anaerobictreatment in decentralized and source-separation- based sanitation concepts. Reviews in Environmental Science and Bio/Technololy. 5(1). p.115-139.
23) Kim, J. Song, I. Oh, H. Jong, J. Park, P. Choung, Y. (2009) A laboratory-scale greywater treatment system based on a membrane filtration and oxidation process - characteristics of greywater from a residential complex. Desalination. 38. p.347-357.
24) March, J. Gual, M. and Orozco, F. (2004) Experience on greywater re-use for toilet flushing in a hotel (Mallorca Island, Spain). Desalination. 164. p.241 247.
25) Nolde, E. (2005) Greywater recycling systems in Germany – Results, experiences and guidelines. Water Science & Technology. 51(10). p.203-210.
26) Jefferson, B. Laine, AL. Judd, SJ. and Stephenson, T. (2000) Membrane bioreactors and their role in wastewater reuse. Water Science & Technology. 41(1). p.197-204.
27) Nolde, E. (1999) Greywater reuse systems for toilet flushing in multi-storey building-over ten years' experience in Berlin. Urban Water.1. p.275-284.
28) Dalas, S. Scheffe, B. and Ho, G. (2004) Reed beds for greywater treatment - case study in Santa

Elena-Monteverde, Costa Rica, Central America, Ecological Engineering. 23. p.55- 61.

29) Jefferson, B. et al. (2004) 'Grey water characterization and its impact on the selection and operation of technologies for urban reuse', J. Water Sci. and Technol., Vol.50 No. 2, pp. 157-164.
30) Ramon, G. Green, M. Semiat, R. Dosoretz, C. (2004) Low strength greywater characterization and treatment by direct membrane filtration. Desalination. 170(3). p.241-250.
31) Lin, J. Lo, S. Kuo, C. Wu, C. (2005) Pilot scale Electro coagulation with Bipolar Aluminum Electrodes for On-Site Domestic Greywater Reuse. Journal of Environmental Engineering. 131(3). p.491-495.
32) Kim J, Song I, Oh H, Jong J, Park J, Choung Y(2009), A laboratory-scale graywater treatment system based on a membrane filtration and oxidation process — characteristics of graywater from a residential complex, J of Desalination 238 pg.347-357.
33) Gual m. Moia, A. March, JG. (2008) Monitoring of an indoor pilot plant for osmosis rejection and greywater reuse to flush toilets in a hotel. Desalination. 219. p.81-88.
34) Li, Z. (2010) Rainwater harvesting and Grey water treatment system for domestic application in Ireland. Desalination. 260. p.1-8.
35) Maheshwari, A. (2010) National Conference Proceedings of Sustainable Development of Urban Infrastructure.
36) Menon, FA. Butler, D. Han, W. Liu, S. Makropoulos, C. Avery, LM. Pidou, M. (2005) Economic assessment tool for greywater recycling. Engineering Sustainability. 158(ES3). p.155-161.
37) Muttukumaru S. and Ramezanianpour, M. (2012) Green technology options for greywater treatment. 27 th National Convention of Environmental Engineers on Green Technologies. 24th to 25th January2012. Mangalore local centre, Karnataka, India.
38) Shaikh, S. and Younus, SK. Grey water reuse: A sustainable solution of water crisis in Pusad city in Maharashtra, India. International Journal on Recent and Innovation Trends in Computing and Communication. 3(2). p.167-170.
39) Pidou, M. Memon, FA. Stephenson, T. Jefferson, B. Jeffrey, P. (2007) Greywater recycling: A review of treatment options and applications. Institution of Civil Engineers. Proceedings. Engineering Sustainability. 160. p.119-131.
40) Manual of National Environmental Engineering Research Institute (2007).
41) Allen, L. Smith, J. Palaniappan, M. (2010) Overview of greywater reuse: The potential of greywater systems to aid sustainable water management. Pacific Institute, Oakland, California, USA.
42) Ecosan Club, Austria (2009). Greywater - treatment and reuse. (1) Sustainable Sanitation Practice. SSP.
43) Gander, M. Jefferson, B. Judd, S. (2000). Aerobic MBRs for domestic wastewater treatment: a review with cost considerations. Separation and Purification Technology 18. p.119–130.
44) Abdel-Kader, M. (2013) Studying the efficiency of grey water treatment by using rotating biological contactors system. Journal of King Saud University - Engineering Sciences. 25. p.89-95.
45) Kuntal, A. Bhatia, A. Sharma, M. Sarkar S. (2014) Characterization of greywater in an indian middle-class household and investi-gation of physicochemical treatment using electrocoagulation, Separation and Purification Technology. 130. p.160-166.
46) Dixon, A., Butler, D. and Fewkes, A. (1999) 'Water saving potential of domestic water recycling systems using greywater and rainwater in combination', Water Sc. Tech., Vol. 39 No.5, pp. 25-32.
47) Ghisi, E. Montibeller, A. and Schmidt, R. (2006) Potential for potable water savings by using rainwater: an analysis over 62 cities in southern Brazil. Building and Environment. 41(2). p.204 - 210.
48) http://www.ncpre.iitb.ac.in/page
49) http://en.wikipedia.org/wiki/2012_India_blackouts
50) Khare V. Nema, S. Baredar, P. (2013),Status of solar wind renewable energy in India. Renewable and Sustainable Energy Reviews. 27. p.1-10.
51) Hagoes, D. Gebremedhin, A. Zethraeus, B. (2014), Solar Water Heating as a Potential Source for Inland Norway Energy Mix. Journal of Renewable Energy. 2014 (2014). p. 1- 11.
52) Chang, K. Lin, W. Chung, KM. (2015) Sustainable Development for solar Heating Systems in Taiwan. Sustainability 7(2). p.970-1984.
53) http://en.wikipedia.org/wiki/Renewable_energy_in_India[54] A Report of Performance of Solar Power Plants in India, 2011.
54) [55]http://www.iea.org/aboutus/fly ashqs/renewableenergy/
55) Alam M. (2012) Potential application of solar power systems for residential buildings in high-density urban pattern: The case of the example district, city of the Barcelona, in Spain. Recent Researches in Environmental and Geological Sciences. 110 (4). p.341-347.
56) Agarwal, A. (2007) Biofuels (alcohols and biodiesel) applications as fuels for internal combustion engines. Progress in Energy and Combustion Science. 33. p.233-271.
57) Schmid, AL. & Hoffman CA. (2004) Replacing diesel by solar in the Amazon: short-term economic feasibility of diesel hybrid systems. Energy Policy. 32. p.881-898.

58) Alazraki, R. Haselip, J. (2007) Assessing the uptake of small-scale photovoltaic electricity production in Argentina: The premier project. Journal of Cleaner Production. 15. p.31-142.
59) Bansal, NK. Sandeep, G. (2000) Integration of photovoltaic technology in cafeteria building, at Indian Institute of Technology, New Delhi. Renewable Energy. 19. p.65-70.
60) Elhadidy, MA. (2002) Performance evaluation of hybrid (Wind/Solar/Diesel) power systems. Renewable Energy. 26. p.401-413.
61) Elhadidy MA. & Shaahid, SM. (2005) Decentralized/stand-alone hybrid wind-diesel power systems to meet residential loads of hot coastal regions. Energy Conversion and Management. 46. p.2501-2513.
62) Shaahid, SM. & Elhadidy, MA. (2004) Prospect of autonomous/ stand-alone hybrid (photovoltaic+diesel+battery) power systems in commercial applications in hot regions. Renewable Energy. 29. p.165-177.
63) Razykov T. Ferekides, CS. Morel, D. Stefanakos, E. Ullal, HS. Upadhyaya, HM. (2011) Solar photovoltaic electricity: Current status and future prospects. Solar Energy. 85(8). p.1580-1608.
64) http://www.n-e-enewables.org.uk/page/technologies/photovoltaics/pv_variations.cfm
65) Pachouri, R. (2012) From Sunlight to Electricity: A practical handbook on solar photovoltaic applications. Fourth edition, TERI, New Delhi, India.
66) Kolhe, M. Kolhe, S. Joshi, JC.(2002) Economic viability of stand-alone solar photovoltaic system in comparison with diesel-powered system for India. Energy Economics. 24. (155-165).
67) Nouni, M. Kandpal, T. Mullick, S. (2006) Photovoltaic projects for decentralized power supply in India: A financial evaluation. Energy Policy. 34. p.3727-3738.
68) Lazou, A. (2000) The economics of photovoltaic stand-alone residential households: A case study for various European and Mediterranean locations. Solar Energy Materials & Solar Cells. 62 (2000) 411-427.
69) Charabi, Y. and Gastli, A. (2011) PV site suitability in Oman analysis using GIS-based spatial Fuzzy multi-criteria evaluation. Renewable Energy. 36. 2554-2561.
70) Makrides, G. Zinsser, B. Georghiou, G. Schubert, M. Werner, J. (2009) Temperature behaviour of different photovoltaic systems installed in Cyprus and Germany. Solar Energy Materials & Solar Cells. 93. p.1095-1099.
71) Yoo, S. and Lee, E. (2002) Efficiency characteristic of building integrated photovoltaics as a shading device. Building and Environment. 37(6). p.615-623.
72) Chow, T. He, W. Chan, A. Fong, K. Lin, Z. Li, J. (2008) Computer modelling and experimental validation of a building-integrated photovoltaic and water heating system. Applied Thermal Engineering. 28. p.1356-1364.
73) Hua, S. Zhou, Q. Kong, D. Ma, J. (2006) Application of valve-regulated lead-acid batteries for storage of solar electricity in stand-alone photovoltaic systems in the northwest areas of China. Journal of Power Sources. 158. p.178-85.
74) Posorski, R. Bussmann, M. Menke, C. (2003) Does the use of solar home systems (SHS) contribute to climate protection. Renewable Energy. 28. p.1061-1080.
75) http://exploringgreentechnology.com/solar-energy/cost-of-solar-panels/
76) Bagul, A. Salameh, Z. & Borowy, B. (1996) Sizing of a stand-alone hybrid wind-photovoltaic system using a three-event density approximation. Solar Energy. 56(4). p. 323-335.
77) Kaldellis, K. Kondili, E. & Filios, A. (2006) Sizing a hybrid wind-diesel stand-alone system on the basis of minimum long-term electricity production cost. Applied Energy. 83. p.1384-1403.
78) Kellog, W. Nehrir, M. Venkataramanan, G. & Gerez, V. (1996) Optimal unit sizing for a hybrid wind/photovoltaic generating system. Electric Power Systems Research. 39. p. 35-38.
79) Borowy, B. & Salameh, Z. (1994) Optimum photovoltaic array size for a hybrid wind/PV system. IEEE, Transaction on Energy Conversion. 9(3). p.482-488.
80) Deshmukh, MK. Deshmukh, SS. (2008) Modeling of hybrid renewable energy systems. Renewable and Sustainable Energy Reviews. 12. p.235-49.
81) Byrne, J. Glover, L. and Hegedus, S. (2005) A report The potential of solar electric applications for Delaware's poultry farms report. Center for Energy and Environmental Policy.
82) GREENTECH KNOWLEDGE SOLUTIONS (P) LTD. (2010) A Report on Solar water heaters in India: market assessment studies and surveys for different sectors and demand segments, New Delhi, India.
83) Fantidis, J. Bandekas, D. Potolias, C. Vordos, N. Karakoulidis K. (2012) Financial analysis of solar water heating systems during the depression: Case study of Greece. Inzinerine Ekonomika-Engineering Economics 23(1). p.33-40.
84) Kalokirou, S. and Tripanagnostopoulos (2006) Hybrid PV/T solar systems for domestic hot water and electricity production. Energy Conversion and Management. 47. 3368-3382.
85) Hang, Y. Qu, M., and Zhao, F. (2012) Economic and environmental life cycle analysis of solar hot water systems in the United States. Energy and Buildings. 45. p.181-188.
86) INDIA. MINISTRY OF NEW AND RENEWABLE ENERGY AND INTERNATIONAL COPPER

PROMOTION COUNCIL (2010) User's Handbook on Solar Water Heaters. New Delhi. MNRE & ICPC.

87) Ayompe, L. (2011) Comparative field performance study of flat plate and heat pipe evacuated tube collectors (ETCs) for domestic water heating systems in a temperate climate. Energy. 36. p.3370-3378.

88) Tiwari, R. Kumar, A. Gupta, S. Sootha, G. (1991) Thermal performance of flat-plate solar collectors manufactured in India. Energy Conversion and Management. 31(4). p.309-13.

89) Dang, A. and Sharma, JK. (1983) Performance of flat plate solar collectors in off-south orientation in India. Energy Conversion & Management.23(3). p.125-130.

90) Amer, E. (1998) Transient method for testing flat-plate solar collectors. Energy Conversion and Management. 39(7). p.549-558.

91) Alvarez, A. Cabeza, O. Mu�z, MC. Varela, LM. (2010) Experimental and numerical investigation of a flat-plate solar collector. Energy. 35(9). 3707-3716.

92) Zambolin, E. Del, D. (2010) Experimental analysis of thermal performance of flat plate and evacuated tube solar collectors in stationary standard and daily conditions. Solar Energy. 84(8). p.1382-1396.

93) Ayompe, L. Duffy, A. McCormack, SJ. Conlon, M. Keeve, M. (2011) Comparative field performance study of flat plate and heat pipe evacuated tube collectors (ETCs) for domestic water heating systems in a temperate climate. Energy. 36(5) p.3370-3378.

94) Huang, J. Pu, S. Gao, W. Que, Y. Experimental investigation on thermal performance of thermosyphon flat-plate solar water heater with a mantle heat exchanger. Energy. 35(9). p.3563-3568.

95) Al-Nimr, MA. Alkam, MK. (1998) A modified tubeless solar collector partially filled with porous substrate. Renewable Energy. 13(2). p.165-173.

96) Hoffmann, R. Brondani, M. Peppias, F. Serafini, S. & Luiz f. (2014), Economic-environmental comparison between flat plate and evacuated tube solar collectors, GlobalNEST International Journal. 16(6). p.1100-1110 �

97) Ghoneim, A. Shabana, H. Shaaban, M. Mohammedein, M. (2016) Performance analysis of evacuated tube collector in hot climate. European International Journal of Science and Technology. 5(3). p.8-20.

98) Islam, R. Sumathy, K. and Khan, S. (2013) Solar water heating systems and their market trends. Renewable and Sustainable Energy Reviews 17(C). p. 1-25.

99) Nahar, NM. (2003) Year-round performance and potential of a natural circulation type of solar water heater in India. Energy and Buildings. 35(3). p.239-347.

100) Duffie, JA. And Beckman (1991), Solar Engineering of Thermal processes. Second edition, Wiley, New York. John Wiley & Sons.

101) Sabiha MA. Saidur, R. Mekhilef, S. Mahian, O. (2015) Progress and latest developments of evacuated tube solar collectors. Renewable and Sustainable Energy Reviews. 51 (2015) 1038-1054.

102) Urban, F. Geall, S. Wang, U. (2016) Solar PV and solar water heaters in China: Different pathways to low carbon energy. Renewable and Sustainable Energy Reviews. 64. p.531-542 (Open access).

103) Purohit, P. & Michaelowa, A. (2007) Potential of wind power projects under the Clean Development Mechanism in India. Carbon Balance and Management. 2(8) (open access). doi:10.1186/1750-0680-2-8.

104) Antonio, M. and Simona, C. (2012) Performances of small wind turbines available in market in South Italy. Energy Procedia. 16. p.137-145.

105) http://www.energywise.govt.nz/your-home/generating-your-own-energy/wind.

106) Kasim, K. (2002) A method for determination of wind speed persistence and its application. Energy. 27(10) p.967-973.

107) Herbert, GM. Iniyan,S. Sreevalsan,E. Rajapandian,S. (2007)A review of wind energy technologies. Renewable and Sustainable Energy Reviews 11. p.1117–1145.

108) Weisser, D. (2003) Wind energy analysis of Grenda: an estimation using the Weibull density function. Renewable Energy. 28. p.803-12.

109) Grant, A. Johnstone, C. Kelly, NJ. (2007) Urban wind energy conversion: The potential of ducted turbines. Renewable Energy. 33(6). p.157-1163.

110) Karothia, K et al (2014) International conference on energy generation and conservation for meeting india's futuristic needs Ghaziabad, https://www.researchgate.net/publication/262379495_feasibility_analysis_of_rootop_wind_turbine_in_India

111) Li, Z. Boyle, F. Reynolds, A. (2012) Domestic application of micro wind turbines in Ireland: Investigation of their economic viability. Renewable Energy. 41. p.64-74.

112) Siddique, N. Chowdhury, A. and Rizwan, S. (2012) A Comparative Study of rooftop micro wind turbines on Bangladesh perspective. 2nd International Conference on Power, Control and Embedded Systems. On Dec. 17-19th 2012.

113) http://centurionenergy.net/types-of-wind-turbines

114) http://www.omafra.gov.on.ca/english/engineer/facts/03-047.htm#availability

115) http://www.quora.com
116) Messineo, A. and Culotta, S. (2012) Evaluating the performances of small wind turbines: A case study in the South of Italy, Energy Procedia.Vol. 16 Part-A pp.137-145.
117) Milanese, M. Risi. A. and Laforgia, D. (2013) Performance Optimization of Building Integrated-Mounted Wind Turbine. Applied Mechanics and Materials. 260(261) p.69-76.
118) Tiwari, K. Harinarayana, T. (2014) Increasing the efficiency of grid tied micro wind turbines in low wind speed regimes. Scientific Research. 5(10). p.249-257.
119) THE GAZETTE OF INDIA. (1999) Ministry of Environment and Forests. Gazette notification. New Delhi.
120) Patil, J. and Dwivedi, A. (2014) Clay - fly ash burnt bricks - An experimental Study. International Journal of Innovative Research in Science, Engineering and Technology. 3(4). p.265 - 269.
121) Jeong, YS. Lee, SE. & Hul, JH. (2012) Estimation of CO_2 emisssion of apartment buildings due to major construction materials in the Republic of Korea. Energy and Buildings.49. p.437- 442.
122) PA (2007) Practical Action. Sustainable Smallscalebrick production: A question of energy. Technical Brief Note. The Schumacher Centre for Technology and Development Bourtonon-Dunsmore Rugby Warwickshire, CV23 9QZ,United Kingdom.
123) Patil, J. Dwivedi, A. (2013) Clay - fly ash burnt bricks - An experimental
124) Study. International Journal of Innovative Research in Science, Engineering and Technology. 3(4). 265-269.
125) Ralegaonkar, RV. Madurwar, MV Raut, SP. Dakwale, VA & Mandavgane, SA. (2014) Application of solid wastes in sustainable building masonry products: A techno environmental study. In International conference on Sustainable civil infrastructure-2014. IIT Hydrabad, 17Thto 18th October 2014.
126) Madurwar, MV. Mandavgane, SA. & Ralegaonkar, RV.(2014) Use of bio-fuel byproduct sugarcane bagasse ash inlow density energy efficient bricks. Construction Materials and Structures. 2(1). p.20-32. Reddy, BVV. (2009) Sustainable materials for low carbon buildings. Low Carbon Technologies. 41.p.75-181.
127) http://www.ntpc.co.in/ash-download/1674/0/fly-ash-cement-concrete-e2%80%93- resource-high-strength-and-durability-structure-lower-cost
128) http://www.teriin.org/ee/pdf/fly ash1.pdf
129) Shweta, O. Rathi, P. Khandve V. (2015) A new eco-friendly material for construction. International Journal of Advance Engineering and Research Development. 2 (4). p. 410-414.
130) Aalka, R. (2016) Stabilized mud block as a construction material. Airo International Research Journal. 7. P.(1-6).
131) http://www.nrel.gov/docs/fy14osti/61019.pdf
132) http://pvwatts.nrel.gov/
133) Leng, GJ. and CANMET Energy Diversification Research (1998). Renewable energy technologies project assessment tool: RETScreen.
134) Lund, H. Duic, N. Krajacic, G. & Carvalho, MDG. (2007) Two energy system analysis models: A comparison of methodologies and results. Energy 32. p. 948-954.
135) www.lindo.com
136) Sinha, S. Chandel, S. (2014) Review of software tools for hybrid renewable energy systems. Renewable and Sustainable Energy Reviews. 32. p.92–205.
137) Gowri K. (2005) Desktop tools for sustainable design, ASHREY Journal. p.43-46.
138) Lalwani, M. Kothari, DP. Singh, M. (2010) Investigation of solar photovoltaic simulation softwares. International Journal of Applied Engineering Research. 1(3). p. 585-601.
139) UNITED STATES. ENVIRONMENTAL PROTECTION AGENCY. (2010) Progress report. EPA.
140) http://projectvendor.com/aac-blocks-eco-friendly-substitute-bricks/
141) Imbabi, M. Carrigan, C. McKenna, S. (2012) Trends and developments in green cement and concrete technology. International Journal of Sustainable Built Environment. 1(2). p. 94-216.
142) INDIA. PUBLIC WORKS DEPARTMENT, NAGPUR. (2015) Current schedule of rates 2015, Nagpur. PWD.
143) http: //www.rainwaterh.org/urban/ components.htm. [accessed December 2015].
144) http://www.rainwaterh.org/urban/ components.htm. [accessed December 2015].
145) http://kscst.org.in/rwh_files/rwh_filter.html. [accessed December 2015].
146) http://www.rainwaterharvesting.org/urban/Components.htm.[accessed December 2015].
147) www.MWRA.com. [accessed July 2012].
148) www.dualflushkit.com. [accessed November 2015].
149) http://www.contractorbhai.com/2015/05/29/top-50-products-for-2015-fly ashucet-aerators/. [accessed December 2015]
150) http://www.conservationwarehouse.com/fly ashucet-aerator-fly ashqs.html. [accessed December 2015].

151) http://www.ebay.in/itm/131633265762?aff_source=sok-goog. [accessed December 2015].
152) www.gizing.com/go/6810. [accessed January 2013].
153) http://www.industry.siemens.com.cn/industrysolutions/cn/zh/Water/.[accessed January 2013].
154) Ecospan club, 2009, Sustainable Sanitation Practice Issue 1.
155) http://wavebrite.co.uk/wp-content/uploads/2011/11/2011-Brochure.pdf. [accessed January 2013].
156) http://www.greenworldinvestor.com/2014/11/05/solar-cell-price-and-solar-panel-cost-in-india-per-watt/. [accessed July 2014].
157) https://www.bijlibachao.com/solar/solar-panel-cell-cost-price-list-in-india.html. [accessed November 2015].
158) http://solarenergypanels.in/price-list/tata-solar-panels-inverter-battery-price-list-in-india. [accessed November 2014].
159) http://www.thesolarindia.com/solar-panels-price-list-in-india/[accessed in 2014].
160) https://www.bijlibachao.com/solar/solar-panel-cell-cost-price-list-in-india.html. [accessed July 2013].
161) http://www.energymatters.com.au/panels-modules/choosing-solar-panels/ [accessed November 2016].
162) http://upsinverterinfo.com/mono-crystalline-vs-poly-crystalline-solar-pv-for-indian-conditions.html.[accessed November 2016].
163) Source:mnre.gov.in/schemes/...systems/solar-systems/solar-water-heatres-air-heating-systems/ [accessed July 2012].
164) http://mnre.gov.in/file-manager/UserFiles/fly ashq_wind.pdf. [accessed July 2012].

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