

Solar Wind, Hybrid Renewable Energy Systems



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Introduction

Energy drives global economic activity. The living standards of the people across the world is on the rise and with ever expanding population, the total demand for energy is expected to increase by 21% by 2030, according to estimates from IEA, 2015. While catering to the energy demands of the people is a priority, Governments across the globe have an obligation to ensure that the climate is protected for future generations. Hence, there is a lot of emphasis on sustainable renewable energy across the world.

According to a report from World Economic Forum, the energy sector influences the vibrancy and sustainability of the entire economy – from job creation to resource efficiency and the environment. Major shifts in the sector can have a strong ripple effect throughout the economy as evidenced in Japan following the 2011 earthquake, or by the recent volatility in oil prices. Making the energy supply more cost effective, reliable, secure and environmentally sustainable thus contributes to the long-term resilience of economic development.

Supported by technology advancements, ever increasing energy demands, steep reduction of manufacturing costs and enabling policies, the deployment of renewable energy solutions has seen a remarkable growth in the past decades. Renewable energy solutions not only improves the energy security but also assists communities in energy accessibility, job creation and fewer adverse climate change impact. According to a report by IEA, the renewable energy sector is expected to provide employment to over 24 million people by 2030.

Trivia:

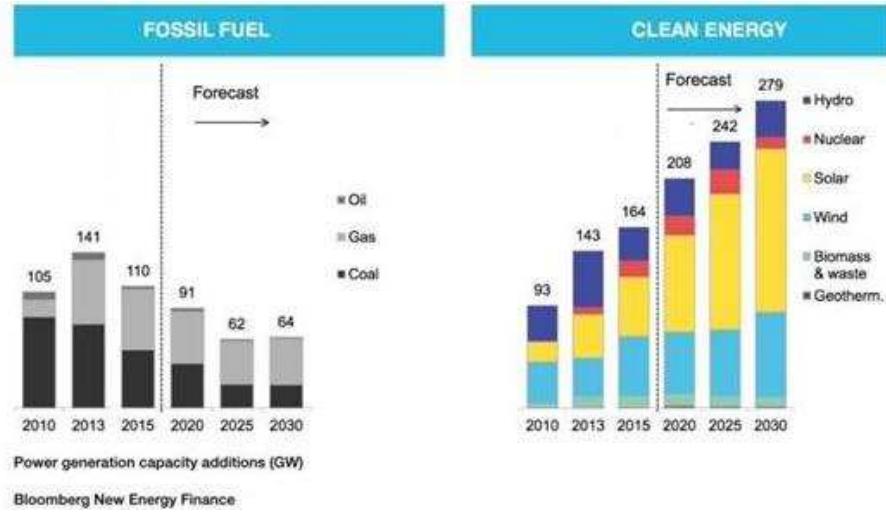
Do you know that peak demand in India is 140 GW and our installed capacity is 260 GW. Despite this, we have power shortages and blackouts. This is due to insufficient fuel availability and excessive costs (NITI Aayog - Report on India's Renewable Electricity Roadmap 2030 – Feb, 2015)

Renewable Energy

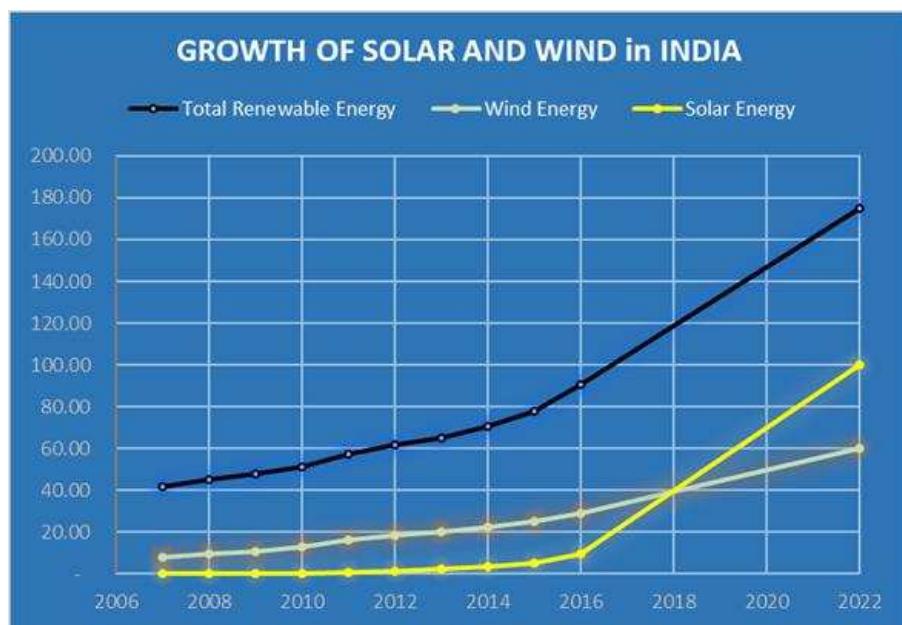
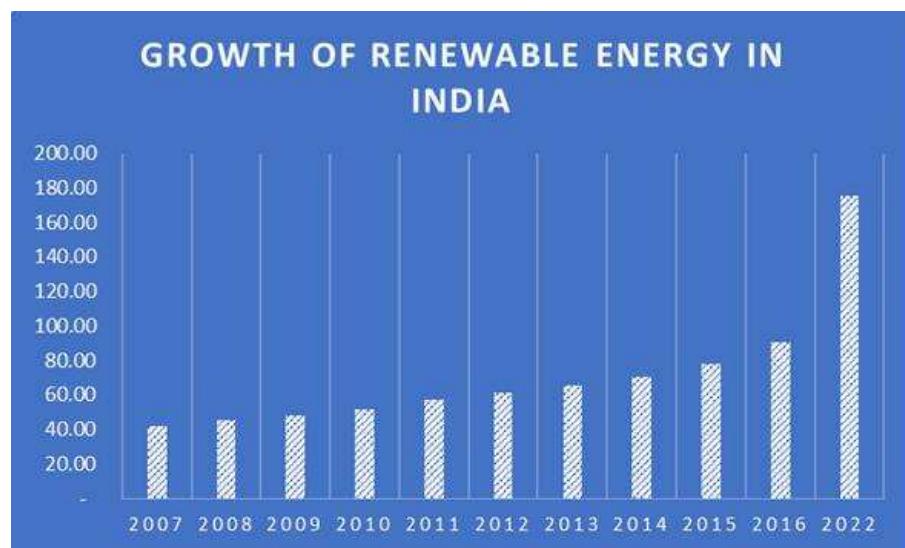
Renewable energy is free source of energy, clean, affordable, and effectively infinite. It produces no emissions and results in cleaner air. The renewable energy cannot be depleted like fossil fuels. Fossil fuels are limited, and will be unavailable but the same scenario will not happen with renewable energy sources because Sun will continue to shine, wind will continue to blow.

Renewable energy generation systems like Solar, Wind and Bio are the promising and the most important renewable energy technologies. The wind power industry is one of the fastest expanding industries because of rapid growth of installed capacity.

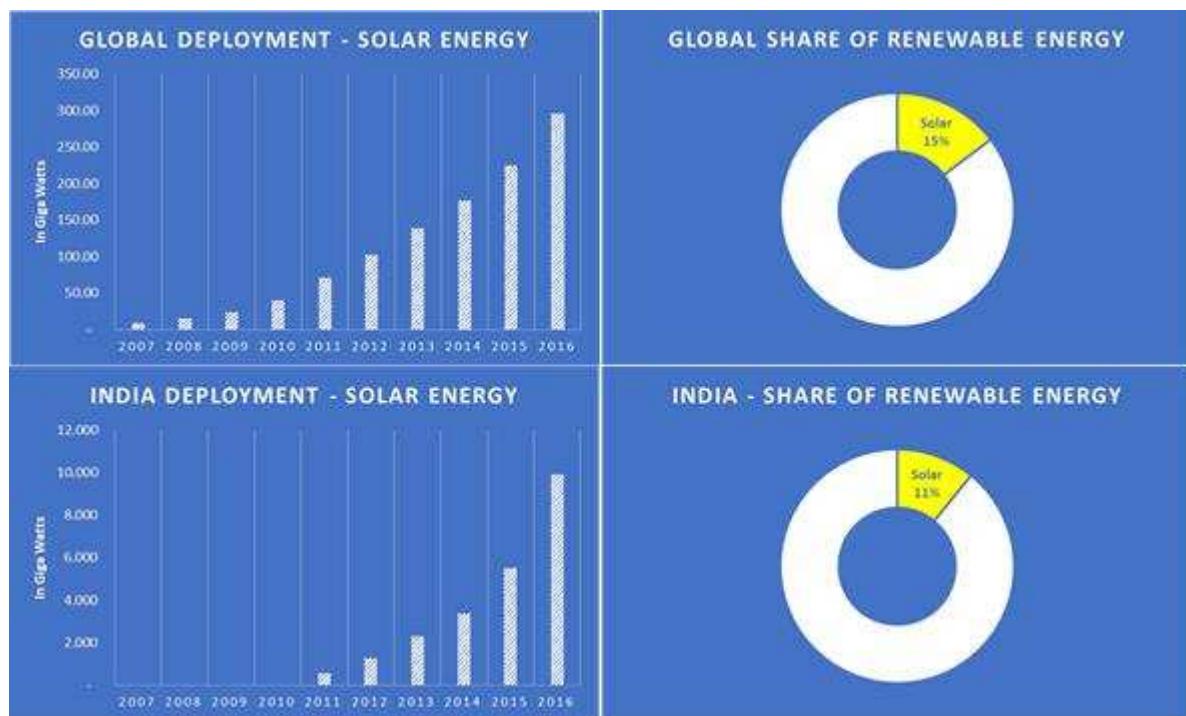
According to a report by Bloomberg, the amount of energy produced using fossil fuels will see a sharp decline in the coming few years while energy produced through clean energy sources will increase substantially. The most preferred sources would be Solar and Wind.



At the end of 2016, Hydro Energy contributes to about 50% of the capacity, Wind – 31% and Solar about 11%. India has been steadily investing in its renewable energy sector and is expecting to increase its overall renewable energy capacity from 90 GW in 2016 to about 175 GW in 2022.



Solar Energy



Solar power is derived from Sun's radiation. It is interesting to note that the energy that Sun provides to earth for an hour can meet the energy demands of the entire planet for a year. However, we are able to harness only 0.001 percent of that energy. Solar Energy was not very popular due to inefficiencies in the systems and higher cost. However, due to higher energy demand, the technology has been improved considerably making it a very efficient source of clean energy.

Solar Energy contributes to about 15% of global renewable energy production. The installed capacity of Solar Energy worldwide has increased from about 9.2 GW in 2007 to about 296 GW in 2016 at a CAGR of 312%. India has made rapid progress from 2010 in Solar Energy, increasing its capacity from a meagre 0.6 GW in 2010 to about 9.9 GW by 2016.

Trivia: Longyangxia Dam Solar Park is the world's biggest solar farm. It is a 850 (MW) photovoltaic power station in Qinghai, China.

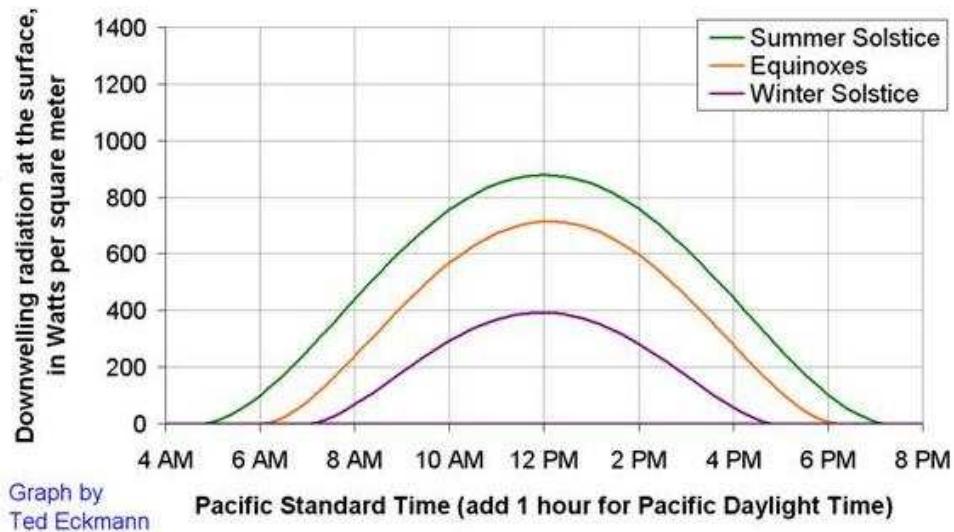
Solar Energy has many advantages.

- ✓ It is a clean source of energy
- ✓ Abundance of the resource – according to estimates by Government of India, India can generate 10,000 GW of solar energy
- ✓ Sustainable
- ✓ Needs less infrastructure compared to traditional fossil fuel based power generation units
- ✓ Easy and Quick Installation
- ✓ Very less carbon footprint for manufacturing of the photovoltaic cells
- ✓ No noise during operations, hence can be installed in residential neighbourhoods
- ✓ Power can be generated at the place of consumption
- ✓ Low cost of operations
- ✓ Technology advancements have driven down the cost of production
- ✓ Affordable. Government Policy on Solar Energy has improved the affordability further
- ✓ Suitability – according to Government of India estimates, most parts of the country are suitable for installation of solar energy units, including Space

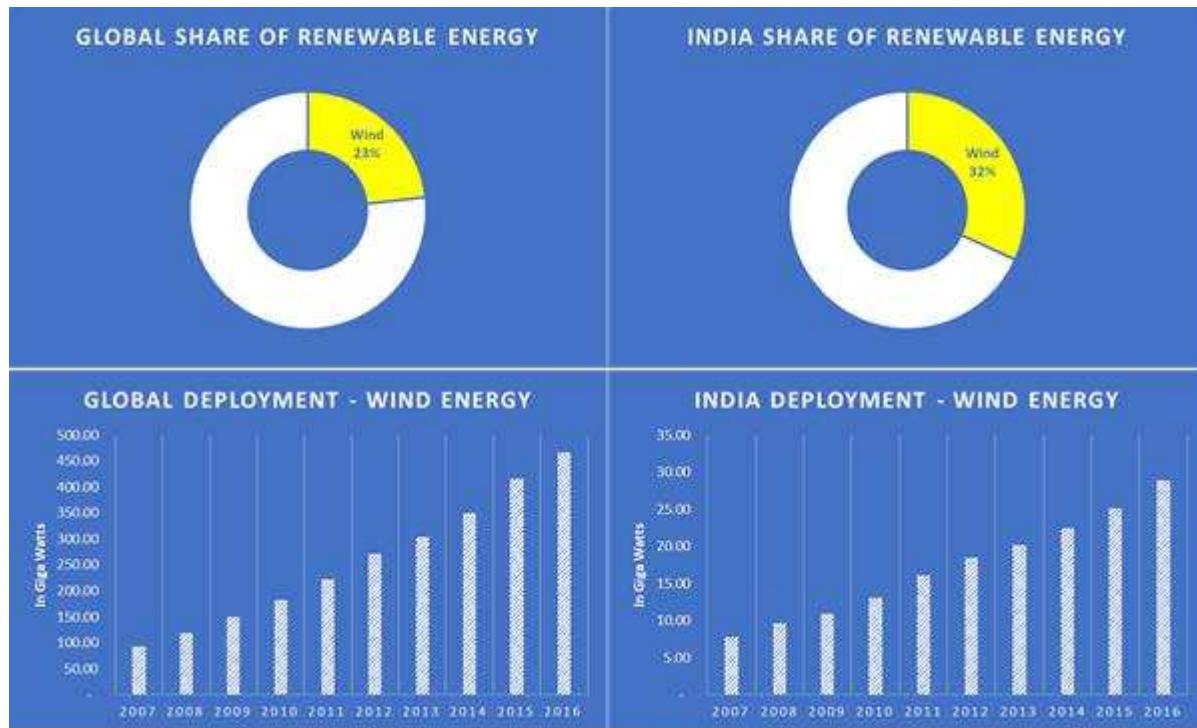
While it has many advantages over traditional energy generation options, it has its share of drawbacks

- Available only for 20% to 30% (4 to 6 hrs) in a day
- For mass production, it requires large surface areas
- Power storage is expensive as it requires more batteries for storage during non-sunny days. Also, solar batteries are relatively expensive

- Seasonality of the source. Power generation reduces dramatically during times of cloud cover
- Not suitable for power generation across all regions
- Efficiency of Solar panels – at present the panels can only convert about 22% of the available sunlight to electricity. Efficiency of the panels can be improved further



Wind Energy



Wind is technically a form of solar energy. Winds are caused by the heating of the atmosphere by the sun, the rotation of the Earth, and the Earth's surface irregularities. Wind energy is derived from the winds that blow across lands and seas. Wind turbines convert the kinetic energy in the wind into electricity. For as long as the sun shines and the wind blows, the energy produced can be harnessed to send power across the grid

Wind power, as an alternative to fossil fuels, is abundant, renewable, clean, widely distributed, consumes no water, and uses little land. Wind farms are established where there is abundance of wind to generate power and is supplied to the grid. Variance in wind speed makes the wind energy unreliable, hence it is always used in conjunction with other energy sources. Offshore wind farms provide more reliable wind energy however they are very expensive to build.

Wind Energy contributes about 23% of global renewable energy production and about 4% of the global energy production. As of 2015, Denmark produces nearly 40% of its electrical power from wind. India produces about 32% of its renewable energy from wind. While the current capacity is about 29 GWs, India aspires to grow that to about 60 GWs by 2022.

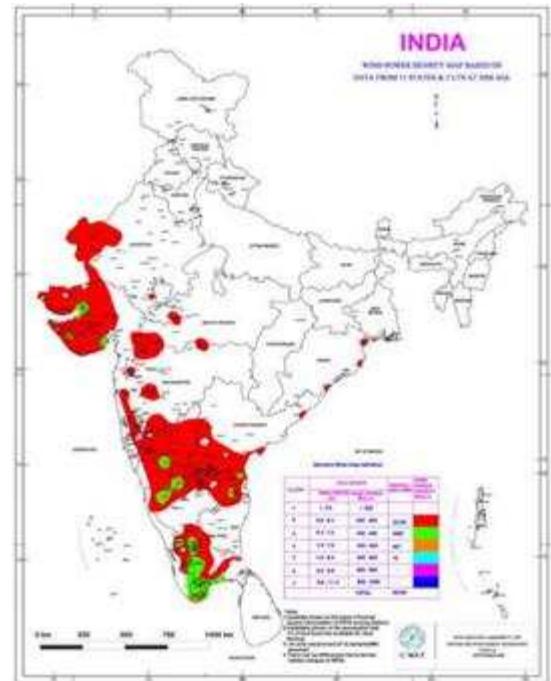
Trivia: Gansu Wind Farm in Gansu, China has the largest installed capacity of over 6,000 MW. The farm is expected to produce 20,000 MW by 2020. India has the world's third biggest wind farm at Muppandal in Tamil Nadu, which generates about 1,500 MW.

Advantages of Wind Power

- ✓ Is a clean source of energy. According to the Wind Vision Report, wind has the potential to reduce cumulative greenhouse gas emissions by 14%, saving \$400 billion in avoided global damage by 2050
- ✓ Sustainable -
- ✓ Larger Capacity in lesser Space
- ✓ Availability of Modern Technologies
- ✓ Can be Built on Existing Farms
- ✓ Does not consume water like the conventional electricity sources
- ✓ Negligible carbon foot print in manufacturing of the equipment
- ✓ Job Creation - In 2016, the wind energy sector invested more than \$8.8 billion of private capital in the U.S. economy to build projects and employed more than 101,000 workers (approximately 30% women, 11% veterans, and 25% minorities), according to the 2017 U.S. Energy and Employment Report.

Disadvantages of Wind Power

- Cost of power – The cost of power generated by wind mills is directly dependent on the wind speed at the site. At lower wind speeds, the cost of wind power is more than the traditional power sources
- Huge installation costs – While the wind energy systems are very expensive to manufacture and install, most of the locations suited for wind energy are in remote places making it even more difficult and escalates the cost of installation
- Noise Pollution – Wind turbines create noise hence not very suitable for installation in residential areas
- Visual Impact to Landscape – Typically wind turbines are setup at a height of 50-80 mts above the ground and hence impacts the view of the landscape
- Danger to wildlife – While the danger to wild life from wind energy is far less compared to traditional sources, birds have been killed flying into rotating turbine blades. Hence wind energy is not suitable for ecologically sensitive areas
- Seasonality – Wind energy across geographies is seasonal, hence the reliability of wind energy is low
- Suitability – Wind energy is not suitable for every geography. In India, only 4 states are very well suited for sustained wind energy
- Higher transmission costs – Since wind mills/farms are established in remote areas, high costs are incurred to setup new transmission lines to connect to the grid

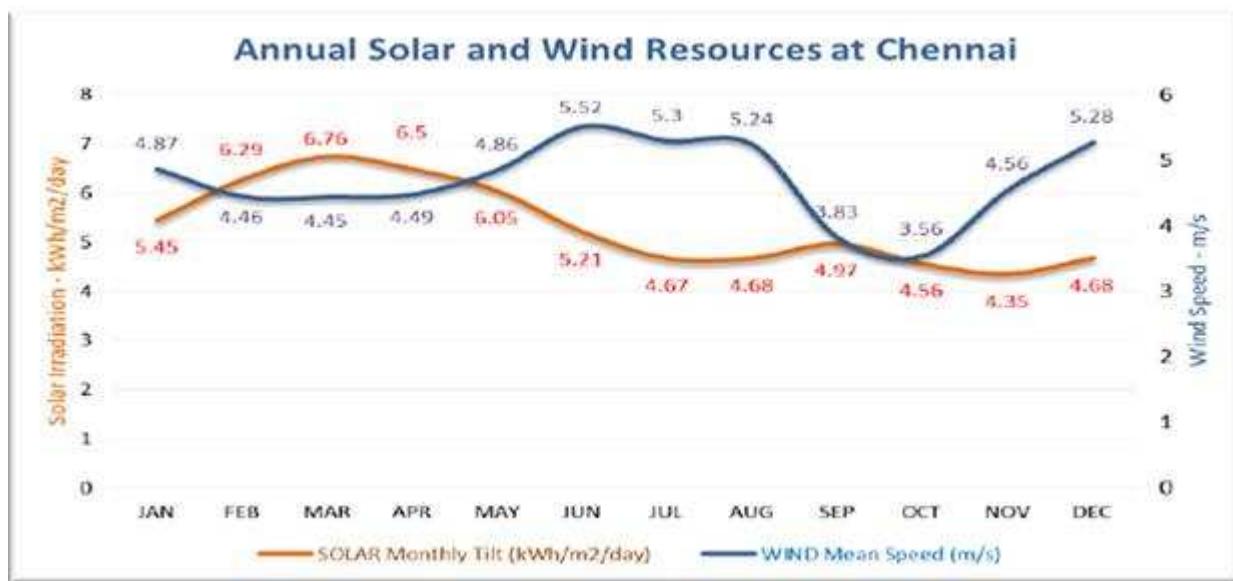


Trivia: The Gansu Wind Farm in China has an installed capacity of 6000 MW. However due to the intermittent and unreliable nature of wind power, low demand and higher transmission costs, many wind turbines have been shut down. Big doesn't mean Best.

Is there a way to combine the positives of both Wind and Solar power units to offset the drawbacks that they individually have and still be effective?

The answer to this question is YES. We can combine both Wind and Solar power units to offset the drawback that they individually offer and still be more effective. The solution is **HYBRID ENERGY**.

Hybrid Energy combines the forces of Solar and Wind to generate electricity. It is interesting to note that the natural resources required for Wind and Solar complement each other and hence a hybrid setup can generate more power reliably than a Solar or wind energy plant individually. The below figure shows the Solar irradiation and wind speeds in Chennai. When you notice the graph closely, you will notice that when the wind energy decreases, the solar irradiation picks up and vice versa, thus ensures continuous production of energy across all seasons and all times of the day.



A hybrid system will help improve the efficiency of the batteries, as the charging and discharge cycles are more uniform, thus reducing the cost of the batteries and improving its life. As a Hybrid system depends both of Solar and Wind, the area required for deployment is also greatly reduced. Below are some of the major advantages of the Hybrid System.

Advantages of a Hybrid System

- ✓ More energy density (energy per sq. meter) can be obtained
- ✓ Best suitable for distributed energy
- ✓ Based on the location and the availability of wind and solar sources at the location, the design of the system can be altered to gain the best from the available sources
- ✓ Battery will work efficiently as continuous power generation can be obtained therefore, smooth charging and discharging can be seen
- ✓ Low cost of operations
- ✓ Increased efficiency – Since the energy density is more, the system can operate at a much higher efficiency than traditional wind and solar systems
- ✓ Because of increased efficiency, hybrid energy systems can be deployed at places of consumption, thus reducing the costs of transmission and transmission losses
- ✓ Lower installation costs compared to Solar and Wind energy only installation
- ✓ Cost of power is much lesser than power from the grid over its life time
- ✓ Due to continuous power generation, there is even an option to supply power to the grid, at times of low usage thus making it more efficient and economical
- ✓ Effective space utilisation – Hybrid systems when designed well can occupy much less space than traditional wind only or solar only installation. Thus, more energy can be produced from the same space



Design of the hybrid system is very important to ensure that the benefits are fully realised. Windstream Technologies Inc has designed a very effective Hybrid Energy solution that is very reliable, modular, scalable, efficient with a very high ROI.

The SolarMill® that WindStream Technologies' manufactures is based on a modular, scalable, distributed renewable energy system designed and optimized for on and off grid installations. At its core is a highly efficient wind energy device, utilizing three (3) low-profile vertical axis wind turbines (VAWT) mounted on a single base. The units can be interconnected to increase energy production capability in low speed and turbulent wind environments commonly found at lower elevations.

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To provide more consistent energy generation than a “wind only” or “solar only” system, WindStream Technologies’ SolarMill® incorporates Photo Voltaic (P.V.) technology within a compact footprint, creating the greatest energy generation density for any product on the market. The hybrid concept of the SolarMill® is unique, seamlessly utilizing wind and solar energy generation in one unit. This allows the product to be an effective solution in markets where the natural resources available for wind or solar energy alone do not justify investment into any small wind product. The SolarMill is simple, efficient and cost-effective way to utilize available wind and solar resources in “India”.

Performance of a well-designed Hybrid System

- ✓ Roof top Wind and Solar Hybrid Energy System.
- ✓ 24-hour power production capability.
- ✓ Higher power density per square foot.
- ✓ Scalable power generation.
- ✓ Mechanical braking at high-speed winds beyond 18.5 m/s.
- ✓ Appropriate for on or off grid applications.
- ✓ Offsets peak energy pricing for grid tied systems.
- ✓ Minimizes backup battery storage requirements.
- ✓ Online tool for power generation monitoring.
- ✓ Power generation starting at 2 m/s wind speed.
- ✓ Easy to mount on any rooftop; no complicated masts, guy wires, or towers.
- ✓ Simple ballasted installation that avoids roof penetration.
- ✓ Visually engaging design complementing building façade.
- ✓ Environment-friendly, silent operation.
- ✓ Cost effective.

Let's compare the benefits of a Hybrid System with Solar and Wind only Installations

	Solar	Wind	Hybrid*
Production	<ul style="list-style-type: none"> • Daytime only • Production varies on the irradiation availability • Dependence on weather conditions • A typical 10KW system generates about 14,850 KW/Year 	<ul style="list-style-type: none"> • Production varies on the wind availability • Higher cut in speed (avg. of 3m/sec) • Production is intermittent and is seasonal 	<ul style="list-style-type: none"> • Produces day and night (24x7x365) • Takes advantage of the complimentary Solar and Wind sources • Reduces the variability in renewable energy production • Low cut in speed of 2m/sec • A typical 10KW system generates about 16,000 KW/Year
Cost of installation	<ul style="list-style-type: none"> • Moderate installation costs • Based on the nature of installation, land costs are accrued • 10 KW on grid system costs about 8.5 Lakhs 	<ul style="list-style-type: none"> • Very high installation costs because of the system as well as the land • Usually Wind Farms are established in remote areas, hence high costs are incurred to setup the transmission lines • 10 KW on grid system costs about 15 Lakhs 	<ul style="list-style-type: none"> • Moderate installation costs • Land requirements are minimised due to increase in energy density • 10 KW on grid system costs about 9 Lakhs
Maintenance	<ul style="list-style-type: none"> • Less maintenance required • Battery replacement costs are high due to inefficient charge and discharge cycles 	<ul style="list-style-type: none"> • High Maintenance & replacement costs due to wear & tear of the gears • Battery replacement costs are high due to bad charge and discharge cycles 	<ul style="list-style-type: none"> • Very Minimum/no maintenance costs involved in the system • Lesser than Solar only solution, as the number of solar panels are less • No gears in the system

			<ul style="list-style-type: none"> Batter replacement costs are minimal as the batter charge and discharge cycles are more uniform
Payback Period	<ul style="list-style-type: none"> 6-8 Years 	<ul style="list-style-type: none"> 10-13 years 	<ul style="list-style-type: none"> 6-8 Years
Cost per KwH	<ul style="list-style-type: none"> \$0.05 – 0.15 	<ul style="list-style-type: none"> \$0.1 – 0.2 	<ul style="list-style-type: none"> \$0.02 – 0.1
Impact on Environment	<ul style="list-style-type: none"> Silent Operation Less impact on environment than traditional systems 	<ul style="list-style-type: none"> High Noise pollution Less impact on environment than fossil fuel based solutions. However, wind mills may harm/kill birds Some trees have to be destroyed to setup the transmission lines 	<ul style="list-style-type: none"> Silent Operation Lower impact than Solar only solution, due to lesser use of solar panels
Energy Efficiency	<ul style="list-style-type: none"> Energy Density of about 13W/Sqft 	<ul style="list-style-type: none"> Variable 	<ul style="list-style-type: none"> Energy Density is 30W/Sqft
Area required for a 10KW system	<ul style="list-style-type: none"> 100 Sqmtrs 	<ul style="list-style-type: none"> 100 Sqmtrs 	<ul style="list-style-type: none"> 70 Sqmtrs
Better Life	<ul style="list-style-type: none"> Low to Medium, as the batteries are charged only during the day time 	<ul style="list-style-type: none"> Low to Medium, as the batter charge cycle is dependent of variable production 	<ul style="list-style-type: none"> High, as the batteries are charge cycles are more uniform (charged 24x7x365)

Note: * Hybrid System as designed by WindStreamTechnologies

The SolarMill™ can generate power at wind speeds as low as 2m/sec to about 18m/sec and is so modular in design that it can be configured to generate the best energy density at any given site. Their hybrid system is scalable to setup a huge hybrid energy farm or setup on any kind of a roof top. WindStream Technologies has deployed their solution across many facilities in India and across the world.

Installation Pictures



**A 10 KW Hybrid Installation @ Industrial area
Shammerpet, Hyderabad**



A 1.75 Kw installation on Railway Crossing

SPECIALITY APPLICATIONS:



11Kw Installation for Telecom Tower



Mobile Mill



40Kw Power Mil installation for Mini Grid application.



MW Scale Installations

Partnering with Educational Institutions

WindStream Technologies was launched in 2008 to create low-cost hybrid, renewable energy solutions for urban, suburban, and on and off-grid environments. In 2009, WindStream partnered with the Purdue Research Center in New Albany, Indiana to perform research and development. Since then, WindStream has opened its doors to student groups for tours of the manufacturing facility and interviews with our engineers. Have a look at our efforts in educational

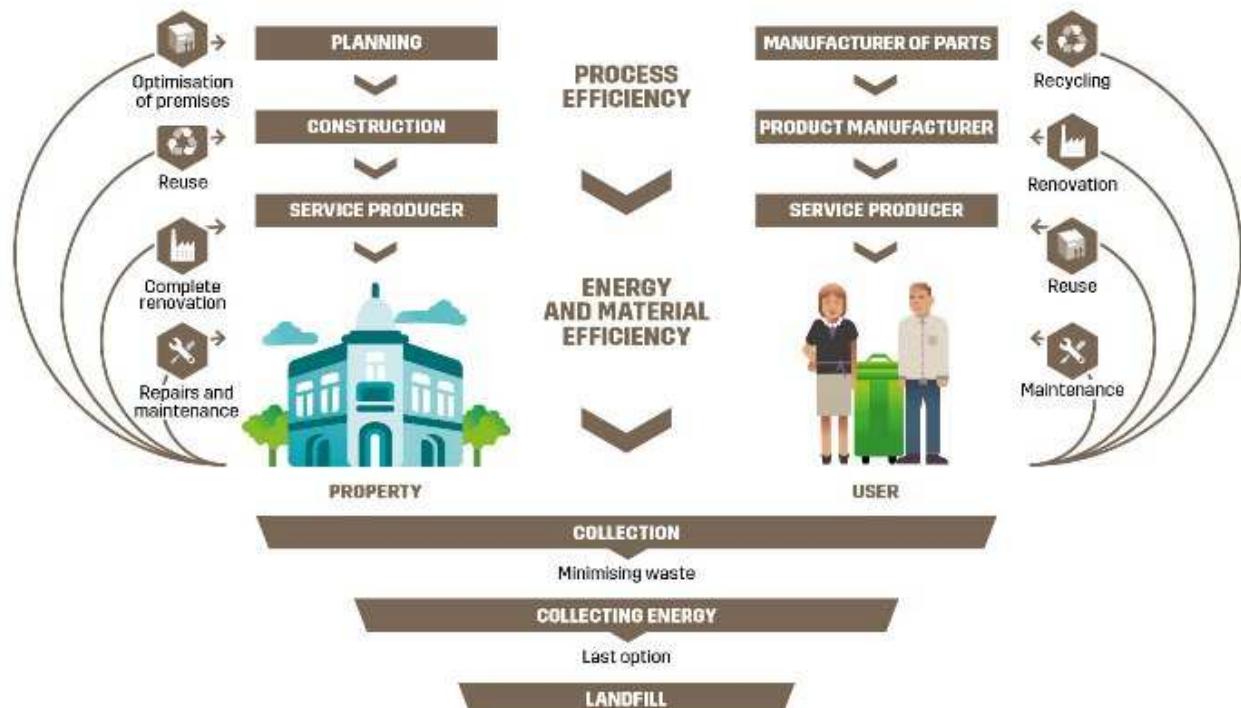
outreach in the pictures below featuring students from South Ripley Elementary School, Columbus Signature Academy, and Jennings County's Summer Enrichment Program.



Conclusion

With ever increasing energy demands and an urgent need to safeguard the world for the future generations, every country in the world is modifying their energy policy to decrease their reliance on fossil fuels and invest in renewable energy. According to a report by [BP](#), world has witnessed a growth of 213 TW-Hours in renewable power generation, which is the largest increment on record. Renewable Energy sector will continue to witness huge demands and will generate millions of jobs around the world. Due to the seasonality and variability in wind energy generation, more and more people are now focusing on the Solar energy. However, due to unavailability of the solar radiation at all times of the day, Hybrid Energy Solutions will be the norm of the future.

Circular Economy and a more efficient use of resources



Source & Courtesy: <http://www.lassila-tikanoja.fi/en/company/lt-in-society/Pages/building-the-circular-economy.aspx>