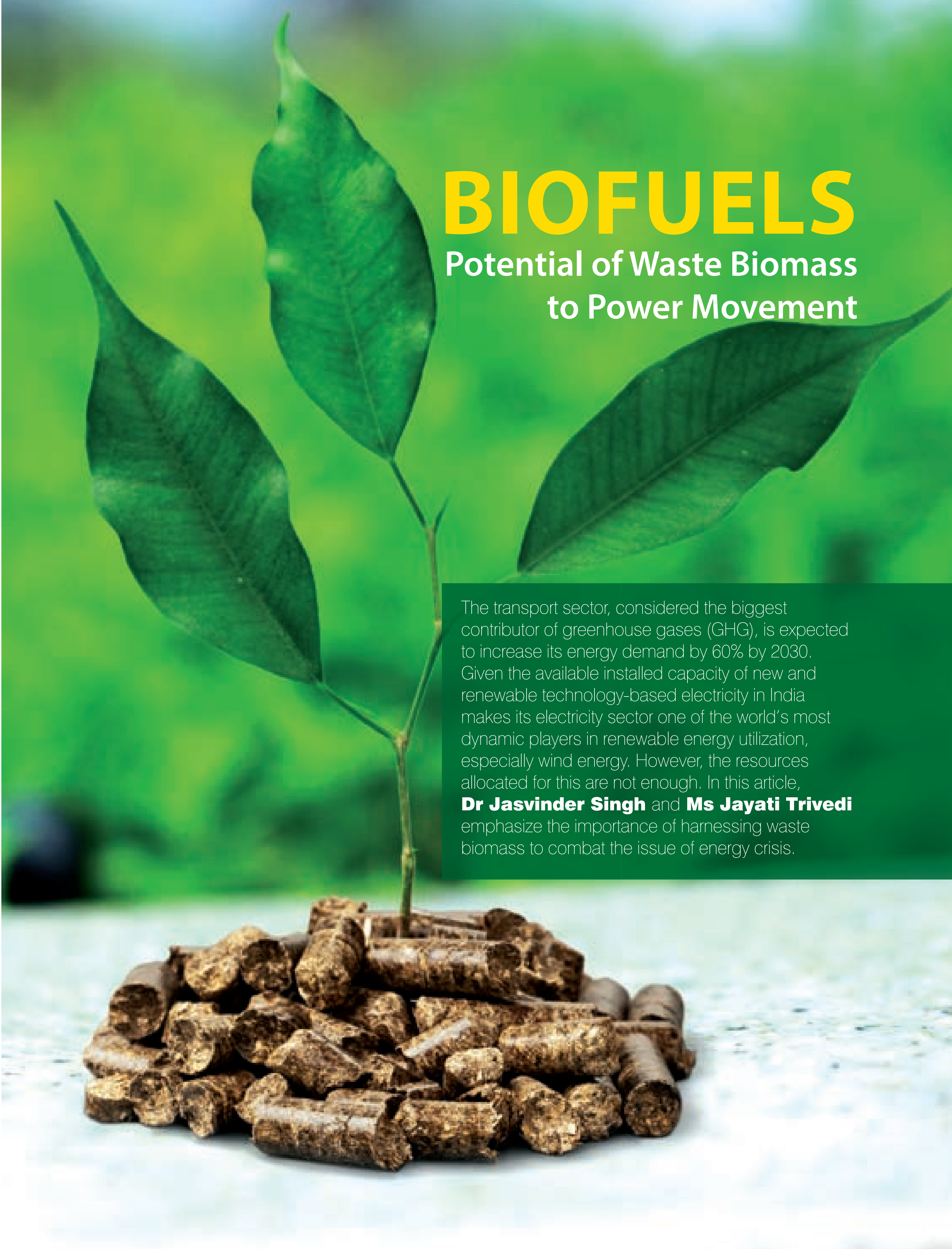
BIOFUELS

Potential of Waste Biomass to Power Movement



The transport sector, considered the biggest contributor of greenhouse gases (GHG), is expected to increase its energy demand by 60% by 2030. Given the available installed capacity of new and renewable technology-based electricity in India makes its electricity sector one of the world's most dynamic players in renewable energy utilization, especially wind energy. However, the resources allocated for this are not enough. In this article, **Dr Jasvinder Singh** and **Ms Jayati Trivedi** emphasize the importance of harnessing waste biomass to combat the issue of energy crisis.

In the current energy scenario, the most important issues are to find renewable energy sources that are simultaneously concerned with environment protection. According to a recent estimate, the energy requirement of developing as well as developed countries in the transport sector shall increase by 60% by year 2030. The transport sector is the biggest contributor of greenhouse gas (GHG) comprising carbon mono and dioxides, nitrogen oxides (NO_x), oxides of sulphur (SO_x), etc. Given the demand hike, global carbon dioxide emissions are expected to increase by 20%. According to a recent report, the per capita total consumption in India was estimated at 914.4 kWh in 2012 which increased to 1,010 kWh in 2014–15 and reached 1,075 kWh in 2015–16. Also, as per recent updates, excluding large hydroelectricity projects, the available installed capacity of new and renewable technology-based electricity in India has reached about 44.24 GW. This makes India's electricity sector one of the world's most dynamic players in renewable energy utilization, especially wind energy. During the Eleventh Five-Year Plan, nearly 55,000 MW of new-generation capacity was created. The target of capacity addition for the Twelfth Five-Year Plan was set at 88,537 MW, which is expected to go up. In spite of that, there was still an overall energy deficit of 2.1% and peak shortage of 3.3% for the year 2015–16. Resources currently allocated to energy supply are not sufficient for narrowing the gap between energy needs and energy availability. In these circumstances it is mandatory for technologists and engineers to look for several sustainable and renewable options of energy. These alternatives may be in the form of solar energy, wind energy, energy from various wastes, and non-edible biomass. Biofuels can make significant contribution in short-to medium-term among these alternates.

Biomass is a wide-ranging term meaning any source of organic carbon that is renewed rapidly as part of the carbon cycle. Biomass is derived from plant materials but can also include all biological material including animal wastes. Biofuels are mainly classified into three generations. First-generation biofuels are made from sugars and vegetable oils found in arable crops, which can be easily extracted using conventional technology. Ethanol is the most common biofuel from the first generation. Second-generation biofuels, also known as advanced biofuels, are manufactured from a variety of biomass feedstocks other than food crops. Second-generation biofuels are made from lignocellulosic biomass or woody crops, agricultural residues, or waste. While it is harder to extract the required fuel from these feedstocks, a series of physical and chemical treatments might be required to convert such biomass to liquid transportation fuels. Third-generation fuels are derived from microalgae feedstocks. Earlier, algae were also grouped with second-generation biofuels. However, faster growth potential and higher yields with lower resource inputs moved the algae feedstocks to their separate category.

India has an incredible biomass potential which is adequate to accomplish most of our energy needs. An estimated 50 MMT (million metric tonnes) of liquid fuels are consumed annually in India. With full utilization of the available biomass resources, India is capable of generating twice as much of energy fuels per annum. These estimates are solely based on the quantum of fuel generation from the crop residues available in the country essentially classified as second-generation fuels. In a country such as India, first-generation (food crop based) fuels appear to be an unreasonable thought. Therefore, scientists need to focus on second- and third-generation biofuel feedstocks, which do not interfere with the food chain and can provide a long-term solution.

The history of biomass-based energy development in India traces back to the mid-1970's, when a rural energy crisis became obvious following the inflated oil prices, growing population, diminution of common lands traditionally supplying wood fuels, increasing water stress, and higher energy demand by irrigation-intensive

agriculture in the course of the 'Green Revolution' movement. The immediate remedial measure was to increase kerosene and diesel import to improve domestic and irrigation water pumping energy needs, respectively. But this led to a larger import budget and consequent financial deficits since both these fuels were subsidized for meeting the basic needs of poor households and farmers.

Three diverse sources of biomass energy available in India are energy plantations, agricultural crop residue, and municipal and industrial wastes. Thus, the Indian villages have always been rich in bio-resources, a potential that should be converted to energy. Table 1 lists the various potential waste biomass feedstocks available for exploitation in India.

A large amount of agricultural residues are produced in India, which constitute a potential biomass feedstock for energy conversion. Here the definition of agricultural residues includes all the byproducts from harvesting and processing of agricultural crops. These residues can be further classified into primary residues which are generated in the field at the time of harvest (e.g., rice straw, sugar cane tops) and secondary residues that are co-produced during processing (e.g., rice husk, corn cobs, and bagasse). Primary residues are less in quantity and also find their application for cattle feed, fertilizers, etc. However, secondary residues are usually available in relatively large quantities at the processing site and may be used as the captive energy source for the same processing plant involving no or little transportation and handling cost. Table 2 lists the quantum of potential secondary residues generated in India. This data has been updated from FAO statistics for the year 2014.

These residues consist of cellulose and lignocellulose that bear a large potential for bioethanol production as well as power generation. From Table 1, it is evident that a massive amount of rice straw and husk is generated in India. The straw contains approximately 35%–40% cellulose, 10%–20% hemicellulose, and 10%–20%

Table 1 Types of waste biomass feedstocks for biofuels

Sl.No.	Source/Origin	Type	Examples
1	Agricultural	Primary residues	Residues left after harvesting the crops, sugarcane leaves and stalks, corn stover, and field residues of wheat and rice, etc.
2.		Secondary residues	Straw obtained from wheat, rice and cereals, corn cobs, and sugarcane bagasse
3		Livestock wastes	Solid manure (chicken manure) Liquid manure (cattle, pig, sheep, and goat manure)
4.		Dedicated energy crops	Sugar energy crops, e.g., sugar beet, cane beet, sweet sorghum, jerusalem artichoke, and sugar millet
5			Starch energy crops, e.g., wheat, potato, maize, barley, triticae, corn cobs, amarnath
6			other energy crops, e.g., flax (linum), hemp (cannabis), tobacco stems, cotton stalks, etc.
7			Dry lignocellulosic herbaceous energy crops, e.g., miscanthus, switch grass, common reed, reed canary grass, giant reed, cynara cardu, Indian shrub
8.		Dry lignocellulosic woody energy crops	SRW–willow, SRC poplar, eucalyptus
9	Forest	Forestry waste/ byproducts	Bark, wood blocks, wood chips from tops and branches, wood chips from thinning, logs from thinning
10	Industrial wastes	Wood energy residues	Wastes from saw mills, timber mills, chipping residues from furniture industry, waste slabs, and off-cuts
11		Pulp and paper industry waste	Fibrous waste and black liquor from pulp and paper industry
12		Food industry waste	Cellulosic wastes from vegetable chopping (e.g., beetroot tails, cauliflower stubs, etc.) fats and oils used for cooking (waste cooking oil), tallow, yellow grease, proteins (slaughterhouse waste)
13.	Urban waste	Parks and garden waste	Grass, prunings, dry tree leaves
14		MSW	Demolition wood, biodegradable municipal waste, sewage sludge, landfill

lignin. Cellulose and hemicelluloses can be easily converted to sugars, such as glucose, xylose, galactose, arabinose, and mannose. According to a study reported by Sardar Patel Renewable Energy Research Institute (SPRERI), Gujarat, 5,775 kg of fermentable sugars may be produced from a tonne of rice straw, which in turn could be converted to around 200 L of ethanol (*Akshay Urja*, Dec 2016). In addition to ethanol, liquid waste generated during pretreatment and solid residues could be utilized to generate 272 m^3 of biogas. Also, a life cycle assessment recently carried out by DBT–Indian Oil Corporation Ltd. (DBT-IOCL) shows that the use of ethanol manufactured from rice straw as motor fuel will result in 77–89% of GHG emission reduction as compared to gasoline fuel.

Residues from the agricultural farms and fields in urban areas may also be considered a potential source of energy. The agro-processing industries, urban vegetable market places, road sweeping, and roadside plantations are some areas which generate significant biomass waste. According to a recent online report, almost 200 million tonnes of household and agro-processing wastes are generated annually in India and disposed of in a haphazard manner. Since they are associated with little or no production costs they are either unused or utilized inefficiently. On the other hand, a massive amount of leafy wastes are burnt resulting not only in air pollution, but also wastage of useful energy. In addition to the residues, waste effluents from many industries, particularly food industries, such as black

Table 2 Production of different crop and their residue availability in India

Sl. No.	Name of the crop	Production, Thousand Tonne	Residue Type	Crop to Residue Ratio, Residue/kg Crop	Total Residue, Thousand Tonne
1	Areca nuts	622.00	Fronds	3[a]	1,378.14
		622.00	Husk	0.8	497.60
2	Bananas	29,724.55	Residue	3	89,173.65
3	Barley	1,830.00	Stalks	1.3	2,379.00
4	Cassava	8,139.43	Solid waste	0.6	4,883.66
		8,139.43	Starch	1.2	9,767.32
5	Chillies & peppers	1,492.00	Stalks	1.5	2,238.00
6	Coconuts	11,078.87	Fronds	4[a]	8,591.77
		11,078.87	Husk and Pith	0.53	5,871.80
		11,078.87	Shell	0.22	2,437.35
7	Coffee, green	304.50	Husk	0.5	152.25
		304.50	Pruning / Waste	4[a]	1,384.88
8	Cottonseed	12,300.00	Boll Shell	1.1	13,530.00
		12,300.00	Husk	1.1	13,530.00
		12,300.00	Stalks	3.8[a]	143,198.53
9	Garlic	1,252.00	Sheath	0.25	313.00
		1,252.00	Stalks	0.05	62.60
10	Ginger	655.00	Stalks	0.05	32.75
11	Maize	23,670.00	Cobs	0.3	7,101.00
		23,670.00	Stalks	2	47,340.00
12	Millet	11,420.00	Stalks	1.2	13,704.00
13	Rice, paddy	157,200.00	Husk	0.2	31,440.00
		157,200.00	Stalks	1.5	235,800.00
		157,200.00	Straw	1.5	235,800.00
14	Sugarcane	352,142.00	Bagasse	0.33	116,206.86
		352,142.00	Top and leaves	0.05	17,607.10
15	Wheat	95,850.00	Pod	0.3	28,755.00
		95,850.00	Stalks	1.5	143,775.00

[a] Tonnes/hectare

Source: FAO Statistics

liquor from pulp and paper industry, wastewater from slaughterhouse, milk processing units, breweries, vegetable packaging industry, and animal manure also add to the problem.

Though the energy-production potential may vary significantly, depending on the nature of effluent and efficiency of the used reactor, these wastes are also potential feedstock for the biofuel production. The estimated biogas-production potential is in the range of 0.15–0.45 m^3 CH_4/ kg of COD removed, calculated on the basis of an average value of 0.3 m^3 CH_4/kg. Hotels, restaurants, and community kitchens produce copious amounts of waste, such as vegetable peels; uneaten food; for example, rice, bread, vegetables, meat, etc; plate and dish washings, as well as fruit and vegetable rejects. Similarly, the confectionary industry also produces a huge amount of waste. All these wastes make a potential feedstock for biogas generation by anaerobic digestion. These wastes are usually disposed of in landfill dumps. Liquid wastes are generated by washing meat, fruits, and vegetables; blanching fruits and vegetables; pre-cooking meat, poultry, and fish; cleaning and processing operations; and wine making. These wastewaters contain sugars, starches, and other dissolved and solid organic matter. These industrial wastes are potential feedstocks for anaerobic digestion to produce biogas and fermentation to produce ethanol.

Furthermore, livestock are a potential source of animal manure. Animal manure is principally composed of organic material, moisture, and ash. Decomposition of animal manure can occur either in an aerobic or anaerobic environment. Under aerobic conditions, CO_2 and stabilized organic materials (SOM) are produced. Under anaerobic conditions, CH_4, CO_2, and SOM are produced. Since the quantity of animal manure produced annually can be substantial for a country like India, the potential for CH_4 production and hence the energy potential of animal manure is significant.

A sizable potential source of biomass in India is municipal solid waste (MSW). The biomass resource in MSW comprises paper and plastic and constitutes 80% of the total MSW collected. This can be converted into energy by direct combustion, or by natural anaerobic digestion in the engineered landfill. The organic fraction of MSW can be anaerobically stabilized in a high-rate digester to obtain biogas for electricity or steam generation.

Sewage is a source of biomass energy that is similar to the other animal wastes. Energy can be extracted from sewage using anaerobic digestion to produce biogas. The sewage sludge that remains can be incinerated or can be made to undergo pyrolysis to produce more biogas. Also, dry sludge has been verified for a significant presence of fatty acids and steroids. These lipids are either assimilated by bacterial species present in sludge from the wastewater or generated by de novo synthesis from other carbon sources, and stored intracellularly as neutral lipids, for example, triacylglycerides (TAGs), wax esters (WEs), or polyhydroxy alkanoates (PHAs). Fatty acids from sludge predominantly fall in the range of C10 to C18, therefore excellent feedstock for the production of biodiesel.

With harnessing agricultural residue waste, rural India can address a sizable demand of its energy needs. Unfortunately, the management of these wastes is generally in the hands of poor farmers and the unorganized sector, rural households, and the low-income, tiny agro-based industry sector. While several commercial examples of waste-to-energy conversion have already been established, a proper conversion of waste biomass residues in rural India still has a long way to go. EF

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Energy Options for Uttara Kannada

Prospects of Wind Energy

Wind resource assessment is the primary step towards understanding the local wind dynamics of a region. Windmills have been used for centuries to grind grain and pump water in rural areas; moreover, it has the advantage of being harnessed locally for applications in rural areas and remote areas. In this article, **Prof. T V Ramachandra** and **Mr Ganesh Hegde,** with Uttara Kannada as a case in point, discuss the importance of harnessing wind energy to meet the energy demand at decentralized levels.

Energy extraction from wind is one of the oldest energy-harvesting technologies that is being used for centuries. Winds are caused by the rotation of the earth and the heating of the atmosphere by the sun. The total annual kinetic energy of air movement in the atmosphere is estimated to be 3 x 105 kWh or 0.2% of the solar energy reaching the Earth. The maximum technically usable potential is estimated to be theoretically 30 trillion kWh per year, or about 35% of the current world total energy consumption.[1] The power in wind blowing at 25.6 km/h is about 200 W/m^2 of the area swept by a windmill. Approximately, 35% of this power can be captured by windmills and converted to electricity. The kinetic energy of the air can be transformed to mechanical and then to electrical form of energy using fans, gears, turbine, and generator system. Windmills—a modern world's electricity-harvesting technology—accounts for more than 2 GW of installed capacity worldwide.[2] Electricity generation from wind is directly proportional to the air density, swept area of blades, and cube of the wind velocity. Since wind velocity is more tentative, hence optimizing the blade area, maximum energy can be extracted for particular wind speed at a given place.[3]

	P = (1/2)* *A*V^3	(1)
where,	*P*: Wind power	*p*: Air mass density
	A: Swept area (area of wind flow)	V: Wind velocity

The annual wind speed at a location is useful as an initial indicator of the value of the wind resource. The relationships between the annual mean wind speed and the potential value of the wind energy resource are listed below:

Annual Mean wind speed @ 10 m Ht. (m/s)	Indicated value of wind resource
< 4.5	Poor
4.5–5.4	Marginal
5.44–5.7	Good to Very Good
> 6.7	Exceptional

Uttara Kannada, a district located in the west coast and in the region of Western Ghats region of Karnataka, is blessed with good wind potential. Since electricity supply is unreliable at most times, harnessing of wind energy could play a prominent role in meeting the energy demand in the region since electricity supply is unreliable in most of the times. Wind energy potential in the district could meet the regional electricity demand through wind energy conversion system (WECS) avoiding plenteous greenhouse gas (GHG) emission and fossil fuel. This can be harnessed locally in a decentralized manner for applications in rural areas and remote areas, such as water pumping for agriculture and plantations. Wind- driven electric generators could be utilized as an independent power source and for purposes of augmenting the electricity supply from grids. In coastal, densely populated *taluks*, such as Karwar, Kumta, and Bhatkal in Uttara Kannada District, decentralized production of electricity would help local industries, especially seasonal agro-processing industries, such as cashew, etc. WECS can be hybridized with solar, biomass, and any other available local energy resources to provide 100% reliable power since wind flow is at its maximum during monsoon when solar insolation and dry biomass availability is comparatively lesser.[4]

Wind resource assessment: Wind resource assessment is the primary step towards understanding the local wind dynamics of a region. Wind flow developed due to the differential heating of the earth is modified by its rotation and further influenced by local topography. This results in an annual (year to year), seasonal, synoptic (passing weather), diurnal (day and night), and turbulent (second to second) changes in wind pattern.[5] Increased heat energy generated due to industries and escalating population in urban areas result in heat islands which also affects the wind flow as well.

Objective

The objective of the present study is to assess the *taluk*-wise annual wind potential in Uttara Kannada district and assess techno-economic feasibility of wind energy harvesting options, to meet the regional electricity demand.

Study Area, Data, and Methods

Uttara Kannada, located between 13°55´ and 15°31´N and 74°9´ and 75°10´E, is the fourth biggest district of Karnataka state, located between 13°55´ and 15°31´N and 74°9´ and 75°10´E. Total population of the district is 1,436,847 and more than 70% of the people live in rural areas or in semi-urban areas. The district is located in the Western Ghats shelters ranges sheltering abundant flora and fauna. More than 75% of the total area is forest covered and has with140 km

1 Wilbur LC. 1985. *Handbook of Energy Systems Engineering: Production and Utilization*. New York: John Wiley and Sons.

2 'Global Wind Report Annual Market Updates'. 2012. http://www.gwec.net/?id=180; last retrieved on June 25, 2013.

3 Ramachandra TV, Subramanian DK, and Joshi NV. 1997. Wind Energy Potential Assessment in Uttara Kannada District of Karnataka, India. *Renewable Energy* **10**(4): 585–611.

4 Balamurugan P, Ashok S, and Jose TL. 2009. Optimal operation of biomass/wind/PV hybrid energy system for rural areas. *International Journal of Green Energy* **6**: 104–116.

5 Hester RE and Harrison RM. 2003. Sustainability and environmental impact of renewable energy resource. *Royal Society of Chemistry, United Kingdom* <http://dx.doi.org/10.1039/9781847551986.

of costal belt.[6] Figure 1 illustrates the topographic undulations of the region. Topographically, the district lies in three distinct zones, namely, narrow and flat coastal zone, abruptly rising ridge zone, and an elevated, flatter eastern zone. The coastal zone is thickly populated with coconut- clad villages. The ridge zone is a part of the main range of the Western Ghats, which runs north to south, parallel to the coast. The flat eastern zone joins the Deccan plateau. The *taluks*, which comprise the narrow flat coastal zone, are: Karwar, Ankola, Kumta, Honnavar, and Bhatkal. Similarly, *taluks*, which comprise the ridge zone, are: Supa, Haliyal, Yellapur, western Sirsi, and western Siddapur. The flatter eastern zone includes Mundgod, eastern Sirsi, and eastern Siddapur. Four agro-climatic zones based on geography and climate are coastal, evergreen, dry deciduous, and moist deciduous. There are 1,291 villages, 7 towns, 5 city municipal corporations/town municipal corporations/outward growth/census towns, and 2 reservoirs in the district (http://uttarakannada.nic.in/, last retrieved on March 14, 2017).

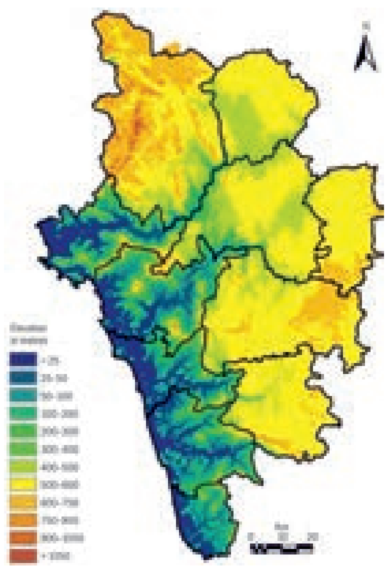

Figure 1 Digital Elevation Model of Uttara Kannada, Karnataka

Data and Method

Synthesized wind data: This wind data available from various sources provide a preliminary understanding of the wind regime of a specific region. Depending on the physiographical features and climatic conditions, these data help in assessing wind potential in the region of interest validated by long- term surface wind measurements.

There are many wind speed data sets that are available of different time periods, such as National Aeronautical and Space Agency (NASA), Surface Meteorology and Solar Energy (SSE), National Oceanic and Atmospheric Administration (NOAA-CIRES), Climate Research Unit (CRU), etc. However, previous studies have evidently showed that CRU data are reliable and are closer to the Indian Meteorological Department (IMD) surface data, and hence used in the present study.[7] CRU at the University of East Anglia maintains climatic average datasets of meteorological variables which contains wind speed data for the period of 1961–~1990 compiled from different sources. Further, inter- and intra variable consistency checks are performed to minimize data consolidation errors. The Global Land One-km Base Elevation Project (GLOBE) data of the National Geophysical Data Center (NGDC) were re-sampled to 10′×10′ (ten- minute spatial resolution) elevation grids where every cell with more than 25% land surface (those below 25% being considered water bodies) represents the average elevation of 100~400 GLOBE elevation points. The climatic average of wind speeds measured at 2 to 20 m anemometer heights (assumed to be standardized during collection) collated from 3,950 global meteorological stations together with the information on latitude, longitude, and elevation were interpolated based on a geo-statistical technique called thin plate smoothing splines. Elevation as a co-predictor considers topographic influence on the wind speed and proximity of a region to the measuring station improves the reliability of the interpolated data. During interpolation, inconsistent data was removed appropriately. This technique was identified to be steadfast in situations of data sparseness or irregularity.[8] The 10′×10′ spatial resolution wind speed data as climatic averages were available for all global regions (excluding Antarctica).[9]

Data from IMD stations located in the district are also acquired for respective locations and which gave the satisfactory results comparing with CRU data set. There are four IMD stations in the districts which are listed in Table 1. Cup counter anemometers with hemispherical cups measuring 7.62 cm in diameter were used in Indian Meteorological Department (IMD) observatories until 1973. During 1973–1979, these anemometers were are replaced with three cup anemometers with 127 mm diameter conical cups, which are placed at 10 m above ground level, over open terrain, in conformity with international practice.

Table 1 IMD stations in Uttara Kannada

Location	Latitude	Longitude	Elevation (m)
Karwar	14° 47′	74° 08′	4
Kumta	14° 26′	74° 25′	8
Honnavar	14° 17′	74° 27′	26
Shirali	14° 05′	74° 32′	45
Sirsi*	14° 62′	74° 85′	610

6 Uttara Kannada official website, http://uttarakannada.nic.in/districtprofile.htm, last retrieved on June 27, 2013.
7 Ramachandra T V and Gautham Krishnadas. 2012. Prospects and challenges of decentralized wind applications in the Himalayan terrain. *Journal of Energy Bioscience* **3**(1): 1–12.
8 New M, Lister D, Hulme M, and Makin I. 2002. A high-resolution data set of surface climate over global land areas. *Climate Research* **21**: 1–25.
9 Climate Research Unit, University of East Anglia, http://www.cru.uea.ac.uk/cru/data/hrg/tmc/, last retrieved on June 10, 2013.

Data from the meteorological observatories at Karwar (for the period 1952–1989), Honnavar (for the period 1939–1989), and Shirali (for the period 1974–1989) obtained from the Indian Meteorological Department, Government of India, Pune, and daily wind data for the period 1990–1993 for these observatories, from the IMD, Bangalore. The primary data obtained by installing a cup counter anemometer with mechanical counter fixed on a 5 m tall guyed masts at Sirsi and Kumta. The anemometer readings were noted down every three hours during the day and mean wind speeds were obtained.

Anemometeres at different meteorological stations are set at different heights levels. The wind speed recorded at each station has to be adjusted to any constant height prior to analysis. The standard height according to the World Meteorological Organization is 10 m above the ground level which is used for the analysis.[10] The horizontal component of the wind velocity varies a great deal with height under the influence of frictional and impact forces on the ground. The most common model for the variation of horizontal velocity with height is given by the logarithmic wind profile equation 2:[11]

$$(V_1/V_2) = (H_1/H_2) \qquad (2)$$

Where V_1 is a wind speed at height H_1 of 10 m above ground level, V_2 is a wind speed at height H_2 above ground level, and is the roughness factor which is determined by substituting the wind speed data obtained with anemometer height in various wind directions, and found to be 0.30. Table 2 gives the month- wise average wind speed in the respective locations.

Figure 2 shows the comparison of mean wind speed in five IMD stations. At higher elevations in the district as well as in coastal regions, mean wind speed is comparatively higher and also in coastal region. Wind speed recorded at Honnavar and Shirali stations are lower which are placed at an elevation of 26 m and 45 m, respectively.

Results and Discussion

Wind profile of Uttara Kannada: Wind speed is seasonal as well as dependent and is, typically, at its maximum during the monsoon. Throughout the year, wind speed varies from 1.9 m/s (6.84 km/hr) to 3.93 m/s (14.15 km/hr) resulting in its minimum in October and maximum in the months of June and July. An annual average wind speed in the district ranges from 2.54 ± 0.04 m/s (9.144 ± 0.144 km/hr) in Haliyal *taluk* to 2.70 ± 0.05 m/s (9.72 ± 0.18 km/hr) in Karwar *taluk*. Figure 3 gives a *taluk*-wise annual average wind speed of the district. Ample amounts of electrical energy can be generated using blowing wind through wind farms which could meet a major fraction of the current electricity demand of the district through decentralized generation.

Seasonal variation of wind speed: Wind speed of Uttara Kannada is quite uncertain and dependent on ambient temperature and pressure, vegetation cover, elevation, topography of the

Table 2 Monthly variation in mean wind speed (km/hr)

Month	Karwar	Kumta	Honnavar	Shirali	Sirsi
January	5.96	5.95	5.95	6.78	6.92
February	6.55	7.76	6.00	6.87	6.88
March	8.15	9.09	6.10	7.03	7.20
April	9.65	9.42	6.20	7.25	8.38
May	11.82	9.87	7.21	7.84	9.09
June	12.01	11.83	7.50	8.30	11.19
July	15.27	13.03	7.72	8.50	18.17
August	11.98	11.54	6.66	7.64	14.19
September	7.44	6.71	4.87	5.56	11.14
October	5.41	6.59	4.55	5.42	8.39
November	4.75	6.29	5.04	6.76	7.72
December	5.04	7.73	6.00	9.51	8.42

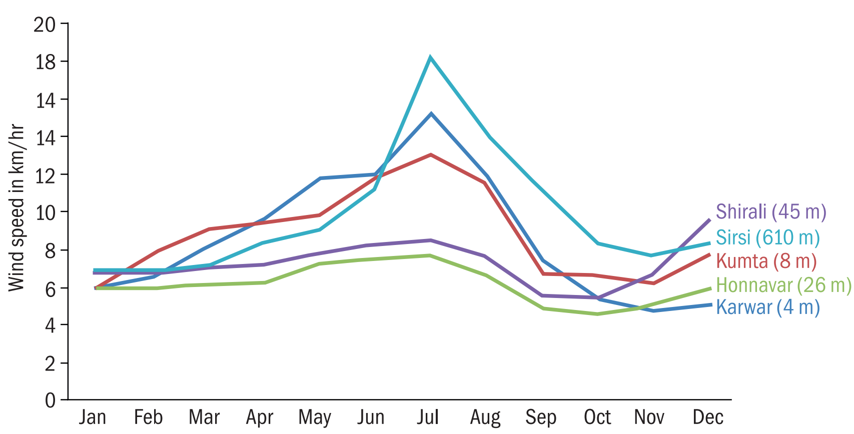

Figure 2 Monthly variations in wind speed

[10] World Meteorological Organization. 1964. *Guide to Meteorological Instrument and Observing Practices*, 4th Edition. WMO, No. 8, TP. 3 Geneva, Switzerland,

[11] Lysen H. 1983. *Introduction to Wind Energy*, 2nd Edition. Consultancy Services, Wind Energy, Developing Countries (CWD) 82–1, The Netherlands.

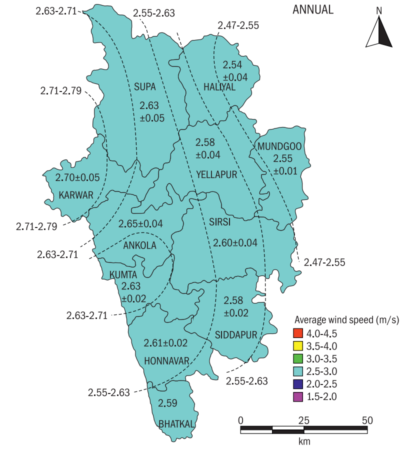

Figure 3 Average annual wind speed of Uttara Kannada

site, etc. Uttara Kannada has a mixed topography, which includes the coastal belt, low and high elevation area with forest cover, as well as planes. From February to May, the district experiences summer with higher temperature in coastal areas (Karwar, Honnavar, Kumta, Bhatkal, and Ankola) and in planes (Mundgod and Haliyal), and a comparatively lower temperature in *taluks* of higher altitudes (Sirsi, Siddapur, Yellapur, and Supa). Figures 4 to 6 give the mean wind speed variability in the district during summer, winter, and monsoon months.

Wind Energy Conversion System (WECS): This is used to extract energy from wind which is in turn converted to mechanical and then electrical energy. Main components of WECS are blades, gears, turbines, generators, and pillars to mount all the equipment at the required height. Wind potential assessment is a prominent pre-installation procedure to assure a perfect selection of site and to harness maximum energy. In order to explore the potential of wind technologies at an increased hub height, hourly surface wind speed measurements at IMD stations were estimated and represented in Figure 7. In almost all the *taluks*, more than 45% of the wind speed is above 2.5 m/s except Honnavar (39.58%). Over 20% of the measured hours crossed 3.5 m/s wind speeds in Karwar, Kumta, and Supa, in which Karwar was the highest (27.38%). These findings along with relatively higher wind speeds (>2 m/s in high elevation zone) observed in seasonal wind profiles (based on CRU data) are indicative of the prospects of small- and medium-scale wind applications in Uttara Kannada which are technically achievable and economically viable.[12] Some of these are listed in Table 3. Wind pump for drawing water is an attractive small-scale wind technology for rural energy needs. The agriculture- and horticulture-intensive zones of Uttara Kannada may benefit by wind pumps that function at low wind speeds. The vertical axis wind turbine (VAWT) that can function in wind speeds as low as 1 m/s could be more effective during low wind speed seasons in the region.[13]

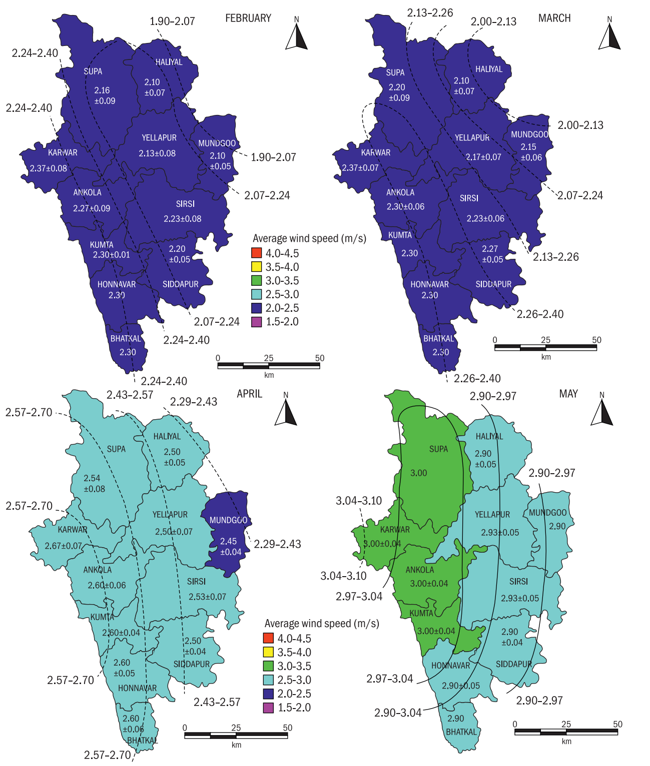

Figure 4 Wind speed variation during summer (m/s)

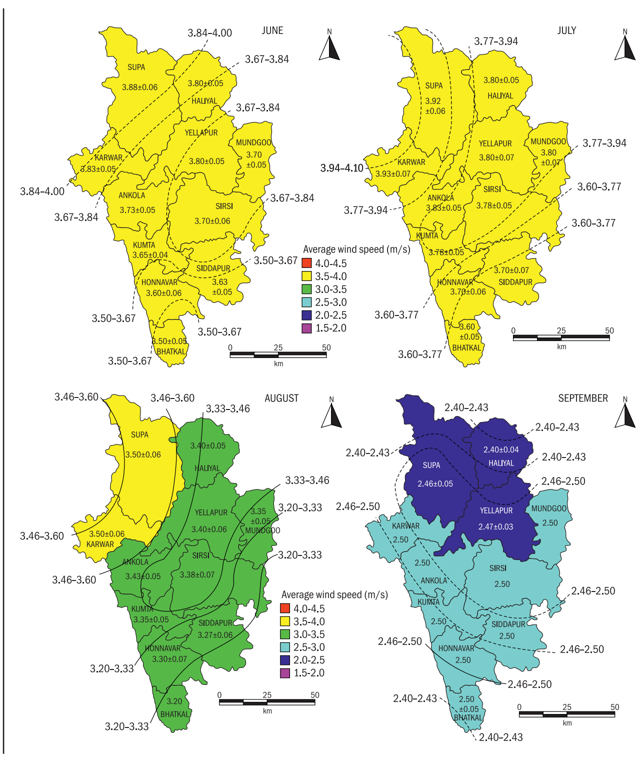

Figure 5 Wind speed variation during monsoon (m/s)

12 Cabello M and Orza JAG. 2010. Wind speed analysis in the province of Alicante, Spain: Potential for small-scale wind turbines. *Renewable and Sustainable Energy Reviews* **14**(9): 3185–3191.

13 Ayhan D and Saglam S. 2012. A technical review of building-mounted wind power systems and a sample simulation model. *Renewable and Sustainable Energy Reviews* **16**(1): 1040–1049.

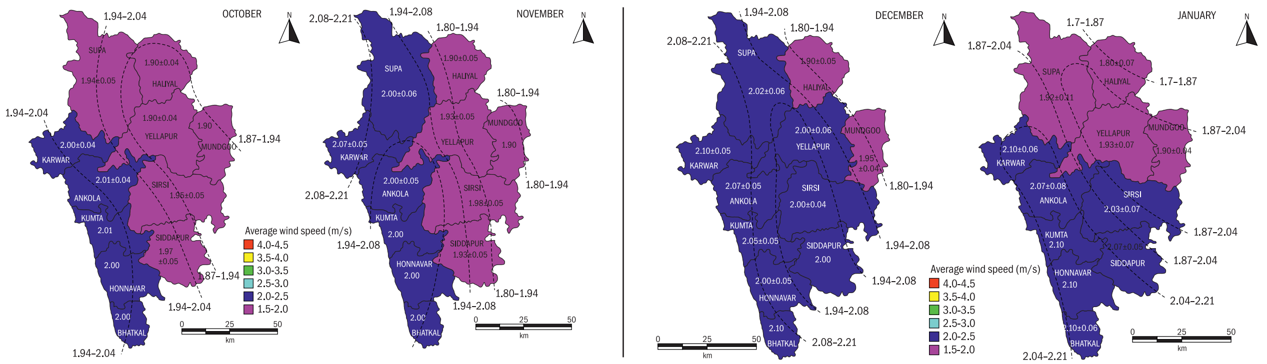

Figure 6 Wind speed variation during winter (m/s)

Reduction in wind speeds and duration could be compensated by hybridizing wind with available alternative resources. Assessment of solar energy potential substantiates that it receives monthly average global insolation (incoming solar radiation) > 5 kWh/m²/day.[14] Hence, wind–solar hybrid systems could be considered for endured energy supply in the region. Small-scale wind turbines could also be used in conjunction with biomass gasifies/diesel generators, especially in remote areas, although diesel is not a clean option.[15] Battery charging based on wind systems supplements the energy requirements during reduced wind speeds.

Techno-economic feasibility: Power harnessed by the WECS can be expressed using expression as given below:

$$P_{avail} = (1/2) \times p \times A \times V^3 \times Cp \qquad (3)$$

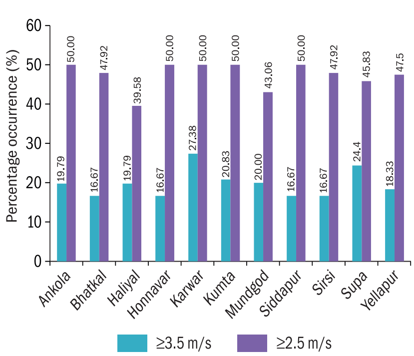

Figure 7 Percentage occurrence of wind speeds

Table 3 Available small-scale wind turbines[16]

Rated power, Prated (kW)	Rotor swept area (m²)	Sub-category
P_{rated} < 1 kW	A < 4.9 m²	Pico wind
1 kW < P_{rated} < 7 kW	A < 40 m²	Micro wind
7 kW < P_{rated} < 50 kW	A < 200 m²	Mini wind
50 kW < P_{rated} < 100 kW	A < 300 m²	(Not defined)

Wind potential available in the district is estimated using equation 3 given in Table 4.

Where,	P: Wind power	p: Air mass density
	A: Swept area (area of wind flow)	V: Wind velocity
and	C_p: Beltz constant (maximum = 59.3%)	taken as 0.4

Estimation shows that Micro and Mini WEC systems are feasible for the district since minimum and maximum power that can be harnessed ranges from 1,611.49 kW to 2,091.91 kW for the swept area of 30 m² (micro model) and

Table 4 Wind power potential estimation

Month	Wind speed m/s		Power harnessed at A= 30 m² (kW)		Power harnessed at A= 160 m² (kW)	
	Min	Max	Min	Max	Min	Max
January	1.80	2.10	42.69	67.79	228.61	363.03
February	2.10	2.37	67.79	97.44	363.03	521.83
March	2.10	2.37	67.79	97.44	363.03	521.83
April	2.45	2.67	107.65	139.33	576.48	746.14
May	2.90	3.00	178.53	197.64	956.05	1058.40
June	3.50	3.88	313.85	427.57	1680.70	2289.71
July	3.60	3.93	341.52	444.31	1828.92	2379.38
August	3.20	3.50	239.86	313.85	1284.51	1680.70
September	2.40	2.50	101.19	114.38	541.90	612.50
October	1.90	2.01	50.21	59.44	268.87	318.33
November	1.90	2.07	50.21	64.93	268.87	347.69
December	1.90	2.10	50.21	67.79	268.87	363.03
Total			**1,611.49**	**2,091.91**	**8,629.85**	**11,202.58**

[14] See Footnote 7.
[15] Mathew S, Pandey KP, and Kumar AV. 2002. Analysis of wind regimes for energy estimation. *Renewable Energy* **25**: 381–399.
[16] See Footnote 12.

from 8,629.82 kW to 11,202.58 kW for swept area of 160 m^2 (mini model). Cost of the wind turbines depends on the size, since the transportation and installation difficulties increase with the size. Cost per kilowatt of typical wind turbine ranges from $1,050 to 1,350 in India.[17] As the capacity increases cost/kW decreases, but the size of the turbine and blade length increases. Table 5 gives the cost estimation of the WEC system.

A typical 1 kW turbine can generate electrical energy of 1,000–3,000 kWh per annum depending on the power density of wind.[18] About 70% of the total system cost is only for wind turbine followed by 9% for battery and 4% for civil work.[19,20] Unit cost of electricity generated from WECS varies from USD 0.5 per kWh to USD 0.75 per kWh. However, with technology improvement and system optimization, lower generation costs can be achieved.

Table 5 Cost estimation of WECS

Particulars	Capacity of the turbine	
	1.5 kW	10 kW
Manufacturing cost	1,950	13,000
Battery bank	237	1422
Civil work and installation	105	702
Inverter	79	527
Maintenance charge & others	263	1756
Total cost	2,634	17,407
Annual energy generated (kWh)	3,500	30,000
Unit cost of electricity (USD/kWh)	0.75	0.58

Scope for renewable energy exploitation: Decentralized electricity generation through renewable sources is gaining importance due to environmental problems with supply-oriented approaches in planning driven by conventional, centralized power generation and distribution. Dispersed generation based on renewable energy (RE) sources addresses issues related to reliability, voltage-profile management, and the associated economic aspects. Micro grids help in exploiting locally available RE sources, which are also fundamental units of smart grid architecture. However, the region's available energy potential and seasonal variability assessment is the primary step to map the viable regions for power harvesting.

Decentralized generation (DG) is the electric energy production at the distribution side of the power supply network or closer to the load centre itself. Distributed energy generation can play a pivotal role to meet the electricity demand in a reliable and environment-friendly way. Dispersed generation exploits locally available

[17] IRENA, Working Paper. 2012. *Renewable Energy Technologies: Cost Analysis Series*. 1(5).

[18] Shandong Huaya Industry Co., Ltd., http://www.huayaturbine.com/te_product_a/2010-12-25/228.chtml, last retrieved on June 28, 2013.

[19] Gökçeka M and Genç MS. 2009. Evaluation of electricity generation and energy cost of wind energy conversion systems (WECSs) in Central Turkey. *Applied Energy* 86: 2731–2739.

[20] Celik AN. 2007. A techno-economic analysis of wind energy in Southern Turkey. *International Journal of Green Energy* **4**: 233–247.

energy resources which will reduce the exploitation of conventional energy resources and also the congestion of generating units. DG-based on RE sources promotes higher penetration of RE resources in the grid. DG plants have the unique advantage of operating in islanded mode (grid isolation mode), during the outage of the central grid. Grid connection can be restored as the grid is energized and electricity can either be transferred to the grid or drawn from the grid. Micro grids are the building units of dispersed generation, which essentially exploit locally available

RE resources. Micro grid is an emerging technology which has evolved as smart grids with higher reliability, limited greenhouse gas (GHG) emission, and reduced transmission and distribution (T&D) losses. Smart grid architecture is in the infancy stage which integrates renewable energy-based distributed generation with the conventional system using control strategies over a two-way communication link.

As Karnataka is facing severe energy and peak-power crisis, decentralied solar and wind energy integration to the grid would narrow down the supply–demand gap. Micro grids need to be promoted to meet the community-level demand through locally available energy resources. Wastelands in the interior *taluks* are best suited for grid connected hybrid energy generation, while, micro grids and rooftop generation can be promoted in metropolis and biodiversity-rich Western Ghat *taluks*. The share of energy sources in installed capacity can be decided depending on the variability and geographic location. Renewable energy exploitation with grid integration needs to be promoted through appropriate policy interventions to mitigate the GHG emission through reduced dependence on fossil fuels.

Conclusion

Wind is one of the promising renewable sources which can substitute fast-depleting fossil fuel sources. Wind energy potential in the district could meet the electrical energy consumption in the domestic sphere through decentralized generation and wind turbine driven pumps and can even decrease the dependency on grid supply for irrigation. Districts experience an annual average wind of 2.5 m/s to 3.0 m/s in all *taluks* which opens a wide range prospects for WECS installation. Hybridizing wind energy systems with other locally available resources (such as solar and bio energy) would assure a reliable energy supply for domestic and irrigation demands. Small- and medium-scale WEC systems are feasible for community-level installations which lead to a massive reduction in carbon dioxide emission. EF

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Virtual Solar Rooftop Projects

Financing Innovation for Solar Power Projects

From 22 GW, India's solar power target has been increased to 100 GW by 2022; however, in order to substantially reduce emission, even this appears to be grossly inadequate. In this article, **Dr Ajay Chandak** and **Mr Anurag Chandak,** using solar power as currency, offer innovative and cost-effective solutions to this pressing concern.

Jawaharlal Nehru National Solar Mission (JNNSM) was launched in January 2010 with a target of 20 GW by 2022. This appeared to be an uphill task as solar PV panels cost a staggering ₹220 per Wp. The Hon'ble Prime Minister of Inida, Shri Narendra Modi increased the target to 100 GW, and with a reduction in the price of solar cells to around ₹32 per Wp; this target seems to be within reach. In view of the Indian government's commitment to the Paris Convention, the 100 GW target seems grossly inadequate and needs to be raised to at least 300 GW to make a sizeable impact in emission reduction.

Current Status

Solar power projects of 100 GW are expected to cost more than ₹6 lakh crore for projects and infrastructure. Such a massive capital outlay from banks and governments can adversely affect the economy and other flagship programmes, such as 'Make in India', 'Digital India', 'Start up India', etc., of the government. Economist Swaminathan Aiyyar has warned against such a huge cash outlay from banks which can adversely affect progressive campaigns, such as 'Make in India'.

A major cost component of solar power is cost of capital, which primarily depends on cost of debt, expected returns on equity (RoE), FOREX variations, and repayment of debt. One needs to be very cautious of the terms of raising capital. Any wrong decision can and will adversely impact the life of the project. At present, there are MW-scale solar power projects which are connected to the grid at high-voltage levels, and solar rooftop projects which work on the net metering principle are connected at low-voltage levels at the tail end of the grid.

Utility scale projects

Grid-tied utility scale projects are promoted on a large scale by the Government of India. Most such projects have come up with a reverse-bidding mechanism where power-purchase agreements are executed with the bidder offering the lowest tariff. After an exceptionally low tariff of ₹4.34 per kWh by Fortum, a major energy company based in Finland, for a 70 MW project in Rajasthan, there has been an upward correction whereby the tariff has been set at ₹4.70 per kWh in many of the recent bids. After discounting VGF (Viability Gap Funding) and tax rebates, the levalised cost of solar power is around ₹6.50 per kWh, which, incidentally, is twice as much of coal-based power and we may need a few more years for solar power to be at par with fossil fuel-based power.

Rooftop solar power installation

Solar rooftop net metering scheme is a big compromise. Solar rooftop projects make distribution networks complex, increase accidents, and compromise quality of power in terms of harmonic distortions and voltage levels. However, 'Solar Rooftop Net metering' systems are adopted worldwide as this is an additional source of financing from retail investors who are also consumers. Reduction in distribution losses is another small advantage.

A study released by economists at the Brattle Group finds that utility-scale solar photovoltaic (PV) systems in the US are significantly more cost effective than residential-scale (rooftop) PV systems. Their study shows that a levellized cost of utility-scale units is half of the solar rooftop systems and utility-scale systems save almost double the carbon emission. The US is now shifting its focus from rooftop to utility scale.

With more and more industries and commercial consumers shifting to solar rooftop net metering, DISCOMs lose cross-subsidy surcharge from these premium consumers, incur additional administrative expenses, and finally end up with huge losses. These losses are generally passed on to consumers in the form of tariff hike.

VSRS, an innovative financing mechanism, is proposed by innovators which uses retail finance to be deployed in utility-scale projects. The returns that are generated by way of solar power is its most innovative feature. DISCOMs get their dues for the services provided.

What is 'Virtual Solar Rooftop Scheme' (VSRS)?

VSRS is a financing innovation where retail investors finance solar projects and all stakeholders use 'solar power' as 'currency'. Retail investors, who generally invest money in banks, gold, bonds, public provident funds, etc., where returns are at 8% p.a., will be the target investors for solar power projects. Furthermore, they are likely to earn 13 to 25% returns. As all rules of physical-rooftop schemes are applied to investors, the scheme is named Virtual Solar Rooftop Scheme. With this innovation, investors will get 100% flexibility and liquidity.

How Does VSRS Work?

The concept of a solar power card—similar to a debit card or mileage card—has been proposed. A project developer is expected to sell solar power cards to retail investors and raise capital for the project. For other stakeholders, such as O & M Company, Distribution licencees (DL), innovators, and land owners, the project developer will issue solar power cards in proportion to their contribution. These contributions are worked out to around 33% of the project cost incorporating Central Electricity Regulatory Commission (CERC) guidelines. Hence, for any solar power project with VSRS, 67% investors will raise 100% capital.
For 100 MW of solar power project, approximately 75,000 solar power cards are generated. These cards, similar to a debit card, use solar power as currency. Out of these solar power cards, 33% are provided to stakeholders for their contribution and services. The proposed distribution for DLs is 15% against wheeling and losses, O & M Company to get 7%, project developers 5%,

innovators 2.5%, and farmers who lease the land get 3.5%. The remaining 67%, that is, 50,500 solar power cards are sold to retail investors at ₹1 lakh each. A capital of ₹505 crore is deployed in the solar power project by project developers through EPC contractors. The operation of the concept on ground will be as outlined below:

a. Once the solar power project starts generating power, this 'solar power' will be recharged in the solar power cards every month. For example, if a project has generated 15 million kWh in a particular month then every solar card will get a recharge of 200 kWh (15 million/75,000) for that month.
b. Similar to the owner of a rooftop scheme, every solar power card holder is free to use the solar power on a net metering basis. All rules of solar rooftop schemes, such as net metering, banking, and selling power to DISCOMs are applicable to the solar power card holder.
c. Furthermore, solar power can be transferred to any eligible electricity consumer of choice of solar power card holder. Actual action on ground will be similar to Internet banking or payment using debit/credit card or a digital valet. A solar power card holder is expected to log in with a unique consumer ID (UID of electrical metre on which the DL raises the bill) and transfer whatever amount of solar power (currency here) is needed from the solar power card to the UID of the consumer. The balance on both sides will be adjusted accordingly.

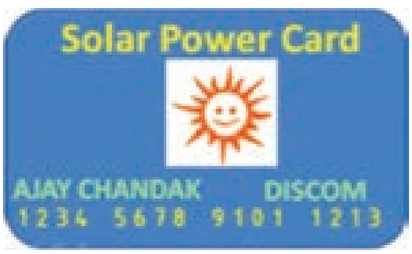

Figure 1: Solar power card

This is explained with the following illustration. Say solar power card holder 'A' has a balance of 500 kWh in his card. He logs in to the account of consumer "B" who has a bill of 700 kWh. Then, if 'A' transfers 300 kWh to account of 'B' then the revised bill of 'B' will be 400 kWh and the balance in solar power card of 'A' will be 200 kWh. This is shown in Figure 3.

In addition to a 15% stake in solar power, DLs will also get 100% renewable energy certificates (RECs) which in no uncertain terms is a big gain for them. As per the Indian government's notification dated July 22, 2016, Renewable Power Obligation (RPO) is set at 2.75% for 2016–17 and increased to 2% every year for the next two years. Every DL will need a large quantity of RECs to comply with the RPO. The concept of a power card can be replaced by an Internet account, digital valet, or a similar instrument which uses solar power as currency. Innovators have initiated IPs for the same.

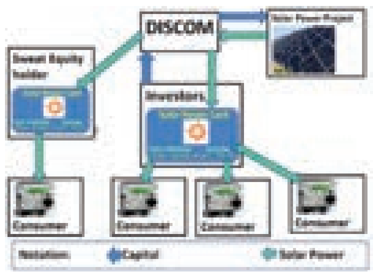

Figure 2: Concept diagrams: Flow of capital and solar power

Concept of Solar Power Exchange

The concept of a retail solar power exchange has also been proposed wherein solar power card holders will sell the power and consumers will purchase the power. Power tariff in turn will be decided by market forces. ERCs can set the guidelines for the retail of such solar power exchange. This will bring 100% transparency in solar power costs. A schematic of solar power exchange is shown in Figure 4.

How Much Power/Returns Will a Solar Card Holder Get?

A CERC order dated March 23, 2016, is used as a basis for capital cost, power

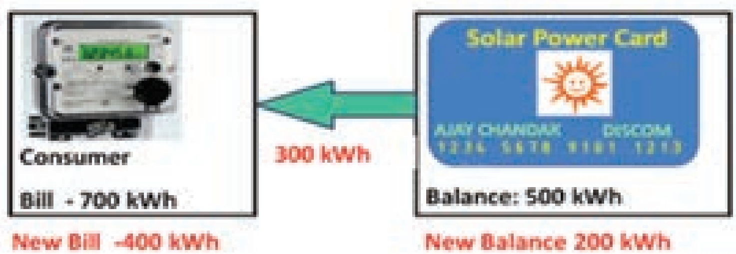

Figure 3: Illustrative transaction of solar power

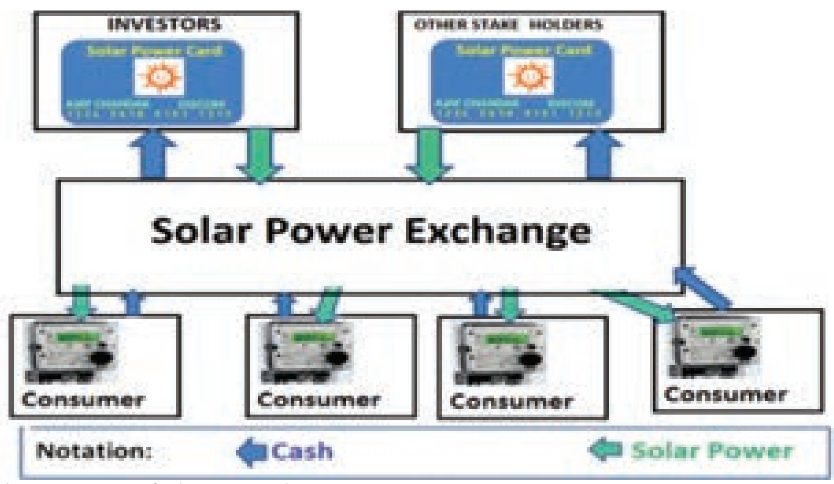

Figure 4 Concept of solar power exchange

generation figures, O & M cost, land cost, etc. as shown below:

- Project cost at ₹530.02 lakh/MW, which includes cost of land. Project cost will be ₹505.02 lakhs/MW excluding cost of land.
- Power generation at 16.64 lakh kWh per MW/year for first year with 19% CUF.
- Module degradation will be at 0.5% per year.
- O & M cost is ₹7 lakh/year.
- Tariff appreciation at 5% per year.

Any investor who invests ₹1 lakh in a project will get approximately 51,800 kWh during the project's lifetime. It is important to note that these are conservative estimates and the actual gains will be higher.

There might be retail investors who will like to sell their share of power to other consumers. Depending on the rate of realization, their returns on the investment scenario is as presented in Table 1.

Who Can Work as a Solar Project Developer Company?

The Solar Energy Corporation of India Ltd (SECI), National Thermal Power Corporation (NTPC), Energy Efficiency Services Limited (EESL), or other such PSUs can launch the project nationwide.

As 'solar power' is the currency in this model, it is insulated from different tariffs in different states.

State Generation Companies, Distribution Licencee themselves, or Special Purpose Vehicles (SPVs) of states or municipal corporations can also launch the project for their limited territory. SPVs of smart cities can become project developers and comply with their solar power obligation. Industry associations, chamber of commerce, such as CII, FICCI, and any association of likeminded people/ professionals/group of companies can also work as solar project developers and pass on the benefits of cheaper solar power to their members. Practically, any association of people who have the capacity to raise finance from thousands of retail investors can work as solar project developers. Organizations with a massive retail consumption, such as banks and oil companies, using this mechanism, can become 100% solar.

How is it Different from 'Rooftop Net Metering' or Captive Consumers?

- One needs a disposable rooftop with suitable orientation which falls within a good solar radiation zone to be eligible to participate in the solar rooftop scheme. VSRS is open for everybody—people without rooftops or living in rented spaces or even pure investors are eligible.
- In rooftops or captive generation, the investor is the consumer. In VSRS, investors need not be consumers. Breaking this link can fetch billions of rupees in the solar power sector. This will also provide 100% flexibility and liquidity to the investor.
- In the rooftop scheme, net metering DISCOMs only get liabilities and no returns. In VSRS, without any investment, DISCOMs get 15% power and 100% RECs.
- Rooftop systems puncture grids at hundreds of locations thereby increasing accidents and the difficulty in grid management. VSRS has no such issues.
- VSRS provides at least 50% more returns to the investors than rooftop systems.
- In rooftop or captive generation, the investor has the responsibility of O & M of system while in VSRS it is taken care of by an expert team at utility scale.

Investment basis: ₹1 lakh		
Rate of Realization in ₹/ kWh	**First Year's Return on Investment in Percentage**	**Average RoI for 25 years in Percentage with 5% Tariff Hike**
6	13.25	19.46
6.5#	14.35	21.42
7	15.46	23.37
7.5	16.56	25.33
8	17.67	27.28
9	19.87	31.19

#Most likely scenario

Why VSRS Is a Win-Win for all Stakeholders?

This financing mechanism creates a win-win situation for all stakeholders as has been described below:

Government of India

- No funding or subsidy is required. By implementing this, the Indian government will save ₹1, 50,000 crore.
- Participation in such projects will resonate along the lines of "*Sabka Sath Sabka Vikas*". The entire capital will be raised from savings of retail investors and consumers without taking any debts from banks, which in turn will have more funding to spare for social campaigns, such as 'Make in India', 'Digital India', and other such missions.
- For governments it will also solve the problem of land acquisition as farmers will be more than willing to offer their land for the projects.

» Those farmers who lease land for the solar project will get ₹2 lakh per year for 3 acres of land. At the national level, this can benefit 2 lakh farmer families and, to a large extent, the issue of farmer suicide can be averted. The projects have to come up in drought-prone areas where water is scare, rainfall is poor, and sunshine hours are more. Putting such non-contributing land to good use will be a national gain worth reckoning.

State governments

With these schemes and innovations, many financial and social problems will be solved and states across the country will only stand to gain with having nothing to lose. The advantages have been discussed below:

» Farmer suicide and land acquisition issues will be resolved.
» Industry will be highly benefited. Farmers, innovators, and investors are likely to sell a major portion of power to 'industries' at a reasonable rate. As solar power does not have fuel adjustment cost (FAC), such tariffs will be stable for a long duration.
» Most DISCOMs are in financial trouble and a system of decentralized expensive solar power will mean more trouble for them. With the help of different subsidies, state governments need to put money in DISCOMs. VSRS is the cheapest cost route for state DISCOMs as it involves no business risk and, with a variety of added administrative, financial, and social benefits, is the perfect replacement for solar rooftop and solar pump schemes.

Solar project developer

» Get 5% sweat equity that will fetch profits for the life of the project; administrative expenses are negligible.
» All profits from the project development are booked upfront.
» Capital is raised in the form of prepaid cards from investors. The project does not have any sensitivity towards interest rates and FOREX variations. Lowest cost offers are expected from EPC companies as capital costs for the projects are paid upfront.
» As all power is to be given back to the investors and other stakeholders, the responsibility of selling power as well as recovery of bills for the power shared gets eliminated.
» Project developers can earn some operating profits through O & M activity.

Industry

Farmers and other investors are likely to sell solar power at reasonable rates to the industry. This is a profitable proposition for both, the industry as well as investors.

Smart cities

As per clause 6.2 of the guidelines, a mandate has been passed for smart cities to get 10% of their power requirement from solar. At present, VSRS is the only mechanism that can fulfill this obligation. The various branches of city administration will be equipped to get this obligation fulfilled without incurring any extra expenditure or raising tax. It can also take credit for raising funds and ask the government for matching the grants.

Distribution licencee: Distribution licencees are the biggest beneficiary

» Get 15% power to compensate for losses and wheeling.
» Get 100% RECs generated from the project. Solar REC target for the year 2016–17 is revised at 2.75% as per the government's order dated July 22, 2016, and is slated to increase by 2% every year for next couple of years. This is a formidable ask and DLs will need large quantities of RECs. VSRS can provide them with the opportunity of getting RECs without any investment.

AS PER CLAUSE 6.2 OF THE GUIDELINES, A MANDATE HAS BEEN PASSED FOR SMART CITIES TO GET 10% OF THEIR POWER REQUIREMENT FROM SOLAR.

» No responsibility of raising bills and recoveries.
» If DLs adopt for rooftop net metering option then they incur losses and operating inconvenience. However, if DLs adopt VSRS, then all prospective beneficiaries who may opt for solar rooftop systems will be encouraged to give it up and participate in this scheme as the returns will surpass the investment. Losses of DLs because of rooftop net metering system can be eliminated and DLs can actually become net gainers.
» The solar pump scheme can be merged in this model with 60% savings in capital cost. Solar power cards can be issued to farmers for them to get their quota of free power. Doing so will eliminate the problem of recovery from farmers. It will also bring discipline in energy and water use.
» For distribution licencee, this is the lowest cost route for the adoption of solar power and financially, a stable model. In comparison with all the existing solar power procurement methods adopted till date, this is a much superior model.

Even in the PPA mode, there remains a possibility of project developers taking recourse to litigation due to some defaults by government thereby resulting in higher tariffs. In VSRS there are no such possibilities.

A customized version of VSRS can be prepared for a suitable group of consumers, such as farmers, MSME, smart cities, etc. Considering the immense benefit VSRS offers, urgent cognizance needs to be taken by authorities and electricity regulatory commissions. The proposal has been evaluated and vetted by many experts in the field of innovation, finance, and solar power sector and deserves early implementation. EF

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India's Wind Power Industry
Steady Growth and Development

The Indian Wind Turbine Manufacturers' Association (IWTMA) works in the field of promoting and harnessing wind energy to achieve inclusive and sustained economic growth. The organization aims to ensure high efficiency in generation of energy through the use of 'green and clean' technologies and achieving cost efficiency in the process. As an expert in the field of wind energy, **Mr Sarvesh Kumar**, Chairman, IWTMA, in this conversation with **Anushree Tiwari Sharma**, takes us through the mandate of the organization in propelling wind energy as a viable renewable energy option throughout the country.

What are your views on the Government of India's policy for repowering of wind energy projects?

While welcoming the newly notified policy on repowering of the wind power projects by the Ministry of New and Renewable Energy (MNRE), Government of India, the Indian Wind Turbine Manufacturers' Association (IWTMA) strongly feels that the concessional interest rate offered by Indian Renewable Energy Development Agency (IREDA), over and above the interest rate rebates available to the new wind projects financed by IREDA, will help boost investment in the wind energy sector.

Welcoming the move, the IWTMA is happy to note that Accelerated Depreciation (AD) and Generation-based Incentive (GBI) are also made available to repowering projects as per the conditions applicable to the new wind power projects. With the new policy, wind turbine generators of capacity 1 MW and below would be eligible for repowering under the policy. Based on the experimental measure, MNRE will extend the repowering policy to other projects also.

Most of the wind-turbines installed up to the year 2000 are of capacity below 500 kW and are at sites having high wind energy potential. It is estimated that over 3,000 MW capacity installation are from wind turbines of around 500 kW or below. In order to optimally utilize the wind energy resources, repowering is required and hence the objective of the repowering policy, according to MNRE, is to promote optimum utilization of wind energy resources by creating a facilitative framework for repowering.

Could you tell us about the status of offshore wind power development in India?

While India is eager to tap all available sources to generate electricity required to power the country, the nation is working out initial plans to set up an offshore wind energy plant with the help of Germany, the world leader in renewable energy.

According to Mr S Gomathinayagam, former Director General of the National Institute of Wind Energy (NIWE), the Institute had already installed a 100 m met mast at Dhanushkodi near Rameswaram in Tamil Nadu and in Gujarat for future offshore developments. The investment required to set up an off-shore plant was more than ₹1,500 crore which would require private capital as well. While agreeing with this fact, Mr Gomathinayagam notes that the wind speed onshore was about 5 m per second while the data collected from the mast revealed the offshore speed of wind was 8.65 m per second, a significant increase. "Also offshore wind energy plants could be functional for 10 months in a year", he said in comparison to the on-shore units that work for only five months in a year. It took more than a decade and a half for Germany to tap offshore wind energy after generating data. India may do it in the next 7 to 8 years", he added.

What is the role of IWTMA in making India a favoured destination for wind energy investment?

As the apex body, IWTMA has been an important stakeholder in the development and growth of the wind power industry.

As an 18-year-old organization, the association has been working towards the formulation of policies for the sector and liasoning between the turbine manufacturers and the government. IWTMA was established to aggressively campaign for a Green Revolution to encompass the economy, business, and rural employment and to contribute towards energy self-reliance for the country.

IWTMA has been instrumental in transforming India wind into a mature industry, thus heralding the 'Make in India' Campaign, continuing dialogues with various stakeholders in their endeavour to broaden wind–solar hybrid, exports, adherence to RPO to make 60 GW a reality, and move further ahead.

How will you rate ongoing efforts to improve the power evacuation infrastructure and grid integration in the country?

Power evacuation is a basic infrastructure requirement. In this regard, the ongoing efforts of the green corridor by Power Grid Corporation of India Ltd (PGCIL) are laudable.

Engagement of the wind industry of original equipment manufacturers' (OEMs), developers, and stakeholders, from various states, are required on a regular basis to achieve targets and integrate the grid with their thoughts on national renewable purchase obligation (RPO).

Sooner or later, renewable energy sources, especially wind and solar, will play a vital role in the energy mix to achieve energy security.

What are your expectations from Windergy India 2017?

At the outset, Windergy is a mega event by the industry and for the industry. Billed as the 'miss not series event' in the wind industry, Windergy provides the right platform to showcase the existing and new technology, interaction with B2B and B2C, and corporate image building.

Organized by IWTMA in partnership with the Global Wind Energy Council, Windergy India 2017 includes all the major wind developers and component manufacturers and Independent Power Producers extending a helping hand to make it a 'miss not event'.

Your thoughts on the pilot project to install wind turbines on cellphone towers.

It is a great idea to save the transportation cost of diesel and reduce pollution. The big operators need to encourage small wind as a possible answer with the powering of trains and charging of batteries.

Please elaborate on IWTMA's plans for the future.

IWTMA has already initiated moves to foster ties with research institutions and sustainable development organizations to explore the feasibility of providing the right impetus to skill training and development and in preparing the workforce to meet the growing needs of the wind developers in particular and the wind industry as a whole.

We are not in the business of selling wind turbines. In our purpose and search, we continue to strive for a clean and green India to achieve energy security and harness power 'literally from thin air'. EF

The Eighth GRIHA Summit

The Eighth Edition of the GRIHA Summit was held in India Habitat Centre, Lodhi Road, New Delhi on March 2–3, 2017. The event was organized by the GRIHA Council, TERI, in conjunction with the Ministry of New and Renewable Energy (MNRE), Government of India. The theme of this year's summit was 'Transforming Habitats'. The 2-day Summit served as a platform for facilitating multi-stakeholder partnerships and networking among governments, academia, civil society organizations, and professionals from different disciplines, such as architecture, engineering, and construction management.

Mr Rajeev Kapoor, Secretary, MNRE, Government of India, launched the GRIHA rating for existing buildings and during the inaugural address said, "MNRE has been associated with GRIHA for over a decade and has supported this green movement. The distinctive aspect about GRIHA is that it is not only about the final product but also about the process of construction. There is a need to improve the entire ecosystem of urbanization, as sustainable 50% of India will be urban in the next 15–20 years. Herein lies the challenge in urban governance and political and economic system." He also welcomed the new initiative of rating existing buildings, which will further spur the green movement and help gain momentum to achieve sustainable habitats. The Summit witnessed deliberations on creating technology that is efficient, beneficial to health, and socially affordable; a solution-driven approach to tackle growing cooling demand, especially in developing countries; to showcase the water conservation strategies undertaken, considering the highly unpredictable availability of water; and the urgency of going green to create a sustainable society. Dr Ajay Mathur, Director General, TERI & President, GRIHA Council, in his welcome address, congratulated the GRIHA team on this momentous feat while emphasizing the importance of managing urban spaces.

Amidst the challenges posed by climate change, transition to cleaner and more energy efficient buildings is the need of the hour, and GRIHA is a tool to transform our habitats towards sustainable development from concept to commissioning. There have been multiple real estate developers, such as BESTECH, Vatika Group, Ireo, and Conscient, who have paved the way forward for green habitats by committing their projects to GRIHA ratings. With the growing stock of buildings, potential for enhancing resource efficiency in existing buildings is an opportunity to reduce consumption, optimize operational and maintenance costs, and augment the indoor comforts of the occupants. The new GRIHA rating for existing buildings has been designed with an underlying objective of simplicity of execution, economic viability, and alignment with national and sub-national policies. With a view to transforming our urban centres into smarter, high-performance habitats, the GRIHA Summit attempted to address alternate solutions to achieve better energy efficiency, less wastage and optimum usage in the construction industry.

Approximately 70% of the buildings that will exist in India by 2030 are yet to be built, which makes energy efficiency, the cleanest, quickest and cheapest way to bring our country out of energy poverty. Energy efficient HVAC systems provide a huge opportunity for the sector to save energy and emissions cumulatively. About 50% of the emissions can be avoided globally by 2030 against the business-as-usual by leapfrogging from high

GWP refrigerants to low GWP natural refrigerants and applying best in class, highly energy efficient appliances. The second day of the Summit set tone for the need for sustainability going hand in hand with financing for ideas and implementation for creating an ecosystem for sustainable habitat. With the recent predication by meteorological department that due to increase in greenhouse gases (GHGs) the upcoming summer will be one degree higher than normal average, and with the amount of unprecedented urbanization India is witnessing at present, the construction sector has a significant impact on climate change. In the Indian context, green penetration in buildings is between 3% and 5% and if the inefficient use of energy, water and embedded materials continues, it could result in approximately 10 times increase in GHG emissions in the construction sector by 2050.

In his keynote address during the session 'Financing Green Buildings', Mr Subrata Dutta Gupta, Principal Financial Officer, IFC said, "With the government leading the charge, just assuming 20% green penetration and 20 million houses constructed by 2022, we can expect annually 4 million tonnes GHG emissions avoidance, which is equivalent to taking 800 thousand cars off the road and 430 million cubic metres of water saved, which is equivalent to water supply to an additional 4 billion homes. This in itself should be a motivator for all of us to create and leave behind a greener India." According to a study undertaken by Dodge Data & Analytics, IGBC and JLL, the green real estate market size is expected to be $180 billion and in India, green building construction is growing faster than any other country in the world. The Government of India's initiatives, such as Housing for All, Smart Cities, and Make in India, are expected to drive investments in the real estate sector. Developers are already building certified green homes, there are several real estate financing instruments that can be utilized for developing green financing, such as conventional bank loans, FDIs, and private equity. Green bonds too could be a major tool to convert INDCs into climate action. Summarizing another session focussing on 'Policy Tools to Promote Energy Efficiency in Buildings,' Mr Sanjay Seth, CEO, GRIHA Council, said, "Policy intervention is equally necessary for both the new as well as the existing stock of buildings." He also emphasized GRIHA's commitment to provide cutting-edge green building rating system based on the underlying principle of 'what gets measured gets managed.' To create an ecosystem driven approach for green buildings, collaborative efforts are required from the government, multilateral agencies, private sector, and the consumer. Private sector will need to work towards enhancing access to finance, promote micro-entrepreneurship, encourage public–private partnership projects, and develop financing structures. Simultaneously, awareness needs to be created among consumers regarding benefits of green buildings to create demand.

In another session on 'Transforming Habitats through Sustainable and Resilient Buildings' focus was laid on several aspects of integrating resilience into buildings keeping the future course of sustainable development in mind. Climate change wreaks havoc on cities, and the brunt of it is borne by the buildings. Hence, the key takeaway from the session was to build resilience into the overall infrastructure through a proactive approach, instead of a reactive one, incorporating climate proofing from the start. Sharing his views on the occasion, Dr A K Tripathi, MNRE, said, "There is no dearth of sound technological ability and financing to build climate resilient green buildings. We need to focus on striking the perfect balance between technology and financial viability to ensure that we have sustainable buildings. In this regard, the planners, technologists and commercial builders need to work together at the helm of affairs."

Sharing his thoughts during the valedictory session, Mr K E Ranganathan, MD, Parryware Limited, emphasized on how green building is all about building a consciousness around sustainability.

Praising the efforts by GRIHA in this regard, he said that Parryware supports this initiative as a responsible corporate brand through their product innovation.

As a telling testament of its commitment to promote green building infrastructure, the GRIHA Council has signed Memoranda of Understanding, both, with the private and public sector entities, viz., Madhya Pradesh Police Housing Society, Vatika Group, IREO, BESTECH, and Conscient Group.

In an endeavour towards development of sustainable buildings in Gurugram, GRIHA Council organized the GRIHA-NASA Trophy during the GRIHA Summit on March 3, 2017. Sinhgad College of Architecture won the Trophy at the 59th Annual NASA Convention 2016/17, organized with the support of Experion Developers, Gurugram. The GRIHA-NASA Trophy is awarded by The GRIHA Council under the aegis of TERI and the MNRE, Government of India, in partnership with the National Association of Students of Architecture (NASA). This year the competition required students to design a sustainable office complex for Experion Developers, a reputed developer committed to sustainable development. The complex, situated at the 32nd Milestone, NH8, Gurugram, was expected to make the best use of the site while providing special attention to massing, solar orientation, wind movement, and passive cooling systems. The proposed design was also required to create spaces that inspire and inculcate environmentally responsible attitude among visitors to the complex. The competition this year witnessed an overwhelming response from the students with participation from 73 colleges. The entries were evaluated by an eminent panel of members. Besides Sinhgad College of Architecture, the winner of the competition, several other institutes, such as the Faculty of Architecture & Ekistics at Jamia Millia Islamia; Academy of Architecture, Mumbai; and Vastukala Academy, College of Architecture, received special mention for their designs. EF

CURRENT R&D SOLAR

Renewable Energy Integrated Desalination: A Sustainable Solution to Overcome Future Freshwater Scarcity in India

Renewable and Sustainable Energy Reviews, Volume 73, June 2017, Pages 594–609

S Manju, Netramani Sagar

Fossil fuels, such as coal, petroleum, and natural gas, have been used as the major sources of energy in the recent past. However, the negative environmental impacts associated with the emission of the greenhouse gases from these conventional energy sources forced the realization of the importance of renewable energy resources. At the same time, average annual exponential rate of population growth in India needs increasing amounts of freshwater for basic necessities. This might result in water scarcity as the overall population in India is expected to increase to 1.60 billion by 2050. It has been forecasted that, by the year 2040, India will rank 40th in the world in terms of water scarcity. To meet the rising freshwater demand, desalination is an intelligent and sustainable option for India, which has a very long coastline measuring 7,517 km. In this paper, an attempt has been made to provide a comprehensive review of water scarcity in India and suggest a possible solution, which is implementing desalination technologies coupled with renewable resources. The paper reviews the groundwater scenario in India and the global desalination market. The authors summarize the energy consumption in various desalination processes and provide a brief outlook of the desalination techniques in India. Apart from this, desalination using non-conventional sources, such as solar, wind, and geothermal energy is discussed. In addition, factors affecting the environment due to desalination and the potential countermeasures are presented. This review aims to provide an awareness of the projected water crisis in India, in the coming decades, and is also aimed to help the policymakers for selecting an appropriate desalination technology.

The Effectiveness of Federal Renewable Policies in India

Renewable and Sustainable Energy Reviews, Volume 70, April 2017, Pages 538–550

Gireesh Shrimali, Sandhya Srinivasan, Shobhit Goel, David Nelson

The Government of India has set ambitious targets for renewable energy. However, unsubsidized renewable energy is still at least 50% more expensive than fossil fuel power and requires policy support at federal as well as state levels. In this context, a comparative evaluation of effectiveness of these policies becomes important. Using financial models, the researchers provide a framework to compare existing federal policies—generation-based incentive, viability gap funding, and accelerated depreciation—for wind and solar technologies with a new class of debt-related federal policies. The authors main finding is that debt-related policies offer the most potential for cost effectiveness in the long term; they also perform well across other criteria. A particularly attractive policy is reduced cost, extended–tenor debt, which compared to existing policies, would reduce total subsidies by up to 78%, have 100% viability gap coverage.

Progressing towards the Development of Sustainable Energy: A Critical Review on the Current Status, Applications, Developmental Barriers and Prospects of Solar Photovoltaic Systems in India

Renewable and Sustainable Energy Reviews, Volume 70, April 2017, Pages 298–313

S Manju, Netramani Sagar

Equality between economic progress and environmental sustainability is essential for a developing country like India. In the present time, the economy of India is growing rapidly in a vibrant mode and in an efficient way, which in turn demands huge uninterrupted energy supplies. The country's energy needs are met mostly by use of fossil fuels and nearly 70% of electricity is generated from coal-based power plants. In India, nearly 840 million people depend on traditional biomass to satisfy their energy necessities. Approximately 74 million rural people do not have access to modern lighting systems and around 81 million households do not have access to electricity, which is a major challenge to India's energy security. In order to achieve stable, sustainable energy in the long run, significant progress in renewable energy sectors is needed. Favourably, due to India's geographic location, the country is blessed with abundant renewable energy resources, which has not yet been exploited completely. So, the central and state governments of the country have framed various policies and are providing subsidies to encourage utilization of solar photovoltaic systems. In this paper, a comprehensive review of the potential, current developmental status, and prospects of solar energy of India is briefed. The various applications of solar energy, such as water heaters, desalination units, pasteurizers, food drying units, water purifier, space heating systems, air-conditioning units, cookers, water pumps, aerators, solar-wind hybrid systems, and grid-connected photovoltaic systems, are explained. The study also mentions the current renewable energy policies, the barriers blocking the progress of the solar manufacturing units, and some possible future recommendations that might speed up renewable energy developments in India. EF

Local Community as Shareholders in Clean Energy Projects: Innovative Strategy for Accelerating Renewable Energy Deployment in India

Renewable Energy, Volume 101, February 2017, Pages 873–885

Sapan Thapar, Seema Sharma, Ashu Verma

The Government of India is promoting renewable energy sector with an ambitious target of 175 GW capacity to be achieved by 2022. The reasons for this energy transition from fossils to renewable energy technologies include facilitating energy access, promoting cleaner forms of energy, and enhancing energy security. The huge capacity shall require about 200,000 ha of land. However, land procurement has been identified as a key impediment in accelerating the growth of renewable energy sector in India. This presents an exciting business opportunity towards setting up community energy projects under community mode with the local people as shareholders. Community members can provide their land for setting up renewable energy projects as well as support in project development activities in lieu of getting up to 15% equity participation. This shall provide them with a constant source of income, estimated at over $4,000 per ha per annum, besides facilitating energy access in villages. Quicker possession of land shall expedite project execution and reduced capital expenditure shall decrease the cost of energy generation by up to 6%. Policymakers in emerging economies like India can pilot the proposed model in upcoming solar parks and wind farms. EF

Renewable and Non-renewable Energy Use–Economic Growth Nexus: The Case of MENA Net Oil Importing Countries

Renewable and Sustainable Energy Reviews, Volume 71, May 2017, Pages 127–140

Montassar Kahia, Mohamed Safouane Ben Aïssa, Charfeddine Lanouar

This study examines the energy use–economic growth nexus by disaggregating energy use into two types of energy—renewable and non-renewable energy use. The researchers' sample consists of eleven MENA Net Oil Importing Countries (NOICs) during the period 1980–2012. A multivariate panel framework was used to estimate the long-run relationship and the panel Granger causality tests was employed to assess the causality direction among variables.

The empirical results provide evidence for long-term equilibrium relationship between real Gross Domestic Product, renewable energy use, non-renewable energy use, real gross fixed capital formation, and labour force. The results provide evidence also for positive and statistically significant elasticities. Moreover, the empirical findings from panel Error Correction Model confirm the existence of bidirectional causality between renewable energy use and economic growth and between non-renewable energy use and economic growth—results that support the feedback hypothesis. Moreover, our empirical findings provide evidence for two-way (bidirectional) causal association in both the short and long run between renewable and non-renewable energy use, which proves the substitutability and interdependence between these two types of energy sources. The policies implications of these results are also proposed and discussed. EF

Renewable Energies Cannot Compete with Forest Carbon Sequestration to Cost Efficiently Meet the EU Carbon Target for 2050

Renewable Energy, Volume 107, July 2017, Pages 164–180
Miriam Münnich Vass

Renewable energies have great potential to contribute to CO_2 emissions reductions by substituting for fossil fuels. This study examines whether renewable energies with learning-by-doing technical change can compete with forest carbon sequestration to cost efficiently achieve the EU carbon target for 2050. Cost-efficient abatement solutions are obtained using a dynamic optimization model that accounts for three kinds of mitigation options: renewable energies and abatement in the forest and fossil fuel sectors. The results show a net present cost of reaching the target of approximately 225 billion Euros and a carbon price of 306 Euro/tonne CO_2 in 2050. Furthermore, the stock of renewables in 2050 can deliver almost twice as much as the current electricity production from renewables, which implies a contribution of 8.2% to meeting the emissions target. However, the average cost per unit emissions reduction is more than twice as high for renewables as for forest carbon sequestration. Hence, the results indicate that renewables are unable to compete with forest carbon sequestration unless they receive continued government support. EF

Optimal Renewable Energy Generation—Approaches for Managing Ageing Assets Mechanisms

Renewable and Sustainable Energy Reviews, Volume 72, May 2017, Pages 269–280
Chinedu I Ossai

Last decade marked a dramatic increase in renewable energy assets investment around the world and a substantial increase of global renewable energy consumption. To enhance investment decisions in renewable energy generation involves optimization studies that can show the expected renewable energy generation in consideration of numerous constraints, while reduced downtime, enhanced safety, and reliability margins of the renewable energy generation plants will reduce the operating cost and increase profitability. To prevent escalation of maintenance costs resulting from unidentified (and lately identified) ageing degradation mechanisms requires proactive techniques to forestall the effect of different stressors on renewable energy generation plant. This paper explores investment decision models for optimizing renewable energy generation and different types of ageing mechanisms and their effects on renewable energy generation. Whereas the decision models provide insight on different optimization models for renewable energy generation, the area of application and the constraints considered in the study, the ageing management framework helps in managing ageing-related stressors for established renewable energy plants. Ageing stressors are induced by components interactions, environmental factors and human errors in design, manufacturing, installation and maintenance, Deming PLAN-DO-CHECK-ACT cycle was used for designing a systematic ageing management framework that stipulates early setoff of ageing management programme through a systematic procedure that uses multidisciplinary team of plant assets management personnel to monitor material degradation, spare parts obsolesce, and human errors. Proper implementation of this framework can result in safe, reliable, and cost-effective renewable energy generation since operating cost can be reduced with minimized downtime. EF

Renewable Energy Investment Risk Evaluation Model Based on System Dynamics

Renewable and Sustainable Energy Reviews, Volume 73, June 2017, Pages 782–788
Ximei Liu, Ming Zeng

China currently faces the dual constraints of developing low-carbon economy and enabling sustainable energy utilization. It is an inevitable choice for the strategic transformation of economy development and energy development in China to develop renewable energy. Since renewable energy is a capital- and tech-intensive industry, which requires a large amount of investment and a high level of technology innovation; investors face many different uncertainties when making a renewable energy project investment decision. Therefore, it has great significance for development of renewable energy to evaluate the risks in renewable energy investment projects and then make the best investment decisions. Based on the above background, the topic of renewable energy investment risk is studied in this paper using system dynamics method. In the first part of the work, three main risks in renewable energy investment—technical risk, policy risk, and market risk—have

been discussed, and then causal loop diagram of investment risk and risk assessment model have been established by the system dynamics method, after that a numerical example was given in the last part of the paper. The result of the numerical example indicated that policy risk was the main factor affecting the investment in the early development stage; while policy risk and technology risk decline gradually, market risk has gradually become the main uncertainty affecting the investment in the mature development stage. EF

Renewable Energy and Biodiversity: Implications for Transitioning to a Green Economy

Renewable and Sustainable Energy Reviews, Volume 70, April 2017, Pages 161–184

Alexandros Gasparatos, Christopher N H Doll, Miguel Esteban, Abubakari Ahmed, Tabitha A Olang

This literature review identifies the impacts of different renewable energy pathways on ecosystems and biodiversity, and the implications of these impacts for transitioning to a Green Economy. While higher penetration of renewable energy is currently the backbone of Green Economy efforts, an emerging body of literature demonstrates that renewable energy sector can affect ecosystems and biodiversity. The current review synthesizes the existing knowledge at the interface of renewable energy and biodiversity across the five drivers of ecosystem change and biodiversity loss of the Millennium Ecosystem Assessment (MA) framework (i.e., habitat loss/change, pollution, overexploitation, climate change, and introduction of invasive species). It identifies the main impact mechanisms for different renewable energy pathways, including solar, wind, hydro, ocean, geothermal, and bioenergy. The authors' review demonstrates that while all reviewed renewable energy pathways are associated (directly or indirectly) with each of the five MA drivers of ecosystem change and biodiversity loss, the actual impact mechanisms depend significantly between the different pathways, specific technologies, and the environmental contexts within which they operate. With this review, the authors do not question the fundamental logic of renewable energy expansion as it has been shown to have high environmental and socio-economic benefits. However, the authors want to make the point that some negative impacts on biodiversity do exist, and need to be considered when developing renewable energy policies. The authors put these findings into perspective by illustrating the major knowledge/practices gaps and policy implications at the interface of renewable energy, biodiversity conservation, and the Green Economy. EF

Rayforce Greentech Private Limited
Innovative solar products

The gentlest way to preserve of food items without degrading their nutritional or taste value completely, which chemical processes do, is through refrigeration. India is the largest producer of fruits and vegetables in the world.[1] Post-harvest loss is also very high in the country due to lack of cold storage options. This affects both producers, especially small vendors, as well as consumers adversely. One of the reasons of slow growth of cold storage is that refrigeration is an energy-intensive process, which needs constant supply of energy to prevent spoilage.

Solar Powered Cool Carts

Rayforce Greentech Private Limited has solved the need for cold storage

[1] http://agritech.tnau.ac.in/agricultural_marketing/agrimark_cold%20storage.html

and transport for small vendors. RayForce is an off-grid solar products development company devoted to providing innovative eco-solutions to India's horticulture, fishery, agriculture and dairy industry. Rayforce is the first company in India to utilize the power of solar energy to operate refrigerated fruits and vegetable cart.

Solar Powered Cool Carts launched in Goa in 2011. These carts enable retail selling of fruits and vegetables in a hygienic and eco-friendly manner. Customers these days are flocking to the supermarkets or malls to buy their food needs such as vegetables, fruits, fish, etc. This is because the items look clean and fresh on the refrigerated shelves. As water is not sprinkled to keep them fresh, these items stay fresh longer. On the other hand, water results in spoilage and huge losses to the retail vendor who does not have refrigeration facilities.

While customers prefer clean and dry food products that require refrigeration, the process is costly and binds the vendor to a particular place. Electric connection required for refrigeration is not always available to small vendors and shortage is even more acute while he is on the move to service more prospective regions. The Solar Powered Cool Carts provide solution to all these problems:

- Provide reliable and independent power, which results in savings while significantly reducing transportation cost and dependency on electricity
- Retail selling of fruits and vegetables in hygienic and eco-friendly manner, which is appealing to today's demanding customers
- Carrying extra water and sprinkling of water on vegetable and fruits not required because the necessary temperature is maintained
- Increase shelf life of perishable items reducing losses for retail outlet/retail hawkers enabling them to sell items for longer duration

The carts have effective cooling for 10 hours. Other state governments, such as Haryana, Chhattisgarh, Gujarat, and Madhya Pradesh, have also supported these carts. The Cool Carts are available in two options: motorized and non-motorized.

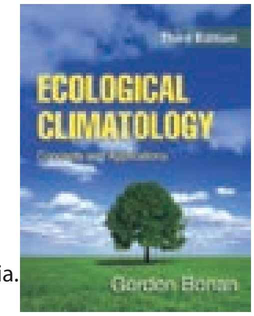
Solar Powered Bulk Milk Cooler

The company has also introduced Solar Powered Bulk Milk Cooler with capacity of 500 L and 1000 L. The intended users of these milk cooling tanks are dairy co-operative societies at village levels, which collect milk mornings and/or evenings from the producers. Unpasteurized milk is a highly perishable product and needs to be chilled rapidly in order to be able to store it and transport it. The milk collected is stored in the Bulk Milk Cooler and cooled to 4°C from room temperature within 3 hours.

The cooling unit enables producers to preserve the quality of their fresh dairy. This also means less dairy waste. It is economically important for small farmers to keep the milk from their cows cooled until it is collected for further processing. The bulk milk cooler powered by solar energy provides the ideal solution. Some of the benefits of using a solar powered milk cooling container over traditional ones are:

- Savings in chilling maintenance and cost
- Reduced emissions and dependence on grid electricity
- Government subsidy and tax saving
- Income through carbon credits. EF

Ecological Climatology: Concepts and Applications, 3rd Edition

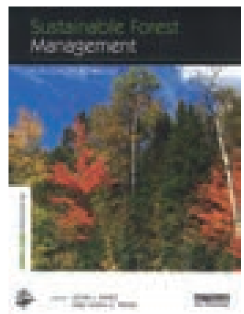


Author: Gordon Bonan
Publisher: Cambridge University Press; Year: 2016

The third edition of Gordon Bonan's comprehensive textbook introduces an interdisciplinary framework to understand the interaction between terrestrial ecosystems and climate change. Ideal for advanced undergraduate and graduate students studying ecology, environmental science, atmospheric science, and geography, it reviews basic meteorological, hydrological, and ecological concepts to examine physical, chemical, and biological processes by which terrestrial ecosystems affect and are affected by climate. The central argument is that plants and terrestrial ecosystems—through their cycling of energy, water, chemical elements, and trace gases—are integral determinants of climate. This coupling between climate and vegetation is explored at spatial scales from plant cells to global vegetation geography and at timescales of near instantaneous to millennia. The book also considers how human alterations to land are important for climate change.

This new edition has been thoroughly updated with new science and references. The scope has been expanded beyond its initial focus on energy, water, and carbon to include reactive gases and aerosols in the atmosphere. The new edition emphasizes the Earth as a system, recognizing interconnections among the planet's physical, chemical, biological, and socioeconomic components, and emphasizing global environmental sustainability. Each chapter contains chapter summaries and review questions and with over 400 illustrations, including many in colour; this textbook will once again be an essential student guide.

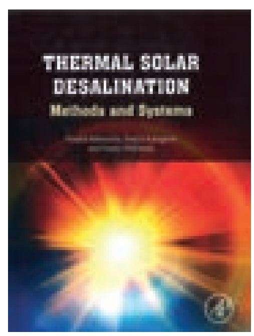
Sustainable Forest Management: From Concept to Practice (The Earthscan Forest Library)



Editors: John L Innes, Anna V Tikina
Publisher: Routledge Year: 2016

Sustainable Forest Management provides the necessary material to educate students about forestry and the contemporary role of forests in ecosystems and society. This comprehensive textbook on the concept and practice of sustainable forest management sets the standard for practice worldwide. Early chapters concentrate on conceptual aspects, relating sustainable forestry management to international policy. In particular, they consider the concept of criteria and indicators and how this has determined the practice of forest management, taken here to be the management of forested lands and of all ecosystems present on such lands. Later chapters are more practical in focus, concentrating on the management of the many values associated with forests.
Overall the book provides a major new synthesis that will serve as a textbook for undergraduates of forestry as well as those from related disciplines, such as ecology or geography, who are taking a course in forests or natural resource management.

Thermal Solar Desalination: Methods and Systems

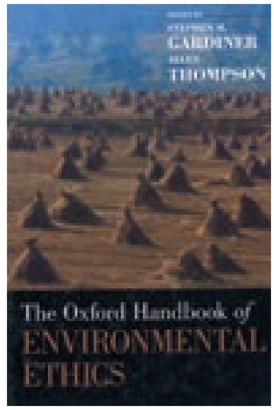


Authors: Vassilis Belessiotis, Soteris Kalogirou, Emmy Delyannis
Publisher: Academic Press; Year: 2016

Thermal Solar Desalination: Methods and Systems presents numerous thermal seawater desalination technologies varying from the very simple, easy to construct, and operate solar stills, to the more advance membrane and indirect distillation methods. All types of solar thermal desalination technologies are presented in detail to enable readers to comprehend the subject, from design details to enabling further research to be carried out in this area.
The various units used in desalination are outlined, along with diagrams of all detailed working principles of desalination methods and systems. The authors consider the economic aspects of these processes, demonstrating successful implementation of desalination units suitable for areas where supply of fresh water in natural ways is limited or non-existent.

- Includes detailed descriptions and design of all types of solar thermal desalination systems;
- Lists a comprehensive record of seawater and fresh water thermophysical properties required in the design of desalination systems; and
- Contains equations to calculate and analyse the performance of the processes examined and assesses their practicality and application.

The Oxford Handbook of Environmental Ethics

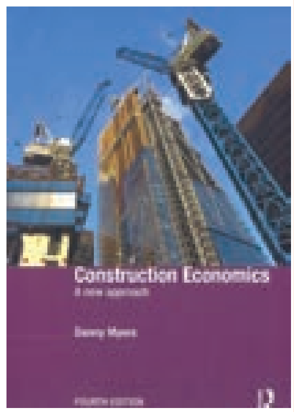


Editor: Stephen M Gardiner, Allen Thompson
Publisher: OUP USA; Year: 2016

We live during a crucial period of human history on the Earth. Anthropogenic environmental changes are occurring on global scales at unprecedented rates. Despite a long history of environmental intervention, never before has the collective impact of human behaviours threatened all of major biosystems on the planet. Decisions we make today will have significant consequences for the basic conditions of all life into the indefinite future. What should we do? How should we behave? In what ways ought we organize and respond? The future of the world as we know it depends on our actions today.

A cutting-edge introduction to environmental ethics in a time of dramatic global environmental change, this collection contains forty-five newly commissioned articles, with contributions from well-established experts and emerging voices in the field. Chapters are arranged in topical sections: social contexts (history, science, economics, law, and the Anthropocene); who or what is of value (humanity, conscious animals, living individuals, and wild nature); the nature of value (truth and goodness, practical reasons, hermeneutics, phenomenology, and aesthetics), how things ought to matter (consequences, duty and obligation, character traits, caring for others, and the sacred); essential concepts (responsibility, justice, gender, rights, ecological space, risk and precaution, citizenship, future generations, and sustainability), key issues (pollution, population, energy, food, water, mass extinction, technology, and ecosystem management); climate change (mitigation, adaptation, diplomacy, and geoengineering); and social change (conflict, pragmatism, sacrifice, and action). Each chapter explains the role played by central theories, ideas, issues, and concepts in contemporary environmental ethics and their relevance for the challenges of the future. EF

Construction Economics: A New Approach, Kindle edition, 4th Edition



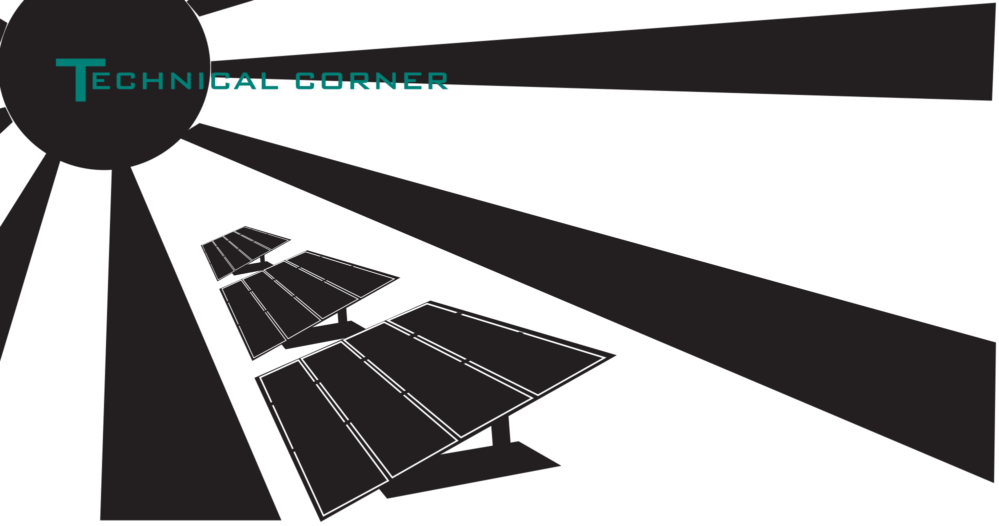
Author: Danny Myers
Publisher: Routledge; Year: 2016

Construction Economics provides students with principles and concepts underlying the relationship between economic theory and the construction industry. This new edition has been fully revised with a new introduction that provides an overview of economic developments since the Global Financial Crisis and introduces new economic thinking.

With new data, examples, initiatives, readings, glossary items, and references, the fourth edition of this established core text builds on the strengths of the previous edition:

- A clear and user-friendly style;
- Use of a second colour to highlight important definitions and formulae;
- Regular summaries of key points;
- A glossary of key terms;
- Extensive use of tables and figures;
- Extracts from the academic journal *Construction Management and Economics* to consolidate and prompt discussion; and
- Reviews of useful websites

This invaluable textbook is essential reading across a wide range of disciplines from construction management and civil engineering to architecture, property, and surveying. EF



RENEWABLE ENERGY TECHNOLOGY DEVELOPMENT

VTT has developed stand-up pouches from renewable raw materials, nanocellulose

VTT Technical Research Centre of Finland Ltd has developed lightweight 100% bio-based stand-up pouches with high technical performance. High performance in oxygen, grease, and mineral oil barrier properties has been reached by using different bio-based coatings on paper substrate. The pouches exploit VTT's patent pending high-consistency enzymatic fibrillation of cellulose (HefCel) technology. According to a senior scientist Jari Vartianinen at VTT, one-third of the food produced for human consumption is lost or wasted globally. Packaging with efficient barrier properties is a crucial factor in the reduction of food loss and their solution offers an environment-friendly option for the global packaging industry.

VTT's HefCel technology provides a low-cost method for the production of nanocellulose resulting in a tenfold increase in the solids content of nanocellulose. Nanocellulose has been shown to be potentially very useful for a number of future technical applications. The densely packed structure of nanocellulose films and coatings enable their outstanding oxygen, grease, and mineral oil barrier properties.

HefCel technology exploits industrial enzymes and simple mixing technology as tools to fibrillate cellulose into nanoscale fibrils without the need for high energy-consuming process. The resulting nanocellulose is in the consistency of 15%–25% when traditional nanocellulose production methods result in 1%–3% consistency. The stand-up pouch is the fastest growing type of packaging, growing at a rate of 6.5% per year between 2015 and 2020. Fossil-based plastic films still dominate the packaging market. However, development of environment-friendly new materials is of growing importance. Nanocellulose has been shown to be potentially very useful for a number of future technical applications. VTT has solid expertise in various bio-based raw materials and their application technologies for producing bio-based coatings, films, and even multi-layered structures, both at lab-scale and pilot-scale. A versatile set of piloting facilities are available from raw material sourcing through processing to application testing and demonstration.

https://www.sciencedaily.com/releases/2017/03/170314092752.htm

World's most efficient, environment-friendly solar cells

In future, solar cells can become twice as efficient by employing a few smart little nano-tricks. Researchers are currently developing environment-friendly solar cells of the future, which will capture twice the energy as the cells of today. The trick is to combine two different types of solar cells in order to utilize a much greater portion of the sunlight.

"These are going to be the world's most efficient and environment-friendly solar cells. There are currently solar cells that are certainly just as efficient, but they are both expensive and toxic. Furthermore, the materials in our solar cells are readily available in large quantities on Earth. That is an important point," says Professor Bengt Svensson of the Department of Physics at the University of Oslo (UiO) and Centre for Materials Science and Nanotechnology (SMN).

The physicists are now making use of the very best of nanotechnology and will develop new solar cells in the European research project, Solhet (high-performance tandem heterojunction solar cells for specific applications), which is a collaborative project involving UiO; the Institute for Energy Technology (IFE) at Kjeller, Norway; and the University Polytehnica of Bucharest, together with two other Romanian institutions.

Their goal is to utilize even more of the spectrum of sunlight than is possible at present. Ninety-nine per cent of today's solar cells are made from silicon, which is one of the most common elements on Earth. Unfortunately, silicon solar cells only utilize 20% of the sunlight. The explanation for this limit is that silicon cells primarily capture the light waves from the red spectrum of sunlight. That means that most of the light waves remain unutilized.

The new solar cells will be composed of two energy-capturing layers. The first layer will still be composed of silicon cells. The trick is to add another layer on top of the silicon cells. This layer is composed of copper oxide and would capture the light waves from the blue spectrum of sunlight. There will also be other layers in the solar cell panel. On the back surface, a protective glass layer will be deposited, along with a metal layer that conducts the electricity out of the solar cell. The front side will have an anti-reflective coating, so that the light rays are captured rather than reflected away.

The solar cell panel will be very thin. The thickness of the individual layers will vary between a hundred and a thousand nanometres. One of the trickiest moves is to create a special layer that will be as thin as one to two nanometres.

All solar cell materials are composed of semiconductor materials that have special electrical properties. These electrical properties are determined by the band gap.

Nanotechnology is used to design materials with a specific band gap. When photons, that is, light particles from the sun, strike the solar cell, energy is delivered to the solar cell. This energy impels an electron through the band gap into what is called the conduction band, where the electrons can be gathered up and removed as energy.

The electrons leave behind electron holes. Both the electron and the electron hole can conduct electricity. "The challenge is to develop copper oxide with a band gap that is precisely large enough so that the electrons can be captured before they fall back down to their electron holes. We've been working on this for a number of years, and we are beginning to understand how this can be done." Although time is scarce, there is a ray of light: if the electrons are removed from the electron holes for more than a millisecond, it is possible to capture them.

https://www.sciencedaily.com/releases/2017/03/170321123825.htm

Liquid storage of solar energy: More effective than ever before

A research team from Chalmers University of Technology in Gothenburg, Sweden, has shown that it is possible to convert solar energy directly into energy stored in the bonds of a chemical fluid—a so-called molecular solar thermal system. The liquid chemical makes it possible to store and transport the stored solar energy and release it on demand, with full recovery of the storage medium. The process is based on the organic compound norbornadiene that upon exposure to light converts into quadricyclane.

According to a team member, the technique means that they can store solar energy in chemical bonds and release the energy as heat whenever they need it. The research project was initiated at Chalmers more than six years ago and the research team contributed in 2013 to a first conceptual demonstration. At the time, the solar energy conversion efficiency was 0.01% and the expensive element Ruthenium played a major role in the compound. Now, four years later, the system stores 1.1% of the incoming sunlight as latent chemical energy—an improvement of a factor of 100. Also, Ruthenium has been replaced by much cheaper carbon-based elements.

https://www.sciencedaily.com/releases/2017/03/170320085445.htm

Scientists harness solar power to produce clean hydrogen from biomass

A team of scientists at the University of Cambridge has developed a way of using solar power to generate a fuel that is both sustainable and relatively cheap to produce. It is using natural light to generate hydrogen from biomass.

One of the challenges facing modern society is what it does with its waste products. As natural resources decline in abundance, using waste for energy is becoming more pressing for both governments and business.

Biomass has been a source of heat and energy since the beginning of recorded history. The planet's oil reserves are derived from ancient biomass that has been subjected to high pressures and temperatures over millions of years. Lignocellulose is the main component of plant biomass and up to now its conversion into hydrogen has only been achieved through a gasification process, which uses high temperatures to decompose it fully.

According to one of the researchers, lignocellulose is nature's equivalent to armoured concrete. It consists of strong, highly crystalline cellulose fibres that are interwoven with lignin and hemicellulose, which act as a glue. This rigid structure has evolved to give plants and trees mechanical stability and protect them from degradation and makes chemical utilization of lignocellulose challenging.

The new technology relies on a simple photocatalytic conversion process. Catalytic nanoparticles are added to alkaline water in which the biomass is suspended. This is then placed in front of a light in the lab that mimics solar light. The solution is ideal for absorbing this light and converting the biomass into gaseous hydrogen, which can then be collected from the headspace. The hydrogen is free of fuel-cell inhibitors, such as carbon monoxide, which allows it to be used for power. The nanoparticle is able to absorb energy from solar light and use it to undertake complex chemical reactions. In this case, it rearranges the atoms in the water and biomass to form hydrogen fuel and other organic chemicals, such as formic acid and carbonate.

The team used different types of biomass in their experiments. Pieces of wood, paper, and leaves were placed in test tubes and exposed to solar light. The biomass didn't require any processing beforehand. EF

https://www.sciencedaily.com/releases/2017/03/170313134927.htm

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NATIONAL AND INTERNATIONAL EVENTS

NATIONAL

International Conference on Sustainable Environment and Energy

April 6–7, 2017

Chennai, Tamil Nadu, India
Website: http://10times.com/icsee-chennai

RenewX

April 7–8, 2017

Hyderabad, India
Website: http://www.renewx.in/

Renewable Asia

April 12–14, 2017

Mumbai, India
Website: http://10times.com/renewable-asia

Argus Asian Petroleum Coke Conference

April 25–27, 2017

Mumbai, India
Website: http://argusmedia.com/aapc/

Windergy India

April 25–27, 2017

New Delhi, India
Website: http://www.windergy.in/

Renewable Energy World India

May 17–19, 2017

New Delhi, India
Website: http://www.renewableenergyworldindia.com/index.html

ProSolar

May 24–25, 2017

Hyderabad, India
Website: http://www.prosolarindia.com/

INTERNATIONAL

The Jordan International Energy Summit

April 2–3, 2017

Amman, Jordan
Website: http://www.jies-summit.com/

Ontario Power Symposium

April 4–5, 2017

Toronto, Canada
Website: https://www.canadianinstitute.com/6th-annual-ontario-power-symposium/

The Africa Renewable Energy Leaders' Summit

April 4–5, 2017

Nairobi, Kenya
Website: http://www.africarenewablesummit.com/

Middle East Petroleum & Gas Conference

April 30–May 2, 2017

Dubai, UAE
Website: http://www.mpgc.cc/

International Conference on Environment and Renewable Energy

May 2–4, 2017
Venice, Italy
Website: http://energy.conference-site.com/

US Offshore Wind

May 8–9, 2017

Hauppauge, New York, USA

Website: http://www.windenergyupdate.com/offshore-usa/

World Hydropower Congress

May 9–11, 2017

Addis Ababa, Ethiopia

Website: https://www.hydropower.org/news/2017-world-hydropower-congress-to-be-hosted-in-addis-ababa

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IX International Renewable Energy Conference, Energy Saving and Energy Education (CIER 2017)

May 31–June 2, 2017

Havana, Cuba

Website: https://cuba-renewables.cwtickets.co.uk/

Offshore Wind Energy 2017

June 6 –8, 2017

London, UK

Website: http://offshorewind2017.com

Solar Asset Management Asia

June 8–9, 2017

Tokyo, Japan

Website: http://solarassetmanagement.asia/#solar-asset-management-asia

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RENEWABLE ENERGY AT A GLANCE

Ministry of New & Renewable Energy			
Programme/ Scheme wise Physical Progress in 2016–17 & cumulative up to the month of January, 2017			
Sector	**FY 2016–17**		**Cumulative Achievements**
	Target	**Achievement (April 2016–January 2017)**	**(as on 31.01.2017)**
I. GRID-INTERACTIVE POWER (CAPACITIES IN MW)			
Wind Power	4,000.00	2,094.14	28,871.59
Solar Power	12,000.00	2,472.39	9,235.24
Small Hydro Power	250.00	67.90	4,341.85
BioPower (Biomass & Gasification and Bagasse Cogeneration)	400.00	157.00	8,182.00
Waste to Power	10.00	7.50	114.08
Total	**16,660.00**	**4,798.93**	**50,744.76**
II. OFF-GRID/ CAPTIVE POWER (CAPACITIES IN MWEQ)			
Waste to Energy	15.00	5.57	164.45
Biomass(non-bagasse) Cogeneration	60.00	0.00	651.91
Biomass Gasifiers -Rural	2.00	0.00	18.34
-Industrial	8.00	4.30	168.54
Aero-Generators/Hybrid systems	1.00	0.38	2.97
SPV Systems	100.00	115.98	423.02
Water mills/micro hydel	1 MW + 500 Water Mills	0.10 MW + 100 Water Mills	18.81
Total	**187.00**	**126.33**	**1,448.04**
III. OTHER RENEWABLE ENERGY SYSTEMS			
Family Biogas Plants (in lakhs)	1.00	0.42	49.52

Source: www.mnre.gov.in

DELENG/2012/49326 ISSN 2278 – 7186