Fuel cell is a low voltage device with non-linear voltage/current source characteristics. Power electronic converter is required to interface a FC stack with power train DC bus voltage. The DC–DC converter is required not only for voltage boost, but also for voltage conditioning as the FC output voltage varies strongly with load. The DC–DC converter uses the fluctuating DC fuel cell voltage as input and converts it to a stable DC voltage output which is fixed at specified value.

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Fuel Cells

Fuelling a New Energy Path

A fuel cell generates electricity from an electrochemical reaction. It utilizes an external supply of chemical energy and can run indefinitely as long as it is supplied with a source of hydrogen and oxygen. Discussing these and many more advantages of fuel cells, Dr Suneel Deambi emphasizes that India needs to manufacture them in a mission-critical mode in order to bridge the gap between the country's demand and supply of energy.

I can safely vouch for the fact that a significant source of immense power is still available at no charge even today! I am sure my statement may have puzzled you. The 'free commodity' being discussed here is universally available sunshine. Just think about it, solar technology would have seen the commercial light of the day if it had some other fuel on a chargeable basis to depend upon. However, there is yet another technology which was born the same year, in 1839, i.e., Solar Photovoltaic (SPV). That is not the lone similarity though between SPV and fuel cell. The fuel cells were named so by its inventor, William Groove as 'gas voltaic battery'. SPV also includes the word 'voltaic', in its full form, which implies 'light derived electricity'. However, the close relation between SPV and fuel cells processing know-hows does not end here. Henry Becquerel, the original inventor of PV effect, worked with a liquid solution-based solar device. The gas voltaic battery too relied on a liquid electrolyte constitution for its power delivery of specified magnitude. The word fuel cells came into being for the first time almost a century later in 1922. Similarly, the first commercially available solar cells were noticed in 1954. A solar cell produced a typical voltage of 0.5 V well matched by a fuel cell in the comparative terms which concludes this basic fact related discussion.

THE BIGGER ISSUE

An obvious question at this juncture is that if fuel cells and solar cells were so closely placed, why is it that solar cells are more widely known today the world over and not the fuel cells as such? This statement does not aim to demean the high potential of a fuel cell in any way. However, fuel cells are yet to occupy the market space already occupied by other new and fast emerging technologies like solar power generation. Several reasons contribute to the technical and economic perspectives of a fuel cell. This article traces the key elemental considerations of a promising fuel cell device in more ways than one.

SIMPLE UNDERSTANDING OF A FUEL CELL

A fuel cell is similar to a battery insofar as it generates electricity from an electrochemical reaction. Both batteries and fuel cells convert chemical potential energy into electrical energy. It also generates heat energy as a by-product of this process. However, a battery stores energy within it. So, it needs to be thrown away or recharged once the charge is depleted. In contrast, a fuel cell utilizes an external supply of chemical energy. It can run indefinitely as long as it is supplied with a source of hydrogen and oxygen (usually air). The source of hydrogen is generally referred to as the fuel and hence, the name is fuel cell. It is interesting to note the absence of any combustion in a fuel cell (Figure 1). The oxidation of hydrogen occurs electrochemically in a very efficient manner. During oxidation, hydrogen atoms react with oxygen atoms to form water.

In the process, electrons are released which flow via an external circuit as electric current. As is true with solar cells, fuel cells too can range from tiny devices capable of producing just a few watts of electricity right up to large-sized MW capacity power plants. Incidentally, the central design of all fuel cell types remains the same, i.e., of using two electrodes separated by a solid or liquid electrolyte. The function of an electrolyte is to carry electrically charged particles between them. Apart from this, a catalyst is often used to speed up the reactions at the electrodes. The different types of fuel cells are in accordance with the type of electrolyte in use, particularly materials and fuel cells.

Justification for using fuel cells

There is a global demand for non-polluting sources of energy in order to meet various end-use applications. Renewable energy technologies, despite being clean, are unable to produce power on a continuous basis. However, fuel cell is free of such a limitation and can run a mission critical application for as long as one wants to.

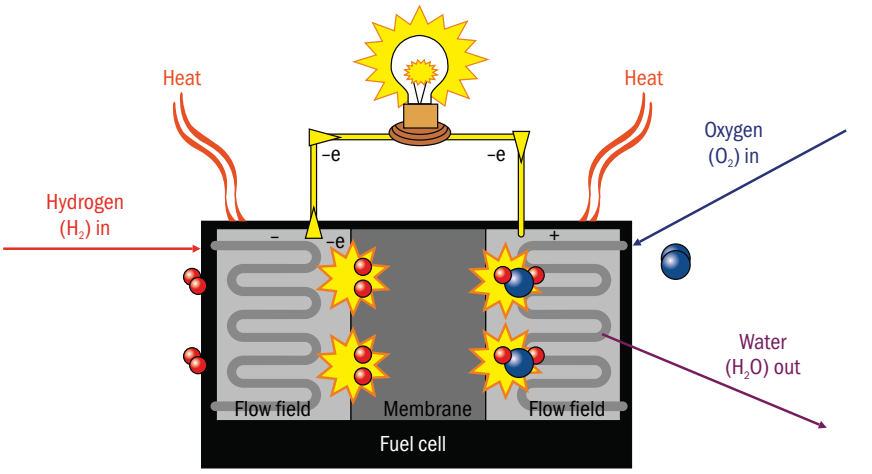

Figure 1: Fuel cell

KEY COMPONENTS OF FUEL CELL

A fuel cell stack is the heart of a fuel cell power system, just like a solar cell being the key constituent of any PV system. Like solar power, the power produced by a fuel cell has the nature of Direct Current (DC). The amount of power produced by a single fuel cell can suffice the needs of small applications only. So, a number of these cells are typically combined in series into a fuel cell stack. A stack is generally made up of hundreds of fuel cells. Typically, the amount of power produced by a fuel cell depends upon the following few parameters:

- Type of fuel cell
- Size of the cell
- Operating temperature of the cell
- Pressure at which the gases are supplied to the cell

Fuel processor is another important constituent of a fuel cell. It basically converts fuel into a usable form by the fuel cell. In case only hydrogen is fed to the system, a processor may not be needed. Alternately, it could simply be utilized to make the hydrogen gas free of impurities. Think of a hydrogen-rich conventional fuel powering the system instead of hydrogen. It may include, gasoline, diesel, methanol or even gasified coal. In that case, a reformer is generally used to convert the hydrocarbons into a gas mixture of hydrogen and carbon compounds. Usually referred to as reformate, these are dispatched to another reactor to rid of impurities such as carbon oxide or sulphur. This process takes place prior to the reformate finding its way to a fuel cell stack.

Further, a process of this nature keeps the impurities, in the gas, away from binding with the fuel cell catalysts. Reformers are not typically needed in case of molten carbonate and solid oxide fuel cells. These cells

A fuel cell is similar to a battery insofar as it generates electricity from an electrochemical reaction. Both batteries and fuel cells convert chemical potential energy into electrical energy. It also generates heat energy as a by-product of this process. However, a battery stores energy within it. So, it needs to be thrown away or recharged once the charge is depleted.

operate at high temperatures allowing fuel to get reformed within the fuel cell itself. Such a process is commonly known as internal reforming. However, such fuel cells which depend on internal reforming may still need traps to eliminate the impurities from the unreformed fuel, prior to approaching the fuel cell. The fact remains that both the internal and external reforming result in release of carbon dioxide but less than the amount emitted by internal combustion engines such as those normally used in gasoline-powered vehicles. Fuel cells can run the DC appliances directly but need to tag along the inverters for driving any Alternate Current (AC) appliances akin to solar cell operation.

It is pertinent to mention here that a large amount of heat is produced by some fuel cell systems such as solid oxide Molten Carbonate Fuel Cells (MCFC) running at elevated temperatures. This surplus energy can be utilized to yield steam or hot water. The other way could be in terms of its conversion to useful electricity via a gas turbine or any other technology. The underlying benefit is to enhance the overall energy efficiency of the systems.

DIFFERENT TYPES OF FUEL CELLS

Several different types of fuel cells are currently available. The basic classification is done in terms of the electrolyte type under use by a fuel cell. Such a classification determines the kind of chemical reactions likely to take place in the cell, besides already highlighted factors. The six main types of fuel cells are as follows:

- Proton Exchange Membrane Fuel Cells (PEMFC)
- Direct Methanol Fuel Cells (DMFC)
- Phosphorus Acid Fuel Cells (PAFC)
- Molten Carbonate Fuel Cells (MCFC)
- High temperature PEMFC fuel cells
- Low temperature PEMFC fuel cells

Table 1 mentions the key characteristic features of these fuel cell types, from practical considerations.

GLOBAL PERSPECTIVE OF FUEL CELLS: AN OVERVIEW

The world of fuel cells is still waiting to get bigger implying thereby that it is still in the formative stages of development. Several big companies have suffered losses previously but the ray of hope for them is the grand entry of Korean conglomerate, Doosan and a newly public commercialization effort by General Electric. Unit shipments in cumulative terms have risen, as compared to 2013, even though there is a downslide in the MW shipments. In the industry arena, PEM and SOFC design configurations steal a clear march over the other fuel cells. However, MCFC cells are the clear winners in larger stationary power plants. The country-wise scenario of fuel cells is varied in terms of the

The country-wise scenario of fuel cells is varied in terms of the available government support. Take for example Japan, where the support is loud and positive both in hydrogen and fuel cells. United Kingdom, France, Germany, etc., continue their support to the fuel cell programme, in the backdrop of renewed public–private partnership support announced by the European Commission. The research and demonstration budgetary outlay in the USA is now stabilized with California boosting the setting up of hydrogen refuelling stations.

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The PEMFC is way ahead of the other types when it comes to megawatt scale power generation as per Table 2. The alkaline fuel cell is virtually non-existent at present.

Asia happens to be the major contributor to the global fuel cell market as per Table 3. Japan, in particular, has emerged as the global leader on the fuel cell front.

SALIENT FEATURES OF PORTABLE FUEL CELL MARKET

SPV cells are capable of meeting the power requirements in the milliwatt to megawatt capacity range. The same is more or less true with reference to fuel cells. The portable fuel cell applications can be divided into the following key areas:

- Charging of consumer electronics (especially mobile phones)
- Auxiliary power needs in leisure applications (i.e., for camper vans and now caravans)
- Defence purposes
- Unmanned aerial vehicles (UAV)

Mobile telephony has led to a huge increase in the tele-density, more so in the developing countries including, India. A promising opportunity is readily presented for fuel cells in the smartphones segment due to their typically high power consumption, even though several competing options such as battery-based chargers, wall sockets, and even super capacitors are already present in the marketplace today. An innovative challenge is to be able to develop miniaturized versions of these options and at a cheaper cost too. Fuel cell chargers of 5W range are using air-cooled fuel cell and metal hydrid storage of hydrogen. The use of fuel cells for military applications is of special significance. The US military has played a pivotal role in early adoption of fuel cells for soldier power. Both the PEM- and SOFC-based chargers with capacity range of 100–1,000 W are capable of offering flexible power at less weight than the conventional power systems.

Fuel cells for transportation

The fuel cell-powered car segment seems to steal the thunder at the moment. There is an increased availability of fuel cell cars, in showrooms, across a few locations worldwide. The Korean company, Hyundai has already started to manufacture, sell, and lease its ix35 first mass-produced vehicles to Europe in 2013 and its first vehicle to a Californian customer in June 2014. Two other giant companies namely, Toyota and Honda have showcased their intentions for their 2015 vehicles which may be offered to Japan. The other companies such as Daimler, General Motors, Ford, and Renault Nissan are currently perfecting their technology for a later launch date. A fuel cell variant of BMW electric i3 may well be in the offing. Outside Europe, fuel cell buses seem to be losing the ground. PEMFC is the key contributor to unit shipments and significant in MW scale front too. Special vehicles, of different types, remain in fashion along with increasing numbers of lift trucks and various other utility vehicles. This year is expected to witness quite a few promising launches of fuel cell-based cars. Table 4 highlights the market share of respective fuel cell-based applications during 2009–14.

The PEMFC fuel cells have accounted for the maximum shipments so far. Shipments in respect of other fuel cell types are almost of a negligible value barring that for the DMFC cell. Table 5 represents the shipment numbers for each fuel cell type during 2009–14.

CALIFORNIA SETS AN EXAMPLE

Hydrogen Refueling Stations (HRS) are being encouraged for deployment under a new legislation, AB8 in 2014. The ready commitment is available at around $20 million per annum, until at least 100 public stations come into being. This covers about 85 per cent of the station cost and up to $10,000 per year for running expenses during a three-year period. In fact, it is an extension of the Alternative and Renewable Fuel and Vehicles Technology Program, which provides about $100 million a year for all such technologies. A total of nine stations

Table 1: Key characteristic features of all fuel cell types

Types of fuel cell	Electrolyte	Operating temperature	Best suited applications	Specific remarks
Proton Exchange Membrane cell (PEMFC) (also known as polymer electrolyte membrane fuel cell)	Water-based, acidic polymer membrane	Below 100°C High temperature variant up to 200°C	Leading technology for light duty vehicles and materials handling vehicles and, to a lesser extent, for stationary and other applications	High temperature cells are not superior to the low temperature cells
Direct Methanol Fuel Cell (DMFC)	Polymer membrane; Platinum-ruthenium catalyst present	600°C to 1,300°C	Suited to modest power needs such as mobile electronic devices or chargers or portable power packs Used as power units for materials handling devices such as forklifts	Relatively recent addition to the suite of fuel cell technologies; developed in 1990s in USA Methanol is inexpensive, has a relatively high energy density, and can be easily transported and stored On-site refuelling of the trucks within minutes as compared to hours taken for battery recharging; elimination of any need for battery charging infrastructure within a warehouse leading to availability of more space
Solid Oxide Fuel Cell	Solid ceramic electrolyte such as Zirconium oxide	800–1,000°C	Used extensively in large and small stationary power generation; 100 kW off-grid fuel cell generators available and few kW units under testing for small Combined Heat Power (CHP) uses in households	Efficiencies of more than 60 per cent in fuel to electricity conversion No need for a metal catalyst
Alkaline Fuel Cells	Alkaline electrolyte such as potassium hydroxide in water	70°C		Originally used by NASA in their space programme Non-precious metals in use as catalysts
Molten Carbonate Fuel Cells	Molten carbonate salt suspended in a porous ceramic matrix	650°C	Well-suited in large stationary power generation; most fuel cell power plants of MW capacity use MCFCs	No catalyst needed at such high temperatures Can run on a variety of different fuels including coal derived fuel gas, methane, or natural gas Overall efficiencies of over 80 per cent achievable in CHP mode
Phosphoric Acid Fuel Cells	Phosphoric acid	Around 180°C	Typically used in stationary power generators with output in the 100 kW to 400 kW range; find use in large vehicles like the buses	Majority of fuel cell units sold prior to 2001 incorporated PAFC technology Overall efficiency of 80 per cent in CHP mode

Table 2: Megawatts by fuel cell types

Types of fuel cell	2009	2010	2011	2012	2013	2014 (Forecast)
PEMFC	60	67.7	49.2	68.3	68.0	69.7
DMFC	1.1	1.1	0.4	0.3	0.2	0.2
PAFC	6.3	7.9	4.6	9.2	7.9	3.8
SOFC	1.1	6.7	10.6	26.9	47.0	32.3
MCFC	18.0	7.7	44.5	62.0	91.9	70.0
AFC	0.0	0.1	0.1	0.0	0.3	0.0
Total (MW)	**86.5**	**91.2**	**109.4**	**166.7**	**215.3**	**176.0**

Table 3: Megawatts by region

Types of fuel cell	2009	2010	2011	2012	2013	2014 (Forecast)
Europe	2.9	5.8	9.4	17.3	17.3	10.4
North America	37.6	42.5	59.6	61.5	74.7	52.3
Asia	45.3	42.5	39.6	86.1	122.9	112.4
Rest of the World	0.7	0.4	0.8	1.8	0.4	1.0
Total (MW)	**86.5**	**91.2**	**109.4**	**166.7**	**215.3**	**176.0**

Table 4: Megawatts by application

Types of application	2009	2010	2011	2012	2013	2014 (Forecast)
Portable	1.5	0.4	0.4	0.5	0.3	0.5
Stationary	35.4	35.0	81.4	124.9	186.9	147.3
Transport	49.6	55.8	27.6	41.3	28.1	28.2
Total (MW)	**86.5**	**91.2**	**109.4**	**166.7**	**215.3**	**176.0**

Table 5: Shipments by fuel cell type

1,000 Units	2009	2010	2011	2012	2013	2014
PEMFC	8.5	10.9	20.4	40.4	58.7	65.3
DMFC	5.8	6.7	3.6	3.0	2.6	3.1
PAFC	0.0	0.0	0.0	0.0	0.0	0.0
SOFC	0.1	0.1	0.6	2.3	5.5	1.8
MCFC	0.0	0.0	0.0	0.0	0.0	0.0
AFC	0.0	0.0	0.0	0.0	0.0	0.0
Total (MW)	**14.4**	**17.7**	**24.6**	**45.7**	**66.8**	**70.2**

Table 6: Shipments by region

1,000 Units	2009	2010	2011	2012	2013	2014 (Forecast)
Europe	4.4	4.8	3.9	9.7	6.0	6.1
North America	3.2	3.3	3.3	6.8	8.7	17.1
Asia	6.7	9.5	17	28	51.1	45.2
Rest of the World	0.1	0.1	0.4	1.2	1.0	1.8
Total	**14.4**	**17.7**	**24.6**	**45.7**	**66.8**	**70.2**

Table 7: Shipments by application

1,000 Units	2009	2010	2011	2012	2013	2014 (Forecast)
Portable	5.7	6.8	6.9	18.9	13.0	21.8
Stationary	6.7	8.3	16.1	24.1	51.8	45.6
Transport	2.0	2.6	1.6	2.7	2.0	2.9
Total	**14.4**	**17.7**	**24.6**	**45.7**	**66.8**	**70.2**

were opened in California in October 2014 with about 10 times that number in the pipeline in addition to two bus fuelling stations. This is supported by a $90 million financing commitment by the state to date. The California legislation requires the California Air Resources Board (CARB) to report the progress on this front annually.

Asia surpasses the rest of the world in terms of the highest number of shipments followed by a distant North America. The share of shipments from Europe is way below that of the Asian region. Table 6 shows the shipments of fuel cells by respective regions.

Fuel cells are clearly commanding a major shipment share for the stationary type applications as per Table 7. The share on the transportation front is quite low in the backdrop of a common perception that fuel cells are very well-suited to the automobile vehicles segment.

Selective few innovative developments

Microsoft Corporation, Redox Power Systems LLC, and the University of Maryland have recently been awarded a $5 million government grant by the US Department of Energy (DoE) to test fuel cell technology in Microsoft's data centres. Redox Power happens to be one of the very few companies to have a large size and kilowatt-scale fuel cell ready for commercialization. This startup may be the world's first commercial scale fuel cell to cost less than a traditional mechanical fossil generator over its lifetime. As far as the fuel cells are concerned, they are either so hard to produce or so expensive that they find it quite difficult to sustain the rigors of the for-profit markets. However, selective few types of fuel cells, especially the small backup power cells for personal electronics, have begun to approach the commercial readiness. Currently, chosen few large commercial scale fuel cell producers in the USA include, Plug Power Inc., Fuel Cell Energy Inc., Ballard Power Systems Inc., Hydrogenics Corporation, and Bloom Energy. All of these fuel cell startups which are targeting the backup power market lost money in 2013, despite generating substantial revenue.

Pioneering effort at University of Delaware

Hydrogen-based fuel cells are deemed to be the most suitable option for emission free vehicles. However, this requires the use of costly platinum. New findings help pin down the basic mechanisms of the fuel-cell reaction on platinum which will help researchers create alternative electro catalysts. The question, an issue of engineering and economics, is being studied by a team led by Prof. Yushan Yan at the University of Delaware. Toyota has just introduced a hydrogen-powered car in Japan and will make them available in the US in 2015. Prof. Yan's group has been working on a new type of fuel cell using alkaline polymers that could employ a number of non-precious metal catalysts such as nickel. Nickel is around 1,000 times cheaper than platinum. However, the use of alkaline polymers leads to high pH and the reaction has been observed to go about 100 times more slowly in this environment, than it does in an acid. Thus, the important issue is to know exactly how the reaction unfolds and what are its most essential mechanisms in practical terms.

Key barriers to expanded fuel cell use

Hydrogen storage is required to make use of fuel cells in vehicles. Majority of fuel cell vehicles run by pure hydrogen must store hydrogen on board as a compressed gas in pressurized tanks. However, hydrogen has a low-energy density which makes it difficult to store enough of it on board. The underlying purpose is to allow vehicles to move the same distance (say around 482–643 km) as gasoline-powered

vehicles prior to refuelling. Aside of hydrogen, it is possible to have high density fuels such as methanol, ethanol, and natural gas including Liquefied Petroleum Gas (LPG) as a fuel. However, an additional requirement is in terms of having an on-board fuel processor. The plain purpose is to reform the methanol to hydrogen. This measure leads to enhanced costs and maintenance requirements. Another drawback is in terms of the release of carbon dioxide gas (which is known as a contributor to greenhouse gas emissions) by the reformer.

Hydrogen-based fuel cells are deemed to be the most suitable option for emission-free vehicles. However, this requires the use of costly platinum. New findings help pin down the basic mechanisms of the fuel-cell reaction on platinum which will help researchers create alternative electro catalysts.

EARLY DEVELOPMENTS ON FUEL CELLS IN INDIA

I vividly remember the research work carried out at The Energy and Resources Institute (TERI) under the overall guidance of Dr Ajay Mathur, currently Director General, Bureau of Energy Efficiency (BEE), in early 1990s. At that time, it had demonstrated the use of digester gas (biogas) for generating electricity from a 2.5 kW PAFC stack imported from a US company namely, Energy Resources Corporation (ERC). TERI had also tested the operation of a MCFC mono cell on simulated coal gas with the purpose of developing a kW level stack to be integrated with a coal gasifier. The molten carbonate fuel cell stack specific work was also being pursued concurrently. Bharat Heavy Electricals Limited (BHEL), Hyderabad, had pioneered the development of a PAFC-based stack of 50 kW. This company also installed a 200 kW fuel cell-based plant using LPG as a fuel. The plant besides producing electricity also supplied hot water for use in the company canteen. The Ministry of New and Renewable Energy (MNRE), Government of India funded the import of a 200 kW PAFC system for its detailed testing-cum-evaluation under the locally available conditions.

The Chennai-based SPIC Science Foundation was actively involved in the development of PEM fuel cells besides producing the stacks. The field demonstration of a fuel cell battery hybrid vehicle 10 kW power plant deserves special mention. The prestigious Indian Institute of Science (IISC) at Bangalore was intensely involved in the development of DMFC. Yet another fuel cell design, the SOFC, received the joint attention of IISC and

Council of Scientific and Industrial Research Institute, i.e., Central Glass and Ceramic Research Institute (CGCRI). Last but not the least, Banaras Hindu University (BHU) undertook Research & Development (R&D) activities related to metal hydrid storage of hydrogen. The BHU also went ahead with the testing of hydrogen-powered motorcycle while pursuing its work on the photoelectric chemical cells as well.

MOBILE TOWER IN INDIA OPERATES ON FUEL CELL

Even today, there are close to 300 million people in India without access to electricity. Presently, mobile telephony is sweeping the telecom revolution in the country. The phone companies are nursing ambitious plans to build more telecom towers across the length and breadth of the country. As per the available market estimates, India at present has around 935 million users obtaining signals from more than 400,000 telecom towers dispersed in different geographical regions of the country. The pivotal objective is to reach an increasing segment of the rural population via an effective mix of both the voice and data services. However, the erratic supply of electricity is forcing the phone companies to bank upon the import dependent (i.e., costly) and polluting diesel.

As per the recently available estimates, the telecom industry in India consumed about 3.2 billion litres diesel last year and the figure is expected to touch a whopping 6 billion litres by 2020. Lately, hydrogen is beginning to emerge as a more efficient and cleaner alternative to the fossil fuels. It is this growing optimism that has made Intelligent Energy (a UK-based company) sign agreements with two Indian companies to manage the requirements of firstly, standalone telecom towers and secondly, telecom equipment mounted on the electricity towers. The latest generation of hydrogen fuel cell power plant developed by Intelligent Energy has already been successfully installed at a mobile telecom tower site in India. The fuel cell unit was installed at a telecom tower owned and operated by Ascend Telecom in Uttar Pradesh. Picture 1 shows a physical representation of this innovative market development.

It is important to mention here that a few site-specific constraints such as its remoteness and regular grid power outages further added to the installation woes. However, an effective transition to the hydrogen mode, in sizable numbers, is expected to result in significant cost savings both for the service providers and customers. The key system specific field data, collected over a period of last few months, points to significant improvements on site power availability. However, this is not all as the fuel intake has reduced by as much as 18 per cent during the last few months, as per the company sources.

Preferred choice of fuel cell for mobile telephony

Traditionally, power backup requirements for the telecom towers have been met by hydrogen supplied fuel cells. It is in terms of either packaged hydrogen cylinders or refilling of

Picture 1: Ascend Telecom Tower

fixed tanks by a trailer. The latter is quite an impractical solution in both the remotely located areas as well as those areas where hydrogen is not commonly delivered for any other purpose. An alternative solution is to provide systems with fuel processors for methanol. It is convenient to handle this fuel instead of hydrogen. Certain selective few companies such as Ballard, ReliOn, and Altergyand which are eyeing the Indian telecom market too have reaped good success with the use of methanol-based systems. However, it is also suggested to look at the possibility of generating hydrogen on-site via the use of solar or wind energy powered electrolyzers. Water on being electrolyzed yields oxygen and hydrogen. Hydrogen thus released could well be used for the specified purpose. India has an abundant availability of sunshine and many wind resource rich sites to make use of hydrogen-based fuel cells as well.

NATIONAL FUEL CELL PROGRAMME

The Ministry of New and Renewable Energy (MNRE) has very recently announced a fuel cell development programme under its renewed thrust initiative of hydrogen energy utilization. The fuel cell types chosen for the first phase of experimentation-cum-development include the following few:

- Low and high temperature PEMFC
- Planar Solid Oxide Fuel Cell (Planar SOFC)
- Phosphoric Acid Fuel Cell

The significant objective of this new programme is to develop state-of-the-art technology accompanied by manufacturing of stand-alone prototypes and demonstration of their performance under the actual field operating conditions. Prototype unit capacities of 1 kW, 3 kW, and 5 kW incorporating indigenous component utilization of at least 50 per cent are stipulated under this newly announced ministry programme. Further, these units should be capable of ensuring a minimum working life of 1,000 hours and less than 10 mV per 1,000 hours of degradation. In addition, the fuel should be bottled hydrogen and air in case of both the PEMFC and PAFC cells, besides natural gas and air for planar SOFC. The financial arm of the MNRE, i.e., Indian Renewable Energy Development Agency (IREDA), too, is promoting the development and rapid commercialization of the fuel cells as viable alternatives to petrol/diesel-run vehicles under its broad framework for 'New and Emerging Technologies'.

Table 8 highlights the ongoing projects awarded by the MNRE under its fuel cell programme development initiative so far.

These projects indicate the diverse nature of fuel cell development from several key points of view. Incidentally, the institutions at which these projects are being pursued at present do not include those with some early leads.

THE UNWINDING PATHWAY

The moot question is whether the Indian fuel cell programme despite its early start will be able to realize its commercial promise in the near future. A lot would depend on how soon the process knowledge of techno-economically viable nature come into being. The SPV technology was being labelled as a sunshine process with no commercial viability till the recent past. However, its adoption in the mission-critical mode, i.e., under the Jawaharlal Nehru National Solar Mission (JNNSM), changed it forever. So, does it mean that fuel cells may need a major umbrella of this nature to power all that is possible around us? The just-begun use of fuel cells, although of an imported nature for powering the base receiver stations of mobile telephony applications in India, may open up a window of opportunity to manufacture it right here under the newly coined 'Make in India' initiative of our honourable Prime Minister. EF

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Table 8: Ongoing projects awarded by the MNRE for fuel cell programme

Name of the project	Institutional arrangement
Development of direct alcohol fuel cell and test protocols	IIT, Delhi
Solid oxide fuel cells that operate directly on hydrocarbon feedstock	IIT, Delhi
Development of high performance intermediate temperature solid oxide fuel cells by low-cost ceramic processing technique	IMMT, Bhubaneswar
Design and development of alkaline fuel cells: Scaling up from bench scale, i.e., 185 W to 500 W	SICES Degree College of Arts, Science and Commerce, Ambernath (W), Mumbai
Development of high performance direct methanol fuel cell	University of Calcutta, Kolkata
Development of PEM for fuel cell by plasma process	Institute of Advanced Study in Science and Technology, Guwahati
Development of non-fluorinated polymeric membrane for direct methanol fuel cells	Birla Institute of Technology, Ranchi

Clean Cookstoves

Avert Choking Planet, People

Sharada Balasubramanian says that in developing countries, there are hundreds of women and children who get exposed to smoke that traditional cookstoves emit. This situation, according to her, can be averted and made better if these people use improved cookstoves which emit negligible black carbon and no smoke. In this article, she discusses the design and other details of the award-winning 'Greenway Smart Cookstove' manufactured in India.

Every day, scores of women in India sweat out in the kitchen, cooking a meal for their family on traditional mud stoves, unaware that the very fumes that emanate out of these stoves hamper their health.

In rural India and other developing nations, women and children spend hours of time in collecting firewood for their cooking and energy needs. Agricultural waste, cow dung, etc., are used to fire their mud stoves. This waste creates smoke which contains finer particles such as black carbon, known to create indoor pollution.

Statistics suggest that indoor air pollution due to black carbon is a relentless killer, causing about 4.3 million deaths worldwide every year. This number is more than the number of deaths caused by the Human Immunodeficiency Virus (HIV), malaria, and tuberculosis put together. Most of those deaths happen in poor countries where people cannot afford cleaner stoves.

Indoor pollution causes respiratory health issues among women and children, since they spend most of the time in household work. The emitted smoke is known to cause serious environmental pollution in the form of black carbon that is released into the atmosphere during the burning process. It contributes to forest degradation, loss of habitat and biodiversity, and climate.

COOKSTOVES AND CLIMATE CHANGE

Formed by incomplete combustion, black carbon is a major component in the tiny particulate matter known as PM2.5 that is now one of the most common measures for air pollution.

According to research led by Veerabhadran Ramanathan, a climate scientist at the University of California, San Diego, a 3-kilometre-thick layer of black carbon pollution over parts of Asia is blocking up to 15 per cent of the sunlight from reaching the Earth in a phenomenon known as 'global dimming'. The scientists found out that the regional pollution contributed to a 36 per cent drop in India's wheat yields in 2010.

The studies also estimate that cookstove contributes to climate change, suggesting it may be responsible for nearly 20 per cent of global warming. For instance, it darkens the ice of the Arctic and high-altitude glaciers. As a result, more sunlight is absorbed and ice melts more quickly.

A large part of the world's population, mostly in developing countries, uses fuelwood for household cooking and space heating. Almost half of the world's population is left with no choice. They have to depend on biomass (wood, charcoal, agricultural residues, and animal dung) and coal for household energy. This leads to burning biomass in inefficient open fires and stoves without proper ventilation.

Energy from traditional biomass fuel is thought to account for nearly one-tenth of human energy demand today (more than hydro and nuclear power put together), and wood-based fuels probably make up some two-thirds of household use.

Using cleaner cookstoves have addressed these issues. For instance, it is believed that clean cookstoves save about 97,000 tonnes/year of non-renewable wood. This cuts greenhouse gas emissions, by about 1.67 tonnes/year carbon dioxide per stove (according to the CDM methodology), or a total of 200,000 tonnes/year carbon dioxide. This estimate, however, does not include cuts from reductions in non-carbon greenhouse gases and particulates including black carbon.

Many studies, nationally and internationally are inching towards enabling an ecosystem where cleaner and efficient stoves and fuels are promoted. Though there are challenges galore, these efforts from experts give a strong promise to save lives, improve forest sustainability, slow climate change, and empower women globally.

CLEAN COOKSTOVES IN MILLENNIUM DEVELOPMENT GOALS (MDGS)

With rapid rise in population, and absence of new policies on this, it is believed that in the number of people relying on biomass will increase to over 2.6 billion by 2015 and to 2.7 billion by 2030. This is one-third of the world's population depending on such fuels.

The United Nations Millennium Project recommended reducing the number of households using traditional biomass for cooking by 50 per cent by 2015. This would mean 1.3 billion people switching to other fuels.

The Millennium Development Goals (MDGs) looked at—(i) efforts to develop and adopt the use of improved cookstoves, (ii) measures to reduce the adverse health impacts from cooking with biomass, and (iii) measures to increase sustainable biomass production.

Over the last decades, many national efforts have introduced millions of fuel-

Indoor pollution causes respiratory health issues among women and children, since they spend most of the time in household work. The emitted smoke is known to cause serious environmental pollution in the form of black carbon that is released into the atmosphere during the burning process. It contributes to forest degradation, loss of habitat and biodiversity, and climate.

Table 1: Population relying on traditional use of biomass for cooking in 2012

Region	Population relying on traditional use of biomass (millions)	Percentage of population relying on traditional use of biomass (%)
Developing countries	2,679	0.5
Africa	728	1
Sub-Saharan Africa	727	1
North Africa	1	0
Developing Asia	1,875	1
China	448	0
India	815	1
Latin America	68	0
Brazil	13	0
Middle East	8	0
World	2,679	0.4

Table 2: Traditional use of biomass for cooking in developing Asia in 2012

Region	Population relying on traditional use of biomass (millions)	Percentage of population relying on traditional use of biomass (%)
China	448	33
India	815	66
Southeast Asia	280	46
Brunei	0	0
Cambodia	13	89
Indonesia	105	42
Laos	4	65
Malaysia	0	0
Myanmar	49	93
Philippines	47	49
Singapore	0	0
Thailand	16	24
Vietnam	45	51
Rest of Developing Asia	332	74
Bangladesh	138	89
DPR Korea	12	47
Mongolia	2	70
Nepal	22	80
Pakistan	112	62
Sri Lanka	15	74
Other Asia	32	76
Developing Asia	1,875	51

(*Source:* IEA, World Energy Outlook 2014)

efficient stoves in countries like China, India, and Kenya. In addition, scientific advances, financial innovation, and several successful clean cookstove initiatives are demonstrating potential to relieve people of this current social burden. Such approaches have resulted in encouraging large-scale and sustainable adoption of clean cooking solutions. However, there

remains a complex challenge of giving cleaner, yet affordable stoves, keeping the policy goals in mind.

GREENWAY GRAMEEN SHOWS THE WAY

Mumbai-based Greenway Grameen Appliances, which won the 2014 'Ashden Award' under the clean energy for women and girls category for their clean cookstoves, found a solution to this problem. The company, which was started in 2010 by two young entrepreneurs—Ms Neha Juneja and Mr Ankit Mathur, aimed at making and selling affordable cookstoves that reduce emissions, improving the lives of both women and children.

The Greenway Smart stove is a metal stove and adheres to the Bureau of Indian Standards (BIS) performance requirements. Their design, which is still awaiting patent, is a stove that can use any kind of solid biomass fuel like wood, cow dung, etc. Ms Juneja says, "In a mud stove, not all the heat reaches the vessel. This issue is easily resolved in the clean cookstove. The product also reduces carbon emission by 70 per cent."

In clean cookstoves, there is higher fuller combustion, which burns small particles that would otherwise escape as smoke. There is an innovative lampshade-shaped reducer cone in this cookstove that pulls air up through the bottom of the stove into the combustion chamber. As a result, the product requires drastically less fuel. Since there are no moving parts in the cookstove, it's a low-maintenance product.

In addition, the product also uses 65 per cent less fuel than traditional mud cookstoves, and has been tested and certified by the Ministry of New and Renewable Energy (MNRE). Ms Juneja says, "We went to the areas with one working odd-looking prototype and asked people for feedback on the product. For instance, questions like, how do you think it looks like? On the basis of their suggestions, 11 prototypes were made. Each prototype had 5–15 stoves of that design. After getting feedback on which was picked the most by people, we finalized the product."

It also became essential to design the product according to the needs of

In clean cookstoves, there is higher fuller combustion, which burns small particles that would otherwise escape as smoke. There is an innovative lampshade-shaped reducer cone in this cookstove that pulls air up through the bottom of the stove into the combustion chamber. As a result, the product requires drastically less fuel. Since there are no moving parts in the cookstove, it's a low-maintenance product.

the women. Though higher efficiency and lower emissions could have been achieved using a top-loading design, since users wanted a more familiar front-loader, the product was developed accordingly. Also, a taller internal chimney would give lesser emissions, but would not have been comfortable for the majority of users who sit down and cook.

Ms Juneja adds, "We initially started working with local distributors who sold unique utensils, buckets, etc., to the end users. The fact that the product is BIS compliant adds credibility and makes the distributor happy."

A study by a third-party Non-Governmental Organization (NGO) revealed that 74 per cent of users were satisfied with the stove. The product is sold on a cash and carry basis. The end users have an Easy Monthly Installments (EMI) option available. Two stoves are available in different sizes. The smaller one is priced at `1,499 and the larger one is available for `4,999. The company has sold 250,000 stoves so far.

However, challenges still remain. Ms Juneja says, "There is a strong need for awareness. The challenge is in the time taken to communicate and convince the people on the importance of this product."

The stoves are sold in Kerala, Karnataka, and Maharashtra, and the company has just launched this stove in Tamil Nadu. Ms Juneja says, "As of now, we are focusing on expanding this product in India, than expanding outside the country."

KEY FACTS

Over 85 per cent of rural and 65 per cent of urban households in India cook with biomass fuels.

Cost of a smart stove can be recovered within 14 weeks by savings on wood. (*Source*: Ashden Case Study on Greenway Grameen)

ADVANTAGES OF CLEAN COOKSTOVE

- Lower smoke exposure reduces throat and eye irritation, and increases life expectancy, cuts household wood use by about 40 per cent (or 1.1 tonnes) per year. This leads to saving of $90 per year for households who buy wood, or 2–3 hours per week for people who collect this. Women and children benefit mostly as they are involved in collecting wood and cooking.
- Cooking time is reduced by about 30 minutes per day and needs less attention.
- The women, having used the product, talk about improved cleanliness, cleaner skin, and hair. That apart, their kitchen and cooking pots need less cleaning after using clean cookstoves.

Table 3 shows additional number of people that are required to gain access to modern fuels.

CLEAN COOKSTOVE ECONOMICS

According to a paper titled 'Cleaner Cooking Solutions to Achieve Health, Climate, and Economic Co-benefits' published in the journal

Table 3: Additional number of people that are required to gain access to modern fuels (millions)

Region	2004–2015	2015–2030
Sub-Saharan Africa	314	406
North Africa	2	3
India	389	394
China	226	168
Indonesia	85	94
Rest of Asia	261	300
Brazil	13	14
Rest of Latin America	30	28
Total	1,320	1,407

Source: United Nations Development Programme (UNDP)

Environmental Science and Technology, many new cookstove models have emerged over the last decade. These improve combustion efficiency and reduce emissions as against traditional cookstoves.

Though the impact of tiny stoves is known to be catastrophic, black carbon is largely unregulated and its costs are not measured. This creates a barrier to garner public and donor funds to promote the use of cleaner cookers. However, that could change now. A team of economists, scientists, and health experts working with 'The Gold Standard Foundation' has developed a uniform way to calculate how much black carbon is released from cooking stoves that use different technologies or fuels. These calculations can be used by programme directors to procure funds, thus showing how such projects can spare the environment from pollution, and save many lives.

Experts say that reducing the constant emission of black carbon offers immediate climate benefits. Black carbon has a short lifespan in the atmosphere unlike carbon dioxide, which can stay for centuries. Hence, financing less polluting cookstoves is a need for the planet too. Globally, many programmes were instituted since 1980 for developing improved biomass cooking stoves for developing countries. Introducing these programmes in a few numbers as national efforts from China and India has impacted many rural households. Efforts are going on to accelerate the process in devising new technologies to cleaner stoves.

In September 2010, US Secretary of State Hillary Clinton, along with several leading international public figures and private companies, launched the Global Alliance for Clean Cookstoves. This public–private partnership catalysed a booming global market for clean cooking solutions. Over 650 partners, including 38 countries, joined the alliance. In its initial two years, the Alliance raised over $30 million. It directly garnered over $120 million in new funding from Alliance partners, and in the process enhanced awareness on this issue, globally. Over 350 global experts were called on to help develop a futuristic plan for overcoming to cut across the barriers that led to limited progress.

This programme helped cookstove charities find some financing through grants and carbon credits. Reports suggest that in total, 227 programmes in the alliance have supplied more than 5 million new stoves. However, that is still 95 million short of its 2020 goal and a tiny fraction of the total global need.

COOKSTOVE COSTING

A recent study by 82 economists for Lomborg's Copenhagen Consensus estimated it would cost $137 billion to give everyone the cleanest burning gas-fuelled stoves.

Every dollar of the huge investment would produce $2 in benefits in terms of lower medical costs, cheaper fuel, and longer lives, the study shows. Since limited resources exist, the study suggests a partial measure, i.e., spending $5 billion to provide half of those in need of more efficient stoves, but those are using solid fuel. This would eliminate the dirtiest stoves first and as a result save half a million lives. Overall, this approach would produce benefits of $10 for every dollar spent.

Experts say that if smaller targets are planned, and value for money is shown, funding for such projects is more likely to come in. To reach global users, it is crucial to build an industry across countries to manufacture and distribute 150–180 million stoves a year. The industry will play a crucial role in meeting the demand within the next 10 years, thus reducing the health impacts due to incomplete combustion and reducing the methane and black carbon particle emission.

IMPACT

Though exposure patterns vary according to individual (age, socioeconomic status, time spent in cooking area, etc.) and household differences (fuel/stove type, cookhouse ventilation, use of biomass for heating, etc.), use of solid fuels in traditional stoves results in air pollution exposure levels that can reach 50 times greater than the World Health Organization (WHO) guidelines for clean air.

The impact of cleaner cooking solutions on fuel use and emissions varies by fuel type, stove design, cooking practice, and environmental conditions. Recent studies found that many stoves in the market reduce fuel consumption by 30–60 per cent. This leads to social benefits as well. The women and children are not burdened to earn income and there is no need for them to venture into insecure places to collect fuel. This leads to lower risk of violence.

Studies indicate that by controlling black carbon, methane, and greenhouse gases that linger for a longer time, the chances for limiting global temperature rise to below 2°C will be higher. The growing literature shows that stove types and fuels vary in their health, environmental, social, and economic benefits over burning solid fuels in traditional stoves. Since various benefits are driven by different factors, solving the prevailing issues due to burning of solid waste needs to be addressed according to a clear criterion. This could be used by the decision-makers on the right stove and fuel combinations that meet their specific needs.

By giving the amount of health, environmental, and socio-economic benefits that clean cookstoves can give, there will be a drive in investment towards this sector.

CRUCIAL EMISSION DATA

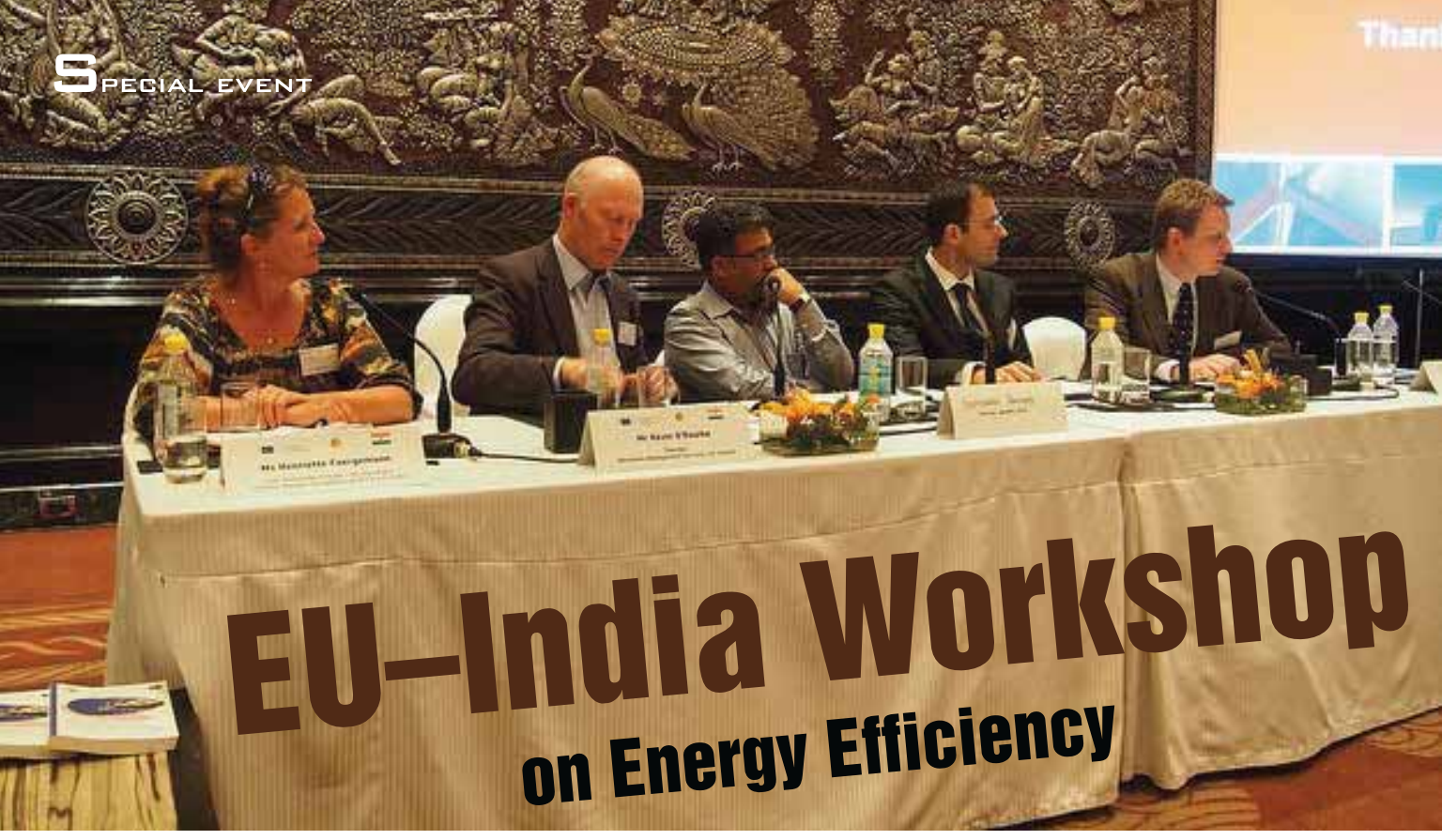
Using improved methods is one of the solutions. By using emission testing, such improved methods can be devised. For instance, instrumentation could give real-time data on size distribution, composition, surface area, light absorption, and light scattering. Developing low-cost instruments for use in the field could lead to a better understanding of cookstove emissions that affect health and climate.

SootSwap, a smartphone mobile application, is one such example of how technology can be used to gather data and help the end users eventually. The application accurately and affordably verifies the use of a clean cookstove, SootSwap, has a mobile phone-based temperature sensing application and a thermal sensor, which connects to the mobile device. Every time the cookstove is fired, the temperature rise activates the sensor, and this data is wirelessly uploaded from the mobile phone to a server. Analysis of the temperature data indicates the number of times a stove is used and the duration of each use. This can be verified remotely. This data can be crucial for funding agencies, donors, among other stakeholders.

SootSwap has been tested and validated in the laboratory and through a pilot project in over 100 rural households in villages around Jagdishpur, a town in Uttar Pradesh.

There is a strong need for such products to support and promote manufacturers, financers, government, NGOs, and the end consumers. This will ensure that health and environmental issues, especially black carbon-induced climate change effects are addressed effectively, and there is a push to cleaner cookstoves globally. EF

Ms Sharada Balasubramanian is an environmental journalist who has been writing on water, conservation, energy, and rural development for eight years. Her stories are linked to understanding the linkages of these issues to people, development, and economics. She was a Deutsche Welle Akademie's Climate Change Reporting Fellow (South Asia) in 2013. In 2014, she was one of the participants in UN's Water and Energy journalism workshop in Tokyo. She was chosen for IUCN's Water Futures II, 'Young Scholars and Professionals fellowship in 2014 under the Ecosystems for Life, India-Bangladesh initiative. Email: sharadawrites@gmail.com



EU–India Workshop on Energy Efficiency

Participants of the EU-India workshop

The first workshop of the European Union (EU)–India on Energy Efficiency was held on May 6, 2015 in New Delhi. It is a formal platform to facilitate the EU–India cooperation on many sectors including energy efficiency. High level technical meetings are aiming to: exchange opinions and views about cooperation needs in the field of energy efficiency; identify main areas of cooperation; set up strategic goals of cooperation; and discuss and monitor the progress of taken actions.

Dr João Cravinho, Ambassador of the European Union and **Dr Ajay Mathur, Director General, Bureau of Energy Efficiency, Ministry of Power, India** chaired the Joint Working Group (JWG) meeting.

DR JOÃO CRAVINHO ON THE EU–INDIA COOPERATION

Dr Cravinho said that India is a strategic partner for the EU, and cooperation on Energy Efficiency (EE) is important for both sides, India and the EU. There are important reasons to focus on energy such as energy security, quality of energy supply, reduction of the energy demand by management of energy consumption patterns, and the challenge of climate change.

One of the biggest challenges for sustained economic growth in India is substantial deficit in the energy. One of solutions would be costly investments in the power generation. It is very much needed to focus not only on the production side, but also on energy efficiency (demand side). Energy efficiency costs less and it is also a very good way to follow green growth in sustainable manner. Energy efficiency is easier and cheaper option than building new supply chains. The EU has substantial achievements in the implementation of EE policy for many years through the Energy Performance of Buildings Directive (EPBD) which was first published in 2002.

India–EU cooperation on EE is very promising, there are new opportunities, new commitments for working together, and new good circumstances creating opportunities to support governmental initiatives related to sustainable grow and development.

The objective of the meeting was to consolidate the way how to work together. To all participants of the meeting I have one advice he said "Bring new ideas, explore new possibilities, and be ambitious".

DR MATHUR ABOUT INDIA-EU ENERGY EFFICIENCY COOPERATION

The building sector is one of the biggest energy consumers, and its importance will last for forthcoming years, likewise in Europe. One of the significant differences between the EU and India is a structure and dynamics of the building stock. In Europe, most of the buildings have been already constructed, and a relatively small number of buildings will be constructed in coming years. That is why the EU policy measures

are focused on renovation. In India, the situation is very different; existing stock is relatively small in comparison with the stock to be built in forthcoming years. The key issue is that these new buildings have to be efficient and have to provide expected level of services. That it is why work on implementation of the Indian Energy Conservation Building Code (ECBC) is very important. There lie enormous opportunities for EE in the building sector in India.

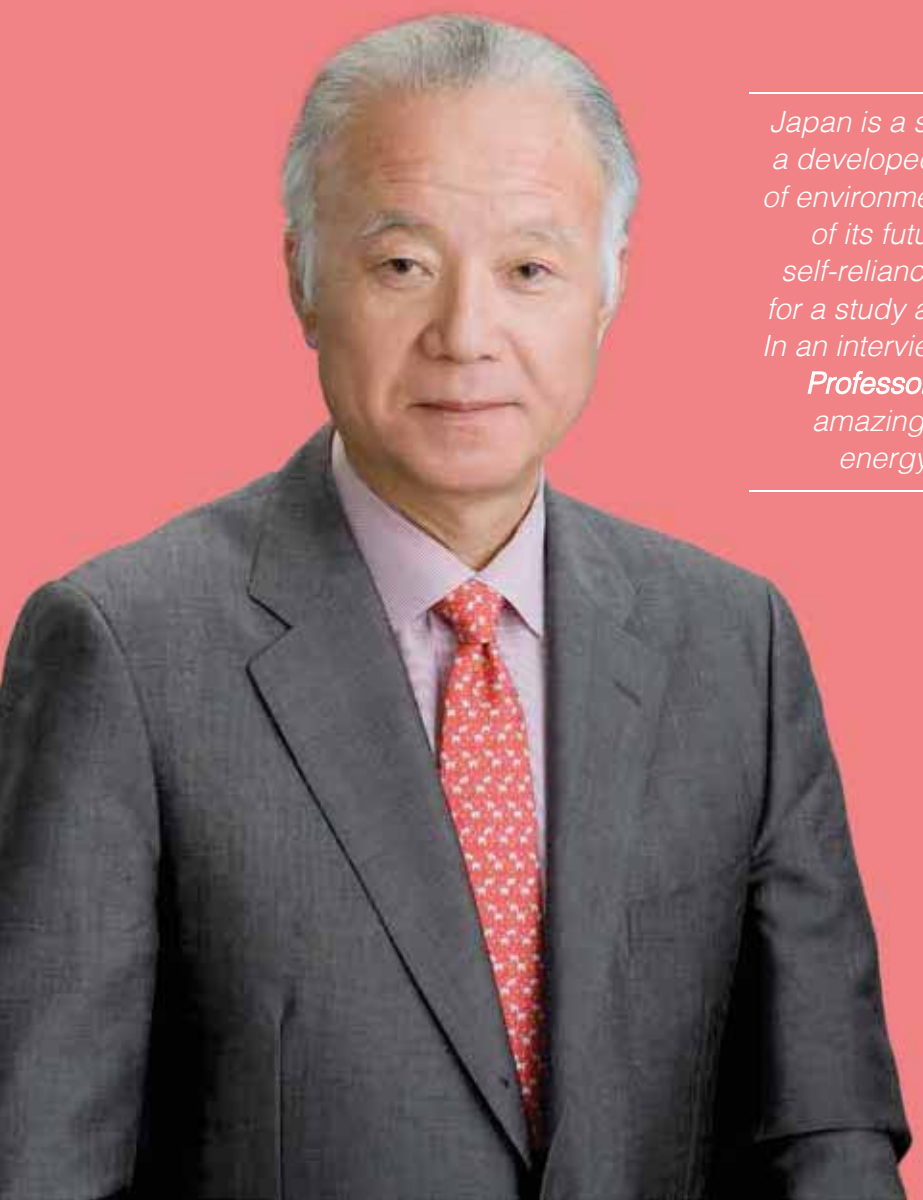
RECOMMENDATIONS AND CONCLUSIONS

- The cooperation and exchange of experience between the EU and India on the implementation of energy efficiency standards in the building sector is very much needed and expected.
- India a great place to implement energy saving measures. There is great opportunity for innovation to suit local conditions.
- The availability of resources at the state level in India is a big challenge and there is hope that cooperation programmes with external partners like the EU would help states to solve this most important problem.
- The support should be focused on creation of ECBC implementation cells, located in states.
- Due to the specificity of the Indian building market, cooperation should be focused on new buildings.
- The four states were identified and nominated for cooperation with EU: BOMM (Bihar, Odisha, Maharashtra, and Madhya Pradesh). The mix of four states is a very good representation of various levels of ECBC development/ implementation.
- The implementation of the ECBC should involve many stakeholder groups such as professional associations, building owners, local authorities, universities and laboratories, and energy auditors. EF

Dr João Cravinho and Dr Ajay Mathur in conversation

Energy Efficiency & Integrated Research System

For Sustainability Science (IR3S)



Japan is a small country; however, it has become a developed nation. This too, not at all at the cost of environment or compromising the energy needs of its future generation. This unique story of self-reliance and sustainable development calls for a study and offers an opportunity to learn a lot. In an interview with ***Pawan Garg*** *for* ***Energy Future****,* ***Professor Kazuhiko Takeuchi*** *discusses this amazing story of sustainable development, energy security, and energy efficiency.*

Professor Kazuhiko Takeuchi is Senior Vice-Rector of United Nations University, Director and Professor of the Integrated Research System for Sustainability Science (IR3S) at the University of Tokyo. He has served, inter alia, as a member of the Science Council of Japan, and a vice-chairman of the Food, Agriculture, and Rural Area Policies Council, Government of Japan, Editor-in-Chief of the journal, *Sustainability Science* (Springer).

What role does the Integrated Research System for Sustainability Science (IR3S) play at present and what are its objectives?

Sustainability science is a new, emerging science. In the world, this special science started to pick up since the beginning of this century. The aim of IR3S is to promote their department of science, which is trying to take a holistic approach by integrating three popular sciences, i.e., natural science, social science, and humanities which is a very important way to contribute to the world's welfare. In this way, we serve the world to deal with challenges, faced by us at present, including, climate change and energy efficiency.

Does the IR3S play any role in energy security and efficiency? If yes how?

Of course, energy efficiency, an important issue, is related to the reduction of carbon dioxide (CO_2) emissions. Energy security is also a very important issue. When we collaborated with different energy companies, we came to know that they have changed the fuels, they used in the past, from oil to renewable energy sources. Now, the important task is to promote renewable energy both in Japan as well as other parts of the world.

Please tell us about any project that the IR3S has commissioned in Japan or elsewhere.

In Southeast Asia, we are trying to initiate a '3-E Nexus', which implies the holistic mix of energy, environment, and ecosystem. Energy usage today is not appropriate from the sustainability science point of view because in every city or rural area, people are faced with their own local problems of environment such as air pollution, water pollution, and deterioration of forests. Therefore, the issue of energy is required to be integrated with other issues. This is the aim of our project. For this project, I hope that India also becomes our partner in the near future.

As you mentioned India, what role do you expect the Indian Government to play, especially, The Energy and Resources Institute (TERI), with regard to your Southeast Project and in general, with the IR3S?

The IR3S and TERI have been enjoying very good relations. We have been inviting people from TERI since the beginning of our project that was inaugurated about 10 years ago by Dr R K Pachauri. Since then, we have been exchanging our views on energy efficiency and environmental problems. We have also been regularly attending the Delhi Sustainable Development Summit (DSDS). The energy resources are crucial for any country, especially an emerging country like India. The energy efficiency issue needs to be improved in the near future, especially, keeping in mind the achievement of sustainability at the global level. In this process, India will play a crucial role to take up the

sustainability pathway. Thus, we are looking forward to collaborate with TERI along with other Indian partners.

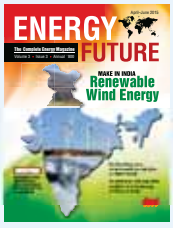
Every project of such a vast scale requires finances. Such projects also call for public–private partnership. What are the plans of IR3S in this regard?

Of course, partnership with the private sector is very crucial, as this sector is one of the important driving forces to completely transform our society towards sustainability. Our aim is not just obtaining the fund from the private sector; but, to also collaborate with them and fully utilize their resources to bring in sustainable change. We can be a partner, coordinator, or adviser to the private sector.

Also I would like to mention about the commitment towards the governmental funding mechanisms. For example, Japan started the environment taxation system that has now accumulated over $2 billion, which is not enough to solve the problem but is good enough for doing 'something'. We are utilizing this fund in collaboration with the Japanese ministries. We use such financial resources for the development programmes not only in Japan, but also in Asian countries, including, India. EF

ENERGY FUTURE

The Complete Energy Magazine



By looking at the technologies, policy decisions, and business ventures that have the potential to overcome energy shortage and our crippling dependence on depleting fossil fuels, Energy Future draws from a deep well of expertise at TERI (The Energy and Resources Institute), India's leading research institute on energy and green growth. Knowledge of energy security and development is a critical requirement in the modern global economy, and Energy Future aims to educate and inform you about the wide world of energy; its history, its future, how the energy industry works, how it has affected the world, and how it continues to affect you and me.

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CURRENT R&D SOLAR

Performance Evaluation of a Hybrid Solar Heating System for Farrowing Houses

Energy and Buildings, Volume 97, June 2015, Pages 162–174
S Tamvakidis, V K Firfiris, A Martzopoulou, V P Fragos, and T A Kotsopoulos

An innovative hybrid solar heating system for farrowing houses was investigated in terms of energy performance. The hybrid solar system consisted of a roof solar collector, a solar mass wall, one heat storage tank, one heat supply tank, and a creep heating slatted floor. The experimental period for the evaluation of the system performance had the duration of eight months; this period was to include both warm and cold periods within a year. During the warm period, around 70 per cent of the heating needs were supplied by this system, while during the cold period the achieved energy saving was approximately 25–30 per cent. The performance of the roof solar collector was better for the creep heating than the performance of the mass solar absorber throughout the experimental period; in fact, the latter contributed more to the heating of the farrowing room. It was also found, that a larger heating storage is necessary for this system in order to achieve improved performance of the excess energy produced during daylight. The results of this research will encourage the promotion of this system as a more economical and ecological for heating livestock buildings.

Comparison of Optimum Tilt Angles of Solar Collectors Determined at Yearly, Seasonal, and Monthly Levels

Energy Conversion and Management, Volume 97, June 2015, Pages 121–131
Milan Despotovic and Vladimir Nedic

The amount of energy that is transformed in solar collector depends on its tilt angle with respect to horizontal plane and orientation of the collector. In this article, the optimum tilt angle of solar collectors for Belgrade, which is located at the latitude of 44°47′N is determined. The optimum tilt angle was found by searching for the values for which the solar radiation on the collector surface is maximum for a particular day or a specific period. In that manner, the yearly, biannual, seasonal, monthly, fortnightly, and daily optimum tilt angles are determined. Annually collected energy per square meter of tilted surface is compared for 10 different scenarios. In addition, these optimum tilt angles are used to calculate the amount of energy on the surface of photovoltaic (PV) panels that could be installed at the roof of the building. The results show that for observed case study placing the panels at yearly, seasonal, and monthly optimum tilt angles, would yield increasing yearly amount of collected energy by factor of 5.98 per cent, 13.55 per cent, and 15.42 per cent, respectively, compared to energy that could be collected by putting the panels at current roofs' surface angles.

Analysis of a Solar Powered Absorption System

Energy Conversion and Management, Volume 97, June 2015, Pages 243–252
S A M Said, M A I El-Shaarawi, and M U Siddiqui

Today, fossil fuel is the primary extensively used source of energy. However, its negative impacts on the environment have forced the energy research continuity to seriously consider renewable sources of energy. Solar energy, in particular, has been the main focus in this regard because it is a source of clean energy and naturally available. This study presents the design and analysis of a solar powered absorption refrigeration system modified to increase its Coefficient of Performance (COP). The modifications include recovering of waste heat from a dephlegmator and utilization of a refrigerant storage unit. The simulation results indicate an increase of 10 per cent in the COP of the conventional design using dephlegmator heat recovery and an increase of 8 per cent in the COP of the conventional design due to the use of a refrigerant storage. The analysis for the combined effect of modifications indicates an increase of 18 per cent in the COP compared to conventional design. Calculated values of coefficient of performance indicate a very good agreement with the ones obtained based on measurement.

Hierarchical Energy Management System for Multi-source Multi-product Micro-grids

Renewable Energy, Volume 78, June 2015, Pages 621–630
Xiandong Xu, Hongjie Jia, Dan Wang, David C Yu, and Hsiao-Dong Chiang

This paper proposes a hierarchical energy management system for Multi-Source Multi-Product (MSMP) micro-grids. Traditional energy hub-based scheduling method is combined with a hierarchical control structure to incorporate transient characteristics of natural gas flow and dynamics of energy converters in micro-grids. The hierarchical Energy Management System (EMS) includes a supervisory control layer, an optimizing control layer, and an execution control layer. In order to efficiently accommodate the systems multi time-scale characteristics, the optimizing control layer is decomposed into three sub-layers: slow, medium, and fast. Thermal, gas, and electrical management systems are integrated into the slow, medium, and fast control layer, respectively. Compared with wind energy, solar energy is easier to integrate and more suitable for the micro-grid environment; therefore, potential impacts of the hierarchical EMS on MSMP micro-grids is investigated based on a building energy system integrating photovoltaic and micro-turbines. Numerical studies indicate that by using a hierarchical EMS, MSMP micro-grids can be economically operated. Also, interactions among thermal, gas, and electrical system can be effectively managed.

Projections of Long-term Changes in Solar Radiation Based on CMIP5 Climate Models and their Influence on Energy Yields of Photovoltaic Systems

Solar Energy, Volume 116, June 2015, Pages 12–24
Martin Wild, Doris Folini, Florian Henschel, Natalie Fischer, and Björn Müller

Traditionally, for the planning and assessment of solar energy systems, the amount of solar radiation (sunlight) incident on the earth's surface is assumed to be constant over the years. However, with changing climate and air pollution levels, solar resources may no longer be stable over time and undergo substantial decadal changes. Observational records covering the past decades confirm long-term changes in this quantity. Here, the paper examines how the latest generation of climate models used for the 5th Intergovernmental Panel on Climate Change (IPCC) report projects potential changes in surface solar radiation over the coming decades, and how this may affect, in combination with the expected greenhouse warming, solar power output from photovoltaic (PV) systems. For this purpose, projections up to the mid-21st century from 39 state-of-the-art climate models from the Coupled Model Intercomparison Project Phase 5 (CMIP5) are analysed globally and for selected key regions with major solar power production capacity. The large model ensemble allows to assess the degree of consistency of their projections. Models are largely consistent in the sign of the projected changes in solar radiation under cloud-free conditions as well as surface temperatures over most of the globe, while still reasonably consistent over a considerable part of the globe in the sign of changes in cloudiness and associated changes in solar radiation. A first order estimate of the impact of solar radiation and temperature changes on energy yields of PV systems under the RPC8.5 scenario indicates statistically significant decreases in PV outputs in large parts of the world, but notable exceptions with positive trends in large parts of Europe, southeast of North America, and the southeast of China. Projected changes between 2006 and 2049 under the RCP8.5 scenario overall are on the order of 1 per cent/decade for horizontal planes, but may be larger for tilted or tracked planes as well as on shorter (decadal) timescales.

Solar Resource-Reserve Classification and Flow-based Economic Analysis

Solar Energy, Volume 116, June 2015, Pages 45–55
Jeffrey R S Brownson, Drew Gardner, and Antonio Nieto

A framework is defined for the flow-based analysis of the solar resource by adapting established mineral economic methods, categorizing the joint degree of uncertainty for the solar resource and the degree of economic risk of project development. Solar energy is expressed as a raw energy commodity (an identified resource). Subsequent classification of the identified resource reflects the degrees of confidence in the meteorological data (measured, indicated, and inferred classes). The reserve base at the locale in question is then assessed for the economic viability for potential to be converted into a diversity of useful goods and services. Two example cases are examined for Andhra Pradesh, southern India. The solar resource-reserve system has been applied to a common product of electricity derived from photovoltaic (PV) technologies here, but the method is sufficiently broad to encompass economic utility derived from any conversion of a flow-based resource. This dynamic classification and analysis method establishes a foundation for communicating the confidence in project development from solar energy conversion, constrained not only by the confidence in the data describing the solar resource, but also in accordance with the techno-economic feasibility for available conversion technologies, and the elasticity of

demand for the solar commodity identified by investor/developers. The resource-reserve framework provides a foundation for solar resource economics; upon which individuals, firms, government agencies, and investors can make rationalized decisions on the allocation of the solar resource for high solar utility.

A New Correlation between Global Solar Energy Radiation and Daily Temperature Variations

Solar Energy, Volume 116, June 2015, Pages 117–124
Antonio Dumas, Andrea Andrisani, Maurizio Bonnici, Giorgio Graditi, Gianni Leanza, Mauro Madonia, and Michele Trancossi

The paper evaluates the energy balance for an atmospheric layer near the soil. By integrating it over the whole day period, a linear relationship between the global daily solar radiation on a horizontal surface and the product of the sunshine hours at clear sky with the daily maximum temperature variation is achieved. The results for the monthly averaged daily values show a comparable accuracy with some well-recognized models such as the Ångström–Prescott one, at least for Mediterranean climatic area. Validation of the results has been performed using old data sets which are almost contemporary and relative to the same sites with the ones used for the comparison.

Energy Management and Parametric Optimization of an Integrated PV Solar House

Energy Conversion and Management, Volume 96, May 2015, Pages 377–383
K K Matrawy, A-F Mahrous, and M S Youssef

This paper concerns with optimum design and performance parameters related to energy management of a small solar house. The house is designed to satisfy the main requirements of electrical power and space heating. The proposed house has a south-facing PV module employed for direct converting of solar energy into electricity as well as an air solar collector that is integrated behind the solar module. Integration of the solar collector with the PV module aims to enhance the efficiency as well as to decrease the capital cost of the unit. A heat and mass flow numerical model for the energy and mass balances of the flowing air behind the PV module is developed. Temperature variation of individual rooms inside the house is also considered in the study. The developed model has been employed to determine: an appropriate size for the solar house as regards to the given area of PV module, the optimum mass flow rate through the solar collector, and the best configuration of the solar cell array. The simulation results show that an area of 2 m^2 of the PV module would satisfy an acceptable room temperature in the season of winter with a solar house size of 24–48 m^3. Besides, there would be a significant enhancement in thermal efficiency at high mass flow rate of flowing air through the system. Furthermore, higher thermal efficiency and an acceptable room temperature would be achieved in longitudinal configuration of PV module.

A Hybrid Method for Forecasting the Energy Output of Photovoltaic Systems

Energy Conversion and Management, Volume 95, May 2015, Pages 406–413
Pamela Ramsami and Vishwamitra Oree

The intermittent nature of solar energy poses many challenges to renewable energy system operators in terms of operational planning and scheduling. Predicting the output of photovoltaic systems is therefore essential for managing the operation and assessing the economic performance of power systems. This paper presents a new technique for forecasting the 24-h ahead stochastic energy output of photovoltaic systems based on the daily weather forecasts. A comparison of the performances of the hybrid technique with conventional linear regression and artificial neural network models has also been reported. Initially, three single-stage models were designed, namely the generalized regression neural network, feedforward neural network, and multiple linear regression. Subsequently, a hybrid-modelling approach was adopted by applying stepwise regression to select input variables of greater importance. These variables were then fed to the single-stage models resulting in three hybrid models. They were then validated by comparing the forecasts of the models with measured dataset from an operational photovoltaic system. The accuracy of the each model was evaluated based on the correlation coefficient, mean absolute error, mean bias error, and root mean square error values. Simulation results revealed that the hybrid models perform better than their corresponding single-stage models. Stepwise regression-feedforward neural network hybrid model outperformed the other models with root mean square error, mean absolute error, mean bias error, and correlation coefficient values of 2.74, 2.09, 0.01, and 0.932, respectively. The simplified network architecture of the hybrid schemes suggests that they are promising photovoltaic output prediction tools, particularly in locations where few meteorological parameters are monitored. EF

Solar Water Heater

With energy savings and reliable operations like never before, solar water heating systems address the everyday hot water requirements for varying family sizes, climate conditions, and building types. Solar water heating systems range from 100, 200, and 300 litres per day stand-alone models to centralized systems of several thousand litres capacity, applicable to all building types; right from individual bungalows, row houses, multi-storied apartments to large townships, swimming pools, and commercial and industrial applications.

ADVANTAGES OF SOLAR WATER HEATER

A standard solar water heater will have the following advantages:

- Durable and long life (i.e., life expectation more than 15 years)
- Specially insulated storage tanks to retain hot water for considerable amount of time, with minimal temperature drop at night
- Optimum conversion threshold, i.e., higher efficiency
- Triple layered evacuated tube technology for rapid water heating
- Easier to install and maintain, thus making the system suitable for varied projects

SOLAR WATER HEATER VARIANTS

There are following variants of the solar water heating systems:

- 100, 200, 300 LDP (Litres per day)
- Pressurized system
- Manifold system

APPLICATION TYPES (WATER TEMPERATURE REQUIREMENTS)

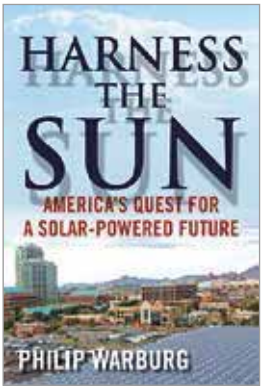
- Commercial: 60–65°C
- Residential: 55–60°C
- Industrial: 65–90°C

INSTALLATION REQUIREMENTS

A solar water heating system can be installed if the following conditions are met:

- Unobstructed sunlight on a flat or slopping roof
- Close to the bathrooms to avoid long piping and heat losses
- A water tank at a minimum of 2.5 m (7 ft) above roof level
- Shadow-free area
- The solar collector tubes facing south EF

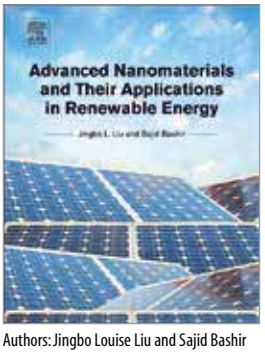
HARNESS THE SUN: AMERICA'S QUEST FOR A SOLAR-POWERED FUTURE



Author: Philip Warburg
Publisher: Beacon Press; Year: 2015

Solar power was once the domain of futurists and environmentally minded suburbanites. Today, it is part of mainstream America—and the solar industry is absolutely booming since it adds workers almost 20 times faster than the overall US economy. Beginning in his Boston-area home, where a rooftop solar array meets most of his family's power needs, the author travels the country and introduces readers to a surprising array of pioneers who are spearheading America's solar revolution, from conservative business leaders and politicians to students and professors committed to greening their campuses. Pollution-ravaged urban industrial areas and Native American groups alike are finding that solar offers the key to revitalizing their communities—all while weaning the country off of fossil fuels. In *Harness the Sun*, the writer argues that solar offers a realistic solution to the urgent problem of transforming our energy sector in a way that meets demand and is technically and economically viable. EF

ADVANCED NANOMATERIALS AND THEIR APPLICATIONS IN RENEWABLE ENERGY



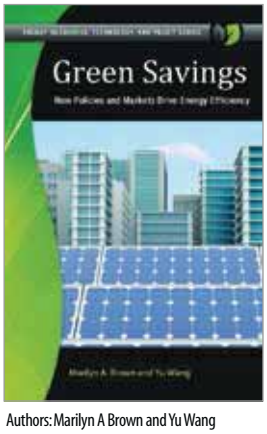
Authors: Jingbo Louise Liu and Sajid Bashir
Publisher: Elsevier Science; Year: 2015

Advanced Nanomaterials and Their Applications in Renewable Energy presents timely topics related to nanomaterials' feasible synthesis and characterization, and their application in the energy fields. In addition, it provides insights and scientific discoveries in toxicity study, with information that is easily understood by a wide audience.

Advanced energy materials are important in designing materials that have greater physical, electronic, and optical properties. This book emphasizes the fundamental physics and chemistry underlying the techniques used to develop solar and fuel cells with high charge densities and energy conversion efficiencies.

New analytical techniques (synchronous X-ray), which probe the interactions of particles and radiation with matter, are also explored, making this book an invaluable reference for practitioners and those interested in the science. The book provides a comprehensive review of solar energy, fuel cells, and gas storage from 2010 to the present, reviews feasible synthesis and modern analytical techniques used in alternative energy, explores examples of research in alternative energy, including current assessments of nanomaterials and safety, contains a glossary of terms, units, and historical benchmarks, and presents a useful guide that will bring readers up to speed on historical developments in alternative fuel cells. EF

GREEN SAVINGS: HOW POLICIES AND MARKETS DRIVE ENERGY EFFICIENCY

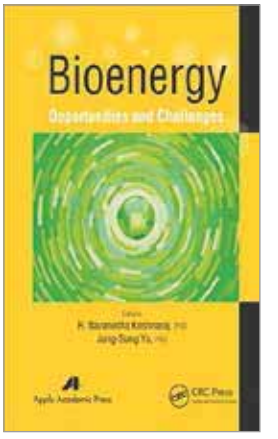


Authors: Marilyn A Brown and Yu Wang
Publisher: Praeger; Year: 2015

US consumers tend to use energy indiscriminately—something they may no longer be able to do with impunity. This game-changing book asserts that reducing energy consumption should be a frontline strategy to address global climate change, threats to energy security, and the challenge of grid reliability. *Green Savings: How Policies and Markets Drive Energy Efficiency* supports two bold arguments—policies motivating greater investment in high energy efficiency should be a priority and energy efficiency can help the nation in times of crisis.

To make their case for the necessity of prioritizing demand reduction, the authors examine the policies and markets operating in a number of leading cities, states, and nations across the globe to uncover the keys to their success. These examples show how demand-side strategies can significantly reduce pollution, cut costs, and make the electric grid more resilient. The authors explain why these technologies are not widely adopted and assess the potential savings they can produce. The book would be an eye-opener for policymakers, energy professionals, and the public as it demonstrates how cost-effective demand reduction policies can improve air quality, strengthen electricity markets, and generate jobs. EF

BIOENERGY: OPPORTUNITIES AND CHALLENGES

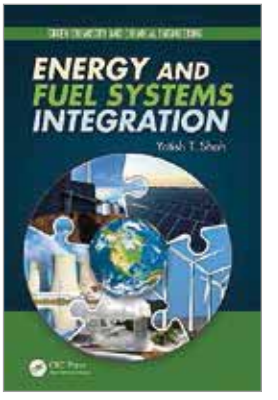


Editors: R Navanietha Krishnaraj and Jong-Sung Yu
Publisher: Apple Academic Press; Year: 2015

Energy is one of the prime needs of the modern world, and energy demands have been rapidly increasing in the recent years owing to rapid advancements in industrialization and population explosion. Conventional fossil fuels are being depleted at rapid rates, and the use of conventional sources such as coal or nuclear sources causes several hazards to the environment. New sources of fuel like bioenergy are an ideal option for fulfilling ever-increasing energy demands. *Bioenergy: Opportunities and Challenges* offers an exploration of these alternate fuel sources, including biohydrogen, microbial fuel cells, bioethanol, and biodiesel production, focusing on the challenges and factors hindering the real-time application of these bioenergy sources.

Researchers all over the world are working in this energy sector, and this has led to drastic improvements in bioenergy research. However, the technology gap between research and industrial application still exists. This important book offers engineers and technologists from different disciplines valuable information on this multifaceted field. The field of bioenergy is interdisciplinary, requiring the knowledge of biologists, chemists, physicists, and engineers. Exploring the current trends and future prospects for biofuels, the information presented in this book will be valuable to the international industrial community for identifying new options to circumvent problems that exist in bioenergy applications. EF

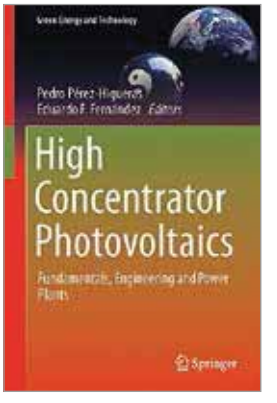
ENERGY AND FUEL SYSTEMS INTEGRATION



Author: Yatish T Shah
Publisher: CRC Press; Year: 2015

Multifuel and hybrid energy systems combine more than one source of power. *Energy and Fuel Systems Integration* discusses the production of different types of multifuels and hybrid energy systems and applications. It covers information on synthetic gas, liquid synthetic fuels, mobile energy systems and nuclear, solar, wind, and geothermal energy systems. It also discusses the many advantages of these systems, including sustainability, flexibility for optimization and scale-up, and more efficient use of storage, transportation, and delivery infrastructures. Examples and success stories are also provided in the book. EF

HIGH CONCENTRATOR PHOTOVOLTAICS: FUNDAMENTALS, ENGINEERING AND POWER PLANTS



Editors: Pedro Pérez-Higueras and Eduardo F Fernández
Publisher: Springer; Year: 2015

High Concentrator Photovoltaics: Fundamentals, Engineering and Power Plants provides a comprehensive overview of the fundamentals and engineering of High Concentrator Photovoltaic (HCPV) technology and elucidates how this complex and emerging technology is applied in power plants. It is the first of its kind to focus exclusively on the HCPV technology and offers a valuable reference volume to readers. This book is the result of an international collaboration among experts and each chapter is written by a specialist in the field.

The conversion of solar energy to electricity plays an important role in power generation and HCPV is signalled by many researchers and professionals as one of the most promising sources of solar power. Therefore, this book provides an important resource for companies, research institutes, and universities to assist with the understanding of fundamentals, different applications, and potential of such a technology. EF

RENEWABLE ENERGY TECHNOLOGY DEVELOPMENT

A SOLUTION TO INTERMITTENT RENEWABLES USING PUMPED HYDROPOWER

Integrating large quantities of renewable generation with low-carbon technology will require the development of large flexible carbon-free generation and storage assets. Over the last 40 years, numerous large capacity Pumped-Storage Hydropower Plants (PSPs) have been built worldwide, many of which could be retrofitted to provide grid-balancing services that the grid of the future will need.

Almost all PSPs are equipped with fixed rotating speed units. This technology imposes a fixed power capacity per unit in pumping mode—the pump is either stopped or operating at full capacity. The result of this is that other types of flexible generation plants must be kept online when the pumps are in operation. In a country like Austria where hydro generation represents a large fraction of the energy mix, keeping some PSP units in generation mode and some units in pumping mode provide a portion of the frequency regulation needed. However, operating this way has a negative impact on the cycle efficiency, literally resulting in the intermittent generation heating up the water in the upper reservoir. The fixed operating speed also limits the ability of the hydraulic unit, when operating in turbine mode, to keep a high efficiency over a large head and flow range.

New variable speed technology for PSPs was recently introduced in Europe. A key benefit of this new technology is that is gives PSPs the ability to regulate power both in pumping and generation modes instead of just in generation mode, like conventional units. Because this new technology allows for additional flexibility for PSPs, once equipped with them, these PSPs are now among the best solutions to provide necessary ancillary services for the grid.

http://www.renewableenergyworld.com/articles/2015/05

CLEAN ENERGY FUTURE: NEW CHEAP AND EFFICIENT ELECTRODE FOR SPLITTING WATER

Scientists at University of New South Wales (UNSW), Australia have developed a highly efficient oxygen-producing electrode for splitting water that has the potential to be scaled up for industrial production of the clean energy fuel, hydrogen. The new technology is based on an inexpensive, specially coated foam material that lets the bubbles of oxygen escape quickly.

Inefficient and costly oxygen-producing electrodes are one of the major barriers to the widespread commercial production of hydrogen by electrolysis, where the water is split into hydrogen and oxygen using an electrical current. Unlike other water electrolyzers that use precious metals as catalysts, the new UNSW electrode is made entirely from two non-precious and abundant metals—nickel and iron.

Commercially available nickel foam, which has holes in it about 200 mm across, or twice the diameter of a human hair, is electroplated with a highly active nickel-iron catalyst, which reduces the amount of costly electricity needed for the water-splitting to occur. This ultra-thin layer of a nickel-iron composite also has tiny pores in it, about 50 nm across. The three-dimensional architecture of the electrode has enormous surface area on which the oxygen evolution reaction can occur. The larger bubbles of oxygen can escape easily through the big holes in the foam. As well, the smaller holes make the electrode surface 'wetter', so the bubbles do not stick to it, which is a common problem that makes electrodes less efficient.

The scientists further seek to understand the science behind it and to further improve its performance. Cleaner sources of fuel like hydrogen will be particularly important for reducing carbon dioxide emissions and solving the air pollution problems caused due to burning of fossil fuels such as coal.

https://www.science.unsw.edu.au

ENGINEERING A BETTER SOLAR CELL: DEFECTS IN POPULAR PEROVSKITES PINPOINTED

One of the fastest-growing areas of solar energy research is with materials called perovskites. These promising light harvesters could revolutionize the solar and electronics industries because they show potential to convert sunlight into electricity more efficiently and less expensively than today's silicon-based semiconductors.

These super-efficient crystal structures have taken the scientific community by storm in the past few years because they can be processed very inexpensively and can be used in applications ranging from solar cells to Light-Emitting Diodes (LEDs) found in phones and computer monitors.

A new study by University of Washington and University of Oxford researchers demonstrates that perovskite materials, generally believed to be uniform in composition, actually contain flaws that can be engineered to improve solar devices even further. The research team used high-powered imaging techniques to find defects in the perovskite films that limit the movement of charges and, therefore, limit the efficiency of the devices. Perovskite solar cells have so far have achieved efficiencies of roughly 20 per cent, compared to about 25 per cent for silicon-based solar cells.

In a collaboration made possible by the Clean Energy Institute, the team used a technique called confocal optical microscopy, which is more often used in biology, and applied it to semiconductor technology. They used fluorescent images and correlated them with electron microscopy images to find 'dark' or poorly performing regions of the perovskite material at intersections of the crystals. In addition, they discovered that they could 'turn on' some of the dark areas by using a simple chemical treatment.

The images offered several surprises and would lead to accelerated improvements in the materials' uniformity, stability, and efficiency. The imaging technique developed by the UW team also offers an easy way to identify previously undiscovered flaws in perovskite materials and pinpoint areas where their composition can be chemically altered to boost performance.

deQuilettes, who spearheaded the project as a Clean Energy Institute graduate fellow, estimates there are more than a thousand laboratories around the world currently researching the semiconducting properties of perovskite materials. Yet there is more work to be done to understand how to consistently make a material that is stable, has uniform brightness, and can stand up to moisture without degrading. The UW research offers new ways for people to think strategically about how to improve the materials and how to extend their applications to high performance light-emitting devices such as LEDs and lasers.

http://global.ofweek.com/news

ULTRAFAST ALUMINUM BATTERY OFFERS SAFE ALTERNATIVE TO CONVENTIONAL BATTERIES

Scientists at Stanford University in collaboration with other scientists from other institutions have invented the first high-performance aluminum battery that's fast-charging, long-lasting, and inexpensive. Researchers say the new technology could replace many lithium-ion and alkaline batteries in wide use today.

Aluminum has long been an attractive material for batteries, mainly because of its low cost, low flammability, and high-charge storage capacity. For decades, researchers have tried unsuccessfully to develop a commercially viable aluminum-ion battery. A key challenge has been finding materials capable of producing sufficient voltage after repeated cycles of charging and discharging.

According to the researchers, the rechargeable aluminum battery that may replace existing storage devices, such as alkaline batteries, which are bad for the environment, and lithium-ion batteries, which occasionally burst into flames, won't catch fire, even if you drill through it. The team describes the battery as an ultrafast rechargeable aluminum-ion battery. An aluminum-ion battery consists of two electrodes—a negatively charged anode made of aluminum and a positively charged cathode. Many have tried different kinds of materials for the cathode, but the team accidentally discovered that a simple solution is to use graphite, which is basically carbon. They have also identified a few types of graphite material that gives very good performance. Aluminum batteries are safer than conventional lithium-ion batteries used in millions of laptops and cell phones today.

Durability is another important factor. Aluminum batteries developed at other laboratories usually died after just 100 charge-discharge cycles. But the Stanford battery was able to withstand more than 7,500 cycles without any loss of capacity. This is the first time an ultra-fast aluminum-ion battery was constructed with stability over thousands of cycles. By comparison, a typical lithium-ion battery lasts about 1,000 cycles. In addition to small electronic devices, aluminum batteries could be used to store renewable energy on the electrical grid. The grid needs a battery with a long cycle life that can rapidly store and release energy. Their latest unpublished data suggest that an aluminum battery can be recharged tens of thousands of times, which is hard to imagine building a huge lithium-ion battery for grid storage. EF

http://news.stanford.edu/news/2015

INDUSTRY REGISTRY

Hangzhou First PV Material Co. Ltd
We are a high-tech enterprise specialized in producing Solar EVA film and backsheet with 10 years experience and 18 GW devotes to innovative technology and continuous improvement.
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Phone/Fax: 86 571 63812086 63710907
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Website: www.firstpvm.com

Eoplly New Energy
Eoplly is a well-known solar panel and solar cell manufacturer in China, with 530 MW production capacity. We provide monocrystalline solar panels range from 5 W to 290 W and polycrystalline range from 5 W to 285 W.
Room B-D, 19th Floor, No. 899 Ling Ling Rd, Cross Region Plaza, Shanghai, China
Phone: 0086-21-51506161
Fax: 51506162
Email: info@eoplly.com
Website: www.eoplly.com

STECA Elektronik GmbH
3 A to 140 A charge solar controllers for solar home, telecom, inverter and hybrid systems. We offer off-grid solutions for rural electrification and industrial markets. Our product range also includes solar thermal controllers and inverters for grid connection.
Mammostr. 1, D-87700 Memmingen, Germany
Phone: +49 (0) 8331 8558-0
Website: www.steca.com

Bonfiglioli Riduttori SPA
Bonfiglioli engineers and manufactures inverter solutions and power conditioners for the Grid integration of Megawatt-Scale storage systems and photovoltaic plants.
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Phone: +390516473111
Email: photovoltaic@bonfiglioli.com
Website: www.bonfiglioli.com

Saj Electric Co. Ltd
Manufacturer of solar inverters and also offer PV monitoring software data acquisition & complete PV system application solutions.
No. 17, Xiangshan Road Guangzhou Science City, GD, China
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Fax: +86-20-6660 8617
Email: info@sajelec.com
Website: www.saj-solar.com

Pasan SA
Pasan sun simulators of outstanding spectral accuracy and light uniformity for standard and large customized dimensions. Applications in crystalline as well as in thin film panels. Advanced cell testers for laboratory and production facilities and high performance cell sorters.
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Phone: +82/2/801-7100
Email: sales@s-energy.co.kr
Website: www.s-energy.co.kr

Amerisolar-Worldwide Energy
A leading solar manufacturer of USA brand 'Amerisolar' with 500 MW capacity in 2012. Certified by TUV, UL, MCS, ISO9001, ISO14001, OHSAS18001, CSTB, Kemco, and CEC listed.
Phone: +86/21-6211-5260
Email: sales@weamerisolar.com
Website: www.weamerisolar.com

The Mount Makers Co. Ltd
Professional manufacturer of solar mounting systems. Maker of complete mounting components and customized designs.
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Phone: +86/510/86877719
Email: info@themountmakers.com
Website: www.themountmakers.com

Wavelabs
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Markranstädterstr. 1 04229 Leipzig, Germany
Phone: +49 341 4924 4830
Fax: +49 341 4924 4839
Email: info@wavelabs.de
Website: www.wavelabs.de

NATIONAL AND INTERNATIONAL EVENTS

INTERNATIONAL

Power Grid Resilience

Sep 01–03, 2015

San Diego, USA
Website: http://10times.com/power-grid

Gulf Coast Oil and Gas Environmental Conference

Sep 22–23, 2015

New Orleans, USA
Website: http://10times.com/gulf-coast-oil-and-gas-environmental-conference

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Thermal Management Systems Symposium

29 Sep–01 Oct, 2015

Troy, USA
Charlotte, USA
Website: http://10times.com/

North American Power Symposium

Oct 04–06, 2015

Charlotte, USA
Website: http://10times.com

Power Efficiency Energy Saving Innovative Technologies & Equipment

Oct 06–09, 2015

St Petersburg, Russia
Website: http://10times.com/energy-saving-exhibition

Voronezh Energy Forum

Oct 07–09, 2015

Voronezh, Russia
Website: http://10times.com/voronezh-energy-forum

Annual Power of Water Canada

Oct 18–20, 2015

Niagara Falls, Canada
Website: http://10times.com/annual-power-water-canada

IEEE Vehicle Power and Propulsion Conference

Oct 19–22, 2015

Montreal, Canada
Website: http://10times.com/vehicle-power-and-propulsion-conference

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Energy Electrical Engineering Energy Efficiency

Nov 10–12, 2015

Ekaterinburg, Russia
Website: http://10times.com/energy-electrical-engineering-energy-efficiency

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Oilgasservice

Nov 10–12, 2015

Ufa, Russia
Website: http://10times.com/oilgasservice

NATIONAL

India International Cable & Wire Expo Rudrapur

Jul 21–23, 2015

Rudrapur, India
Website: http://10times.com/cable-wire-rudrapur

World Renewable Energy Technology Congress & Expo

Aug 21–23, 2015

New Delhi, India
Website: http://10times.com/wretc

India International Cable and Wire Expo Hyderabad

Aug 21–23, 2015

Hyderabad, India
Website: http://10times.com/india-international-cable-and-wire-expo

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Electrical, Electronics and Energy Expo & Conferences Ludhiana

Aug 29–31, 2015

Ludhiana, India
Website: http://10times.com/electrical-energy-ludhiana

Renergy

Sep 09–10, 2015

Chennai, India
Website: http://10times.com/renergy

Electrical Electronics & Energy Expo & Conference

Sep 18–20, 2015

Bangalore, India
Website: http://10times.com/electrical-electronics-energy-expo-conference

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India Nuclear Energy

Oct 15–17, 2015

Mumbai, India
Website: http://10times.com/india-nuclear-energy

Intersolar India

Nov 18–20, 2015

Mumbai, India
Website: http://10times.com/intersolar-india

International Conference and Exhibition on Energy Storage and Microgrids in India

Dec 08–09, 2015

New Delhi, India
Website: http://10times.com/energy-stotage-and-microgrids

Energy Storage India

Dec 08–09, 2015

New Delhi, India
Website: http://10times.com/energy-storage-indias

Renewable Energy at a Glance

Programme/Scheme wise Physical Progress in 2014–15 (During the month of March, 2015)			
Sector	**FY 2014–15**		**Cumulative Achievements**
	Target	**Achievement**	**(as on 31.03.2015)**
I. GRID-INTERACTIVE POWER (CAPACITIES IN MW)			
Wind Power	2,000.00	2,312.00	23,444.00
Small Hydro Power	250.00	251.61	4,055.36
Biomass Power & Gasification	100.00	45.00	1,410.20
Bagasse Cogeneration	300.00	360.00	3,008.35
Waste to Power	20.00	8.50	115.08
Solar Power	1,100.00	1,112.07	3,743.97
Total	**3,770.00**	**4,089.18**	**35,776.96**
II. OFF-GRID/ CAPTIVE POWER (CAPACITIES IN MW_{EQ})			
Waste to Energy	10.00	21.78	154.47
Biomass (non-bagasse) Cogeneration	80.00	60.05	591.87
Biomass Gasifiers -Rural -Industrial	0.80 8.00	0.61 6.15	17.95 152.05
Aero-Genrators/Hybrid systems	0.50	0.27	2.53
SPV Systems	60.00	60.00*	234.35
Water mills/Micro hydel	4.00	4.00	17.21
Biogas-based Energy System	0.00	0.30	4.07
Total	**163.30**	**93.16**	**1,174.50**
III. OTHER RENEWABLE ENERGY SYSTEMS			
Family Biogas Plants (numbers in lakh)	1.10	0.65	48.18
Solar Water Heating – Coll. Areas (million m^2)	0.50	0.72	8.82

** Progress from some states is awaited*
Source: www.mnre.gov.in

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