January–March 2015

ENERGY FUTURE

The Complete Energy Magazine
Volume 3 • Issue 2 • Annual-`800

QUEST FOR AN ALTERNATIVE ENERGY FUTURE

TEAM... From Organic Waste to Energy

Organic Waste in India's Energy Supply

VIEWPOINT

Prof. Michael A Borowitzka
Director, Algae R&D Centre, Murdoch University, Australia

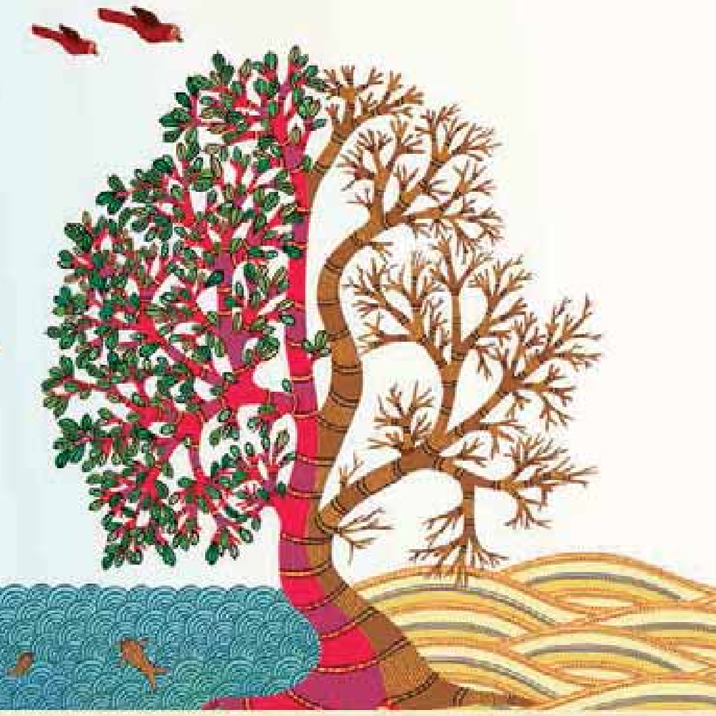
World Sustainable Development Forum
DSDS 2015

teri

15th DELHI SUSTAINABLE DEVELOPMENT SUMMIT

Sustainable Development Goals and Dealing with Climate Change

February 5–7, 2015, New Delhi, India



Curtain Raiser – February 4, 2015
High Level Corporate Dialogue

High Level Corporate Dialogue | February 4, 2015

DELHI TO PARIS: CORPORATE ACTION TO COMBAT CLIMATE CHANGE

Since 2004, the **High Level Corporate Dialogue (HLCD)** has become an integral part of DSDS, bringing together over 1,500 international and Indian CEOs, senior government officials and luminaries from across the globe. The HLCD provides a platform for industry captains to brainstorm ideas for conducting business while protecting the environment.

"A large share of economic activity will be in the hands of business organisations in the future. Hence, decision making in the corporate sector would have a major impact on the form of development that a country as a whole pursues. Consequently, if the nation is to move in the direction of sustainable development, business would have to be a major driver for bringing this about."

- Dr RK Pachauri, Director General, TERI

FORMAT

- High-profile plenary sessions
- Break-away brainstorming sessions
- Open, interactive discussion
- Formulation of action plan

SCOPE

Encouraging inclusive, multi-stakeholder problem solving

Promoting active participation of the corporate sector

Enhancing existing and new initiatives to maximize impact

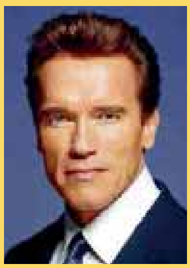
IMPACT

- Corporate Vision on Climate Change
- Roadmap for Corporates
- Highlighting distinct challenges and opportunities
- Document to be tabled at COP 21

CATCH

Arnold Schwarzenegger
Special Luncheon Session at HLCD 2015

Other dignitaries include
- Henrik O. Madsen
- Paul Polman
- Jonathon Porritt



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From the editor's desk...

Since the advent of the industrial revolution, mankind's quest for energy is continuing unabated. Indeed, to fuel ever-increasing demands arising out of economic growth as well as lifestyle changes, the energy needs are growing exponentially. And thus far, conventional resources have been used to meet these demands. However, various studies have shown these very resources to be in finite quantities, even with the technological advancements. Moreover, these resources have irreversible impact on climate, locally as well as globally. These two factors put together have forced scientists and industries to look for alternatives that not only can satisfy growing energy demands, but more importantly, do it in a fashion that does not put human kind in peril of climate change. In addition to developing alternate fuels, the ongoing endeavours are also focusing on how to use conventional fuels albeit in much more environmentally benign fashion. This is especially critical for countries like India that has been banking on its large reserves of coal to supply affordable electricity to its millions of populace that currently does not have access to electricity. Here, latest technological innovations like carbon capture and storage could play an important role once they reach an adequate maturity level and are well demonstrated at a reasonably large scale.

While looking for alternate energy sources, one omnipresent resource—waste—is generally given a miss. It is rather ironical that while the society and the industry alike are grappling with the problem of waste disposal and management, cohesive strategies to convert these wastes in to useful energy forms are still missing, certainly in the developing economies. Today, there are technologies available that can convert different kinds of organic wastes into various forms of clean energy, whether for the stationary applications or for the automotive ones, besides helping in scientific disposal of wastes. When one envisages the future of energy, this valuable resource would be playing a critical role.

Amit Kumar

Amit Kumar
Director, TERI

Editor: Amit Kumar Radheyshayam Nigam
Printed and published by Dr R K Pachauri for The Energy and Resources Institute, Darbari Seth Block, IHC Complex, Lodhi Road, New Delhi- 110 003. Tel. +91(11) 24682100, 4150 4900, Fax +91(11) 2468 2144 or Email teripress@teri.res.in, and printed by Batra Art Press, A-41 Naraina Indl. Area PH- II, New Delhi-28.

The cover story on microgrids was very informative. The article discusses the background, design, characteristics, benefits, and applications of microgrids. This makes a lot of information available to the readers interested in exploring their future ventures in the field of energy. I must compliment the author–editor duo for this informative article.

Varuni Sharma
New Delhi

The story of the South Asia project made an interesting read. It talks about the development done in the villages of Odisha. It talks about how the community-based approach can lead to the betterment of the whole village and how the administrative machinery can help in the implementation of this valued project. I hope such measures are taken up at other places in the country as there are many rural areas that are still waiting for the right action to be taken with regard to energy (electricity) supply.

Jitendra Prashad
Odisha

The article that highlights the application of solar energy in the dense forest of Sunderbans makes a fine read. It explores the various aspects of the solar energy in that area, and at the same time, provides data related to electricity usage and cost incurred. It also provides comparison of the various kinds of fuels used, such as kerosene, solar power, gas, etc. In the end it discusses the future of the solar power in that region. I think the article should reach to the desks of energy authorities so that they could chalk out a future plan and bring happiness to the people living there.

R C Baneerji
Kolkata

The article that discusses how our buildings can use the naturally available energy is very interesting to read. The article discusses the design of an institutional building. It also discusses the various features which make that building user friendly, in addition to being sustainable and having zero % damage to the environment. I think through public-private partnership we should promote such buildings in our country.

Manisha
Hyderabad

Thank you very much for your encouragement. The editorial team of Energy Future will ensure that the magazine caters to your information and knowledge needs. We welcome your suggestions and comments to further improve our content and presentation.

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Editor
Energy Future

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BHEL COMMISSIONS POWER PLANT IN TRIPURA

Bharat Heavy Electricals Ltd (BHEL) commissioned the second module of a 726 MW power plant of Oil and Natural Gas Corporation (ONGC) Thermal Power Corporation in Tripura. Setting up of the 2 × 363.3 MW gas-based Combined Cycle Power Plant (CCPP) at Palatana, about 50 km from Agartala, was a herculean task. Harsh terrain, incessant rains, and inadequate road infrastructure made the conventional mode of transportation from BHEL's works in Hyderabad to the remote site almost impossible. However, BHEL carried out the task well. The company has commissioned the first module of the project in January 2013. In Tripura, the public sector company has so far commissioned 911 MW of gas-based and hydro sets, which accounts for 100 per cent of the state's generating capacity.

The Palatana project is the first and largest of its kind in the entire northeast region of the country. In view of the logistic constraints, BHEL previously commissioned only gas turbines, 14 of them, of smaller rating (up to 21 MW). The company is executing another gas-based project, of 100 MW, of North Eastern Electric Power Corporation Limited (NEEPCO) at Monarchak in Tripura. EF

Source: www.kseboa.org

INDIA, ISRAEL TO COOPERATE IN RENEWABLE ENERGY SECTOR

India and Israel are set to conclude a broader agreement on cooperation in the renewable energy sector between the two countries. This follows earlier agreements between the two countries to work on the renewable energy sector. Daniel Carmon, Israeli ambassador to India informed that the Free Trade Agreement (FTA) talks could not be held due to other engagements. But they are poised to be taken up again as both the Governments are committed to reaching a consensus on the agreement.

He also said that the India–Israel trade which had humble beginnings at $2,00,000, a little over 20 years ago, had now topped the $6-billion mark and the same was poised to get a lot bigger as both countries get into more areas of mutual interest. The $6 billion bilateral trade is without the defence business, which is another big area. Israel has developed strong and sound relationships in the defence sector and work is underway to identify a few other clusters of common interest. EF

Source: www.thehindubusinessline.com

IREDA, US EXIM BANK INK $1 BILLION PACT FOR CLEAN ENERGY

A Memorandum of Understanding (MoU) has been signed between the Indian Renewable Energy Development Agency (IREDA) and the Export-Import Bank of the United States (US Ex-Im Bank) with respect to cooperation in clean energy investment. The MoU was signed by Mr K S Popli, Chief Managing Director (CMD) of IREDA, and Mr Fred P Hochberg, Chairman and President, the Export-Import Bank of the United States.

This initial pact is intended to establish a framework for cooperation in the financing of credit worthy entities for renewable energy projects and facilitate export of goods and services of US origin or manufacturers in India besides various forms of collaboration between IREDA and the US Ex-Im Bank. The US Ex-Im Bank shall provide $1 billion medium- and long-term guaranteed and/or direct dollar loans to finance the US technologies, products, and services utilized during commercial development activities within the clean energy sector by IREDA.

The proposed credit facility carries no specific commitment on the part of IREDA and will depend on the import of the US equipment to India and attractiveness of credit facility to the project developers in India. The US Ex-Im Bank facility will be available for financing of imported US equipment besides loans for 30 per cent of domestic component. The credit facility will be available for a repayment period of 18 years with the same fixed rate of interest. Solar, wind, hydro, and other renewable energy projects have been identified as priority areas of clean energy investment cooperation under this MoU.

Source: www.thestatesman.net

NAVI MUMBAI TO HOUSE LARGEST SOLAR PANEL INSTALLATION ON DAM

The Morbe dam on Dhavari river in Navi Mumbai is going to house a solar panel installation big enough to generate 20 MW power. A three-year-old company which carrying out the ₹162-crore project claims that the installation will be the largest in the world on a dam barrier, and the first in India. India already has several solar power installations on top of canals, the biggest being an under construction 10 MW project on a Narmada canal in Gujarat, but none on a sloping wall. Mr Rahul Gupta, an IIT-Roorkee alumnus and founder of Rays Power Experts, which got the contract from the Navi Mumbai Municipal Corporation, said that the Morbe gravity dam has an earthen slope, which added complexity to the project.

"The other side of the wall will have a huge amount of water, so the construction has to be done in a way that it does not puncture the wall", said Mr Gupta adding, "it also needs to be made sure that future maintenance is easy and the solar panels are not spoilt by salty water". The project is scheduled to be completed by the end of March 2015.

Source: www.articles.economictimes.indiatimes.com

NHPC TO BUILD INDIA'S LARGEST HYDEL POWER PROJECT IN ARUNACHAL PRADESH

National Hydroelectric Power Corporation (NHPC) is in the process of building India's biggest hydro plant, a 3,000 MW project, i.e., the Dibang Hydel Project in Arunachal Pradesh. It is equivalent to about half its current total capacity and three times the size of its biggest unit. Recently, NHPC has received approvals from the Forest Advisory Committee for the Dibang Hydel Project and plans to approach the Cabinet Committee for a final nod within a year.

"We will execute the Dibang project in partnership with one of the public sector units and the state government at an investment of 15,000–16,000 crore. Due to its large scale, the per-MW project cost will be much less than the average of 7–8 crore", said NHPC Chairman and Managing Director Mr R S T Sai. He added that NHPC expected to build more plants as the Narendra Modi government had been pushing for faster clearances for infrastructure projects in a bid to boost the economy. EF

Source: www.articles.economictimes.indiatimes.com

RELIANCE POWER STARTS OPERATIONS AT RAJASTHAN'S SOLAR PLANT

Reliance Power started operations at its 100 MW solar energy plant, which is said to be the world's largest Concentrated Solar Power (CSP) project. It has been built at a cost of N 2,100 crore in Rajasthan's Jaisalmer District.

The project has been successfully synchronized with the grid, and power generation has commenced. With this project, Reliance Power's generation capacity has increased up to 5,285 MW, which includes 5,100 MW of thermal capacity and 185 MW of renewable energy-based capacity. The project is the largest investment undertaken by any private sector entity in the CSP technology in India. The technology used in the project is called Compact Linear Fresnel Reflector, which focuses the sun's heat onto a system of tubes through which water flows. The concentrated sunlight boils the water and generates superheated steam, which is then used for running a power generator. Rajasthan Sun Technique Energy Pvt. Ltd, a wholly owned unit of Reliance Power, was awarded the project in December 2010, after an international competitive bidding conducted by state-run National Thermal Power Corporation's (NTPC) unit—NTPC Vidyut Vyapar Nigam—under the government's Jawaharlal Nehru National Solar Mission (JNNSM). EF

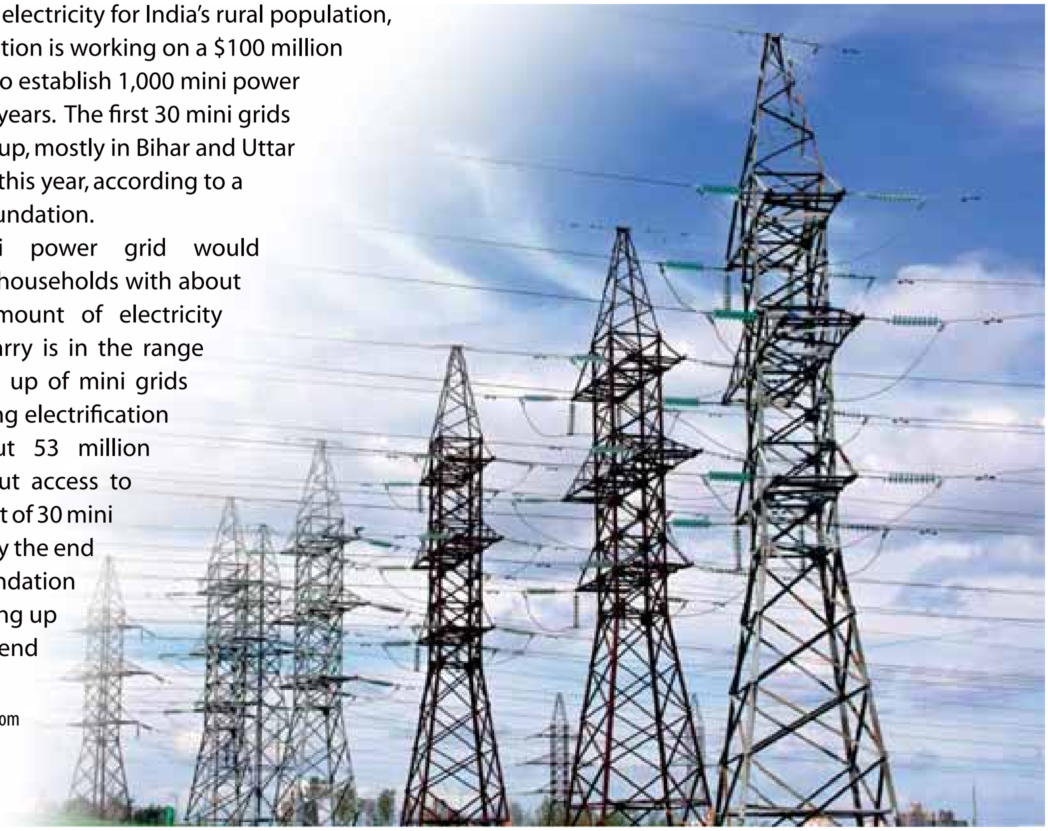
Source: www.articles.economictimes.indiatimes.com

ROCKEFELLER FOUNDATION TO SET UP 1,000 MINI POWER GRIDS

In its efforts to provide electricity for India's rural population, the Rockefeller Foundation is working on a $100 million (N614 crore) initiative to establish 1,000 mini power grids in the next three years. The first 30 mini grids are expected to be set up, mostly in Bihar and Uttar Pradesh, by the end of this year, according to a senior official of the foundation.

Generally, a mini power grid would help cater to 150–250 households with about 1,000 people. The amount of electricity that such grids can carry is in the range of 65–75 kWh. Setting up of mini grids would help in increasing electrification in India where about 53 million households are without access to power. While the first set of 30 mini grids would be ready by the end of this year, the foundation has set a target of setting up 200 such grids by the end of 2015. EF

Source: www.thehindubusinessline.com



SUZLON SETS UP WORLD'S TALLEST HYBRID WIND TURBINE IN KUTCH

Suzlon Energy commissioned the world's tallest hybrid wind generator turbine in the Kutch region of Gujarat. The turbine will generate 12–15 per cent more energy. The 120-m hybrid turbine has been designed and developed by local engineers. The wind turbine tower is taller by 40 m than conventional wind turbine towers.

According to Mr Tulsi Tanti, Chairman and Managing Director of Suzlon, "With this new turbine, the installed wind energy capacity at the Kutch region of Gujarat has gone up to 1,100 MW. And, this makes it Asia's biggest wind energy park at one location."

Mr Tanti added, "This tower is ideal for low-wind areas, and the potential is huge. In the next three years, this region will have 2,000 MW of wind energy capacity, and this will make it the world's biggest wind energy park in one location. Six years ago, we had signed a Memorandum of Understanding (MoU) with the Gujarat Government to set up 2,000 MW capacity here. Out of that, we have now crossed 1,100 MW." Suzlon has set up 25,000 MW wind energy capacity for its customers in 31 countries, including 9,000 MW in India. EF

Source: www.thehindu.com

AFRICA TO SET UP FIRST GEOTHERMAL ENERGY RESEARCH CENTRE

Africa is set to open its first ever geothermal energy research centre at the Dedan Kimathi University of Science and Technology (DeKUT), Kenya. As interest in the African geothermal market grows, the region is now focused on building a strong workforce to spur exploration and development of the increasingly important source of renewable energy.

According to the US–East Africa Geothermal Partnership (EAGP), the Rift Valley countries of Djibouti, Ethiopia, Kenya, Uganda, and Tanzania have a combined resource potential of more than 15,000 MW. This is more than the current installed electricity capacity for all of East Africa, a region with more than 200 million people. Efforts to exploit geothermal energy have intensified in recent years. Kenya leads the way with 280 MW of installed capacity to west of its capital city Nairobi.

The centre will offer a wide variety of comprehensive training and research programmes. Experts from around the globe will offer knowledge on subjects ranging from resource discovery, utilization, drilling, engineering, and plant design to environmental impacts and business principles. EF

Source: www.renewableenergyworld.com

CHINA'S CWE TO BUILD 60 MW HYDROPOWER PLANT IN GHANA

The China International Water and Electric Corporation (CWE) has won a $307 million contract to design and build a 60 MW hydropower project in Ghana. According to the contract, awarded by Ghana's Ministry of Energy and Petroleum, the CWE would build a 34-m-high dam on the Pra river in Ghana's western region, which is prone to power outages.

Construction of the Hemang plant, as it is called, is expected to take 42 months. The signing of this contract marks CWE's new firm step in the water and hydropower field in Ghana, which is of great significance to the country's in-depth development of the Ghanaian market and will help the company further enhance its international brand image.

In addition to the dam, the scheme involves the CWE building a reservoir with a storage capacity of about 46 million cubic metres and a 64-km-long 161 kV transmission line. The CWE is a wholly-owned subsidiary of the China Three Gorges. The company's other recent efforts in Africa include work on Cameroon's 30-MW Lom Pangar and Uganda's 188-MW Isimba Falls projects. EF

Source: www.globalconreview.com

EU LEADERS AGREE TO TOUGH CARBON REGULATIONS TO SPUR RENEWABLE ENERGY DEVELOPMENT

The European Union (EU) leaders backed the most-ambitious carbon emission goals of any major economy in a bid to increase pressure on the US and China. Heads of government from the bloc's 28 nations endorsed a binding target to cut greenhouse gases by at least 40 per cent from 1990 levels by 2030 at a summit in Brussels. According to the EU estimates, meeting this goal would cost about $48 billion a year.

The agreement on emissions ensures that the EU remains the leader in the fight against global warming before the United Nations Climate Summit, where delegates aim to persuade other large polluters to sign up for worldwide accord they aim to clinch in 2015.

An energy security strategy for Europe is one of the pillars of the deal. The leaders' endorsement for the plan to diversify energy–supply sources and cut the region's dependence on fossil fuels came after a pricing dispute led to the cut-off of Russian natural - gas supplies to Ukraine, the transit country for around 15 per cent of the EU's need for the fuel.

The leaders agreed to improve cross-border power interconnections, which currently can handle about 8 per cent of the bloc's potential power output, less than the 10 per cent target set by the EU leaders in 2002." EF

Source: www.renewableenergyworld.com

WORLD'S FIRST SOLAR-POWERED BICYCLE PATH BUILT IN THE NETHERLANDS

The Netherlands unveiled the world's first solar bike path, a revolutionary project to harvest the sun's energy that could eventually also be used on roads. The so-called 'SolaRoad' bike path is made of concrete modules each measuring 2.5 × 3.5 m (8 × 11 feet), embedded with solar panels covered in tempered glass. To help prevent accidents, the glass has been given a special non-slip surface. The solar cells currently put the electricity they generate onto the national grid, but future plans include using this energy to power street lights. Sten de Wit, a physicist who helped develop the project, says, "Electric bikes and cars will one day be able to refuel using contactless charging directly from the road or bike path. The idea is that in the Netherlands we have approximately 140,000 km of road which is much bigger than all the rooftops put together. We have 25,000 km of bike paths in the Netherlands. If we can integrate it in our roads then we'll have huge extra potential for generating solar electricity."

"During the trial of 16 days, the path generated 140 kWh of electricity. It is equivalent to around 140 washing machine cycles," said SolaRoad spokeswoman Jannemieke van Dieren. The cost of the project has been $3.7 million till now.

The SolaRoad will be tested over the next two years on a path that carries around 2,000 cyclists a day. The aim is to have the solar road commercially available on Dutch roads within the next five years as the number of electrically-powered cars and bicycles grows. EF

Source: www.asianage.com

SM NORTH EDSA NOW WORLD'S BIGGEST SOLAR-POWERED MALL

Located in Quezon City, Manila, Philippines, the SM City North EDSA is now the world's largest solar-powered mall. Recently, its rooftop solar power project was commissioned. President Benigno Aquino and SM Prime President Hans Sy led the switch-on (commissioning) ceremony at the rooftop of SM North's multi-level car park, where the 5,760 solar panels are installed.

"This is significant in light of the challenges that will confront our energy sector," Aquino said. Solar Philippines, led by 21-year-old Leandro Leviste, partnered with SM Malls to build the solar panels that could generate up to 1.5 MW power. This is SM's second solar power project after it installed a 1.1 MW project at its SM City Xiamen Mall in China.

SM Supermalls President Annie Garcia said that the 1.5 MW of electricity generated by the solar panels could power 16,000 light fixtures, 59 escalators, and 20 elevators of SM North at the same time. This represents five per cent of the mall's total electricity requirements. EF

WORLD'S LARGEST SOLAR POWER PLANT NOW IN OPERATION

California's Topaz project is the largest solar power plant in the world with a capacity of 550 MW, and it is now in full operation. It is located in San Luis Obispo County and has nine million solar panels. Its construction began just two years ago.

The electricity produced by the plant will be purchased by Pacific Gas and Electric. The solar panels were manufactured by First Solar and the project was developed by First Solar. Solar Energy Industries Association (SEIA) says about 200 homes in California are powered for each MW of solar power capacity. So, for a 550 MW solar plant, about 110,000 homes could be powered when the sun is shining. First Solar has said that this figure could be 160,000 homes in the case of Topaz.

The San Luis Obispo County's population is about 276,000. A majority of this population could be powered by a single solar power plant. Energy storage is a growing field, so the excess electricity generated by solar power could be stored for night time use and for overcast days, extending the impact of Topaz even further." EF

Source: www.cleantechnica.com

UK APPROVES 750 MW OFFSHORE WIND PROJECT

The UK approved construction of one of the biggest offshore wind farms as the country wants to achieve the target, i.e., to get 15 per cent of all energy from renewables by 2020. This target has been set by the European Union.

The consent allows Dong Energy A/S, the biggest offshore wind developer, to install up to 750 MW of turbines at the Walney Extension project in the Irish sea off northwest England's Cumbria. Denmark's Dong said that it expected to put in about 660 MW of turbines, enough to power as many as a half-million homes.

The UK already has more than half of the world's installed offshore wind-generating capacity, and is pushing the technology to help meet its renewable energy targets. Dong expects to use 6- to 8-MW turbines. The utility owns 50.1 per cent of the project, SSE Plc owns 25.1 per cent, and a joint venture between Dutch pension administrator PGGM and Ampere Equity Fund own the remainder. It is the second approval in less than two months for a UK project by Dong. The UK currently has 22 operational offshore wind farms totalling 3,653 MW of capacity. The biggest is the 630-MW London Array, which is a collaboration between four companies, including Dong and EON SE. EF

Source: www.renewableenergyworld.com

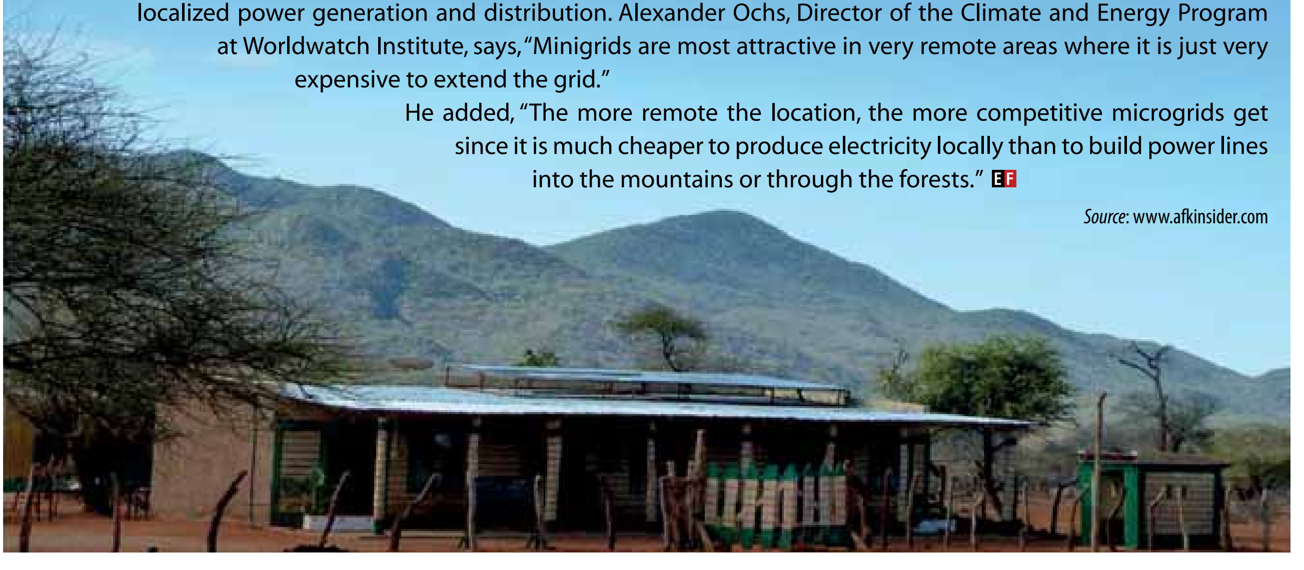
MICROGRIDS BECOMING POPULAR IN RURAL AFRICA

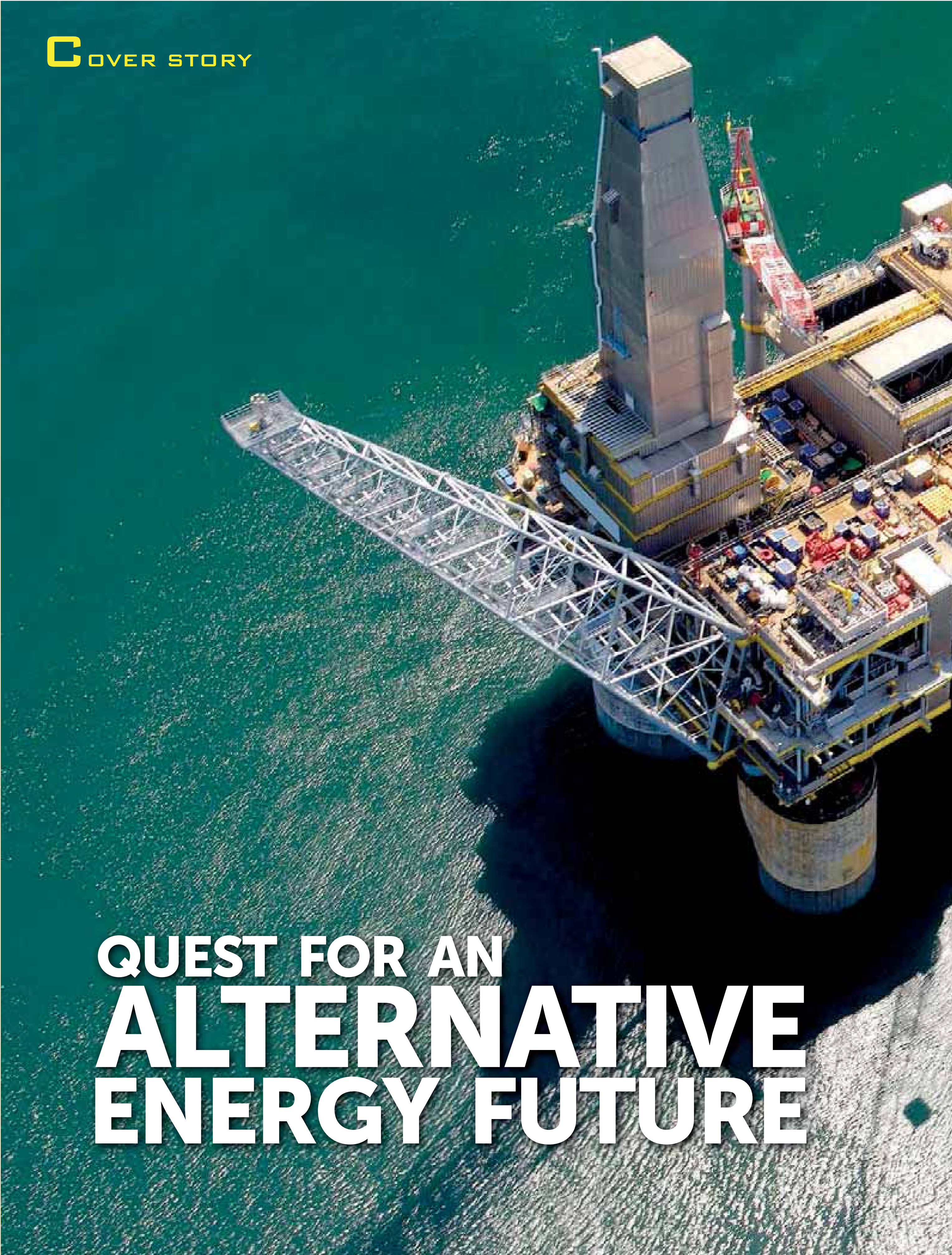
With Africa's push for rural electrification, microgrids—especially those that use renewable energy rather than expensive, polluting diesel generators—are fast becoming a cost-effective way to extend electrical service.

In those countries where extending the grid is often not financially viable, mini grids or microgrids offer localized power generation and distribution. Alexander Ochs, Director of the Climate and Energy Program at Worldwatch Institute, says, "Minigrids are most attractive in very remote areas where it is just very expensive to extend the grid."

He added, "The more remote the location, the more competitive microgrids get since it is much cheaper to produce electricity locally than to build power lines into the mountains or through the forests." EF

Source: www.afkinsider.com





QUEST FOR AN ALTERNATIVE ENERGY FUTURE

Harish Alagappa looks at the past, present, and future of alternative energy, exploring lesser-known fuels, scouting their potential, and looking at how they can contribute to the energy mix and help us build a more secure and sustainable energy future.

A History of Energy

Alternative energy encompasses a wide variety of energy sources that began as alternatives to the then-mainstream trends of energy consumption. Many of these alternatives supplanted the mainstream sources until they were replaced by other alternatives as our appetite for energy kept growing. It should be noted that the term 'alternative energy' should not be treated as being synonymous with renewable energy. There were and are many alternative energy sources that are highly unsustainable and dangerous to the environment. For example, towards the end of the 19th century, oil and natural gas were seen as alternatives to the then-predominant energy sources, such as wood and coal. However, in this century since, oil and gas have proven to be as unsustainable as their predecessor energy sources and consequently, humanity is currently engaged in the search for new alternatives to the 'alternatives'. There are many contenders vying to fill the gaps that will emerge as we continue to exhaust the planet's supply of fossil fuels. Alternatives such as solar, wind, and hydropower are known to most of us already, but there are other, non-mainstream energy sources being developed that have the potential to be game-changers as far as the search for non-traditional forms is concerned.

From our earliest beginnings and right up to the modern world, there has been one energy source that has powered every great leap forward in human history. It powered our earliest tools; it was the fuel that drove the construction of the pyramids, the fuel that helped build and destroy the first great empires, and even today, is the energy source for the writing of this very article. This fuel source is, of course, food. Until the industrial revolution, almost all tasks in human society were performed utilizing labour that came from the muscles of human or animal workers. Of course, even in the prehistory of humanity, we had already learned to harness certain types of energy and using specific tools, we could repurpose that energy to do some of our work for us. Wind powered boats, whose sails were one of the earliest known examples of wind energy known to man, would ferry people and cargo up and down rivers and even across seas, as long as 6,000 years ago. Additionally, people used fuel sources such as wood, straw, and dry dung to burn for heat. And of course early mills would utilize the

The steam engine continued to evolve over time, but it was not until the 17th and 18th centuries that we saw them being put to use in machines. Engineers such as George Stephenson, Thomas Newcomen, and James Watt refined the design of the steam engine and used coal, rather than wood for the fire.

potential energy stored in the water of a flowing river to ground wheat or irrigate crops, one of the world's earliest known uses of hydropower. . So, we begin our journey into the world of alternative energy with the first examples of traditional or mainstream energy known to man, that would ferry people and cargo up and down rivers and even across seas, as long as 6,000 years ago. Additionally, people used fuel sources, such as wood, straw, and dry dung as a source of heat. And of course, early mills would utilize the potential energy stored in the water of a flowing river to ground sources viz. person or animal power and wood, the two chief fuels of human history.

Chugging along the Energy Pathway

The first alternative to traditional forms of energy consumption was steam power. Recent archaeological finds have revealed that the ancients were perhaps aware of the potential of steam as a source of fuel for machines. Heron was a Greek philosopher, mathematician, and engineer who lived in the famed city of Alexandria in then Roman-controlled Egypt between 10 and 70 CE. One of the great experimental scientists of the classical age, he developed perhaps the earliest known steam engine in the world. Called the Aeolipile, it consisted of a large covered basin filled with water connected to a sphere by two pipes that also acted as a stand, holding the sphere in position some distance above the water basin. The sphere had two exhaust pipes fitted on either side that pointed in opposite directions. The principle is the same as found in any steam-powered turbine even today. The basin was heated, usually with a wooden fire below it, until the water inside started to turn into steam. The steam would rise up the pipes into the sphere and then come out rather forcefully through the two exhaust pipes attached to the sphere—much like steam escaping a pressure cooker—and cause the sphere to rotate. Whether this machine had any practical usage or was it just a way through which certain laws of nature could be divined is still not known, but it remains the only surviving instance of people nearly 2,000 years ago utilizing the power of steam to create what we could call an engine.

The steam engine continued to evolve over time, but it was not until the 17th and 18th centuries that we saw them being put to use in machines. Engineers such as George Stephenson, Thomas Newcomen, and James Watt refined the design of the steam engine and used coal, rather than wood for the fire. This was a time when coal was found in abundance in the UK and labour was expensive. James Watt, along with William Murdoch, most famously used the principle of the steam engine to create the first locomotives and thus are regarded as being the people who ushered the industrial revolution, which after the agricultural revolution of 10,000 years

ago, has probably had the greatest impact on the way humans live and interact with the world.

Burning Our History (and Future)

Coal, crude oil, and natural gas were formed when organic matter such as trees, bones, leaves, and other plant and animal remains were buried under layers of sediment and compacted by the immense amount of heat and pressure subjected on them over millions of years. Every bit of oil and all its derivative products, kerosene, Plastics, petroleum jelly, soap, and fertilizer, they were all once living beings millions of years ago. Hence, the name fossil fuels; these fuels are flammable fossilized remains of once living things. To put it succinctly, every time we burn a lump of coal or a litre of crude oil, we are quite literally burning our past. Coal, oil, and natural gas are enshrined in the way the world works for many of us. They form the basis of the modern global economy and have done so for as long as anyone alive on the planet can remember. And yet, on a macroeconomic scale, they are but minor blimps in the history of energy sources that humanity has

been dependent on. What does make them extremely noteworthy, however, is the impact they have had on the world in such a short space of time; both in terms of how much humanity changed as a consequence of their use and also how their incessant usage has brought us to the brink of an environmental disaster.

Ever since the industrial revolution, immense quantities of coal were used to fuel the economic growth of the West. This consequently led to an unprecedented change in the way people lived. Traditional small village communities gave way to urban metropolises and while many people left their farms to work in horrific conditions of the factories in the city, others grew to be extremely wealthy. At the dawn of the industrial revolution, fossil fuels would have appeared to be nothing short of the ideal energy source on which to run the machines that were changing the world. When we picture the industrial revolution, the first thing we think of are steam locomotives. They have been described as "the quintessential machines of the industrial revolution". One of the reasons why they used coal as a fuel source right from the beginning was not only that coal fires generated more energy and hence more steam, but in the 17th and 18th centuries, firewood and charcoal were running in short supply.

Coal was, surprisingly, the sustainable fuel of the future for the people living in the midst of wood-burning economy. There was what would have appeared to a then global population of less than a billion people an ostensibly endless supply of coal that was furthermore easier to exploit thanks to its presence in seams near the ground surface, and finally, coal did not require any further refining or shaping for use. It was the ideal alternative to wood. By the mid-1800s, railroads—the symbol of industrialization and the chief utilizer of coal fuel—were present in almost all major countries around the world, including India. The year 1885 is significant in the history of energy consumption around the world. It was when coal overtook wood to become the singular most used source of fuel across the world. However, even at the time, it was ascending to its peak of power; coal's days as the global fuel source *du jour* were numbered.

The Quest for Black Gold

The ancient Sumerians, Egyptians, Assyrians, and Babylonians all talk about finding oil in their fields. These civilizations were centred in a part of the world that today is the home to nations whose entire economies depend on oil exports. Back 5,000 years ago, the gelatinous black liquid oozing out of the ground was seen as a nuisance. Sure, it could be used to light torches and fires, but it was otherwise ruining land that could have been used to grow crops. The word asphalt comes from Aslphatites, the old name for the Dead Sea in modern-day Israel, as it was common for crude oil to bubble up to its surface and wash up on its shore.

Meanwhile in North America, oil would be found on the surface of streams and lakes, particularly in the south-western part of the continent, and it was common for native American tribes to use blankets and try to absorb this oil from the surface of streams, rivers, and lakes. Crude oil was used by native Americans as a sort of medicine to treat wounds and diseases (the efficacy of these treatments is unknown, but we can assume they would not have been too great). A great practical use of this crude was to make their canoes and boats water-proof. Crude oil may not have been discovered in the United States, but it is because of the country that it has come to reshape the way the world works. The first major demand for oil came for heat and light, those most basic of needs. During the mid-1800s, whaling was perhaps one of the most critical energy-based industry known to most of the world. Most of Europe and the US used lamps that required whale oil to give out any light and indeed warmth. This led to humanity embarking on a mission that to the intelligent and sentient, whales would have appeared to be nothing short of an invasion and attempt at genocide. Tens of thousands of whales were slaughtered every year by whaling ships that left from a hundred ports in the Atlantic and Pacific in a vendetta against an animal that had not much of a history of harming human beings. However, whales, like any other energy source, come in a finite quantity. And as we refined our killing techniques, we became rather too efficient at killing whales. Whalers would kill a mother whale, orphaning the child, who would then starve to death or be eaten by sharks and there would be no way for the to be replenished. As the number of people using whale oil lamps grew, the number of whales to kill for their blubber started to diminish and consequently, the price of whale oil started to skyrocket. At this time, people started to switch to lamps that used petroleum oil. At that time, petroleum oil came from one of two main processes, distilling coal into a liquid and the ancient native American practice of skimming it off the surface of lakes.

We remember significant moments in human history as big events that saw the participation of thousands or even millions of people. But sometimes, days that change the world make no headlines that itself and can involve just one person. On August 27, 1859, Edwin L Drake struck liquid oil at his well near Titusville, Pennsylvania. It was an unexceptional day; striking oil was incredibly easy in the US around that time. What he did to change the world irrevocably was discover a technique that would allow him to access the oil he found under the ground and then pump it to the surface. He would pump this liquid oil from the ground and store it in barrels made of wood. This method of drilling for oil is still being used today all over the world in areas where oil can be found below the surface. And even to this day, we still measure the volume of crude oil that is pumped out of the ground in barrels.

From its modest beginnings in the middle of the 19th century, the oil industry grew to become one of the most lucrative and globally dominant forms of commerce in the modern world. After initial use as a source for kerosene used to light and heat homes, the drilling technique discovered by Edwin Drake allowed larger and larger quantities of oil to be extracted from the oil wells that seemed to sprout up suddenly like flowers in spring across the vast expanse of the US helping the country become a global economic behemoth by the time the 20th century arrived. The US was gripped by oil fever and the industry drew some of the smartest and shrewdest business minds towards its fold. The growth of the oil industry and the technology that grew to facilitate it could be argued to be the most important factor in making the US the global superpower it is today. Petroleum was and continues to be consumed as the primary energy source for everything from transportation, first in the form of automobiles and ships, and later aeroplanes, to being utilized for generating electricity, while continuing its old business as a form of heating for people living in cold climates.

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Future Needs an Alternative

However, nothing lasts forever and even the joys of an oil-fuelled economy can only last for so long. Oil is a limited resource and while it has given humanity an unprecedented period of growth in the last century and a half, it has also seriously devastated the planet and is soon going to run out permanently. Our need for oil has only grown in the last few decades and yet despite the numerous crashes and warnings about Peak Oil, which started as far back as 1964, we do not seem to be able to kick our global crude habit. If human civilization is to survive in its present form and if we are to avoid catastrophic natural calamities, it is imperative for us to work together to build an energy future whose foundation and edifices are made of energy sources that are clean, renewable, and can help us maintain a sustainable and green growth model. What options do we have, then? The standard ones people have been exploring are solar, wind, and hydropower. The third option is the most familiar to us. Human beings have been harnessing the power of moving water, right from Ancient Egypt. Solar and wind powers are newer concepts to most people, even though they have been around for decades now. However, it is essential to look at other alternative energy sources that might turn out to be dark horse contenders in the search for the next big energy player.

Hydrogen: Fuel of the Future?

Hydrogen would be the ideal fuel of the future. It is high in energy and yet the process of burning pure hydrogen produces almost no pollution. Since the 1970s, space agencies around the world have been using pure liquid hydrogen as a fuel source to launch rockets and the space shuttle. It also fuels the space shuttle's rockets and its electrical systems. Once again, the only byproduct of this process is water, which the astronauts drink while aboard the station. Hydrogen is the most abundant substance in the whole universe; 74 per cent of all known matter in our universe is hydrogen. Thus, as far as supply is concerned, humanity should in theory feel a bit confident about it. Nevertheless, nothing in life comes so easy and making hydrogen a viable alternative energy source comes replete with its own set of challenges. The biggest problem is that it does not occur in its natural form on Earth. It is the lightest element in the universe and the power of the Earth's gravity is not enough to keep it tethered in our atmosphere. This is a good thing because hydrogen is a highly reactive gas that combines with almost every other element there is. Similarly, on the Earth, hydrogen is usually found combined with oxygen to create a compound that we are all very familiar with—H_2O, or water.

Hydrogen can also be found in many natural organic compounds that are found in the Earth's crust, most conspicuously in the hydrocarbon chains that form the building blocks

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of most of our current sources of energy through fuels, such as petroleum, natural gas, and methanol. The challenge, however, remains synthesizing hydrogen in its pure form and using it as a fuel source. While burning, hydrocarbons produce carbon dioxide and other noxious and dangerous Greenhouse Gases (GHG); burning pure hydrogen produces only one byproduct, i.e., water. Therefore, the question remains, how does one synthesize hydrogen from the atmosphere or more abundant sources, like, the oceans, which cover over 70 per cent of the Earth's surface area? The most dominant method for producing hydrogen on industrial scale today is steam reforming, where hydrogen is separated from hydrocarbons (predominantly natural gas) through the application of heat and pressure. This process does release some amount of carbon dioxide and other GHGs into the atmosphere as a by product and is thus not the ideal way to produce hydrogen. The ideal way to extract hydrogen through water is yet to be discovered but there are some contenders, such as electrolysis, radiolysis, where nuclear radiation can be used to break down the bonds of water molecules to release hydrogen, and hydrogen from biological processes, such as generating hydrogen from waste or through living creatures such as fungi and algae. A hydrogen fuel cell combines hydrogen and oxygen to produce electricity, heat, and water. Fuel cells are sometimes compared to batteries as both batteries and fuel cells convert the energy produced by a chemical reaction into usable electric power. However, unlike a battery, the fuel cell will produce electricity as long as its fuel is being supplied, thus making it more akin to a generator than a battery. These cells are a technology with nearly limitless uses; they can be used for providing electricity for buildings and gated communities in residential localities and commercial properties, and can also act as a backup source of power for large-scale power distribution networks. Research is currently underway to evaluate the usability of hydrogen fuel cells in powering consumer electronics, such as laptops and even for smartphones, if they can be shrunk to that size. This would mean that these devices could run for months or even years at a time without needing to be recharged or rather refuelled.

The primary use of these cells in the world today, and a use of theirs that has the potential to revolutionize the way we live, is in the sphere of transportation. Hydrogen fuel cells are now inside cars, trucks, ships, trains, and experimentally even airplanes, powering them to match the speed, handling, and reliability of traditional gasoline powered vehicles while emitting nothing but water from their exhaust pipes. The Honda FCX Clarity, the Audi A7 H-Tron Quattro, the Mercedes Benz F-Cell, and the Alfa Romeo MiTo FCEV are just a few examples of traditional major automobile companies investing heavily in making alternative energy powered cars.

Making Them Ourselves: Synthetic Fuels and Carbon Neutral Fuels

It is possible to artificially synthesize fuels on an industrial scale, just not on an economic one. Synthetic fuels, as the name indicates, are artificially

produced fuels, created by the effective utilization of ultimately rather simple chemical processes. Carbon-neutral fuels are a category of synthetic fuels produced by treating waste carbon dioxide with hydrogen in a chemical process known as hydrogenation. This waste carbon dioxide is usually recycled from any number of sources using the principles of carbon capture and storage. Some of these sources include power plant flue-gas emissions, automotive exhaust gas emissions, and it can even be derived from carbonic acid in seawater. Another synthetic fuel that is slowly entering the energy mainstream is Renewable Methanol (RM), a fuel manufactured from when carbon dioxide reacts with hydrogen through a process known as catalytic hydrogenation. It can be used as a fuel for vehicles, making it yet another alternative to fossil fuels in the transportation sector.

Extra-heavy oil is a synthetic fuel that can act as a source of another synthetic fuel; Syncrude, a fuel whose properties closely resemble those of traditional crude oil. However, extra-heavy oil is not completely manufactured artificially. It can be found in nature and is formed when deep oil is extracted from within the surface of the Earth and is exposed to bacteria that process the hydrocarbons in it and thus, alter its physical and chemical properties. A serious problem with mass-producing extra-heavy oil, however, comes from the extraction process. The process itself is highly dangerous towards the environment and requires clearing vast quantities of land and destroying the habitat of many animal and plant species. This makes the fuel a viable but highly unsustainable alternative to traditional fossil fuels.

As global oil prices seem to rise higher every day, governments and energy companies alike have been desperately searching out ways in which they can find alternatives to traditional energy sources, such as coal, crude oil, and natural gas. When one looks at the political and military instability rampant in many of the geopolitical regions that supply the world with most of its fossil fuels, the problem is further exacerbated and the need for alternative energy sources becomes more acute. The key advantage of artificially synthesized fuels is that they can be produced by chemical reactions where the primary ingredients are easily available to most countries. This is especially true of many kinds of ethanol that are manufactured by chemically treating plant waste from agriculture. Furthermore, many synthetic fuels emit fewer quantities of dangerous GHGs than traditional fossil fuels and can thus, help lower the total GHG emissions currently being pumped into the earth's atmosphere.

However, one must always look deeper when examining the environmental impact of any large-scale industrial process and it is possible that the process of manufacturing synthetic fuels is just as harmful to the environment as using traditional fuels. This could negate or worsen the impact of using synthetic fuels whose GHG emissions are lower than traditional fossil fuels. Another serious drawback is the price. Synthetic fuels are extremely expensive to produce, and it would require even more funding into research and development to find ways in which these fuels can be made cheaper and less harmful to the planet.

A Return to Nuclear Power

Once touted as the fuel of the future, incidents such as the Chernobyl disaster, the Three Mile Island accident, and the Fukushima leak, as well as concerns over nuclear waste and third world countries using their nuclear fuel to create weapons of mass destruction have since put a damper on the growth of nuclear power across the world. However, with the growing global demand for energy juxtaposed with the impending global crisis in energy caused by fossil fuel production peaking sometime over the next couple of decades has meant that the world is looking at nuclear power as a low-carbon established alternative to fossil fuels, at least until more sustainable forms of energy become readily available. Within the wide gamut of possibilities in nuclear power, an interesting potential alternative energy source is the element thorium.

One of the main advantages of thorium over traditional nuclear fuel such as uranium is that according to recent estimates, thorium is estimated to be four times more abundant than uranium. Moreover, unlike uranium, thorium deposits are more or less evenly distributed across the world. Large amounts of thorium reserves are found in India as well as China, Australia, the US, Turkey, and Norway. Furthermore, intensive research into safe and efficient thorium powered nuclear reactors could see this fuel used highly efficiently. It is estimated that around 6,600 metric tonnes of thorium could generate enough or indeed more power than that generated by all the fossil fuels and traditional nuclear energy in the world at the moment.

Thorium is dark, shiny, and slightly radioactive metal which is not fissile in its natural form, indicating that it cannot split to sustain a nuclear chain reaction on its own. However, if a small amount of starter fuel, usually in the form of fissile nuclear elements such as uranium-235 and plutonium-239 are used to bombard thorium's atomic nucleus with neutrons; it causes thorium to convert into uranium-233, the ideal fuel for a nuclear power plant. Once this reaction is started, the thorium that was converted into uranium-233 can then convert more thorium into more uranium-233, thus creating a chain reaction that generates even more nuclear fuel.

Advantages of such reactors are that the fluoride salt that is used as a coolant has an extremely high boiling point, namely 1,400 °C. The system itself operates at a temperature of around 750 °C, thus the system does not need to be pressurized like current nuclear reactors are. With no pressurization, there is no risk of a catastrophic leak. Furthermore, since the core is already in liquid form, there is no fear of a meltdown, implying that catastrophic accidents like Chernobyl and Fukushima are not a possibility with thorium fuel reactors. Even if the core overheats, there is a backup in the form of a plug of frozen fluoride salt, which would then melt and drain the thorium into a containment vessel until it cools down. And this cooled down nuclear component can be reused once again. The nuclear waste residue of thorium nuclear reactors lasts for about 30 years, with some components requiring 300 years of storage. However, this is a marked improvement of the 10,000 years current nuclear waste needs before it becomes inert.

Conclusions

The quest for an alternative fuel source is one of the oldest challenges that has continuously faced humankind, and as the modern energy crisis becomes more severe by the day, it has become imperative for global society to focus on figuring out a way we can create an effective alternative to fossil fuels that are easily available, economical, and better for the environment. People of the 19th Century could not have predicted that burning coal and oil could lead to an industrial revolution that would in turn result in an explosion of the human population on the earth leading to more burning of coal and oil. This vicious cycle eventually led to humanity emitting so much GHGs into the atmosphere that completely changed the climate of the earth. Could we do something equally dangerous if one of the alternatives described were to be adopted globally in the near future? The possibility exists, but the risk of not acting far exceeds the potential risks of acting. Thus, it is in our best commercial, humanitarian, political, and just sheer survival interests to find an alternative energy source at the earliest opportunity. EF

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TEAM... From Organic Waste to Energy

The success of the popular 'Clean India' campaign is impossible until the problem of organic waste management is addressed. **Dinesh Chander Pant** and **Nagendra Kumar** discuss the various aspects of a technological solution called TEAM... which treats the organic biodegradable waste in a scientific manner.

The 'Clean India' campaign, initiated by Prime Minister Narendra Modi aims to completely tidy the country by 2019. This mission has motivated every citizen to dispose of different types of waste in a scientific manner. The organic biodegradable waste, generated at a rate of 0.25 kg per capita per day, poses a challenge to civic bodies, in addition to putting burden on our environment. Further, the problem of waste disposal and compliance with the Municipal Solid Waste (Management and Handling) Rules, 2000 in India has popped up a challenge for industries, institutions, and upcoming townships. This is also due to the non-availability of technologies suitable for the Indian conditions. The imported technologies are either too costly or unsuitable for them.

According to a report on Waste to Energy (WTE) published by the Planning Commission of India, about 50 million tonnes of Municipal Solid Waste (MSW) is generated every year by the India urban population. This has a potential for generating over 2,600 MW of electricity in the country. In India, MSW comprises organic and inorganic waste, including recyclables in the following proportion:

- Organic matter (biodegradable and non-biodegradable) 35–65%
- Inert materials 20–30%
- Recyclable matter 5–15%

The organic fraction of MSW is an efficient source of energy and can be easily utilized while the recyclable matter can be reused, leaving inert matter for the landfills. It is essential to segregate the organic biodegradable waste from MSW. In this regard, many state governments have launched several campaigns to spread awareness about the importance of segregation. In many places, such as hotels, hostels, institutional canteens, and fruit and food processing industries, the organic waste is generated devoid of any other matter but gets mixed with the MSW due to lack of decentralized treatment technologies. On the other hand, this waste is the best suited form of waste for recovery of resources (biogas and manure), if subjected to an appropriate technology. By doing so, these organizations/industries would not only comply with the Municipal Solid Waste (Management and Handling) Rules, 2000 and 'Citizen's Charter', but also add on to their green rating. Hence, utilizing the organic waste for recovery of resources turns out to be a win-win situation for the society as a whole by reduction of Greenhouse Gas (GHG) emissions. It should be noted that wet biodegradable waste can be converted into useful energy through biological route. Anaerobic digestion technology is the most suitable biological process for energy and manure recovery from such waste.

Anaerobic Digestion Technology

Anaerobic Digestion (AD) technology consists mainly of four processes, i.e., enzymatic hydrolysis, acidogenesis, acetogenesis, and methanogenesis (Figure 1).

Hydrolysis

The first and primary stage of biomethanation is conversion of biopolymers, such as carbohydrates, proteins, and lipids by extracellular hydrolases excreted by microbes. The hydrolytic bacteria are made up of both facultative and strict anaerobes. For complex substrates with high organic content, hydrolysis is the slowest and hence, the rate limiting step in the overall anaerobic digestion process. Polysaccharides such as cellulose, starch, and pectin are hydrolyzed by celluloses, amylases, and pectinases. The hemicelluloses and cellulose are broken down by extracellular hydrolytic enzymes, whereas lignin is quite resistant to degradation. Lipids are transformed into long-chain fatty acids by the action of lipases. *Clostridia* and *Micrococci* appear to be responsible for most of the extracellular lipase production. Proteins are generally hydrolyzed to amino acids by proteases, secreted by *Bacteroids, Butyrivibrio, Clostridium, Fusobacterium, Selenomonas,* and *Streptococcus.*

Acidogenesis

Acidogenesis is the conversion of soluble organic molecules produced by hydrolytic bacteria into simple organic compounds, such as volatile fatty acids, alcohol, lactic acid, and mineral compounds, such as carbon dioxide, hydrogen, ammonia, and hydrogen sulphide. In the case of cattle manure, the acidogenic bacteria grow on soluble products of hydrolysis, consisting of a readily degradable component, hemicelluloses; and a slowly degradable component, i.e., cellulose.

The following chemical reactions show the end products of acidogenesis such as acetic and butyric acids:

$$C_6H_{12}O_6 + 2H_2O \rightarrow 2CH_3COOH + 4H_2$$

$$C_6H_{12}O_6 \rightarrow CH_3CH_2CH_2COOH + 2CO_2 + H_2O$$

Acetogenesis and dehydrogenation

Although acidogenic fermentation of biopolymers produces some acetate (20 per cent) and H_2 (4 per cent), both products are also derived from the acetogenesis and dehydrogenation of higher volatile fatty acids. The organisms that convert

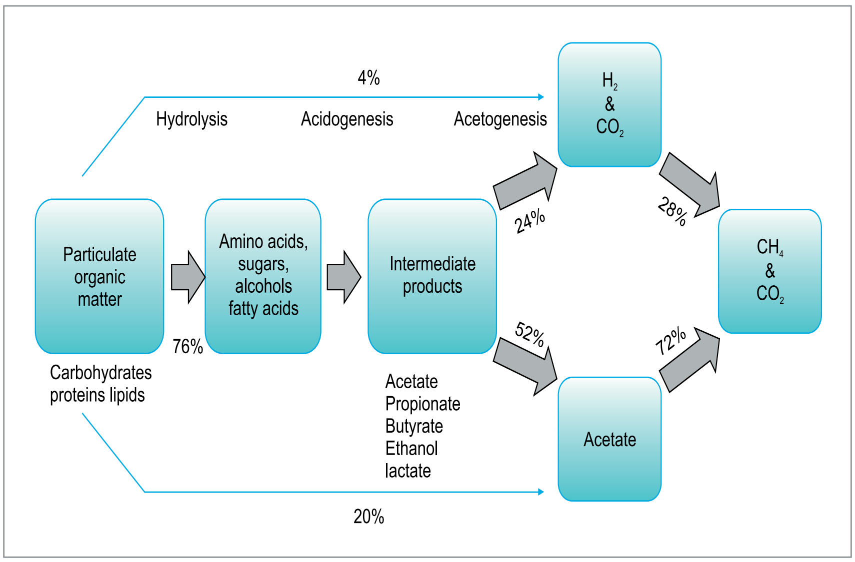

Figure1: Stages of biomethanation

(Source: McCarty PL 1982 and Mirzoyan *et al.* 2010)

intermediates, such as propionate, acetate, butyrate, lactate, and ethanol to acetate are obligate hydrogen producing acetogenic bacteria. An excess of hydrogen often leads to an increase in longer chain Volatile Fatty Acids (VFA) and lowering of pH and inhibition of acetogenesis. The H_2 utilizing bacteria in turn rely on acetogens for their hydrogen source. The following are the principle reactions involved in acetogenesis step:

$\text{Propionate} + 3H_2O \rightarrow \text{acetate} + HCO_3 + H^+ + 3H_2$

$\text{Butyrate} + 2H_2O \rightarrow 2\ \text{acetate} + H^+ + 2H_2$

Methanogenesis

The methanogens are obligate anaerobes belonging to the *Archea* kingdom. Methanogenic substrates include acetate, methanol, carbon dioxide, methylamines, and methyl mercaptans. In the gastrointestinal system, more than 70 per cent of methane formed is derived from acetate, depending upon the starting organic carbon. In contrast, in ruminants where acetic acids, propionic acids, and butyric acids are removed by adsorption through the rumen wall and then metabolized by the host, methane is produced from the reduction of CO_2 and H_2.

The following are the principle reactions involved in the process of methanogenesis:

$4H_2 + HCO_3^- + H^+ \rightarrow CH_4 + 3H_2O$

$\text{Acetate}^- + H_2O \rightarrow CH_4 + HCO_3^-$

Based on the AD technology, The Energy and Resources Institute (TERI), Delhi has developed a bi-phasic AD process which has been named as TERI's Enhanced Acidification and Methanation (TEAM) process for the treatment of organic solid wastes (Patent no. 2655/Del/97).

Evolution of TERI's Enhanced Acidification and Methanation (TEAM) Technology

The TEAM technology is a culmination of the enormous experience gained through field research and development by the organization. In fact, TERI gained versatile experience through research, design, development, and installation of about 150 biogas plants in one of the districts of Haryana in the later part of 1980s. These plants were installed for biogas generation from cattle dung for cooking application. During operation and monitoring of these plants in the field, it was experienced that the efficiency of the plant reduces on account of the many operational and maintenance problems, such as:

- Scum formation in small-size-plants
- Accumulation of sediments at the bottom;
- Reduction in active reactor/digester volume leading to incomplete digestion of waste and lesser gas volume;
- Switching over to different feedstock was not possible;
- Managing slurry was also a challenge;

Using this experience and realizing the potential of wet biodegradable waste and lack of decentralized system for the treatment of such waste, the TEAM process evolved as a technological solution.

TEAM Technology

The TEAM technology is a two-stage process comprising acidification and methanation (Figure 2). In the acidification phase, the organic content of the solid waste is leached out to make a high strength liquid by decomposition of the waste with intermittent sprinkling water. In the methanation phase, this high strength leachate is treated in a high rate Upflow Anaerobic Sludge Blanket (UASB) reactor to produce biogas. The process has been designed to overcome the basic hurdles experienced in conventional anaerobic digesters like scum formation, floating of waste, long retention time, etc. Also, the separation of the acidification and the methanation phase can solve the problem of control of pH during the methanation phase of digestion.

The digester has been successfully tested for different types of solid wastes for the generation of useful resources, i.e., biogas and manure. The promising results ensure the viability of the technology for wastes from varied sources. Based on the studies, food waste from hotels and canteens was found to have maximum potential for biogas generation. The volume of waste reduces to 10 per cent after digestion and the sludge is dried to produce good quality manure. Due to its unique design and bi-phasic nature, the technology can treat any kind of organic waste within a short retention time of seven days without use of mechanical mixing. Its uniqueness also lies in its capability to recycle the water within the process and production of non-flowable slurry after digestion of the waste resulting in reduced water consumption and aesthetic conditions around the plant.

Salient features of TEAM

Some of the key features of TEAM are as follows:

- High rate methane producing reactor
- Low Hydraulic Retention Time (HRT) of seven days
- Digested waste has high Nitrogen Phosphorous Potassium (NPK) values
- High methane content in biogas (>75 per cent)
- Elimination of scum formation—a feature in small-size plants
- Production of non-flowable/semi-solid digested residue

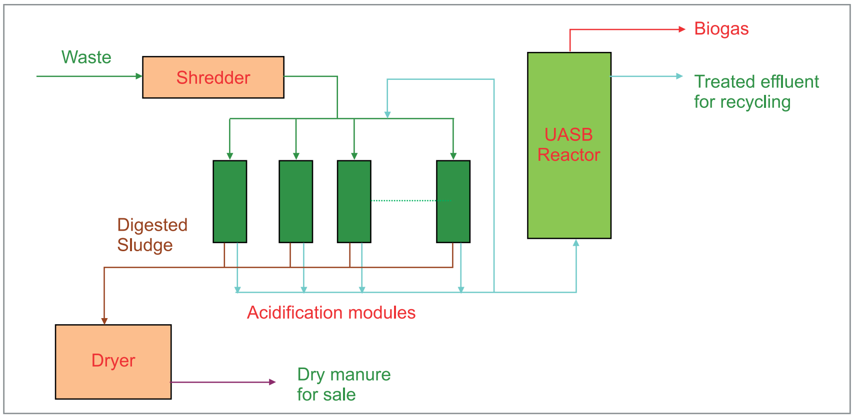

Figure 2: Schematic diagram of the TEAM process

- Suitability for small and decentralized application
- Very low water requirement due to recycling within the process
- Aesthetic look with low maintenance cost
- No environmental impact
- Successfully tested for wastes, such as leafy residue, food, press mud, food-processing leftover , tea waste, vegetable market waste, township waste, etc.

Field Implementation of TEAM

TEAM has created a good number of footprints in the field. It has been well accepted and appreciated by many institutions, Public Sector Undertakings (PSU), corporate houses, and municipalities. It has been disseminated at various capacities/ packages (50–2,000 kg/day) with different materials of fabrication like Mild Steel (MS), Stainless Steel (SS), Fibre Reinforced Plastic (FRP). Simultaneously, it has also been a matter of further improvement for the research team of TERI. Few of the prestigious installations of TEAM are as follows:

- NTPC Ltd, Kahalgaon, Bihar
- New Mumbai Municipal Corporation (NMMC), New Mumbai
- Sirsi Municipal Corporation, Sirsi, Karnataka

A TEAM plant at Neptha Cracker Unit, IOCL, Panipat, Haryana

Bio-Methanation Plant, NTPC Ltd, at Kahalgaon, Bihar

A TEAM plant at CIDCO, NMMC, Mumbai

- IOCL Panipat Refinery, Panipat, Haryana
- Naphtha Cracker Unit, IOCL, Panipat, Haryana
- NTPC Ltd, Dadri, Gautam Budh Nagar, UP
- Tehri Hydro Development Corporation Ltd, Rishikesh, Uttarakhand
- Numaligarh Refinery Ltd, Assam
- NTPC Ltd, Kawas, Surat, Gujarat
- IOCL R&D Centre, Faridabad, Haryana
- M/S Vedanta Aluminium Ltd, Lanji Garh, Odisha
- ONGC Colony, Sector 39, Noida, Uttar Pradesh
- CIDCO, Navi Mumbai
- NTPC Ltd, Singrauli, UP
- Gujarat State Fertilizers and Chemicals Ltd, Vadodara, Gujarat
- Sona Koyo Steering Systems Ltd, Gurgaon, Haryana
- NTPC, Faridabad, Haryana
- IBIS Hotel, Bengaluru
- TERI Campus, Gual Pahari, Gurgaon, Haryana

The technology is suitably designed for treatment of organic waste in decentralized manner for recovery of resources. TEAM is ready to be adopted in any part of the world except for extremely cold regions. The target areas could be any source of organic waste, such as industrial canteens, townships, vegetable markets, small cities, food and fruit processing units, sugar industries, etc.

Case Studies

Plant at NTPC for household waste

Influenced by the features of the TEAM process, National Thermal Power Corporation (NTPC) Faridabad gas power plant decided to treat their household organic waste with the help of this process. For successful continuous operation of the plant, NTPC organized an awareness programme and inculcated the habit of segregation of organic waste among their fellow residents at their respective household level. This practice helped them to dispose of their waste appropriately with dual motives of production of biogas and manure from organic waste and enhanced the hygienic conditions within the campus as well.

This is indeed an exemplary concern shown by NTPC towards the 'Citizen's Charter' chalked out by the Parliament and also speaks volumes of its social responsibility.

Waste was procured from locations, such as townships and guest houses. The total quantity of organic waste collected was approximately 50 kg/day. The biogas so produced is being utilized in a hospital and the manure is used for horticultural purposes.

Specifications of the plant are as follows:

- Capacity of the plant: 50 kg/day
- Type of waste treated: Household waste
- Material of fabrication: Mild steel

- Year of installation of the plant — 2006
- Amount of waste treated — 146 tonnes
- LPG replaced till date — 2.9 tonnes
- Manure generated — 14.6 tonnes
- Savings on GHGs — 44 tonnes of CO_2 equivalent

Plant at Sona Koyo Steering Systems Limited, Gurgaon

Sona Koyo Steering Systems (SKSS) Limited had a conventional biogas plant for the treatment of their canteen waste, which was not functioning properly for a long time. This conventional plant was replaced with the TEAM technology. SKSS serves meals to their 2,000 staff members in three shifts During this exercise, a huge amount of waste is generated. Approximately 100 kg of waste is being produced every day by the canteen. After installation of the TEAM process, their waste disposal problem has not only been solved, but they are also partially replacing their Liquefied Petroleum Gas (LPG) with biogas. Since the time of installation, the plant is performing efficiently.

Specifications of the plant are as follows:

- Capacity of the plant — 100 kg/day
- Type of waste treated — Canteen waste
- Material of fabrication — Stainless steel
- Year of installation of the plant — 2006
- Amount of waste treated — 250 tonnes
- LPG replaced till date — 6.5 tonnes
- Manure generated — 25 tonnes
- Savings on GHGs — 100 tonnes of CO_2 equivalent

Cost and space optimization: A regular feature of TEAM development

The TEAM technology is being upgraded from time to time with a perspective of cost and space optimization. In this regard, TERI developed a compact system wherein acidification reactors were developed in a common chamber with separation walls to divide the chamber into six different reactors. With this, the recirculation pumps, which were six in numbers in the previous model, have also been reduced to two. Thus, through this new design, a reduction in footprint area and about 20 per cent reduction in the cost of the plant has been achieved. This new design has also been implemented in the field at various locations like:

- TERI Campus, Gual Pahari, Gurgaon
- IOCL Refinery, Panipat, Haryana
- IOCL Naptha Cracker Unit, Panipat
- New Mumbai Municipal Corporation (NMMC), Mumbai

Efficiency optimization of TEAM

In order to further improve the efficiency of TEAM in terms of biogas generation, efforts are being put into extraction of residual biogas from the digestate. The concept of residual biogas extraction has been successfully tested at pilot scale. A TEAM technology merged with this concept will soon be implemented in the field.

TEAM has proved to be an excellent technological solution for organic waste treatment. It can be designed for any capacity and in any materials (MS/SS/FRP/RCC etc.). It is most suitable for segregated organic waste. More so as small pieces of paper, plastic, glass, metal, etc., come mixed with waste, it will not impact the performance of the digester. EF

Dinesh Chander Pant, Fellow, and Nagendra Kumar, Research Associate, TERI. Email: dpant@teri.res.in

A TEAM plant at Neptha Cracker Unit, IOCL, Panipat, Haryana

A TEAM plant at Sona, Haryana

ORGANIC WASTE IN INDIA'S ENERGY SUPPLY

Shantonu Roy and **Debabrata Das** advocate the case of fuels made from organic waste to meet the country's increasing demand for energy. They discuss the characteristics of different kinds of organic waste, and technologies that are applied to extract energy.

The global energy scenario revolves around the usage of fossil fuels. These hydrocarbon fuels have limited reserves and are gradually depleting as the anthropological use of such fuel, increases. At present, the global energy demand is growing at an exponential rate. Globally, every year, over 11 billion tonnes of oil, in the form of fossil fuels, is consumed. For fulfilling such humongous demand, crude oil reserves are vanishing at the rate of 4 billion tonnes a year. According to a study by Shahriar Shafee and Erkan Topal published in 2009, with the current rate of energy consumption, the hydrocarbon reserves such as petroleum, coal, natural gas, etc., would get exhausted in next six to eight decades The rapid industrialization and urbanization has been driven by extensive and non-judicious use of fossil fuels. The use of hydrocarbon-based fuel has casted an evil eye on the environment. The emission of Green House Gases (GHG) such as carbon dioxide (CO_2), methane, and furfurals, has increased the global temperature. This phenomenon is regarded as global warming. Out of the total energy consumption of India, more than 50 per cent is contributed by coal followed by petroleum (36 per cent) and natural gas (7–9 per cent) (Figure 1). Nominal portion of

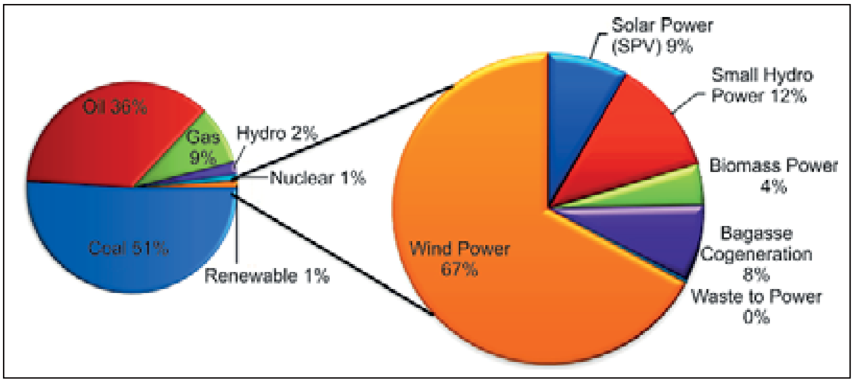

Figure 1: Energy generation scenario in India

(*Source*: IEA, 2006, World Energy Outlook 2006)

the energy requirement is fullfilled by nuclear and renewable energy resources.

Organic waste is the most abundant and renewable source of energy in the world (Figure 2). It is any organic matter, particularly cellulose or hemicellulosic, which is available on a renewable or recurring basis, including trees, plants, and associated residues, poultry litter and other animal waste, industrial waste, and the paper components of municipal solid waste. Globally, organic waste is increasingly becoming important as a clean alternative source of energy due to the rising energy demand, higher costs of fossil fuels, dwindling fossil fuel reserves, and contribution of fossil fuel usage to greenhouse effect. Organic waste has low energy density material with a low bulk density. This waste degrades on storage and is difficult and costly to transport, store, and use. Organic waste can be converted into fuels using different technologies (Figure 3). At present, about 500 million metric tonnes per year of organic waste is generated in India. This biomass has a potential of generating about 18,000 MW of energy India has around 580 odd sugar mills which generate bagasse which has the potential of generating about 5,000 MW energy by cogeneration technique.

Availability of Different Types of Organic Waste

Lignocellulosic and agro-forestry based biomass

In plants, starch and cellulose are the two abundant polymer molecules whose basic unit is glucose. Plants store energy in the form of starch whereas, cellulose forms the structural skeleton of cell walls for the leaves, stems, stalks, and woody portions. Moreover, plant cell walls and some algae also contain xylans which are polymeric sugar having xylose (a pentose sugar) as basic unit. Similar to cellulose, xylans also have predominantly glycosidic bonds betweenxylose subunits. Thus, due to large abundance of lignocellulosic raw materials, it might be considered as a suitable feedstock for the future biofuel industries. Lignocelluloses are biopolymer consisting of tightly bound lignin, cellulose, and hemicellulose. Sugar-rich plants such as *Miscanthus*, corn, beetroot, etc., could be considered as a source of fermentable sugars. Cultivation of such crops for biofuel purpose has evoked the debate on food versus fuel issues. Use of switch grass, rice husk, fodder

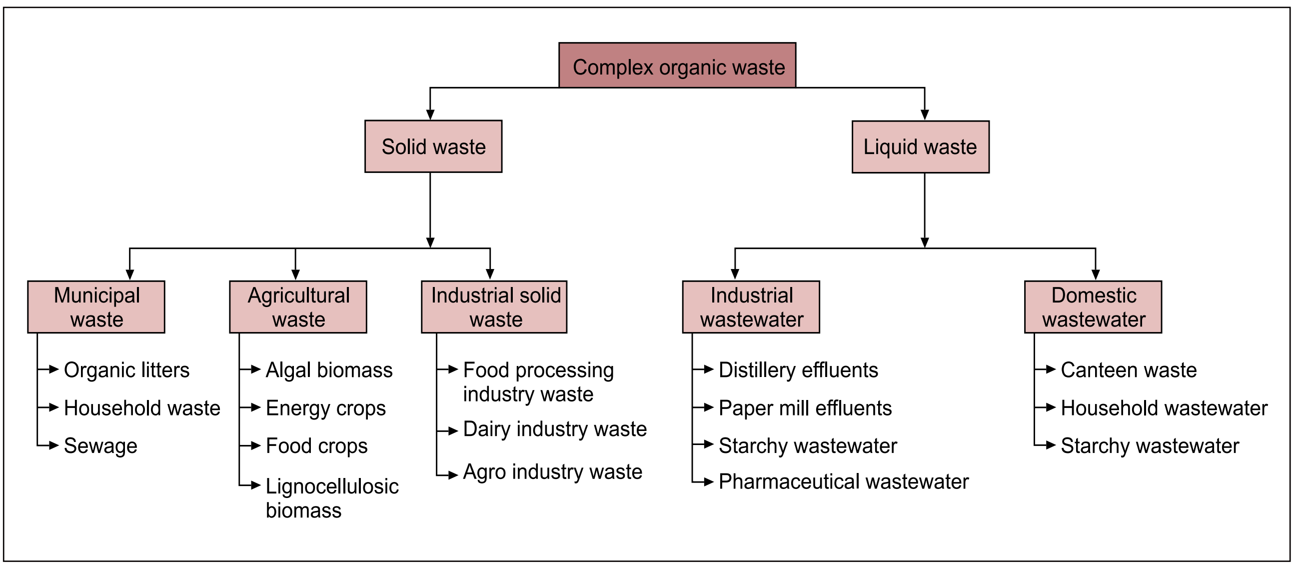

Figure 2: Different types of organic waste

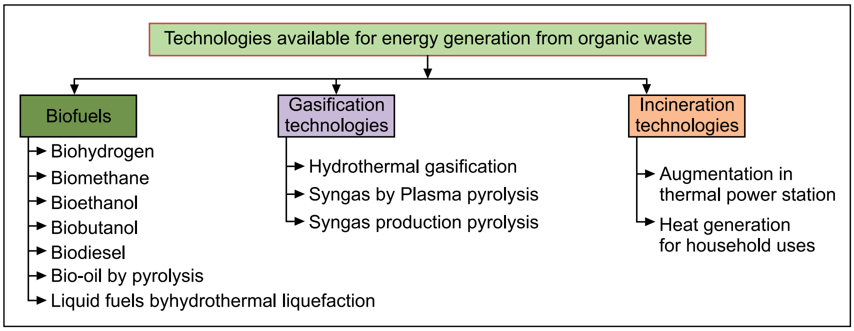

Figure 3: Avenues of energy generation processes from different organic waste

straw, etc., for biofuel production has gained importance in recent years. Lignocellulosic crops like these need a systematic pretreatment step to remove the lignin content. After lignin removal, the crystalline cellulose is still not accessible to microbes. Further saccharification of this crystalline cellulose yields simple sugars that could be used for bioH_2 production. Requirement of pretreatment and saccharification process increases the operational cost of the process. Moreover, many growth inhibitors such as furfurals are produced during pretreatment and saccharification processes. Lignocellulosic biomass might be in high abundance but requirement of harsh pretreatment and saccharification processes limits their use as feedstock. In recent times, algal biomass gained importance as feedstock for fermentation. Very few reports were available on the usage of algal biomass as feedstock for hydrogen production. This biomass is devoid of recalcitrant polymer such as lignin. Main food reserve in algae is either starch or semi-crystalline cellulose.

Food industry waste

Food processing industry is one of the booming businesses that contribute a chunk towards India's Gross Domestic Product (GDP). The processed food industries generate a lot of organic rich wastewater and solid waste. Disposal of food waste possesses a great environmental threat. It contains about 90 per cent volatile suspended solids, i.e., high organic content that makes them suitable feedstock for microbial fermentation.

Dairy industry wastewater

Dairy has been an essential part of India's rural economy. According to the Ministry of Food Processing Industries (MoFPI), the milk production capacity of milk industry is about 135 million tonnes a year. The milk-based industries generate a lot of organic-rich wastewater. These effluents have high Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD), which makes them hazardous for environment, if discharged untreated. The organic content of wastewater makes them an ideal contender as a feedstock for fermentative bacteria. Usage of such wastewater has been successful for the biogas production. Hydrothermal pyrolysis could also be used to a produce variety of liquid fuels.

Alcohol industry waste

According to a report cited by M Selvamurugan, P Doraisamy, and M Maheswari in 2013, India produces 1,680 million litres of distillery effluent per year. One litre of ethanol produces approximately 12 litres of effluent. Distillery or alcoholic beverage industry wastewater, is rich in biodegradable organic material such as sugars, hemicelluloses, dextrin, resins, and organic acids. Molasses-based distilleries generate 8–15 litres of wastewater/alcohol. This is wastewater has high COD (80–160 g/litre). It is also used for biogas production. Other technology of energy generation is incineration of distillery silage.

Municipal wastes or sewage water

In terms of availability, a recent report by A Pappu, M Saxena, and R Shyam, shows that India produces more than 38,254 million litres of sewage every day. The migration of rural population

to cities due to industrialization and population explosion is a major contributor towards generation of huge amount of Municipal Solid Waste (MSW). The quantity would further increase in the near future by virtue of development of the the country's economy. Organic fractions of MSWs are a widely available renewable resource which could be explored as feedstock for biofuel production. It is rich in polysaccharides and proteins. The dried sewage sludge is generally incinerated to generate heat energy. Anaerobic digestion of this waste generates good amount of methane that utilized be used to produce electricity.

Energy Generation Process

Biofuels from organic waste

Biohydrogen

Hydrogen could be projected as a possible source of clean and renewable energy in the future. It could decrease our dependency on hydrocarbon-based fuel with a high energy density (143 GJ/tonne) and low molecular weight. Hydrogen on combustion produces combustion and water as a byproduct. So, hydrogen can be considered as a zero-carbon fuel, which causes no GHG emissions, no toxic gas emission, and least propensity of acid rain and ozone layer depletion. Although hydrogen is the most abundant element in the universe, it must be produced from other hydrogen-containing compounds, such as biomass, organic wastewater, or water. In recent times, the idea of hydrogen-based economy has gained importance. India imports nearly 80 per cent of its crude oil needs which creates an immense pressure on the government's fiscal deficit. The conventional techniques involved in hydrogen production are steam methane, reforming, oil/naphtha reforming of refinery/chemical industrial off-gases, coal gasification, and water electrolysis. However, it was interesting to observe that hydrogen is produced mostly from coal. This makes the process energy-intensive with a high carbon footprint. Biohydrogen is considered a source of renewable energy as it can be easily produced from the biomass. Thus, energy generation could be coupled with waste management. Biohydrogen is mainly produced through the photolysis of water (direct and indirect biophotolysis) by blue-green algae and microalgae; oxidation of organic acids by photo fermentation and dark fermentation (using mesophilic or thermophilic bacteria). However, these processes have their own advantages and disadvantages. Biophotolysis of water and photo fermentation are marred with very low rate of hydrogen production and require light as an additional energy source. It also faces difficulty in scaling up of the process. Amongst the various other processes, dark fermentation appears to be promising as it is independent of light energy and yields more hydrogen.

In dark fermentative hydrogen production, glucose is considered as a principle substrate. The complex polymeric organic substrates are hydrolyzed to simple sugars like glucose. It is further metabolized via glycolytic pathway to produce pyruvate. By this, microbes produce their energy source, i.e., Adenosine Triphosphate (ATP). Subsequently under anaerobic conditions, the pyruvate is converted into acetic acid and butyric acid. The Pyruvate-Ferredoxin Oxidoreductase (PFOR) enzyme oxidizes pyruvate to acetyl coenzyme A (acetyl-CoA). This pyruvate oxidation step requires Ferredoxin (Fd) reduction which in its reduced form is oxidized by (FeFe) hydrogenase and catalyzes the formation of hydrogen. The overall reaction is shown in equations 1 and 2.

$$\text{Pyruvate} + \text{CoA} + 2\ \text{Fd (ox)} \rightarrow \text{Acetyl-CoA} + 2\ \text{Fd (red)} + CO_2 \quad 1$$

$$2H^+ + \text{Fd(red)} \rightarrow H_2 + \text{Fd(ox)} \quad 2$$

Stoichiometry shows that four moles H_2/mole glucose can be produced if acetate is the sole end product of pyruvate oxidation whereas, if butyrate is sole end product then two moles H_2/mole glucose is produced. The overall biochemical reaction with acetic acid and butyric acid as the metabolic end products is shown in equation 3 and 4, respectively.

$$C_6H_{12}O_6 + 2H_2O \rightarrow 2CH_3COOH + 2CO_2 + 4H_2 \quad 3$$

$$C_6H_{12}O_6 \rightarrow CH_3CH_2CH_2COOH + 2CO_2 + 2H_2 \quad 4$$

The facultative anaerobic bacteria, such as *E. coli*, *Enterobacter* sp., etc., follow a different pathway for H_2 production. It involves formation of acetyl-CoA and formate from oxidation of pyruvate.

This reaction is catalyzed by pyruvate formate lyase (PFL) shown in equation 5.

$$\text{Pyruvate} + \text{CoA} \rightarrow \text{acetyl-CoA} + \text{formate} \quad 5$$

The formate is then further cleaved to produce carbon dioxide and hydrogen. This reaction is catalyzed by formate hydrogen lyase (FHL) enzyme (equation 6).

$$HCOOH \rightarrow CO_2 + H_2 \quad 6$$

For commercial production of biohydrogen, cheap feedstock/raw material should be used. Most of the studies on biohydrogen are based on the utilization of simple sugars such as glucose, sucrose, maltose, and lactose. These simple sugars are expensive and their usage is not economically viable. To address this issue, production of biohydrogen using different organic waste resources as substrate is a promising approach. There is a relatively high availability of complex sugars (polysaccharides) in the nature. Most of these polymeric sugars (cellulose, hemicellulose, amylase, etc.) are inaccessible to microorganisms. In order to tap the energy bound in these polymeric sugars, a detailed research is required targeting the pretreatment and saccharification techniques. As mentioned earlier, biohydrogen could be considered as renewable and cheap as it is produced from low value resources (Figure 4).

The Department of Biotechnology, IIT Kharagpur, is known for its focused and directive research on different possibilities of biohydrogen production. More than 15 years of research has lead to the development of an in-depth knowledge and expertise. The Institute is actively aims to improve the biohydrogen production process with an emphasis on the theme 'Organic Waste to bioH2'. It has already identified a wide range of potential H_2 producing microorganisms (which includes thermophiles and mesophiles). The Institute has successfully designed and commissioned a pilot plant for biohydrogen production using an 800 litre biohydrogen reactor (Figure 5).

Their effort towards commercialization of biohydrogen production process has been the principle motivation towards fabrication of a large-scale bioreactor i.e., in 10 m^3 in length. A decentralized energy solution could be possible if the technological challenges are overcome in the future.

Figure 5: An 800 litre bioreactor plant for biohydrogen production, IIT Kharagpur

Biomethane

Biomethane production using anaerobic digestion of solid organic waste, such as biowaste, sludge, cattle manure, energy crops, and different biomasses is a well-established technology. The advantage of this technology is that it can utilize a wide range of feedstock. Methane formation from water saturated decaying organic plant materials was first time reported by Volta. The anaerobic degradation process is a complex system which is an outcome of a dynamic microbial activity along with the involvement of biochemical and physico-chemical factors. In this process, the complex high molecular weight carbohydrates, fats, and/or proteins are hydrolyzed by enzymatic action of microbes. These complex organic fractions of the wastes are fermented by acetogenic bacteria to form volatile fatty acids, H_2, CO_2, etc. Volatile Fatty Acids (VFAs) are suitable substrate for methanogenic bacteria. They convert these metabolites to CO_2 and CH_4. The synergy between acidogenic and methanogenic microbes plays a critical role in the stability of the process.

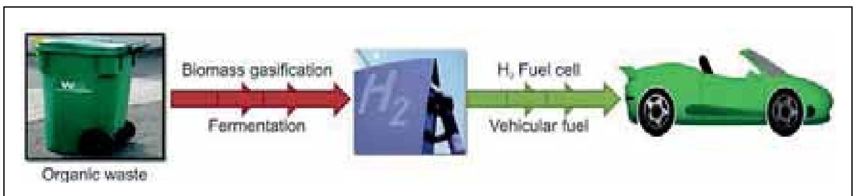

Figure 4: Utilization of hydrogen produced from organic wastes for transportation

Bioethanol

Different feedstock, such as cellulosic biomass, agricultural waste, and wood waste are commonly used for bioethanol production. Complex sugars present in the feedstock are first converted to simple sugars (mainly hexose). These simple sugars are then utilized by solventogenic organisms to produce ethanol by the fermentation (equation 7).

$$C_nH_{2n}O_n \longrightarrow \frac{n}{3}CH_3CH_2OH + \frac{n}{3}CO_2 + 227.0 \text{ kj/mole} \quad 7$$

The ethanol thus produced can be recovered by fractional distillation. The ethanol on combustion gives 1,370.7 kJ/mol of energy (equation 8) that can be harnessed for cooking, automobile combustion engine, etc.

$$CH_3CH_2OH + 3O_2 \xrightarrow{\text{Combustion}} 2CO_2 + 2H_2O + 1370.7 \text{ kJ/mol} \quad 8$$

The exemplary characteristics of bioethanol are as follows:

- Easy storage and no separate infrastructure required for distribution
- Highly suitable automobile fuel when blended with naturally occurring fossil fuels
- Emission of harmful unburned hydrocarbon and carbon monoxide is extremely low as compared to fossil fuel combustion

The technologies and skills of ethanol production were once confined to a handful of countries around the globe. However, its production and usage as fuel has now started to show its presence globally. At present, the viability of bioethanol production from starch or sugar in a wide variety of crops is debatable as a replacement for fossil fuels. It has lead to a debate of 'food vs fuel'. The production of ethanol from lignocellulosic biomass promises to assuage the above concerns. Lignocellulosic biomass such as sugarcane bagasse, wheat straw, rice husk, rice straw, corn straw, etc., are explored as feedstock for ethanol production. To exploit the entrapped sugars from their complex polymeric forms, various pretreatment techniques have been developed, viz., physical, chemical, physio-chemical, and biological. The plant cell wall is a rigid and complex structure composed of lignin, cellulose, hemicelluloses, etc., which makes them resistant to pretreatment techniques and thus, leads to poor sugar yield.

Biobutanol

As liquid fuels are easy to transport it is important to study them. It gives the necessary impetus towards research on liquid biofuels, such as alcohol from organic matter. At present, bioethanol and biodiesel production solely cannot fulfil the demand of biofuel. This has resulted in a research focusing on biofuel with higher calorific values. Biobutanol is considered superior to bioethanol by virtue of its energy density and non-hygroscopic properties. The Acetone–Butanol–Ethanol (ABE) fermentation is well-established and one of the oldest fermentation technology. There are many hindrances to the commercialization of biobutanol production. A few examples of such hindrances are availability of cheap feedstock, choice of feedstock, low product yield, intolerance of higher concentration of butanol by the production strain, formation of undesirable end products such as acetone, acetoin, etc., and separation of butanol in downstream processing. Biobutanol is produced exclusively by obligatory anaerobe such as Clostridium species. However, the creation of complete anaerobicity inside a large reactor is a cumbersome and expensive process.

Biodiesel

Biodiesel consists of monoalkyl esters that are derived from different oil sources, such as seeds of plants, animal, algae, etc., via transesterification process. The chemical reaction for biodiesel transesterification involves hydrolysis of ester bond between glycerol and fatty acid chain and then further esterification with methanol as shown in equation 9.

$$\text{Triglyceride} + 3\text{ Methanol} \xrightleftharpoons{\text{Catalyst}} \text{Glycerine} + 3\text{ Methyl Esters (Biodiesel)} \quad 9$$

The presence of a catalyst and alkali such as potassium hydroxide enhances transesterification. It is a reversible reaction, i.e., an excess of methanol could be used to force the reaction in a forward direction. Elevating temperature to 60 °C could increase the kinetics of the reaction and the process is completed in 90 minutes. The edible oils such as soybean, rapeseed, canola, sunflower, palm, coconut, and corn oil are the most common feedstock for biodiesel production. The dependency on edible oil has strengthened the 'food vs fuel' debate. Our country imports most of its edible oil and hence, the establishment of biodiesel technologies based on edible oil is not feasible. Among different oleaginous seeds, biodiesel production using *Jatropha curcas* seed was found to be more promising in terms of yield and productivity. Jatropha oil is a non-edible. This oil has low acidity, good stability, and low viscosity. Besides, it has a higher cetane number

compared to diesel. This makes it a good alternative fuel with no modifications required in the engine.

Many available reports suggest that algae could also produce more oil in stressed or unfavourable conditions. Under favourable growth conditions, fatty acids are synthesized principally for esterification into glycerol-based membrane lipids. It constitutes about 5–20 per cent of their Dry Cell Weight (DCW). Composition of fatty acids present under such conditions can be categorized into medium-chain (C_{10}–C_{14}), long-chain (C_{16}–C_{18}), and very long chain (C_{20}), and fatty acid derivatives. The scenario changes under unfavourable or stressful conditions, for instance, algae redirect their lipid biosynthetic pathways towards the formation and accumulation of neutral lipids (20–50 per cent DCW). The major constituents of such lipids are in the form of Triacylglycerol (TAG). The role of TAGs is not to perform a structural role in phospholipids cell membrane but to serve as storage energy. The accumulated TAGs are stored in the cytoplasm of the algal cell as densely packed lipid bodies. Lipid accumulation also takes place in the inter-thylakoid space of the chloroplast in certain green algae. However, constraints in operational conditions (low temperature, low light intensity, and nitrogen deficiency) that lead to accumulation of high grade oil in microalgae pose challenges in the production cost of high-grade algae oils. In the current scenario, it is quite difficult to obtain cheap algae biomass with 20 per cent lipid content.

Bio-oil

Pyrolysis of the biomass produces bio-oil. In fast pyrolysis, higher fuel yields make this process a promising technology for commercial biofuel technology. The liquid product from biomass pyrolysis is known as biomass pyrolysis oil, or bio-oil, pyrolysis oil, or bio-crude. The chemical composition of the bio-oil tends to change toward thermodynamic equilibrium during storage. At high temperatures, complex polymers undergo depolymerization along with production of fragments of cellulose, lignin, hemicelluloses, etc. The bio-oil is a complex mixture of acids, alcohols, aldehydes, esters, ketones, sugars, phenols, guaiacols, syringols, furans, lignin-derived phenols, and extractible terpene with multi-functional groups.

Gasification technologies for organic waste

Hydrothermal gasification

By definition, hydrothermal process involves an aqueous system which is subjected to high temperature and pressure. Since the pressure remains above the saturation pressure at the respective temperature, the liquid water phase remains predominant. Hydrothermal gasification of biomass and other organic matter has many advantages over steam reforming. On manipulating the process parameters, methane or H_2 rich gas can be produced in this process. Another advantage is the efficient removal of tar. Tar is solubilized in water under high temperature and pressure as at this condition water behaves as a non-polar solvent. Hydrothermal gasification can be applied for gasifying a variety of wet biomass such as manure, sewage sludge (biosolids), etc. In contrast to the anaerobic digestion, higher biomass, utilization has been reported. Recalcitrant such as lignin is also gasified under hydrothermal conditions. This is an emerging field of biofuel generation, and it would require an effort to commercialize the process.

Syngas (synthesis gas) by plasma pyrolysis

In plasma gasification, the ionized gas at high temperature can be used to catalyze the conversion of organic biomass to synthetic gas and solid waste (slag) (Figure 6). It is used commercially as a form of waste treatment and has been tested for the gasification of biomass and solid hydrocarbons, such as coal, oil sands, and oil shale. At high temperature, the organic waste undergoes gasification. The feedstocks for plasma pyrolysis are municipal solid waste, organic waste, biomedical

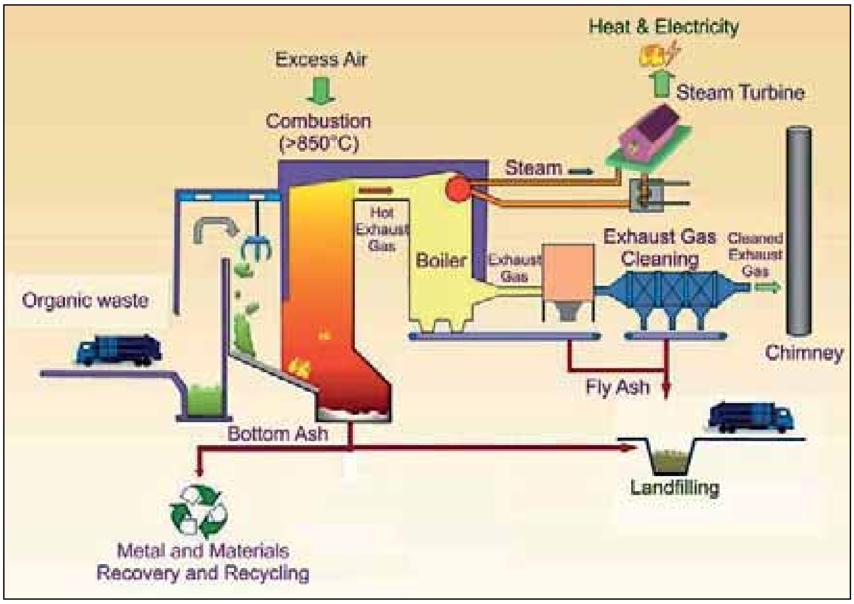

Figure 6: Biomass gasification process for the production of syngas

waste, and haircut materials. The presence of inorganic materials such as metal and construction waste leads to slag formation. This decreases the syngas production. Slag is a chemically inert material which can be used for the recovery of metals. Smaller particle size improves the efficiency of plasma pyrolysis. The chemical compositions of syngas are Carbon Monoxide (CO), H_2, and CH_4. The gasification efficiency of plasma pyrolysis is around 99 per cent. Moreover, this process is ecologically clean. As there is incomplete combustion during pyrolysis, many toxic materials are not produced. Toxic compounds, such as furans, dioxins, nitrogen oxides, or sulphur dioxide are generally formed during proper combustion of organic wastes. The major disadvantage of plasma technologies is a requirement of large initial investment costs and regular maintenance expenditure.

Energy generation by incineration

The most commonly used waste disposal method is combustion/incineration. The heat generated in this process can be tapped for electricity generation. The technology involved in harnessing biomass-based thermal power is similar to the conventional coal-based thermal power plant. The only difference is the boiler. The overall efficiency of the process is about 23–25 per cent. The steam turbine thus, generated could be used to produce power or for another useful heating activity (cogeneration). India has as many as 288 biomass power and cogeneration projects. The total power generation of 2,665 MW capacity has already been installed in the country.

Economics of Different Energy Generation Processes

Biofuel generation from organic waste is less energy-intensive in nature. Particularly, biohydrogen production showed better potential of commercialization as compared to other biofuels. The table given above shows the comparison in terms of cost of production of fuel on using different technologies. The need of pre-treatment and saccharification increases the production cost of biofuel from lignocellulose wastes. Moreover, substrate conversion efficiency and rate of H_2 production is quite low as compared to conventional process. The cost of electricity generated from biomass-based thermal power plant is still not comparable with that of coal-based thermal power plant. The disposal of ash and GHG emissions are the issues that are concomitant with such technologies.

Table: Economics of different energy generation processes

Energy Sources	Source and Process (large-scale technology)	Cost of Production
Hydrogen production	Natural gas (via steam reforming)	$4–5/kg
	Wind (via electrolysis)	$8–10/kg
	Nuclear (via electrolysis)	$7.50–9.50/kg
	Nuclear (via thermochemical cycles)	$6.50–8.50/kg
	Solar (via electrolysis)	$10–12/kg
	Solar (thermo-chemical cycles)	$7.50–9.50/kg
	Organic waste (dark fermentation)	$1.3/MBTU
	Gasoline	$23.5/MBTU
	Natural gas	$2–7/MBTU
Ethanol	Synthetic	$0.15/kg
	Fermentation	$0.4/kg
Syngas	Pyrolysis of coal	$24.47/TCM*
	Pyrolysis of organic waste	$10.62/TCM*
Incineration	Co-firing	$0.17/kWh
Anaerobic digestion (biomethane)	Biomethane-based generator	$0.4/kWh

*TCM: thousand cubic meters

Conclusions

The high abundance of organic wastes is suitable as feedstock for fuel generation. Many technologies have been developed to tap the immense potential of organic biomass for energy generation. Solid and liquid organic wastes have some inherent issues related to their disposal. Therefore, an effective waste management and energy generation is the need of the hour. Biofuels production from organic wastes demands less energy input as compared to other processes. But the low substrate conversion efficiency and low yield of fuel has negatively affected its production process. The realization of the vision of a carbon neutral fuel could be achieved by using hydrogen as a fuel. Production of hydrogen from cheap renewable sources like biomass could make the process sustainable. Syngas-based energy generation is also environmentally favourable, though energy-intensive. Incineration-based thermal power plant might provide a quick solution towards utilization of biomass for energy production. This establishment is similar to coal-based thermal power station. However, the production of obnoxious gases, slag, and ash is a demerit that goes against its clean fuel status. EF

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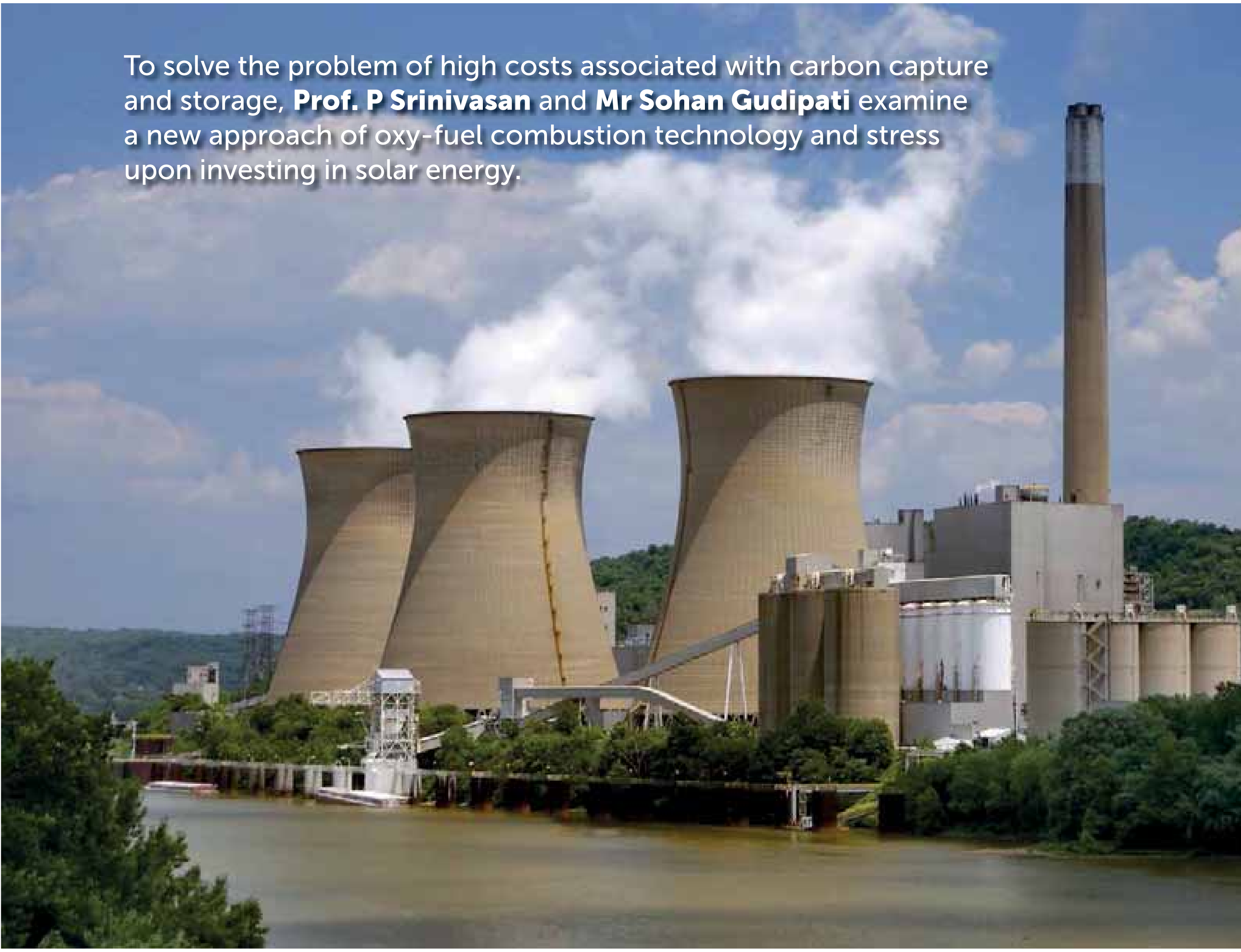
CARBON CAPTURE AND STORAGE

THE FUTURE OF POWER GENERATION IN INDIA

To solve the problem of high costs associated with carbon capture and storage, **Prof. P Srinivasan** and **Mr Sohan Gudipati** examine a new approach of oxy-fuel combustion technology and stress upon investing in solar energy.



Coal is the primary fuel for electricity generation in India and its usage is continuously increasing to meet the energy demands of the country. Parameters such as Human Development Index (HDI), which is a combination of life expectancy at birth, education, disposable per capita income, and also per capita electricity usage, explain how India lags behind the global average. There is also a dire need for more power plants in the country. In 2010, India had a HDI of 0.56 and an average electricity use of 700 kWh/capita/year. Globally, average electricity use in 2010 was 2,100 kWh/capita/year and the average HDI was 0.7, as per the Human Development Reports of the United Nations Development Programme (UNDP). India needs to increase the installed capacity of power generation at a faster pace. This however, results in higher emissions of carbon dioxide (CO_2) and other harmful gases. Computed estimates show that CO_2 emissions increased by 50 per cent during the decade 2001–10. This can be tackled by new technologies, such as Carbon Capture and Storage (CCS) which reduces the emissions and so the externalities associated with it. This article discusses the cost of this technology and its benefits and also introduces an approach to evaluate the cost of oxy-fuel combustion technology which proves to be the solution for the problem of high costs associated with CCS. Towards the end, the need for investing in solar energy, which will be of utmost importance in the future is also discussed.

Externalities of CO_2 Emissions from Conventional Power Plants

As on March 2010, the capacity for electricity power generation from coal and lignite-based thermal power plants is accounted for 93,772 MW. This includes the private and captive power plants. In a study by Moti L Mittal, based on the 'Performance Review of Thermal Power Stations 2010' by the Central Electricity Authority (CEA) for the 86 coal and lignite-based power plants, the emission estimates and the future trends are clearly discussed. All these plants are designed with different installed capacities and varying number of units and also different efficiencies.

The CO_2 emission estimates are based on the carbon content as

India needs to increase the installed capacity of power generation at a faster pace. This however, results in higher emissions of carbon dioxide (CO_2) and other harmful gases.

obtained from the elemental analysis of coal. A small percentage remains as unburnt carbon due to several factors. In another study by the CEA, the average cost of electricity production at the supply end has also been assessed.

An external cost, also known as an externality, as defined by ExternE (External Cost 2003), arises when the social or economic activities of one group of persons have an impact on another group and when that impact is not fully accounted, or compensated by the first group. Thus, a power station that generates CO_2 emissions causes damage to the environment since it is a Greenhouse Gas (GHG).

ExternE later undertook projects which explored these issues in more depth using two models—FUND and the Open Framework. The assumptions, in both the models are both explicit and consistent and also take into account the scenarios developed by the Intergovernmental Panel on Climate Change (IPCC). Results of both the models provide the external cost of CO_2 emissions in the unit "$/per tonne of carbon". The values used in our study have been taken from the Global MARKAL method which is a multi-regional partial equilibrium model of the global energy system. These values are specific to Asia region with high population density and different coal composition. This is the estimation available, as of now in the

Table 1: Cost of electricity after internalizing external cost due to CO_2 emissions

Year	Production Cost (Rs/kWh)	CO_2 Emissions (kg/kWh)	Externality Cost (Rs/kg of CO_2)	Externality Cost (Rs/kWh)	Total Cost of Electricity
2000	2.28	0.93	2.8	2.604	4.884
2010	3.78	0.93	4.87	4.529	8.309
2020	5.98	0.93	8.46	7.868	13.848
2030	9.46	0.93	14.72	13.686	23.146
2040	14.96	0.93	25.62	23.826	38.786
2050	23.67	0.93	44.6	41.478	65.148

literature. However, it does not reflect other damage categories such as agriculture, etc.

The Externality cost of CO_2 used in the calculations in Table 1 is determined by the FUND model and is equal to $170 per tonne of carbon, or $46.7 per tonne of CO_2 which is approximately equal to ₦2.8 per kg of CO_2. The CO_2 emissions per unit of electricity are average of emissions recorded in 86 coal and lignite-based power plants for the past 10 years.

Externality Cost Associated with Retrofitting of Conventional Power Plants with CCS

Several research institutes in the US and Europe have provided comparative cost analysis for power plants with the CCS facility and a reference plant with conventional design. One such study gives the best cost estimates for three designs of power plant, namely (1) Integrated Coal Gasification Combined Cycles (IGCC), (2) Pulverized Coal-fired Simple Cycles (PC), and (3) Natural Gas Fired Combined Cycles (NGCC).

An energy penalty of 25 per cent is observed when a conventional power plant is retrofitted with the CCS technology. This is a disadvantage making it less economically viable. The mitigation cost of CO_2 is very high, i.e., around ₦2,500 per tonne of CO_2 avoided. This cost includes the capture, transportation, and storage of CO_2; however, the post-storage monitoring costs are not included in this analysis. Carbon dioxide after being converted into carbonates is injected in the underground. As per the United States Environmental Protection Agency, these formations are over 6,000 feet below the ground. Newer combustion technologies and other improvements which ensure reduction of cost of the CCS will be beneficial in making coal a cleaner fuel for electricity generation.

"Total Cost of Electricity 1" corresponds to lower capacity (75 per cent relative output), and to account for the same output of conventional power plant, the cost is extrapolated to 100 per cent output which is equal to "Total Cost of Electricity 2". Table 2 gives a clear picture of the cost of electricity generation through our conventional design power plants coupled with the CCS technology. This would ensure safer emissions, though it is not economically viable.

Oxy-Fuel Combustion Technology

In coal-fired power plants, there are two main options for CO_2 capture: removal of nitrogen from the flue gases which is a complicated task due to high temperature of flue gases, or removal of nitrogen prior to the combustion process. In the oxy-fuel combustion design, fuel is combusted in the presence of pure oxygen rather than air. This technology recycles flue gas back into the furnace to replace the volume of missing nitrogen and maintain the temperature. An additional advantage

Table 2: Cost of electricity after internalizing external cost due to CO_2 emissions in power plants equipped with CCS technology

Year	Production Cost (Rs/kWh)	CO_2 Emissions (kg/kWh)	Externality Cost (Rs/kg of CO_2)	Externality Cost (Rs/kWh)	Total Cost of Electricity 1	Total Cost of Electricity 2
2000	4.626	0.0933	2.8	0.261	4.887	6.516
2010	7.323	0.0933	4.87	0.454	7.777	10.369
2020	11.591	0.0933	8.46	0.789	12.38	16.506
2030	18.347	0.0933	14.72	1.373	19.72	26.293
2040	29.04	0.0933	25.62	2.39	31.43	41.906
2050	45.967	0.0933	44.6	4.161	50.128	66.837
Relative Power Output w.r.t. Reference Plant					75%	100%

Table 3: Cost of electricity after internalizing external cost due to CO_2 emissions in power plants equipped with oxy-fuel and CCS technology

Year	Production Cost (Rs/kWh)	CO_2 Emissions (kg/kWh)	Externality Cost (Rs/kg of CO_2)	Externality Cost (Rs/kWh)	Total Cost of Electricity 1	Total Cost of Electricity 2
2000	4.181	0.0906	2.8	0.253	4.434	5.5425
2010	6.619	0.0906	4.87	0.441	7.06	8.825
2020	10.478	0.0906	8.46	0.766	11.244	14.055
2030	16.585	0.0906	14.72	1.333	17.918	22.397
2040	26.252	0.0906	25.62	2.321	28.573	35.716
2050	41.554	0.0906	44.6	4.048	45.602	57.002
Relative Power Output w.r.t. Reference Plant					80%	100%

of this technology is substantial reduction in NO_x emissions. Adopting this technology has several key advantages—thermal output of the boiler is higher, in the case of oxy-fuel and the surface area of all the heat exchangers is lower, in the case of oxy fuel design. Also, another study by MIT Energy Initiative suggests that oxy-fuel power plant technology has the potential of lower cost of electricity generation and lower CO_2 mitigation costs compared to other methods. The methodology used to calculate externality cost, in the case of conventional design and power plant with the CCS is also used here to get a future estimate of the cost of electricity when adopting the oxy-fuel design (Table 3).

Solar Energy in India

The average intensity of solar radiation received in our country amounts to 20 MW/km^2. With a geographical area of 3.287 million km^2, this amounts to 657 million MW, and approximately 12.5 per cent of this area can, in theory, be used for solar energy installations. But the efficiency of conversion of solar energy to useful energy is very low; therefore, the actual energy output would be lower in magnitude than the aforementioned estimates. Electricity generation through solar PV is attempted for captive power generation in many small and medium enterprises. Unlike coal-based power plants, once the solar power plant is installed the cost of power is almost constant for an average period of 25 years.

Table 4: Technical details of solar power plant for the year 2013

Solar Power Plant Capacity and Location	Investment Cost (in crore INR)	Cost of Electricity (Rs/kWh)	Tonnes of CO_2 Mitigated Annually
151 MW, Madhya Pradesh	880	8.05	216,372
60 MW, Tamil Nadu	400	6.49	98,122
20 MW, Maharashtra	135	8.56	33,288

Welspun Renewables Energy Pvt Ltd (WREPL) is one of the major companies which have established solar power plants in partnership with the Government of India. The technical details are listed in Table 4.

According to the agreement between the WREPL and the Government of Tamil Nadu, the cost of electricity will be increased by 5 per cent annually to ensure sustainability of the power plant. This has been used to predict the future cost of electricity generation using solar technology.

Discussion of the Outcomes

Table 5 shows the comparison of emissions, externality costs, and total cost of power generation. From Figure 1, it is observed that the cost of electricty generation from a conventional power plant with retrofitting with the CCS is costlier when compared to oxy-fuel combustion technology after internalizing the external cost of power generation.

We should consider another important parameter in determining

Table 5: Comparison of emissions, externality costs, and total cost of power generation

Year	Conventional Design			With CCS			Oxy-Fuel with CCS			Solar Power Plant, Cost of Electricity (Rs/kWh)
	CO2 Emissions (kg/kWh)	Externality Cost (Rs/kWh)	Total Cost (Rs/kWh)	CO2 Emissions (kg/kWh)	Externality Cost (Rs/kWh)	Total Cost (Rs/kWh)	CO2 Emissions (kg/kWh)	Externality Cost (Rs/kWh)	Total Cost (Rs/kWh)	
2000	0.93	2.604	4.884	0.0933	0.261	6.516	0.0906	0.253	5.542	
2010	0.93	4.529	8.309	0.0933	0.454	10.369	0.0906	0.441	8.825	7.7
2020	0.93	7.868	13.848	0.0933	0.789	16.506	0.0906	0.776	14.055	12.54
2030	0.93	13.686	23.164	0.0933	1.373	26.293	0.0906	1.333	22.397	20.42
2040	0.93	23.826	38.789	0.0933	2.39	41.906	0.0906	2.321	35.716	33.26
2050	0.93	41.478	65.148	0.0933	4.161	66.837	0.0906	4.048	57.002	54.17

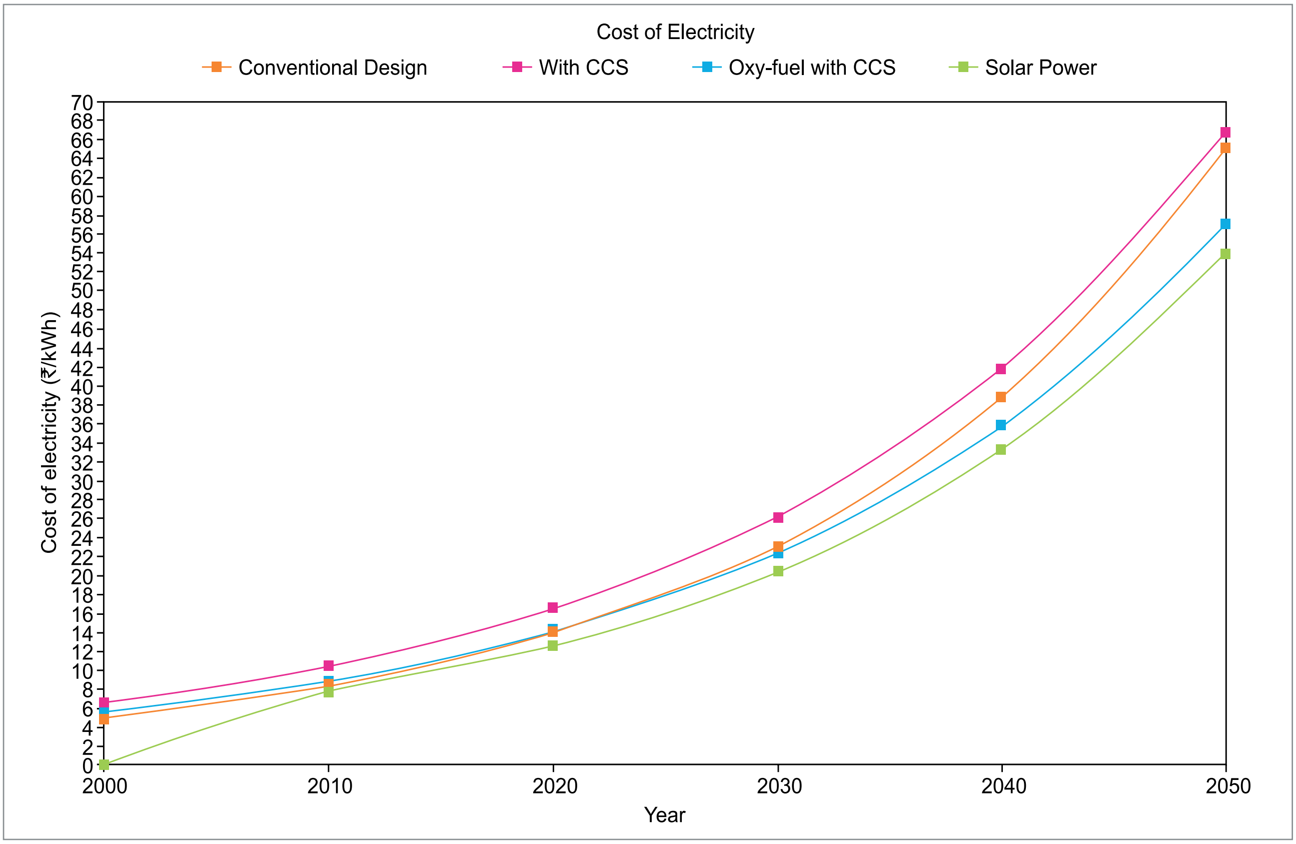


Figure 1: Predicted cost of electricity generation using different technologies for the period 2010–50

the energy policies worldwide, i.e., the CO_2 emissions. Figure 2 predicts the future estimate of CO_2 emissions per annum from a power plant of 500 MW capacity using different technologies. This gives a clear indication that the oxy-fuel combustion coupled with CCS is a promising technology in the future to protect the environment from GHG emissions. It is assumed that the growth changes in these emissions are coherent to the past data of rise in installed capacity (Table 6). Solar power is considered to be a clean energy, but in reality it does have a non-zero carbon footprint. Various studies, such as the IPCC report 2014, have indicated an average of 48g carbon dioxide equivalent emissions for every unit of electricity generated. These are not direct GHG emissions, but these arise from manufacturing and transportation of several components of a solar power plant. For a 500 MW capacity solar power plant, this amounts to 90,000 tonnes of CO_2 emittied annually.

Table 6: Total CO_2 emissions for a 500 MW initial capacity design

Year	CO_2 Emissions (million tonnes/year)		
	Conventional Design	With CCS	Oxy-fuel with CCS
2010	3.209	0.458	0.401
2020	5.481	0.782	0.684
2030	9.362	1.335	1.168
2040	15.991	2.803	1.995
2050	27.314	4.787	3.407

Conclusions

Retrofitting a conventional plant with oxy-fuel technology results in 20 per cent reduction in net power output because of the increase of auxiliary power consumption. The Air Separation Unit (ASU) is the major consumer among the auxiliary systems.

Retrofitting of conventional power plants with the CCS will require large investments. On an average, the capital cost increases by

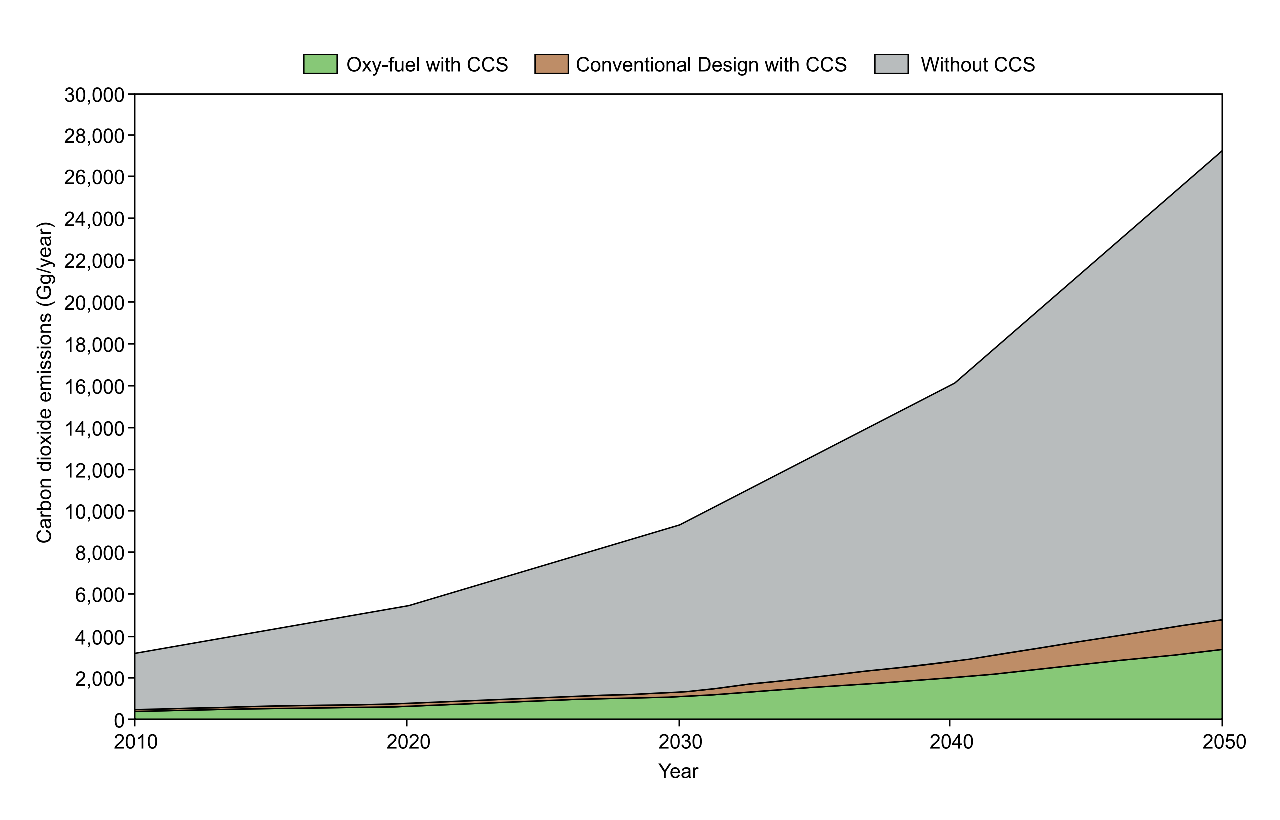


Figure 2: Cost of electricity after internalizing external cost due to CO_2 emissions in power plants equipped with CCS technology

50 per cent. This makes it less economical, but government energy policies and stricter norms on emissions along with improved technology is certainly an option. This may lead to a reduction in the costs and thus, make coal a cleaner fuel. However, it is observed that the cost of oxy-fuel technology based power plants with CCS may be cheaper in the future to reduce the emission levels. The investments in solar power plants are increasing at the rate of 40 per cent anually. The International Energy Agency (IEA) projects that solar power could generate 22 per cent of the world's electricity by 2050. This would remove a significant fraction of the growing global CO_2 emissions from fossil generation. Such a target is ambitious and achievable as well. On a side note, a major disadvantage of solar power is storage of electricity. Energy storage is currently limited due to the high cost, size, and relatively high carbon intensity of batteries. Research and development is underway in creating new battery materials and reducing the costs of existing technologies may also reduce the cost of energy storage. Another disadvantage is the high carbon footprint of solar photovolatics manufacturing process. The median for this value is 48g CO_2 per unit of electricity generated. This will hopefully reduce in the forthcoming years with technological advancement. EF

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India's Solar Ambition and its Place in the Solar World

As 2014 ends and we continue our journey of making this world an energy-secure place, **G Ravikumar**, analyses the happenings of previous year and looks at the opportunities available in 2015 in the renewable energy sector as he discusses the actions taken by the MNRE, JNNSM, SECI, and various state governments.

India was among the very few countries to realize the potential of solar energy and invest in developing the photovoltaic (conversion of sunlight, ***photons***, into electricity, ***voltage***-PV for short) technology. Solar cell and module manufacturing technologies were developed indigenously in the early 1980s and several offgrid solution such as solar lanterns, home and street lighting systems, pumping and remote signalling systems were commercialized. Almost all the solar subsidy programmes by the Government of India routed through the State Nodal Agencies (SNAs) were focused on off-grid systems meant for rural and remote areas and this supported the few solar companies that were in operation.

The solar industry, despite an early start, remained very small and insignificant, with electricity and diesel available at very affordable prices. The Ministry of Non-Conventional Energy Sources—MNES—now the Ministry of New and Renewable Energy (MNRE) reported in 2003, an installed solar cell and module manufacturing capacity of a meagre 22 and 23 MW, respectively, (Figure 1). Dr Rangan Banerjee, currently a Professor in Department of Energy Science and Engineering, IIT-Bombay, in his paper comparing various options for distributed generation showed that while it cost just N 4.8/kWhr to generate electricity through industrial diesel generator sets, at N 16/L diesel price in 2001, the cost of grid-connected battery less PV systems of size 1 to 5 kW

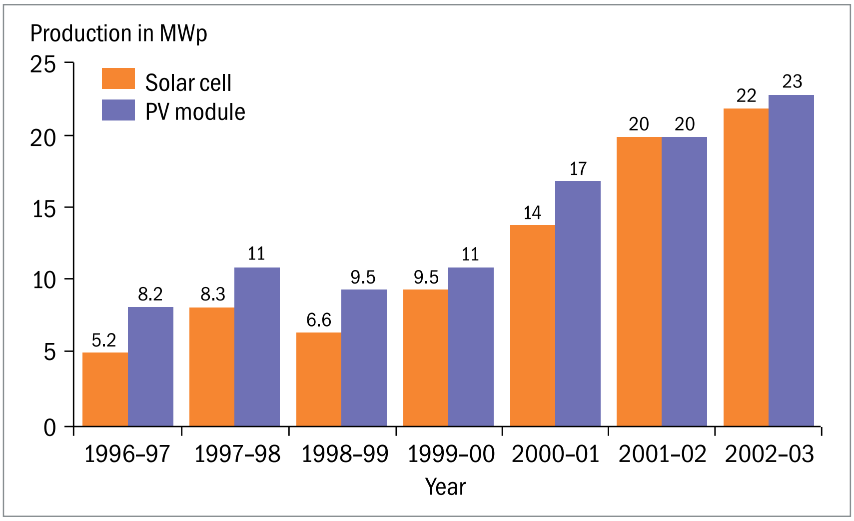

Figure 1: PV cell and module production 1996–2003

(Source: MNRE)

available then, varied between N 10.98 and N 16.34 depending on the capital cost considered. PV was clearly not an option.

Global RE Sector Scenario

Globally, Renewable Energy (RE) sources, including solar energy were identified to be developed as alternatives to oil along with nuclear power and natural gas, in response to the oil embargo in 1973, when oil price quadrupled in a short time. For the US and Japan, who depended heavily on oil imports to meet their very large energy consumption it came as a shock (termed as *oil shock*). US Federal Reserve History records show that the price shot up from $2.90 to $11.65 per barrel. However, with the rapid expansion of nuclear power capacities, extensive use of natural gas for heating and electricity generation; and ethanol-blended gasoline for automobiles, the demand for oil fell and with it the oil prices. With additional generation capacities added, electricity prices also fell. With the energy costs coming down drastically, the high cost PV solution became unattractive and the expected volume growth that

Table: US share of the global PV shipments 1997–2004 (*Source*: National Renewable Energy Laboratory, US)

Technology	1997	1998	1999	2000	2001	2002	2003	2004
Single Crystal Si	30.15	30.16	32.91	46.69	63.23	67.4	54.65	50.15
Polycrystalline Si	12.2	13.5	16.14	16.72	17.5	23.8	15.89	14.2
Ribbon Si	2.95	4.04	2.05	5.15	4.9	6.7	11.7	17
Thin Film Si	2.2	3.14	3.95	6.96	9.66	7.5	6	14
Other Thin Films	0.2	0.16	0.25	0.7	1.43	2.4	3.3	7.15
Total US Shipments	47.7	51	55.3	76.22	96.72	107.8	91.54	102.6
Total World Shipments	114.1	134.8	175.5	252	352.9	504.9	675.3	1,030.03
US Share of World (in %)	42	38	32	30	27	21	14	10

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would have driven down prices did not happen. As per the US National Renewable Energy Laboratory (NREL) statistics, the US shipments across various solar PV technologies which was 40 per cent in 1997 fell gradually to 10 per cent in 2004 (see Table).

Solar energy, even though it fell out of favour of energy planners and global leaders with receding energy security threat, attracted the climate scientists and environmental groups who saw its potential to mitigate the growing impacts of the alarming rise in heat trapping Greenhouse Gases (GHGs) emitted by fossil fuels. Their sustained campaigns to reduce GHG emissions, lead to the adoption of the *United Nations Framework Convention on Climate Change – UNFCCC* in 1992 whose ultimate objective was *"to stabilize greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system".* UNFCC entered into force two years later in 1994 and with it, RE received the importance it deserved as clean and sustainable energy resources. Thus, climate security concerns resurrected the fading interest in promoting RE resources. The first major action to adopt RE to reduce emissions came from the environmentally sensitized Germany. Driven by the Green Party, whose stated policy is *to work for environmental protection and sustainable development*, German Renewable Energy Act (EEG) came into force in 2000 with a primary aim to promote renewable energy and replace progressively conventional fossil fuels and atomic energy. The act helped Germany to bring in a very remarkable "energy transition", *Energiewende*, over the last 14 years. In Figure 2, the electricity generation in Germany over the first 10 months' period in 2014, as compiled and reported by the globally recognized Fraunhofer's Institute is shown. It is clear that RE generation of 128 terawatt-hours (TWh) out of a total

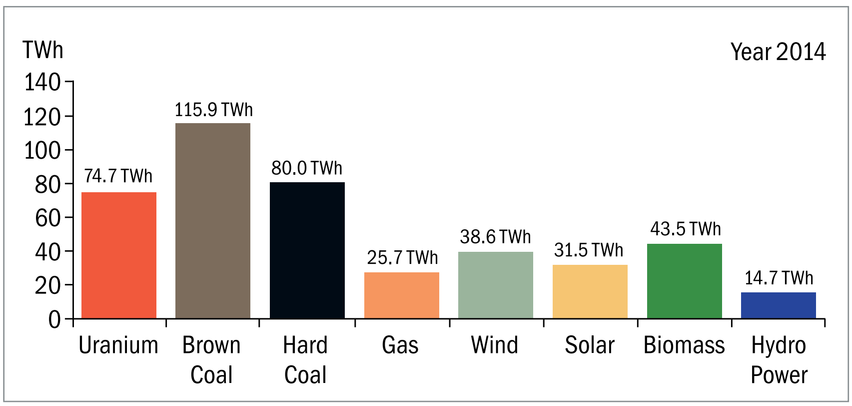

Figure 2: Electrical power generation between January and October 2014

(*Source*: Burger, Fraunhofer ISE; Data: European Stock Exchange EEX, energetic corrected values)

generation of 424 TWh constituted 30 per cent of the total electricity generation which is the highest in the world. With the zeal, commitment and the very high capability demonstrated by Germany, 100 per cent transition from fossil fuel dependent energy generation to RE generation as planned under *Energywende* is likely to be achieved even earlier than the targeted 2050.

RE Sector Scenario In India

For our country with unmatched complexity, rising demand for energy and the compulsion to keep emissions under check, in our own interest, *Energiewende* is an urgent need for us.

We did start early, taking small steps by developing solar PV and solar thermal technologies, and applications in the early 1980s. However for the same reason, as elsewhere in the world, the high initial investment and the relatively easy access to low-cost and subsidized grid power made solar an expensive option, except in remote, mountainous, and unelectrified areas. Our solar programme therefore remained focused on off-grid systems with individual system sizes varying between 10 and 75 W capacity each and the solar contributed a very insignificant 8.4 per cent share to the RE basket (Figure 3). In India solar energy is available throughout

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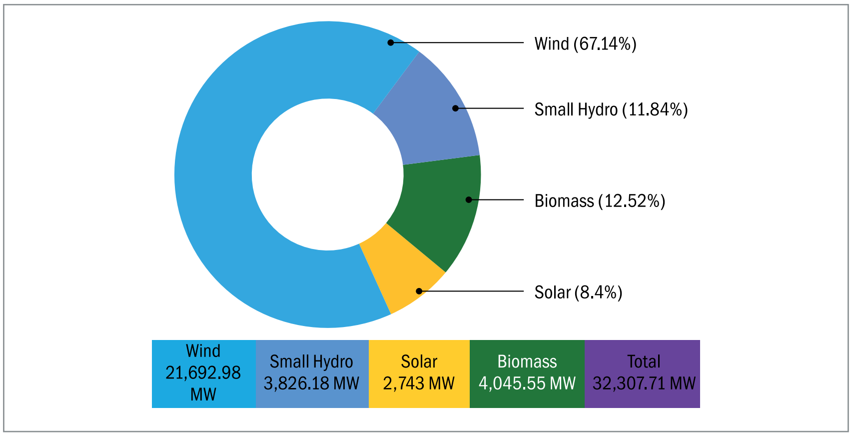

Figure 3: Renewable energy generation in India September 2014

(*Source*: MNRE)

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the year across most of parts of the country unlike wind energy which is restricted to few states—Tamil Nadu, Gujarat, Karnataka, and Maharashtra. On an average, we have nearly 300 sunny days with average incident solar energy ranging between 5–5.5 kWhr/m^2, which is nearly twice as much as the incident solar energy in Germany.

Plans for large-scale tapping of the abundantly available solar energy in India came in 2008 when the government announced the National Solar Mission, among other missions, as part of its *National Action Plan on Climate Change*. A comprehensive National Solar Policy was released in January 2010 to ensure large-scale utilization of solar energy—both solar thermal and solar photovoltaic. The policy envisaged a cumulative PV power generation capacity of 20 GW by 2022. A year earlier, in 2009, the Gujarat Government had declared its own ambitious solar policy.

With the almost simultaneous roll out of the two ambitious solar programmes, the installed grid-connected PV installations reached the remarkable GigaWatt (10^9 Watts) milestone in 2012 from a meager 20 MW (1 MW = 10^6 Watts) in 2010. The MNRE announced this great moment in India's PV history in July 2012. The rapid roll out of these two policies prompted several states to announce their own policies, the most significant being the Tamil Nadu Solar Policy announced in October 2012 which set a target of installing 3,000 MW in a very short span of three years between 2013 and 2015. These developments promised rapid scaling up of the market and both domestic and global PV companies were very upbeat. However, the growth in the more than

two year period between July 2012 and September 2014 turned out to be discouraging (the MNRE reported an addition of just about 1.7 GW in that period).

Amongst the top reasons for the declining market sentiment was the delay in the launch of Phase II of the Jawaharlal Nehru National Solar Mission (JNNSM) with a target to add 10 GW of grid-connected power between 2013 and 2017. Under Phase I, 1,000 MW of solar projects were allocated equally between solar thermal and solar PV. Of the 500 MW planned for PV, only 470 MW were actually allotted and they were successfully executed. The delay in the launch of Phase II, Batch 1 therefore, caused deep anguish and concern to the industry. Only in February 2014, projects totalling 750 MW were allocated under Phase II, Batch 1 with the allocations made equally between two categories: Domestic Content Requirement (DCR) and Open category. Allocation of projects by state governments also got delayed for various reasons. For example, the ambitious Tamil Nadu Solar Programme got stuck because of the difference in tariff fixed by the government and the regulatory commission and in the case of the erstwhile united Andhra Pradesh, the uncertainty over its bifurcation cast a shadow on the programmes announced. As for allocated projects, delays in signing Power Purchase Agreements (PPA), land acquisition, statutory clearances, and power evacuation infrastructure were roadblocks and project execution got delayed. Indecision stemming from the announcement of General Election and the protracted and bitter dispute between manufacturers and developers on the imposition of anti-dumping duties on module imports also contributed to the slowing down of the solar market in the two years.

However, there were very positive developments especially in the second half of 2014 that revived the industry's positive sentiments. The most significant being the Finance Ministry's decision to drop the Commerce Ministry's recommendation to levy anti-dumping duties on solar panel imports from the US and China. The decision was taken after much debate and on the basis that the installed manufacturing capacity was too less to support the rapid generation capacity addition planned by the government. However, to protect the interest of the domestic manufacturers, publically–owned companies were required to procure solar panels from domestic companies. In the JNNSM

Phase II, Batch 1, of the 750 MW of projects allocated in February 2014, 50 per cent were allocated under Domestic Content Requirement under which the solar cells and modules used in the power plant must both be made in India.

States of Karnataka, Andhra Pradesh, Telangana, Uttar Pradesh, and the Central Public Sector Undertaking National Thermal Power Corporation (NTPC), engaged primarily in the business of electricity generation, together allocated projects totalling a significant 2 GW in the III quarter of 2014. Rajasthan, Madhya Pradesh, and other states are also vigorously expanding their solar installation capacities.

Simultaneously, the more promising distributed generation through solar rooftop segment which was initiated almost along with the large grid-connected programmes by the Solar Energy Corporation of India (SECI, MNRE) and Government of Gujarat drew attention of other states. With major learnings from these two rooftop programmes and the compulsion to respond to the rising demand for electricity, 11 states, including Kerala, announced their own rooftop policies and programmes.

The rooftop programmes, which rapidly accelerated Germany's solar growth, will have huge impact in India as well, more so with land acquisition and the associated clearances being non-issues. Attractive feed-in tariffs and enabling policies, as announced by the Karnataka Energy Regulatory Commission, the rooftop market segment would help the market grow. More importantly, rising industrial and commercial electricity tariffs and the steep fall in prices of PV components, especially PV modules, is pushing PV generation closer to grid parity and a growing and sustainable rooftop market looms large on the horizon.

With substantial JNNSM and state projects allocated and with the further roll out of the rooftop programmes by the SECI and the state governments, the PV capacity expansion by the end of 2015 can be expected to be in the range of 2.5–3 GW. The recent announcement by the government, of its intention to enhance the current 20 GW target of the JNNSM to 100 GW by 2022 and the Global RE Investor's Meet being organized by the MNRE's Indian Renewable Energy Development Agency (IREDA), in February, will revive global interest in Indian market. We can expect the growth in 2015 to jump start

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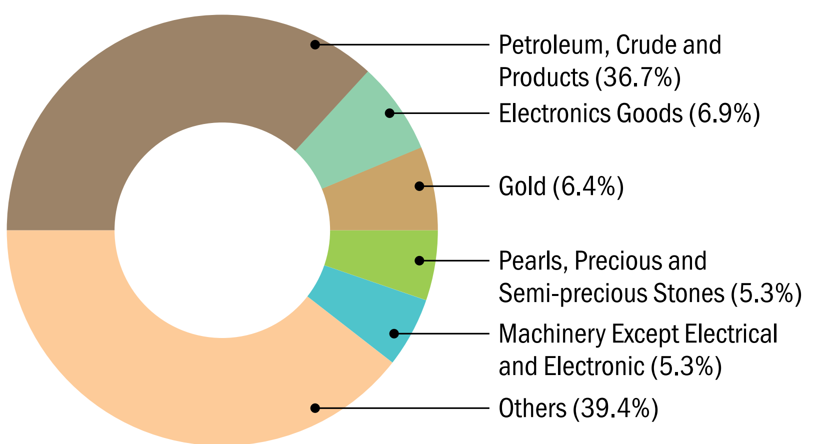

Figure 4: Share of top five commodities in India's imports

(*Source*: Trends in India's Foreign Trade, Ministry of Commerce)

the ambitious PV expansion. With the anticipated growth, the demand for human resources would rise sharply in the next one or two years. In its August 2014 report, the Natural Resources Development Council (NRDC), an enterprise under the Ministry of Science and Technology, reported that a 20 MW solar PV project generated a total of 180.8 Full Time Equivalent (FTE) jobs, primarily for highly skilled personnel and construction workers. With the roll out of the ambitious PV expansion plan, the need for trained manpower would rise sharply. Solar would therefore be top sector for the government to implement its avowed intention to provide employable skills, especially to rural youth.

While facilitating and expanding solar power generation capacity addition, we should not lose sight of the importance of setting up a very robust manufacturing base. We missed a great opportunity to build a semiconductor manufacturing industry in our country and we are already a witness to the consequences. At 6.9 per cent of the import bill, electronic import is next only to oil import bill (Figure 4). Experts opine that our electronics import could surpass the oil import bill very soon. As if this was not enough, recently there has been heightened security concern relating to imported communication equipment.

In order that we do not repeat the mistake of the past and to more importantly ensure our future and climate securities are not threatened, we must invite reputed global and domestic manufacturers to engage in India's own solar energy revolution and provide all incentives to set up not only GW-size, state-of-the-art cell and module manufacturing plants, but also to set up facilities to manufacture raw materials like polysilicon. Basic research in key cell and module materials, innovation and technological developments in batteries and inverters, high efficiency pumps, refrigeration, etc., should be massively encouraged and supported. We enter the year 2015 with a very exciting and massive expansion plan for solar that would ensure access to electricity in every nook and corner of the country and create a positive social impact as never before, even while addressing the climate and energy security concerns. We cannot afford to miss or go wrong in realizing what appears to be a highly ambitious goal, with a massive N6 trillion investment over a short period and a whole range of complex challenges to be addressed.

When we add large PV generation capacities and set up huge manufacturing base backed by top class R&D infrastructure, we will realize the true potential of solar energy which we are so richly blessed with. We will in fact be ushering in our own solar driven *Energiewende,* which we may choose to call *Tejomay (brilliant, in Sanskrit)* and become an unassailable *Leader of the Solar World.* EF

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Clean India with BIO-CREMATION

Arisha Mutahir and **Dr Mamta Baunthiyal** discuss the technique of bio-cremation, a process which converts the human body into a sterile liquid form in lieu of ashes. As an eco-friendly technique, bio-cremation saves energy while disposing of the human remains.

Clean India with Bio-Cremation

With the growing popularity of the 'Clean India Mission' and 'Clean Ganga Mission', this is the perfect time to discuss another concept: 'Clean Environment with Bio-cremation'.

Bio-cremation is a technique that ensures that the human body is converted into a sterile liquid form in lieu of ashes. This process which has been legalized recently in the US and Canada, is an environment-friendly option.

It utilizes less energy and releases a reduced amount of carbon dioxide in the atmosphere.

What is Bio-Cremation?

In 2011, a Florida funeral home became the first in the world to bring about bio-cremation. About 3,000 people are believed to have chosen this method for the disposal of their remains in the US. The process is also known as chemical hydrolysis which is an environment-friendly substitute to the present-day tradition of disposal of bodies. The technology utilizes water replacing the flame. The water blended with an alkali solution of potassium hydroxide (KOH) is used. Alkali hydrolysis includes 95 per cent water and 5 per cent potassium hydroxide (KOH). Generally, it requires a pH range of less than 10.5–11.5. The temperature

is raised to 350 °F (160 °C) at a high pressure which prevents boiling. When the temperatures are kept low, around 199 °F–208 °F, the required atmospheric pressure is 14.696 psi but at high temperatures, approximately 302 °F, less than 65 psi pressure is required. The body is placed in a stainless steel cremation chamber and then water, an alkali additive, heat, and pressure are added. The body is reduced to bone fragments and a sterile solution, which is then recycled. An average adult body takes approximately two or three hours to be bio-cremated. It takes six or seven hours for the completion of the whole process which includes heat up, process, cool down, and discharge. Bio-cremation utilizes only protein-based materials, so clothing made of silk, wool or leather must be used during the process. Upon completion of the cremation cycle, the bones are dried and processed to a powdery substance which is then placed in an urn and given back to the family. The technique, though not new, has only been used to discard laboratory animals and medical research cadavers at a few institutions.

Current Scenario

In New Delhi, the central government has decided to clean the Ganges by tackling the practice of disposal of bodies in the river. Every day, lakhs of dead bodies are disposed of in the river, some in the form of ashes and others are drowned off directly. The river is not only a source for performing various rituals, but also provides livelihood to many people. Hence, it has been widely felt that the process of bio-cremation is one of the steps to save the river.

Nevertheless, certain issues have been observed in the bio-cremation technique. The Catholic Church in

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parts of the US has objected stating that "the practice is not a respectful way to dispose of human remains". In California, some people had problem with the pumping of the chemically treated remains of millions of dead people into the oceans which pollutes the marine life.

Despite several issues, there are many countries that have already given a green signal to bio-cremation due to its environmental-friendly aspect. For instance, the President of Matthews' Cremation and Anderson–McQueen funeral homes says, "Today we live in a world that encourages us to protect and preserve our natural resources and lower our carbon footprint by reducing greenhouse gas emissions. Bio-cremation gives individuals and families another choice at the end of life's journey, allowing them to honour a legacy created on this planet with a final gesture to preserve it".

However, experts feel that it is important to also address some misnomers surrounding bio-cremation. The biggest misconception is that the process 'boils' a body which is false. This technology creates an environment that uniquely combines water, alkali, heat, and pressure that biochemically hydrolyses the human body, leaving only bone fragments.

Future Prospects

There are a lot of reasons why this technique must be promoted. First of all, it is an eco-friendly technique as there is eight times less use of energy and less emission of gases, such as carbon dioxide and mercury. There is four times less carbon impact versus the traditional flame cremation. This also means reduction in the release of toxic gases and microbial contaminants, which are harmful to the environment, human beings, and animals as well as to the aquatic life. In electric cremation, more time is consumed and more power is needed, which is about 100 kW. Constant power supply is difficult at many places. So, it

There is four times less carbon impact versus the traditional flame cremation. This also means reduction in the release of toxic gases and microbial contaminants, which are harmful to the environment, human beings, and animals as well as to the aquatic life. In electric cremation, more time is consumed and more power is needed, which is about 100 kW.

appears that bio-cremation is better as compared to electric cremation. In India, people cremate dead bodies near rivers.

This causes air pollution and the residual particles get dissolved in the river water, which directly affects the aquatic life. Moreover, in India, for cremation of dead bodies, people use huge amount of wood. Every year, about 50–60 million trees are chopped off for the cremation rituals.

Deforestation, as we all know, is one of the major problems related to the environmental degradation. Thus, in the long run, bio-cremation will not only help to stop deforestation, but also help in controlling air pollution and saving power. In a country like India, it is a challenging endeavour to implement the idea in people's mind because of the rituals and traditions attached with it. We must understand that even though following religious traditions is necessary but taking care of our environment, with the adoption of eco-friendly techniques, is equally essential.

Promotion of Bio-cremation in India

Earlier, the government and several environmental groups had tried to promote the use of electrical crematoriums but faced severe objections as traditional rituals could not be performed, such as *kapal kriya*, where a long bamboo pole is used to crack open the burning skull to relieve the soul from its earthly existence. Therefore, it is evident that promotion of bio-cremation too would be a challenge. The government should reduce the cost of bio-cremators by using proper scientific techniques so that maximum people can afford to use it.

Also, awareness generation is vital in order to promote the technique of bio-cremation. With the help of the NGOs and other environmental groups, the government should conduct different programmes to educate people. Hence, it needs to be seen when India will set up its first bio-crematorium. EF

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6TH INTERSOL

With over 20 years of experience, Intersolar has the unique ability to bring together members of the solar industry from across the world's most influential markets. Intersolar exhibitions and conferences are held in Munich, San Francisco, Mumbai, Beijing, and São Paulo. These global events are complemented by the Intersolar Summits, which take place in emerging and growing markets worldwide.

With events spanning four continents, Intersolar is the world's leading exhibition series for the solar industry and its partners. It unites people and companies from around the world with the aim of increasing the share of solar power in our energy supply. Intersolar India is the country's largest exhibition and conference for the solar industry. It is also one of the largest solar events in Asia. This event takes place annually at the Bombay Exhibition Centre (BEC) in Mumbai. The event's exhibition and conference both focus on the areas of photovoltaics, PV production technologies, energy storage, and solar thermal technologies. Since its inception, Intersolar has become the most important industry platform for the manufacturers, suppliers, distributors, service providers, and partners in the global solar industry.

Sixth Edition of Intersolar India 2014 in Mumbai

The sixth edition of Intersolar India 2014, the three-day (November 18–20, 2014) solar show hosted by Messe Munchen International (MMI) India was held at the BEC, Mumbai. The show is recognized as an integral part of the power industry in India by the associations and the industries at large. The first day of Intersolar India 2014 proved that 'Solar Energy' is the need of the hour, no matter how the economy is, with over 200 exhibitors from across the globe, such as the UK, Germany, China, Japan, Singapore, the US, the Netherlands, Greece, Spain, Belgium, and Korea in addition to India, showcased their products and technologies for the solar industry. Intersolar India featured various national pavilions, which gave especially small and medium companies from abroad the opportunity to present their products and services to the Indian solar market. It was also for the first time that the exhibition witnessed a state pavilion of Madhya Pradesh (MP). The MP pavilion showcased the latest developments and policies in the state which is now considered to be the top runner for solar space considering its achievements in the past one year. Welspun, SunEdison, and Urjaas were the three major developers who participated inside the state pavilion.

AR INDIA 2014

Dr R K Pachauri at the Inauguration of Intersolar India 2104

The grand inauguration of Intersolar India 2014 was attended by many dignitaries, such as Dr R K Pachauri, Director-General, The Energy and Resources Institute (TERI), India and Chairman of the Intergovernmental Panel on Climate Change (IPCC); Mr Riccardo Amoroso, Vice President, European Photovoltaic Industry Association (EPIA), Belgium; Mr Marcus Wiemann, Secretary-General, Alliance for Rural Electrification (ARE), Belgium. The summit brought together senior solar professionals from Consulate General of India, Frankfurt, Solar Energy Society of India (SESI), New Renewable Energy Department, Government of Madhya Pradesh, VDMA Photovoltaic Equipment, Alliance for Energy Efficient Economy (AEEE), Semiconductor Equipment and Materials International (SEMI), India Business Group (IBG), Bundesverband Solarwirtschaft (BSW), Emergent Ventures India Ltd (EVI), EPIA, ARE, and other private companies from the solar sector. Intersolar India 2014 was marked by an award felicitation programme that paid tribute and gave further impetus to the innovative power of the industry.

The different categories of the awards were—Off-grid Solutions, Industrial and Commercial Application, and Utility-Scale Project. The companies that received the award in these categories were Tata Power for Utility-Scale Project, Bosch for Industrial and Commercial Applications, and Trojan Battery Company for Off-grid Solutions.

At the event, Dr R K Pachauri said, "Solar energy has a unique quality of transforming lives of people where conventional power cannot reach like the interiors of North-Eastern region. India receives the highest amount of solar irradiation throughout the year; therefore, we should efficiently harness this energy resource and utilize this for the areas where is shortage of conventional power. India is fortunate to experience such magnitude of solar energy and with other forms of energy in short supply solar energy is a great blessing for all of us."

Intersolar Press Conference

Subsequent to the inauguration ceremony, the event had a press conference which housed eminent names like Mr Markus Elsasser, CEO, Solar Promotion, Ms Katharina Schlegel, Deputy CEO and COO, MMI, besides the ones present for the opening ceremony.

The world is on the cusp of change and India is going to take-off in a big way in solar energy. Human influence on the climate system is very clear. Global warming that is taking place since the middle of the last century is extremely likely to be the result of human actions.

The more we disturb our climate the more severe, pervasive, and irreversible impact it will have on the earth. Fortunately, we have means to limit climate change to build a more prosperous and sustainable future. Intersolar India 2014 was recently awarded a certificate by EVI for being a carbon neutral event. The carbon footprint of the event is estimated to be 632 tonnes CO_2 based on ISO 14064 guidelines and consisted of travel, stay, and venue-related emissions. In order to achieve neutrality, EVI on behalf of Intersolar India, retired equivalent amount of Verified Carbon Standard (VCS) certified emission reduction credits from 12-MW grid-connected Wind Power Project, Gujarat, India.

Ms Katharina Schlegel said, "It has been proved without doubt that solar power would provide the vital link, which would bridge the gap between the nation's demand for power and supply. Recognizing that need, Intersolar India 2014 would provide the perfect platform for stakeholders from the solar community to come together and address challenges that have acted as speed bumps to this growth." EF

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Commercial Challenge in **Algae for Biofuels** Still Very Large

Algae are considered the potential source of biofuels to resolve the ongoing energy crisis. But it's not an easy task; there are many constraints to it. In this interview with Energy Future, **Prof. Michael A Borowitzka**, Director, Algae R&D Centre at Murdoch University, Australia speaks to **Sapna Gopal**, a freelance environment and clean energy writer, on the current relevance of algal biofuels, apart from detailing on the potential it holds in the years to come.

Over the last couple of years, algae have shown immense promise as a potential biofuel. Could you elaborate on its growing prospects?

Firstly, algae are not the biofuel, but they can be converted into biofuels. Algae were proposed as a source of oil for biofuel as early as 1942. However, serious work on this did not begin until the oil crisis in the late 1980s. But once the oil prices dropped, so did the interest in algae. Then, about a decade ago, algae as sources of biofuels and bioenergy were 'rediscovered'.

It has long been possible to produce microalgae on a large scale. However, for a low-value product such as biofuel, the production cost is too high. The current commercial production of microalgae is for high value products such as the carotenoids, beta-carotene, and astaxanthin, and microalgae for health food, etc. Most of the work, done by very many people and with very large amounts of funding, not just in the US but also in most other parts of the world, has made some advances in algae for biofuel production, but the commercial challenge is still very large. Significant ongoing research and development is still needed if the goal of a commercially viable process is to become a reality.

Prof. Borowitzka was part of the team which developed and commercialized the production of beta-carotene from *Dunaliella salina*. He was also responsible for the design, construction, and operation of the pilot plant. The process production of beta-carotene from *Dunaliella salina* was commercialized in the late 1980s at Hutt Lagoon, Western Australia (WA), and the current production plant is the largest microalgae production plant in the world. In 2010, Prof. Borowitzka and the team from Murdoch University and the University of Adelaide commissioned the first algal biofuels plant in Australia in Karratha, WA.

Having been involved in research in algae and biofuels, could you tell us a bit about some interesting findings that you have discovered?

We have been working on commercial-scale algae products and processes for over 35 years. Our first success was the development of the process of producing beta-carotene from the green alga *Dunaliella salina*. This process was commercialized and we now have in Australia the two largest algae production plants producing beta-carotene from this alga. Each of the two plants is over 450 ha in area.

With regard to biofuels, we at the Murdoch University have isolated and characterized several strains of microalgae which show reliable high productivities with high oil contents in an outdoor pilot scale trial. These trials have now been carried out for over several years. A key and very important factor is that the algae can grow over a wide range of salinity, so we only need to use saline water and thus we will not compete with freshwater, which is a scarce resource.

At present, the process is being further developed by a company called Muradel, which has just completed the next scale of its demonstration plant that fully integrates the algae production and the production of biofuels using hydrothermal liquefaction. The next few years

will show whether the process can be commercialized.

Do you feel that microalgae-based biofuel has the potential to meet a significant part of the world's energy demands?

No. Algae are highly unlikely to be able to replace our demand for liquid fuels, but they can be part of the renewable liquid fuel mix; but by how much degree—this will very likely be dependent on the region as some countries have the climate, land, and water resources required, whereas others do not.

Recently, the US Department of Energy (DoE) opened a $25 million funding opportunity for algal biofuels. The initiative aims to reduce the cost of algal biofuels to less than $5 per gasoline gallon equivalent (gge) by 2019. The DoE has set a goal to achieve a cost of $3 per gge by 2030. Is this possible?

These are very much 'stretch' targets and it is worth noting that the $5 target is still about two times the current price at the pump in the US (as the pump price also includes about 12 per cent of federal and state taxes). However, this target may be achievable in the proposed timeframe.

After a decade or so of research, a number of companies from around the world are moving to demonstration plants on a realistic scale. These are essential to demonstrate what can actually be done at the full production scale, both in terms of producing the algal biomass, and also regarding harvesting and downstream processing. These large facilities will also show what the problems at scale might be (or what the advantages of scale are), so that these problems can be solved. Given that there are many people from different backgrounds and disciplines with a variety of essential skills, it makes it much more likely that the current limitations and difficulties will be resolved. Some exciting new developments, especially in converting the algal biomass to liquid fuel using a hydrothermal liquefaction process, are important components in reducing the cost of algal biofuels. These new processes are yet to be optimized and improved further.

A Korean research team at the Department of Biotechnology at Korea University successfully defined the fermentation process of red algae and found a clue to making ethanol, a third generation fuel for vehicles. Is this likely to help the automobile industry in the years to come?

The key question will be the supply of enough biomass so as to ferment, produce the ethanol, and getting this supply at an acceptable cost. The availability of supply of these seaweeds will be the major limiting factor. However, seaweeds such as the red algae are likely to be a source of ethanol in the relatively near future. Ethanol blends are already used in many countries for automobiles.

Researchers from the American University of Beirut (AUB) recently identified an algae species that can be a possible source of cheap renewable energy. Will such findings help in combating the energy crisis worldwide?

Many people have been isolating algae species and are making many claims; however, these claims are almost always based on very small-scale laboratory studies and it is a long way from the laboratory to an actual process. But, the ongoing search for new and better species and strains (are different isolates or genotypes of the same species) is an important part in the attempt to develop a reliable, sustainable, and economical process of producing biofuels from algae.

The airline industry has used biofuels to some extent. What is the scope of growth of the biofuels in the times to come?

The airline industry has the most urgent demand for a renewable liquid fuel and is a major fuel consumer worldwide.

Also, the airlines have no real alternative to liquid fuels, unlike the automotive industry which can also make electric vehicles, hybrid vehicles, and use a much wider range of liquid fuels than the airline industry. Hence, the airline industry is a key supporter of research and development on algal biofuels as well as other sources of renewable biofuels.

For a country like India, what are the prospects of algae in making biofuel?

India is well placed and significant research and development is going on in this regard. It has the highly skilled scientists and engineers, large areas with suitable climate too. Also, India will be able to capitalize on developments in other countries. So, the prospects of algae for biofuel production are favourable. EF

Invitation for applications to Girish Sant Memorial Young Researcher Fellowship 2015

Girish Sant, a pioneering policy researcher and public interest advocate in the energy sector passed away unexpectedly in February 2012. Prayas and several friends and well-wishers of Girish, have set up a Young Researcher Fellowship to encourage young researchers to imbibe his values and approach of high quality analysis, commitment to social equity and emphasis on policy impacts. The objectives of the fellowship are to encourage young Indian researchers to take up public interest oriented research and advocacy in the Indian energy sector, and to provide some financial and professional support to youngsters at an early stage of their career.

Applications are invited from interested candidates to avail of the fellowship for 2015. The fellowship is open to all Indians below the age of 35. The last date for submitting fellowship applications is February 10, 2015. Please visit http://tinyurl.com/yrf2015 or write to gsm-yrf@prayaspune.org for more details on the fellowship and how to apply for it. Please visit www.prayaspune.org/peg for more information about Prayas (Energy Group) and the work of Girish Sant.

CURRENT R&D SOLAR

Renewable Energy Gathers Steam in South Africa

Renewable and Sustainable Energy Reviews, Volume 41, January 2015, Pages 390–401

David Richard Walwyn and Alan Colin Brent

Producers Procurement Programme (the REI4P) is an extensive initiative to install 17.8 GW of electricity generation capacity from renewables—wind, solar, biomass, biogas, and hydropower—over the period 2012–30. Although at the outset, the REI4P seemed an expensive option, designed only to deflect criticism of South Africa's high carbon footprint and excessive dependence on coal-based electricity generation, the escalating costs of the latter, the rapidly falling costs of photovoltaic and wind power, and the increasingly competitive bidding process of the REI4P have changed this prospect. At the conclusion of round three, the weighted cost of energy has reached a 23 per cent discount to the cost of new coal-based generation and a 28 per cent discount to global renewable energy prices. The bidders' commitments to local employment creation have similarly increased from 11–18 jobs/MW. The programme is now well placed to deliver on a broad range of objectives, including regional development and black economic empowerment. However, maximum benefit from the REI4P will not be secured without some revision to aspects of the bidding and procurement process. More specifically, the local content provisions need to be tightened to drive higher levels of local manufacturing.

Barriers to Renewable/Sustainable Energy Technologies Adoption: Indian Perspective

Renewable and Sustainable Energy Reviews, Volume 41, January 2015, Pages 762–776

Sunil Luthra, Sanjay Kumar, Dixit Garg, and Abid Haleem

Rapidly increasing energy demand and growing concern about economic and environmental consequences call for renewable/sustainable energy technologies' adoption in India. Renewable or sustainable energy technologies have faced a number of constraints that have affected their rate of adoption. In this paper, an attempt has been made to identify and rank the major barriers in the adoption of 'renewable and green' energy technologies in the Indian context. Twenty-eight barriers have been identified from an extensive literature review. These identified barriers have been categorized into seven dimensions of barriers, i.e., Economical and Financial; Market; Awareness and Information; Technical; Ecological and Geographical; Cultural and Behavioural; and Political and Government Issues. Analytical Hierarchy Process (AHP) technique has been utilized for ranking of barriers to adopt renewable/sustainable technologies in the Indian context. All pair comparisons in AHP have been made based on experts' opinions (selected from academia and industry). Sensitivity analysis has also been made to investigate the priority ranking stability of barriers to adopt renewable/sustainable technologies in the Indian context. This paper may help practitioners, regulators, and academician to focus their future efforts in adoption of 'renewable/sustainable energy technologies' in India. Further, this understanding may be helpful in framing the policies and strategies towards adoption of renewable/sustainable energy technologies.

Ocean Renewable Energy in Southeast Asia: A Review

Renewable and Sustainable Energy Reviews, Volume 41, January 2015, Pages 799–817

Mary Ann Joy Robles Quirapas, Htet Lin, Michael Lochinvar Sim Abundo, Sahara Brahim, and Diane Santos

This paper presents preliminary research on Ocean Renewable Energy (ORE) in Southeast Asia (SEA). It gives an overview of the ORE status of the region in terms of its potential and existing policies that support the utilization of ORE as an alternative source of energy. The study argues that there is potential to harness ORE in this region; however, there are a number of challenges to fully utilize

this potential. This work presents: (1) collated ORE resource information, (2) collated policies relevant to increase uptake in the region, and (3) an ORE development matrix which is important for analysing the gaps in utilizing ORE in SEA. A review discussion on the unique conditions of SEA in terms of resource and ORE-relevant policies are tackled. Special attention is given to existing policy frameworks and regional non-economic barriers to see how these could impact the development of ORE in SEA.

India's CO_2 Emission Pathways to 2050: What Role Can Renewables Play?

Applied Energy, Volume 131, October 15, 2014, Pages 79–86
Gabrial Anandarajah and Ajay Gambhir

Renewable energy can play an important role in India's climate change mitigation, as India has great potential for renewables, especially solar and wind. This paper analyses the role of renewables to meet India's possible 2050 climate change mitigation targets using a multi-region global energy system model called TIAM-UCL, where India is explicitly represented as a separate region. TIAM-UCL is a cost optimization model. The climate policy is applied to all regions in the model based on equal per capita emissions of 1.3 tCO_2 by 2050. Analysis shows that renewable energy can play an important role to decarbonize the economy, especially the power sector.

Two low-carbon scenarios are explored, the first allowing for Carbon Capture and Storage (CCS) technology deployment and the second excluding this technology. In the first low-carbon scenario (LC1), the most critical renewable energy technologies in the power sector are biomass with CCS, solar, and wind. In the second low-carbon scenario (LC2), without CCS, there is an even greater role for solar and wind. Over the whole Indian economy, by 2050 renewables contribute 57 per cent of the total CO_2 reductions in LC1 (relative to a reference scenario with no CO_2 target) and 63 per cent of the CO_2 reductions in LC2.

Renewable Energy Education: A Global Status Review

Renewable and Sustainable Energy Reviews, Volume 34, June 2014, Pages 300–324
Tara C Kandpal and Lars Broman

Need for renewable energy education and training at all levels is globally recognized. During the last three decades, a large number of countries across the globe have initiated academic programmes on renewable energy technologies and related aspects. A review of published literature on renewable energy education initiatives across the globe, challenges faced, and potential approaches towards efficient and effective solutions are presented in the paper.

The Main Support Mechanisms to Finance Renewable Energy Development

Renewable and Sustainable Energy Reviews, Volume 40, December 2014, Pages 876–885
Shahrouz Abolhosseini and Almas Heshmati

Considering that the major part of greenhouse gases is carbon dioxide, there is a global concern aimed at reducing carbon emissions.

In addition, major consumer countries are looking for alternative sources of energy to avoid the impact of higher fossil fuel prices and political instability in the major energy supplying countries. In this regard, different policies could be applied to reduce carbon emissions, such as enhancing renewable energy deployment and encouraging technological innovation and the creation of green jobs.

This study compares three main support mechanisms employed by governments to finance renewable energy development programmes, such as feed-in-tariffs, tax incentives, and tradable green certificates.

Considering that many of the promising technologies to deploy renewable energy require investment in small-scale energy production systems, these mechanisms could be used to enhance renewable energy development at the desired scale. Employing a carbon emission tax or emission trading mechanism could be considered ideal policies to mitigate emissions at the lowest cost.

The comparison of feed-in-tariffs and renewable portfolio standard policies showed that the former is good when a policy to develop renewable energy sources with a low level of risk for investors is considered.

However, the latter is an appropriate policy when a market view policy is applied by the government. Finally, considering technological progress and the cost reduction for power generation by renewable energy sources, we suggest that support mechanism policies should be reconsidered from the financial point of view.

Perspectives of Microalgal Biofuels as a Renewable Source of Energy

Energy Conversion and Management, Volume 88, December 2014, Pages 1228–1244

Bala Kiran, Ritunesh Kumar, and Devendra Deshmukh

Excessive use of fossil fuels to satisfy our rapidly increasing energy demand has created severe environmental problems, such as air pollution, acid rain, and global warming. Biofuels are a potential alternative to fossil fuels. First- and second-generation biofuels face criticism due to food security and biodiversity issues. Third-generation biofuels, based on microalgae, seem to be a plausible solution to the current energy crisis, as their oil-producing capability is many times higher than that of various oil crops. Microalgae are the fastest-growing plants and can serve as a sustainable energy source for the production of biodiesel and several other biofuels by conversion of sunlight into chemical energy. Biofuels produced from microalgae are renewable, non-toxic, biodegradable, and environment friendly. Microalgae can be grown in open pond systems or closed photobioreactors. Microalgal biofuels are a potential means to keep the development of human activities in synchronization with the environment. The integration of wastewater treatment with biofuel production using microalgae has made microalgal biofuels more attractive and cost-effective. A biorefinery approach can also be used to improve the economics of biofuel production, in which all components of microalgal biomass (i.e., proteins, lipids, and carbohydrates) are used to produce useful products. The integration of various processes for maximum economic and environmental benefits minimizes the amount of waste produced and the pollution level. This paper presents an overview of various aspects associated with biofuel production from microalgae, including the selection and isolation of microalgal species, various cultivation and harvesting techniques as well as methods for their subsequent conversion into biofuels.

Collective Institutional Entrepreneurship and Contestations in Wind Energy in India

Renewable and Sustainable Energy Reviews, Volume 42, February 2015, Pages 999–1011

Suyash Jolly and R P J M Raven

With 21,136 MW of wind energy installed in 2014, India is considered a success story in terms of net installed capacity. Few existing studies on Indian wind energy have highlighted the important role of institutions, and how they stemmed from the work of advocacy groups; studies also tend to focus on short time periods. This paper uses the notion of collective institutional entrepreneurship to analyse Indian wind energy across three time periods (1985–1995, 1995–2003, and 2003–13). The analysis shows that Indian wind power development was driven by collective efforts of institutional entrepreneurs using two aggregated strategies, that is, supportive techno-economic and socio-political networks and an indigenous innovation infrastructure. The paper highlights setbacks, controversies, and tensions between various entrepreneurship groups and argues that actions must be taken for including actors who have been marginalized.

Modelling an Off-Grid Integrated Renewable Energy System for Rural Electrification in India Using Photovoltaics and Anaerobic Digestion

Renewable Energy, Volume 74, February 2015,
Pages 390–398

J G Castellanos, M Walker, D Poggio, M Pourkashanian, and W Nimmo

This work describes the design optimization and techno-economic analysis of an off-grid Integrated Renewable Energy System (IRES) designed to meet the electrical demand of a rural village location in West Bengal—India with an overall electrical requirement equivalent to 22 MWh/year. The investigation involved the modelling of seven scenarios, each containing a different combination of electricity generation (anaerobic digestion with biogas Combined Heat and Power [CHP] and photovoltaics) and storage elements (Vanadium redox batteries, water electrolyser, and hydrogen storage with fuel cell). Micro-grid modelling software HOMER, was combined with additional modelling of anaerobic digestion, to scale each component in each scenario considering the systems' ability to give a good quality electricity supply to a rural community. The integrated system which contained all of the possible elements—except hydrogen production and storage presented the lowest capital ($71 k) and energy cost ($0.289 kWh) compared to the scenarios with a single energy source. The biogas CHP was able to meet the electrical load peaks and variations and produced 61 per cent of the total electricity in the optimized system, while the photovoltaics met the daytime load and allowed the charging of the battery which was subsequently used to meet base load at night. EF

OPzS

Storage Battery Systems's (SBS) recombination plug has a simple and reliable construction. When the recombination device is directly placed within the gas-containing part of the battery, the flow of gasses through the catalytic and absorptive deposits becomes easy.

BATTERY

Recombination Plug—RecPlug1

As chemical constituents are charged with electricity, hydrogen and oxygen are released. These are the byproducts of the breakdown of water in the electrolyte. These gases are then released into the atmosphere, creating an explosion hazard. At the same time, this process reduces the electrolyte's water level, which then has to be replenished periodically. One means of successfully eliminating this undesirable phenomenon is to use a system that recombines the gases externally. Hence, a recombination plug is very useful in this regard.

The plug, which recombines water from oxygen and hydrogen released during the charging of the chemical constituents, consists of a casing containing the recombination device—a specially designed ceramic cylinder filled with a catalytic deposit and a deposit having absorptive properties.

Storage Battery Systems's (SBS) recombination plug has a simple and reliable construction. When recombination device is directly placed within the gas-containing part of the battery, the flow of gases through the catalytic and absorptive deposits becomes easy. This effectually eliminates the flow of gases from the battery into the atmosphere. Such a construction thus significantly enhances the following:

- Safety associated with battery use
- Prevents the flow of gas into the immediate surroundings under normal conditions
- Eliminates the risk of ignition
- Eliminates the need for water refilling
- This device is economical from the perspectives of installation and maintenance.

Main Features of the Recombination Plug

The main features of the recombination plug such as lifetime, safety, economy, and flexibility are as follows:

- Recombination plug has a lifespan of more than 20 years. Flooded batteries with recombination plugs have much longer life than Valve-Regulated Lead-Acid (VRLA) batteries, in which it is not possible to add make-up water.
- The recombination plug has increased safety of operation of cells with liquid electrolyte, since electrolyte fumes and poisonous gases do not leak from the battery into the immediate surroundings. In this way, none of the gases capable of causing explosions are released into the surrounding area.
- Having significantly reduced the frequency of water refilling (12–15 years topping-up interval), the recombination plug is optimized to work for the full lifetime of the battery.
- It also has the ability to match the type of plug to specific capacity of batteries.

Principle of Operation

Operation of lead-acid batteries results in the electrolysis of water and releases hydrogen and oxygen as part of this process. These gases in air may form explosive mixtures.

Additionally, the electrolysis reduces the amount of water in the electrolyte, which must be frequently replenished in the battery. The conversion of hydrogen and oxygen into steam is an exothermic process. The heat emitted during the recombination process inside a VRLA-sealed battery significantly accelerates the degradation of the lead electrodes immersed in the electrolyte.

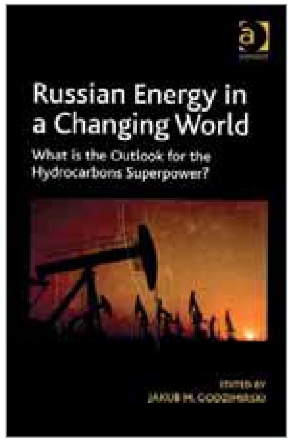
Therefore, when the process is preferably performed away from the recombination with the electrodes and within the recombination plugs, the life of the entire battery is increased.

Water vapour then condenses on the walls of plug after cooling and the water flows back in to the battery. Recombination plugs reduce the maintenance task of frequently replenishing the electrolyte level in the battery. This increases the safety of the battery in areas with limited ventilation. EF

Source: www.renewableenergyworld.com

Russian Energy in a Changing World: What is the Outlook for the Hydrocarbons Superpower?

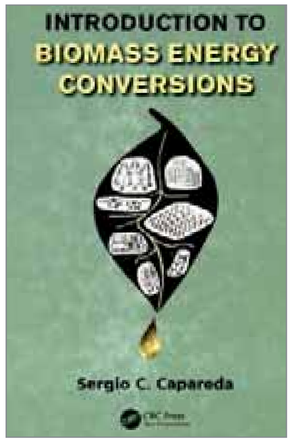
The book highlights Russia's position as a key global energy player which has enhanced Moscow's international economic and political influence whilst causing concern amongst other states fearful of becoming too dependent on Russia as an energy supplier. The Global Financial Crisis shook this established image of Russia as an indispensable energy superpower, immune to negative external influences, and revealed the full extent of Russia's dependence on oil and gas for economic and political influence. This led to calls from within the country for a new approach where energy resources were no longer regarded wholly as an asset, but also a potential curse resulting in an over reliance on one sector thwarting modernization of the economy and the country as a whole. In this fascinating and timely volume, leading Russian and Western scholars examine various aspects of Russian energy policy and the opportunities and constraints that influence the choices made by the country's energy decision makers.



Editor: Jakub M Godzimirski,
Publisher: Ashgate Publishing Ltd
Pages 199

Introduction to Biomass Energy Conversions

This book is intended to serve as a textbook for the courses in biomass energy conservation. It reveals the potential that biomass energy has to supplement traditional fuels and reduce greenhouse gas emissions. While much has been written about biomass conversions, no single textbook contains all the information needed to teach a biomass conversion course—until now. *Introduction to Biomass Energy Conversions* presents a comprehensive review of biomass resources available for conversion into heat, power, and biofuels. This book covers biomass characterization and discusses facilities, equipment, and standards (e.g., ASTM or NREL) used for analysis. It examines the range of biomass resources available for conversion and presents traditional biomass conversion processes along with extensive biomass characterization data tables, illustrations, and graphical presentations of the various biomass energy conversion processes. The author also describes how to set up a laboratory for biomass energy conversion.

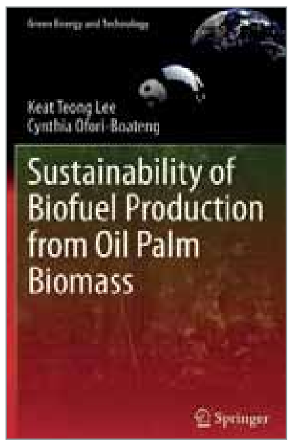


Author: Sergio C Capareda
Publisher: CRC Press, Taylor and Francis Group
Pages 585

Sustainability of Biofuel Production from Oil Palm Biomass

This book evaluates and discusses the main sustainability challenges encountered in the production of biofuel and bio-products from oil palm biomass. It starts off with the emphasis on oil palm production, oil palm products recovery, and oil palm wastes utilization. The simultaneous production of these bio-products for sustainable development is also discussed. This is followed by the key factors defining the sustainability of biofuel and bio-product production from oil palm biomass.

The environmental issues including ecological, life cycle assessment, and environmental impact assessment of oil palm plantation, milling, and refining for the production of biofuels and bio-products are presented in this book. Socio-economic and thermodynamic analysis of the production processes are also evaluated. Lastly, methods of improving biofuel production systems for sustainable development are highlighted.



Author: Keat Teong Lee and Cynthia Ofori- Boateng
Publisher: Springer
Pages 323

Urban Energy Systems: An Integrated Approach

This book analyses the technical and social systems that satisfy certain energy needs and asks how methods can be put into practice to achieve the set energy goals. Drawing on analytical tools and case studies developed at Imperial College London, the book presents state-of-the-art techniques for examining urban energy systems as integrated systems of technologies, resources, and people.

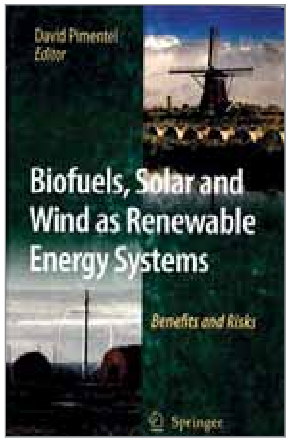
Case studies include a history of the evolution of London's urban energy system, from pre-history to present day; a history of the growth of district heating and cogeneration in Copenhagen, one of the world's most energy–efficient cities; an analysis of changing energy consumption and environmental impacts in the Kenyan city of Nakuru over a thirty year period; an application of uncertainty and sensitivity analysis techniques to show how Newcastle-upon-Tyne can reach its 2050 carbon emission targets; designing an optimized low-carbon energy system for a new UK eco-town, showing how it would meet ever more stringent emissions targets. EF

Editors: James Keirstead and Nilay Shah
Publisher: Rutledge
Pages 313

Biofuels, Solar and Wind as Renewable Energy Systems: Benefits and Risks

This book features 20 chapters by worldwide experts in the field who illuminate the global discussion. It stimulates the discussion on the use of biomass for biofuels, and thus contributes to the growing interest in alternative energy sources.

With shortages of fossil energy, especially oil and natural gas, and heavy biomass energy use occurring in both developed and developing countries, a major focus has developed worldwide on renewable energy systems. Renewable energy systems include wind power, biomass, photovoltaics, hydropower, solar thermal, thermal ponds, and biogas. Currently, a heavy focus is on biofuels made from crops, such as corn, sugarcane, and soybeans, for use as renewable energy sources. Wood and crop residues are also being used as fuel. Though it may seem beneficial to use renewable plant materials for biofuel, the use of crop residues and other biomass for biofuels raises many concerns about major environmental problems, including food shortages and serious destruction of vital soil resources. EF

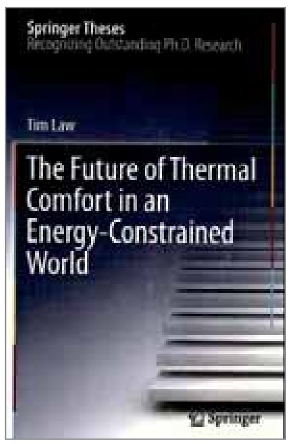


Editor: David Pimentel
Publisher: Springer
Pages 504

The Future of Thermal Comfort in an Energy-Constrained World

This dissertation, presented in a book form, investigates the scientific and business factors that have resulted in air-conditioning being a major contributor to climate change. With his architectural background, the author demonstrates how a design methodology, not commonly adopted in scientific studies, may actually be a suitable way of dealing with a complex problem: the 'business-as-usual' scenario involving building science, sociological values, and consumer behaviour.

Using his innovations as case studies, the author shows how good ideas cannot be evaluated on scientific merit alone and demonstrates why commercialization may have a pivotal role in deployment of research-based technology. He advances the theory of personalized thermal comfort which can potentially resolve the air-conditioning conundrum. EF



Author: Tim Law
Publisher: Springer
Pages 329

RENEWABLE ENERGY TECHNOLOGY DEVELOPMENT

Assessing employment in renewable energy technologies: A case study for wind power in Brazil

Environmental concerns and the search for climate change mitigation have led to the deployment of Renewable Energy Technologies (RET) in several countries. The adoption of incentive policies, especially those based on heavy subsides, has motivated the discussion of social and economic benefits brought about by these technologies, on employment rates. In this context, several studies have been conducted to quantify job creation by RET, concluding that the latter are more labour intensive than traditional fossil-fueled technologies. However, results for different assessments vary largely due to distinct methodological approaches, and are frequently highly aggregated. Thus, results are not comparable or applicable to other contexts. Previous studies have failed to quantify the effects of imports and exports of RET equipment in total employment, usually associating employment and installed capacity in the year studied. This study has aimed to address these issues, creating an index for employment quantification based on production, instead of installed, capacity. We have estimated both direct jobs in manufacture, construction, and operation and management, and indirect jobs both in the upstream supply chains of materials and inputs to manufacture of wind turbines and construction of wind farms. We have also performed an assessment of jobs created in wind energy projects which are expected to begin operation in Brazil by 2017. The resulting job potential in Brazil corresponds to 13.5 persons-year equivalent for each MW installed between manufacture and first year of operation of a wind power plant, and 24.5 persons-year equivalent over the wind farm lifetime. Results show that major contribution from wind power for job creation are in the construction stage and, despite the low amount of jobs created in operation and maintenance relative to new installed capacity, those stable jobs stand out as they persist over the entire wind farm's lifetime.

www.researchgate.net/.../259522014_Assessing_employment_in_renewable_ energy_ technologies_A_case_study_for_wind_power_in_Brazil

Equipment sizing in a coal-fired municipal heating plant modernisation project with support for renewable energy and cogeneration technologies

The paper presents results of design parameters optimization of a woodchips fired steam boiler-based heat and power block in a sample project of coal-fired municipal heating plant modernization. The project assumes the conversion of the heating plant into a dual fuel heat and power plant. The problem that is presented is selection of cogeneration block structure and thermodynamic parameters taking into account financial support mechanisms for cogeneration and renewable energy technologies. There are examined energy conversion and financial performances of the project. The results show that without the financial support the project is not profitable although it generates savings of primary energy of fossil fuels. If administrative incentives are applied the optimal technical solution is different than suggested by energy conversion efficiency or fossil fuel savings. Financial calculations were performed for Polish marked conditions in the years 2011 and 2014 showing the impact of relatively short-term variations of prices and support intensity on optimal plant design parameters.

www.cabdirect.org/abstracts/20143336817.html

Diffusion of renewable energy technologies in South Korea on incorporating their competitive interrelationships

Renewable Energy Technologies (RETs) have attracted significant public attention for several reasons, the most important being that they are clean alternative energy sources that help reduce greenhouse gas emissions. To increase the probability that RETs will be successful, it is essential to reduce the uncertainty about its adoption with accurate long-term demand forecasting. This study develops a diffusion model that incorporates the effect of competitive interrelationships among renewable sources to forecast the growth pattern of five RETs: solar photovoltaic, wind power, and fuel cell in the electric power sector, and solar thermal, and geothermal energy in the heating sector. The two-step forecasting procedure is based on the Bayus, (1993. Manage. Sci. 39, 11, 1319–1333) price function and a diffusion model suggested by Hahn et al., (1994. Marketing Sci. 13, 3, 224–247). In an empirical analysis, the model is applied to the South Korean renewable energy market.

https://ideas.repec.org/a/eee/enepol/v69y2014icp248-257.html

Role of renewable energy technologies in rural communities' adaptation to climate change in Nepal

The aim of this paper is to analyze the role of renewable energy technologies (RETs) such as biogas, Improved Cooking Stoves (ICSs), Micro Hydro (MH), and Solar Power (SP) in helping rural communities in Nepal to adapt to climate change. The analysis considers the energy efficiency of different RETs as well as their socio-economic and environmental impacts. The efficient use of biomass in new technology, such as biogas and ICSs for cooking, has increased energy security and reduced the negative effects of traditional biomass usage. MH and SP systems are replacing candles and kerosene lamps, and are the most promising RET models for electricity generation in rural Nepal. The improved illumination from these technologies also produces better education, health, environments, and social harmony in rural communities. This study uses the Long-range Energy Alternatives Planning model (LEAP) model to develop a plan for long-term RETs use in Nepal, and specifically focuses on household energy use in rural areas. It assesses the role of biogas and ICSs in rural communities and climate change adaptation in Nepal, along with the potential role of MH and SP technologies. According to the LEAP analysis, the planned implementation of MH for a period of 20 year will result in the reduction of 2.553 million tonnes of CO_2 emissions. Similarly SP, biogas, and ICSs will result in a reduction in CO_2 emissions of 5.214 million tonnes, 35.880 million tonnes, and 7.452 million tonnes, respectively.

econpapers.repec.org/RePEc:eee:renene:v:68:y:2014:i:c:p:793-800

Renewable energy technologies: Panacea for world energy security and climate change?

The rapid increase in anthropogenic greenhouse gas concentrations in the last several decades has caused observable changes in global climate on all continents. Carbon dioxide, the primary causative agent of climate change has increased from long-term mean average of 275 ppm to the current level of 400 ppm. About 85 per cent of the current global energy production and use is based or derived from fossil fuels. If there is no concerted action by the global community, CO_2 levels could increase by 130 per cent by mid-century resulting in large-scale climate changes, such as the disintegration of the West Antarctic ice sheet, large-scale coral reef bleaching, and shutdown of the ocean circulation system. Stabilization of CO_2 levels will require a deceleration in the rate of increase in fossil fuel consumption, and the use of emission-free power sources in the immediate future. The former can have immediate ameliorative effects, whereas the latter will require substantial investment in research and development to find and implement innovative technologies. However, there are limits to technological solutions to sustainable development. Renewable energy technologies and low-carbon emission technologies will have material and environmental constraints with as yet undetermined consequences. In addition to technological solutions, it is important to develop needed social and political infrastructure to decrease future energy demand by controlling population growth and energy intensity.

www.sciencedirect.com/science/article/pii/S1877050914006838

How government policies affect the export dynamics of renewable energy technologies: A subsectoral analysis

This study explores the long- and short-term dynamic relationships between government policies and exports of Renewable Energy Technologies (RETs) at the subsector level (biomass, wind, and solar energy technologies). This allows a more robust exploration of the relationships, in which differences in cost structures and maturity levels exist for different RETs, without losing the generality of the results. Dynamic panel econometric techniques are employed to analyse the relationships, using data of annual measures for 18 countries during 1992–2008. The Vector Error

Correction Mechanism (VECM) is used to test the dynamic relationships among government policies, exports, and Gross Domestic Product (GDP) for biomass and wind energy technologies, and the Vector Auto-Regression (VAR) model, for solar energy technologies. The study indicates that each subsector has a unique path-dependent process, showing the presence of different positive feedback mechanisms based on interactions among technology-push policy, market-pull policy, exports, and/or GDP in the short and long run. We suggest some policy implications based on the results of this study.

ideas.repec.org/a/eee/energy/v69y2014icp843-859.html

Everbright International in waste to energy project for China

The Gaochun waste to energy project is designed to process 500 tonnes of household waste a day. China Everbright International has signed an investment agreement for the development of a waste to energy project in Jiangsu Province with a 500-tonne daily capacity. The Chinese arm of business conglomerate Everbright International has signed the agreement with the Gaochun District government for the household waste to energy project, which will be constructed in the Gaochun District of Jiangsu Province in East China. With a total investment of approximately HKD 400 m, the Gaochun project, is designed to have a daily household waste processing capacity of 500 tonnes and generate green electricity of over 54,000,000 kWh annually. In addition to household waste, the Gaochun project will also process other solid waste including agricultural straw and municipal sludge. The waste to energy project will be constructed on a BOT (Build-Operate-Transfer) basis for 30 years and its gas emission will comply with the Euro 2000 Standard. China Everbright International said through the introduction of plasma gasification technology as the project's preferred technical solution, it will "accelerate the research of new waste treatment technology". This will be done with the ultimate goal of manufacturing the technology domestically by adopting it to local markets. The project marks the latest waste to energy plant planned for China this year. It follows French firm Suez Environment announcing a joint venture to build a waste to energy plant for hazardous waste in China's Nantong in March.

http://www.renewable-energy-technology.net/geothermal-bioenergy-news/everbright-international-waste-energy-project-china

World's biggest 100% biomass-fuelled power plant launched in Poland

The 205 MW biomass-fuelled power plant is made up of tree farming and agricultural byproducts. The world's largest 100 per cent biomass-fuelled power plant has been launched in Poland.

Polish provider GDF SUEZ has inaugurated the 205MW Green Unit biomass plant, which is made up of tree farming and agricultural byproducts, at Polaniec in southeast Poland. The company claims it is the world's biggest power plant entirely fuelled by biomass. Green Unit, which has a capacity of 205MW, is the first of the very large-scale 100 per cent biomass plants to run on a mixture of byproducts: 80 per cent from tree farming and 20 per cent from agriculture. GDF SUEZ said it has a very high yield due to the use of state-of-the-art technology for this type of combustion. This includes a circulating fluidized bed boiler, with cutting-edge facilities for combustion gas treatment.

The plant provides the equivalent of the annual electricity consumption of 600,000 households, and avoids 1.2 million tonnes of CO_2 emissions a year. It is part of the GDF SUEZ Energia Polska thermal plant, which has a total capacity of 1,780MW.

With Green Unit, GDF SUEZ said it has become the leading renewable electricity producer in Poland, with 102MW of capacity in land-based wind power, 205MW in biomass and some capacity in biomass in co-combustion with coal. The company said it aims to put 2,000MW of additional renewable energy capacity into service by 2017.

http://www.renewable-energy-technology.net/geothermal-bioenergy-news/world%E2%80%99s-biggest-100-biomass-fuelled-power-plant-launched-poland

World's largest biomass plant launched in Finland

The plant is the latest development in large-scale biomass gasification. The world's largest biomass gasification plant has been inaugurated in Finland. The technology for the plant has been supplied by Finnish process technology firm Metso. The company said that the plant is ground breaking because it is the first time biomass gasification has been adopted on such a large scale for the replacement of fossil fuels. The technology of the new plant is based on Metso's long-term development work.

Metso's delivery includes fuel handling, a large-scale dryer, and a circulating fluidized bed gasifier, as well as modification work on an existing coal boiler and a Metso DNA automation system. The bio-gasification plant was constructed as part of an existing coal-fired power plant. The produced gas will be combusted along with coal in the existing coal boiler.

The recent gasification technology projects are an indication of Metso's strategy of offering energy solutions in which technologies related to fuel refining have been brought forth alongside traditional combustion. In May

2012, a similar event was held in Lahti, Finland, with the inauguration of the world's first waste gasification plant.

http://www.renewable-energy-technology.net/geothermal-bioenergy-news/world%E2%80%98s-largest-biomass-plant-launched-finland

India to establish first geothermal energy plants

India is estimated to have 10,000MW geothermal potential. Plans to build India's first geothermal power plants are underway. Indian states like Gujarat, Chhattisgarh, Andhra Pradesh and West Bengal are the first of many to announce interest in developing the BRIC country's first geothermal energy plant, with power capacity in the range of 3MW to 5MW. The news follows reports in July that the Ministry of New and Renewable Energy of India (MNRE) plans to set up a geothermal energy policy later this year to guide future projects.

Companies involved in the Indian geothermal projects include Oil and Natural Gas Corporation (ONGC) in Gujarat. The company has started exploring clean energy to create growth opportunities and maximize shareholder value.

Earlier this year, Indian electric utilities company NTPC signed a Memorandum of Understanding with Chhattisgarh State Renewable Energy Development Agency. The aim of the agreement is to explore the potential of geothermal resources and implement a geothermal power project in Tattapani, Chhattisgarh, according to the Government of India. NTPC has started exploratory and preparatory work in this area. The company has also started talks with ONGC and other international organizations to discuss drilling operations. NTPC expects to start the project activities within the next 18 months after finalization of the detailed project report.

India is said to have a geothermal potential of 10,000MW, according to India Energy Portal. The Tattapani geothermal field is the most promising geothermal resource in central India, the government has said. Work to assess geothermal resource in Tattapani has been carried out over the last 30 years.

http://www.renewable-energy-technology.net/geothermal-bioenergy-news/india-establish-first-geothermal-energy-plants

California canyon to become showcase bioenergy facility using methane to power local homes and clean up air

Methane gas produced from the old landfill site will help power up to 2,000 homes. A decommissioned landfill is being turned into a methane-fuelled power station as part of a major renewable energy project in the US. The Santiago Canyon landfill in Orange Country, California, which closed in the late 1980s, is being transformed into a power station that will run on methane gas to clean up polluted air and provide power to local homes. Firm Flex OC Renewables, a subsidiary of Californian company FlexEnergy Inc, will build the power station. It will run on methane produced by decomposing waste in the landfill.

The power station is being built as part of the Santiago Canyon project, which aims to turn the landfill into a source of renewable energy that will provide methane-based power to homes in the area. Once completed, later this year, it will supply an estimated 1.5MW of power to the local area, enough to power 1,500 to 2,000 homes. The project will also progress Orange County's adaptation to new air quality standards for waste gas emissions, which will take effect in 2013.

Since the landfill closed in 1988, waste has burned off the methane released by its decomposition, releasing the pollutant into the atmosphere. Flex OC Renewables will use its turbine technology to destroy the methane and produce energy.

The company says its Flex Powerstation FP250 turbines will transform the gas from an air pollutant into a source of clean energy. They will operate at a temperature that will prevent the creation of harmful elements such as nitrous oxide, carbon monoxide, and Volatile Organic Compounds (VOCs).

http://www.renewable-energy-technology.net/geothermal-bioenergy-news/decommissioned-us-landfill-be-transformed-methane-fuelled-power-station

US enzyme tech to boost biofuel production

The enzyme product developed will boost biofuel production. A US biotechnology company has advanced its enzyme technology to boost biofuel production. Firm Dyadic's next generation enzyme solution, "AlternaFuel CMAX3", has increased performance over broader pH and temperature ranges. The company said this produces biofuels more efficiently and cheaply. Jan Wery, Science Director at Dyadic Netherlands, said the technology "achieved a similar saccharification yield at pH 5.0, and substantially better results at pH 6.0, than those achieved by the current leading competitive biofuels enzyme product." AlternaFuel CMAX3 is the latest generation of a cellulase and hemicellulase complex based on Dyadic's C1 platform technology. It enables the conversion of multiple forms of non-food biomass into fermentable sugars that can be used to produce biofuels, biogas, and other bio-based products.

http://www.renewable-energy-technology.net/geothermal-bioenergy-news/us-enzyme-tech-boost-biofuel-production

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Eoplly New Energy

It is a well-known solar panel and solar cell manufacturer in China, with 530MW production capacity that provides monocrystalline solar panels ranging from 5W to 290W and polycrystalline ranging from 5W to 285W.

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Email: sales@chinasunergy.com
Website: www.chinasunergy.com

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Producers of 3A to 140A charge solar controllers for solar home, telecom, inverter and hybrid systems; also offering, off-grid solutions for rural electrification and industrial markets. Product range also includes solar thermal controllers and inverters for grid connection.

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Morningstar Corporation

Supplier of high-quality MPPT & PWM solar charge controllers and sine wave inverters for off-grid PV. Products provide high reliability and better battery charging. Available through PV distributors worldwide—SureSine, TriStar, ProStar, SunSaver, SunLight, SunGuard, and SHS.

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Studer Innotec SA

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Website: www.studer-innotec.com

Trannergy

Manufacturer of grid-tied solar inverters with power ranging from 1 kW to 30 kW; grid safety regulation of VDE-AR-N 4105, VDE0126-1-1+A1, AS4777, UTE, ENEL, RD1663, G59/2, G59/3, G83/2, IEC61727, IEC62116, MEA, PEA, etc.

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NATIONAL AND INTERNATIONAL EVENTS

INTERNATIONAL

World Biofuels Market
March 2–3, 2015
Amsterdam, The Netherlands
Website: http://www.bioenergy-news.com/index.php?/Global-Events

Ecobuild 2015
March 3–5, 2015
London, UK
Website: http://www.therenewableenergycentre.co.uk/events.html#UK-Events--Industry-Trade-Only

Biogaz Europe 2015
March 19–20, 2015
Nantes, France
Website: http://www.bioenergy-news.com/index.php?/Global-Events

Salon Bois Energie
March 19–22, 2015
Nantes, France
Website: http://www.bioenergy-news.com/index.php?/Global-Events

Energy
April 13–17, 2015
Hannover Messe, Germany
Website: http://www.therenewableenergycentre.co.uk/events.html#International-Events

Argus European Biomass Trading
April 14–16, 2015
London, UK
Website: http://www.bioenergy-news.com/index.php?/Global-Events

International Biomass Conference & Expo
April 20–22, 2015
Minneapolis, US
Website: http://www.bioenergy-news.com/index.php?/Global-Events

NEMEX 2015
April 21–23, 2015
London, UK
Website: http://www.therenewableenergycentre.co.uk/events.html#UK-Events--Industry-Trade-Only

WETEX 2015
April 21–23, 2015
Dubai, UAE
Website: http://www.wetex.ae/

All Energy
May 6–7, 2015
Glasgow, Scotland
Website: http://www.therenewableenergycentre.co.uk/events.html#UK-Events--Industry-Trade-Only

NATIONAL

Traffic Infra Tech 2015
January 15–17, 2015
New Delhi, India
Website: http://www.tradeindia.com/TradeShows/

PowerElec-East 2015
February 21–23, 2015
Kolkata, India
Website: http://www.tradeindia.com/TradeShows/

GRIDTECH
April 8-9, 2015
New Delhi, India
Website: http://www.ifbf.in/index.php?option=com_content&view=article&id=53&Itemid=60

India Nuclear New Build Congress 2015
April 21–22, 2015
Mumbai, India
Website: http://www.szwgroup.com/nuclear-new-build-congress-india-2015/

GREEN Summit 2015
April 23–25, 2015
Bangalore, India
Website: http://www.greensummit.in/greensummit_2015/index.php

ISRMAX-- India International Sugar, Rice, Maize & Agriculture Expo
May 2–5, 2015
New Delhi, India
Website: http://www.ifbf.in/index.php?option=com_content&view=article&id=53&Itemid=60

Power Gen India & Central Asia co located with Renewable Energy World India & Hydero Vision India 2015
May 11–16, 2015
New Delhi, India
Website: http://www.ifbf.in/index.php?option=com_content&view=article&id=53&Itemid=60

Smart Cities India 2015 Expo
May 17–22, 2015
New Delhi, India
Website: http://www.ifbf.in/index.php?option=com_content&view=article&id=53&Itemid=60

Robotics & Automation
June 26–28, 2015
Chennai, India
Website: http://www.ifbf.in/index.php?option=com_content&view=article&id=53&Itemid=60

Renewable Energy at a Glance

PROGRAMME/ SCHEME-WISE PHYSICAL PROGRESS IN 2014–15 (DURING THE MONTH OF SEPTEMBER) VIS-À-VIS 2014–15

Sector	FY 2013–14			FY 2014–15			Achievements during September		Cumulative Achievements	
	Target	Achievement	Ach as % of Target	Target	Achievement	Ach as % of Target	2013–14	2014–15	(as on 30.09.2013)	(as on 30.09.2014)
I. GRID-INTERACTIVE POWER (CAPACITIES IN MW)										
Wind Power	2,500.00	808.48	32.34	2,000.00	864.95	43.25	102.53	176.25	19,881.43	**21,996.78**
Small Hydro Power	300.00	94.50	31.50	250.00	53.00	21.20	15.00	24.00	3,726.75	**3,856.68**
Biomass Power and Gasification	105.00	20.00	19.05	100.00	0.00	0.00	20.00	0.00	1,284.80	**1,365.20**
Bagasse Cogeneration	300.00	55.05	18.35	300.00	41.00	13.67	55.05	0.00	2,392.48	**2,689.35**
Waste to Power	20.00	3.00	15.00	20.00	0.00	0.00	3.00	0.00	99.08	**106.58**
Solar Power	1,100.00	395.13	35.92	1,100.00	134.81	12.26	111.13	12.81	2,079.97	**2,765.81**
Total	4,325.00	1376.16	31.82	3,770.00	1093.76	29.01	306.71	213.06	29,464.51	**32,780.40**
II. OFF-GRID/ CAPTIVE POWER (CAPACITIES IN MW_{EQ})										
Waste to Energy	10.00	0.00	0.00	10.00	3.60	36.00	0.00	0.95	115.57	**136.33**
Biomass(non-bagasse) Cogeneration	80.00	19.69	24.61	80.00	23.84	29.80	4.00	8.00	490.84	**555.66**
Biomass Gasifiers -Rural	1.00	0.00	0.00	0.80	0.00	0.00	0.00	0.00	16.92	**17.48**
-Industrial	9.00	4.74	52.67	8.00	2.20	27.50	2.94	2.20	146.32	**149.40**
Aero-Generators/ Hybrid systems	1.00	0.03	3.00	0.5	0.089	17.80	0.00	0.00	2.14	**2.34**
SPV Systems	40.00	14.32	35.80	60.00	35.54	59.23	7.13	35.54	138.99	**209.89**
Water Mills/Micro Hydel	2.00	0.00	0.00	4.00	0.00	0.00	0.00	0.00	10.65	**13.21**
Bio-gas-based Energy System	2.00	0.00	0.00	0.00	0.30	0.00	0.00	0.30	0.00	**4.07**
Total	145.00	38.78	26.74	163.30	65.57	40.15	14.07	46.99	921.43	**1,088.38**
III. OTHER RENEWABLE ENERGY SYSTEMS										
Family Biogas Plants (numbers in lakh)	1.10	0.15	13.64	1.10	0.12	10.91	0.09	0.12	46.83	**47.53**
Solar Water Heating – Coll. Areas(million m2)	0.60	0.27	45.00	0.50	0.04	8.00	0.10	0.00	7.27	**8.19**

Source: www.mnre.gov.in

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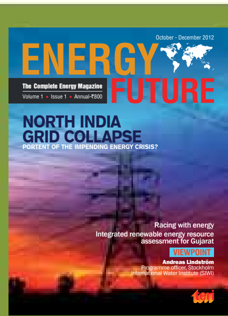

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Artwork preference:	Print ready, minimum 300 dpi (tiff, eps, pdf, or cdr) files with all fonts with high quality print proofs and progressives for colour reference.

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