October–December 2015

ENERGY FUTURE

The Complete Energy Magazine
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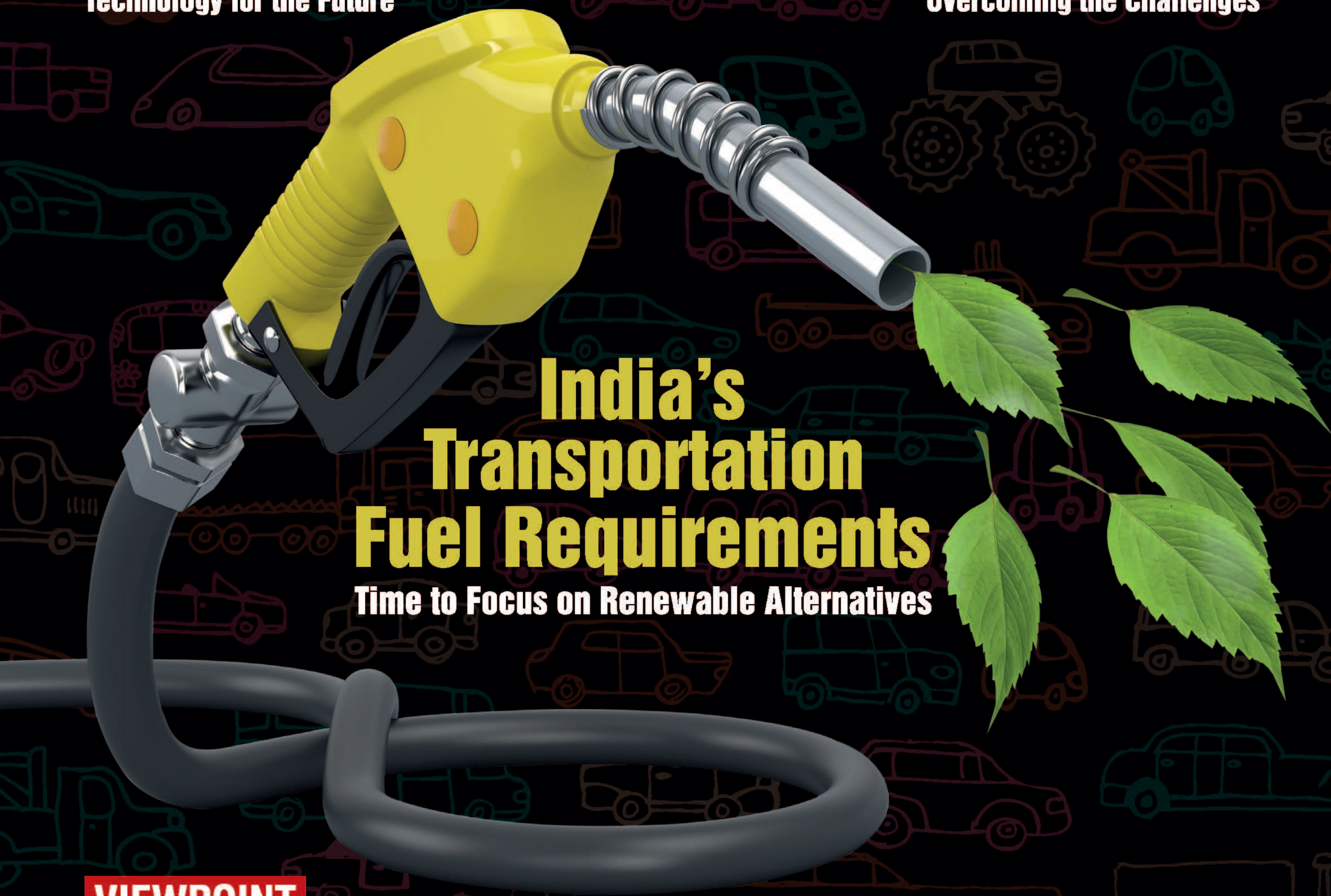
Engineering Non-Food Crops for Biodiesel Production
Technology for the Future

Utilizing the Sustainable Solar Power Efficiently
Overcoming the Challenges



India's Transportation Fuel Requirements
Time to Focus on Renewable Alternatives

VIEWPOINT

Martin Hiller
Director General
The Renewable Energy and Energy Efficiency Partnership (REEEP)

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World Sustainable Development Forum
DSDS 2016

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"To start a good initiative is commendable in itself; to sustain it, is even better."

Atal Bihari Vajpayee ,
at DSDS 2002

Year 2015 is all set to be a milestone for the discourse on sustainable development as the post-2015 development agenda is defined in the form of Sustainable Development Goals. DSDS 2016 will be the first international platform that will assess, measure and further deliberate on the global assurances and pledges made at CoP 21 in Paris. The attempt at DSDS 2016 will be to devise ways and an agenda to realise these Goals beyond 2015.

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From the editor's desk...

As per the 5th Assessment Report of the Intergovernmental Panel on Climate Change, 'the transport sector was responsible for approximately 23 per cent of total energy-related CO_2 emissions…Without aggressive and sustained mitigation policies being implemented, transport emissions could increase at a faster rate than emissions from the other energy end-use sectors'. In its 'Intended Nationally Determined Contribution (INDC)' India envisages to reduce the emissions intensity of its Gross Domestic product (GDP) by 33 to 35 per cent by 2030 from 2005 level. And towards this one of the priority areas listed pertains to 'reducing emissions from transportation sector'. One of the effective ways to do this is to effect the behavioural change and switch from personal vehicles to public transportation. The other one is to shift to non-fossil fuels such as biofuels, hydrogen, and clean electricity to name a few. This field is definitely much more challenging than electricity generation. Many alternatives are being tried out in the laboratories and pilot research projects but the major challenges remain the economics, convenience, and the scale. Naturally, the scenario becomes even more complex once the 'food versus fuel' debate enters into picture but it also underlines the importance of technological breakthroughs. Nonetheless, this is an area that requires sharper focus, both from the point of view of personal choices as well as technology development.

On clean electricity generation front, while the renewable energy is becoming synonymous with solar—and to an extent wind—small hydro seems to have been relegated to background. As against 20 GW potential, barely one-fifth has been exploited in the country so far although small hydro projects do not pose any negative environmental impacts. Given that these provide steady electricity supply as opposed to the intermittent power, there is all the more reason to give it due importance. And the best part is that such seemingly small resources can also be harnessed equally efficiently for meeting mechanical energy needs. Ultimately, the sustainable future of the posterity is closely interlinked with the energy and lifestyle choices that we make today.

Amit Kumar

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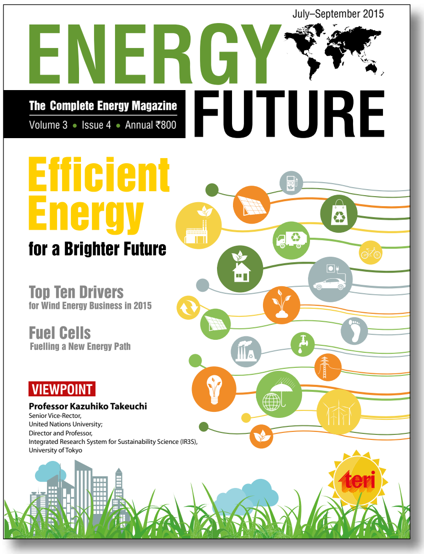

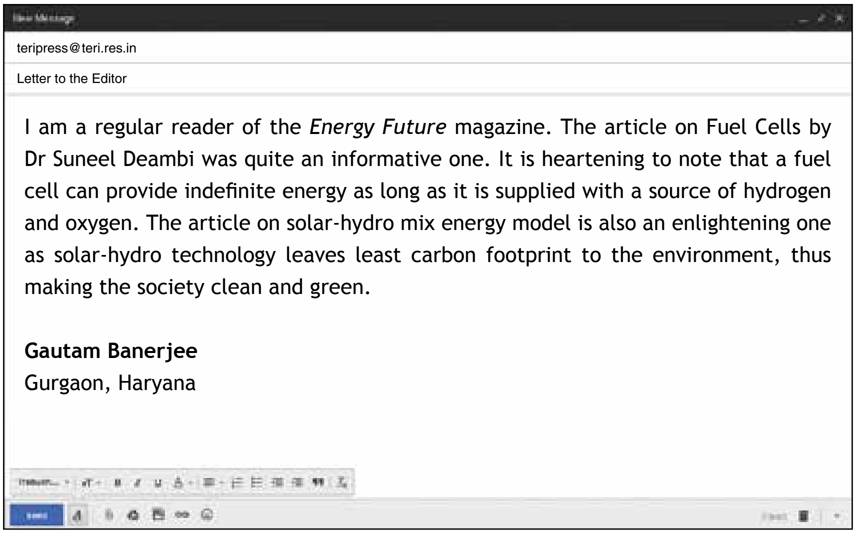
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Letter to the Editor

I am a regular reader of the *Energy Future* magazine. The article on Fuel Cells by Dr Suneel Deambi was quite an informative one. It is heartening to note that a fuel cell can provide indefinite energy as long as it is supplied with a source of hydrogen and oxygen. The article on solar-hydro mix energy model is also an enlightening one as solar-hydro technology leaves least carbon footprint to the environment, thus making the society clean and green.

Gautam Banerjee
Gurgaon, Haryana

"I read the July–September 2015 issue of **Energy Future**. The Cover Story "Efficient energy for a brighter future" dwells on the current situation with regard to energy efficiency all over the world and rightly points out that attaining energy efficiency in transportation, buildings, and industry sectors will immensely help to bridge the gap between energy demand and supply. It is an urgent need of the hour that we implement the solar and hydro mix energy model as they provide a continuous and reliable power supply without any harmful byproducts, pollution and waste to the environment."

Anushka Jaykar
Pune, Maharashtra

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.

Email: teripress@teri.res.in

Editor
Energy Future

"With reference to the feature article "Top Ten Drivers for Wind Energy Business in 2015" by Mr P Vinay Kumar, I would like to suggest that the top ten pointers presented in this article is an interesting way of presenting the status of the renewables sector in the world. It was good to note that the renewables sector is passing through optimistic times. Innovations in technology, dropping project costs, and grid parity are good signs for the sector."

Akhilesh Dubey
New Delhi

"I liked the article on Clean Cookstoves as it discussed about improved cookstoves which emit negligible black carbon and no smoke. Kudos to the Greenway Grameen Appliances for developing the 'Greenway Smart Cookstove' in India, which reduces carbon emissions by 70 per cent. Lower smoke exposure reduces throat and eye irritation and increases life expectancy. It should prove itself to be a boon for Indian women."

Sushma Balakrishnan
Hyderabad, Telangana

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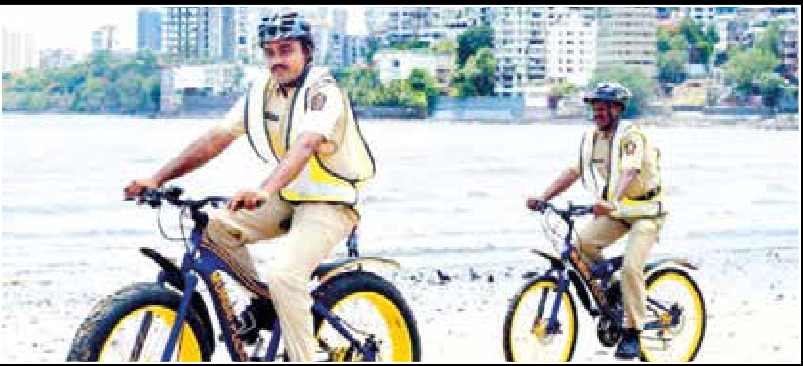

BHEL COMMISSIONS 500 MW THERMAL POWER PLANT AT VINDHYACHAL

Bharat Heavy Electricals Limited (BHEL) has added one more coal-based power plant to the grid by successfully commissioning the 500 MW Unit-13 of Vindhyachal Super Thermal Power Station (STPS), Stage-V of NTPC. The project is located in Vindhyanagar in Singrauli district of Madhya Pradesh. Significantly, BHEL had earlier commissioned six units of 500 MW rating each, at Vindhyachal power station. With the commissioning of this unit, BHEL has now commissioned seven sets of 500 MW each aggregating to 3,500 MW, the highest by BHEL in a power project.

BHEL's scope of work in the contract envisaged design, engineering, manufacture, supply and erection and commissioning of steam generator and steam turbine generator along with associated auxiliaries and state-of-the-art controls and instrumentation. The equipment for the project was manufactured at BHEL's Tiruchi, Ranipet, Haridwar, Hyderabad, Bengaluru, and Bhopal plants, while the company's Power Sector—Western Region undertook erection and commissioning of the equipment. EF

Source: www.thehindu.com

CLP INDIA RAISES ₹600 CRORE THROUGH DOMESTIC CORPORATE GREEN BONDS

CLP India, one of the largest foreign investors in the Indian power sector, has raised ₹600 crore for its wind portfolio—CLP Wind Farms—by issuing green bonds. The issue is the first green bond issued by a company in India, even though some lenders, such as YES BANK Ltd, have raised funds by issuing green bonds to agencies such as the International Finance Corporation, the private sector lending arm of The World Bank.

Green bonds enable capital-raising for projects with environmental benefits. These could include projects related to renewable energy, energy efficiency, sustainable waste management, sustainable land use, biodiversity conservation, clean transportation, sustainable water management and climate change adaptation, among others. Money raised through such bonds has to be exclusively used for such projects through a separate account earmarked for these investments. In India, the market is just developing with CLP India being the first corporate issuer to close such a bond issue.

"The proceeds from these bonds will be used for funding the capital expenditure of its projects in the renewable space. This move will help CLP sustain its expansion of the renewable energy portfolio in alignment with the company's vision to lower carbon emission footprint," the company said in a statement. The bond issue was assigned a rating of AA by India Ratings and Research. Instruments with this rating are considered to have high degree of safety regarding timely servicing of financial obligations and very low credit risk. EF

Source: www.livemint.com

BAJAJ GROUP COMMISSIONS 660 MW THERMAL PLANT

The Bajaj Hindustan group's ₹16,000 crore Lalitpur Power Generation Co. Ltd (LPGCL) has commissioned its first unit (of 660 MW) at the supercritical thermal plant at Mirchwara, in Uttar Pradesh's Lalitpur district. The project has come up on an area of 1,300 acres of land. This is the first major unit to be commissioned by the private sector in the present Akhilesh Yadav government. The other two units of the plant are in an advanced stage of completion and are scheduled for commissioning in December 2015 and April 2016, respectively. The main plant package is being executed by BHEL, while other important packages have been undertaken by L&T, Simplex, and Paharpur.

LPGCL, a part of the Bajaj group, had signed a Memorandum of Understanding (MoU) with the Uttar Pradesh government in April 2010 for setting up a 1,980 MW (3 units of 660 MW each) state-of-the-art Super Critical Thermal Power Plant at Lalitpur in the Bundelkhand region.

The plant is yet to secure a permanent, long-term coal linkage for its three units. "At present, the company has secured temporary coal availability for only 1,320 MW power for its first and second units only from CCL, while it is still negotiating for the coal linkage for its third unit," said a source adding that the total power produced from this project will be supplied to the UP State discoms as per regulated tariff. EF

Source: www.financialexpress.com

KSRTC SET TO RUN BHARAT STAGE III BUSES ON BLENDED FUEL

The Karnataka State Road Transport Corporation (KSRTC) is set to run its Bharat Stage III buses on blended fuel that consists of biodiesel and ethanol, is less harmful to the environment, and gives better performance.

The KSRTC has successfully run its BS I and II buses on blended fuel, becoming the first state transport undertaking in the country to reduce carbon emission in this manner. Now, it is ready to use the same fuel in its BS III buses. It will start trials on 1,000 BS III buses of select depots in Mysuru division in the near future. Once the trials roll, their results will be judged on three parameters: reduction in emission levels, effects on the health of bus engine and effects on kmpl (kilometres per litre)/performance of the buses. The KSRTC is already running its BS I and II buses on blended fuel. But, these vehicles are being phased out as they have already run for 6–7 lakh km. Accordingly, more than 220 buses of BS I were phased out and now BS II buses are being weeded out. Twenty-one depots under the KSRTC are equipped with automated underground ethanol-blending facility, according to officials. EF

Source: www.deccanherald.com

RENEWABLE ENERGY PUSH: INDIA SET TO ALLOW 100 PER CENT BIODIESEL FOR VEHICLES

In a bid to push higher use of renewable energy, India is set to allow 100 per cent biodiesel for vehicles. The decision will pave way for manufacture of new engines that can use this fuel. The compatibility of vehicle to the level of biodiesel blend will be defined by the vehicle manufacturer and the same will also be displayed on the vehicle. Vehicle manufacturers will submit the vehicle to the test agencies specified by the government for type approval.

The government has already sent the draft notification of the same to law ministry for vetting. As per the government notification, the newly manufactured vehicles fitted with compression ignition engine compatible to run on diesel or mixture of biodiesel up to 100 per cent biodiesel (B 100) will be type approved as per the prevailing diesel emission standards.

These standards have been long awaited by the industry especially those manufacturing biodiesel and will provide alternate source of income to the farmers and the forest dwellers. Large areas of degraded land in the country have a vast potential of producing biodiesel, which can be utilized as a source of fuel for transportation in the country. EF

Source: www.economictimes.indiatimes.com

NSE FIRST TO INVEST IN WIND ENERGY

The National Stock Exchange (NSE) has become India's first stock exchange to invest in wind energy. The bourse completed 6.25 MW wind power project with Suzlon being the technical partner for supply and commissioning of the project. The project seeks to meet 65 per cent of the energy consumption of the NSE office located in Mumbai. The project, comprising five units of Suzlon's S66, 1,250 kW wind turbine generators, will help in reducing around 12,730 tonnes of CO_2 emissions annually, according to Suzlon.

"The investment in wind power project is part of our long-term focus on sustainable development. We are committed to conduct business in a way that protects the environment by using green technology. Harnessing wind energy for our operations is a step in that direction. This is in addition to the various power saving and energy efficient measures being undertaken at the premises," NSE spokesperson Mahesh Haldipur said. EF

Source: www.deccanherald.com

KOCHI AIRPORT FIRST IN THE WORLD TO BE SOLAR-POWERED

The Kochi Airport has become the first airport in the world to rely solely on solar power for its electricity needs. The airport commissioned a 12-MW solar power plant, which was installed by Bosch. Electricity generated from the solar plant was used to power airport facilities during the day and additional power was fed into the state grid. At night, the airport would draw power from the grid. The solar plant at the Kochi airport was built on 50 acres, making it the single largest solar project in an airport in the country.

The plant is estimated to generate approximately 50,000 units of electricity a day. Through this project, coupled with an earlier installed capacity of 1.1 MW, the Kochi Airport would technically become 'grid-power neutral'. Other airports in the country, too, have developed solar plants or are planning to, in order to reduce carbon footprint. The Delhi airport has a 2.1-MW solar plant and the Mumbai airport has a 650-kW rooftop solar plant. The Directorate General of Civil Aviation had earlier issued instructions to airports to take energy efficiency measures.

Source: www.business-standard.com

WELSPUN RENEWABLES BREAKS GROUND BY COMMISSIONING PUNJAB'S LARGEST SOLAR PROJECT

Welspun Renewables, India's largest solar energy generator has set up its first solar power project—the Bhatinda 34 MW (DC), in Punjab. This is the largest commissioned solar capacity to come up in the state. Like all its projects before, Welspun Renewables has developed it ahead of committed deadlines, in five months. It will annually be feeding 48 million units of clean and emission free energy into the Punjab state grid, for the next 25 years. Spread across 140 acres in the state's Bhatinda district, in the next 25 years the project will have mitigated 1,331,525 tonnes of CO_2 emissions. The company is among the first few to set up a project in Punjab.

Source: www.evwind.es

MAJOR RENEWABLE ENERGY DEVELOPER EDF EXPANDS INTO COMMUNITY WIND, ACQUIRES OWNENERGY

SunEdison acquired First Wind in November 2014 and now EDF Renewable Energy (EDF RE) has announced that it has snapped up OwnEnergy, a developer of mid-sized wind projects. The transaction encompasses 100 per cent of OwnEnergy's assets, including its pipeline of future wind projects. Since its founding in 2007, OwnEnergy has built partnerships with individuals, companies, and communities with one simple goal: To create a platform for local clean energy entrepreneurs to lead the development of renewable energy projects. Today, the 20-person team has eight wind projects either in a construction or operating phase, representing 329 MW of developed wind energy assets sold to third parties. In addition, the company has built a portfolio of development assets through its local partner business model. Jacob Susman, founder and CEO of OwnEnergy said that EDF RE is acquiring the company "for the same reason that brand name corporations are buying our clean power," adding that OwnEnergy "puts the community first."

Source: www.renewableenergyworld.com

UNIQUE MATERIAL CREATED FOR THE NEXT GENERATION

Researchers at Kaunas University of Technology (KTU) Organic Chemistry laboratories have developed a material which offers much cheaper alternative to the one which is currently being used in hybrid solar cells. The efficiency of the semiconductors created by the team of KTU's chemists was confirmed at Swiss Federal Institute of Technology, Lausanne. "The material created by us is considerably cheaper and the process of its synthesis is less complicated than that of the currently used analogue material. Also, both materials have very similar efficiency of converting solar energy into electricity, which means that our semiconductors have similar characteristics to the known alternatives, but are much cheaper," said Professor Vytautas Getautis, head of the chemistry research group responsible for the discovery.

The solar cells containing organic semiconductors created at KTU were constructed and tested by physicists at Lausanne. The tests revealed outstanding results: The effectivity of the cells' converting solar energy into electricity was 16.9 per cent. There are only a few organic semiconductors in the world affording such a high solar cell efficiency. Prof. Getautis said that the material created at KTU will be used in the construction of future solar cells: Almost all solar cells are made from inorganic semiconductors. Hybrid, semi-organic solar cells are still being developed and perfected at the research centres all over the world.

Source: www.sciencedaily.com

US, CHINA RESEARCH INSTITUTES SIGN HISTORIC CLEAN POWER GRID ACCORD

China's State Grid Energy Research Institute (SGERI) and the US Department of Energy's (DOE) National Renewable Energy Laboratory (NREL) have signed a historic clean power memorandum of understanding (MoU). The MoU will see the two government organizations voluntarily share and exchange information and collaborate on research and development projects aimed at accelerating deployment of renewable energy generation capacity and the integration of emissions-free and cleaner, more efficiently produced electricity onto the nations' respective power grids.

Some nine or ten months in the making, and building on related NREL's projects in China, the MoU is a first, non-binding step in what could be an expanding range of collaborative renewable, clean power grid initiatives that will enable both China and the US—the world's two largest sources of carbon and greenhouse gas emissions—to better mitigate and adapt to rapidly changing climate conditions. EF

Source: www.renewableenergyworld.com

ATTENBOROUGH AND COX JOIN CALL FOR ACTION ON CLEAN ENERGY

Sir David Attenborough has urged countries to sign up to a global scheme to make clean energy cheaper than fossil fuels, warning the Earth is in danger from climate change. He is one of the 27 top scientists, business executives, academicians, and politicians who have called on nations to adopt the Global Apollo Programme by the time key international talks on a new global treaty to tackle climate change take place in Paris in December 2015 (COP21). Sir David has been joined by figures including leading Physicist and TV Presenter Brian Cox, Unilever Chief Executive Paul Polman, Former Energy Secretary Ed Davey, Former Cabinet Secretary Lord O'Donnell, and Astronomer Royal Lord Martin Rees, in signing an open letter calling for action ahead of the climate talks.

The Global Apollo Programme has a clear goal, in this case to make electricity from solar and wind cheaper than power from coal in every country and to do so within a decade. The international scheme will focus on including ways of storing electricity, smart grids which balance supply and demand and solar and wind technology. EF

Source: www.energyvoice.com

TEKMAR INSTALLS NEW SYSTEM ON DUTCH WIND FARM

Cable protection specialist Tekmar Energy has installed its cutting-edge TekTube system on an offshore project for the first time. The system was successfully installed on Westermeerwind near-shore wind farm in the Netherlands. Tekmar supplied cable installation contractor, VBMS, with 92 of its systems to protect the cables into the 48 wind turbine foundations for the Siemens' EPC (engineering, procurement, and construction) project located along the dykes of the Noordoostpolder.

Installation work ran more quickly than initially expected with up to six systems put in place within each 12-hour window for work. Tekmar's chief executive James Ritchie, said: "TekTube was designed as a result of our ongoing investment into researching and developing next generation cable protection systems. It was the first new patented product that was produced at Tekmar's new manufacturing facility in the north-east of England. Tekmar claims the system improves offshore installation rates and ensures cable integrity for the service life, which is typically 25 years. EF

Source: www.energyvoice.com

WORLD'S FIRST INTEGRATED GEOTHERMAL AND BIOMASS PLANT GOES ONLINE

Enel Green Power has announced the completion of a 5 MW biomass power plant in Italy's Tuscany region that integrates biomass with geothermal steam generation.

A first-of-its-kind, the newly constructed biomass plant will use locally sourced virgin forest organic matter and a 'super-heater' boiler to increase steam temperatures at the nearby 13-MW Cornia 2 geothermal plant. Geothermal steam temperatures entering the Cornia 2 plant will be raised from 300°F to over 700°F. The result, according to Enel Green Power, will be an increase in the geothermal plant's net electricity generation capacity. It is projected that the integration of the biomass plant will boost the overall Cornia 2 geothermal plant output by some 30 GWh a year. It will also mitigate the emission of 13,000 tonnes of CO_2 annually. This innovative technological approach will result in minimal local environmental impact and secure 'total renewability' within the resources used and the cycle of energy generation.

Francesco Venturini, CEO of Enel Green Power, said the combination of the two technologies is "a major step forward for the future of renewable energy" and expects that it will result in the establishment of a replicable model that "opens up new local energy, economic and employment opportunities." Enel Green Power reports that the project, which had cost an estimated €15 million, will result in the creation of as many as 40 direct and indirect jobs. Most of the jobs will relate to the sourcing of the biomass materials needed. EF

Source: www.renewableenergyworld.com

'SMART' SOLAR PALM TREES POWER WI-FI, PHONES IN DUBAI

A new species of palm tree has started sprouting around Dubai. But instead of producing dates, the fronds of the 'Smart' Palm harness the sun's energy to allow people to look up city information, access Wi-Fi, and charge their phones, all for free. Topped with nine leaf-shaped photovoltaic modules, a six-metre-tall smart palm can generate around 7.2 kW hours per day, enough to operate without ever drawing off the grid.

The two prototype palms that have already been installed—one at a beach near the Burj Al Arab hotel and other at centrally located Zabeel Park—each carries a Wi-Fi hotspot, eight charging stations for phones and tablets, and a touch-screen panel giving local details on things like weather and transportation. The company behind the device, Dubai-based D Idea, feels connectivity is just the start of the smart palm's potential. "Subsequent smart palms will have ATM machines and utility bill payment services," said CEO of D Idea Viktor Nelepa. In the near future, D Idea plans to install 103 smart palms across the city of Dubai. The next generation of the device, will be created by 3D printer and have a different design. Made from a combination of fibre-reinforced plastic and concrete, the new smart palms will also be better able to withstand Dubai's tropical desert climate. EF

Source: www.economictimes.indiatimes.com

SOLARWORLD SETS NEW WORLD RECORD FOR SOLAR-CELL EFFICIENCY

SolarWorld AG has set a new world record for efficiency of industrially produced solar cells made using so-called PERC-technology (passivated emitter and rear cell). The CalLab of the Fraunhofer Institute for Solar Energy Systems has confirmed that the global manufacturer of premium-quality products surpassed its own record by reaching a new height of 21.7 per cent in its solar cell efficiency. The cells, based on crystalline p-type silicon wafers, were manufactured using industrial production processes, meaning that they can be quickly placed into mass production.

"SolarWorld has been the first company to rely on PERC in its cell production. With this new record, we expand our technological lead even further. We can offer customers more electricity production on the same area and at the highest quality and durability," says Dr-Ing. E h Frank Asbeck, CEO of SolarWorld AG.

800 MW of the company's cell capacity have already been changed to PERC. Thus, SolarWorld AG possesses the largest production capacity worldwide to manufacture this high-performance technology, which the company is going to expand. As a result of new coating processes on cells' fronts and backs, the PERC technology achieves much higher efficiencies. EF

Source: www.renewableenergyfocus.com

India's Tra
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newable Alternatives

*With the expected increase in the number of vehicles, India would be the biggest market globally for transportation vehicles by 2050. With the dwindling natural resources, India's transportation fuel requirements currently fed by fossil-based fuels like petrol and diesel would fail to do so in the coming decades. With this perspective, **Er Anshu Yadav** examines some options which may be utilized as alternative fuels in the transportation sector. This would help to decrease the burden on the fossil fuels in India as well as the world.*

The aim of the very ambitious 'Make in India' campaign is to project India as a manufacturing hub. Despite the fact that manufacturing in India has remained healthy due to strong domestic demand, its contribution to GDP is only 17 per cent (2013), compared to 31 per cent (2013) in China, and largely oriented to the domestic market. *(Source: The World Bank)*

Some of the key points to realize the idea and increase its manufacturing competitiveness are:

- Huge capital investment in India's manufacturing sector
- Innovation in manufacturing is crucial; India's competitive edge is not only in labour arbitrage but in technologically intensive manufacturing.

Both shortages of roads and power pose challenges to the manufacturing sector in India. Power shortage in energy deprived country like India draws greater attention and realizing the additional shortage of power for new development initiatives, it seems to be bit challenging as India is already the fifth largest energy consumer in the world. While the world consumes around 13 billion tonnes of oil equivalent (btoe) of energy resources, India consumes around 600 million tonnes of oil equivalent (mtoe) which comes out to be 4.7 per cent of the world's total primary energy in 2013. In India, the growth rate of demand is around 6.8 per cent, while the supply is expected to increase at a Compound Annual Growth Rate (CAGR) of only 1 per cent. Of the India's total primary energy consumption basket, oil and gas constitute 37 per cent share in the total energy basket mix.

Because of the fact that around 73.6 per cent of the total energy and 92 per cent of the total primary energy needs of India are met through fossil-based fuels, India's contribution to global CO_2 emission is around 1,931 million tonnes CO_2 equivalents with 5.5 per cent to the global share in 2013. It is important to review the energy situation in the country in the context of the global and local energy balance and rising environmental concerns.

For emerging economies like India, being energy deficit is not the only challenge. It also faces the challenge posed by climate change in addition to the challenges of economic development, poverty alleviation, and livelihood protection. The pressure of 2020 Country Emissions Targets pledged under The United Nations Framework Convention on Climate Change (UNFCCC) International Emissions Targets is one of the biggest challenges. India has pledged 20–25 per cent reduction in emissions per unit of GDP (excluding agriculture sector) from 2005 level by 2020. Recently, the Government of India has pledged to reduce its greenhouse gas emissions intensity by 35 per cent by 2030, compared to the 2005 levels. A number of initiatives have been taken by the Indian

For emerging economies like India, being energy deficit is not the only challenge. It also faces the challenge posed by climate change in addition to the challenges of economic development, poverty alleviation, and livelihood protection.

government to meet the pledged levels of emission reductions. It includes India's first National Action Plan on Climate Change (NAPCC) and the Jawaharlal Nehru National Solar Mission (JNNSM).

More efforts should be made to solve the multi-objective problem which includes two parameters:

- CO_2 emission reduction
- Identification and production of energy dense alternate fuel for meeting the total energy needs.

There are many ways to reduce CO_2 emission but the prominent ones are as follows:

- Carbon free fuel options
- CO_2 capture, storage, and utilization
- Conversion of CO_2 to fuel.

The prominent ways by which any nation's energy needs could be met are by:

- Improvements in energy efficiency (saving energy is adding energy)
- Energy generation from non-conventional and non-fossil based sources (including identification of alternate fuels).

There are technologies available to capture CO_2 but these are viable and possible only if CO_2 emits from point sources (i.e., thermal power plants, refineries, and other fossil-fuel-based industries), but the challenges are associated with the non-point sources of CO_2 emissions (such as, vehicular emissions, etc.). A lot of research has been done on all these sub-themes but the advantages associated with the idea of converting CO_2 into fuel is that it serves three purposes at a time, i.e., indirect CO_2 capture, CO_2 storage, and utilization of a new alternate source of energy. The impact and potential could be easily understood from the CO_2 emission data. Global average per capita emission is 4.88 tonnes of CO_2. India's per capita CO_2 emission is way below the global average with 1.6 tonnes of CO_2 as compared to 16.4 tonnes of CO_2 for USA in the year 2013. India, being one of the largest consumers of energy (through petroleum products), transport sector contributed 11 per cent of total CO_2 emission with 1,899 million tonnes of CO_2 in the year 2012.

CHALLENGES FOR INDIA IN THE TRANSPORTATION SECTOR

With the expected increase in the number of vehicles, India would be the biggest market globally for transportation vehicles by 2050 with 600 million vehicles as compared to 160 million registered motor vehicles as of 2012 *(Source: TEDDY-2015)*. Such data on this potential source of CO_2 emission seems to make the Greenhouse Gas (GHG) emission reduction target even more challenging. Significant CO_2 emission from fossil-based vehicle fuels and the depletion in accessible crude oil reserves have created the need to explore the alternate fuels. It is important to realize that the growth of transport sector, primarily driven by road transport will be heavily dependent on the sustainability (Availability, Accessibility, Affordability, and Accountability) of alternate fuels.

Therefore, going for identification and production of fuels for vehicles from CO_2 makes more sense because of the following reasons:

- It addresses the problem associated with non-point CO_2 emission sources (due to cyclic nature of CO_2 generated fuels)
- CO_2 storage and utilization (i.e., utilization as a fuel)
- Added source of energy and power (i.e., as a fuel, it can reduce the burden of energy needs, especially of vehicular fuel).

Significantly, converting CO_2 into fuels would be the best strategy because at the first place the source of CO_2 emission is fuel only, considering it as a fuel would be like completing the artificial CO_2 cycle.

OIL AND GAS: GLOBAL AND NATIONAL CONSUMPTION PATTERN

India is the fourth largest consumer of crude oil and petroleum products in the world (2013), right after the United States, China, and Japan. The share of these top four nations alone is almost 40 per cent of global crude oil and petroleum products consumption. India imported 80 per cent of oil to meet the domestic demand in 2014. It is interesting to know that oil and gas contribute 39.2 per cent to primary energy consumption.

The second highest demand for energy comes from transportation sector just after industrial sector, as it consumed about 5 per cent (29 mtoe) of the total primary energy (597 mtoe) in 2013–14 *(Source: Energy Statistics 2015)*. Also, the transport sector consumed 34 per cent of the total volume of petroleum products used in India. Looking at the global scenario, in total the world consumes nearly 12.7 btoe.

Industrial sector has the largest share of the world's primary energy consumption which consumed around 2,540 mtoe in 2012 and not far behind, transport sector consumed 2,507 mtoe in 2012 of the total primary energy. Also, the transport sector consumed around 64 per cent of the total volume of world's oil consumption in 2012 *(Source: Key World Energy Statistics 2014)*.

OPTIONS AS ALTERNATIVE FUELS FOR TRANSPORTATION NEEDS

Here we discuss a few options which may be utilized as alternative fuels in the transportation sector.

Carbon to fuels

i. Methanol

Methanol is the simplest form of a hydrocarbon, one oxygen atom attached to a simple methane molecule. It is volatile, colourless, and flammable liquid at room temperature. With calorific value of 5,500 Kcal/kg it is not easy to ignore methanol as potential alternate fuel for engines/vehicles. Methanol is an ideal fuel for transportation because of its efficient combustion and a methanol compatible designed engine has the capability to operate at greater efficiency as compared to that of the standard gasoline engines. Methanol is a high octane fuel (octane number 112) that translates into a very efficient and powerful engine performance.

Comparison of various fuel properties of methanol and other potential biofuels are presented in Table 1.

Generally, methanol production is carried out in two steps:

In the first step, feedstock (i.e., natural gas, biomass, coal, etc.) is converted into syngas (i.e., CO, CO_2, H_2, etc.). Steam methane reforming, coal and/or biomass partial oxidation (i.e., gasification) are some of the techniques to produce the syngas.

The second step is the catalytic synthesis of methanol from the

$$CH_4 + H_2O \xrightleftharpoons{\text{Ni Cat.}} CO + 3H_2 \qquad \Delta H_{298K} = 49.1 \text{ kcal / mol}$$

$$CH_4 + 1/2\, O_2 \rightleftharpoons CO + 2H_2 \qquad \Delta H_{298K} = -8.6 \text{ kcal / mol}$$

$$CO + 1/2\, O_2 \rightleftharpoons CO_2 \qquad \Delta H_{298K} = -67.6 \text{ kcal / mol}$$

$$H_2 + 1/2\, O_2 \rightleftharpoons H_2O \qquad \Delta H_{298K} = -57.7 \text{ kcal / mol}$$

First Step

$$CO + 2H_2 \rightleftharpoons CH_3OH \qquad \Delta H_{298K} = -21.7 \text{ kcal / mol}$$

$$CO_2 + 3H_2 \rightleftharpoons CH_3OH + H_2O \qquad \Delta H_{298K} = -11.9 \text{ kcal / mol}$$

$$CO + H_2O \rightleftharpoons CO_2 + H_2 \qquad \Delta H_{298K} = -9.8 \text{ kcal / mol}$$

Second Step

Significant CO_2 emission from fossil-based vehicle fuels and the depletion in accessible crude oil reserves have created the need to explore the alternate fuels. It is important to realize that the growth of transport sector, primarily driven by road transport will be heavily dependent on the sustainability (Availability, Accessibility, Affordability, and Accountability) of alternate fuels.

Table 1: Fuel properties comparison *(Source: Alternate Fuel Data Center, US DOE)*

	Fuels						
Property	**Gasoline/ E10**	**Low Sulphur Diesel**	**Biodiesel**	**Ethanol/ E100**	**Hydrogen**	**Liquefied Natural Gas (LNG)**	**Methanol**
Chemical Structure	C_4 to C_{12} and Ethanol ≤ to 10%	C_8 to C_{25}	Methyl esters of C_{12} to C_{22} fatty acids	CH_3CH_2OH	H_2	CH_4 same as CNG with inert gasses <0.5%	CH_3OH
Fuel Material (feedstocks)	Crude Oil	Crude Oil	Fats and oils from sources such as soy beans, waste cooking oil, animal fats, and rapeseed	Corn, grains, or agricultural waste (cellulose)	Natural gas, methanol, and electrolysis of water	Underground reserves and renewable biogas	Natural gas, coal, or, woody biomass
Gasoline Gallon Equivalent	97%–100%	1 gallon of diesel has 113% of the energy of one gallon of gasoline	B100 has 103% of the energy in one gallon of gasoline or 93% of the energy of one gallon of diesel. B20 has 109% of the energy of one gallon of gasoline or 99% of the energy of one gallon of diesel	1 gallon of E85 has 73% to 83% of the energy of one gallon gasoline (variation due to ethanol content in E85). One gallon of E10 has 96.7% of the energy of one gallon of gasoline	1 kg or 2.198 lbs. of H_2 has 100% of the energy of one gallon of gasoline	5.38 pounds of LNG has 100% of one gallon of gasoline and 6.06 pounds of LNG has 100% of the energy of one gallon of diesel	1 gallon of methanol has 49% of the energy of one gallon of gasoline
Energy Content (lower heating value)	112,114 –116,090 Btu/gal	128,488 Btu/gal	119,550 Btu/ gal for B100	76,330 Btu/ gal for E100	51,585 Btu/lb	21,240 Btu/lb	57,250 Btu/ gal
Physical State	Liquid	Liquid	Liquid	Liquid	Compressed Gas or Liquid	Cryogenic Liquid	Liquid
Cetane Number	N/A	40-55	48-65	0-54	N/A	N/A	N/A
Pump Octane Number	84-93	N/A	N/A	110	130+	120+	112
Flash Point	-45°F	165°F	212 to 338°F	55°F	N/A	-306°F	52°F
Autoignition Temperature	495°F	~600°F	~300°F	793°F	1,050 to 1,080°F	1,004°F	897°F

synthesis gas. Each of these steps can be carried out in a number of ways and various technologies offer a spectrum of possibilities which may be most suitable for any desired application.

Apart from efficient combustion, ease of distribution and wide availability makes methanol a desirable choice as a transportation fuel. Methanol could be used in transportation in three main ways—directly as fuel or blended with gasoline, converted in dimethyl ether (DME) to be used as a diesel replacement, or as a part of the biodiesel production process.

The major advantage of methanol over gasoline fuels is that on combustion, reformulation gasoline produces a number of harmful and toxic byproducts that are reduced or eliminated by replacement with methanol. Also, emissions of unburnt carbon and carbon monoxide are much lower when consuming methanol fuel and methanol greatly reduces NO_x emissions as well. Methanol also burns with almost no particulate matter—which can lead to respiratory problems like asthma. Emissions from methanol fuel are also less reactive, and create less ground-level ozone and smog. But at high levels, methanol fuel is corrosive to certain materials commonly used in engines and fuel lines. In order to be able to operate on high-level blends like M-85 (a mixture of 85 per cent methanol and 15 per cent gasoline), small modifications must be made to an engine to include methanol compatible components.

ii. Dimethyl Ether

Dimethyl ether is a clean, colourless gas, non-toxic but highly flammable. DME is the simplest ether that is gas at normal temperature and pressure, easy to liquefy, and transport. DME has a high heating value of 6,900 Kcal/kg. DME has a high cetane number of 55–60 (as compared to diesel, which has a cetane number of 45–55). The easy liquefaction and other properties, including a high oxygen content, lack of sulphur or other noxious compounds, and ultra-clean combustion make DME a versatile and promising solution in the mixture of clean, renewable, and low-carbon fuels under consideration worldwide as a pure fuel or blended with diesel. DME can be derived from many sources, including renewable materials (biomass, waste, and agricultural products) and fossil fuels (natural gas and coal). DME and Bio-DME is more energy dense fuel as compared to diesel, gasoline and methanol, so it has a great potential to be used as a diesel substitute. Today, DME is primarily produced by converting hydrocarbons via gasification to synthesis gas (syngas). Recent developments in gasification technologies provide the opportunity to also use biomass based fuels, such as byproducts from the paper and pulp industry, forest and agricultural residues, solid municipal waste, and other renewable feedstocks.

Apart from the fact that DME could be produced from a number of renewable and sustainable resources, DME also holds advantage over traditional diesel fuel because of its high cetane number which measures the combustion quality of diesel fuel during compression ignition. Unlike most of the petroleum products, DME has no C-C bond which means no soot formation on combustion and yet higher H/C ratio. DME offers high potential CO_2 emission reductions, higher efficiency, and better mileage for engines tailored to run on DME. Dimethyl ether has commercial availability and acceptability. A Bio-DME demonstration plant was put into operation in Piteå, Sweden in 2010. The first Bio-DME was produced in July 2011 in the plant. Volvo has performed field tests of 10 Volvo trucks fuelled by Bio-DME and not only that, Volvo is also commercially offering DME trucks. Oberon Fuels is producing DME in the US with annual production exceeding 7 million metric tonnes. The International DME Association (IDA) was formulated to promote the use of DME as a clean alternative fuel worldwide, to gather and communicate authoritative information about DME, and to coordinate international DME activities and initiatives.

Carbon neutral fuels

i. Biodiesel

Biodiesel (Figure 1) also known as FAME (Fatty Acid Methyl Ester), is a degradable, non-toxic, renewable fuel that can be manufactured domestically from vegetable oils, animal fats, or recycled restaurant grease. Biodiesel has high heating value of 8,450 Kcal/kg. It has a high cetane number of 48–65 (diesel has cetane number 45–55). Biodiesel could be derived from several feedstocks, the main feedstocks are vegetable oils from rapeseed, mustard, soybean, sunflower, and palm oil. Oil extracted (mechanically and chemically) from these feedstocks will undergo a process, called transesterification, that converts oils and fats into chemicals called long-chain mono alkyl esters, which is called biodiesel when used as a fuel. Some of the distinct advantages of biodiesel as compared to fossil fuels are as follows:

- Biodiesel as a vehicle fuel increases energy security (source of alternate energy)
- Improves air quality (reduces nitrogen oxide [NOx] emissions to near zero levels)
- Biodiesel improves fuel lubricity and raises the cetane number of the fuel (improves fuel performance efficiency)
- Flashpoint for biodiesel is higher than 130°C, compared with about 52°C for petroleum diesel (safe to store and transport).

Though it has lots of advantages yet there are challenges associated with biodiesel, a few of them are as follows:

- Biodiesel quality changes with time during storage (due to oxidative and hydrolytic reactions)
- Availability of raw material for biodiesel production (seasonal availability and distributed and non-point source of feedstocks)
- Its usage as direct fuel/pure fuel and upper limit of blending percentage in conventional fuels.

ii. Bioethanol

Ethanol (CH_3CH_2OH) is a clear, volatile, flammable, and colourless liquid. Ethanol has a calorific value of 6,410 Kcal/kg and with a flash point around 63°C, it is in contest as a potential gasoline substitute. Ethanol (octane number 108.6) has a higher octane number than gasoline (octane number 90), providing premium blending properties. Apart from its potential as a fuel, it can also be used as an additive to the fuels like gasoline to increase the octane number of low-octane gasoline by blending it with ethanol to attain the standard (octane number 87) octane requirement. Bioethanol is mainly derived from cellulosic feedstocks (such as wood chips or crop residues), starch- and sugar-based feedstocks (such as corn grain, sugarcane, etc.). Regardless of the feedstocks, ethanol has the same chemical formula whether it is produced from starch- and sugar-based feedstocks, or from cellulosic feedstocks.

Presently, the key raw materials for bioethanol production are sugarcane in Brazil, corn in the USA, corn and wheat in China, and molasses in India. The production method of ethanol depends on the type of feedstock used. The process is shorter for starch or sugar-based feedstocks than with cellulosic feedstocks.

Making ethanol from cellulosic feedstocks (such as crop residues, woods, etc.) is more challenging than using starch-based crops. There are two primary pathways to produce cellulosic ethanol: biochemical and thermochemical. The biochemical process involves a pretreatment to release hemicellulose sugars followed by hydrolysis to break cellulose into sugars. Sugars are fermented into ethanol and lignin is recovered and used to produce energy to power the process. The thermochemical conversion process involves adding heat and chemicals to a biomass feedstock to produce syngas, which is a mixture of carbon monoxide and hydrogen. Syngas is mixed with a catalyst and reformed into ethanol and other liquid co-products.

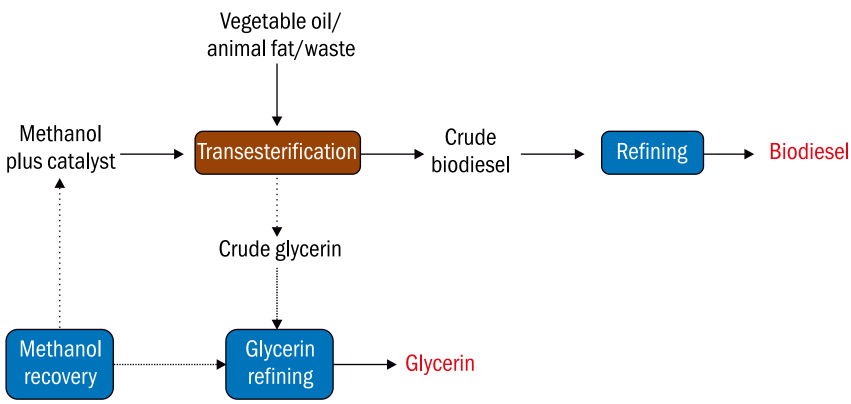

Figure 1: Schematic of biodiesel production path
Source: Alternate Fuel Data Center, US DOE

Apart from efficient combustion, ease of distribution and wide availability makes methanol a desirable choice as a transportation fuel. Methanol could be used in transportation in three main ways—directly as fuel or blended with gasoline, converted in dimethyl ether (DME) to be used as a diesel replacement, or as a part of the biodiesel production process.

Inline to the National Policy on Biofuels, to achieve an indicative target of 20 per cent blending of biofuels both for biodiesel and bioethanol by 2017, it is important to identify the potential feedstocks, their availability, and relevant/compatible technologies. Ethanol as a blending fuel/additive would increase the ethanol demand nationally, approximately 1.3 billion litres annually of ethanol is needed to achieve the target of 5 per cent blending and 5.3 billion litres annually to achieve the target of 20 per cent by 2017. Despite being less energy denser fuel, ethanol has a higher octane number than gasoline, providing premium blending properties. Ethanol has much better anti-knocking property that improves the efficiency and performance of the engine.

iii. Biobutanol

Biobutanol or n-Butanol is a colourless and refractive liquid. Because of its longer hydrocarbon chain, it is fairly non-polar; it is more similar to gasoline than it is to ethanol.

The octane rating of n-butanol is similar to that of gasoline but lower than that of ethanol and methanol. n-Butanol has an octane number of 96 while t-butanol has octane rating of 105. n-butanol has high calorific value of 8,920 Kcal/kg. Biobutanol has many similarities to bioethanol not only that it can be produced by the fermentation of biomass and can use same feedstocks as bioethanol, such as sugarcane bagasse, agro residues, etc. Modern butanol is produced almost entirely from petroleum. Renewed interest in biobutanol as a sustainable vehicle fuel has spurred technological advances to ferment it.

Biobutanol is an alternative to conventional transportation fuels due to the following properties:

- Relative higher energy content among gasoline alternatives
- When compared with ethanol, biobutanol has a lower vapour pressure, which ensures reducing evaporative emissions.

Butanol is used as an additive in gasoline but cannot be used as a fuel in its pure form because of its relatively high melting point which causes it to gel and solidify near room temperature.

iv. Bio-oil

Bio-oils are dark brown, free-flowing organic liquids that comprise highly oxygenated compounds. Chemically, bio-oil is a complex mixture of water, alcohols, acids, aldehydes, ketones, carbohydrates, furans, pyrans, aromatics, and hydrocarbons. It can be obtained from the different kind of agro-residues and industrial wastes. Bio-oils can be made from a variety of forest and agricultural biomass wastes. Waste biomass feedstocks with good potential include bagasse (from sugarcane), cashew nut shells, karanja cake, jatropha cake, rice hulls, rice straw, peanut hulls, oat hulls, switch grass, wheat straw, and wood. The calorific value of bio-oil depends on the kind of feedstock considered for experimentation and generally ranges in between 6,000 Kcal/kg to 8,370 Kcal/kg.

Bio-oils, also known as pyrolytic oils, are obtained on heating biomass at high temperatures in the total absence of oxygen, the process is known as pyrolysis. Heat supplied to the biomass will heat the unbound and bound volatile components of the biomass to come out of the structure. These vapours (volatile biomass components) are drawn out of the reactor and condensed using condensers. The percentage of bio-oil obtained from the pyrolysis depends on the volatile percentage in biomass and the rate of heat supplied to the reactor. The bio-oil produced is oxygenated, but otherwise has similar characteristics to petroleum.

Bio-oil produced from the process would be viscous having flash point

It is understandable that the whole world is in pursuit of developing ways to meet their energy needs, this particular issue is more relevant and challenging for emerging economies such as India, China, South Africa, etc., because of the fact that the scale of interventions needed are of higher order.

of 160–180°C and cetane number very low around 10. It has been observed that the presence of polyalcohols and/or glycols enhances the cetane number of the crude pyrolysis oil. Bio-oils have a potential as a fuel for engines and have properties very close to furnace oil. Despite having several advantages over conventional fuel, bio-oil has challenges like limited shelf-life due to polymerization of oil, and high viscosity.

v. Biogas

Natural gas is an odourless, gaseous mixture of hydrocarbons—predominantly methane (CH_4). Biogas is primarily methane (CH_4) and carbon dioxide (CO_2) and may have small amounts of hydrogen sulphide (H_2S), moisture, and siloxanes. Approximate calorific value of biogas is 4,500 Kcal/kg; it also depends on the composition of biogas. An additional advantage of biogas is its high octane number of 120.

Alternatively, Renewable Natural Gas (RNG), also known as biomethane, is produced from organic materials—such as waste from landfills and livestock—through anaerobic digestion. Biogas typically refers to a mixture of different gases produced by the breakdown of organic matter in the absence of oxygen. Biogas can be produced from raw materials such as agricultural waste, manure, municipal waste, plant material, sewage, green waste, or food waste. The energy from biogas can be used as a fuel; it can be used for any heating purpose, such as cooking. It can also be used in a gas engine to convert the energy in the gas into electricity and heat. Also, biogas can be compressed; the same way natural gas is compressed to CNG, and used to power motor vehicles. However, there are certain challenges associated with biogas from the storage and transportation perspectives.

Zero carbon fuels

Ammonia is a gas at normal temperature and atmospheric pressure but a liquid at higher pressures (10 bar at 25°C). So, it can be stored and transported as a liquid but used as a gas. Ammonia has a high octane rating (octane number 120) as compared to gasoline (octane number 86–93). The calorific value of ammonia is 5,400 Kcal/kg. Commercially, ammonia has been produced using Haber-Bosch process at high pressure in presence of catalyst. Along with hydrogen, ammonia is one of the fuels that has no carbon emission when combusted because it does not contain carbon. It may contribute a small amount of nitrous oxide emission, which can be controlled.

Ammonia can be used in internal combustion engines with minor modifications. It can be used in gas turbines and ammonia fuel cells. Ammonia can also be used specifically in diesel engines. However, ammonia will not compression ignite except at very high pressures. So, a small amount of high-cetane fuel could be added. Lots of work has been going on regarding the identification of efficient and low emission ways for ammonia combustion.

Hydrogen and hydrazine are more such fuels which can be called zero carbon fuels/zero emission fuels with great potential.

CONCLUSION

It is understandable that the whole world is in pursuit of developing ways to meet their energy needs, this particular issue is more relevant and challenging for emerging economies such as India, China, South Africa, etc., because of the fact that the scale of interventions needed are of higher order. Clearly, lot of options are available at laboratory and pilot scale but it is also equally important to identify the kind of solution which would best fit geographically by considering the local conditions. This broader perspective towards identifying the solution will help not only in developing the best solution but at the same time sustainable also. Apart from the technological options that are supposed to be emitting less GHGs, one should perform and consider Life Cycle Assessment (LCA) and its analysis regarding the corresponding technologies for the overall GHGs emissions perspective. Considering the scale of intervention needed to solve the problem, one must also consider very important raw material and economic aspects associated with the corresponding technology because everything finally comes back to economics and the newer technology must compete with the older ones on that front. EF

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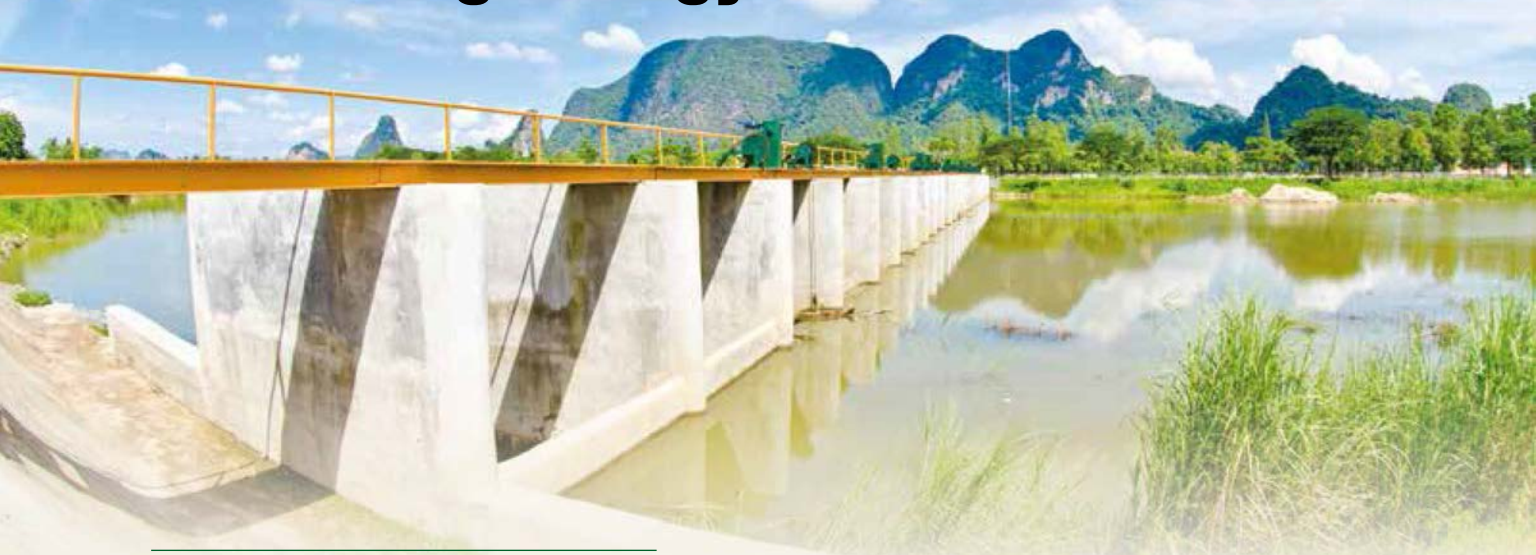
Small Hydropower for Sustainable Development

Promising Energy Potential for India



*In this article, **Dr Sunil Kumar Singal** and **Dr Varun** discuss the suitability of small hydropower for sustainable development in emerging economies of the world, such as India. They point out that in India, the SHP potential is about 20,000 MW, out of which about 3,800 MW could be installed so far. Therefore, the small hydropower potential in all the states in India needs to be tapped and harnessed in the right direction. They have also dwelled on the technological aspects of small hydropower. Read on.*

Energy is one of the most important inputs in the process of development for a nation and there is continuous increase in the demand of energy. To meet the growing demand of energy, installation capacity of electricity needs to be enhanced the world over, particularly in developing countries such as India. Sustainability is a discourse intended to promote new strategies for the development of energy, water, and environmental systems. Maintaining quality of environmental, sustainable development is the foremost objective of a nation. In April 1987, the United Nations World Commission on Environment and Development defined sustainable development as "development that meets the needs of the people today without compromising the ability of future generations to meet their own needs". The quest for sustainable development requires integrating economic, social, cultural, political, and ecological factors. However, economic and environmental factors seriously restrict the exploitation of hydropower potential through conventional large capacity projects and thermal-based conventional electricity generation systems. Due to these constraints, renewable energy sources are being considered to meet the growing electricity demand in an environmentally benign manner.

The development of infrastructure is an important factor to sustain economic growth and power sector is one of the most important constituents of infrastructure. The achievement of energy security necessitates diversification of the energy resources and the sources of their supply, as well as measures for conservation of energy. So far, conventional sources of energy, such as thermal, hydro (large hydro), and nuclear, were considered the main sources of energy generation. These sources have limited life and associated problems. The impact of the energy crisis is particularly felt in developing countries like ours, where an ever-increasing percentage of national budgets earmarked for development are diverted for the purchase of petroleum products. The ideal hydro–thermal mix should be in the ratio of 40:60 as hydropower stations have an inherent ability for instantaneous starting, stopping, load variations, etc., and help in meeting peaking and intermittent requirements, thus, improving the stability and reliability of power system and thermal power plants can serve as base stations.

Hydropower is a prominent renewable resource that India possesses. However, only about 40 GW of hydropower has been harnessed so far out of a potential of 150 GW. Further, due to the recent hydro-meteorological disasters and concerns raised about social and environmental aspects of hydropower from many quarters, its development has not progressed as much as expected during the last few years. As a consequence, the state of Uttarakhand in India has been able to exploit only 3.64 GW from hydropower projects out of a projected potential of 27 GW. Therefore, there is a huge opportunity for India to harness the hydropower potential in an optimal manner towards acquiring energy security and green energy growth.

Table 1: Top 10 hydropower producing countries in the world

S. No.	Country	Hydroelectricity (TWh)	Share of Electricity Generation (%)
1.	China	694	14.8
2.	Brazil	403	80.2
3.	Canada	376	62.0
4.	United States	328	7.6
5.	Russia	165	15.7
6.	India	132	13.1
7.	Norway	122	95.3
8.	Japan	85	7.8
9.	Venezuela	84	68
10.	Sweden	67	42.2

GLOBAL HYDROPOWER ENERGY SCENARIO

Hydropower is a mature technology throughout the world and currently contributes about 6 per cent of the total world energy production and 16 per cent of the total world electricity generation.

The worldwide total hydropower capacity in operation is 848 GW with annual generation of 3,045 TWh/year. The contribution of Small Hydropower (SHP) in total hydropower installed capacity is about 5 per cent with 34,000 MW. Presently, hydropower contributes more than 50 per cent of electricity supply in about 50 countries. There is about 157 GW of hydropower installation under construction in 106 countries. Hydropower (large and small) has been a prominent source of electricity generation in all European countries possessing hydropower potential. This development continued till about 1960 when the national grid was extended. The grid supply was found cheaper than the operation and maintenance of isolated small hydropower plants. Due to the oil crisis as well as protest against nuclear power, the European Union (EU) outlined the strategy and action plan to promote renewable energy sources in Europe in 1997. They targeted 12 per cent share of renewable energy in the total energy by the year 2010 against 6 per cent in 1996. Small hydropower accounts for approximately 7 per cent of total hydropower in Europe. Presently, total installed capacity in 30 European countries is 12,600 MW, generating 50,000 GWh under small hydropower. The leading countries are Italy, Germany, Spain, Sweden, Norway, Austria and Switzerland, which combine 86 per cent of SHP production. The details of electricity generation from hydropower in the topmost 10 hydropower producer countries are given in Table 1.

SMALL HYDROPOWER SCENARIO IN THE WORLD

Small Hydropower (SHP) is the development of hydroelectric power on a scale serving a small community or industrial plant. SHP is defined by the installed capacity of the power plant. This definition is not universal and different countries follow it differently. Most of the countries define installed capacity up to 25 MW as SHP. Range of SHP defined by some of the countries is given in Table 2. The capacity range under small hydro can be further classified as micro (up to 100 kW) and mini up to 2,000 kW.

Table 2: Range of Small Hydropower (SHP) defined by different countries

S. No.	Country/Organization	Installed Capacity (MW)
1.	Australia, Colombia	≤ 20
2.	China, India	≤ 25
3.	France	≤ 8
4.	Italy	≤ 3
5.	New Zealand, Philippines, Turkey	≤ 50
6.	Sweden	≤ 15
7.	UK (NFFO)	≤ 5
8.	UNIDO (United Nations Industrial Development Organization)	≤ 10
9.	USA	≤ 30

Small hydropower has been a major contributor to electrification in developing countries with over 50 million households and 60,000 small enterprises served by it at the village level as well as feeding power to grid networks. In the developing countries, China is the leading country having 35,000 MW installed capacity through 43,000 SHP stations. The growth rate in Chinese SHP sector is about 9 per cent per year. Other developing countries with significant SHP capacity are India (3,600 MW), Brazil (1,932 MW), Peru (237 MW), Malaysia and Pakistan (both 107 MW), Bolivia (104 MW), and Vietnam (70 MW). In the last 30 years, China, India, Nepal, Vietnam, and many South American countries have developed a large number of micro hydro projects to provide electricity to rural and remote areas.

SMALL HYDROPOWER POTENTIAL IN INDIA

In India, the SHP potential is about 20,000 MW, out of which about 3,800 MW could be installed so far. The state-wise details of SHP potential, power stations installed, and projects under implementation are given in Table 3.

It is encouraging to note that among all the renewable energy sources, SHP is considered as one of the most promising source. Energy from SHP is probably the oldest and yet, the most reliable of all renewable energy sources. In India, our forefathers have used this energy for grinding food grains for centuries; with the result that India's expertise in this sector today is at par with the most developed nations in the world. SHP development can reduce the load on conventional sources of energy. Technology for SHP development is mature and proven.

SMALL HYDROPOWER TECHNOLOGY

Small hydropower is a clean source of power, produced when water turns a hydraulic turbine. Hydro-turbine converts water pressure into mechanical shaft power, which is used to drive an electric generator, or other machinery. The power available is proportional to the product of pressure head and volume flow rate of water. The power generated for any hydro system is given by the following equation:

$$P = \rho g Q H \eta$$

Where, P is the rated output power (W), g is the acceleration due to gravity (m/s^2), Q is the discharge passing through the turbine (m^3/s), H is the effective pressure (net) head of water (m) across the turbine, and η is the natural combined efficiency of the generating units comprising turbine and generator. SHP potential is available in high hills as well as in

Table 3: State-wise details of small hydropower projects

S. No.	State/Union Territory	Potential		Power Stations Installed		Projects under Implementation	
		Nos.	Total Capacity (MW)	Nos.	Capacity (MW)	Nos.	Capacity (MW)
1.	Andhra Pradesh	387	978.40	68	221.030	13	32.04
2.	Arunachal Pradesh	677	1,341.38	149	103.905	44	22.23
3.	Assam	119	238.69	6	34.110	3	12.00
4.	Bihar	93	223.05	29	70.700	5	17.70
5.	Chhattisgarh	200	1,107.15	9	52.000	4	115.25
6.	Goa	6	6.50	1	0.050	-	-
7.	Gujarat	292	201.97	5	15.600	-	-
8.	Haryana	33	110.05	7	70.100	2	3.35
9.	Himachal Pradesh	531	2,397.91	158	638.905	33	76.20
10.	Jammu & Kashmir	245	1,430.67	37	147.530	7	17.65
11.	Jharkhand	103	208.95	6	4.050	8	34.85
12.	Karnataka	834	4,141.12	147	1,031.658	23	173.09
13.	Kerala	245	704.10	25	158.420	11	52.75
14	Madhya Pradesh	299	820.44	11	86.160	3	4.90
15.	Maharashtra	274	794.33	58	327.425	9	43.70
16.	Manipur	114	109.13	8	5.450	3	2.75
17.	Meghalaya	97	230.05	4	31.030	3	1.70
18.	Mizoram	72	168.90	18	36.470	1	0.50
19.	Nagaland	99	196.98	11	29.670	3	3.20
20.	Odisha	222	295.47	10	64.625	4	3.60
21.	Punjab	259	441.38	47	156.200	11	19.45
22.	Rajasthan	66	57.17	10	23.850	-	-
23.	Sikkim	88	266.64	17	52.110	1	0.20
24.	Tamil Nadu	197	659.51	21	123.050	-	-
25.	Tripura	13	46.86	3	16.010	-	-
26.	Uttar Pradesh	251	460.75	9	25.100	-	-
27.	Uttarakhand	448	1,707.87	99	174.820	46	174.04
28.	West Bengal	203	396.11	23	98.400	17	84.25
29.	Andaman & Nicobar Islands	7	7.91	1	5.250	-	-
	Total	**6,474**	**19,749.44**	**997**	**3,803.678**	**254**	**895.40**

plain areas. In hilly areas, the streams have steep gradients or vertical falls, thereby, offering high heads in short stretch of the stream whereas in plain area, the rivers have mild slopes.

Normally, hydropower projects are constructed in combination with water utilization for irrigation purposes. Hydropower plants may be connected to conventional electrical distribution networks as a source of low cost renewable energy. Pumped storage schemes are perfect centralized peaking power stations for the load management in the electricity grid. Pumped storage schemes would be in high demand for meeting peak load demand and storing the surplus electricity. They also produce seasonal power at no additional cost when rivers are flooding with excess water. Storing energy by other systems, i.e., batteries, compressed air storage systems, etc., is much more costly as compared to pumped hydro system. India has already established nearly 6,800 MW pumped storage capacity, which is part of its installed hydropower plants.

TYPES OF SMALL HYDROPOWER SCHEMES

Small hydropower schemes can be categorized into three types, i.e., run-of-river, canal-based, and dam-based. Based on head, these schemes are further classified as high head, medium head, and low head schemes. Under a head range from 3 m to 20 m, SHP sites are considered as low head SHP schemes. Medium head sites have head range from 20 m to 60 m, while those above 60 m head sites are considered as high head schemes. Low head schemes can be canal-based, run-of-river, and dam toe while, high and medium head schemes are run-of-river and dam-based schemes. Small hydropower projects in the hills on small streams are mostly medium and high head schemes utilizing small discharges. In case of high head schemes, there is uncertainty about the geology and hydrology. Due to these uncertainties, medium and high head schemes are considered site specific. Low head schemes in the canals meant for irrigation system have established hydrology and are free from geological and discharge uncertainties.

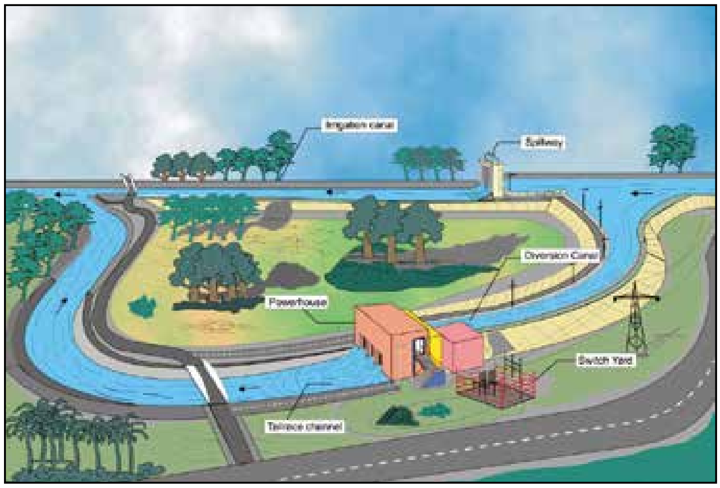


Figure 2: Schematic of a typical canal-based SHP scheme
Source: Alternate Hydro Energy Centre

Run-of-river scheme

In run-of-river scheme, storage of water is not envisaged and the power generation depends on instantaneous flow of water, which is not same throughout the year. Water availability varies in different seasons. Also in the same season, water availability is not the same every year. Thus, uncertainty about water availability is present. Figure 1 shows a schematic of a typical run-of-river SHP scheme.

Run-of-river SHP schemes comprise a diversion weir across the stream to divert the water, water conductor system including desilting tank and power channel, forebay, penstock, powerhouse, and tail race channel. The head for power generation is created by the difference in the water level at the diversion site and the water level of the stream at its junction with the tail race. The discharge for power generation is obtained from inflow discharge of the stream at the diversion site. The best combination of head and discharge, with due consideration of topographical, geological, and hydrological aspects determine the most appropriate layout for the scheme. In such schemes, geological and hydrological investigations are more important as these are not planned on existing facilities. The criteria for selection of scheme and components should include logistics in terms of accessibility. Inaccessible locations should be given the last preference as creation of infrastructure facilities for such schemes would involve considerable time besides costs.

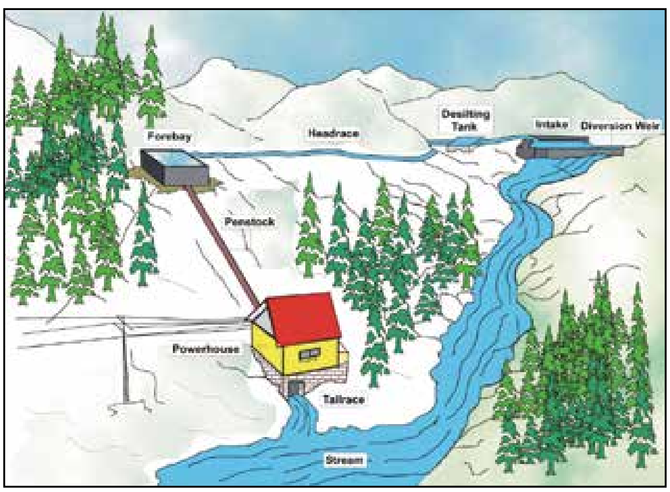


Figure 1: Schematic of a typical run-of-river SHP scheme
Source: Alternate Hydro Energy Centre

Canal-based scheme

These schemes are planned to utilize the head and discharge available on canal falls for power generation. The powerhouse is located in the canal alignment with intake on the upstream and tail race on the downstream of the fall. In most of the running canals, it is not possible to locate the powerhouse in the canal alignment, as it requires the closure of the canal for a considerable period for the construction. Figure 2 shows a schematic of a typical canal-based SHP scheme. These schemes can be planned in the existing canal system or canal system under construction. If a canal system is under planning, consideration must be given to plan concentrated drops at certain locations to utilize them for power generation. In case of existing canals, two or more number of drops in the proximity can be clubbed together to provide the consolidated single drop in the bypass channel for power generation.

It is easier to build a cost-effective SHP plant while an irrigation canal is being built, as civil works cost reduces due to avoidance of re-excavation, demolition, rebuilding, raising banks of canal, etc. In canal-based SHP projects, the major components of civil works are diversion channel, spillway, and powerhouse building. Spilling arrangement is generally carried out through existing canal.

Further, the construction of powerhouse building and diversion channel before charging of the canal will save on account of dewatering cost. Other infrastructure facilities available for construction of canals shall be used for hydropower structure in order to save the cost and time for mobilization of facilities.

Dam toe scheme

In SHP scheme, construction of dams is not envisaged. However, such schemes can be planned on existing dams. Dams are constructed to store seasonal water for flood mitigation, supply of water for irrigation, and drinking needs. When water flows from dam outlets under pressure due to water level difference between upstream and downstream of the dam, there is a possibility of power generation. These schemes are known as dam toe hydropower schemes, where powerhouse is located at the toe of the dam. However, in case of dam-based schemes, water is diverted from the reservoir created by the dam through water conductor system and powerhouse is built away from the dam. In dam toe schemes, a powerhouse building is located at the toe of the dam and penstock is taken through the body of the dam. The major components of civil works are intake, penstock, powerhouse building, and tail race channel. These schemes are planned on the existing irrigation facilities like irrigation dams/anicuts/weirs and cost of the dam is not considered as the part of SHP scheme. Since, the facilities already exist; there will be no question of eco-damage due to development of SHP schemes.

A schematic of dam toe type SHP scheme is shown in Figure 3. Irrigation sluices available in the dam can be used for dam toe schemes in order to reduce the cost and the sluices can be modified to act as the intake.

SMALL HYDROPOWER: A SUSTAINABLE SOURCE OF ENERGY

Hydropower projects that are developed and operated in an economically viable, environmentally sound, and socially responsible manner represent sustainable development at its best. Hydropower has an important role to play in meeting long-term sustainable development goals; it is a renewable and clean source which is available in regions where its need is greatest. The prominent benefits of SHP are summarized as follows:

- Abundant potential available in the country
- It is ideal to meet peak demands
- It can ideally lead to energy security
- It is cost effective
- It has additional benefits, such as irrigation, flood control, tourism, etc.
- It improves system stability
- It opens avenues for socio-economic development of the remote areas
- It provides inflation free power
- It is environment friendly.

The installation cost of SHP projects depends upon the location, layout, capacity, and head of the scheme. The generation cost from such schemes can be in the range of ₹2.50–6.00 per kWh depending upon the location, layout, and load factor based on water availability. To make SHP more sustainable and economical, additional opportunities are also available through Clean Development Mechanism (CDM) benefits and subsidy from Ministry of New and Renewable Energy (MNRE), Government of India.

CONCLUSION

Since SHP is environment friendly with short gestation period having no fuel cost, it is considered to be a promising source of renewable energy. Optimally utilizing available water resources and hydropower development has been recognized as one of the key drivers in achieving the objective of sustainable development of a nation.

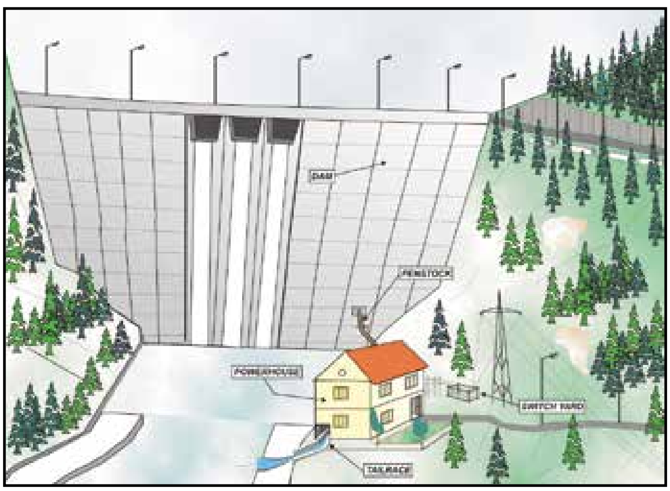


Figure 3: Schematic of a typical dam toe SHP scheme
Source: Alternate Hydro Energy Centre

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Engineering Non-Food Crops for Biodiesel Production

Technology for the Future

Recently, using food crops as raw materials for biofuels has caused concerns among environmentalists due to agricultural land limitation and their competition with food source. Therefore, alternatives such as engineering non-food crops like microalgae, Jatropha, Camelina, etc., are now favoured for biodiesel production and the trend is expected to continue in future. In this article, Dr Mamta Baunthiyal *and* Priyanka Sajwan *discuss how genetic engineering could be employed more effectively on non-food crops for biodiesel production.*

The use of biofuels allows a balance to be sought between agriculture, environment, and economic development. In general, these fuels are carbon neutral since the raw materials on which they are based are photosynthetic organisms such as the plants from which biodiesel oil is extracted (rapeseed, soya, sunflower, palm, etc.) or fermented bioalcohols (corn, sugarcane, etc.). Biodiesel is a clean-burning fuel which is produced from different feedstocks such as vegetable oils, animal fats, or grease. Chemically, biodiesel is monoalkyl (methyl, ethyl, or propyl) esters of fatty acids manufactured by transesterification of fatty acid and alcohol. Biodiesel can effectively be used in pure form in the diesel engines or blended with fossil diesel fuel. There are many advantages of biodiesels which makes it very useful, such as ready-availability, renewability, higher combustion efficiency, lower sulphur content, high cetane number, and higher biodegradability. The main disadvantages of biodiesel apart from high price are its higher viscosity, lower energy content, higher cloud point and pour point, higher nitrogen oxide emissions, lower engine speed and power, injector coking, engine compatibility, etc. Further, several other factors such as raw material, driving cycle, and vehicle technology should also be taken into consideration before quantifying the effects of biodiesel. The present biodiesel sector can be improved through enhancing the crops, either in terms of production efficiency or their suitability for conversion into biodiesel.

CHALLENGES FOR BIODIESEL PRODUCTION

Recently, using food crops as raw materials for biofuels has caused concerns among environmentalists due to agricultural land limitation and their competition with food source. Thus, food crop-derived biofuel is considered only the first-generation biofuel. Biofuels made from more sustainable biological materials are termed as second-generation biofuels. The increased demand and supply of edible oils has questioned the use of edible oils for the production of biodiesel. Usual raw materials of biodiesel are oils from rapeseed, soybean, canola, sunflower, and palm. Animal sources include beef and sheep tallow, and poultry oil. Other biodiesel sources of plant origin are babassu (*Orbignya* sp.), barley, rice, wheat, rubber seed, sesame, sorghum, camelina (*Camelina sativa*), coconut, *copra*, cumaru (*Dipteryx odorata*), *Cynara cardunculus*, groundnut, *Jatropha curcas*, karanja (*Pongamia glabra*), mahua (*Madhuca indica*), oat, piqui (*Caryocar sp.*), tobacco seeds, etc. Microalgae (*Chlorella vulgaris*) and microorganisms, such as yeast and *Escherichia coli,* are also being exploited for the production of biodiesel. As the list includes non-edible oils from sources such as neem, mahua, jatropha, microalgae, etc., they may be used over edible oils. Earlier, biodiesel production could not be preferred due to the shortage of edible crops for human consumption but recently engineering non-food crops, such as microalgae, jatropha, camelina, etc., is favoured for biodiesel production and the trend is expected to continue. Major sources of biodiesel, e.g., oil palm, soybean, rapeseed, sunflower, and feedstock, account for approximately 79 per cent of the world's total production. For growing non-edible oil crops less fertilizers, herbicides, and insecticides are required. In addition to this, these non-edible oil plants have unique ecological requirement and botanical features which make them suitable to be cultivated in lands where it is difficult to grow typical oil crops. For instance, algae can grow practically anywhere where there is enough sunshine. Microalgae are the fastest-growing photosynthesizing organisms as they can complete their entire growing cycle every few days. Approximately, 46 tonnes of oil/hectare/year can be produced from diatom algae. Algae contain proteins, carbohydrates, lipids, and nucleic acids in varying proportions. There are algae types in which fatty acids comprise up to 40 per cent of their overall mass. The most distinguishing characteristic of algal oil is its yield. The oil yield can exceed over 200 times the yield from the best-performing plant/vegetable oils. Hence, third-generation biofuels are derived from microalgae and/or seaweeds to produce bioethanol and/or biodiesel and from green microalgae and microbes to produce hydrogen and/or other biofuels.

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GENETIC ENGINEERING FOR IMPROVED BIODIESEL PRODUCTION IN PLANTS

New technologies, and more specifically genetic engineering, may play a role in enhancing bioenergy production and hence making it a viable component of the energy sector. Genetic engineering may be used to optimize the productivity of biomass of first-generation and second-generation energy crops, as well as to modify crops to enhance their conversion to fuels. There is also an opportunity to utilize genetic engineering to facilitate the downstream processing of biomass into fuels. While conventional breeding methods continue to play an important role in developing new crops and cultivars, genetic engineering of existing crops may enhance the magnitude and accuracy of such modifications and a diversity of plant products available for industrial use. These plants can be made drought-, pest- and disease-resistant in order to enhance their growth and productivity. Drought stress is a major constraint to the production and yield stability of crops. Considerable effort has been directed towards identifying traits associated with drought resistance.

Genetic engineering can manipulate the oil accumulation system of plant cells to release oil in extracellular space. Similarly, undesirable properties can be removed or suppressed. One example is suppressing the methyl bromide producing gene in canola oil. Methyl bromide is a broad spectrum pesticide used in the control of pest insects, nematodes, weeds, pathogens, and rodents. Its exposure affects not only the target pests it is used against, but also non-target organisms.

Genetic engineering permits the redesign of crops for easier processing and for creation of new types of raw materials. Plant varieties can be modified or selected for characteristics that enhance their conversion to fuels. For example, a pretreatment process in corn biomass that disrupts the lignocellulose and removes the lignin biomass from corn allows the access of microbial enzymes for cellulose degradation. Both the pretreatments

and the production of enzymes are expensive. Plant genetic engineering could reduce biomass conversion costs by developing crop varieties with less lignin, crops that produce cellulase enzymes (cellulose breaking enzymes) for cellulose degradation and ligninase enzymes for lignin degradation, or plants that have increased cellulose or an overall biomass yield. Recently, biologists have been using genetic engineering to overcome two major difficulties that are hindering the conversion of lignocellulose into fuels: the high cost of cellulases, and the limited ability of the microbes to ferment the breakdown products.

Therefore, shifting towards non-edible plant oil and genetic engineering are two important strategies for reducing the cost imposed by the required raw materials. Various researches in genetic engineering have been coupled with advanced cultivation and downstream technologies to benefit the future development of biodiesel production. The National Renewable Energy Laboratory (NREL) in the USA has established the lipid engineered microalgae. The lipid content of the engineered microalgae increased to above 60 per cent in laboratory conditions and above 40 per cent in outdoor cultivation as compared to 5–20 per cent in common natural conditions.

It is essential that the source plant has a proper fatty acid and lipid composition as the fatty acid composition determines the physiochemical properties of the oil and its subsequent usage in production of biodiesel. Inexpensive and better quality biodiesel can also be produced by altering the fatty acid composition of the biodiesel, such as chain length and unsaturation level. An appropriate blend of various fatty acids containing higher amounts of monounsaturated fatty acids, such as oleate, and lesser amount of saturated and polyunsaturated fatty acids would yield a better quality biodiesel. Fatty acyl chain length plays an important role in maintaining the viscosity and cold flow properties of biodiesel where, short- to medium-chain length fatty acids (C8–C14) have lower viscosity and higher cloud points than long-chain fatty acids (C16–C18). Researchers have demonstrated that the insertion of certain enzymes that cleave the fatty acids from the growing acyl-ACP in the fatty acid biosynthetic pathway, can lead to accumulation of up to 90 per cent short- and medium-chain fatty acids. For this purpose, chain length-specific enzyme, acyl-ACP thioesterases were introduced in *Umbellularia californica* (Figure 1) and *Cuphea hookeriana* seeds.

To improve the oil composition of several oleaginous plants, various metabolic engineering methods have come to aid. This includes genetic manipulation of lipid biosynthetic pathways through manipulation of metabolic flux towards oil production. For example, increasing activity of enzyme, Acetyl-CoA Carboxylase (ACCase) may increase the lipid synthesis by increasing the Malonyl-CoA utilization in the lipid biosynthetic pathway. A substantial increase of 53–121 per cent seed oil content (weight/plot) was also reported in *Brassica napus* by introduction of yeast sn-2 acyltransferase gene.

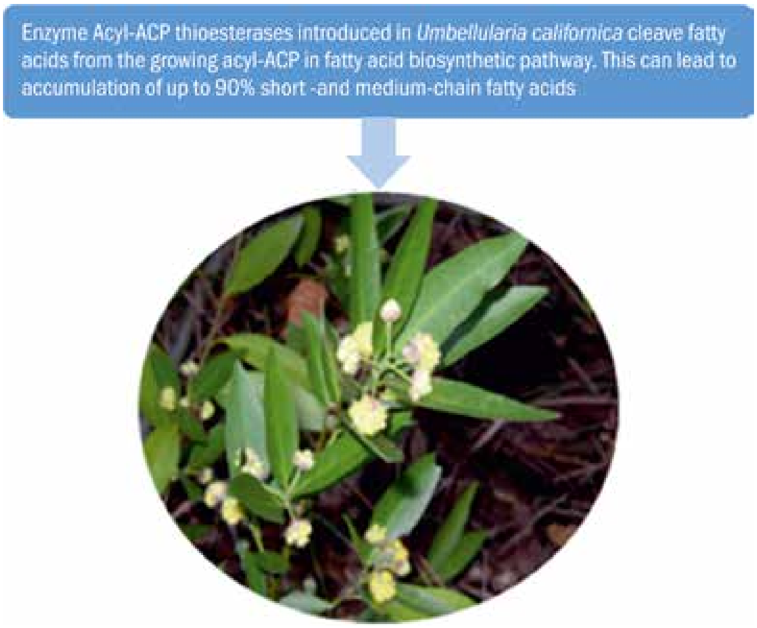

Figure 1: Insertion of acyl-ACP thioesterases for increasing production of short- and medium-chain fatty acids in *Umbellularia californica*

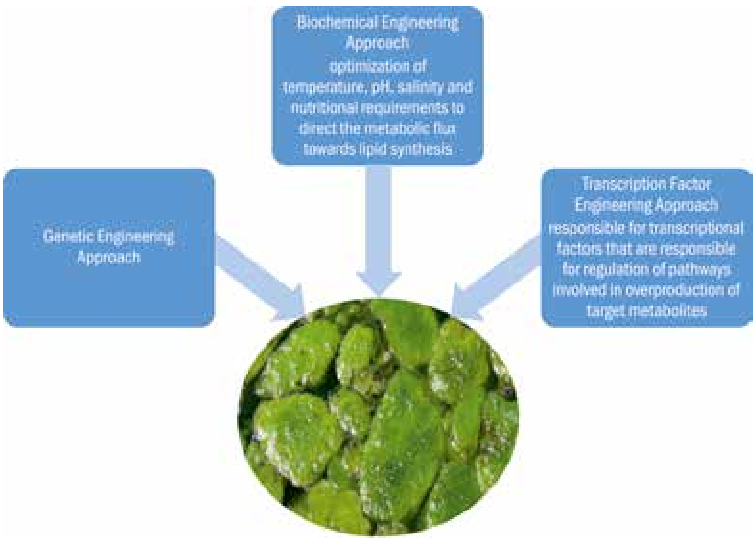

Figure 2: Three strategies are employed for the enhancement of lipid production in algae

Therefore, shifting towards non-edible plant oil and genetic engineering are two important strategies for reducing the cost imposed by the required raw materials. Various researches in genetic engineering have been coupled with advanced cultivation and downstream technologies to benefit the future development of biodiesel production.

The problem of the release of methyl bromide by *Brassica* species can also be addressed by genetic engineering. A bifunctional methyl transferase enzyme was found to be involved in methylation of halides to methyl halides and bisulphides to methanethiol in *Brassica oleracea* and *Arabidopsis*. Suppression of this gene in *Arabidopsis* resulted in plants that produced less than 1 per cent the amount of methyl halides.

In recent years, much attention has been given on microalgae as a feedstock for biodiesel production (third-generation biofuel) due to their beneficial characteristics as described earlier in this article. Third-generation biofuels are considered to be viable alternatives that can avoid major drawbacks associated with first- and second-generation biofuels. Broadly, three strategies are employed for the enhancement of lipid production in algae: (1) Biochemical engineering approach; (2) The transcription factor engineering approach; and (3) Genetic engineering approach (Figure 2). 'Biochemical engineering' approach involves regulating the physiochemical conditions of cultivation, such as optimization of temperature, pH, salinity, and the nutritional requirements to direct the metabolic flux towards lipid biosynthesis. The 'transcriptional factor engineering' approach employs the controlled expression of transcriptional factors (proteins that regulate DNA transcription) that are responsible for regulation of the pathway(s) involved in the overproduction of target metabolites. This could substantially improve the production of valuable metabolites but it is in its juvenile stage at present as there was relatively low success in such engineering approaches. Scientists at the NREL have succeeded in achieving a remarkable increase of 60 and 40 per cent, respectively, in lipid content of the engineered microalgae in laboratory and outdoor cultivation conditions by high expression of ACCase gene. Recent research in diatom *Thalassiosira pseudonana* has also shown that targeted shutdown of lipid catabolism via antisense expression knockdown (a genetic technique in which one of an organism's genes are made inoperative) increases the cellular lipid content (up to 3.3- and 4.1-fold) under both nutrient-complete and nutrient-limited conditions, without compromising the growth (Figure 3).

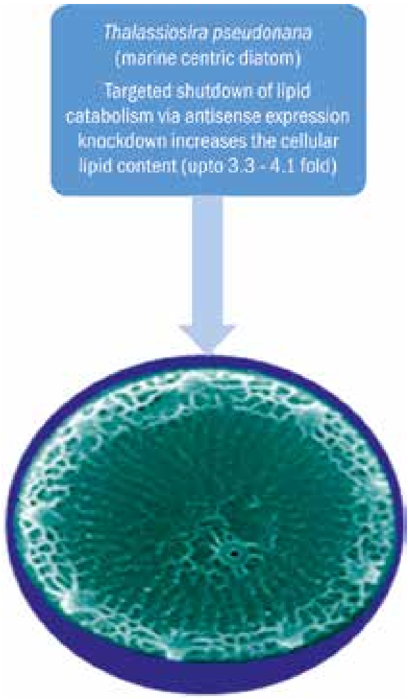

Figure 3: Antisense expression knock-down in *Thalassiosira pseudonana* to increase cellular lipid content

REDUCING THE DOWNSTREAM PROCESS COST OF BIODIESEL PRODUCTION

One of the major causes of higher cost of biodiesel is its downstream processing. It is a very high energy and material consuming process. Though it seems that genetic engineering technology has little role to play in making the production process economical, there are some issues that can be addressed by this technology towards economic feasibility of the process. The amount of waste water produced is approximately 0.2 tonne per tonne biodiesel produced. The need for extensive downstream processing makes alkaline transesterification expensive and not environmentally friendly. Continuous production process is a method of production where the oil or FAME (biodiesel) produced by the organism is secreted to the external medium. This process saves a lot of energy and reduces several steps in the downstream processing typically being used in biomass-based technologies. Use of cheaper carbon sources is another area to make the biodiesel feedstock production economically feasible at a large scale, though is yet to be fully focused. For example, alteration of lipid synthesis metabolic pathways that can utilize cheaper carbon and nitrogen sources can be industrially worthy when low-cost raw materials (such as molasses, glycerol, wheat bran fermentation solids, wastewaters of animal fat treatment, and oil mill wastewaters, etc.) are concerned. Utilization of enzymes such as lipases and cutinases in transesterification process as an alternative to chemical transesterification process also reduces the downstream processing costs. The lipase enzyme can be engineered by recombinant DNA technology with desired fatty acid chain length specificity. The enzymes can be immobilized in whole cells that may further lower the overall cost of downstream processing.

CHALLENGES IN GENETIC ENGINEERING

Sometimes, the genetic engineering methods seem to be technically successful but commercially a failure at large-scale production. For example, the production of desired fatty acids from genetically modified plant at sufficiently high levels for commercial viability is still a challenge. Most of the transgenic species accumulate at relatively low levels (5 per cent) of desired fatty acids. The main reason for this drastically low oil yield is that merely transferring the relevant desaturase or hydroxylase gene into a plant does not mean that the corresponding polyunsaturated or hydroxyl fatty acid will necessarily accumulate at high levels in the storage oil of the recipient plant. Moreover, to predict which additional enzymes/genes may be required to accumulate a given fatty acid seems to be a challenging task. In some crop species, such as rapeseed, novel acyl groups are not always channelled to store lipids. Instead, some of the fatty acids may accumulate on membrane lipids. This can stimulate a regulatory response, which results in their removal from membranes and subsequent breakdown via the ß-oxidation and glyoxylate cycle pathways. This is also one of the reasons why some transgenic plants are unable to accumulate high levels of desirable fatty acids.

CONCLUSION AND FUTURE PROSPECTIVE

In the coming decades, biodiesel will form a small but very important part of the global energy supply (Figure 4). Genetic engineering of non-food crops with new technologies has improved the efficiency as well as production process but relatively slow (although continuous) improvement especially in producing cleaner

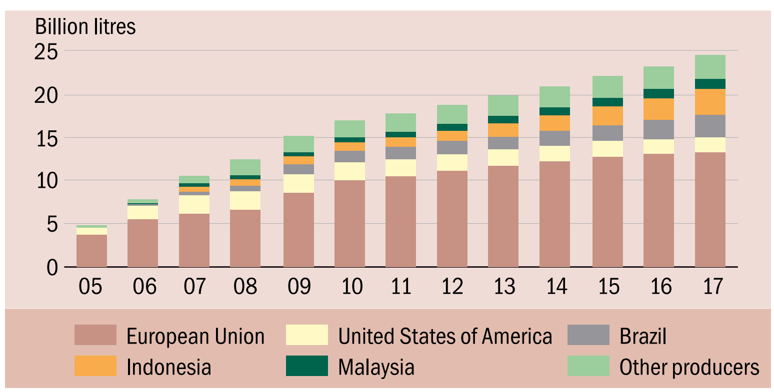

Figure 4: Major biodiesel producers, with projections to 2017
Source: Based on data from OECD-FAO, 2008

Table 1: Research institutes involved in developing technology for biofuel and biodiesel production in India

Name of the Institution	Focus Area
1. International Centre for Genetic Engineering and Biotechnology (ICGEB), New Delhi	• Discovery and design of novel enzymes and enzyme systems for biofuels. Engineering bacteria to produce biofuels
2. DBT-ICT-Centre of Energy Biosciences, Mumbai, Maharashtra	• Development of biotechnologies for deriving energy from renewable resources
3. DBT- ICGEB, Centre for Advanced Bioenergy Research, New Delhi	• Engineering microbes for direct conversion of biomass into biofuel • Engineering microbe for production of higher value advance biofuel molecules—butanol and hydrocarbon • Engineering algae for higher lipid and biomass yield, strengthening the existing capacity in Synthetic Biology and to promote the cutting-edge research • Genomic and metagenomic approaches for identifying novel cellulolytic enzymes
4. DBT-IOC Center for Advanced Bioenergy Research, Faridabad, Haryana	• Lignocellulosic based biofuels • Development of new and economical pre-treatment process • Feedstock selection/development and characterization • Process optimization for saccharification/ fermentation and scale-up • Bio-assisted/chemical lignin de-polymerization and lignin value addition • Algal research scale-up studies on algal cultivation and harvesting • Gas fermentation syngas fermentation for biofuel
5. Sardar Swaran Singh National Institute of Renewable Energy (SSS-NIRE), Kapurthala, Punjab	• Development of state-of-the-art R&D covering the entire spectrum of bioenergy leading to commercialization • R&D in the area of biomass and energy, thermochemical conversion, biochemical conversion, chemical conversion, electrochemical processes including hybrid energy systems • Human resource development at all levels in the field of bioenergy
6. CSIR-Central Salt and Marine Chemicals Research Institute, Bhavnagar, Gujarat	• Marine Biotechnology and Ecology
7. Center for Alternate Energy Research, University of Petroleum & Energy Studies, Dehradun, Uttarakhand	• Includes biofuels, bioenergy, solar, wind energy, hydrogen and fuel cell and new technology
8. Biofuels Division of CSIR-Indian Institute of Petroleum (CSIR-IIP)	• Biofuel Division is dedicated to developing technology for biofuel development
9. Centre for BioEnergy, IIT Kharagpur, West Bengal	• Aims to work in the area of bioethanol, biobutanol, biohydrogen, MFC and algal biodiesel
10. CSIR-Indian Institute of Chemical Technology, Hyderabad, Telangana	• National mission mode project sanctioned by Ministry of New and Renewable Energy (MNRE) to develop waste to commercially viable hydrogen conversion technology
11. DIBER , Haldwani, Uttarakhand	• Biodiesel production

emission should be taken care of. The incentives provided by government can help in the promotion of biodiesel production and usage in establishing biodiesel as a sustainable fuel. Research experiences on plant genetic engineering dates back to the 1990s when the first genetically modified (GM) rice was produced in 1997. Since then, different kinds of crops have been developed. A lot many genetic engineering researches in the field of biodiesel production from non-food crops are in the pipeline. Many research institutes in India have emerged as capable candidates to accomplish projects on microalgae genetic engineering in order to meet growing biodiesel requirement in the future (Table 1). Many oil crops, such as *Camelina sativa* and *Brassica carinata*, with lower production cost have been studied and their studies have demonstrated that these oil crops display physiochemical properties which make them suitable to be used as biodiesel fuel. A huge work is already done on microalgae and algae and research still continues. Researchers believe that implementation of this technology into biodiesel production could be the next big breakthrough not only in process magnification but also in development economics.

Currently, India's position in the global fuel map is not very prominent. The biodiesel industry in India is still in its infancy stages despite the fact that the demand for diesel is five times higher than that for petrol. Though, the Central government and several state governments are providing fiscal incentives for supporting plantations of *Jatropha* and other non-edible oilseeds, they should set up rules to regulate the mechanism of cultivation of edible crops for biodiesel production. The genetic engineering of non-food crops should be encouraged to increase the yield of biodiesel in the future. EF

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Solar Future in Sundarbans

A Case Study of Sagar Island in West Bengal

*In this article, **Anwesha Haldar** discusses about the current power scenario at Sagar Island in the Sundarbans area of West Bengal. After dwelling on the rural electrification programme and its outcomes in the Sagar Island she examines new solar energy initiatives in West Bengal and India on the whole, and concludes that the future of renewable technologies in West Bengal is not as bleak as it seems and newer uses are being brought into the market as a step towards conservation of the diverse ecosystems, human environment, and the natural fossil fuel reserves.*

The Sagar Island occupies the south-western corner of district South 24 Parganas in the state of West Bengal in India and is bordered by the Hooghly River in the West and the Muriganga channel on the East. Sagar Island is an island in the Ganges delta, lying on the continental shelf of Bay of Bengal about 100 km south of Kolkata. The island is situated at a point where the Hooghly River enters the Bay of Bengal and is one of the largest islands of this estuary. Although this region is in close proximity to one of the largest metropolis in India, almost negligible awareness can be observed about resource conservation and sustainable development, especially in its underdeveloped rural areas located in the coastal part.

The main issue of Sagar is the non-availability of grid power since linking is both expensive and cumbersome in the face of frequent climatic hazards and requires high maintenance, which is mainly a problem for all power generating organizations operating in the island. Initially, electrification of Sagar was planned using a Solar Photovoltaic (SPV) hybrid system with diesel generators and the scheme became operative in February 1996. The first phase of the project was completed with good quality SPV power to 50 houses. Wide distribution was always an issue due to their low purchasing power capacity and low awareness standards. Another step towards the issue of Sagar Island's energy starvation was initiated through the implementation of Wind-Diesel Project with 10 wind generators of 50 kW capacity each, two 180 kVA diesel generators, and a controlling system but this too could cater to the needs of only a handful of villages.

In this backdrop, the present electrifying proposals are a dream-come-true for the locals of the island. They have enormous expectations and it is not unjust of them to believe that only thermally originated gridded electricity can bring in their long desired infrastructural and economic prosperity just as they have seen in the metropolitan development processes.

RURAL ELECTRIFICATION

Currently, all generation, transmission and distribution of renewable electricity falls under the broad ambit of Electricity Act 2003. The Electricity Act has been drafted with centralized non-intermittent power in mind. Since 2003, the global and Indian electricity landscape has changed fundamentally. Wind and solar power have risen from the fringes to the mainstream. The Ministry of Power approved proposals amounting to ₹630 crore last year, for the states of Kerala, West Bengal, and Rajasthan for renovation and upgradation of protection system at their substation and a proposal of powergrid installations to enhance grid security.

In consultation with State electricity boards and State government the definition for village electrification adopted in 1997 states, "A village will be deemed to be electrified if electricity is used in the inhabited locality within the revenue boundary of the village for any purpose whatsoever".

In February 2004, this was made more target-specific. A village would be declared electrified, if:

- The basic infrastructure, such as distribution transformer and distribution lines are provided in the inhabited locality as well as the *dalit basti*/hamlet where it exists
- Electricity is provided to public places, such as schools, panchayat offices, health centres, dispensaries, community centres, etc.
- The number of households electrified should be at least 10 per cent of the total number of households in the villages.

The Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY) in April 2005, aimed at providing electricity in all rural villages with at least a 33/11 kV sub-station, a distribution transformer in a village, and standalone grids with generation where grid supply is not feasible. It also proposed a subsidy towards capital expenditure of 90 per cent, through Rural Electrification Corporation Limited (REC), and unelectrified Below Poverty Line (BPL) households would be financed with 100 per cent capital subsidy at the rate of ₹1,500 per connection in all rural habitations. It was only in September 2011 that the Sagar Island was assured grid electricity in the near future from a project that proposed to connect Sagar Island with grid power available at Kakdwip 33/11 kV sub-station via Lot 8 and Gouranga Math and a crossing over river Muriganga at Harwood point on towers to the proposed Rudranagar 33/11 kV sub-station. Over 2,000 families at Sagar Island who had been getting electricity six hours per day from the gridded solar plants and diesel generators in the favourable climatic season readily joined the network of the state-owned power company that laid cables across the Muriganga several kilometres wide. The grid power was said to cost 70 per cent less than using diesel generators. Sources in the West Bengal State Electricity Distribution Company Ltd (WBSEDCL) said that diesel-generated electricity costs around ₹13 per unit but the cost of grid power can be brought down to ₹4 per unit. This project was conceived to electrify all the *mouzas* of Sagar Island with 100 per cent household electrification work. Taking into consideration the decadal growth from 2001 census, it is almost certain that there will be an ever increasing demand of power in the island and the requirement of power is estimated at about 9.5 MW by 2017–18.

With the sole objective of making the people of Sagar feel that they are not alienated from their counterparts at the mainland, when it comes to providing the basic infrastructural facilities and to shore up the human development index, grid-based thermal electricity lines have been strongly proposed against all odds by the governments. But three years after the report was officially announced, the situation now is quite different.

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THE PREVAILING POWER CONDITIONS AT SAGAR ISLAND

Some years ago, Sagar Island in the Bay of Bengal was a shining example of India's efforts to power remote, impoverished areas with solar energy. Between 2000 and 2004, a range of solar power systems—including household photovoltaic panels, home and street lighting, and mini grids—were installed on Sagar Island with large state subsidies. The government also helped cover generation and distribution expenses, at a cost of around ₹15 crore. The solar and wind–diesel hybrid generation facilities were generating close to 1 MW of electricity, distributed through mini grids to around 2,000 households. But government's decision to hook up the island with the electric grid has left the solar scheme in tatters.

As per various estimates, the average annual solar radiation is about 1,600 kWh/m^2 on horizontal surface and on an average a trend of 250 sunny days and 115 overcast days yearly is observed in the Sagar area. The annual average solar radiation on horizontal surface is about 4.91 kWh/m^2/day. The island's 11 solar stations can each produce between 25 kW and 100 kW power, totalling close to 800 kW, distributed via power lines 2–3 km long. They supply 1,400 households and commercial establishments. The generation cost is about ₹10 per unit (100 watt/hour), which is then sold for ₹7, the ₹3 difference being borne by the West Bengal Government.

Sagar Island was connected with the grid under the ambitious national scheme—RGGVY, which aimed to bring electric power to all villages without it by 2012. People below the poverty line were to get free electricity with the pay rates as low as ₹3.5 per unit. The present average domestic load in Sagar Block is 140 kW per consumer and average commercial load is 620 kW per consumer. Since Sagar Island started to access power from the grid, some islanders stopped using solar energy, and the state government is no longer paying to maintain the solar facilities. As a result, solar capacity is gradually declining and the state of the generation equipment is deteriorating, a trend that will continue if demand for solar power declines further, experts warn. Local consumers in Sagar may be pleased with the policy U-turn, as they will get cheaper (compared to the solar–diesel hybrid systems) and perhaps more reliable electricity. But one side-effect is that Sagar's solar energy facilities are being neglected, and could even become defunct rather than contributing to the Indian government's target of installing 100 GW of solar power capacity by 2022.

Recent field studies at the Sagar Island have indicated that electricity has reached the major connecting points of the island. In places where grid electricity is gaining ground, it can be closely noticed that infrastructural development and lighting is only tourism-based, i.e., only those places have electric connection where pilgrims, tourists, or government officials have access. The West Bengal Renewable Energy Development Authority (WBREDA) had stopped

operation in almost all the windmills and solar plants in Sagar and all such renewable sources of power that had been previously installed in the last three years. The popular reason being the Government wished to provide subsidy for only one type of power (grid electricity). The RGGVY on paper shows marked infrastructural development in the Sundarbans. Nation-wide this would have facilitated overall rural development, employment generation, and poverty alleviation but it has been observed that none of these were still available here.

Importantly, at present no government subsidies are available for getting a grid connect. The unit rating is marked at ₹7 for people owning a meter and ₹10 for those who are hiring someone else's meter amounting to ₹600–700 electricity bills in three months. There is also an initial set-up cost of ₹800–1,000. This in case of solar plant on-grid supply costed them ₹8 per unit or a rent charge of ₹80 for 60 W capacities and as for the standalone installations it was a one-time charge of ₹14,000 (all inclusive). The only difference thermal grids have brought to the lives of the people here (apart from higher electricity bills) is that they can now easily get a fan, television, and motor connections which were unthought-of earlier with the low wattage alternative energy supplies. However, connecting a thatched roof mud house with 220 V electric supply continues to pose fatal risks to the islanders (Figure 1). There also persist the problems of poor connectivity to the sources of power, frequent power cuts, voltage fluctuations and worst still—the condition of the transmitters and light posts wreak havoc during

Figure 1: Electric poles near the eroding edge of Beguakhali coast-line, Sagar Island

times of climatic hazards. Preventive maintenance works including periodical trimming of tree branches near the lines, maintenance of High Tension (HT) lines, distribution transformers, load balancing, and other associated activities are not regularly done. Besides this, restoration of supply within 48 hours in case different system outages as a part of maintenance work is also poor till date. The poles and lines too were set up in some extremely hazardous and vulnerable areas, hence, increasing shock and supplyline-breakage risks for the locals.

Though the people were satisfied with the renewable technologies—exterior motifs and imposed preferences have urged them to lose their dependence on these alternative sources of power and wait for the grid connected electric supply to be installed in their villages. Shaktipada Ganchowdhury, former director of the West Bengal Green Energy Development Corporation Ltd which managed the solar project, was not only pessimistic about its future but also lamented that the capital cost, transmission loss, and the generation expenses (incurred) in extending the main grid will become far greater, which the government will eventually need to pay as subsidies. Instead, far less subsidy would be required to spread solar connectivity and generation, an option which is far more environment-friendly.

NEW INITIATIVES IN WEST BENGAL TOWARDS ALTERNATE SOURCES OF ENERGY

Technological innovations, alternative uses, trial and error methods, and modifications in the Indian solar energy harnessing genre is fast progressing inspite of hindrances from the political and coal-based blocks. Pumping water is a universal need around the world now and the PV-powered pumping systems offer simplicity, reliability, and low maintenance for a broad range of applications between hand pumps and large generator driven irrigation pumps (Figures 2a and b). In West Bengal too, this trend has been silently working towards the goals. One of the eminent persons working in this field is Mr Sumit Kumar Banerji, a renewable energy expert and chief technical advisor in this field, West Bengal. He has been associated for 35 years with a major power electronic equipment company based in Kolkata, which is a 100 per cent subsidiary of Exide Industries Limited.

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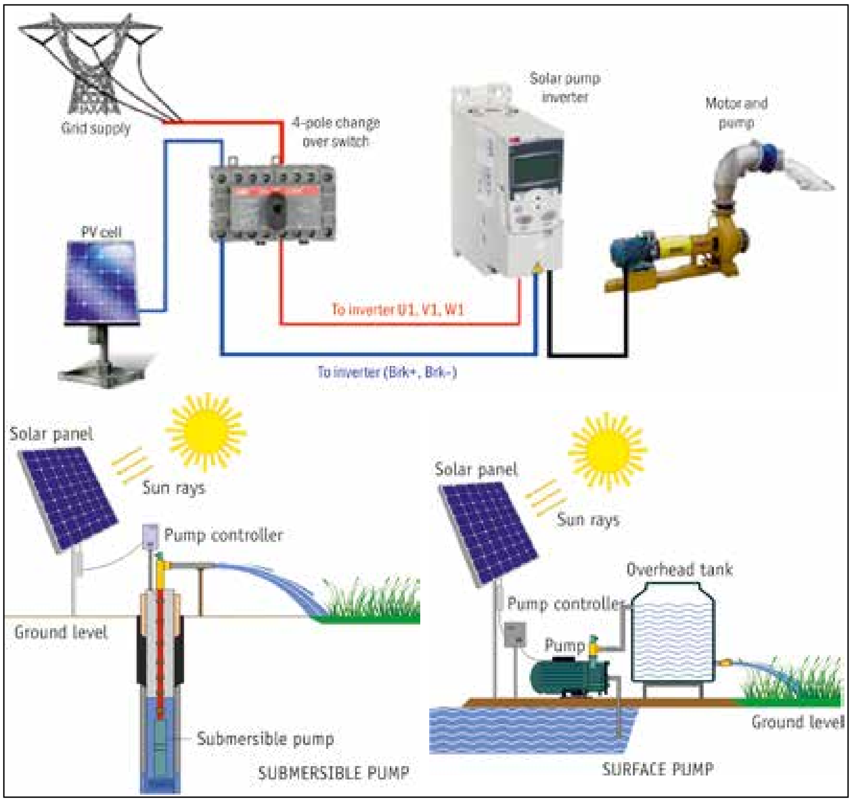
but foraging into the rural irrigation and pumping systems. Promotion of solar pumps in groundwater abundant eastern India has the potential to catalyse an 'ever-green revolution' in eastern parts of the country. Irrigation pumps used in the agriculture sector account for about 25 per cent of electricity and 12 per cent of the diesel consumed. But, these pumps irrigate only 44 per cent of the area under cultivation; the farmers elsewhere are left waiting for the monsoon season for rainfall. The grid, which supplies electricity to the farmers, is itself in bad shape with frequent outage. To add to this, the farmers care neither for the pumping systems nor for the water being pumped, as a result degrading both. Banerji opines that the batteries are an integral part of the solar system but are also a major cause of failure. The main reasons being very poor maintenance in the rural surroundings, they are never regularly topped with



Figures 2a and b: The solar pump drive system water and neither the terminals are cleaned properly to ensure correct operation of the battery throughout the evening and night. Secondly, the dust accumulation on the solar panels which has to be cleaned on a regular interval is hardly taken care of. The battery requires to be initially charged for proper operation during solar connect which is a major cause of concern as this needs a stable electric supply for charging. In fluctuating voltage points, charging cannot be done.

As the scenario of battery operated solar home lighting and street light system is not encouraging, hence, the next step for solar applications is to devise some technologies which will work without a battery backup and that will eliminate this major drawback of solar systems. Hence, in this new process the solar power is directly fed to pulse-width modulated (PWM) invertor systems that generate a three phase clean AC supply fed to an induction motor connected from indigenous manufacturers either to a submersible pump (in case of low ground-water table for irrigation) or a centrifugal pump depending on the availability of water level. Even though the sets have a steep initial cost, it can be still termed as cost-effective because with a handsome government subsidy, the entire cost can be recovered within a year of its operation. This power mode for operating the irrigation pump sets not only eliminates the high diesel costs but also markedly reduces the black soot and pollution. In ecologically sensitive places, solar energy is also wildlife friendly as solar pumps produce no noise. In traditional systems, the noise produced by the pumps is a big menace for animals and birds.

FUTURE POTENTIAL

Even though the total number of solar pumps in India, as reported in August 2014 has been found to be less than 12,000 compared to nine million diesel pump-sets, the demand is expected to increase in the coming years. The Government should subsidize the green technology on the one basic criterion that even if 50 per cent of the diesel pump-sets are converted to solar-powered pumps, it will save 25 billion litres of diesel per year. And because solar pumps will save a lot of electricity, villages will conserve the electricity, which can be used for other purposes. Rajasthan, Andhra Pradesh, Maharashtra, and Punjab have already taken this initiative in a big way. It can be inferred that the future of renewable technologies in the economic and political scenario of West Bengal is not as bleak as it seems and newer uses are being brought into the market as a step towards conservation of the diverse ecosystems, human environment, and the natural fossil fuel reserves. EF

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