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ENERGY FUTURE

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FEATURE

TECHNO-ECONOMIC PERSPECTIVES AND IMPORTANCE OF RENEWABLE ENERGY TECHNOLOGIES

COVER STORY

THE RACE TO REDUCE CARBON EMISSIONS

VIEWPOINT

PURSUING INDIA'S CLIMATE VISION

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Editorial

Currently, innovative technology developments characterize climate efforts globally. While there is a focus on scaling-up the use of time-tested climate mitigation strategies—one may think of rapid expansions in the field of solar energy—the world also has its eye on finding (and bettering) new inventions that may turn out to be game changers. The many optimistic advantages of these less-popular technologies, like CCUS, or even the ever-elusive fusion, are accompanied by reservations and logistical challenges. The biggest offside, however, of this explorative zeal may be time and cost. Do we have the time to look into and improve these technologies, for they may offer exceeding benefits if employed successfully? Or should we focus our energies on judiciously implementing the plans that we are sure will work, if done at the right pace and scale? Time and the related costs are of the essence in either of these choices, along with an uncertainty over the results. What one can be certain of is that the renewables industry is growing at an enormous scale, and so are the economic possibilities it offers.

This issue of Energy Future represents this coupling of advancements. From our cover story—that discusses the various possibilities presented by CCUS in combating the climate crisis—to an exploration of the '*Explorer Tool*' presented by Sapna Gopal in a *Solar Quarterly* article, the issue provides an overview of how the growth in renewables presents several economic opportunities. Carrying on this theme of duality in the feature article, *Techno-economic Perspectives and Importance of Renewable Energy Technologies*, Dr V N Lad discusses how relying on renewable sources of energy can help India achieve the twin goal of reaching net-zero and address issues of energy security. The article highlights how the most important significance of such renewable technologies is their cost competitive nature, with many applications related to conventional techniques.

The first *Solar Quarterly* of this issue once again, brings focus to the potential of decentralized solar models. This article, by Gayatri Ramanathan and Aneesh Anand, presents the potential of solar mini-grids as an enabler for enhancing rural livelihoods. The possibilities presented by this article may also make a case for the importance of striking a balance between energy security and sustainability; something also represented by the cover story, *The Race to Reduce Carbon Emissions: is CCUS a Promising Solution?*

The world's struggle to successfully meet its climate goals has resulted in several interesting inventions. We may choose to focus on finding 'the cure' to climate change in some novel technology. Or deploy our energies to successfully translate proven theories (through our actions) into a reality. With either of these choices, our goal remains unchanged and fast approaching: saving the planet and its future.

Girish Sethi

Girish Sethi
Senior Director – Energy Programme, TERI

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New Message

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Letter to the Editor

The feature article in the September 2022 issue on traditional building materials and designs was quite intriguing. Having stayed in a traditional Assamese house as the one talked about in the article, it was interesting for me to understand the science behind it and relate it to my brief experience (which was extremely comfortable) as a tourist. The pictorial representations of traditional buildings complimented the article very well and elevated its impact. The twin advantage of vernacular architecture practices, that they not only help reduce energy intensity and carbon emissions, but also preserve historic traditions, was a particularly attractive and effective point that the author made for encouraging vernacular architecture.

Srishti Baliga
Bengaluru

Send

"The *Solar Quarterly* article in this issue of Energy Future, was highly informative and insightful. While India is swiftly scaling up its solar energy capacity, the expansion is heavily focused on industrial scale projects. Given this scenario, it was good to know that people like the author are properly investigating the potential that decentralized, or small-scale solar installations offer. I agree with the author that a definitive reason behind the laggard pace of decentralized solar is the lack of clarity in its political economy, which is the opposite of the well-defined policy and financial landscape of centralized solar.

M Madan Pillai
Chennai, Tamil Nadu"

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

"Coal is the most important and abundant fossil fuel in India, accounting for 55% of our energy needs. Built upon indigenous coal, India is still a rapidly developing nation. Yet, phasing-out coal is a key global and national concern. In the cover story, '*The Other Side of Coal*', the authors have raised compelling arguments about hazards of using coal—moving beyond the obvious issue of carbon emissions and highlighting the overall environmental and social degradation. What was interesting to me was that given the many risks posed by coal, it is also dangerous to immediately and/or entirely stop its use. As expertly pointed out, this may lead to entire communities being vulnerable due to lack of alternative sustenance options. To answer the fundamental question posed by the article in its conclusion: '*whether transition away from coal and switching to a cleaner choice is a utopia, or is it a plausible construct*', I believe that a key aspect that may determine the success of this process is community engagement, awareness, and capacity building. On that account, it was heartening to read about TERI's fieldwork in the coal belt of Odisha and the concerns of stakeholders that it brought to the forefront.

Mohan Kumar
Kanpur, Uttar Pradesh"

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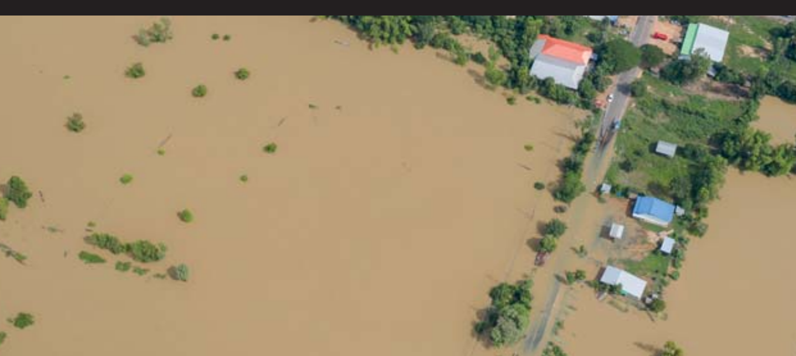


BIOGAS PROJECT RUNS OUT OF STEAM AFTER WITHDRAWAL OF SUBSIDY BY CENTRAL GOVT

Post withdrawal of subsidy under the Union Government's National Biogas and Manure Management Programme (NBMMP) for setting up of biogas plant in 2020, there has been a marked decline in number of farmers opting to install family-type biogas plants in the past two years in the Malwa region.

The scheme run was primarily aimed at providing biogas as a source of clean cooking fuel and lighting in rural and the semi-urban areas of the country. But after withdrawal of the subsidy under the scheme two years ago, the biogas installation project, which was providing cheaper cooking fuel to farmers in the state, has run out of steam.

As per data procured from the Punjab Energy Development Agency (PEDA), the nodal agency to carry out the project in the state, on an average 400 to 450 family-type biogas plants were installed annually in one district until 2019. Sources in the agency confirmed that after subsidy was withdrawn, now on average 60 to 80 farmers opt for the installation of biogas plants and in some districts the number is even below 50. EF

Source: https://www.tribuneindia.com/

GREEN BONDS' FUNDS MARKED FOR CLEAN ENERGY, POLLUTION CONTROL

India's maiden sovereign green bond issuance will fund projects in nine categories, the government said. These include renewable energy, pollution control, green building, clean transportation, and water and waste management. The proceeds from the issue will not be used to fund hydropower plants larger than 25 megawatt (MW), nuclear projects, or any biomass-based power generation with biomass originating from protected areas, according to the green bond framework released on Wednesday. The government aims to issue INR 16,000 crore of green bonds between October and March. The proceeds would be deposited in the Consolidated Fund of India and the framework provides the flexibility to roll over unallocated proceeds, if any, to successive years for investment in eligible green projects. The centre has set up a Green Finance Working Committee headed by Chief Economic Adviser V Anantha Nageswaran to oversee the selection of projects and fund allocation. EF

Source: https://economictimes.indiatimes.com/

MINISTRY SEEKS 40 RAIL LINKS TO MEET POWER DEMAND

Citing increasing coal demand to meet the electricity needs of a rapidly urbanizing India, the Union coal ministry has sought more than 40 rail link expansions to ensure timely evacuation of the solid fuel. It has also cautioned that a serious challenge could arise if adequate rail evacuation infrastructure is not ready in time to meet the country's coal demand. These new rail links are over and above the 13 'critical gap' projects flagged off with the Gati Shakti inter-ministerial coordination team. Team Gati Shakti is, in fact, looking at a whole gamut of issues related to the 2022 coal and power crisis. Work is in full swing to get the 13 'critical gap' projects—missing links in coal evacuation—moving. Five of the 13 critical gap projects are expected to be completed between March to May 2023, as per a recent round of Gati Shakti meetings. EF

Source: https://economictimes.indiatimes.com/

ENERGY CONSERVATION BILL GETS RAJYA SABHA NOD

The Rajya Sabha on Monday approved the Energy Conservation (Amendment) Bill, 2022, which empowers the Centre to specify a domestic carbon credit trading scheme and makes it mandatory for big power consumers to meet a portion of their energy needs from renewable sources. There was a lengthy debate in the Rajya Sabha on various issues related to the carbon trading scheme. Opposition MPs asked why the carbon market scheme was envisaged under the power and not the environment ministry, which is the key nodal agency to implement India's climate commitments. There were also questions on the structure of the trading scheme and benefits accruing from it.

Some MPs also said the bill has a centralized structure, despite the fact that each state has its own dynamics of energy production and consumption. The legislation places the onus of regulation on the Bureau of Energy Efficiency, a centrally governed organization. EF

Source: https://www.hindustantimes.com/

INDIAN OIL CORPORATION TO INVEST INR 2,200 CRORE IN TAMIL NADU

The planned projects include a 'grass-roots terminal' at Asanur and Vallur, a 'captive petroleum' project, oil and lubricant-LPG jetty at Kamarajar port among others, said V C Asokan, executive director and Tamil Nadu State Head of the Indian Oil Corporation.

Apart from the ongoing projects in the Ennore-Tiruvallur sector, Bengaluru-Puducherry-Nagapattinam-Madurai-Turicorin gas pipeline, and augmentation of Chennai-Tiruchirappali-Madurai pipeline projects, the executive director detailed on the company's plan set up integrated Lube complex at Ammulaivoyyal village on the outskirts of Chennai.

In line with fuel diversification plans, the Indian Oil Corporation has achieved

10% ethanol blending with petrol in Tamil Nadu and Puducherry. Asokan added that the company is now on the way to increasing ethanol blending to 20%, as per the mandate of the Union Government. The company constitutes 57% share in liquified petroleum gas (LPG), 36.9% in petrol, and 43.9% in diesel in the state of Tamil Nadu. EF

Source: https://www.livemint.com/

EIGHTY PER CENT OF DELHI'S BUS FLEET WILL RUN ON ELECTRIC BY 2025: CM ARVIND KEJRIWAL

Eighty per cent of Delhi's bus fleet will run on electric by 2025, Chief Minister Arvind Kejriwal said on Monday, asserting that acquisition of e-buses will go a long way in reducing pollution in the national capital. Sharing a roadmap for procurement of electric buses, he said the government will be buying 1,500 such buses in 2023 and by 2025, 6,380 electric buses will be procured.

"We have 300 electric buses now. Delhi has 7,379 buses plying on its roads currently which is the highest number of buses plying on the roads in the last 75 years. New buses were not purchased for many years and we were also questioned over it," he said at a ceremony at the Rajghat Depot to flag off 50 electric buses. Out of the 7,379 buses, more than 4,000 are being operated by the Delhi Transport Corporation and over 3,000 through the DIMTS, he said.

The Chief Minister also said the process installing charging points for e-buses at depots are going on and three already have the facility. "By June this year, the work of electrification of 17 bus depots will be completed and by December, 36 bus depots will be electrified," Kejriwal said. The electric buses are equipped with facilities like panic buttons, GPS, cameras. EF

Source: https://www.financialexpress.com/

IEX FORMS SUBSIDIARY TO EXPLORE BUSINESS OPPORTUNITIES IN CARBON MARKET

Indian Energy Exchange (IEX) announced setting up a wholly-owned subsidiary, International Carbon Exchange Pvt. Ltd (ICX), to explore business opportunity in the voluntary carbon market. The ICX will enable participants to buy and sell voluntary carbon credits at competitive prices through its transparent and reliable platform and facilitate reduction of global GHG (greenhouse gases) emission by 45% by 2030 to get on track to limit global warming to 1.5 degrees, an IEX statement said.

The new company will facilitate corporates to meet their climate commitments goals. The Exchange platform will provide a robust market signal for attracting further investments in the sustainable projects and help corporates to allocate capex towards energy transition in most optimum manner, it added.

As per industry estimates, the annual demand for voluntary carbon credit globally is expected to reach around 1.5 gigatonnes, with India contributing around 200 million tonnes by 2030, it noted. S N Goel, Chairman and Managing Director, IEX stated that the ICX will be India's first voluntary carbon Exchange platform. EF.

Source: https://www.business-standard.com/

J&K'S LOSSES ON POWER PURCHASES EXCEED MORE THAN INR 3,500 CRORE: CHIEF SECY

Jammu and Kashmir Chief Secretary Arun Kumar Mehta on Sunday said losses suffered by the Union Territory on power purchases exceed more than INR 3,500 crore annually, with liabilities piling up each passing year. He directed the officials that overall transmission and distribution losses should be brought down to less than 20%.

“These resources belong to our people and should optimally be utilized in creation of jobs for youth or other welfare measures for the people of J&K," Mehta said addressing a high-level meeting here. He also emphasized on having a proper mechanism to redress the grievances related to the billing of consumers. Mehta also stressed on making flat rates less attractive so that people prefer switching to metering of their power connections. The new mantra should be 100% payment and 100% electricity, he said. The Chief Secretary exhorted upon the officers that the smart metering of all urban areas should be completed by August this year.

He impressed upon the officers of the Power Development Department (PDD) to run a mass campaign to make people aware of the judicious use of electric appliances. Mehta said the gap in power purchase and revenue realization should be minimized for the general good of the masses. EF

Source: https://www.business-standard.com/

EUROPE SET THE BAR ON RUSSIAN GAS HIGH ENOUGH TO LEAVE INDIA UNAFFECTED

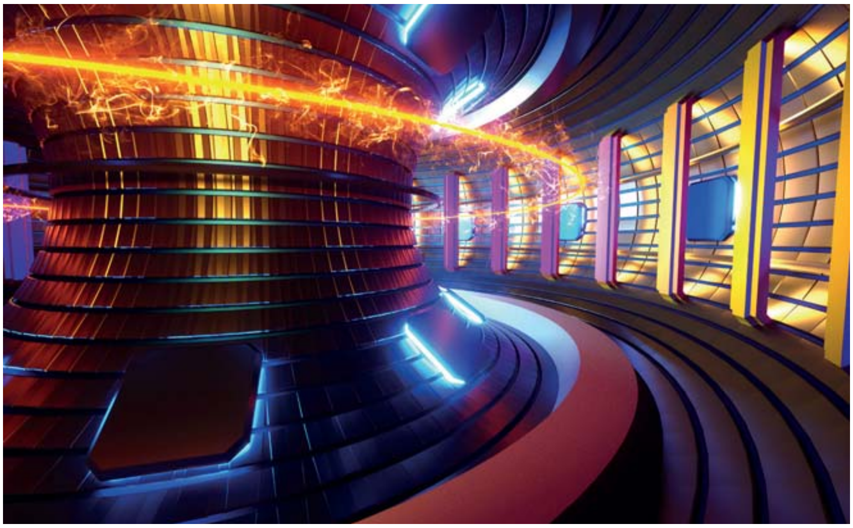
The movement of fuel prices in 2023 will dictate how much India will be affected by the combined impact of two petroleum price caps imposed by western nations.

On December 19, a fortnight after the US-led G7 group of nations had imposed a price cap on crude oil supplied by Russia, the energy ministers of the European Union (EU) agreed on a "market correction mechanism" to cap prices of natural gas in Europe. Both these measures taken together were designed to reduce Russia's earnings from exports of petroleum and stabilize prices of fuel, a key inflationary determinant, in the US and Europe.

However, the measures, which currently have little impact because of lower commodity prices amid a higher sanction bar, threaten to hurt energy import-dependent nations such as India, if prices of crude and gas surge. The impact of the gas price cap on India may, however, be muted as the EU, fearing disruptions to domestic gas supplies in winter, set the bar very high. EF

Source:https://www.business-standard.com/

HOW FUSION BREAKTHROUGH AT US LAB CAN CLEAN UP OUR AIR



Development of a nuclear fusion reactor is the Holy Grail of clean energy that scientists have been striving to find for decades. So, reports about scientists at California-based Lawrence Livermore National Laboratory (LLNL) achieving a "net energy gain" from an experimental fusion reactor signal a game changer. That is because, for the first time, a fusion reaction has produced more energy than it consumes.

Fission and fusion are two different types of nuclear reactions that produce energy. Fission-based power plants have been around since the 1950s, and India has several of its own. But scientists have been working for years to develop a reactor based on nuclear fusion, which is touted as a clean, abundant, and safe source of energy that could eventually allow humanity to break its dependence on fossil fuels that are driving a global climate crisis. EF

Source: http://timesofindia.indiatimes.com/

WORLD'S MOST-CRUCIAL FUEL HEADS FOR SHORTAGE TOUCHING EVERYTHING

Within the next few months, almost every region on the planet will face the danger of a diesel shortage at a time when supply crunches in nearly all the world's energy markets have worsened inflation and stifled growth.

The toll could be enormous, feeding through into everything from the price of a Thanksgiving turkey to consumer bills for heating homes this winter. In the US alone, the surging diesel cost will mean a USD 100 billion hit to the economy, according to Mark Finley, an energy fellow at Rice University's Baker Institute of Public Policy.

There are major constraints globally on refining capacity. Supplies of crude oil are already fairly tight. But the bottleneck is much more acute when it comes to turning that raw commodity into fuels like diesel and gasoline. That is partly a function of the pandemic, after lockdowns destroyed demand and forced refiners to close some of their least profitable plants. But the looming transition away from fossil fuels has also dented investments in the sector. Since 2020, US refining capacity has shrunk by more than 1 million barrels per day. Meanwhile in Europe, shipping disruptions and worker strikes have also eaten into refinery production. EF

Source: https://www.livemint.com/

ENERGY, CHIPS, TAIWAN: FLASHPOINTS FOR 2023 IN A FRACTURED WORLD

With a hot war raging in Europe and a cold one escalating between the US and China, the rest of the world is under pressure to pick sides. Political leaders are imposing new economic priorities, as they battle to avert shortfalls of vital commodities—from natural gas to semiconductors—and use the ones they control as leverage. The risk is a global subsidies race where the winners are the countries with the deepest pockets, and the losers are economies in the developing world already suffering from growing debt burdens.

Debate at the World Economic Forum will revolve around these emerging geo-economic risks. Some centre on key goods or markets, like the worldwide focus on energy security since Russia's invasion of Ukraine, or the US campaign to deprive China of cutting-edge technology. Others are geographic, above all the threat of conflict in Taiwan.

"We're living in a more fragmented world that includes financial fragility, so one thing that is clearly on everyone's mind is: Where to invest, and how to invest, in a more multi-polar world," said Karen Harris, New York-based managing director of the Macro Trends Group at consulting firm Bain and Co, before flying out to Davos. EF

Source: https://economictimes.indiatimes.com/

RENEGOTIATE INDUS TREATY TO OPTIMIZE WATER USE

SA long-awaited yet unprecedented development finally took shape with India sending a notice to Pakistan for modification of the 1960 Indus Waters Treaty (IWT). This treaty has weathered various twists and turns in bilateral relations, three wars and multiple terror attacks from launch pads in Pakistan, including the attack on Parliament (2001) and the incidents in Uri (2016) and Pulwama (2019). Article XII (3) of the IWT provides that this "treaty may from time to time be modified by a duly ratified treaty concluded between the two governments."

In order to harness the hydropower potential of the shared water courses in the Indus basin, both countries need to consider a joint design and implementation of hydroelectric power projects. The current chill in bilateral ties makes the treaty's immediate modification a difficult task.

There have been calls for renegotiation of the IWT on the ground that the treaty "does not reflect all of the main and future challenges" such as climate change, population growth, environmental flow needs, transboundary aquifer management, and the growing water needs in the Indus basin. This would necessitate the adoption of a benefit-sharing approach instead of an engineering river-dividing approach so that water management can deliver mutual benefits.

Source: https://www.tribuneindia.com/

HOW WILL INDIA AS G20 PRESIDENT STEER ENERGY TRANSITION?

The growing climate change crisis requires that major economies of the world intensify their shift to cleaner and renewable energy. It is moot how India shapes G20 response in this matter while protecting the needs of energy security and energy access.

With India having assumed Presidency of G20 this month, there is intense speculation on the priorities and thrust areas that G20 may pursue under India's captaincy. The most recent statement of G20 Leaders issued in Bali in November 2022 highlights a few key issues that the G20 is expected to focus on. The Declaration talks, amongst others, about the challenges of food security, stability of global supply chains, climate change and just transition, trade and investment cooperation, digital transformation, fiscal sustainability, and stability of international financial system.

For the first time, the importance of oceans as an important instrument of climate stabilization was highlighted at Sharm El Sheikh. Cooperation in this area can have huge economic benefits for economies of several countries having large coast lines. Nature based solutions are being projected as promising area for carbon market finance. India should welcome it if it promotes agroforestry, expansion of tree cover outside forests, and carbon-plus benefits in term of protection of biodiversity and ecosystem. These benefits can be quantified and rewarded through a global fund under G20 leadership.

Source: https://economictimes.indiatimes.com/

SUN, WIND APLENTY, SPAIN VIES TO LEAD EU IN GREEN HYDROGEN

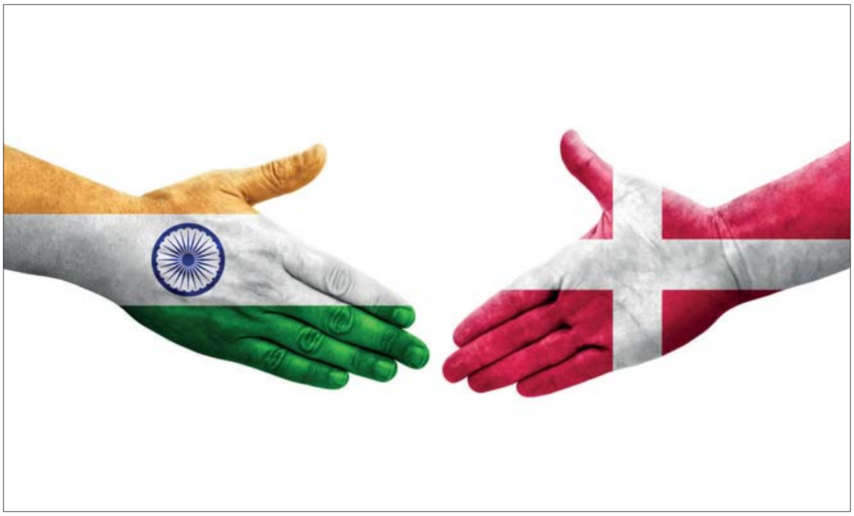
With an abundance of sun and wind, Spain is positioning itself as Europe's future leader in green hydrogen production to clean up heavy industries. But some energy sector experts express caution over ramping up an industry that would be wholly reliant on massive increases in the availability of zero-carbon electricity.

Ecological transition minister Teresa Ribera hosted a major conference earlier this month for global renewable energy players. It focused on measures "to guarantee our energy security" as the European Union refocuses on intra-bloc supply chains for its energy needs.

The Spanish government announced a Hydrogen Roadmap in 2020, but the sector has taken on greater importance in Europe since Russia's invasion of Ukraine. Russia is the world's second-largest producer of natural gas, which powers most global hydrogen production. The International Energy Agency said in December that Spain would account for half of Europe's growth in dedicated renewable capacity for hydrogen production. EF

Source: https://economictimes.indiatimes.com/

INDIA SET TARGET FOR GREEN ENERGY IN PARTNERSHIP WITH DENMARK



Union Climate Change and Environment Minister Bhupendra Yadav said that India and Denmark have set ambitious targets for green energy in partnership. They will prove a milestone in environmental protection for the entire world and will contribute to the implementation of the Paris Agreement.

The Minister was speaking at a function of the Indo-Danish Green Strategic Partnership in Delhi. He said the friendship can promote a sustainable lifestyle including life not only between the two countries but also for Europe and the whole world. It can also provide a meaningful platform for the exchange of ideas, best practices, knowledge, technology, and capacity building for its dissemination.

Yadav said together both countries will achieve the ambitious climate and sustainable energy goals before the world and in this endeavour, they will also commit themselves to the founding principles of the Rio Convention which is of utmost importance. If we have to meet the challenges related to the global environment and climate change in the present scenario, there is an urgent need to address unsustainable production and consumption. EF

Source: https://www.thestatesman.com/

THE RACE TO REDUCE CARBON EMISSIONS

Is CCUS a promising solution?

Tackling carbon emissions takes centre stage in most climate debates. However, carbon capture, utilization, and storage (a plausible solution) remains a controversial topic due to the debate on it's feasibility. In this article, **Anshuman Gupta** and **Urja Zaveri** discuss the various possibilities presented by CCUS in combating the climate crisis.

We all know the saying 'Reduce, Reuse, Recycle' but what about 'Capture, Utilize, Store'?

Carbon capture, utilization, and storage (CCUS) are seen as a key solution for reducing greenhouse gas emissions. The deployment of carbon capture and storage (CCS) technologies have experienced a surge in recent years, fuelled by the global recognition of their importance in addressing climate change. The Paris Agreement of 2015 brought CCUS into the limelight as a key tool in the fight against rising carbon emissions. And while CCUS is ready to swoop in and save the day, is it prepared for the task at hand? As the world becomes increasingly aware of the need for immediate action, we present to you an overview of the deployment of CCUS technologies, and with it, its limitations.

However, before going into the nitty gritty, let's take a moment to refresh our understanding of how carbon capture and storage (CCS) works. The initial stage in a carbon capture, utilization, and storage (CCUS) project involves the capture of carbon dioxide (CO_2) emissions from industrial processes and power generation facilities. CO_2 can be captured through various techniques, including post-combustion, pre-combustion, oxyfuel combustion, and more recently, direct air capture methods.

The next stage involves the more defining aspect: getting rid of the CO_2. One way this can be done is by the utilization of CO_2 for producing new raw materials such as chemicals, materials, and transportation fuels. Another way—with a greater potential in terms of capacity—is transporting the carbon dioxide to geological storage sites such as depleted oil and gas reservoirs, or saline aquifers and pumping them in the subsurface for a long time (at least 10,000 years). An overview of this can be seen in Figure 1.

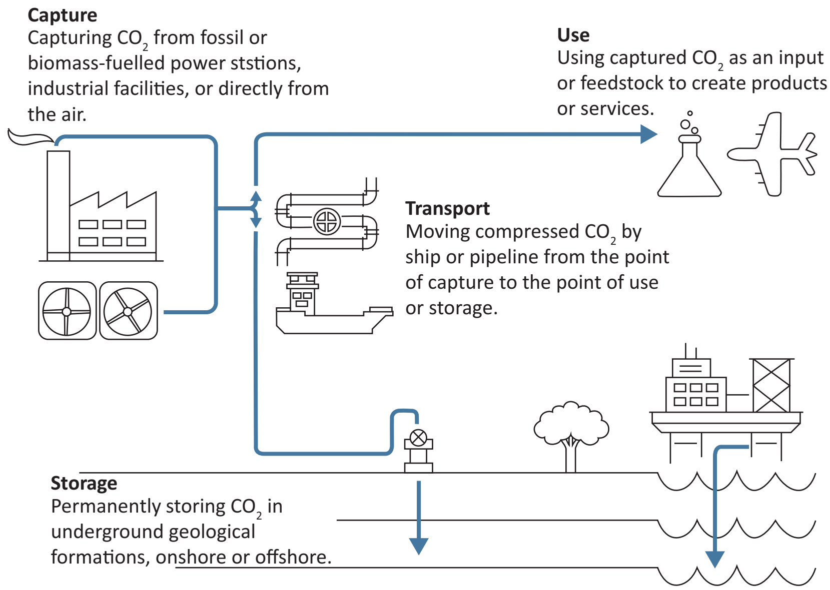


Figure 1: Overview of CCUS system

Source: IEA.org

Setting the wheels in motion

The concept of CO_2 capture, transport, and storage for reducing anthropogenic CO_2 emissions was first proposed by Cesare Marchetti in 1977.[1] However, CO_2 capture has been used since the early 1920s in natural gas reservoirs from salable methane gas. Moreover, CO_2-enhanced oil recovery (EOR) has been carried out in the US and Canada since the early 1960s. The EOR technique removes the otherwise unextractable oil, while increasing the overall pressure of an oil reservoir by injecting a fluid.[2] The Sleipner CCS project and Weyburn Project, launched in 1996 and 2000 respectively, were pioneers in the game of demonstrating the strength of CCUS.

The Weyburn project was a ground breaking initiative that proved to be a technological marvel. This project has been able to safely store over 35 million tonnes of CO_2 in the largest geoscience test site in the world, located at the Weyburn field in Canada. It brings together some of the most influential players in the industry; such as the US Department of Energy, the Saskatchewan government, and Natural Resources Canada.

Initially launched as a scientific research project, the Weyburn Project has successfully transitioned into a commercial venture over the years. It's also the first-ever project to conduct large-scale carbon capture and long-distance transportation of both low and high-concentration CO_2, for both EOR and storage. It is also important to note that they executed this in an age where no government subsidies existed

Figure 2: Weyburn Project Field Site

Source: hatch.com

1 On geoengineering and the CO_2 problem | SpringerLink
2 Information_Sheets_for_CCS_2.pdf (ieaghg.org)

for CO_2 removal, simply by creating a unique business model. In our opinion, the Weyburn Project's success served as a testament to the power of technology and the human spirit to make a positive impact on the planet.

Since the Weyburn Project, several other CCS projects (Figure 3) across the world have been implemented for research and commercial purposes. As of April 2022, majority of the CCS facilities have been concentrated in the US and Europe, with 16 and 4 projects currently in operation. The number of CCS projects under development in the US and Europe are about 80 and 46, respectively. Apart from these two regions, there are 9 CCS facilities currently operational and 5 under development across the rest of the world.[4]

The potential of CCUS

The UN's International Panel on Climate Change (IPCC) recently published its Assessment Report. This report, or AR5, which summarizes all the scientific, technical, and socio-economic knowledge available about climate change and its potential impact on our future.[5] It is evident that human activity has already caused the planet to warm by around 1°C above pre-industrial levels. We are already seeing the impact of this increase through extreme weather events, rising sea levels, and increased disease prevalence.

To combat such catastrophes, the IPCC AR5 focused on adapting the Representative Concentration Pathways (RCP) trajectory (Figure 4). Instead of predicting what we will emit by 2100 due to socioeconomic factors, these models focused on what the trajectory will be in four different scenarios, and the resultant adaptions we would have to make to stay on those trajectories.[6] The RCP1.9 trajectory was also the inspiration for the 1.5°C limit popularized during the Paris Agreement.

According to the IPCC's Special Report on 1.5°C, some level of net-negative emissions are required to meet the target under 88 out of the 90 scenarios it has considered. Three of the four pathways under the 1.5°C placed an important emphasis on CCUS for carbon removal. Net-negative emissions can be achieved through CCUS in areas where direct mitigation is currently not possible, such as thermal power plants in regions with energy poverty. These reports highlight the deployment of CCS as a hedge and not a substitute for other climate mitigation efforts.[7]

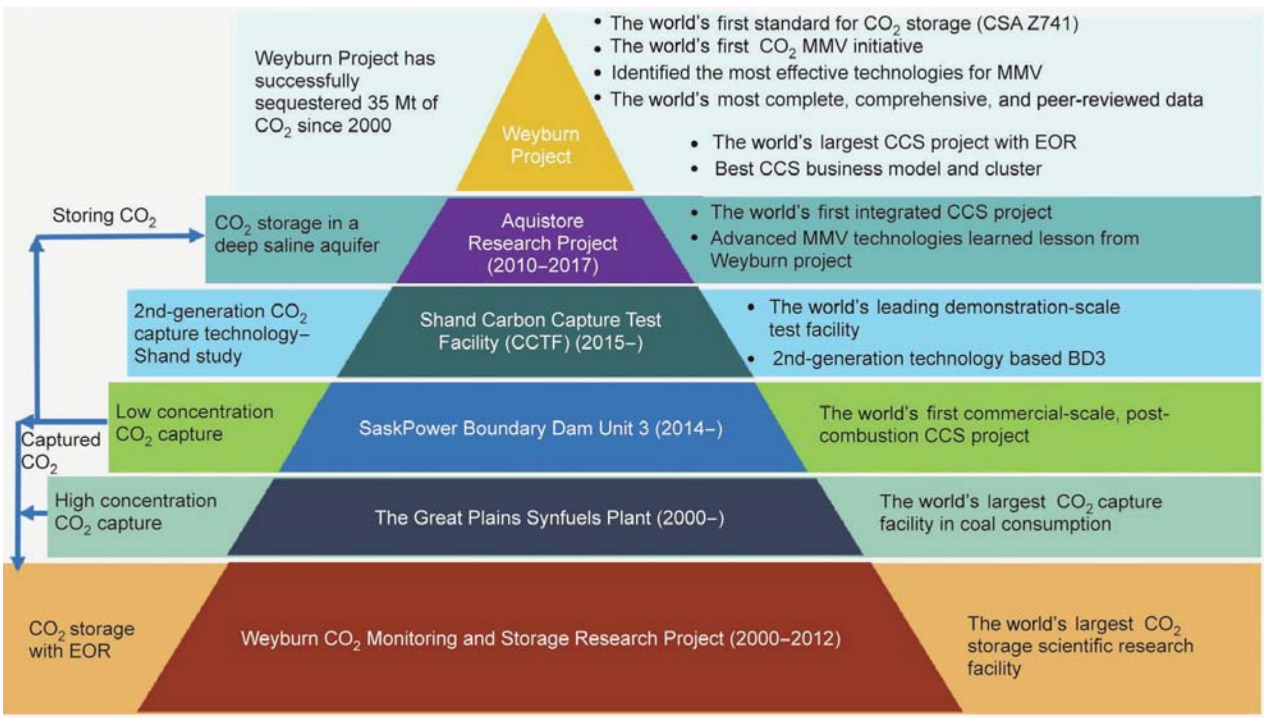


Figure 3: Progress of CCUS projects over the years

Source: Ma et al. 2022[3]

3 Carbon Capture and Storage: History and the Road Ahead - ScienceDirect

4 Global CCS facilities 2022 by region | Statista

5 The Latest IPCC Report: What is it and why does it matter? (nature.org)

6 1.5°C vs 2.0°C: What's in half a degree for climate change? | Spectra (mhi.com)

7 Global Warming of 1.5 ºC — (ipcc.ch)

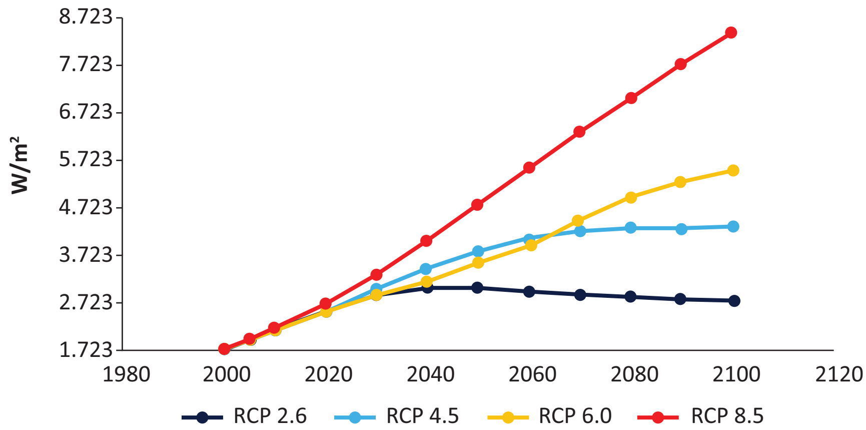


Figure 4: Progress of CCUS projects over the years

Source: RCP Database

Technical bottlenecks

Unfortunately, captured CO_2 emissions currently account for 0.12% of energy-related emissions only, despite CCUS being around since the 1970s.[8] The IEA estimates that the CCUS capacity needs to grow 50% YoY, or 40-fold from the current levels by 2030 for the world to limit global temperature rise below 1.5°C. The reasons for this are multi-fold: ranging from economic turndown, to public acceptance, to uncertainty about the liability of already stored carbon. Let us look at some of the key problems.

The investment dilemma

In the recent past, high capital requirements have been the biggest hurdle in scaling up Carbon capture and storage as a viable solution. With high upfront costs and almost no promise of returns, banks and private investors cannot be blamed for not jumping at an opportunity to invest in CCUS projects. While tax credits like the 45Q in the US may help reduce investor risk, their value may not be enough to overcome the risks in the power sector. To succeed, CCUS projects need strong market drivers and diverse financing methods, similar to other successful low-carbon technology projects.[9]

Safety comes first

Let us look purely at CCUS in geological storage and consider its safety aspects; including subsequent monitoring, reporting, and verification of CO_2 emission reduction. These are certain basis upon which companies are allowed to enter the carbon trading market and unlock government incentives in countries that have established the same in the form of tax breaks.

Measurement, monitoring, and verification (MMV) of CO_2 reduction, along with assessment to ensure the underground storage risk and capacity have been a pressing challenge. MMV of geological CO_2 storage requires assessment from various aspects such as geology, geochemistry, geophysics, and engineering, among others, for long-term geological CO_2 storage without leakages.[10] Governments across the world, particularly fossil fuel exporting countries have been heavily investing in research to solve these challenges.

As for the safety of geological storage, one of the biggest concerns is leakages during injection or production wells connecting the geological storage bodies, underground layers, and the atmosphere. Injected CO_2 in these geological storages can induce earthquakes, open faults, or break-through caprocks, causing leakages. Induced seismicity can also damage the geological storage leading to leakages and CO_2 being released back into the atmosphere.

To address issues of geological nature, the only solution is active and interdisciplinary research of geological storage potential and safety.

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8 CCUS: Where is carbon capture working? – Energy Monitor

9 A critical review on deployment planning and risk analysis of carbon capture, utilization, and storage (CCUS) toward carbon neutrality - ScienceDirect

10 Carbon Capture and Storage: History and the Road Ahead - ScienceDirect

1. Setting up a legal framework

Establishing a regulatory and legal framework for CCUS is crucial to manage risks and support technology investment. However, the current legal framework for CCUS varies in different countries and regulatory barriers exist due to economic, political, and cultural differences. The lack of an internationally standardized regulation framework on application and permission, technical and environmental management standards, and liability allocation regime is a significant issue.[11]

The goals of CCUS deployment in regulations are unclear and the role of CCUS in specific emission reduction targets has not been validated. There is no clear provision on liability allocation and transfer over each party of the CCUS supply chain, as well as project insurance and compensation.[12]

[11] A critical review on deployment planning and risk analysis of carbon capture, utilization, and storage (CCUS) toward carbon neutrality - ScienceDirect

[12] Regulations for carbon capture, utilization and storage: Comparative analysis of development in Europe, China and the Middle East - ScienceDirect

2. Convincing the public

Carbon capture, utilization, and storage (CCUS) has been facing public perception issues due to the perceived risks associated with carbon storage locations. Despite low public awareness of CCS, those who are familiar with the technology tend to have a positive or neutral perception of it. However, the NIMBY (Not-In-My-Back-Yard) effect, where people reject large projects being built near their homes, is a major concern for CCS implementation.[13] Public resistance is often due to concerns about health risks and impacts on their lifestyle, as well as a perception of unfairness that the project is being built near them instead of elsewhere. A study by scientists at the St. Petersburg Mining University in Russia confirms that public awareness of CCS is low worldwide, highlighting the need for more education and communication about the technology to increase public acceptance.[14]

[13] Carbon Capture and Storage (CCS) Pros and Cons - TreeHugger

[14] Public perception of carbon capture and storage: A state-of-the-art overview - Heliyon

The age-old problem of greenwashing the blackgold

Several oil and natural companies like Shell and ExxonMobil have been accused of knowingly pushing for increased production and consumption of fossil fuel; despite knowing the impact CO_2 emissions have had on the environment all the way since the 1970s. This begs the question as to why would the world's largest polluters continue to pour in millions of dollars over the years into technologies that would cut into their record annual profits in the near future.

At both COP26 and COP27, several countries, particularly the oil-producing countries had their pavilions advocating strongly for CCUS. At major multilateral events and conferences, a consortium of major oil producers such as BP, Chevron, and Southern Company, along with pro-CCUS NGOs also centred their pavilions and engagement around CCUS and hydrogen fuel to be seen as climate-friendly. In essence, their pitch can be understood as such that digging for more oil and gas could help mitigate

climate change by creating more room for CCUS plants to be implemented.[15] Another argument can be made on the amount these big oil and gas companies spend on advertising about their green initiatives, versus how much they truly spend that is hidden between the lines.[16] Database and assessment from InfluenceMap show that oil companies spend around 750 billion dollars each year on climate-related communications based on the number of communications staff the company employs. The figure does not account for external advertising or PR, making the final amount even more gargantuan.

Furthermore, whether EOR is as climate-friendly as it shown to be continues to be hotly debated—with environmental groups opposing it because of the potential impact it has on groundwater. A strong argument against CCUS, particularly EOR, questions the oil groups' solution to exploit more natural gas for making space to store captured CO_2. The solution will escalate the use of natural gas and other polluting fuels that will continue to emit more CO_2 in the atmosphere. In essence, it will ensure that oil groups continue to prosper even though their products are the ones that are responsible for the highest share of emissions. A good case can be made if one looks at their latest profit statements (Figure 5).

Shell reported a profit of around USD 40 billion, the highest since inception. However, they left their capital spending unchanged, thus focusing more on new oil and gas exploration and dedicating a mere 14% of all of their capital spending towards renewables and energy solutions in 2022.[17] Chevron posted a record profit of USD 35.5 billion in 2022 and what did they do? They announced their plans to return USD 75 billion to their investors through share buybacks, with only USD 2 billion to be invested on low-carbon technologies, with a capital expenditure of USD 14 and USD 10 billion between 2023–2028. In 2022, Exxon Mobil, BP and TotalEnergies earned a profit of a USD 56 billion, USD 27.2 billion, and USD 36.2 billion, respectively. Overall, the five big oil companies made a combined profit of a jaw-dropping USD 196.3 billion and rewarded their shareholders handsomely with top of the line dividends.

All these companies have two things in common: commitment of further investments in oil and gas exploration and very little boost to their transition initiatives.[18]

Oil companies are also accused of deceiving messaging when advertising their investments in climate-friendly

15 Climate change: Is enhanced oil recovery a friend or foe? - Vox

16 Big oil companies are spending millions to appear 'green.' Their investments tell a different story, report shows | CNN Business

17 What Big Oil's bumper profits mean for the energy transition | Financial Times (ft.com)

18 Big Oil rakes in record annual profit, fueling calls for higher taxes (cnbc.com)

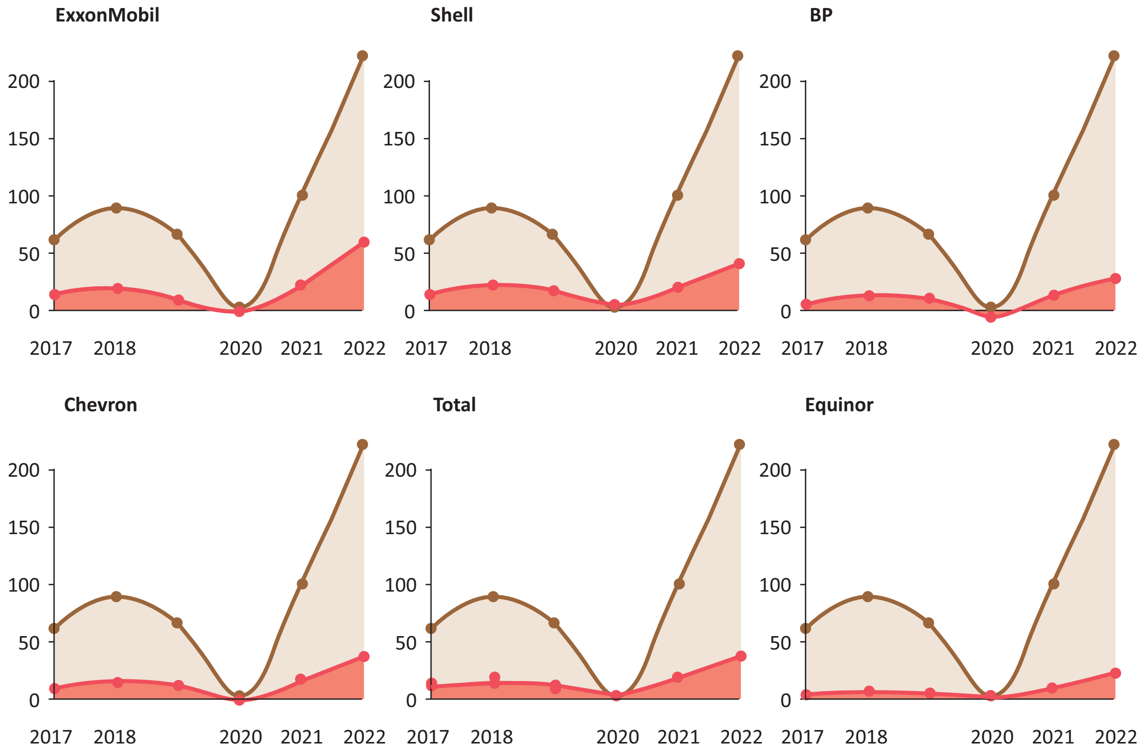

Figure 5: Chart explaining profitability of major oil and gas producers

Source: Financial Times[21]

technology and transitioning away from fossil fuels. They have been known to lobby political spaces to get policies in favour of expanding oil and gas production. The industry's history in discrediting climate science over decades has led big oil executives to be summoned to the US congress. Despite being warned about the impact of burning fossil fuels on the climate as early as 1959, big oil has spent billions on disinformation campaigns emphasizing the uncertainty related to available climate information and trying to reposition global warming as a theory.[19] They have also pushed the perception that a clampdown on oil and gas production would lead to severe economic downturn and loss of employment. Furthermore, they have peddled various technological solutions for climate change that are not economically feasible or scalable and have shown mixed results.[20] Ironically, despite all of this, they project themselves as leaders of green transition while being the key cause of the climate crisis.

Regardless, the public perception has turned against big oil and natural gas in light of the evidence of their misdeeds related to climate disinformation and contributing the most emissions to the atmosphere. Due to their role in perpetrating the climate crisis almost entirely, oil and gas companies have been under fire since the past couple of years by concerted efforts of activists, environmental groups, and the general public (Figure 6).

Figure 6: Public protest on the streets of Glasgow during the 2nd day of COP26, Glasgow

19 The forgotten oil ads that told us climate change was nothing | Environment | The Guardian

20 The forgotten oil ads that told us climate change was nothing | Environment | The Guardian

21 What Big Oil's bumper profits mean for the energy transition | Financial Times (ft.com)

What's the fix?

The fight against climate change and the pursuit of carbon-neutrality have become top priorities for governments and academics worldwide. As a result, there has been a surge of interest in CCUS, which has spurred the rapid development and deployment of related technologies and infrastructure. It's clear that the push towards a cleaner, more sustainable future is in full swing.

In our opinion, a few possible solutions for different problems discussed above include:

» Governments and international organizations should collaborate to establish a legal and regulatory framework for CCUS that covers all aspects of the technology: including the storage of carbon, liability and responsibility, and safety standards.

» Similarly, an international regulatory body must have the responsibility of holding serious emitting sectors (such as oil companies) accountable. The regulatory body should enforce strict penalties for non-compliance, and companies should be required to disclose their emissions data to the public.

» The issue with people's perception can be addressed through education and outreach. Responsible parties—ranging from climate activists, to science communicators, to scientists from the field—must be encouraged to inform public about the safety of CCUS technology, its need and benefits.

» To bolster the financial viability of the projects, policies can be implemented to reduce capital costs for CCUS financing and provide opportunities for CCUS projects to generate revenue by offsetting carbon emission quotas.

While the intricacies of implementing of such suggestions would require another article of its own, we hope to have informed you sufficiently about the various possibilities that exist. CCUS is not a silver bullet, but rather a crucial puzzle piece in the broader picture of achieving a sustainable future. To that end, we believe it is important to continue the conversation on how to best explore leveraging CCUS in mitigating climate disasters of the future. EF

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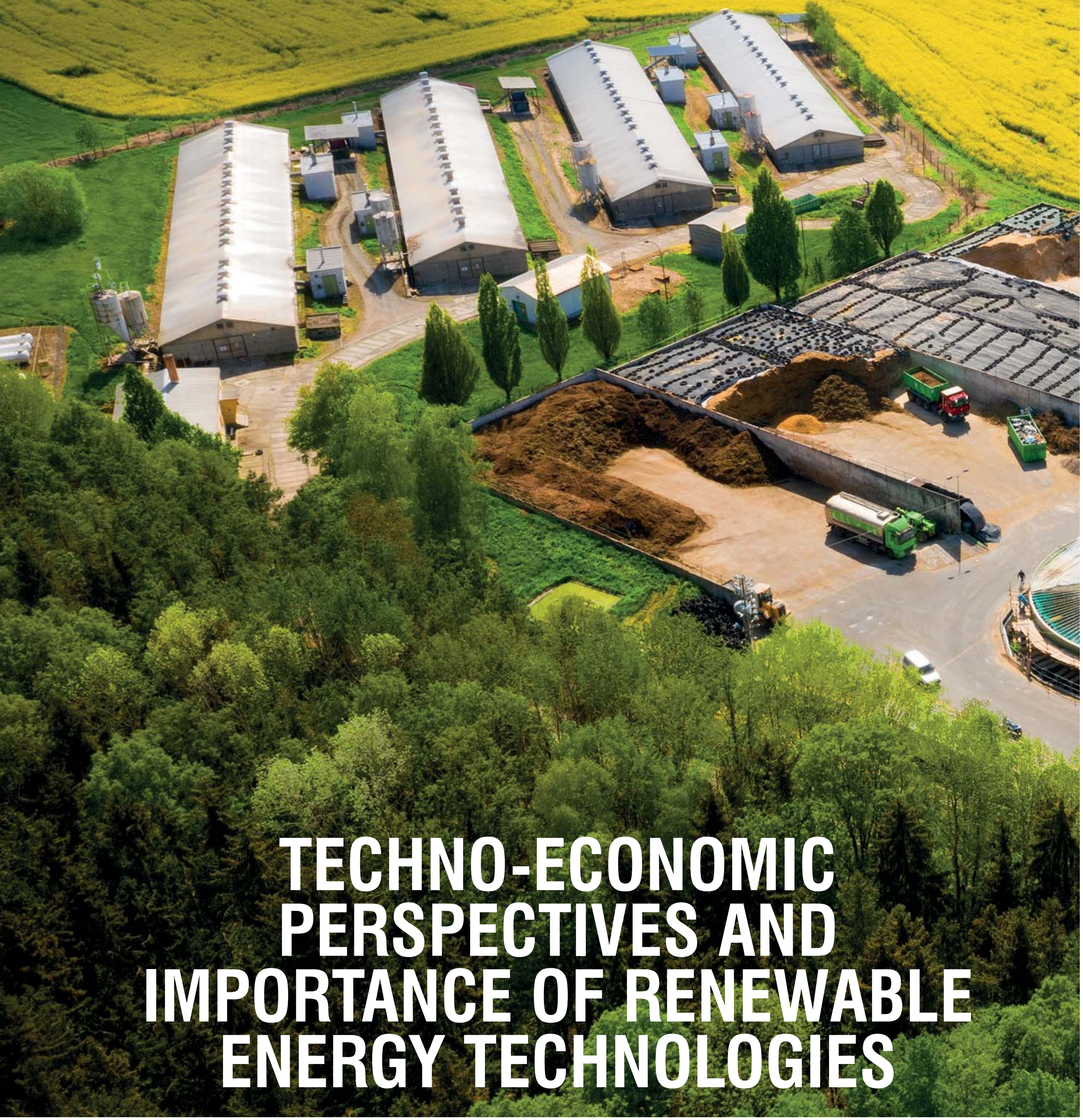

TECHNO-ECONOMIC PERSPECTIVES AND IMPORTANCE OF RENEWABLE ENERGY TECHNOLOGIES

Relying on the renewable sources of energy can obviously help India achieve the twin goal of achieving net-zero and addressing issues of energy security. In this article, **Dr V N Lad** espouses the importance of renewable energy technologies in ensuring sustainable growth of the country.

Renewable energy technology is the most propitious energy option particularly for long term implementation. Even though the capital cost incurred while installing renewable energy systems, such as wind mills, solar photovoltaic cells, biogas plants, etc., is considerable, but life cycle analysis demonstrates them as a highly competitive option considering the environmental implications. Awareness about such renewable energy alternatives can definitely provide a contrivance to brawl against conventional options of fuel and power, ensuring sustainable growth of the society.

Introduction

Energy integration is one of the emerging techniques used by the design engineers while designing any commercial plants intended to produce petrochemicals or other chemicals used in pharmaceuticals, food products, paint and pigments, fertilizers, etc. Even though most of the large-scale plants in India use state-of-the-art facilities for energy production through their captive power plants and its utilization, it is very difficult to feasibly fulfill total industrial power requirement by such captive power plants. Growth of the transportation and infrastructure sectors also predominantly demands more energy which includes fuel, electrical power, etc. Indigenous sources of crude oil and coal are not sufficient for meeting even the existing demand of energy. As a result, a large portion of the total crude oil used in India is imported, which also directly affects the economy. On the other hand, a wide variety of geographical benefits are available in India; in addition to the *super power* resources having the ability to transform and utilize the renewable energy more effectively and efficiently. Renewable energy such as solar energy, wind energy, hydropower and biofuel is derived from the natural resources and replenished continuously.

Thanks to the technological revolution

Technological advancement has really improved the effectiveness and adoptability of renewable energy concept in many areas of interest for mankind. Interesting work is being done by various research groups to design increasingly efficient wind mills.

Being the largest source of energy, the sun continuously radiates thermal energy which is being converted to electrical energy in solar cells. Researches in the field of materials technology and energy engineering have offered novel materials for solar panels. Thin film solar cells are more effective than the conventional techniques and very popular nowadays. Thin film technology offers benefits of higher conversion efficiency, durability, etc., for solar energy applications (Lad 2008). It is very necessary to bring the awareness in general public and also to the persons engaged in engineering activities. As pointed out by Kandpal and Garg (1998), education of renewable energy is indeed very important to the students, technicians or technocrats to make them aware about natural energy replenishment, to have alternatives of the fossil fuels, to understand energy related policy measures and to adopt suitable strategy to implement the renewable energy technology in their own domain.

Techno-economic feasibility of renewable energy technologies

Even though many professionals argue about the economical viability of solar energy, wind energy, and

small-scale hydropower, the most important significance of such renewable technologies is still their cost competitive nature with many applications related to conventional techniques; for instance, off-grid electrification, power generation through bio mass, electrification by the power generated using bio mass (particularly for rural area), and solar heaters. As per the estimation of the World Bank, the developing countries will require five million mega watts of power in coming couple of decades (Painuly 2001). While making feasibility study the choice of the most appropriate alternative among the available renewable energy sources is the striking factor in ultimate economic evaluation of the entire project. Besides, socio-economic influences, commercial viability and pay-back period (or break-even-point) are major factors in implementing the new facility, or in changing existing facilities.

Life cycle assessment approach for renewable energy systems

Life cycle analysis of any system deals with impacts on overall performance of the system incorporating all the implications during the usage of the technology or product. Much attention is currently being paid to the implementation of negative emissions technologies to remove carbon dioxide from the atmosphere which can be addressed through the life cycle assessment (Briones-Hidrovo *et al*. 2022). A comparative life cycle assessment has been studied (Gandiglio *et al*. 2022) to evaluate the potential of the renewable energy sources-based systems which may be able to address the problems, including climate change, ozone depletion, marine and terrestrial eutrophication, etc. Life cycle assessment of a biogas system has been studied by Lin *et al*. (2021). Life cycle assessment of lithium-ion batteries and vanadium redox flow battery-based renewable energy storage systems is reported by Lima *et al*. (2021). Gouveia *et al*. (2020) have also reported the life cycle assessment of a renewable energy generation system with a vanadium redox flow battery. The life cycle assessment study of energy systems for residential applications has been also reported (Bahlawan *et al*. 2020). Multi-dimensional life cycle assessment of decentralized energy storage systems was proposed by Stougie *et al*. (2019). Life cycle assessment approach also considers all the environmental consequences occur due to utilization of the renewable energy technologies throughout its entire course of life cycle from exploration of the suitable raw materials, accessories, fuels and their supply to the processing of the material and ultimately disposal of the waste generated or managing the material or entity accumulated including recycling. The dynamic approach of life cycle analysis is more beneficial in identification of inherent environmental bottlenecks in comparison with that of the static approach of analysis (Pehnt 2006). Further, most of the renewable energy alternatives including bioenergy products can be evaluated by energy analysis incorporating pertinent direct and indirect energy inputs, the former being a large portion of the total energy and the later includes smaller fraction often energy used for maintenance and repairs.

Conclusion

Ample opportunities in the sector of renewable energy are existing for large- scale industries as well as small-scale industries. Relying on the renewable sources of energy can obviously help the power crisis of the country and prove more economical and environmentally benign in long term. In addition to the option to decrease the intensified discourse on the climate change and its consequences, from social perspective as well, the renewable sources of energy can provide environmental friendly techniques for generation of electrical power, use of bio fuel for transportation, utilization of biogas with exaggerated effectiveness.

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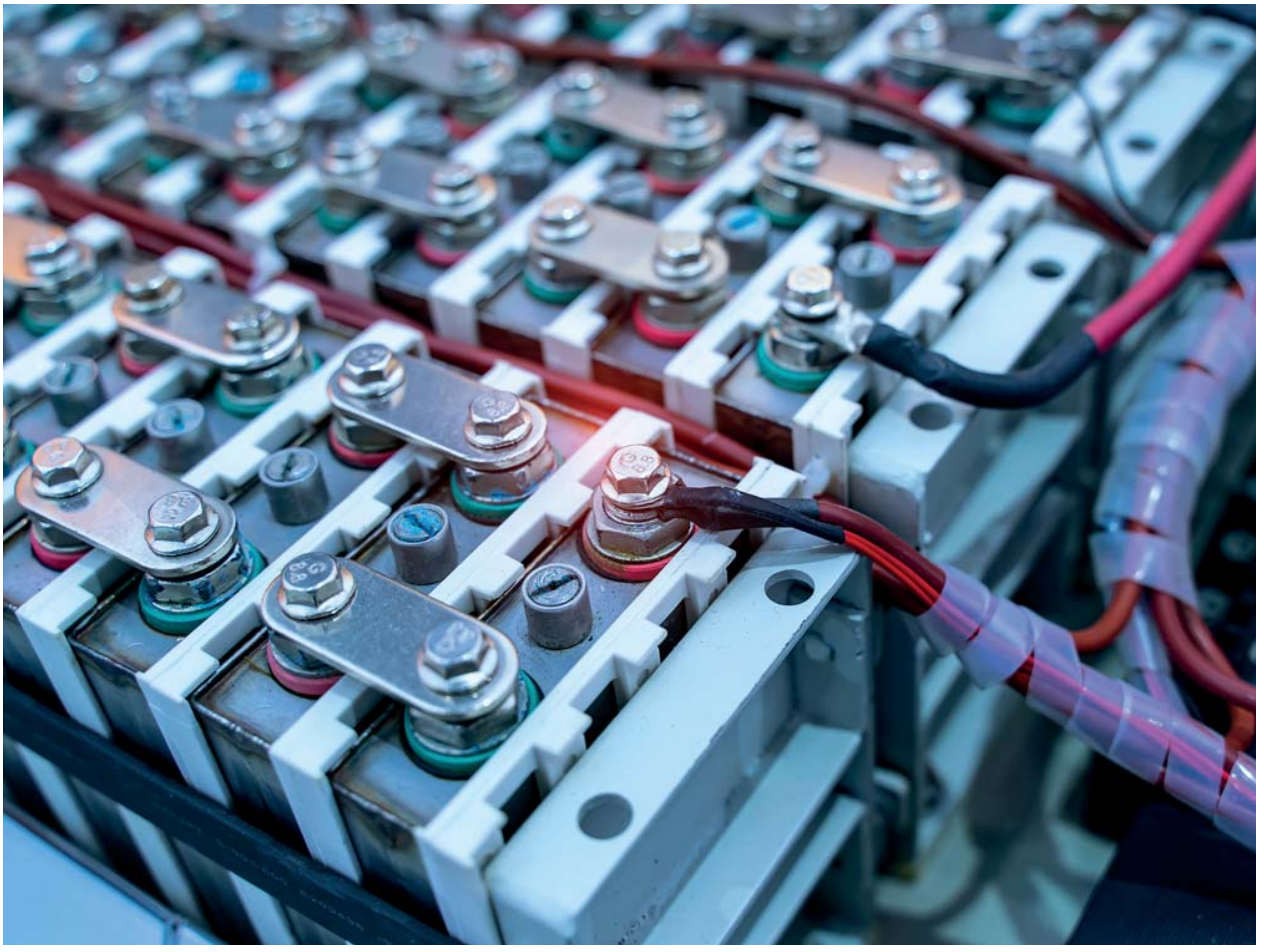

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SUPERCHARGING THE EV HOME CHARGING LANDSCAPE

Potential policy interventions

EV markets across the globe have been gaining traction over the last few years. The EV home charging landscape, however, does not reflect a similar increase. This is owing to the several problems that need to be addressed for successful adoption of EVs in the near future. In this article **Rohit Pathania** and **Pradeep Karuturi** talk about the various challenges in the Indian EV home charging landscape.

India has set an ambitious target of achieving 30% EV penetration by 2030. As electric mobility gains traction in India, the policy environment will play a major role in boosting EV adoption in the country. Range and time anxiety are cited as major impediments to faster EV adoption, and this challenge is aggravated when combined with limited charging availability. While range anxiety is being addressed through technological advancements, the need to act on charging infrastructure is acutely felt. Locating charging infrastructure at strategic locations is needed to address concerns around ease of charging and ensure healthy utilization rate.

One particular challenge deserving more attention is home charging. Currently, 94% of passenger vehicles are charged at home in India.[1] It is not in sharp variance to global norms which shows that nearly 90% of the chargers worldwide are placed in homes, apartment buildings, and workplaces.[2] For that matter, the usage patterns of personal electric vehicles around the world demonstrate the importance of home charging more than ever. This makes it necessary to create a suitable, facilitative policy framework for home charging. Another reason to focus on home charging is the fact that when battery swapping becomes more common, the need to charge EVs (particularly two- and three-wheelers) would be restricted to the home environments.

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Currently, two kinds of policy provisions exist in India on the subject of home charging. Some states mandate separate, new connections for setting up charging stations, segregating domestic connections from EV charging. For instance, Madhya Pradesh has mandated separate metered connections to charge electric vehicles with a special tariff being set for EVs.[3] States like Maharashtra,[4] Punjab,[5] and Odisha[6] have also made announcements around introducing amendments for building by-laws to provision for additional power demand needed for EV charging. The separate charging mandate is a sign that separate charging tariffs to create an alternative revenue stream for discoms is being foreseen, which in turn may end up reversing the gains by increasing lifetime cost of ownership of electric vehicles.

There is also the provision of charging via existing electricity connections, subject to an upper limit of the sanctioned load. The Government of India had, in 2022, revised the *Charging Infrastructure for Electric Vehicles – Guidelines*. With this revision, states can allow EVs to be charged at residences/offices using existing

electricity connections. However, only a few states, such as Uttar Pradesh,[7] Rajasthan,[8] Chandigarh,[9] and Delhi,[10] allow consumers to charge EVs from the existing sanctioned load and electrical connection.

Additionally, it has been noted that state-owned distribution utilities pose operational challenges. Discoms have been seen to delay clearances for setting up charging facilities wherever requested. This can lead to the potential escalation of costs for existing housing societies. Increased penetration of electric vehicles can create the situation where the demand for larger and more powerful charging stations can rise substantially. This can lead to a peculiar situation where the apparent, absolute cost of procurement may not decline, or could even increase, even as hardware is getting cheaper at a component level (Nelder and Rogers, 2019).[11] As a result, the prospective buyers could become wary of such purchases.

Another particular challenge from a discom perspective is the need to balance power demand for charging of vehicles. It has been pointed out that such demand can have an impact on the local distribution system operations, particularly led by the increase in the number of electric four wheelers in the near future. This is especially the case due to the concept of night charging, which creates a higher peak for mornings and evenings (Ghosh *et al*, 2022).[12] However, real-time purchase

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of electricity from the markets may become a challenge, given how sharply prices can rise in the market. Given the financial stress faced by several state-owned electricity distribution companies, the market price in real-time may create more problems of delayed payments, leading to adverse consequences. The latest example of this stress was witnessed in August last year, when the Power System Operation Corporation (POSOCO) instructed the three power exchanges in the country to restrict 27 discoms across 13 states from trading on their platforms, on account of non-payment of outstanding dues.[13]

At the consumer end too, home charging currently faces certain other challenges in India as well.[14] Easy installation, affordability of charging hardware, ease of billing/collection, ability to measure power consumption, and limited awareness continue to hobble efforts to expand the home charging network in India. Ease of installation remains an issue, more so from community-based challenges. An example of this is the fact that the Bombay High Court is hearing a public interest litigation (PIL) seeking direction to issue guidelines for installing EV charging stations on the premises of cooperative housing societies.[15]

This leads to other challenges seen presently in metro cities. Families living in societies or apartment complexes face a challenge of charging at their homes due to common meter connection of basements or ground floors with other neighbours. This gets more acute, since the lack of separate metering in community housing areas makes it difficult to separately measure and bill charging of vehicles. Potential socialization of charging costs may not be acceptable to people in the absence of separate accounting and payment. This is particularly the case with the cost of charging hardware. While price point of charging hardware has fallen below INR 10,000 (Bose, 2021), this is true only for small wall point chargers. Many states have policies that want common charging stations in societies, which implies larger equipment, ranging in the price of at least INR 1 lakh (Gautam, 2021). Additionally, the cost of separate connections and metres (though one time) is another factor of consideration.

Limited awareness and anxiety also prevent faster adoption of home charging. Home owners and Resident Welfare Associations have often raised concerns around setting up charging points citing incidents of fire.[16] While such incidents are indeed unfortunate, the government and industry have been working in a concerted fashion to adopt safer practices.

Addressing technical and financial challenges

It is necessary to address the identified challenges for realising the full potential of the electric vehicle market. From a discom perspective, there is a need to strengthen the distribution infrastructure and upgrade it to be able to deal with the increasing power demand for EV charging. The Revamped Distribution Sector (RDS) scheme run by Power Finance Corporation (PFC) and REC Limited (previously, Rural Electrification Corporation Limited) for upgradation of distribution infrastructure should also seek to financially support projects that account for improving distribution transformer level infrastructure to

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support vehicle charging at home (PIB, 2021).[17] A mandate on planning of provisions for electric vehicle charging should be placed on projects that are approved under this scheme. Single window clearances can also be set up by discoms to facilitate the installation of private chargers; where consumers can view the suitable EV chargers, place a request, and get the installation completed in a fixed period of time, as seen in Delhi. Such a window helps interested parties know about types and prices of approved charging equipment and apply easily with nodal agencies who are bound by service rules to deliver.

Implementation of certain policy guidelines is essential to facilitate the growth of home charging. Domestic charging should be treated the same as domestic consumption across all states. This is needed particularly for small form factors that have lower power demand and can suffice with home charging. This domestic charging can be subject to a maximum cap of connected load for safety reasons. Guidance from the Ministry of Power to the regulatory authorities in this regard can help clarify the position and enable them to take the necessary steps. Revision of, or building by-law amendments for accommodating charging stations in designated areas' residential societies and group housing societies also needs to be accelerated across the states.

Equipment cost and cost to get a new connection remain major challenges. To reduce these, special rebates can be provided for equipment being purchased for this specific purpose. These rebates can be sourced from a fund similar to the FAME Scheme fund. This fund should be entitled with a target of providing a certain number of charging points across the top 100 Indian cities (by population). The fund may be financed through the green cess on petrol and diesel. In particular, this fund should be made accessible to the developers of charging equipment in some ways, e.g., lower cost of capital as a first loss mechanism. Such an arrangement can help them bring down equipment costs faster so as to bring down the cost at source.

Innovative business models can also help to overcome the challenge of the high initial cost of equipment and installation. Similar challenges have been seen in other domains like energy efficiency promotion, where costs were an initial challenge. As in that domain, the government can promote specialized businesses that are modelled on the lines of the energy service company (ESCO) model, for charging business as well and allow housing societies/communities. Under this model, charging service providers can be asked to set up stations against a fixed monthly contractual payment related to the energy utilization by EVs. This model can particularly overcome the challenges for societies/private enclaves—for which mandates are now being introduced on the EV charging equipment.

Lastly, a comprehensive awareness campaign around good practices and safety measures is also needed to reduce the anxieties around electric mobility. It has repeatedly surfaced that the information and awareness on how electric vehicles and charging stations function continues to be limited. Safety and reliability are also questions that do not get adequately addressed. Even the process of obtaining charging stations for residential societies is not known to many people. Local discoms and charging equipment providers can come together to raise awareness and undertake the necessary outreach to allay concerns across the board and enable applications wherever needed.

Ease of access and time dictates that home charging be identified as a crucial enabler which has the potential to boost EV adoption. A healthy adoption of home charging can actually help to adequately address anxiety issues of the consumers related to delays in clearances and subsequent installation and encourage greater adoption of electric vehicles across different form factors. Thus, there is a clear need to address impediments that create hurdles to the adoption of EVs, which are seen as a crucial part to India's pursuit of a net-zero transport sector.

Electric vehicle adoption in India is at an inflection point, and the direction hereon will depend on a variety of factors; one of which in particular will be the charging ecosystem. In this, the role of home charging is critical, and steps are needed so that the rate of EV deployment can be maximised across varying form factors and among vehicle users. EF

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[17] PIB (2021, Jun 30). Cabinet approves Revamped Distribution Sector Scheme: A Reforms based and Results linked Scheme. Retrieved from Press Information Bureau: https://pib.gov.in/PressReleasePage.aspx?PRID=1731473

PROSPECTS OF ETHANOL FROM AGRO-RESIDUES

Being an agrarian economy, efficient management of agricultural residues is an issue faced by numerous states across India. This article, by **T V Ramachandra** and **Deepthi Hebbale**, presents the prospects of biofuel production from agricultural residues based on the distribution of major biomass (rice and wheat) residues across the country.

For a nation, the greatest challenge of the 21st century is to cater to the growing demand for energy for transportation, heating, lighting, and industrial processes. The increased demand for fossil oil and its impacts on the environment, with greenhouse gas (GHG) emissions, have necessitated finding sustainable energy alternatives. Biofuel is emerging as a viable alternative to fossil fuels, with the potential for renewability and optimal use of biological residues. Ethanol is the most common renewable fuel being produced from biomass such as bagasse or straws. Unlike fossil fuel deposits, biomass is considered a potentially sustainable renewable resource due to its shorter period of cycling time as well as availability at decentralized levels for biofuel production and energy generation to meet the local energy demand.

Ethanol is being manufactured conventionally from first-generation feedstocks, such as sugar cane and starch-containing food crops, which pose severe challenges due to the potential threat to food and water security. Subsequent research focused on lignocellulosic biomass (second generation) feedstocks, involving the conversion of lignocellulosic polymer to ethanol through hydrolysis—which involves breakdown of the lignin-cellulose matrix and producing simple sugars such as glucose. This is followed by fermentation, the process of metabolizing glucose towards ethanol.

Research involving bio-ethanol production from lignocellulosic waste materials has included agricultural residues, forest products, municipal solid waste, industrial wastes, municipal sludge, leaf and yard waste, and a few studies involving cattle and dairy manures. Large-scale burning of agricultural residues, the consequent environmental implications in developing countries, and the need for sustainable energy alternatives, have necessitated an assessment of the potential of agriculture residues and their conversion to technically feasible and economically viable fuel.

Bio-residues in India

Agriculture is practised predominantly in India with a generation of large quantum of residues, which are partially being used as fodder, while the major fraction is being burnt or mismanaged, posing serious environmental implications. There is wide scope to convert bio-residues into bio-fuels, to cater to the burgeoning demand for liquid fuel in the industrial, agricultural, and transportation sectors. India is next to China in the production of cereals, such as rice and wheat, which have been serving as the staple source of nourishment for billions of Indians. These crops generate residues (stalk, husk, straws, etc.), which can be utilized in the unprocessed or processed form, depending on the end use. Potential uses of these residues are as animal feed, production of bioenergy, composting, or deployment in other agricultural activities, like mushroom cultivation. According to the National Policy for Management of Crop Residues (NPMCR), among the Indian states, Uttar Pradesh generates the highest crop residues (60Mt), followed by Punjab (51Mt) and Maharashtra (46 Mt). Rice and wheat contribute to nearly 70% of the crop residues (Figure 1). Among the total residue generated, the surplus residue after utilizing for various other purposes is burnt and the remains are left in the agricultural fields. According to NPMCR, approximately 92 to 100 Mt of residues are being burnt annually in India. Adverse effects of crop residue burning includes greenhouse gases (GHGs) emissions, increase in particulate matter (PM) and smog, evident from higher PM levels in Delhi due to crop residue burning in Punjab. This is 17 times more than that from all other sources,

Table 1: Crop biomass residue potential in India

Crop group	Crop	Growing season	Residue	Gross potential (Mt)	Surplus potential (Mt)	Residue available for 1 kg of crop
Cereal	Rice	Kharif, Rabi, Summer	Straw	154	43.5	1.5
			Husk			0.2
	Wheat	Rabi	Stalk	131.1	28.4	1.5
			Pod			0.3

*Note – **Kharif**: From June/July–October, **Rabi**: From October/November–March/April, **Zaid/Summer**: From April-June*

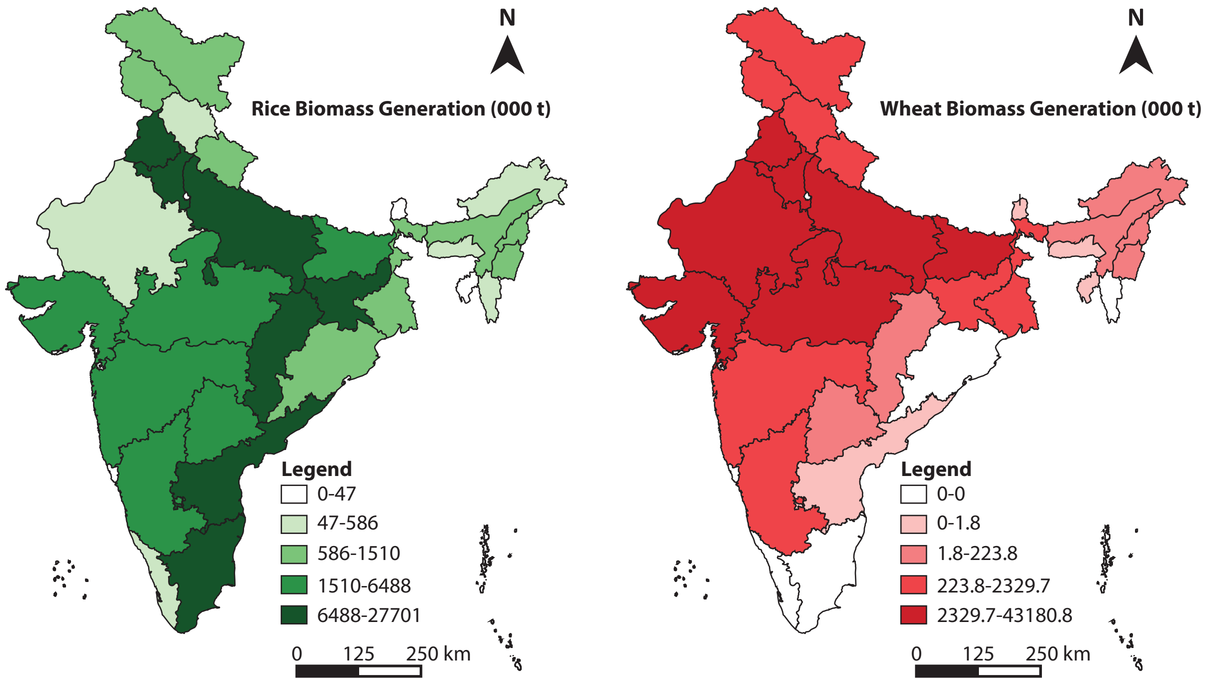

Figure 1: Representation of paddy and wheat-producing states across India

such as garbage burning, industries, and vehicle emissionsthe second largest agro-based economy with year-round crop cultivation, generates a large amount of agricultural waste, including crop residues. In the absence of adequate sustainable management practices, approximately 92 seems a very small number of metric tonnes of crop waste is burned every year in India, causing excessive particulate matter emissions and air pollution. Crop residue burning has become a major environmental problem causing health issues as well as contributing to global warming. Composting, biochar production and mechanization are a few effective sustainable techniques that can help to curtail the issue while retaining the nutrients present in the crop residue in the soil. The government of India has attempted to curtail this problem, through numerous measures and campaigns designed to promote sustainable management methods such as converting crop residue into energy. However, the alarming rise of air pollution levels caused by crop residue burning in the city of Delhi and other northern areas in India observed in recent years, especially in and after the year of 2015, suggest that the issues is not yet under control. The solution to crop residue burning lies in the effective implementation of sustainable management practices with Government interventions and policies. This manuscript addresses the underlying technical as well as policy issues that has prevented India from achieving a long-lasting solution and also potential solutions that have been overlooked. However, effective implementation of these techniques also requires us to look at other socioeconomic aspects that had not been considered. This manuscript also discusses some of the policy considerations and functionality based on the analyses and current practices. The agricultural waste sector can benefit immensely from some of the examples from other waste sectors such as the municipal solid waste (MSW). These crop residues are composed of cellulose, lignin, and hemicellulose, which serves as ideal raw material for biofuel production.

National Biofuel Policy

The share of road transport is around 6.7% of India's Gross Domestic Product (GDP), of which diesel makes up about 72% and petrol 23%. In India, domestic crude oil production only meets about 17.9% of the demand, the rest is sufficed by importing crude oil. This vulnerable status of India needs to change with the utilization of alternative fuels produced from indigenous renewable feedstock. The government of India has undertaken multiple interventions to promote biofuel production and blending of bioethanol with petroleum, as well as reducing import by 10% in 2022 (India, 2018). In this regard, the National Biofuel Coordination Committee (NBCC), recently constituted under the National Policy on Biofuels, has allowed the production of ethanol from maize and surplus rice available from the Food Corporation of India (FCI). This has been done by involving public sector oil marketing companies (OMCs), such as IOCL, BPCL, and HPCL under the ethanol blended petrol (EBP) programme.

Large-scale bioethanol production in the country can be taken forward with the establishment of a transparent framework of policy, mandates, and subsidies that dwell on the production of biofuels using various conversion technologies and promoting utilization of locally available feedstocks—generated in large quantities in the agri-states of India.

Production of bioethanol from bio-residues: Production of bioethanol entails three main processes, namely:

i. pretreatment of raw materials to break down recalcitrant lignocellulose structure;
ii. enzymatic hydrolysis of polysaccharides (e.g., cellulose and hemicellulose) to release simple sugars; and
iii. fermentation of these simple sugars to bioethanol (Figure 2).

A major limitation to commercializing bioethanol production using lignocellulosic biomass is the presence of a complex assembly of polymers, such as cellulose, hemicelluloses, and lignin that are naturally recalcitrant to enzymatic conversion. Pretreatment to break the recalcitrant structure is crucial to make cellulose accessible to enzymatic saccharification. Assessment of the biochemical composition of lignocellulosic biomass aids in developing appropriate pre-treatment technologies for the deconstruction of rigid structure and in selecting enzymes to release the fermentable sugars for bioethanol production.

During hydrolysis, lignocellulosic biomass is broken down into several compounds other than glucose, such as weak acids, furans, and phenolic compounds, which are inhibitors in the fermentation process. Alkali pretreatments using NaOH, KOH, CaOH, and Na_2CO_3 are being widely applied for the removal of lignin from lignocellulosic biomass due to the efficient removal of ester bonds between lignin, hemicellulose, and cellulose. Fermentation of lignocellulosic biomass is carried out using the strain of *Saccharomyces cerevisiae*. But, this strain is unable to ferment inhibitor compounds, which are generated during the hydrolysis step. Detoxification of these inhibitory compounds is performed by extraction with ether or ethyl acetate and treatment with alkali or sulfite. Also, using enzymes extracted from either ligninolytic or cellulolytic fungi, or bacteria for hydrolysis would circumvent the detoxification step. Cellulolytic enzymes play a vital role in the degradation of lignocellulosic biomass and these enzymes have been employed in industries to produce fermentable sugars. Fungal cellulases are most employed as they are inducible enzymes excreting into the environment.

This article presents the prospects of biofuel from agriculture residues based on the distribution of major biomass (rice and wheat) residues across India, which is an important factor in assessing the feasibility of plant installation for bioethanol production and discusses the challenges in the technology so far. Bioethanol production from rice and wheat straw is feasible using marine cellulolytic bacteria for hydrolysis and isolated yeast strain *Pichia kudriavzevii* for fermentation.

Methods

- **Feedstock (lignocellulosic residues):** Dried paddy and wheat straw were dried at 50–60°C for 15 to 20 minutes, pulverized using a grinder, and then sieved to get powder of < 0.1mm. These samples were stored in air-tight zip lock covers for further analysis.
- **Pretreatment of feedstock (bio-residues):** Dilute acid pretreatment was carried out using 2% H_2SO_4 for 10 g of straw and autoclaved at 121°C for 45 minutes. After pretreatment, the biomass was washed with distilled water and subjected to simultaneous saccharification and fermentation (SSF).
- **Fermentation of bio-residues:** Saccharification was carried out using *Vibrio parahaemolyticus* isolated from marine source exhibiting higher cellulolytic activity. Yeast strain *Pichia kudriavzevii*, isolated from toddy strain exhibiting thermotolerance, was selected for fermentation. SSF was carried out at 55°C, 100 rpm for 24 hours. Reducing sugar after hydrolysis was estimated using DNS method. The ethanol present in the fermented broth was analysed using GC-FID (gas chromatography with flame ionization detection).
- **SEM** (scanning electron microscope) **analysis:** Lignocellulosic biomass surface morphology (untreated, acid-treated, and enzyme-treated biomass) was qualitatively analysed using SEM (JEOL-IT 300). Pulverized straw samples were placed on an aluminium

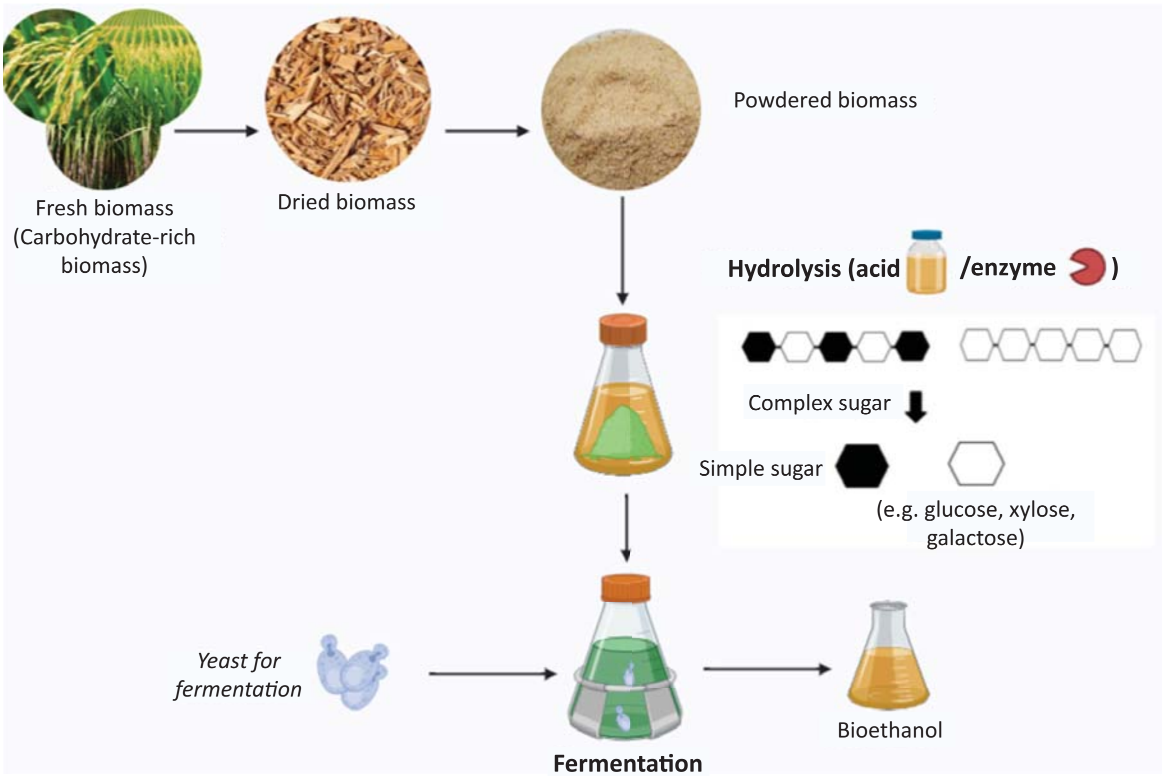

Figure 2: Schematic representation of bioethanol production using lignocellulosic biomass

specimen mount using conductive carbon tape. Sputter gold coating was performed to prevent charging. Samples were then examined in SEM under vacuum conditions at an accelerating voltage of 10 kV.

Results and Discussions

» **Lignocellulosic residue:** Key factor in bioethanol production from lignocellulosic biomass is its chemical composition. The composition of lignocellulosic biomass is variable base on their environmental conditions and interactions. The biochemical composition of rice and wheat straws is listed in Table 1. Major components of these residues (paddy and wheat straw) are lignin $[C_9H_{10}O_3(OCH_3)_{0.9\text{-}1.7}]_n$, cellulose $(C_6H_{10}O_5)_x$, and hemicellulose $(C_5H_8O_4)_m$. with the relative share of about 18.81%, 36%, and 19%, respectively. Cellulose is mostly composed on glucose subunits that are linked linearly by hydrogen bonding. Rigidity to the residue is imparted by the number of additional hydrogen bonds and also the orientation of linkages.

» **Bioethanol from lignocellulosic residue:** Simultaneous saccharification and fermentation of feedstock (paddy and wheat straw) was carried out by taking 10 g of biomass. Biomass was subjected to 2% H_2SO_4, and the pre-treated biomass was hydrolysed using V. parahaemolyticus. It was simultaneously saccharified using yeast strain P. kudriavzevii. Paddy straw produced 0.28 g/g of ethanol (36.7 L/100 kg) with a conversion efficiency of 76.62%, and wheat straw produced 0.42 g/g of ethanol (53.73L/100 kg) with a conversion efficiency of 64.82%. Lower ethanol production from rice straw is due to high silica content compared with other lignocelluloses. The presence of silica in the outer layer of rice straw reduces enzymatic hydrolysis and ethanol production yield. In order to improve the ethanol yield from rice straw, alkali treatment is carried out using sodium carbonate. It was seen that this pre-treatment was efficient (>91%) in removing silica from the straw. Subjecting rice straw to acid pre-treatment with ultrasound and subsequent enzyme hydrolysis using enzyme extracted from T. reesei, obtained ethanol of 11g/L after 7 days of fermentation with S. cerevisiae. Subjecting rice straw to subcritical water treatment and enzyme hydrolysis obtained ethanol of 0.011g/g (1.39L/100 kg). Lower ethanol yield in this study is due to utilization of non-domesticated strain for hydrolysis as well as fermentation. However, good ethanol is produced in a shorter period than other studies, which can be further improved by selecting strains with specific characteristics, through hybridization or evolutionary engineering techniques.

» **Effect of pre-treatment on straw morphology:** SEM images were taken to investigate the lignocellulose morphology, structures, and characterization at the nanoscale. SEM images of untreated and acid-treated biomass were compared, untreated biomass had a smooth surface, whereas the acid-treated biomass indicated loosened structures exposing the cellulose structures for enzyme hydrolysis.

» **Bioethanol prospects from agricultural residues in India**: Tables 2 and 3 indicate the availability, seasonality, total and surplus biomass production of rice and wheat along with its bioethanol potential across states in India. Higher quantity of bioethanol potential is directly proportional to the large quantity of biomass generated by the state. However, a major challenge is the dispersed nature of agriculture residue availability, which necessitates setting up mobile biorefineries or biorefineries at disaggregated levels.

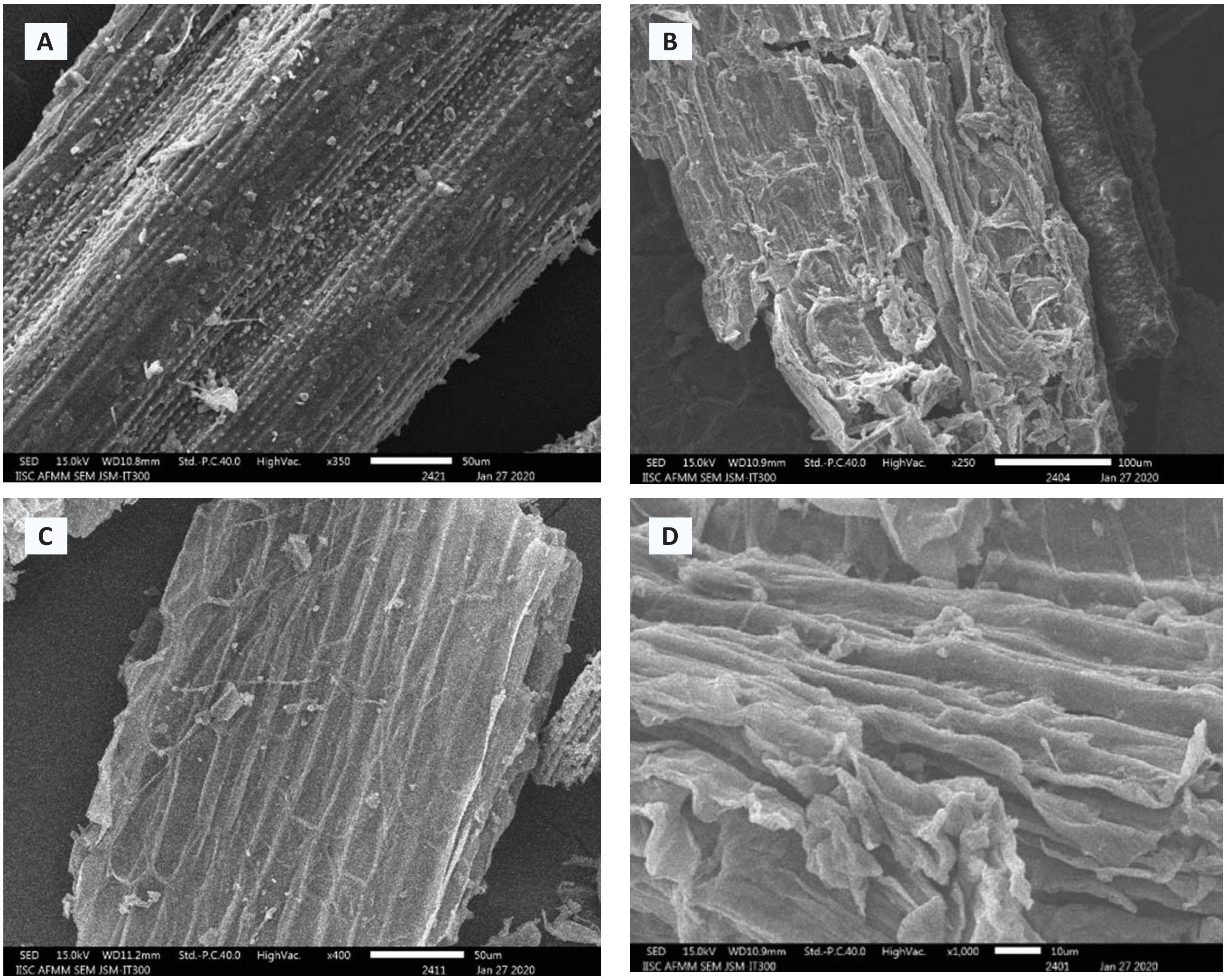

Figure 3: Scanning electron microscopy images of paddy straw; **A**: Untreated, **B:** Acid treated and wheat straw; **C:** Untreated, **D:** Acid treated

Table 2: Biochemical composition of selected biomass residue

Biomass residue	Carbohydrates (per 100g)		Fat (g)	Proteins (g)	Water	Energy (kJ)	Cellulose (%)	Hemicellulose (%)	Lignin (%)	Ash (%)
	Sugar (g)	Dietary fibre (g)								
Paddy straw	0.05	0.4	0.28	2.6	68.44	540	36	19	18.81	11.88
Wheat straw	0.41	12.2	1.54	12.61	13.1	1368	36.6	18.9	16.2	6.6