EXECUTIVE & CONFERENCE COMMITTEE

Alumni Association, N.C.E. Bengal & Jadavpur University

(Mumbai Branch)

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- Rudranath Banerjee - President
- Amitava Mukhopadhyay - Vice President
- Santanu Nandi - Secretary
- Partha Pratim Khan - Treasurer
- Anandarup Dutta - Joint Treasurer
- Sumit Bardhan
- Dr. Pranesh Sengupta
- Madhumita Ghosh
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- Santanu Nandi -Convenor

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- Shubhojit Bose - Convenor
- Amitava Mukhopadhyay
- Sumit Bardhan
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Event Sub-Committee

- Sumit Bardhan
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- Santanu Nandi

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- Ashok Adhikary
- Gorachand Chakraborty
- Paromita Khan

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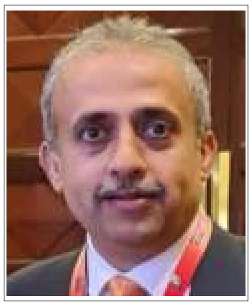
- Anjan Chatterjee
- Prosenjit Das
- Srijit Bandyopadhyay
- Netidipta Banerjee
- Shrobona De
- Souvik Roy

For more Details : Mr. Ashok Adhikary, Ph: 9820190336

From the President's Desk



Rudranath Banerjee

Since its establishment in 1956, the Mumbai Chapter of the (JUAAM) Alumni Association of NCE Bengal & Jadavpur University has been providing a platform for all alumni to meet, greet, interact, and socialize with each other. Having a sense of community amongst us has not only helped us professionally but also built a sense of cooperation.

Our organization has been closely following the various trends in the country that impact India's development and affect her people's lives and livelihoods. Today, JUAAM is a hallmark of integration and solidarity in India's commercial capital. We maintain close relationships with eminent academic institutions and industrial houses of national and international repute. We hold regular workshops, conferences, and technical debates, conduct technical paper contests, and impart value-based specialized training programs.

India, the 5th largest economy with a GDP of USD 3.7 trillion, is projected to grow 90% by 2030, potentially becoming a USD 7 trillion economy. This growth is linked to job creation, with McKinsey estimating 90 million new jobs by 2030. However, AI advancements may impact employment. Historically, new technologies create more jobs than they eliminate.

Economic growth depends on factors like employment and energy. As the economy expands, it needs more energy, creating a circular relationship. The shift from fossil fuels to clean energy adds complexity. Global commitments to net zero emissions by mid-century will create millions of clean energy jobs.

This context shapes our conference topic: "INDIA@2030: Energy, Economy, Employment," focusing on the interplay between these elements.

As you explore the pages of AANCEB 2025, I hope you find our efforts valuable and share your suggestions to help us improve.

It would be my pleasure to take this opportunity to thank the Conference Committee and the AANCEB Editorial team for all their efforts and dedication as we strive to bring this conference to fruition.

Namaskar

Rudranath Banerjee

President
The Alumni Association, N.C.E Bengal & Jadavpur University, Mumbai

Message from Secretary

Santanu Nandi

Alumni Association, NCE Bengal and Jadavpur University Mumbai Branch (JUAAM) was formed with the mission of nurturing the spirit of camaraderie among former students of Jadavpur University. JUAA endeavoured to contribute towards the enrichment of education in society continuously.

To fulfil our social responsibility and to make this a consistent contribution, the Jadavpur University Alumni Association Mumbai Branch Trust was formed in 1980. Through this Trust, we provide financial support to educational institutions in Mumbai to promote education among deserving students coming from less privileged sections of society.

We organize social events such as get-togethers and educational tours to promote bonding among members and their families. In addition, we organize conferences, seminars, and workshops that inform our members of the latest trends and help them advance professionally.

We have organized many such events in the last couple of years. Our distinguished alumnus, Late Syamal Gupta, was honoured at an event organized in his memory. The event titled "Syamal Gupta's Life and Ideas - Inspiring India to Go Global" was held at the MIG Club in Bandra, Mumbai on 1st June 2024. Mr. R. Gopalakrishnan, former director of Tata Sons, delivered the keynote address at the event. There were also other Tata Group leaders in attendance, such as Mr. Arun Vora and Mr. AP Mull. More than 60 people attended the event, including family members and alumni of Syamal da.

In addition, we organized our annual Educational Field Trips and Bijoya Sammelani & Educational Book release events along with Annual General Meetings, which had very encouraging participation from alumni and their families.

This year's National Conference will bring together alumni of Jadavpur University, academicians, policymakers, business executives, and alums from other top universities in the country. The National Conference titled "India@ 2030: Energy, Economy, Employment" will discuss the key issues affecting India's progress and its aspirations to become a global force by the end of the decade.

We've put a lot of effort into organizing a very high-quality event, and I'm sure you'll enjoy it as much as we did.

I take the opportunity to thank everyone for their support in organizing the event. Please feel free to write to us to provide your feedback. That will help us improve future events. I appeal to each and every alumnus to come forward with new ideas, advice, and support so that the Association.

Thank you,

Santanu Nandi

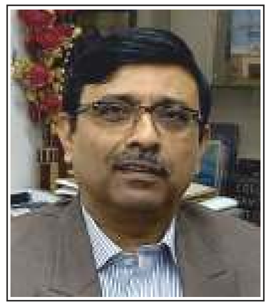
Secretary
The Alumni Association, N.C.E Bengal & Jadavpur University, Mumbai

যাদবপুর বিশ্ববিদ্যালয়

PROF. AMITAVA DATTA
Pro-Vice-Chancellor
অধ্যাপক অমিতাভ দত্ত
সহ-উপাচার্য

*JADAVPUR UNIVERSITY
KOLKATA-700 032, INDIA

OFFICE OF THE PRO-VICE-CHANCELLOR : AUROBINDO BHAVAN



Message

I am very happy to know that the AlumniAssociation, N.C.E. Bengaland Jadavpur University (Mumbai Branch) will be organizing a National Conference on the theme "India@2030: Energy, Economy, Employment". The IVl umbai Branch of the Alumni Association is one of the most vibrant Alumni group of the University and it is good to know that they regularly organize seminars on contemporary subjects to discuss and disseminate knowledge for the benefit of the society. The topic chosen for this year's conference is apt in the present

context and lam sure that it will bring about important deliberations from the experts in the field and help to formulate a road map for the future.

India as a country is fast moving in the path of development and has envisioned to be a developed nation by the centenary of its Independen ce in 2047 . Presently, the economy of the country is the fifth largest in terms of nominal GDP and the third largest in terms of purchasing power parity. The transformative policies and reforms and strategic initiatives taken at various levels have aimed to double the size of the economy by the turn of the decade. Energy lies at the heart of each country's core interest and plays significant role in economic development, education, health, job creation and security concerns. The energy sector of India remained largely dominated by fossil fuel resources. However, as a responsible nation in terms of global sustalnability, the country has committed to take measures in shifting towards clean energy generation. A significant step has been taken in the thermal sector by going for the advanced ultra-supercritical technology of higher efficiency with carbon capture, which will lead to zero carbon emission from the fossil fuel generation. The clean energy installation in the electricity sector has reached 47% of the total capacity and measures are being taken to overcome various technological challenges in meeting the renewable integration in the power system. The transportation sector also looks for a change towards the electric vehicle as a step towards decarbonisation. All these changes in the energy sector will bolster the growth in the economy while safeguarding the environment. Exchanges of ideas and thoughts both in terms of technology and policy matters will spearhead the changes and I am sure that the conference will give an ideal platform for the same.

India also has the highest number of young population of the world, which is a great strength for taking the country forward. Employment of the youth under the face of economic development and new technologies will remain as a challenge. The introduction of Artificial Intelligence, robotics and machine learning may shrink the job market in certain sectors. Alternative employment generation and skill development for the right opportunities will be a key factor to get dividend out of the demographic distribution. There is the possibilities of significant job creation in the clean energy sector as well. I hope that the policy makers and industry leaders will give their thoughts on the matter. llook forward to engaging and productive discussions inspiring further exploration and foster deeper understanding in the important topic of the conference and wish the conference a great success.

Professor Amitava Datta
Pro-Vice Chancellor

* Established on and from 24th December, 1955 vide Notification No.10986-Edn/IU-42/55 dated 6th December, 1955 under Jadavpur University Act, 1955 (West Bengal Act XXIII of 1955) followed by Jadavpur University Act, 1981 (West Bengal Act XXIV of 1981)

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Jadavpur University Alumni Association Bombay Branch Trust

Jadavpur University Alumni Association Bombay Branch Trust was established in 1980 by the Alumni Association, NCE Bengal and Jadavpur University (Mumbai Branch), which started operation in Mumbai in 1956.

Trust is a registered body under the Societies Registration Act 1860 and Mumbai Public Trust Act 1950 and is also approved by the Charity Commissioner of Maharashtra. With generous donations from the members and the Alumni Association, Mumbai, the corpus fund as of today has grown to around more than Rs.1.4 crore, and constant effort is being made to scale up this fund further.

Over the past few decades, Trust has played an active role by promoting social gatherings, organizing international seminars on relevant topics, conducting management development programs, hosting enlightenment lecture series, facilitating cultural programs, and producing annual publications, among other activities.

The interest accrued from the corpus fund, which was established through donations, is used to provide annual scholarships and stipends to needy and meritorious students, totalling Rs. 7.5 lakhs to various institutes in and around Mumbai, as well as to Jadavpur University in Kolkata.

Over the past 21 years, the trust has disbursed more than Rs. 70 lakhs for educational purposes in line with its objectives. Additionally, significant grants are being considered for Jadavpur University to support the **'Earn While You Learn' (EWYL)** project in collaboration with the JU Alumni Association in Kolkata.

Objectives of the Trust:

In response to the significant involvement and growth of our Alumni members, the idea of forming a Trust was proposed. This initiative came to fruition in 1980 with the primary objective of promoting education for our alma mater in Kolkata, as well as for students in and around the operational area of Jadavpur University Alumni Association in Mumbai.

The main objectives of the Trust are as follows:

- To provide assistance to deserving students pursuing further studies in engineering, applied sciences, or research.
- To offer financial support to meritorious or needy students in the form of scholarships that cover school and college fees, including tuition.
- To extend financial help to deserving students.
- To organize honoraria for prominent individuals to deliver lectures in India.
- Publication of journals promoting, advancing, and benefiting education.

Board of Trustees:

Currently, the JUAA BB Trust disburses 15 scholarships and stipends annually at JU in Kolkata and various schools and institutes in Mumbai:

Sr. No.	Institution	Scholarship	Type of Scholarship/Stipends	No. of Scholarships	Amount (INR)
1	Sashi Mangalam Goregaon, Mumbai	A K Sinha	Adopting 2 students under lighting the lamp	2	40,000
2	Vivekananda Education Society, Chembur, Mumbai	Mihir R. Lodh	Adopting 5 students	5	45,000
3	VJTI, Matunga, Mumbai	C K Radhakrishnan	2nd Mechanical Engg. Topper	1	20,000
4	SNDT Women's University, Churchgate, Mumbai	Hemlata R Trivedi	2nd Year Engg., Pharmacy & Nursing Toppers	3	45,000
5	Jadavpur University, Kolkata	Supriya K Basu	2nd Year Engg. Topper 3rd Year Engg. Topper 2nd Year Science & Arts faculty Topper	4	80,000
6	Jadavpur Vidyapith, Kolkata	Sushil K Ganguly	Adopting 4 students	4	40,000
7	Jadavpur Vidyapith, Kolkata	B C Rakshit	Teacher of the year	1	25,000
8	Sousheelya, Anushaktinagar	R K Debnath	Handicapped students	1	20,000
9	VES Institute of Technology, Chembur, Mumbai	Tarun K Basu	2nd. year Engg. Topper	1	20,000
10	VES Institute of Technology, Chembur	R.M.Bardhan & Mamata Bardhan	3rd year Engg. Topper	1	20,000
11	Jadavpur University Alumni Assoc., Kolkata	Anil K. Trivedi	Earn While You Learn (EWYL) Program	1	1,00,000
12	Logic Centre, Powai	Dr. A. Bhattacharya	Welfare to promote education	1	80,000
13	Jadavpur University, Kolkata	Amal Kumar Basu	Ph. D Research Scholarship, JU Mechanical /Chemical/ Computer /E&TCE/ F&BT	1	1,00,000
14	Vijay Army School and Junior College, Panvel	Amal K. Mukerjee	8th, 10th. & 12th. Toppers & Teacher of the year	6	45,000
15	JU Alumni Association, Kolkata	Syamal Gupta	Meritorious and needy students of JU	6	60,000

Office Bearers: Present and Past

Chairman	Year / Dept.	Tenure	Secretary	Year / Dept.	Tenure	Treasurer	Year / Dept.	Tenure
S. P. Ray	1971/IEE	2022 -till date	Sukumar Pramanik	1981/IEE	2021 -till date	Anjan Chatterjee	1981/MET	2022 -till date
R. K. Dasgupta	1956/Mech	2005-2022	Sukumar Pramanik	1981 /IEE	2021 -till date	Sushovan Datta	1987/CIV	2007-2021
R. K. Dasgupta	1956/Mech	2005-2022	S. P. Ray	1971/IEE	2016-2020	Sushovan Datta	1987/CIV	2007-2021
R. K. Dasgupta	1956/Mech	2005-2022	Sushanto Jana	1965/Physics	2014-2015	Sushovan Datta	1987/CIV	2007-2021
R. K. Dasgupta	1956/Mech	2005-2022	M.N. Saha	1974/IEE	2012-2013	Sushovan Datta	1987/CIV	2007-2021
R. K. Dasgupta	1956/Mech	2005-2022	Ashok Adhikary	1970/ELE	2006-2011	Sushovan Datta	1987/CIV	2007-2022
R. K. Dasgupta	1956/Mech	2005-2022	M.N. Saha	1974/IEE	2004-2005	S.K. Bandyopadhyay	1970/Ch	2006-2007
Amal K. Basu	1946/ Ch	1980-2005	M.N. Saha	1974/IEE	2000-2004	Kaushik Nandi	1993/Mech	2000-2005

Contact:
Jadavpur University Alumni Association (Bombay Branch) Trust
403, Nirmal, A2/9, Gokuldham, Goregaon (E), Mumbai-400063
E-mail: juaamtrust@gmail.com

Bank details for Donations:
Jadavpur University Alumni Association (Bombay Branch) Trust
Bank: **Punjab National Bank**, Anushakti Nagar
Branch: **Mumbai 400094**.
S/B A/c no: **1207000100274905**, IFSC code: **PUNB0120700**.

Note: The Trust issues a receipt along with an 80G certificate for obtaining IT exemption for the donation amount.

CAPTURED MOMENTS

NATIONAL CONFERENCE ON
NEW INDIA @ 2030
TAILORING FOR SUSTAINABLE GROWTH
REFORM PERFORM TRANSFORM

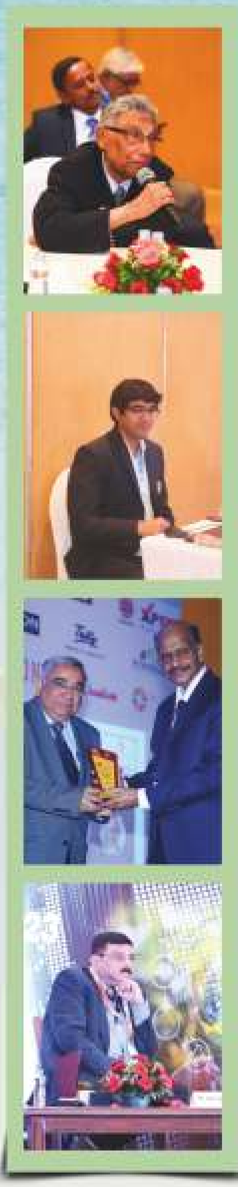
held at Hotel LALIT, on 4th March, 2023

ALUMNI ASSOCIATION

NCE Bengal and Jadavpur University, Mumbai Branch

Website : http://www.juaam.com

Throwback Conference 2023



The Silent Lifeline Behind

IN MEMORY OF SHYAMAL GUPTA

"na jayate mriyate va kadachit; nayaṁ bhutva bhavita va na bhuyaḥ
ajo nityaḥ śhaśhvato 'yaṁ purāṇo; na hanyate hanyamāne śharīre"

The soul is neither born, nor does it ever die; nor having once existed, does it ever cease to be. The soul is without birth. It is eternal, immortal, and ageless. It is not destroyed when the body is destroyed.

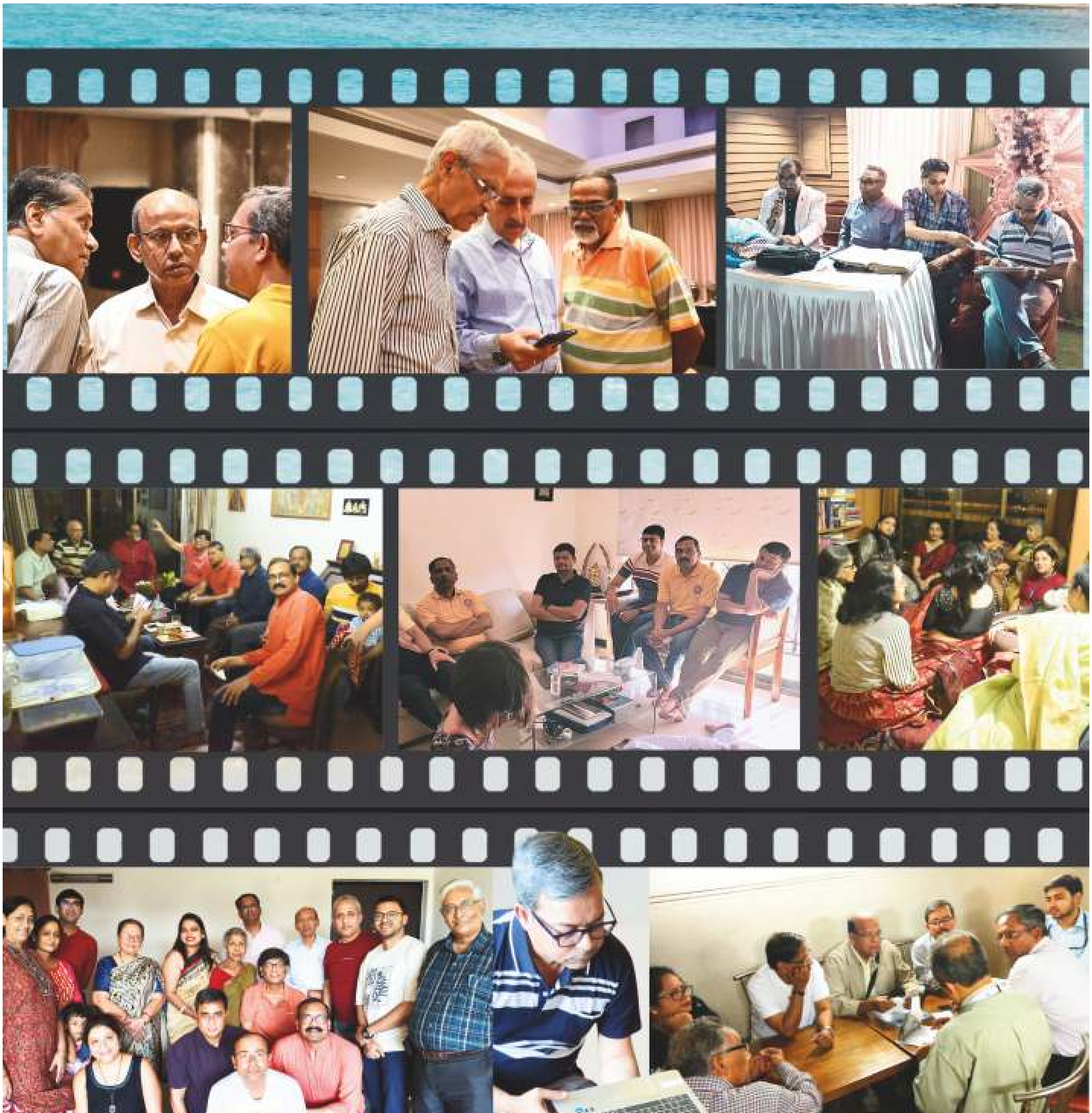
BIJOYA EDUCATIONAL PROGRAMME 2023

FRAME BY FRAME, LOVE STAYS THE SAME.
TWO GENERATIONS... ONE LIFETIME APART

BIJOYA EDUCATIONAL PROGRAMME 2024

FIELD TRIP
2024

FIELD TRIP 2025



Beyond the Spotlight

"The Efforts That Made It Happen"

JADAVPUR UNIVERSITY ALUMNI ASSOCIATION BOMBAY BRANCH TRUST ACTIVITIES

T.K. BASU & R.M. BARDHAN SCHOLARSHIP AWARD CEREMONY AT VIVEKANANDA EDUCATION SOCIETY, CHEMBUR, MUMBAI

SUSHIL GANGULY SCHOLARSHIP AWARD – TEACHER OF THE YEAR 2023: OUR SENIOR TRUSTEE WITH AWARDEES AT JADAVPUR VIDYAPITH, KOLKATA

SYAMAL GUPTA MEMORIAL SCHOLARSHIP AWARD CEREMONY – HONORING 6 MERITORIOUS AND FINANCIALLY UNDERPRIVILEGED STUDENTS OF JADAVPUR UNIVERSITY, ORGANIZED BY JUAA KOLKATA

VIJAY ARMY SCHOOL, CELEBRATING AMAL MUKERJEE SCHOLARSHIP AWARD

OUR TRUSTEES WITH THE WINNERS OF THE A.K. BASU & S.K. BASU SCHOLARSHIP AWARD, AT JADAVPUR UNIVERSITY, KOLKATA

OUR TRUSTEE SUKUMAR PRAMANIK HANDED OVER C.K. RADHAKRISHNAN SCHOLASHIP AWARD TO MECHANICAL ENGINEERING TOPPER, VJTI, MUMBAI

SCHOLARSHIP AWARD CEREMONY FUNCTION AT VJTI, MUMBAI

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			Vice-President	Sougata Datta	'02 Electrical Engg		
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			Treasurer	Abir Basu	'89 Chemical Engg		
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				Website :	**http://www.jualumniuk.org/**		
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				Website :	**http://www.juaasocal.org/**		
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			Founder member :	**Late AniruddhaBhattachrya**			
			Chapter email id:	**JUAANC@googlegroups.com**			
22	USA	Washington Metropolitan Area	President Vice President	Dibyendu Paul MadhumitaSircar Rama Saha Debabrata Das	 '83 Civil Print E '94	ia_ccc@yahoo.com msircar1@gmail.com ramasaha@verizon.net debabrata.das@gmail.com	 Ph -+1 202-531-5500
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23 USA Georgia

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Energy Transition to a Viksit Bharat

- **Vinayak Pai**
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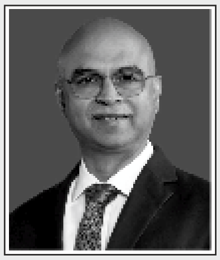
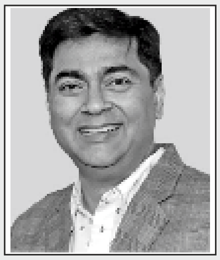


Vinayak Pai is the MD & CEO of Tata Projects Limited, India's Sustainable Technology Engineering, Procurement, & Construction (EPC) company. Prior to Tata Projects, Vinayak worked in the US & Europe, leading global businesses in over 50 countries, first as President – of ECR at Jacobs, one of America's leading EPC companies and later as Group President of Energy and Chemical Services business at Worley, Australia, 's top EPC company.



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Abstract

India's energy transition is a critical aspect of its economic and environmental future, balancing the need for sustainability with the demands of rapid industrialization and urbanization. As the country aims for net-zero emissions by 2070, its energy landscape will undergo a fundamental shift. This paper explores India's energy transition till 2047, the centenary of its independence, and the evolving role of fossil fuels in this period. While renewable energy sources are expected to dominate, fossil fuels—particularly coal, oil, and natural gas—will remain crucial in India's energy mix, albeit with decreasing prominence. Additionally, small modular nuclear reactors (SMRs) and pumped storage hydropower (PSH) will play a growing role in ensuring grid stability and addressing renewable energy intermittency. The paper examines policy measures, technological advancements, and economic challenges that will shape India's energy future.

Introduction

India is one of the world's fastest-growing economies and the third-largest energy consumer globally. The country's energy transition is driven by multiple factors, including energy security, climate change commitments, and economic growth. The government has set ambitious renewable energy targets and plans to decarbonize critical sectors. However, given the scale of energy demand, fossil fuels will continue to play a role, albeit a diminishing one. This paper analyzes India's energy trajectory till 2047, focusing on the interplay between renewables and fossil fuels.

India's Energy Transition Goals and Policies

Net-Zero Target by 2070

India has pledged to achieve net-zero emissions by 2070, as announced at COP26 in 2021. To reach this goal, the country has set intermediate milestones, including:

- 500 GW of non-fossil fuel capacity by 2030
- 50% of total energy requirements from renewables by 2030
- Reducing emissions intensity of GDP by 45% by 2030
- Eliminating 1 billion tonnes of carbon emissions by 2030

Key Policy Initiatives

National Electricity Plan (NEP) 2023: Focuses on reducing coal dependency and expanding renewable capacity.

Green Hydrogen Mission: Aims to produce 5 million metric tons of green hydrogen annually by 2030.

Energy Conservation (Amendment) Act, 2022: Introduces carbon trading and mandates renewable purchase obligations.

Faster Adoption and Manufacturing of Electric Vehicles (FAME) Policy: Encourages EV adoption to reduce oil consumption.

National Bio-Energy Mission & Ethanol Blending Program: Targets 20% ethanol blending in petrol by 2025 and expands biofuel use.

The Role of Fossil Fuels in India's Energy Transition

Despite the push for renewables, fossil fuels—coal, oil, and natural gas—will continue to be a major part of India's energy mix till at least 2047.

Coal: The Dominant Fuel with Declining Share

Coal currently accounts for nearly 55% of India's energy generation. While its share is expected to decline, it will remain important due to the following reasons:

Energy Security: Domestic coal reserves ensure supply stability.

Base Load Power: Coal-fired plants provide reliable electricity, especially when renewable generation fluctuates.

Industrial Demand: Sectors like steel and cement will still rely on coal till alternative technologies mature.

However, efforts to reduce coal dependence include:

- Phasing out old coal plants and replacing them with supercritical units.
- Carbon Capture and Storage (CCS) investments.
- Coal gasification and blending with biomass to reduce emissions.

Oil: Strategic Importance but Increasing Electrification

India is the world's third-largest oil importer, relying on imports for 85% of its crude oil needs. The role of oil will decline in:

Transportation: With EV adoption and biofuels, demand for gasoline and diesel is expected to decrease.

Industrial Use: Transition to hydrogen and electrification in industries will lower oil dependency.

However, crude oil will still be required in:

Aviation and Heavy Transport: These sectors will take longer to electrify.

Petrochemicals: Demand for plastics and other derivatives will keep oil relevant.

Natural Gas: A Transition Fuel

Natural gas is being promoted as a bridge fuel in India's energy transition. The government aims to increase its share in the energy mix from 6% to 15% by 2030 through:

City Gas Distribution (CGD) networks for urban households and transport.

Gas-based power plants as backup for renewable energy.

LNG for heavy industries and transport.

Challenges include pricing volatility and the need for more domestic production.

Role of Biofuels in India's Energy Transition

Biofuels plays a pivotal role in reducing dependence on fossil fuels, particularly in transportation. India is scaling up:

- *Ethanol Blending in Petrol*: Targeting **20% ethanol blending by 2025**.
- *Biodiesel Production:* Encouraging waste-to-biodiesel programs.
- *Sustainable Aviation Fuels (SAF):* Developing bio-jet fuel for aviation, with an expected mandate in the coming years , aligned with Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) norms
- *Compressed Biogas (CBG):* Expanding *Sustainable Alternative Towards Affordable Transportation* **(SATAT)** program for biogas use.

Role of Small Modular Nuclear Reactors (SMRs) in India's Energy Transition

India has a well-established nuclear power program, but the focus has been on large reactors. Small Modular Reactors (SMRs) offer a new approach:

Scalability: SMRs can be deployed in remote locations and integrated with industrial applications.

Grid Stability: Provides consistent baseload power to balance intermittent renewables.

Lower Costs & Faster Deployment: Compared to traditional nuclear plants, SMRs are cost-effective and quicker to install.

Potential for Hydrogen Production: Can support the green hydrogen economy by providing process heat.

Renewable Energy and the Decline of Fossil Fuels

India is rapidly expanding its renewable energy capacity and on track to meet its 2030 goals

Solar Power: Expected to be the dominant source by 2047, with ultra-mega Solar parks and rooftop installations.

Wind Energy: Offshore wind projects are being explored for coastal states.

Hydropower: Continues to provide stable electricity and storage solutions.

Green Hydrogen: Emerging as a long-term fossil fuel replacement.

As renewables scale up, coal and oil will decline, while gas might play a transitional role before being phased out.

Pumped Storage Hydropower (PSH) for Renewable Energy Integration

Pumped storage is the most viable large-scale energy storage solution for managing renewable energy intermittency. India is focusing on:

- Expanding PSH capacity from 4.7 GW to over 30 GW by 2047.
- Utilizing existing hydro reservoirs for pumped storage.
- Providing grid flexibility to integrate solar and wind power.

Advantages of PSH

- Stores excess renewable energy during off-peak hours and releases it during high demand.
- Enhances grid stability by balancing fluctuations in solar and wind generation.
- Prolongs the life of coal and nuclear plants by reducing cycling.

Challenges in India's Energy Transition

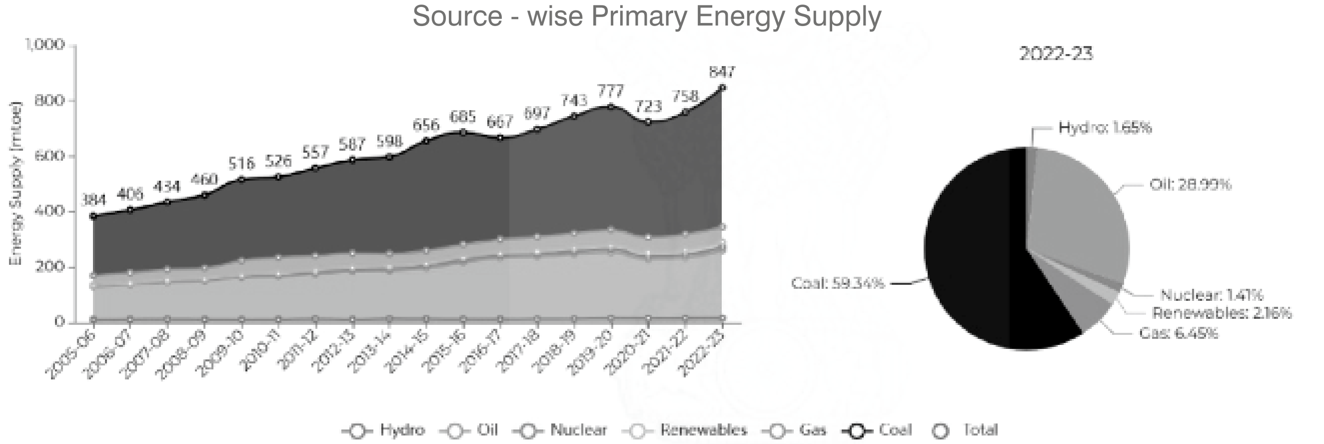
India's energy transition faces several obstacles:

- Infrastructure: Expanding grid capacity and storage for renewable energy integration.
- Investment Needs: Estimated at $10 trillion by 2070 for decarbonization.
- Energy Equity: Ensuring affordable energy access for all.
- Coal Sector Dependence: Over 4 million jobs linked to coal mining and power plants.

Conclusion

India's energy transition till 2047 will be a complex process involving a gradual shift from fossil fuels to renewable energy. While coal, oil, and gas will continue to play a role, their share will decline as renewables, hydrogen, and electrification expand. Government policies, international cooperation, and technological advancements will determine the pace of this transition. By 2047, India is likely to achieve significant decarbonization, but fossil fuels will still have a limited role, particularly in industrial and backup power applications.

Source - wise Primary Energy Supply



*Non-commercial sources including biomass are not included in this graph.

Clean Hydrogen and Development of Marginal Gas Fields – A Step Towards Energy Transition

- Rajib Roy

Rajib Roy, a seasoned oil and energy professional with over 13 years of experience, holds undergraduate and postgraduate degrees in Chemical Engineering from Jadavpur University, Kolkata. He specializes in conceptual engineering for oil and gas processing, enhanced oil recovery, well completion design, and formation damage remediation. His expertise extends to mature field development, well integrity optimization, and energy efficiency. Additionally, he is a WellSharp IADC Well Control Trainer and has experience in procurement and SAP operations.

Currently pursuing a PhD in Chemical Engineering at IIT Delhi under Prof. K. K. Pant, Rajib focuses on hydrogen energy and carbon-free fuel production. A thought leader in energy transition, he has delivered guest talks on hydrogen's role in the future energy mix. Passionate about sustainability, he aims to drive a decarbonized economy through innovations like in-situ aquathermolysis for low-carbon fuel production and seeks collaborations in hydrogen and sustainable energy solutions.

Abstract

The increasing global demand for energy and the need to reduce carbon emissions have positioned hydrogen as a key element in the transition to sustainable energy. This paper explores the role of clean hydrogen in the development of marginal gas fields, evaluating its production methods, economic feasibility, and environmental benefits. A comparative analysis of fossil fuel-based and hydrogen-based energy systems is presented, highlighting the potential of hydrogen in achieving India's net-zero emissions target by 2070. Furthermore, hydrogen storage, transportation, and integration with city gas distribution networks are discussed to address infrastructure challenges. This study provides insights into the hydrogen economy, emphasizing the necessity of policy support, technological advancements, and strategic investments to facilitate the transition.

1. Introduction

Global energy demand is projected to increase by 50% by 2030, driven by industrialization, population growth, and urbanization. At the same time, the urgency to mitigate climate change has accelerated the shift towards cleaner energy sources. Hydrogen, particularly clean hydrogen, emerges as a viable alternative, offering significant reductions in carbon emissions.

India, as a major consumer of fossil fuels, has committed to achieving net-zero emissions by 2070. One promising approach is leveraging marginal gas fields—small, economically unviable reserves—to produce hydrogen, reducing dependency on conventional fossil fuels. This paper examines the feasibility of clean hydrogen production from marginal gas fields, analyzing its potential contributions to energy security and carbon reduction.

2. Hydrogen as an Energy Source

2.1 The Need for Hydrogen in the Energy Transition

Hydrogen serves as an essential energy carrier, with applications in power generation, transportation, and industrial processes. Unlike fossil fuels, hydrogen combustion produces only water vapor, making it an attractive solution for decarbonizing various sectors.

2.2 Global Hydrogen Market and Trends

The hydrogen market is expanding, with projections indicating a compound annual growth rate (CAGR) of 6.5% from 2021 to 2030. Key developments include:

- The European Union's Hydrogen Strategy, aiming for 40 GW of electrolyzer capacity by 2030.
- The United States investing $9.5 billion in clean hydrogen under the Bipartisan Infrastructure Law.
- India's National Hydrogen Mission, targeting 5 million tons of hydrogen production annually by 2030.

These initiatives underscore hydrogen's role in a decarbonized energy system.

3. Hydrogen Production Methods

3.1 Conventional Hydrogen Production (Grey Hydrogen)

Grey hydrogen is produced from natural gas via steam methane reforming (SMR), emitting significant amount of CO_2. This methods economically viable but unsustainable from an environmental perspective.

3.2 Low-Carbon Hydrogen Production (Blue Hydrogen)

Blue hydrogen utilizes SMR with carbon capture and storage (CCS) to mitigate emissions. While this reduces carbon footprints, the high costs of CCS technology present economic challenges.

3.3 Renewable Hydrogen Production (Green Hydrogen)

Green hydrogen is generated via electrolysis using renewable energy sources such as solar and wind. Despite its zero-emission advantage, green hydrogen faces hurdles related to high energy consumption and electrolyzer costs.

3.4 Hydrogen from Marginal Gas Fields

Marginal gas fields, typically uneconomical for traditional exploitation, can be repurposed for hydrogen production through:

- **Gas-to-Hydrogen Conversion:** Extracting methane and reforming it into hydrogen with integrated CCS.
- **Subsurface Hydrogen Generation:** Utilizing biological or catalytic processes to convert residual hydrocarbons into hydrogen in situ.

This approach optimizes resource utilization while minimizing environmental impact.

4. Comparative Analysis: Fossil Fuels vs. Hydrogen Energy

The following table compares the emissions profile of fossil fuels and hydrogen combustion:

Energy Source	CO_2 Emissions (kg/MJ)	NOx Emissions	Sulfur Content
Coal	0.095	High	High
Natural Gas	0.056	Medium	Low
Diesel	0.073	High	Medium
Hydrogen (Grey)	0.070	Low	Zero
Hydrogen (Blue)	0.020	Low	Zero
Hydrogen (Green)	0.000	Low	Zero

Green hydrogen emerges as the most environmentally sustainable energy source, offering near-zero emissions.

5. Hydrogen Economy: Cost and Efficiency Analysis

5.1 Cost of Hydrogen Production

The cost of hydrogen production varies significantly based on the technology used:

- Grey Hydrogen: $1.5–2.5/kg
- Blue Hydrogen: $2.0–3.0/kg (including CCS costs)
- Green Hydrogen: $4.0–6.0/kg (dependent on renewable energy costs)

While green hydrogen remains the most expensive option, ongoing advancements in electrolyser technology and renewable energy integration are expected to reduce costs.

5.2 Efficiency of Hydrogen Production Methods

Efficiency comparisons highlight the need for technological improvements:

Production Method	Energy Efficiency (%)
Steam Methane Reforming (SMR)	65–75%
Electrolysis (PEM)	55–65%
Electrolysis (Alkaline)	60–70%
Biomass Gasification	50–60%

Higher efficiency processes can make hydrogen more competitive with conventional fuels.

6. Hydrogen Storage and Transportation

6.1 Hydrogen Storage Methods

Hydrogen is stored in three primary forms:

- Compressed Gas (350–700 bar): Most common but energy-intensive.
- Liquid Hydrogen (-253°C): Suitable for large-scale transport but costly due to cryogenic conditions.
- Metal Hydrides: Emerging technology with potential for solid-state storage.

6.2 Hydrogen Transportation Challenges

Hydrogen transportation requires significant infrastructure investments. Current options include:

- Pipeline Networks: Viable for high-demand regions but expensive for new installations.
- Tube Trailers: Effective for small-scale distribution but limited by storage capacity.
- Ammonia as a Carrier: Enables easier transport and storage, with ammonia cracking as a reconversion method.

Strategic infrastructure development is essential to facilitate hydrogen adoption.

7. Hydrogen Integration into City Gas Distribution (CGD)

Blending hydrogen with natural gas for CGD offers an interim solution to reduce emissions while utilizing existing pipeline infrastructure. Studies indicate that up to 20% hydrogen can be blended with natural gas without significant modifications to pipeline materials.

However, challenges such as hydrogen embrittlement, leakage risks, and combustion efficiency variations must be addressed through pipeline material upgrades and advanced sensor technologies.

8. Challenges and Future Prospects

8.1 Challenges

- High Production Costs: Green hydrogen remains cost-prohibitive without subsidies.
- Infrastructure Gaps: Storage, transport, and distribution networks require substantial investment.
- Technological Barriers: Electrolysis and photochemical water splitting technologies need further development.

8.2 Future Prospects

- Cost Reduction Strategies: Scale-up of electrolyzers, improved catalysts, and integration with renewable energy can drive costs down.
- Government Policies and Incentives: Subsidies, carbon pricing, and tax benefits can accelerate hydrogen deployment.
- Public-Private Partnerships: Collaboration between industries and governments can foster a robust hydrogen economy.

9. Conclusion

Clean hydrogen presents a transformative opportunity for global energy transition. By leveraging marginal gas fields for hydrogen production, nations can optimize resource use while achieving emissions reduction targets. Addressing cost, infrastructure, and policy challenges will be critical to realizing hydrogen's full potential.

India's commitment to net-zero emissions by 2070 can be significantly bolstered through strategic hydrogen initiatives, positioning the country as a leader in sustainable energy solutions.

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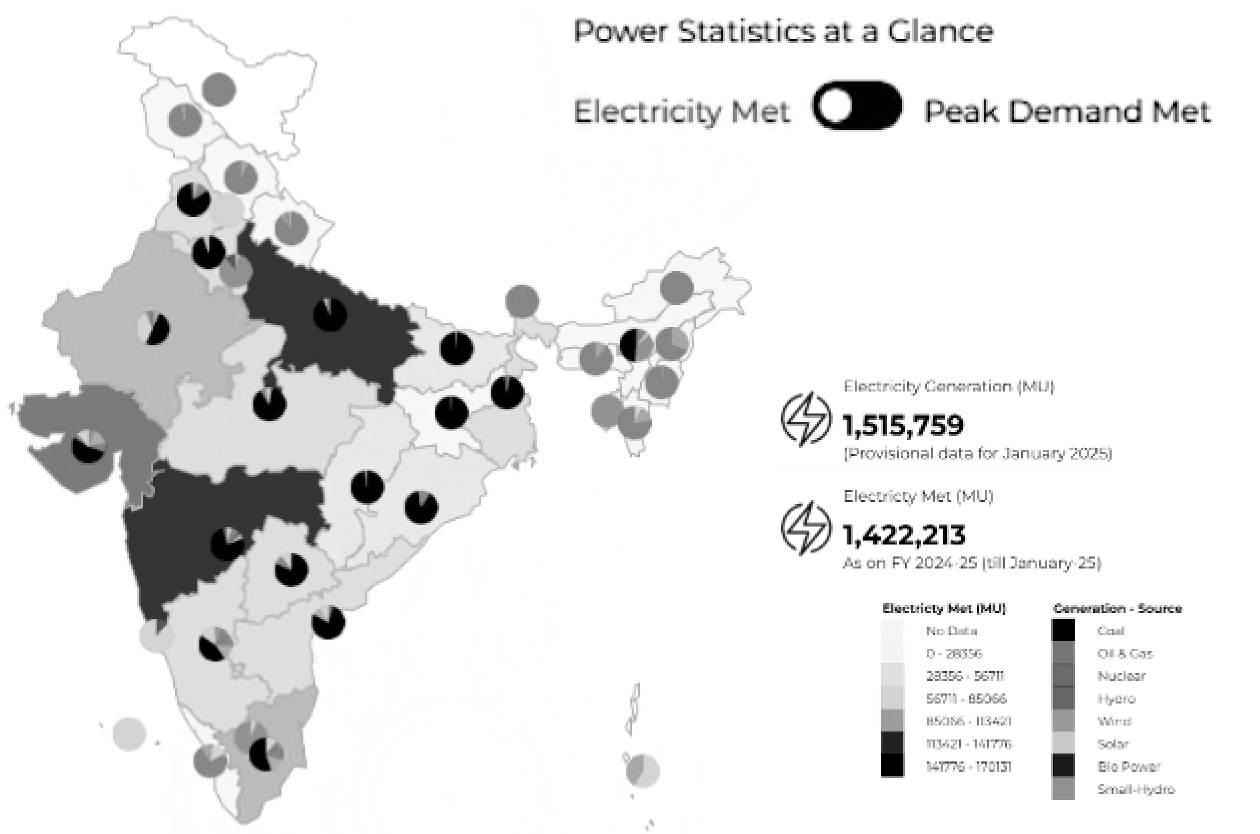

The information on this platform is mainly taken from official sources. However, in some cases, a few assumptions have been made and some data derived or assumed and is given in the detailed. While we believe that the data is reliable and adequately comprehensive, India's Climate and Energy Dashboard does not take guarantee that such information is in all respects accurate. India's Climate and Energy Dashboard does not accept any liability for any consequences resulting from the use of this data.

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*The map shows information for states with available data. However, the gaps are regularly filled as and when data is available. Utmost care has been taken to ensure that all maps used in the website conform to Survey of India boundaries.
Provisional data for January'25

*Capacity and generation presented in the graph based on the geographical location of the power plant.

Navigating the Path to a Brighter India though Energy Transition

- Subrata Guha

Subrata Guha completed his graduation in Civil Engineering from Jadavpur University in 1992. A project management professional in the energy sector, Subrata is keen on exploring the exciting new energy landscape. Driven by the potential of emerging opportunities in this dynamic energy transition, he is an avid reader of books focused on business strategy and innovation. Subrata believes the transition to renewable energies will unfold a new vista for the Indian economy, building a prosperous and sustainable nation.

India's aspirations towards achieving net zero emissions by 2070 while attaining sustainable development objectives heralds significant opportunities for the nation. This paper tries to assess the status of energy transition in India as well as the opportunities and challenges associated with Energy transition, considering the burgeoning energy demand and commitment to combat climate change.

A multi-pronged approach is adopted to achieving the net zero target that includes policy reforms, technological innovation with societal participation. India's decarbonization is a vision for a cleaner, greener, and more self-reliant India. For any nation, energy security remains a cornerstone ensuring availability, reliability, and affordability of energy. For India, a significant part of the energy is imported that is putting severe strain on the balance of trade. With the fluctuating currency and external factors, it gets amplified, which impacts all facets of the economy including competitive advantages from exports.

To mitigate vulnerabilities due to climate change, India needs to proactively pursue energy transition opportunities to minimize the impact on natural habitats, agriculture and bio- resources, including powering the communities at remote places, as a significant section of our nation is still dependent on agriculture.

Electricity consumption

India's electricity consumption rose to 1,395 kWh (per capita) in 2023-24 from 957 kWh in 2013-14, primarily led by increase in manufacturing activity, rising domestic consumption, household electrification and extended hours of supply.

Despite this healthy increase, the per-capita electricity consumption remains significantly lower than other major economies. Even developing countries, such as Brazil and China, have significantly higher per capita electricity consumption than India. In 2022, per capita electricity consumptions of Brazil and China were 2.5 MWh and 5.3 MWh respectively, while in the United Staes, it was 12.7 MWh.

Per capita electricity consumption is expected to gradually grow over the next decades (~ 5-7% CAGR, by some estimates). Power demand picks up, in terms of quality and reliability, rising per capita income, increasing EV penetration, railway electrification, on account of intensive rural electrification, resulting in realization of latent demand from the residential segment, increased penetration of consumer durables. However, factors such as improved energy efficiency would also impact on the projected demand. CRISIL has projected per capita electricity consumption to reach approximately 1,600-1,650 kWh by fiscal 2029.

Renewable energy (RE) installed capacity

India's strides in renewable energy deployment, reflect a clear direction towards reducing its carbon footprint. Renewable energy (RE) power generation installed capacity has grown ninefold over the past decade, from nearly 24 gigawatts (GW) in FY 2014-15. As on 20th Jan 2025, India's total non-fossil fuel-based energy capacity has reached close to 218 GW, almost 47% of total 462GW total capacity, on her way to achieving 500GW of RE power by 2030.

The year 2024 saw close to 25 GW of solar and 3.4 GW of wind capacity addition, reflecting more than two-fold increase in solar and 21% rise in wind installations compared to 2023. Solar energy remained the dominant contributor to India's renewable energy basket, accounting for approximately 46% of the total installed renewable energy capacity. For solar, Rajasthan, Gujarat, and Tamil Nadu emerged as the top performing states, contributing close to 71% of total solar installations while Gujarat, Karnataka, Tamil Nadu, Maharashtra, Rajasthan, Andhra Pradesh and Madhya Pradesh lead the way for wind power, accounting for almost 98% of the total installed capacity.

Contribution of RE in overall Power Mix

Despite significant growth in renewable energy installations, actual contribution of renewables to the overall electricity consumed in India remains quite low due to several factors like:

- Weak and unstable grids
- High reliance on coal (historically)
- Inadequate grid integration capabilities
- Weather downtime
- Challenges with project finance & development

Transmission and distribution grids are central in the energy transition goals to integrate renewable energy sources (RES). Existing grids are not compatible with such a dynamic energy system. There are several challenges when integrating RES into the existing grids, stemming mainly from network inadequacy (lack of physical capacity to accommodate supply and demand in locations with the best resources) and poor real-time network management (as share of RES increases, low voltages could lead to network instability, frequency inconsistency of the power system). Consequently, production from RES at such times is throttled down, as production exceeds demand.

Following the Greening the Grid (GTG) studies, a model framework is being followed at regional and national levels for faster RE integration into the grid system. An efficient transmission network for integrating higher variable renewable energy (VRE) is a must and would pave the way for power system flexibility, particularly on the supply side.

Power Transmission and Distribution

India faces real challenge with transmission and distribution (T&D) losses that remained quite high, reported to be around 15-20% of generation, which is more than twice the world average.

However, India's power T&D sector is currently undergoing significant expansion to support growing renewable energy capacity. Grid expansion witnessed an increase of transmission lines of 180,000 km over the past decade, representing a 60% growth in grid capacity.

While T&D losses have come down significantly from 25-30% to 15-20% over the past decades, the current high numbers are still a concern. Federal and state governments have been working to reduce T&D losses through various initiatives like:

- Upgrading Infrastructure
- Smart Grid Technologies
- Metering and Billing
- Addressing Theft

The T&D sector's growth is intrinsically linked to the expansion of renewable energy capacity. The needs for designing a suitable network and stabilizing the integration of RE into the national grid were are being addressed by Ministry of New and Renewable Energy under the Green Energy Corridor project that is expected to lay the foundation for a total transformation of the grid system for future RES.

The government's commitment to invest $30 billion in T&D infrastructure and renewable grid integration by 2030 underscores the sector's importance for energy transition. This is aimed at ensuring reliable power supply and facilitating integration of renewable energy sources into the grid.

Economic Implications

Renewable energy deployment and energy efficiency measures are emerging as central ways in which governments around the world can improve energy security, especially for countries where the risks related both to the availability as well as the price volatility of fossil fuels is pronounced. Thus, for India, energy transition is not only a tool to combat climate change, but also an opportunity to grow and strengthen the economy, making it more resilient that stems out from the facts that:

- India is a net importer of fossil fuels and relies heavily on imports to meet its energy needs. Consequently, volatility in prices of energy commodities impacts the national economy. Energy transition provides a pathway for India to reduce its reliance on imports and achieve greater energy independence by using domestically available resources.
- It is estimated that approximately US$150 to 200 billion of investments will be required annually till 2030 to underpin energy transition in India. This provides obvious opportunities for new investments to meet the needs of a growing economy and to tap opportunities for creating new businesses, technologies and industries.
- Optimized cost of power generated from RE sources would make them more competitive

that is expected to help India increase the share of manufacturing from current 17% of GDP.

- In general, a decarbonized energy system would make Indian economy more competitive with implementation of measures, such as Carbon Border Adjustment Mechanism (CBAM). Availability of decarbonized energy will positively impact India's export competitiveness paving the way to attract more investments.
- Given the natural advantages of scale and adequate sunshine, India has huge potential to emerge as an export hub for both carbon-efficient manufactured goods as well as hydrogen-related (new energy) products.

Macro-economic factors related to fossil fuel reliance impact India significantly leading to higher inflation with forex outflow widening trade deficit. This usually forces RBI to raise interest rates, which dampens investment and makes it harder to invest in new projects and ventures across the economy. This can pose an important risk to critical long-term policy objectives, such as industrial development, decarbonization, and social and economic development.

A whopping USD 4.2 billion in fuel import costs were saved in the first half of 2022 due to solar power alone, avoiding import of 19.4 million tons of coal that could have further stressed domestic supply, per report by Ember. The use of renewables in place of coal is expected to save India between US$ 8 - 10 billion annually, as estimated by IBEF.

RE deployment has been able to create millions of new jobs world-wide in past decades. Globally, the renewable energy sector employed about 12 million people in 2020. This number could increase to more than 38 million by 2030 and 43 million by 2050, as estimated by IRENA. Renewable energy technologies are typically quite labor intensive compared to conventional energy technologies. Renewables such as small-scale hydro, rooftop solar and biomass create more employment for every MW of installed capacity. By some estimates, rooftop solar employs 24 people, small hydro employs 13 people and biomass employs 16 persons for construction and operation of a 1MW plant in India. A study by Deloitte argues that green energy program has an employment-generating capacity of 150 direct and indirect jobs per million US$ invested, compared to 44 jobs created from fossil fuel programs.

According to CEEW study, India could almost double the number of employees in the power sector by 2030 (from 2020 level), following a pathway with high shares of renewables. Biomass and solar energy could be the major drivers of employment.

Energy efficiency

Energy efficiency measures equally create many employment opportunities. Typically, energy efficiency sector jobs include energy auditor, building energy modeler, energy consultant, retrofit coordinator, insulation installer, HVAC technician, smart grid specialist, appliance efficiency expert, lighting design engineer, project manager for energy efficiency upgrades, policy analyst for energy efficiency regulations, and research scientist in energy efficiency technologies, with a focus on areas like building renovation, industrial process optimization, and appliance development etc.

Raw materials and Energy Transition

Energy transition goals are intricately linked to the robustness of the supply chains for renewables. In a volatile global landscape characterized by adverse climate shocks and geological concentration of key input materials, the significance of a resilient and adaptable supply chain is paramount that would support and shield the domestic economy from geopolitical fragilities in a cost-efficient manner. Transition Critical Minerals (TCMs) such as lithium, nickel, cobalt and rare earth elements (REE) are crucial for manufacturing renewable energy products such as batteries for EVs, solar PV panels, wind turbines, etc.

Many TCMs are more geographically concentrated than fossil fuels. While Democratic Republic of the Congo produces the lion's share of world's Cobalt needs (circa 70%), Australia, Chile and China are home for more than 90% of global lithium production. Furthermore, RE technologies are typically more material-intensive, e.g., five to six times more materials are needed for electric vehicles than their internal combustion variants. Per IEA estimates, the demand for TCMs is expected to rise by more than four to six folds in 2030 compared to 2020 levels.

India's RE transition goals rely heavily on solar power. The manufacturing of photovoltaic cells requires minerals like gallium that are either unavailable or not produced domestically. Manufacturing wind turbines requires chromium, nickel, and rare earth metals. Adoption of EVs is also a significant part of India's energy transition journey. Lithium, cobalt and rare earth metals are the key minerals required for manufacturing EV batteries. The supply chain of batteries is highly dependent on China which produces three-quarters of all lithium-ion batteries including lion's share for production of cathodes and anodes (both are key components of batteries).

With limited domestic production capacity and low reserves of lithium/cobalt, India has relied heavily on imports for battery cells. With the growing demand for EVs, the demand for lithium-ion batteries is expected to surge from 4 GWh in 2023 to nearly 140 GWh by 2035.

Several policies are being adopted by Government to enhance India's domestic battery manufacturing capabilities, including Production-Linked Incentives (PLI) scheme for National Program on Advanced Chemistry Cell (ACC) Battery Storage.

Access to TCMs is a national security concern. Ongoing geopolitical tensions are increasingly making it more challenging to access and manage TCM supply chains. This highlights the vulnerability of supply, geographical concentration of production in a small number of countries led to the international demand towards diversification of supply chains that would be potentially beneficial for long-term growth, especially for developing economies.

To build secured supply chains and limit vulnerabilities associated with geographical risk of disruption to supply chains, India needs to foster appropriate alliances through holistically designed framework that supports long term objectives with a dynamic policy framework. The use of recycled materials would also help support resilience of supply chains.

For India, International cooperation will be crucial, and a multilateral approach would be better than a bilateral one. International coordination and collaboration across supply chains need to aim to increase resilience and address the risks posed to the different segments of the chain to ward off delays and disruption. International collaboration will be helpful to increase investments in innovations, access to efficient technological advancements, to optimize the use of TCMs while promoting circular economy through recycling and reuse.

Social Economy of Transition

The transition offers a large variety of socio-economic benefits that include :

- Agricultural growth through low-cost power (for irrigation), sourced from solar panels, at remote places that are out of the power grid system
- Rural electrification with local employment generation and access to internet, enabling better access to buy/sell products and services
- Industrial development & economic growth
- Enhanced energy security and reduced cost for fossil fuel imports
- Increased employment opportunities
- Reduced health costs (reduced air pollution)
- Opportunities related to green hydrogen economy

Challenges from phasing down fossil fuel-based industries, especially coal, are concentrated in a few Eastern states, that are among the country's major coal producers and are at the same time relatively dependent on energy-intensive industries. Phasing down of coal is likely to happen at a slower pace to begin with that would allow transition with minimal adverse socio-economic impacts. For the transition of people mindset in the so-called coal belts, it is important to prepare a meticulous plan that would develop people around the affected areas for other professional avenues breaking the age-old inclinations to get into traditional industries.

Reduction in Healthcare costs

The use of fossil fuels is a major source of air pollution leading to considerable health costs.

Replacing fossil fuels, especially coal, with renewable energy sources can lead to fewer premature deaths, lower financial costs for national health systems and improved economic output by reducing the number of restricted activity days. Globally, the World Health Organization estimated that indoor and outdoor air pollution is responsible for about 7 million premature deaths every year. About 65% can be attributed to air pollution due to fossil-fuel-related emissions.

Based on data available from for Ontario, health concerns were central to the coal phase out, even more than climate concerns. Costs for the health care system were estimated at $4.4 Billion CAD in the early 2000s due to coal fired power plants.

For India, ambient air pollution is a major concern. In early 2022, Delhi topped the list of the world's most polluted major cities, pollution that is leading to a profound and far-reaching health crisis in the country.

Air pollution is the second leading health risk factor in India, significantly contributing to the country's burden of cardiovascular diseases, chronic respiratory diseases and lower respiratory tract infections. The mean PM2.5 concentration is five times higher than that recommended by the World Health Organization (10 μg/m3). As per The Energy Research Institute (TERI), Air pollution is responsible for more than 4 % of total mortality in India and more than 6% of the country's DALY (disability-adjusted life years) according to the Indian Council of Medical Research (ICMR).

Interestingly, air pollution primarily results from the industry sector and the residential sector and the respective use of coal and biomass. Contributions of the transport sector are comparatively low because of increasingly stringent emission standards. Without any changes to the current policies in India, almost 500,000 people will die prematurely due to exposure to particulate matter (PM10). This number could rise further to 600,000 premature deaths during 2030 and 830,000 during 2050, as noted by TERI.

The negative impact on human health in India would create considerable economic losses. Following current trajectory, economic losses related to health costs could increase from about USD 65 billion in 2020 to USD 660 billion in 2050. By reducing the share of coal in the power mix and increasing the share of renewables, economic losses could be reduced by as much as USD 168 billion, concluded by TERI.

Research and Development

R&D is one of the core pillars of a sustainable RE journey. It is imperative that India's RE journey is strongly supported by a dedicated, dynamic and innovative national research policy.

A few eminent institutes may be identified that have necessary resources, competence or can be developed to exclusively focus on energy transition-related missions. Accelerated objectives must be set with a timeline and collaborations with other institutions should be highly encouraged both at national as well as international levels. A strong industry-oriented alignment is needed to deliver commercially attractive outcomes.

Research areas that seem essential for the green transition may include:

- Solar energy panels/ systems (more efficient)
- Electric vehicles (battery technologies, like Solid-State, Graphene Batteries)
- Wind energy
- Biomass
- Sustainable Aviation Fuel
- Green maritime technologies
- Energy grid flexibility
- Power-to-X (a process that converts renewable electricity into other forms of energy, such as hydrogen, synthetic natural gas, or liquid fuels)
- Carbon capture and storage
- Carbon capture and utilization
- Further innovation for Pumped Storage Hydropower (currently, PSH global installation ~ 200 GW that is more than 94% of world's energy storage)
- Alternative cement
- Artificial Intelligence (AI), Internet of Things (IoT) in the context of smart buildings & cities
- Circular Economy (e-waste management will become a critical issue. India is projected to produce large solar panel waste and absence of large-scale recycling facilities poses environmental risks)

Most of the advanced countries have invested in such R&D activities with a strategic goal which are being supported by both Government as well as private sector. Innovative development and operating models must be explored to attract private sector participation, including allowing FDI in such efforts with major equity participation, if necessary.

Stability of Policy regime

Stability in the policy regime is imperative to build confidence among the investors. However, Indian RE sector witnessed several flip-flops over the years and some of them are as follows:

Renewable Purchase Obligations (RPOs) mandate that a certain percentage of electricity distribution companies' (DISCOMs) power supply must come from renewable sources. However, these targets have been revised frequently for various reasons that adversely affect project return expectations.

Net metering allows consumers to generate their own electricity and feed excess power into the grid, receiving credit for it. Changes, in the feed-in tariff or imposing restrictions on the amount of power to be fed, can discourage homeowners and businesses from investing in solar. Also, changes in feed-in tariffs, which guarantee a certain price for renewable energy fed into the grid, have also been subject to change, which also led to disputes with developers.

Changes in GST rates on RE equipment and components also affect project profitability.

Government must recognize that a stable and predictable policy regime is imperative for investors to make long-term investment decisions.

Funding the Transition

Globally, investment in energy transition assets has accelerated significantly, rising from about US$1.2 trillion in 2020 to over US$2 trillion in 2024. It is estimated that almost three times as much a year would be needed in the second half of this decade to meet Paris Agreement targets.

Faster RE transition needs access to latest technology and adequate funding for which, it is estimated by E&Y that India would need investments of US$150 to 200 billion annually. Several avenues may be followed to garner funds such as green bonds, green deposits, green taxonomy, favorable disclosure norms under the securities law, etc.

Conclusion

India's clean energy transformation offers a compelling opportunity for investment and economic growth, potentially making the sector one of the largest economic opportunities in the past decade. With ambitious renewable targets, significant investments in grid infrastructure, and a burgeoning electric transportation sector, India has the potential to reshape its economy while addressing pressing environmental challenges.

India's green energy sector, encompassing renewables, electric transportation, and power T&D, presents compelling investment opportunities, supported by favorable government policies, with a growing domestic market. Investors, however, are cognizant of potential challenges such as policy changes, technological disruptions etc.

India's values and traditional practices inherently align with circularity which aligns with her entrepreneurial spirit and innovative drive, provide the opportunity to integrate circularity into economic growth strategies and fostering innovation across critical sectors—such as agriculture, water, energy, and manufacturing. This would help advancing India's energy transition and climate goals while generating new employment opportunities.

The government, private sector, academics, and Indian population need to stage a concerted effort and collectively drive this transformation, transitioning the country for a sustainable and prosperous future.

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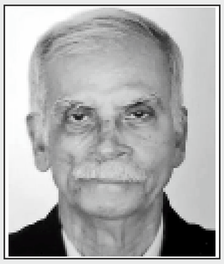
Hyacinth: Can it become a source of energy

- Bishnupada Bhattacharya and Nikhil Khedkar



Bishnupada Bhattacharya is a Mechanical Engineer with a special interest in Thermodynamics. He graduated in 1970 from Jadavpur University. He designed and operated a variety of power plants in India and abroad for 46 years, from 1971 to 2016. While working, he returned to study and earned a Masters degree in Sanskrit at Pune University. Presently, he works as a consultant to improve and design new power plants. In addition, he teaches postgraduate engineering courses at Pune University.

Introduction:

Years ago, I was a visiting faculty member at Savitribai Phule Pune University, teaching at the postgraduate (M.Tech) level. Coincidentally, my paper on using water hyacinth for power generation, written for my colleague Nikhil, aligns with this year's alumni group's focus. This paper combines our understanding with various other sources. We used water hyacinth for our thesis before completing the academic curriculum. Now, we present the nature of water hyacinth with more experiments and insights from others. This article combines our previous understanding with additional details and perspectives from others, and is now credited to me and my student Nikhil Khedkar.

<u>What is water hyacinth and where are they found?</u>

Water hyacinth is a perennial aquatic plant found *mainly* in freshwater bodies. It is an attractive flowering plant with glossy leaves and beautiful violet flowers. This plant survives in extreme environmental conditions. It is present in regions/areas with temperatures of 10 to 43 oC, pH of 2 to 12, and high nutrient content waters with total nitrogen content of 160 mg/L and total phosphorus content of 32 mg/L.

Water hyacinth is one of the fastest-growing plants, which can double in number in 6-18 days under optimal conditions. This plant reproduces by sexual as well as asexual means. Vegetative propagation is important for its proliferation by stolons or runners producing daughter plants. Its seeds remain viable for 6-20 years, making it difficult for complete eradication. Due to its high growth rate, the yield of water hyacinth per hectare per year on a wet basis is around 270-600 tons. Water hyacinth contains 90-95% water by weight; therefore, on a dry basis, it yields between 13.5 – 66 tons per hectare per year. *The water* hyacinth may rise up to 1 meter above the water surface, and it has bulbous green eaves, 6-10 in number, 10-20 cm in size, and a dense mat that expands by 60 cm/month. Due to its noxious nature, it is enlisted in the world's 100 most invasive species and in the top 10 worst weeds.

Figure1: Water Hyacinth

<u>When was water hyacinth known to the world?</u>

It is possible that what we call water hyacinth was present for a long time before anyone took serious note. Presently available information indicates it was known in various areas of the world, as shown in Table 1.

Table 1: Period of Water Hyacinth known to different regions.

Country	Period
North America	1800
Africa	Early 1900
Europe	1930
China	1900

Hyacinths have both positive and negative aspects

Water hyacinth, which is causing a menace to atmospheric and water ecology, can be treated with the bio-methanation pathway, yielding high methane-rich biogas. Various studies have been carried out to understand the impact of this aquatic body on the environment, ecology, and economy in various regions of the world.

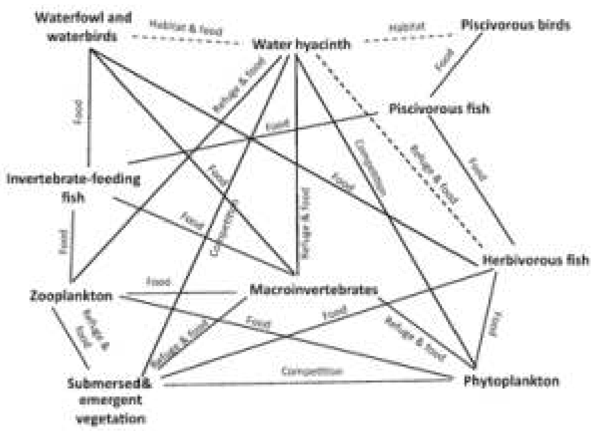
The Negatives:

- While this element has been used in various ways, it has negative impacts such as clogging of waterways, fishing activities, breeding grounds for pests and diseases, reduction of water quality, and loss of biodiversity.
- Water hyacinth disrupts water transportation by forming thick mats that cover the surface of water bodies, thus preventing people's access to school, communication, health facilities, fishing grounds, and even the local market. Sometimes, when the level of backwaters increases, the presence of water hyacinth causes a severe impact and challenge to the residents.
- The presence of water hyacinth in water leads to excessive water loss due to a very high evapotranspiration rate. It is known that the water evaporation rate in the presence of water hyacinth is 3.5-10 times greater than the normal evaporation rate in open water sources. This has also been experimentally validated by us at Pune University during our research.

  With the available data on infested water sources in Pimpri Chinchwad Municipal Corporation, Maharashtra (PCMC), we have estimated the water loss due to evapotranspiration. By assigning an economic value to the water, the monetary loss due to evaporation is presented in the table below.
- Water hyacinth excludes native vegetation and associated fauna. It creates threats and imbalances in the water ecosystem.
- An ecological study indicates that water hyacinth affects both the light and nutrient availability for photosynthesis in phytoplankton and other submerged vegetation. Thus, without natural control, water *hyacinths* can outcompete phytoplankton and other submerged vegetation.

  The diagram below illustrates the change in ecological interactions in the presence of water hyacinth. Once dead, the plant submerges in water, and its decomposition leads to a reduction in dissolved oxygen. This also causes a severe impact on fish, etc.

Figure 2: Interaction within an ecosystem with an established non-native water hyacinth population. Solid lines represent relationships between ecological components (i.e. energy flow and habitat use). Dashed lines represent potential relationships that have yet to be documented.



Water hyacinth, wherever available in any form, if not utilized properly, will create a threat to the people living nearby. Our main challenge is to use water hyacinth to do some good and reduce the problems discussed above. Even our economy is impacted by water hyacinth, so more emphasis has to be given to utilizing it so that it does not cause harm but helps us create some value out of it. Our lives will be easier if we understand all the nuances and use them for positive aspects, which are

Water Evaporation Kohler Method (mm/month)	Water Evaporation Kohler Method (m/year)	Water loss due to water hyacinth pe unit area per year (m3/m2/year)	Water Price 30 Rs/m3. Total Economic Loss per unit area per year (Rs/m2/year)	As per 2019 data Total Water Hyacinth infested area in PCMC	Total Water loss due to water hyacinth (m3/yr)	Economic Loss (Rs. Cr/yr)
149.5	1.8	17.9	538	2725960	48913536	147

Table 2: Water Loss due to water hyacinth.

described in the following section.

The Positives:

- Water hyacinth as a phytoremediation agent: Water hyacinth absorbs various types of pollutants, including heavy metals present in water, which is why it was introduced in Nigeria for water pollution treatment. It also absorbs minerals and inorganic substances, finding its application in drinking water pre-treatment.
- Water hyacinth is used for biogas production: Laboratory experiments indicated that the methane content of biogas is enhanced when water hyacinth is added along with cow dung into the biogas digester. Table 2 illustrates the enhanced composition of biogas.

Table 3: Composition of Biogas produced from Cow dung and Cow dung+ water hyacinth

Name of Gas	Typical Composition of Biogas (%)	Cow dung + Water Hyacinth (%)
Methane (CH_4)	55-65	91.1
Carbon Monoxide (CO)	0.1	1.34
Hydrogen Sulphide (H_2S)	Traces	1.11
Carbon Dioxide (CO_2)	27-45	0.02
Trace Gases (Oxygen, Nitrogen, Hydrogen)	18-20	6.43

- It has been established that the average biogas production from water hyacinths is in the range of 245 L/kg TS or about 20 L per kg of freshwater hyacinth. Other literature cites that 4000 L of gas per ton of semi-dried WH was obtained with a methane content of 64%.\n\n1.
- Water hyacinth is used for making fuel briquettes along with cow dung. The figure below shows a water hyacinth briquette. Briquettes with water hyacinth to cow dung ratios of 80:20 and 70:30 have densities of 1296 kg/m^3 and 1157 kg/m^3, respectively. The calorific values of the briquettes prepared with different quantities of binders are found to increase when higher proportions of binders are used. The same is reflected in the table below.

Figure 3: Water Hyacinth Briquette

- Various other applications of water hyacinth include the production of pulp, paper, rope, baskets, and various other handcrafts, such as mulch in fields, and as a feedstock for animals. Figure 4 shows the same.

Figure 4 : Applications of water hyacinth.

Analysis of water hyacinth for Power generation

As the electricity requirement started increasing more and more due to an increased population and mechanization for various reasons, the conventional fuel for power plants started becoming less and less. At one point, it was found that the water hyacinth, because of its chemical characteristics, can also be used as fuel. With an understanding of water hyacinth now, its use for power generation has started. It can either be used as a standalone fuel or as a co-fuel.

Based on the calorific value of different fuels, the

Combustion parameters	Binder ratio 10%	20%	30%	40%	50%
Thermal fuel efficiency (%)	19.67 ± 0.23d	21.82 ± 0.35c	23.67 ± 0.21b	31.24 ± 0.48a	31.73 ± 0.93a
Calorific value (Kcal/kg)	3563 ± 76.94e	3791 ± 83.15d	3864 ± 41.03c	4195 ± 32.96b	4281 ± 90.78a
Ignition time (min.)	73.54 ± 3.37e	88.27 ± 1.23d	93.54 ± 3.82c	114.37 ± 4.12b	123.42 ± 3.47a
Burning rate (g/min)	2.25 ± 0.01a	2.01 ± 0.03b	1.89 ± 0.04c	1.71 ± 0.02d	1.63 ± 0.02e

Table 4: Combustion characteristics of water hyacinth briquettes and binder properties

quantity of fuel required for generating one kWh (one unit) of electricity is calculated as indicated in Table 5. When a water hyacinth briquette with a calorific value of 3400-3600 kCal/kg is used, 0.72-0.76 kg of water hyacinth (dry basis) is required to generate one kWh of electricity.

This means setting up a 300-kW power plant with 0.22-0.23 TPH of water hyacinth (dry basis). To cultivate this quantity of water hyacinth, approximately 224 hectares of land is required. Please refer to Table 5 for the various cases considered. This land need not be continuous but can be spread in the area near the power plant station from where it can readily be made available to the power plant.

Here are a few final thoughts to conclude this article. Financially, power generation from water hyacinths may not be very attractive today. However, considering the nuisance it creates and the proper use we are discussing, it is important to take the subject forward enthusiastically.

Table : Different fuel quantities required for producing 1 kWh (1 unit) electricity (kg/kWh), the quantity of fuel required for setting up a 300 kW power plant (TPH) is calculated considering plant heat rate of 2600 kCal/kWh.

Type of Fuel	Fuel	CV (kCal/kg)	Fuel required per unit power generation (kg/kWh)	Fuel required per hour for 300 kW plant (TPH)
Solid	Cow Dung Cake	2090	1.24	0.37
Solid	Water Hyacinth 1	3400	0.76	0.23
Solid	Wood 1	3441	0.76	0.23
Solid	Coal1	3500	0.74	0.22
Solid	Water Hyacinth 2	3600	0.72	0.22
Solid	Wood 2	4700	0.55	0.17
Solid	Coal2	6000	0.43	0.13
Liquid	Ethanol	7098	0.37	0.11
Liquid	Kerosene	7680	0.34	0.1
Liquid	Diesel	10707	0.24	0.07
Liquid	Paraffin	10994	0.24	0.07
Liquid	Petrol	11472	0.23	0.07
Gas	Coal gas	2330	1.12	0.33
Gas	Gobar Gas	3770	0.69	0.21
Gas	LPG	11017	0.24	0.07

Table 6: Calculations to determine the area required for the cultivation of water hyacinth for setting up a 300 kW thermal power plant with different total solid contents (TS) and different production yield per hectare.

Description	Unit	Values					
Capacity of Power Plant	kW	300					
Plant Heat Rate	kCal/kWh	2600					
Total input energy required per hour	kCal/h	780000					
Fuel 1 : Coal		Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
CV	kCal/kg	3700	6000				
Coal required per unit power generation	kg/kWh	0.70	0.43				
Coal required per hour	TPH	0.21	0.13				
Fuel 2 : Water Hyacinth							
WH mass wet basis per hector per year	kg/hector.year	270000	400000	600000	270000	400000	600000
WH mass wet basis per Sqm per year	kg/m2.year	27	40	60	27	40	60
Total Solid contents of WH	%	4	4	4	11	11	11
WH mass dry basis per Sqm per year	kg/m2.year	1.08	1.6	2.4	2.97	4.4	6.6
CV of Water Hyacinth	kCal/kg	3400	3400	3400	3400	3400	3600
WH required per unit power generation	kg/kWh	0.76	0.76	0.76	0.76	0.76	0.72
WH required per hour	TPH	0.23	0.23	0.23	0.23	0.23	0.22
Area required to cultivate water hyacinth required for generating one unit electricity	m2	0.71	0.48	0.32	0.26	0.17	0.11
Area required for 300 kW Plant crop)Area to be harvested per hour)	m2	212.42	143.38	95.59	77.24	52.14	32.83
Total area required for 300kw plant	hector	186.08	125.60	83.74	67.66	45.67	28.76

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