THE ENERGY CONSORTIUM
IIT MADRAS

An Institute of Eminence Center

ANNUAL REPORT 2024

Accelerating Net Zero

www.energyconsortium.org

The Energy Consortium, IIT Madras Annual Report 2024
Accelerating Net Zero

Jan 2025

Edited By: Nikhil S Tambe, Deepa Maria Alexander, Swetha Vedasubramaniam

Design: Shivom Agency Pvt Ltd

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ANNUAL REPORT 2024

PREFACE

Prof. Raghunathan Rengaswamy

I am really happy to write this short note for the Annual Report of The Energy Consortium. It seems like yesterday when we discussed the formation of an Energy Consortium at IIT Madras in the ICSR 2nd-floor Conference Room. The idea of The Energy Consortium was based on the significant faculty strength and expertise in the general area of energy across various departments at IIT Madras. Personally, another motivation for me was the desire to demonstrate a Consortium model for industry-academia interaction that all Centres of Excellence at IIT Madras could follow. There are several successful Consortiums in the West, however, in India, this has not been a successful model for various reasons. The Energy Consortium was designed to address these challenges, and the results indicate that it is indeed possible to build a successful Consortium in an academic institution in India. One of the critical choices made was to hire a CEO for the Consortium right at the beginning and this has been a game-changer. The support from our IITM alumni has also been incredibly impactful and heartwarming. Far beyond our original expectations, the Consortium now has industry members from different verticals, several multi-crore projects, top-notch publications, the lead role in the Australia-India Centre for Energy (AICE), and membership in global climate action collectives. I assume many of these accomplishments will be highlighted in this report and I wish this Energy Consortium continued success and growth.

Dean, Global Engagement, IIT Madras
Marti Mannariah Gurunath Institute Chair Professor, Department of Chemical Engineering, IIT Madras
Fellow, Indian National Academy of Engineering (INAE)
Chair-Advisory Council, IIT Madras Zanzibar

FOREWORD

Prof. Satyanarayanan Seshadri

When we set up the advisory group consisting of a few alumni and faculty to conceptualise the Energy Consortium, we had three clear goals. One was to enable and bring in faculty to work collaboratively on projects with potential disruptive impact. The second was to co-create the consortium with the industry and be relevant to the overall strategic objectives. The third was to be present in relevant forums and have a voice in policymaking. The Energy Consortium is now a thriving centre with active participation from at least 20+ faculty members and their postgraduate students, delivering over 50 patents and 300 publications. We now support the post-graduate (IDDD MTech) program at IIT Madras, the Joint MTech in Energy Systems with Kathmandu University and the joint M.Sc. program in Sustainable Energy Systems with the University of Birmingham. Consortium faculty have also established five start-ups and are working to build more with partners in the eco-system.

Faculty members from the consortium have also been very successful in engaging the industry and leveraging the platform we have created to raise more grants to establish foundational centres like the Hydrogen Valley. We have alsodeepened collaboration with some industry members to extend research projects and set up joint centres such as the Shell IITM Centre for Energy Research (SICER). The consortium's 8 Centres of Excellence (CoEs) work across six hubs (Hydrogen, CCUS, Energy Efficiency, Microgrids, Renewable Energy, and Microgrids) focusing on over 25 research thrusts including micro-modular nuclear reactors (MMR). Recognising the need for science-backed policymaking, the climate action tool (CAT) was conceived by our faculty and developed as an open-source tool to help accelerate the net-zero transition. CAT is being designed as a ground-up tool that allows self-consistent models to be built of components (such as boilers, furnaces, etc.) used in industry, aggregation on models to construct firms, aggregating them further to create industrial sectors and a collection of sectors to form a national output. This sets CAT as a one-of-a-kind tool that policymakers can use to study the impact of specific incentives or penalties. It also allows the research community to delve deeper into the levers of decarbonisation and prioritise the most impactful for both the longer and shorter timeframe, aligning with our national goals.

In this first performance summary report of the Energy Consortium, we are happy to present the scientific outcomes and technological progress we have enabled in pursuing global net-zero goals. However, we also recognise that this is just the first step and that significant efforts are needed to realise some goals fully. We will strive towards scaling our efforts to be a global centre of action in this initiative with our ears to the ground and goal in sight.

Head, Energy Consortium
Shell Chair Professor, and Head Shell IITM Centre for Energy Research
Associate Head, School of Sustainability
National coordinator, Kotak IITM Save Energy Mission (KISEM)
Associate Professor, Department of Applied Mechanics and Biomedical Engineering

RING SIDE VIEWPOINT

Prof. Mahesh Panchagnula

The Consortium is leading the transition to net zero through technology and accelerating the rate of adoption of new technologies. This makes The Energy Consortium the country's preeminent Energy organization.

When we think of developing net zero technologies and innovation then there is no better microcosm of the world than India. It is the crucible of every kind of test situation that a technology would experience in the entire world. We have pockets in India that are so well developed that they would possibly mimic any Western European context, and then there are also pockets of India that are very green and forested remote islands providing a context of other parts of the world. As a microcosm we believe, this is a great place to come and experiment with technologies that would help the whole world become net zero.

The idea of net zero and climate change is a very unique problem that is been posed for the first time in our civilizational journey. Never has mankind experienced a global scenario that requires a global solution with survival at stake. This presents us with a situation where we really have to look at technologies in a global context with adoption and efficacies of technologies also in a global context and India is providing that kind of context. Technologies that are either developed in India or those that are developed elsewhere but test-bedded in India will provide the right kind of feedback and answers for the world context.

At IITM we have been focused on energy-related technologies for several decades and the overall ecosystem that we have put together, in terms of faculty, in terms of research infrastructure, innovation culture, and the student-driven ecosystem are all the reasons why one will see energy research going that much farther.

We have had faculty members at IITM working on power electronics and solar PV for decades. We have had people working on wind energy and ocean and tidal energy which is unique to IITM. There are not many people in India working on this. This kind of ecosystem is where we have multifaceted research activity coupled with a culture that emphasizes the translation of that research from the lab all the way to where some stakeholders in the field will see the benefit and create a large-scale impact. That's the reason why we believe IIT Madras and The Energy Consortium will actually make a difference in the broader context of how these technologies will be adopted in the world.

The main driving role of a Consortium is to bring together stakeholders from different technological areas, to solve the more vexing and perplexing problems, such as accelerating net zero. Energy consortium provides a forum where all different faculty can come together, think through their technology areas and the underlying challenges, and go that extra mile of taking technologies from the lab, and deploying them in the field for end-user benefit. That crucial piece of bringing together stakeholders under a single roof and helping provide an extended platform for translating lab research into technologies that society can benefit from are the two main asks from the Energy Consortium

I am quite confident that we will see a difference even in a very short period of time!

Professor, Dept. of Applied Mechanics and Biomedical Engg.
Chairperson – Governing Board, Energy Consortium
Dean (Emeritus), IIT Madras
Head, Centre for Sports Science and Analytics

RING SIDE VIEWPOINT

Dr. Nikhil Tambe

The Energy Consortium was established three years ago with the vision to become the largest hot spot for advanced research and innovation in energy in the world! It was the perfect opportunity given the momentum that was developing around energy transition around the world, and was in the backdrop of the announcement of the India's nationally determined contributions made by honorable Prime Minister Shri Narendra Modi at the Conference of Parties (COP) 26 meet of the UNFCCC in 2021 in Glasgow, that have been christened the 'panchamrit' and essentially have become the guiding beacons as national goals and objectives in India's own quest to mitigate climate change related challenges for itself and across the world.

The Energy Consortium was also built on the backdrop of the Institute of Eminence initiative at IIT Madras as part of which were identified 7 centers of excellence in various energy domains as exemplary centers for conducting world class research and technology development work and they were further encouraged to coalesce under a common single coalition umbrella that encompasses energy generation, conversion, storage, distribution and utilization.

A key element that transformed it into a formidable consortium was the aggregation of industry partners and government organizations to drive collective action in the development and deployment of technology. It was truly and ambitiously decided to create and deploy technology solutions for India because solutions demonstrated at scale in India would go on to become technology solutions for the world. We have completed inducting our tenth and final founding members at the start of the calendar year and have since decided to expand the format by inducting upto two more core members. The eleven industry partners are representing geographies in North America, Europe, Middle East, and Asia, as well as sectors such as O&G, mining, construction material, refineries, transportation and the digital realm.

We are bringing out this first annual report in our third year and take the opportunity to chronicle some of the exemplary contributions and success stories from industry members, faculty and students affiliated with the Centers of Excellence that have justified the objective and also made the entire Consortium family proud of being able to drive a common agenda on the world stage.

The year 2024 has marked many firsts for us and there is no clear way to pick favorites but it is healthy to witness us grow, in two forms, one with our signature TRENDsetter program that has now 16 active research projects with 24 faculty members involved from over 8 departments at IIT Madras. The second growth indicator for us in the form of the addition of the eighth Center of Excellence on Wind Energy, the expansion of our boundaries of operation outside India with the formation of our first chapter that is based at our IIT Madras Zanzibar campus and the large delegation of 24 members that we flew to Melbourne, Australia for conducting our flagship Energy Summit in collaboration with Deakin University. Also, it has been a year with many of our colleagues taking up new leadership assignments and making it to our 'Energy People on the Move'!

It is exciting times ahead for sure and we look forward to continuing the collective vision that has enabled academia-industry-government collaborations to Accelerating Net Zero!

CEO – The Energy Consortium, IIT Madras
Adjunct Faculty, Dept. of Applied Mechanics, IIT Madras
Co-Founder - Arantree Consulting Services Pvt Ltd
Advisor – Green Transition Alliance India
Academy Expert – India Energy Storage Alliance
Adjunct Faculty, Dept. of Mechanical Engineering,
BITS Pilani-Hyderabad

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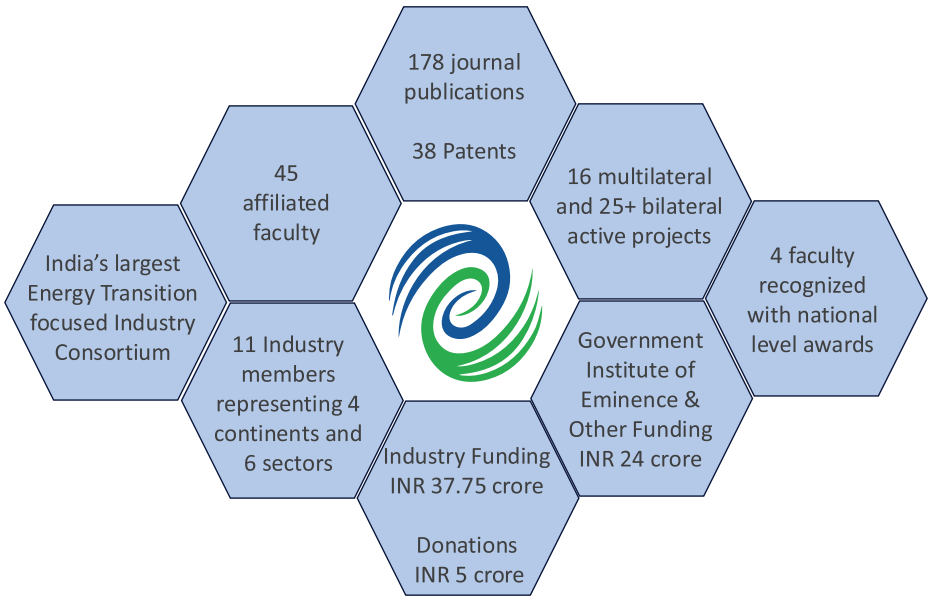


The Energy Consortium is helping accelerate net zero for hard to abate and hard to electrify sectors.

We are a Channel for Technology Translation, licensing and start-ups creation.

Leading as an Institute of Eminence

The Energy Consortium at IIT Madras is a recognized Institute of Eminence Center and an umbrella effort that brings together global industry, academia and government to collaboratively take on grand challenges in the energy domain to accelerate net zero solutions. We firmly believe that technology solutions when deployed at scale in India will become technology solutions for the world.

We have eight research initiatives that span the whole spectrum of energy generation, storage, conversion and distribution. They will pursue cutting-edge interdisciplinary research and forge global networks to address India's energy challenges. The core expertise areas include carbon capture and storage, gas hydrates, coal and biomass conversion to useful chemicals, renewable energy systems, wind energy, energy storage technologies beyond lithium, distributed energy management including for AC and DC microgrids, and electrolyser technologies for CO2 conversion and green hydrogen generation. We have active participation from more than 50 IIT Madras faculty, with significant technology expertise and demonstrated contributions on the world stage. In addition, we have over 250 postgraduate students (PhD and MS) and about 20-30 post-doctoral fellows working in various domains related to energy research.

IIT Madras offers industry partners greater research productivity and an innovation ecosystem that is unparalleled in comparison to peer institutions globally. The Energy Consortium has ten global energy majors as its founding members who are funding and advising on the strategic research directions aligned to the broader energy transition agenda and the national net-zero targets. These include Shell, Baker Hughes, FLSmidth, Cummins, Aditya Birla Group, Infosys, Chevron, Chennai Petroleum Corp Ltd, Technip Energies, NLC India Ltd and Aramco.

In addition, the Energy Consortium draws upon the global linkages incubated by IIT Madras. Specifically, it has taken the responsibility of being the India lead in establishing the Australia India Center for Energy (AICE). The AICE will work towards achieving UN Sustainable Development Goal 7, which seeks to "ensure access to affordable, reliable, sustainable and modern energy for all" specifically in strategic areas such as critical minerals, clean technology, education and innovation. .

The Consortium is a strategic partner to help incubate and groom technology that is in the discovery and feasibility stages and to assist those in the pilot demonstration levels through use case scenario validations and techno-economic studies geared to understand scaling and commercialization aspects. The idea is to enhance and accelerate the R&D efforts of the consortium members on topics of mutual interest/ benefit by partnering with IITM.

The three broad outcomes envisaged by the Consortium are:

- Stakeholder engagement, encouraging responsible choices for energy solutions
- Methodologies for transparent and clear metrics such as achieving reduction in GHG emissions and addressing sustainability development goals overall
- Preparing future leaders with diverse perspectives, who would be capable of navigating the cultural rewiring that comes about from a sustainable energy-dominated future.

Centers of Excellence

Advanced Gas Turbine Engine Technologies

Prof. Muruganandam TM

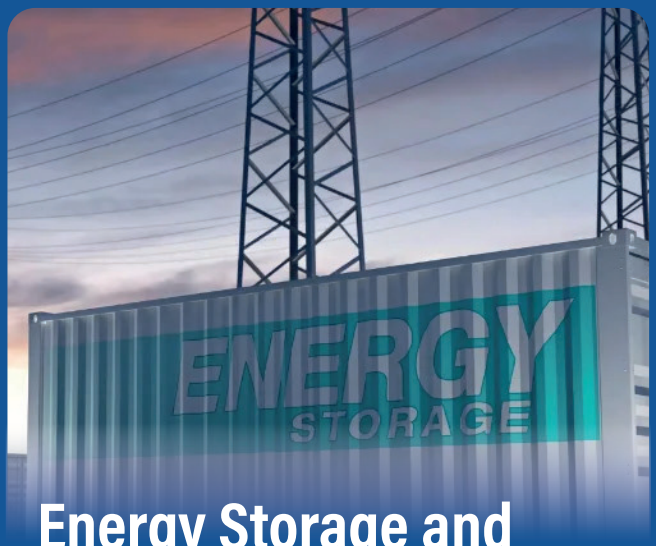
The Center focuses on advancing technologies for next-generation gas turbine engines that enhance efficiency and reduce carbon emissions. Key areas include combustor designs for hydrogen and sustainable aviation fuels, advanced thermal management systems, high-performance seals and rotors, and hybrid-electric propulsion components while addressing key challenges such as higher combustion temperatures, increased flow velocities to prevent flame flashbacks, enhanced safety measures, and advanced thermal management. The team is also working on high-temperature seals, high-rpm and high-pressure capability rotors, and innovative electrical machines that serve as both starter motors and generators. By developing these technologies and establishing dedicated test facilities, the Center aims to make the country self-reliant in hydrogen-powered gas turbine technology.

Carbon Capture, Utilization and Storage

Prof. Rajnish Kumar

The Centre is driving innovation in carbon dioxide capture, utilization, and storage technologies to address global climate challenges. In CO_2 separation, projects include calcium looping, solid adsorbent-based capture using advanced materials like MoFs and amine-based composites, and physical solvent and hydrate-based processes for high-pressure mixtures. These efforts employ a multiscale approach, from atomistic simulations to pilot-scale demonstrations. In CO_2 utilization, the focus is on catalytic hydrogenation for converting CO_2 to methanol or hydrocarbons, direct conversion to olefins, and the development of catalysts and reactors for selective and scalable reduction. Given the challenges in immediate large-scale CO_2 utilization, the Centre also emphasizes safe storage methods, including deep-ocean sequestration, leveraging natural analogs like methane hydrates to ensure long-term stability. This comprehensive approach aligns with global efforts to meet Paris Agreement goals.

The Energy Storage and Conversion Center at IIT Madras focuses on developing novel materials and methods to address challenges in lithium-sulfur (Li-S) battery technology and photovoltaics. In Li-S batteries, the Center aims to overcome limitations such as dendritic growth of lithium metal during charging, dissolution of lithium polysulfides into the electrolyte, and enhancing sulfur loading at the cathode. In photovoltaics, the emphasis is on creating organic and hybrid organic-inorganic perovskite solar cells with high power conversion efficiencies, low production costs, and improved stability against atmospheric degradation. By innovating in these areas, the Center seeks to advance energy storage and conversion technologies for both commercial and space applications.



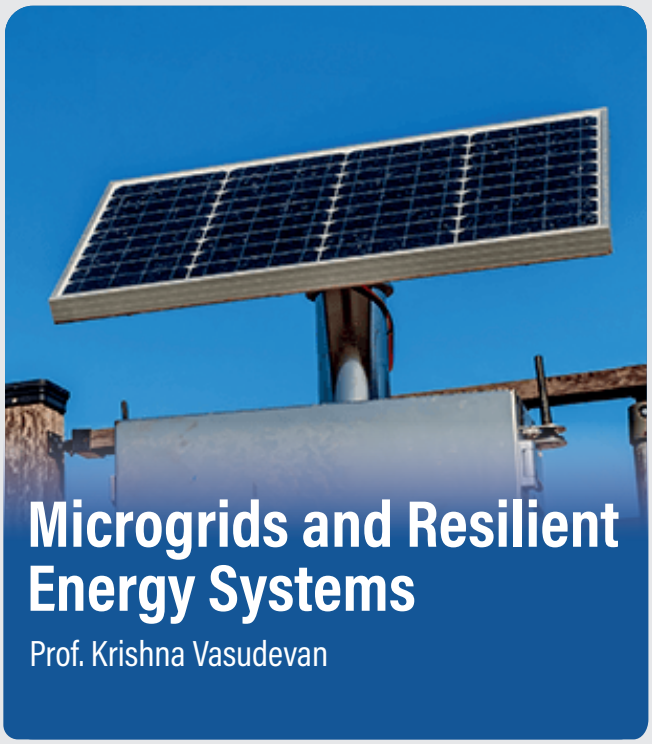
Energy Storage and Conversion

Prof. Kothandaraman R

Photo-and Electro-Chemical Energy

Prof. Aravind Kumar Chandiran

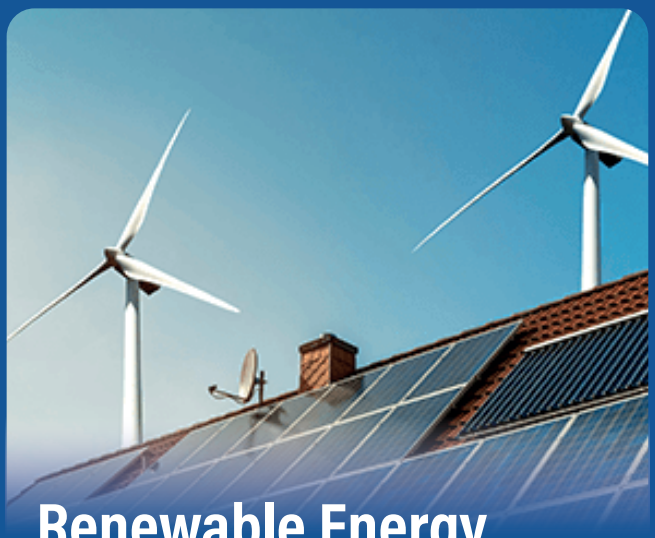
The Center for Photo- and Electro-Chemical Energy Sciences at IIT Madras focuses on developing advanced energy storage and conversion technologies. Key research areas include polarization electrochemistry for solar fuel generation and mechanically rechargeable metal-air batteries for electric vehicles. The Center aims to create efficient catalysts for water splitting to produce hydrogen fuel and to design high-energy-density metal-air batteries utilizing abundant resources like aluminum and zinc. By integrating these technologies, the Center seeks to promote sustainable energy solutions and reduce dependence on fossil fuels, contributing to India's energy security and environmental goals.



Microgrids and Resilient Energy Systems

Prof. Krishna Vasudevan

The Center is advancing the next generation of microgrid technologies by focusing on collaborative, multi-source power systems. Moving beyond traditional diesel-dominated grids, it explores integrating diverse capacity-level sources with innovative control and management strategies. A key emphasis is on developing efficient, high-power-density power electronic interfaces, along with primary control methods and protection strategies, to seamlessly connect multiple energy sources. The Center also prioritizes resilience through novel energy storage solutions and the integration of marginal capacity sources, including low-head water turbines, low-speed wind systems, steam-based generation, and waste-to-energy technologies. Decentralized control approaches are being investigated to reduce dependency on communication infrastructure. Leveraging emerging power electronic devices like SiC and promising GaN technologies, the Center aims to enable compact, efficient, and robust microgrid systems for sustainable energy solutions.



Renewable Energy Enhancement

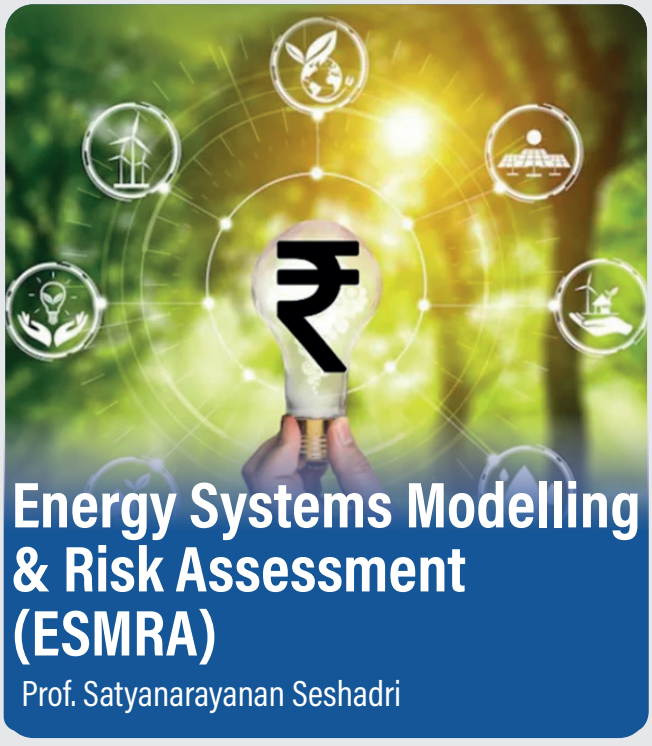
Prof. Satyanarayanan Seshadri

The Renewable Energy Systems project at IIT Madras focuses on accelerating the adoption of renewable energy (RE) in India's commercial complexes. With solar and wind energy costs now competitive with coal, the project aims to develop commercially viable mechanisms enabling approximately 40,000 commercial complexes to transition entirely to RE. This initiative emphasizes integrating energy storage solutions to manage the intermittent nature of solar and wind power, ensuring a reliable 24/7 energy supply. By promoting large-scale RE deployment, the project seeks to reduce dependence on fossil fuels, decrease greenhouse gas emissions, and position India as a global leader in sustainable energy practices.

India aims to achieve 302 GW of wind power in the near future, which requires new ideas and technologies suitable for our conditions. The power from a wind turbine is competitive in comparison to other sources. This new Center tackles the full spectrum of wind power, from rooftop turbines bringing clean energy to remote locations to large-scale offshore wind farms. The Center will also emphasize research into both onshore and offshore wind energy innovations, aiming to advance technological solutions that maximize energy generation efficiency and minimize environmental impact across diverse geographical landscapes.

Jaisri and Venkat Rangan Wind Energy CoRE

Prof. Chandramouli P



Energy Systems Modelling & Risk Assessment (ESMRA)

Prof. Satyanarayanan Seshadri

The research goals of ESMRA are broadly a) to leverage data-driven analysis and quantitative modeling in optimizing India's energy transition and decarbonization strategy, b) to generate novel insights that drive energy efficiency and material circularity in India's industrial sectors, c) to determine the optimum ways of balancing CO_2 emissions targets with operating costs and viability, and d) to quantify climate-induced risks to critical assets and devise mitigation solutions. In alignment with these goals, the ESMRA group is undertaking efforts to develop a state-of-the-art framework - the Climate Action Tool (CAT)

Demonstrators and New Lab Facilities

Mobile Carbon Capture and Storage (CCS) Unit

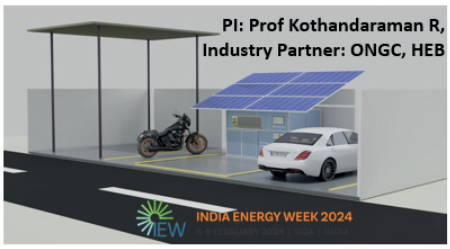
Prof. Rajnish Kumar

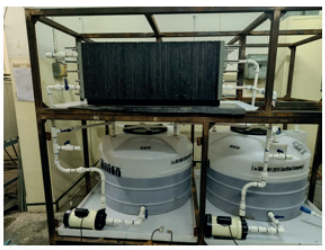
We have developed a cutting-edge mobile Carbon Capture and Storage (CCS) unit with a capacity of 10 kg/hr CO_2 capture. This fully automated unit showcases India's capability in scaling up CCS infrastructure, a crucial step towards achieving the nation's net-zero emissions goal by 2070.

The mobile CCS unit incorporates both solid-based adsorption (using zeolite) and liquid-based absorption technologies, offering valuable insights into their respective performance and potential. The unit's indigenous development encourages innovation and fosters a vibrant ecosystem of startups focused on developing novel CCS techniques. In addition to capturing CO_2, this fully automated unit regenerates the material and stores the CO_2 for further use or sequestration.

The mobile CCS unit serves as a valuable research and demonstration platform, enabling hands-on experience and advancing the understanding of CCS technologies in India.

5 kW/10kWh Vanadium Redox Flow





Vanadium Redox Battery: Advancing Energy Storage Solutions

Prof. Kothandaraman Ramanujam

The Energy Consortium-IIT Madras , in partnership with ONGC and High Energy Battery, successfully showcased a Vanadium Redox Battery at India Energy Week 2024. This collaborative effort exemplifies the Consortium's commitment to fostering industry-academia partnerships for the development and deployment of advanced energy storage technologies in India. Prof Kothandaraman was felicitated with the Researcher of the Year at India Energy Storage Week 2024 for this innovation.

Green Hydrogen Microgrid

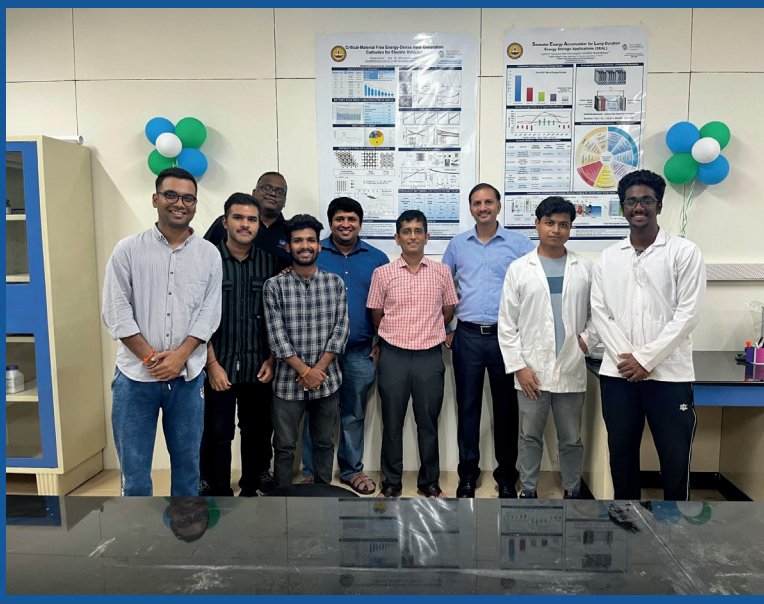
Prof Aravind Kumar Chandiran

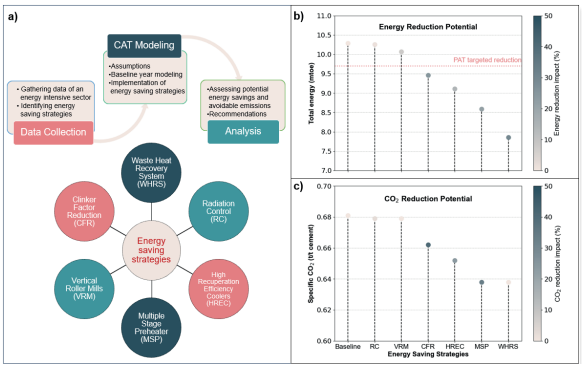
IIT Madras, in collaboration with Indus Towers Limited, commissioned a state-of-the-art Green Hydrogen Microgrid at the Chemical Engineering Laboratory. This initiative represents a significant milestone in our commitment to decarbonization and the adoption of clean energy solutions. Designed to power common areas of the laboratory building, the microgrid serves as a modular field test rig for small-scale electrolyzers and fuel cells. It supports research into techno-economic assessments, the Levelized Cost of Hydrogen/Energy (LCoH/E), and provides a platform for teaching and demonstration purposes. As India transitions towards renewable energy sources, the ability of hydrogen to offer long-duration energy storage makes it an essential component of decentralized energy systems. This project underscores IIT Madras' dedication to pioneering sustainable energy technologies and fostering innovation for a greener future.

BAT Lab – Advancing Battery Technologies

Prof Nitin Muralidharan

The Battery Analysis & Testing Lab (BAT Lab) at IIT Madras, part of the EMERGE R&D Group, is now fully operational. It focuses on advanced battery technologies, including novel cathode and anode materials for Li, Na, and K chemistries, metal batteries, solid-state architectures, and battery recycling. Inaugurated at IIT Madras Industry Day by Dr. Hariprasad J. Subramani (Chevron), Prof. Satyanarayanan Seshadri (Shell Chair Professor), and Dr. Nikhil Tambe (CEO, Energy Consortium), the BAT Lab symbolizes The Energy Consortium's commitment to innovation and sustainable energy solutions. The facility benefits from continued support from the Chemical Engineering Department, IIT Madras, ICSR, and The Energy Consortium.





Advanced Gas Turbines

Prof Muruganandam T M

The Advanced Gas Turbine Technology Development Center is a state-of-the-art facility that drives innovation for sustainable aviation. Focused on reducing carbon emissions, the Center develops cutting-edge technologies, including combustor systems for hydrogen and SAF, next-gen thermal management, advanced seals and rotor dynamics, and hybrid-electric components. Leveraging advanced manufacturing techniques, it aims to address complex design challenges and foster collaboration between academia and industry for the future of aviation.

High-pressure Hydrogen/H_2-HC blend GT combustor: The combustor is designed to operate at a pressure of 10 bar and a temperature of 300°C, with an airflow rate ranging from 0.15 to 2 kg/s. It accommodates fuels such as CH_4, CNG, and H_2 blends in varying proportions (0–100% of each gas) for combustion up to 10 bar under gas turbine engine (GTE) conditions. The rig has been assembled, with the flow control system currently being set up, and testing scheduled as the next phase. It includes optical diagnostic capabilities for a single-sector combustor under GTE conditions. The combustor is housed in the National Centre for Combustion R&D at IIT Madras - one of the largest academic combustion centers in the world.

Climate Action Tool

Prof Satyanarayanan Seshadri

CAT is currently being used to perform rigorous techno-economic assessments of sectors that are especially relevant to GHG-emissions and Climate Change, including Cement and Steel Manufacturing, Power, Refineries, Petrochemicals, Aluminium, Fertilizers, and Agricultural & Urban Systems. In particular, the goal of these assessments is to leverage multi-sector models to derive unique insights for improving energy efficiency and increasing material circularity while reducing GHG-emissions and operational costs.

Preliminary analyses using cross-sector models of the Cement, Steel, and Power sectors show that for reducing overall emissions, switching to Natural Gas from Coal is preferred over Green Hydrogen due to lower operational costs. In the Steel industry, this also indicates a transition towards steel production using the Direct-Reduced Iron (DRI) method. On the other hand, CAT reports that the optimum CCUS pathway is sequestration in the power and cement industry. However, due to constraints on the sequestration capacity, CCUS must eventually involve the conversion of carbon dioxide to grey methanol.

Publications in 2024

Advanced Gas Turbine Engine Technologies

multi-jet electrospray propulsion

Prof Pravendra Kumar
Prof TM Muruganandam

Energy Systems Modeling and Risk Assessments

Hybrid cooling, heat pump, AI4NZ, Environmental modeling

Prof Santosh Kumar Sahu
Prof Satya Seshadri
Prof Preeti Aghalayam
Prof Raghunathan Rengaswamy

Microgrids and resilient energy systems

Energy markets, cyber-security, smart grid control, grid connected inverters, DC-DC converters, ML

Prof Arun Karuppaswamy B
Prof Krishna Vasudevan
Prof. K. Shanti Swarup
Prof. Lakshminarasamma N

Photo- and Electro-chemical energy sciences

Double Perovskites, photoreduction of CO2, Bilayer Porous Electrocatalysts

Prof Aravind Kumar Chandiran
Prof Raghuram Chetty

Renewable energy enhancement

Biomass pyrolysis, Catalytic Copyrolysis, Microwave-assisted torrefaction, hydrothermal liquefaction, Multiphase Reactor Simulations

Prof Himanshu Goyal
Prof Varunkumar S
Prof Vinu R
Prof Rajnish Kumar
Prof. Dhiman Chatterjee

Carbon Capture

Prof Jitendra Sangwai
Prof Jithin John Varghese
Prof Rajnish Kumar
Prof Swapna Singha Rabha

Sequestration /Storage

Prof Jitendra Sangwai
Prof Rajnish Kumar

Utilization

Prof Niket Kaisare
Prof Preeti Aghalayam

Others

Prof Himanshu Goyal
Prof Swapna Singha Rabha
Prof Jitendra Sangwai
Prof Niket Kaisare
Prof Jithin John Varghese
Prof Preeti Aghalayam
Prof Rajnish Kumar

Hydrates, methane, hythane, hydrogen storage, CO2 sequestration, amine solvents, bio-diesel

Energy Storage

Prof Kothandaraman Ramanujam
Prof Nitin Muralidharan
Prof Raghuram Chetty
Prof Venkatakrishnan P

Energy Conversion

Prof Aravind Kumar Chandiran
Prof Kothandaraman Ramanujam
Prof Nitin Muralidharan

Zinc-ion, vanadium redox flow, fuel cells, membranes, ammonia, formate, solid state batteries, supply chains

Publications

White Paper Series: Accelerating Net Zero

As per the Ministry of New & Renewable Energy data, India, at the end of 2023, became 4th globally in Renewable Energy Installed Capacity, 4th in Wind Power capacity and 5th in Solar Power capacity. We recognize that the time has come to elevate our mission. We must transition from enabling progress to actively accelerating the realization of a Net Zero future. Together with our partners in industry and government, we can ensure that Net Zero is not just an aspiration, but an imminent reality for India and the world. Building on our vision, we are now in mission mode, fully dedicated to Accelerating Net Zero at the Energy Consortium. This commitment is reflected in our new mission statement and our revised strategy of advancing research in clean energy sources, including offshore wind, green hydrogen, green fuels, and large-scale industrial electrification, while intensifying our efforts in carbon capture, utilization and storage.

In this short series, we bring together five seminal topics that are going to shape how we accelerate achieving net zero. The authors discuss an overall roadmap and an ambitious vision to reach Net-Zero in India by 2047 through an analysis of Environmental, Health and Economic Benefits. We explore through two topics the role that will be played by carbon dioxide capture technologies and its centrality to achieving net zero, as well as the role of green ammonia in this journey. In addition to the role of technology, it is also important to unlock the decarbonization potential through a critical analysis of the various GHG contributors and systematically reducing not just Scope 1 & 2 emissions but also Scope 3 emissions. One topic is therefore specifically on exploring the strategies required for addressing Scope 3 emissions. Finally, in this short series, we also through our fifth topic explore the key enablers for financing climate change and the role of public-private partnership.

Contributions to Energy Policymaking

The Energy Consortium-IIT Madras actively contributes to shaping energy policy in India with technological and innovative inputs. It also fosters a skilled workforce through comprehensive skilling, reskilling, and upskilling programs, enabling informed and impactful energy policy decisions.

HYDROGEN

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Green Hydrogen: Leading the Charge on Future Renewable Fuels

Hydrogen has emerged as a potential key player in the energy transition, garnering increased attention in recent months. While the primary goal is to rapidly reduce greenhouse gas emissions, it is now clear that the transition away from fossil fuels is more complex than envisaged.

However, renewable energy growth over the past couple of decades, particularly in India, has enabled more aggressive actions towards sustainability. India ranks 4th and 5th globally in wind and solar capacity, respectively, with new policies supporting further expansion. The economic viability of these sources has significantly reduced electricity production costs, and this affordability opens up opportunities to leverage renewable energy in innovative ways, including the production of hydrogen through electrolysis. Hydrogen's potential applications are vast, particularly in hard-to-abate and hard-to-electrify sectors, offering promising solutions for decarbonization efforts.

The Global 'Mission Innovation'

Countries worldwide are developing 'hydrogen ladders' to identify optimal applications and assess hydrogen's viability across sectors. Mission Innovation[1], a global initiative comprising 23 countries, aims to make clean energy accessible and advance the Paris Agreement's goals. Its Clean Hydrogen Mission targets reducing hydrogen costs to USD2/kg by 2030 through advancements in production, handling, transportation, and storage. India's National Hydrogen Mission aspires to make the country a global hub for green hydrogen production, usage, and export. As India pursues its goal through this mission, addressing storage and transportation challenges without compromising economic feasibility is crucial. Research at the Energy Consortium by IIT Madras (IITM) is exploring these aspects to support the mission's broader objectives.

Win-win Benefits

Hydrogen boasts the highest calorific value among fuels, but suffers from poor volumetric energy density due to its gaseous nature. Liquefaction, requiring high pressures (>13.1 atm) and low temperatures (<33 K), is necessary to improve this density. However, storage and transportation under these conditions are challenging and expensive.

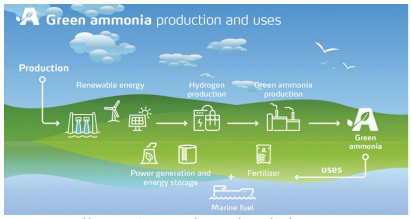
Hydrogen carriers offer an alternative. Promising options include methane (25 wt% H2), ammonia (17.6 wt% H2), and metal hydrides (<12.5 wt% H2). Green ammonia, produced through electrochemical nitrogen reduction, is particularly promising due to its high hydrogen content, ease of liquefaction (240 K at atmospheric pressure), and existing global infrastructure.

[1] https://mission-innovation.net/

IITM Initiatives.. contd from pg 21

Compared to liquid hydrogen and metal hydrides, electrochemically produced ammonia can be synthesized, stored, and transported in near-ambient conditions. It can be directly combusted with zero carbon emissions or cracked into hydrogen when needed. This process is more eco-friendly than steam methane reformation, which releases tons of carbin dioxideinto the atmosphere.

Green ammonia production uses renewable energy, supporting green hydrogen initiatives. It can be produced centrally using nitrogen and water, then shipped to where hydrogen is needed. Ammonia cracking can be done chemically at 673-873 K, with research ongoing for ambient electrochemical cracking.



Source: https://www.weforum.org/agenda/2021/01/green-ammonia-stop-fossil-fuels/

The versatility of hydrogen across various applications such as power generation and chemical processes can further help bring down these sectors' carbon footprint. These factors make ammonia a viable candidate for large-scale hydrogen storage and transport in a decarbonized energy system.

Our research faculty at IIT Madras (IITM) are contributing to the national green hydrogen mission in multiple ways. We have ambitions to set up a Hydrogen Resource Hub at our Discovery campus. These efforts are already underway and will see us establishing the capability to evaluate a typical hydrogen application by mimicking the entire value chain on a pilot scale. We are planning to study green hydrogen production with transportation as one sector in mind, and are collaborating with Hyundai for this initiative. There are other numerous active research activities exploring the use of sea water electrolysis, solid oxide electrolyzer cells as well as hydrogen as a fuel, at IITM.

Susstains Engineering, an IITM-incubated startup, recently won ArcelorMittal's XCarb®[2] challenge for their unique approach that proposes biochar as an alternate to coal used in blast furnaces for steel making. XCarb® is designed to bring together all of ArcelorMittal's reduced, low and zero-carbon products and steelmaking activities, as well as wider initiatives and green innovation projects, into a single effort focused on achieving demonstrable progress towards carbon neutral steel. Alongside the new XCarb® brand, ArcelorMittal has launched three XCarb® initiatives: the XCarb® innovation fund, XCarb® green steel certificates, and XCarb® recycled and renewably produced, for products made via the Electric Arc Furnace route using scrap.

[2] https://corporate.arcelormittal.com/climate-action/xcarb

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Capacity & Capability Building

IWTMA
INDIAN WIND TURBINE MANUFACTURERS ASSOCIATION

Special Issue
Indian Wind Power
A BI-MONTHLY MAGAZINE OF INDIAN WIND TURBINE MANUFACTURERS ASSOCIATION
indianwindpower.com

OCT - NOV 2024
VOL. 10 • ISSUE 4

AUTHORS

Torben Kirkegaard, founded Energy and Climate Academy in 2013. He has worked in post-graduate education since 1980 in companies such as Grundfos Pumps and Ørsted, as well as university colleges.
Energy and Climate Academy offers courses in various areas connected to the green transition and has customers from many different countries, including the USA, most of Europe, and China.

Nikhil Tambe is the Chief Executive Officer for the Energy Consortium at IIT Madras. He oversees development of industry-academia-government collaborations with a core focus on technologies that will enable the energy transition towards a low carbon future.

Rahul Muralidharan's research lies in the intersection of energy-environment linkages and its outcomes on society and sustainability. He has a PhD in Conservation Science and Sustainability Studies. He is currently a Research and Development Specialist at the Energy Consortium, IIT Madras.

Why Timing Is Essential In Capacity Building For The Offshore Wind Industry In India

Investing in a Workforce That is Trained and Ready

The offshore wind (OSW) industry faces many challenges in the future, where an increasing number of wind farms will be installed all over the world. New technologies, changing weather conditions, grid connection and operation and maintenance, just to mention a few will require huge investments in research and development.

India's ambitious target of achieving 30 GW of offshore wind energy by 2030 presents significant opportunities and challenges. The transition to offshore wind energy is critical to India's broader strategy to enhance its renewable energy capacity and reduce its carbon footprint.

However, there is a topic that must evolve and grow even faster: Education, training, re-skilling, up-skilling, on-the job training, post-graduate education, capacity building, and competence development – you pick your favourite. Reaching the ambitious targets requires substantial investments in infrastructure and more importantly a skilled workforce equipped to handle the complexities of offshore wind projects.

CSR Funded Projects

Project Name	Partner	Principal Investigator
Development of a 250 W Compact Polymer Electrolyte Membrane (PEM) Fuel Cell Stack	SCHAEFFLER	Raghuram Chetty
Kotak IITM Save Energy Mission	kotak	Satyanarayanan Seshadri Mahesh Panchagnula
Net Zero Rural Home	aspire SYSTEMS attention. always.	Satyanarayanan Seshadri
CCHP on Fuel Cells	Johnson Controls	Satyanarayanan Seshadri
Ladakh Heatpumps	Baker Hughes	Satyanarayanan Seshadri
Green Hydrogen Microgrid	indus TOWERS	Aravind Kumar Chandiran
Hydrogen-powered marine vessel	Avalon manufacturing your success	Nikhil Tambe
Hydrogen resource hub	HYUNDAI	Aravind Kumar Chandiran

TRENDSetter PROGRAM

The Energy Consortium is a recognized Institute of Eminence Center at IIT Madras. It is an umbrella initiative that spans the whole spectrum of research in energy generation, storage, conversion, and distribution. We are an industry-academia-government collaborative effort established with the aim of accelerating the development of technologies that shall enable the energy transition towards a low-carbon future.

As per the charter of the Consortium, a fair portion of the industry membership funding is intended for exploratory and collaborative research that enables the Energy Consortium to become one of the key technology hubs. The TRENDsetter program aims to identify a few areas aligned with the long-range research initiatives of the industry and build capability within the Consortium.

The Energy Consortium invited a team of faculty members to submit a crisp proposal aimed towards Exploratory R&D and Fundamental research that enables breakthrough innovation. It is anticipated the work done through this grant will enable the faculty teams to develop follow-on larger proposals for external funding. Industry and institutional partners can be identified and enabled by the Consortium.

Research on Industrial Carbon Efficiency

Santosh Kumar Sahu : My project aimed to contribute to understanding the industrial energy consumption, particularly focusing on CO_2 emissions that were computed using a bottom-up approach. This allowed us to determine how much emission a specific firm generated during production and linking those findings to emission standards and classifying them as high energy or high carbon intensive. From there, the concept of carbon productivity was examined.

For example, if a firm produces 100 items while consuming 20 units of energy, it achieves an energy intensity of 5 items per unit of energy. Similarly, another firm may produce 120 items with the same energy consumption, resulting in an intensity of 6 items. Here, the second firm is more efficient. The energy efficiency could have been achieved by many means like altering energy mix, optimizing material usage, increasing production while maintaining the same energy usage, … But for an accurate measure, understanding carbon efficiency is necessary. I proposed measuring carbon productivity by evaluating the output generated per unit of CO_2 emitted. This approach assigns a value to carbon emissions, prompting discussions on potential carbon pricing.

One of the key conclusions we've reached is that we need to establish a price for carbon. Additionally, firms that are effectively engaging in carbon mitigation should receive incentives from the government to encourage broader participation in this market. We also need to integrate the concept of circularity by identifying technologies that can help mitigate carbon emissions. Estimating the social cost of carbon is crucial, which includes evaluating health outcomes related to pollution and understanding the associated costs.

Another challenge is reaching a consensus on an appropriate carbon cost, which necessitates extensive consultations with various stakeholders. Companies are unlikely to pay for emissions simply because they exist; they need to be engaged in policy discussions that highlight the implications of their pollution. We should be able to create regulations that offer incentives for adopting new technologies and practices.

One of the most rewarding aspects of this project has been the academic rigor. We've had multiple project meetings to track our progress, with regular monthly updates on our activities – something that's not common in most projects. Additionally, I've had the opportunity to present the preliminary results at about seven conferences, and two manuscripts are currently in the process of being published in academic journals.

For researchers from non-technical backgrounds, it provides an opportunity to learn about technology. This understanding will help create synergy and industries begin to recognize the value of involving economists in their projects.

TRENDsetter offers a highly structured research platform and each project benefits from diverse insights by a heterogeneous group of participants. It fosters a sense of community among all awardees in a cohort. This reliance on knowledge transfer is invaluable, as experts from different disciplines come together, share their expertise, and address technical questions collaboratively. The time-bound nature of the projects adds to the challenge but also emphasizes the importance of continuity.

Guidance from industry partners, elevates our research beyond pure academics, ensuring it has practical applications.

The upcoming cohort should aim to set clear, achievable milestones within a one-year timeframe, as even a small delay can impact the project. Maintaining continuity in research activities is crucial. Even marginal progress in our work is significant, especially since industry funding sets high expectations and is crucial for continuing support to future TRENDsetter initiatives.

My research focuses on three key areas. First, I'm continuing my work in energy economics. Second, I'm delving into climate change economics as part of a climate economics course. Lastly, I've started exploring institutional economics and its implications for climate issues.

Specifically, I'm examining how corruption can explain energy-related carbon emissions and inefficiencies. The absence of effective regulations due to corruption leads to higher emissions and hinders progress toward sustainable development goals. I am trying to see if it is an issue of institutional structures, corporate governance, or purely economic factors? This inquiry is guiding my understanding of institutional economics and the economics of climate change.

Additionally, I'm exploring technology validation through the lens of behavioural economics. My PhD student and I are working on a project focused on, how to encourage acceptance of new technologies, such as microgrids, solar PV, water management systems, …

Since the last decade, energy related research has deepened significantly. Numerous research papers have been published, making it one of the most prioritized Sustainable Development Goals (SDGs). Energy is critical, particularly for a country like India that relies on imports. This raises the question: can renewable energy serve as a safeguard for India's future energy demands? Consider a scenario where oil supplies are suddenly cut off due to geopolitical tensions. In such a case, renewables become essential. To address this, we need robust, competitive and affordable energy technologies that leverage our geographical advantages.

However, a crucial gap exists between technologists and economists. While there's extensive laboratory work happening, we need more focus on the economics of energy technology and how it can be integrated into viable government policies. Interdisciplinary research is key to addressing energy challenges effectively and accelerating the transition to sustainable solutions. Given IIT's strength in technology, we have the opportunity to merge energy technology with economics, generating valuable insights for public policy that can ultimately support governments to create a roadmap for future development.

Research Towards Transforming India's Battery Manufacturing Landscape

The main charter point of the Energy Consortium is to focus on exploratory and collaborative research. The TRENDsetter program is one such initiative with an aim to identify the long-range research initiatives of the industry and build capability within the consortium to address it. Faculty members are invited to address industry challenges, and eight were chosen for the first cohort in 2023.

Nitin Muralidharan, Assistant Professor, Department of Chemical Engineering details his research on Low to Zero Cobalt Nickelate Cathodes for Modern Lithium-Ion Battery Applications

Lithium-ion batteries remain the dominant technology in electric vehicles. The cathode part of the battery represents about 60% of the total cost, making it the most critical and value-adding component in battery manufacturing. If we can optimize the cathode, we can significantly reduce the overall cost of the battery. One of the main goals of the research was to develop new cathode materials for lithium-ion batteries, specifically cobalt-free or low-cobalt, and nickel-rich formulations. This is in alignment with India's national mission to develop indigenously produced, high-performance battery materials. Currently, India heavily imports battery-grade materials, and the goal of this research is to create formulations that can be produced locally, thus supporting the country's growing battery manufacturing infrastructure.

We explored different compositions of these materials, evaluated their performance, and selected the best-performing variants. One of the key objectives was to design processes that are compatible with commercially available methods, ensuring a smooth transition to large-scale production.

The consortia-driven approach has been highly beneficial, as it allows for real-time feedback from industry partners. This model works like an ultimate focus group, where we receive valuable inputs from the industry on the progress

and direction of the project. An industrial advisory board oversees this process, which has been a great initiative to ensure that the project aligns with industry needs and requirements.

As the battery industry continues to grow, more targeted funding for battery innovations would be highly beneficial for accelerating advancements in this critical field.

The ultimate goal of any R&D project is not just to conduct research, but to also drive development and, if possible, facilitate the implementation of the outcomes in real-world applications. The researchers should ensure that the industry partners involved are able to derive tangible benefits too This alignment with practical utility will make R&D truly impactful.

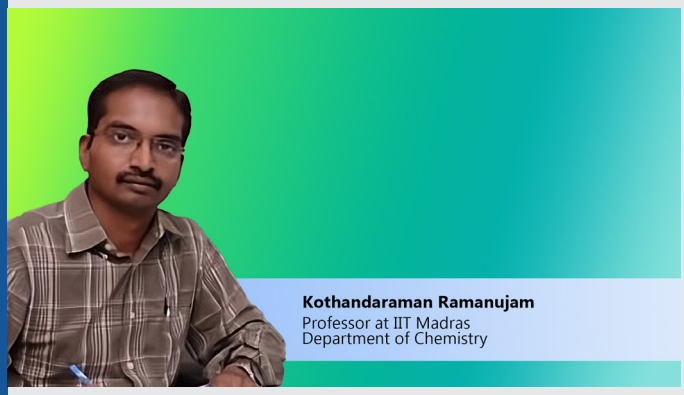
Currently, we are working on several cutting-edge areas within the battery field, including developing long-duration energy storage systems, exploring new recycling approaches, and researching alternative battery chemistries such as sodium-ion, divalent (calcium) and trivalent (aluminum, magnesium) chemistries.

One of the key aspects of my research is focused on these alternative battery systems, including sodium-ion, calcium, magnesium, and solid-state batteries. Solid-state batteries, in particular, are seen as a promising solution to some of the limitations of current lithium-ion technology. The flammable electrolyte in lithium-ion batteries is a key safety issue, and solid-state batteries, which use a solid electrolyte, can address this problem. Additionally, solid-state batteries enable the use of lithium metal as the anode, which has a much higher capacity than traditional graphite anodes, potentially leading to higher energy-density batteries. However, solid-state batteries present their own challenges, especially around the interface between the solid electrolyte and the electrodes. Unlike liquid electrolytes, solid electrolytes do not interact with the electrodes in the same way, so understanding and optimizing these interfaces is a major research focus.

While lithium-ion batteries are used for EVs due to their high energy density, for long-duration energy storage, especially renewable energy integration into the grid, requires different characteristics. For instance, with solar power, electricity is produced when the sun is shining, but we need to store that energy for use when the sun isn't available. This kind of application does not necessarily need the same high-performance standards as EV batteries. Instead, the priority is long cycle life, low cost, and durability. That's why chemistries like sodium-ion, or even alternative options like multivalent (calcium, magnesium) batteries, are being considered as alternatives for large-scale, long-duration energy storage.

As the adoption of EVs grows, we will have a growing number of batteries that will eventually need recycling. The battery recycling ecosystem in India is still in its early stages. This is very crucial because, India lacks significant domestic resources for battery-grade materials and imports most of the critical elements. The current situation is akin to buying valuable resources, using them, and then exporting the waste, which isn't ideal. We need to recycle these materials domestically, so we can fully recover the critical materials, rather than exporting them for recycling and then importing them back as finished batteries. The goal is to create an efficient, self-sustaining recycling ecosystem where recycled materials are reintegrated into local battery manufacturing, thus capturing more value from the resources we are already spending money on. We are also exploring upcycling, which means enriching recycled materials by adding fresh elements or replacing lost components to improve their quality for reuse in new batteries.

Research Towards Sustainable Ammonia Production



With concept of circular economy catching pace in industries, Kothandaraman Ramanujam, Professor, Department of Chemistry's research on Renewable Ammonia Fuel for Circular Energy Economy – A Carbon Free Approach holds good promise to decarbonize several hard to abate sectors.

Ammonia is typically produced using hydrogen generated through methane cracking, which generates carbon dioxide alongside hydrogen. This hydrogen is then combined with nitrogen from the atmosphere at very high temperatures and pressures. Maintaining these extreme conditions requires burning fossil fuels. For every ton of ammonia produced, about 30 tons of carbon dioxide are released.

Our method, in contrast, eliminates carbon dioxide production entirely. The project focuses on synthesizing ammonia through an electrochemical method using nitrogen, which is abundant in the environment. Initially, we took a theoretical approach to identify suitable 2D materials for nitrogen absorption. After selecting certain materials, we aimed to replicate their properties in experiments. While the results were not exact replicas, we were able to test the chosen materials, and we found that

one or two of them successfully produced ammonia. This process becomes green, if we can harness renewable energy for this. With the increasing focus on green hydrogen, ammonia, and green ammonia in the context of the energy transition, our work is highly relevant.

Our goal is to develop a reactor for ammonia production. We have identified the materials needed for this process, but constructing the reactor is more labor-intensive. While we've met all our project objectives, we also want to showcase a tangible product, which will take longer than the initial one-year timeframe we expected.

The aim of the project is to produce liquid nitrogen ammonia. To achieve this, we need to create a prototype that accurately mimics what occurs in the laboratory. The issue stems from the unavailability of suitable substrate materials to host the electrode materials identified for the NH3 production. We've been using simple carbon paper, which produces a lot of hydrogen alongside nitrogen and ammonia, but we need a type of carbon that generates less hydrogen and more ammonia. This specific substrate material is called glassy carbon. Unfortunately, we only have access to small electrodes, about 3 mm to 4 mm in diameter, while we require larger pieces, around 10 cm. We will continue to search for alternative substrate materials or larger glassy carbon substrate materials to build our reactors but sourcing them may take some time.

This project has allowed us to explore new materials, leading to the creation of at least two patents and two publications, which are crucial for securing larger funding and impressing the industry with our ammonia production technology. This lays the groundwork for expanded research efforts.

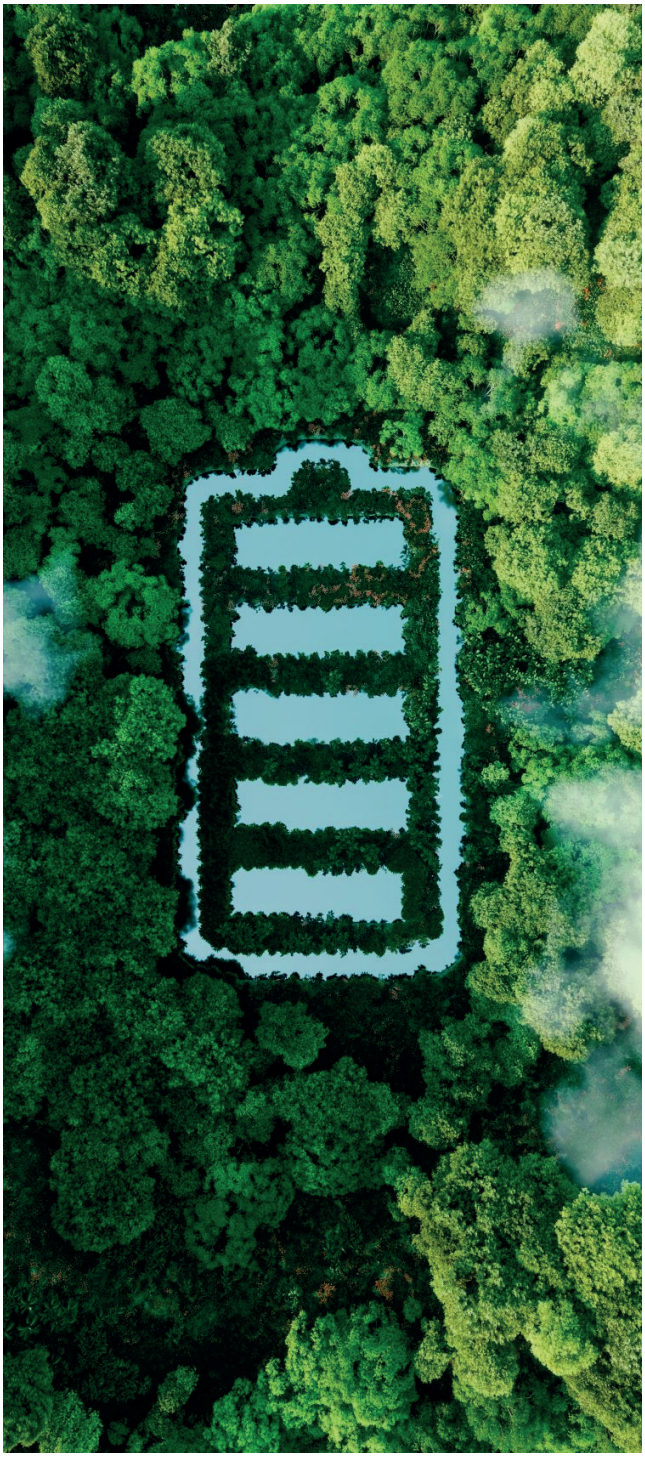
I collaborated on this with other researchers, including Professor V Subramanian from Chemistry and Professors S Ramanathan and Rajneesh Kumar from Chemical Engineering. We have had opportunities to present our findings to industry partners during events like the Industry Day organized by The Energy Consortium.

In terms of the impact, once it moves beyond the lab scale to a larger production model, it could revolutionize the ammonia industry, making it greener and more self-sufficient. With carbon and nitrogen available abundantly in the environment, industries could rely solely on electricity, preferably from renewable sources, to produce ammonia, thus transforming their supply chains and reducing dependence on external raw materials.

That said, it's important to manage expectations; while the potential is significant, we are still at the laboratory stage. Moving forward, we plan to refine our proposal for the Department of Science and Technology, GoI's call for Hydrogen and Fuel Cell research initiatives to secure further support for our research.

From the TRENDsetter program, we seek support for fundamental research. Typically, the Energy Consortium presents problems faced by industries, but in this case, we are suggesting that industry too could directly fund as well. Since the industry has already identified a problem, we can get funded for the implementable research and on the other hand, through grants like TRENDsetter, we can focus on the fundamental research part of the same project.

For example, while we already have the capability to build a reactor, its efficiency could be significantly improved with the discovery of new catalytic materials. Such a collaboration would allow us to implement our findings with the industry while still focusing on the underlying science. The intellectual property generated from this research could be directed to The Energy consortium, while the reactor development would remain in partnership with the industry. This model will benefit all, creating a win-win situation.



2024 Awardees

Dr Anita Gupta and Rajnish Kumar, Vikrant Urade, VInu R, Nikhil Tambe, Maneesh Pandey, Rahul Wagh, M S Srinivasan, Ramasubramaniam Arunachalam, Virginie LEHNING, Sagar Sourav, Hari Subramani, Pandiarajan P, Ajay Patil, Manoj Manoj Chulliparambil, John Soosaialphonse, Guhan Jayaraman, Lavanya, Mohanakrishan Logan, Richa Karmakar, Satya Seshadri, Ranjan Ghoshal, Himanshu Goyal

The Energy Consortium - IIT Madras at Indian Institute of Technology, Madras's Industry Day culminated in an enriching second day. A call for collective action was re-emphasized, and the power of partnership with the industry founding members was underscored by Director Kamakoti Veezhinathan and Dean Mahesh Panchagnula, Dean ACR, IITM in their encouraging words to the Energy Consortium. On the occasion, the first in a series of white papers under the theme Accelerating Net Zero was launched. Topics in this first release include CCUS, green ammonia, emission reductions and climate finance.

Dr. Anita Gupta delivered the keynote highlighting some of the key initiatives in Climate, Energy and Sustainable Technology (CEST) from the Department of Science and Technology as well as shared more about the newly established Anusandhan National Research Foundation that aims to seed, grow and promote research and development (R&D) and foster a culture of research and innovation.

2023: Two proposals in a high-risk high reward track and six in an early career track were awarded a total of ₹ 1,70,78,400

2024: Two proposals in a high-risk high reward track and five in an early career track were awarded a total of ₹ 1,91,00,000

FACULTY IN SPOTLIGHT

Prof. Kothandaraman Ramanujam Recognized at India Energy Storage Week 2024

Prof. Kothandaraman Ramanujam was honoured with the Researcher of the Year award by the India Energy Storage Alliance (IESA) and CES at the 2024 India Energy Storage Week. This recognition highlights his groundbreaking work on Vanadium Redox Flow batteries, including a successful prototype demonstration at India Energy Week in Goa in partnership with High Energy Battery and ONGC Energy Trust Centre. This marks the second consecutive year that a faculty member from the IIT Madras Energy Consortium's Center for Energy Storage and Conversion has received this prestigious award, following Prof. Aravind Kumar Chandiran's recognition in 2023.

Prof. Preeti Aghalayam Leads IIT Madras' New Zanzibar Campus

IIT Madras marked a historic milestone by launching its first international campus in Zanzibar, Tanzania earlier this year. This global expansion strengthens IIT Madras' commitment to delivering world-class education and fostering innovation beyond borders. Leading the campus as the Director-in-Charge is Prof. Preeti Aghalayam, making history as the first woman to head an IIT campus. Prof. Preethi Aghalayam, a faculty member of the Chemical Engineering department and an IIT Madras alumna, also serves as the Dean of the School of Science and Engineering at Zanzibar.

The academic activities commenced in October 2024, featuring senior faculty from IIT Madras alongside local academic professionals. The campus, a collaborative effort with the Zanzibar government, aims to drive impactful education and research in the region.

Prof. Niket Kaisare Takes Charge as Head of the Department of Chemical Engineering

Prof. Niket Kaisare assumed the role of Head of the Department of Chemical Engineering at IIT Madras. With a commitment to fostering innovation and academic excellence, he envisions building on the Department's strong legacy while driving impactful research and promoting an inclusive environment. His leadership aims to enhance collaboration and elevate the Department's contribution to addressing global challenges.

Prof. Jitendra Sangwai

Dr. Jitendra Sangwai, Professor in the Department of Ocean Engineering, has been inducted as a Fellow of the Indian National Academy of Engineering (INAE), one of the highest honours in the engineering field. Recognized for his pioneering research in CO_2 capture and sequestration, Dr. Jitendra Sangwai has made groundbreaking contributions, including significant publications and a patent addressing critical challenges in climate change mitigation.

As the youngest awardee from his department, Dr. Sangwai continues to contribute to academic excellence at IIT Madras, mentoring over 25 PhD scholars and collaborating on impactful research projects with leading organizations. His induction reflects the institute's commitment to advancing research and innovation in engineering.

Editorial DEBUT

Nitin Muralidharan, Assistant Professor in the Department of Chemical Engineering, has been appointed as the Editor-Elsevier Journal of Power Sources (Impact factor of 8.1). The Journal of Power Sources is a highly regarded, peer-reviewed publication by Elsevier that serves as a leading platform for researchers, engineers, and professionals to share groundbreaking studies and advancements in fields such as batteries, fuel cells, supercapacitors, and other energy storage and conversion technologies. The Journal emphasizes both fundamental research and applied science, highlighting innovations that address real-world energy challenges. Topics considered include the research, development and applications of nanomaterials and novel componentry for these devices.

ESTABLISHMENT OF CENTERS

We are committed to fostering cutting-edge research, industry partnerships, and entrepreneurial initiatives to accelerate the energy transition. By establishing strategic collaborations with global leaders like Shell, CPCL, Technip Energies, and expanding internationally through the Energy Consortium Zanzibar Chapter, we are creating a robust ecosystem for innovation in renewable energy, efficiency, and sustainable technologies. These centers and initiatives serve as catalysts for translating research into real-world impact, strengthening India's leadership in energy innovation. As we continue to build on these efforts, we remain dedicated to advancing solutions that drive net-zero ambitions.

CPCL IITM Research Cell

The CPCL-IITM Research Cell (CIRC) shall pursue to collaborate in the areas including but not limited to Core Research, Technology demonstration/s (Pilot/demo scale ranges), Start-Up Initiatives, Hydrogen Valley Innovation Cluster, Energy Consortium, student-based research activities through NIRMAAN, etc. The activities of CIRC shall be directed to effectively utilize the research potential, the capability of pre-incubation and incubation centres, relevant infrastructure, expertise and experience already existent in IIT Madras and IIT-Research Park.

Technip Energies India Innovation Hub

Technip Energies is setting up an R&D Centre at the IIT Madras Research Park as part of its India Innovation Hub. Technip Energies will work in close conjunction with the faculty and researchers at IIT Madras to collaboratively advance research and innovation thrust areas of strategic interest for driving Energy Transition.

The Shell IITM Centre for Energy Research

The Shell IITM Centre for Energy Research (SICER) continues to drive innovation and collaboration in the energy sector, marking significant milestones in its second year. By fostering a synergistic partnership between Shell and the Indian Institute of Technology, Madras (IITM), SICER has successfully initiated transformative research projects focused on renewable energy technologies, energy efficiency, and sustainable solutions. Through workshops, industry engagements, and the incubation of energy-focused start-ups, SICER is advancing academic excellence and translating research outcomes into real-world applications.

Dr. Satyanarayanan Seshadri has been appointed the inaugural Shell Chair Professor and will be vital in steering SICER's research initiatives and bridging expertise between academia and industry. As part of this initiative, ongoing collaborations are set to catalyze the incubation of energy start-ups, leveraging IIT Madras' robust entrepreneurial ecosystem. As SICER embarks on its journey, it is poised to make substantial contributions toward sustainable energy solutions, reinforcing the bond between academic research and practical industry applications while striving to unlock the full potential of this transformative collaboration.

EC Chapter in Zanzibar

The Energy Consortium-IIT Madras has expanded its global footprint with the establishment of a chapter at the IIT Madras Zanzibar Campus. This strategic move signifies our commitment to engaging with Africa and contributing to its sustainable energy future. To mark the launch, a roundtable discussion titled "Responsive Engagement with Africa" was co-hosted with the Zanzibar campus. This event brought together experts from across Tanzania, Kenya, Nigeria, and Botswana to explore innovative solutions and collaborative opportunities for a net-zero future.

The IIT Madras Zanzibar Campus, inaugurated in June, is poised to become a hub for sustainable energy research and education. The Energy Consortium's chapter at this campus will play a crucial role in driving impactful initiatives tailored to the region's specific needs and challenges.

Jaisri & Venkat Rangan Wind CoRE

As part of our ongoing efforts to advance sustainable energy solutions, The Energy Consortium-IIT Madras established the Jaisri & Venkat Rangan Wind Energy Centre of Research Excellence (CoRE) during the year. Under the leadership of Prof. Chandramouli Padmanabhan, this new centre is dedicated to pioneering advancements in wind energy technology.

The CoRE focuses on a broad spectrum of wind energy applications, ranging from small-scale rooftop turbines to large-scale offshore wind farms. By prioritizing research in both onshore and offshore wind innovations, the centre aims to develop technologies that maximize energy generation efficiency while minimizing environmental impacts across varied geographical landscapes. This strategic initiative reinforces our commitment to fostering cutting-edge research and development in renewable energy, contributing significantly to a cleaner and more sustainable future.

GLOBAL ACADEMIC COLLABORATIONS

Recognizing that energy challenges are shared across borders, The Energy Consortium, IIT Madras collaborates with global academic leaders to develop innovative, sustainable solutions. These partnerships not only uplift India's energy sector but also create pathways for global impact through knowledge-sharing and cutting-edge research.

IIT Madras – Deakin University Research Academy

The Indian Institute of Technology Madras (IITM), an Institute of Eminence in India and Deakin University, ranked among the top 1% of universities worldwide, have established a strategic research alliance to offer a Joint PhD program with research tackling global challenges in science, engineering and technology. 5 research scholars have begun their projects in Clean and Green Energy Transition. Our Energy Consortium affiliated faculty – Prof K S Swarup, Prof Kothandaraman R, and Prof Krishna Vasudevan and collaborators from Deakin are looking forward to welcoming the next cohort to their projects.

Joint MSc in Sustainable Energy Systems with University of Birmingham

The program offers a unique opportunity to study at two premier institutions, IIT Madras and the University of Birmingham, combining academic excellence with industry engagement across two countries. This interdisciplinary program focuses on energy systems and technologies to address net-zero targets, covering topics like fuel cells, hydrogen, energy storage, solar and nuclear energy, smart grids, and policy frameworks.

Students benefit from innovative curricula, hands-on industrial training, and research-led teaching by experts from academia, industry, and policy. The program includes a substantial individual research project with internationally recognized groups at both institutions, enabling participants to develop solutions for the global energy crisis.

With options to specialize through the IIT or Birmingham majority pathways, graduates gain a global perspective, advanced technical knowledge, and practical expertise in decarbonization technologies, making them leaders in the sustainable energy sector. The program commenced in 2024, with a cohort of 10 students.

University of Leeds and IIT Madras - Joint Centre of Excellence in Sustainability

In June 2024, the Indian Institute of Technology Madras (IIT Madras) and the University of Leeds, UK, signed a Memorandum of Understanding to establish a Joint Virtual Centre of Excellence on Sustainable Development (VCoE-SD). This initiative aims to enhance collaboration between the two institutions and strengthen existing connections with other Indian universities in the field of sustainable development. The Centre will facilitate joint research projects, academic activities, and exchanges of personnel and publications, fostering multidisciplinary teams to address global challenges.

Swinburne University of Technology - Strengthening Academic and Research Ties

IIT Madras and Swinburne University have built a robust partnership through collaborative research, joint publications, and knowledge exchange initiatives. Their engagement includes student exchange programs, joint doctoral degrees, and impactful academic events. Notably, the two institutions co-hosted the Responsible AI for Net Zero Workshop on the sidelines of the Energy Summit 2023 and presented at the Energy Summit 2024 on Responsible AI for Net Zero: An Australia and India Collaborative Approach towards Practice, Governance and Ethics in Energy Future.

Mobility Grant Exchanges

The Jointly Funded Bilateral Mobility Program (JFBMP) was initiated in 2024 by the Office of Global Engagement, IIT Madras, to further strengthen global partnerships. This flagship program aims to foster international research collaborations through mobility funding for faculty and students. Its key objectives include facilitating long-term student exchanges, joint research supervision, and exploring bilateral regional grants. Projects in Energy transition have been awarded to faculty collaborating with the University of Sydney, University of Hull, Deakin University, and University of Exeter.

Academic Partners

Jointly Funded Bilateral Mobility Programs - University of Hull 1st December 2023	University of Exeter- Prof Advaith S :Optimizing Building Performance with Smart Glazing: A Multi-Aspect Analysis for Energy Efficiency and Renewable Integration
Jointly Funded Bilateral Mobility Programs - University of Sydney 1st March 2024	University of Sydney - 1. Raghu Chetty: Advanced Free-breathing Direct Ammonia Fuel Cells, 2. Murugaiyan Amrithalingam: Microstructural engineering for hydrogen embrittlement resistant high-strength steels. 3. Niket S Kaisare: Carbon Capture and Recycling Technologies 4. Kothandaraman Ramanujam: Boron doped diamond based electrolysis: Giving a second life to industrial waste water 5. Shanti Swarup: Optimizing Oceans: Strategic Risk Management and Economic Modelling for Enhancing Offshore Wind Energy Systems in India and Australia – A Study on Transmission Corridor Routing, Power Trading Dynamics, and Legal Frameworks in Wind Energy Conversion
Jointly Funded Bilateral Mobility Programs - Deakin University 1st November 2023	Deakin University - 1. Chester Rebeiro: Realizing Zero Trust Security in Emerging Energy Infrastructure, 2. Shanti Swarup: Optimal Energy Management and Pricing Strategies for Microgrids Enabled by Data Analytics and Machine Learning, 3. Nithin Muralidharan: Next-Generation Lithium Batteries Enabled by Novel Ni-Rich, Co-Free Cathodes and low-cost and safe Fluorine-free Electrolytes
University of Sydney-Australia Award Fellowships 1st November 2023	University of Sydney - 15 professors nominated under the Australia Awards Fellowship 2023 from both IITM & Anna University. (11 from IITM). Australia – India R&D Energy Priority Roadmap" was launched as part of the AAF fellowship activity on 22 November 2023
AICCTP (Australian-India Cyber and Critical Technology Partnership (AICCTP) Grant Round 3, funded by the Department of Foreign Affairs and Trade.)	The Swinburne University of Technology (SUT) in partnership with the Indian Institute of Technology Palakkad (IIT Palakkad), the Indian Institute of Technology Madras (IIT Madras) and industry partners Siemens Australia and Maxbyte Technologies Singapore awarded grant for their project 'Responsible AI for Net Zero – An Australian and India Collaborative Approach towards Practice, Governance and Ethics in Energy Futures'.

Partnerships

Danish Green Alliance 8th January 2024	Green Fuels Alliance India (GFAI) is a Denmark initiative under the Green Strategic Partnership with India. The objective is to boost collaborative efforts between the two countries in sustainable energy solutions sector and advance their joint global goal towards carbon neutrality
PManifold Contract 3rd March 2023	Study and recommendations for development of internationally compatible green hydrogen standards in India
RITES 4th April 2024	Team Building and making RITES an interface with IITM and The Energy Consortium and clients on projects of Green Energy, conservation, storage, usage and sustainable combined transport solutions and providing advisory/technology agnostic Consultancy Services in the field of Green Energy Solutions in the Transport/Mobility
BEE 1st March 2024	Collaborating on research, development, demonstration, training, and knowledge exchange for Energy Efficiency and Decarbonisation Projects
Energy Efficiency Services Ltd (EESL) 23rd July 2024	Enhancing energy efficiency in Indian process industries across various parts of India by aggregating the demands for various energy efficiency technologies idnetified through energy assessment. EESL will be the implementation partner for the identified ECMs or technologies and this also involves joint initiatives in conducting targeted energy audits and DPR services on case to case basis
Tamil Nadu Industrial Investment Corporation (TIIC) 24th January 2024	Promoting sustainable growth within the Tamil Nadu State's industrial sector. This partnership aims to empower Micro, Small, and Medium Enterprises (MSMEs) by facilitating energy efficiency and sustainability practices. The collaboration will focus on joint initiatives and activities that support the implementation of these goals, and also by providing training sessions on the energy assessment via Energy Audit Tool developed by IEAC
INNOWIND 22nd September 2023	Wind Energy Innovation Collaboration between India and Denmark To support the offshore wind venture in India, this project will identify and facilitate opportunities for innovation and industry-led collaborations for offshore wind development in India, based on the transfer and positioning of Danish best practices, know-how, and innovative services and solutions. The expected results are to Support building a cluster landscape in India and to share know-how on an integrated approach to offshore wind power deployment into the Indian market.

POWERING CONVERSATIONS

The Energy Consortium is actively engaging with global partners – whether its industry, academia or government agencies – in discovering shared vision and collaborative pathways for fast-tracking technology translation. Together, we're placing emphasis on accelerating early-stage technologies and boosting those at mid-stage Technology Readiness Levels (TRL), all with a shared mission to advance the energy transition. We have been a host to many experts in the energy field during the past year and have also benefited from visiting many of their facilities and engaging in outcome-oriented dialogue.

E.ON Senior Leadership Visit

From October 29-30, 2024, senior leadership from E.ON visited the Indian Institute of Technology, Madras to explore opportunities for collaboration in energy transition, climate technology, and sustainable solutions. The visit included discussions with leaders from The Energy Consortium-IIT Madras and the School of Sustainability, as well as tours of advanced research labs and technology demonstrators at IIT Madras and the IIT Madras Research Park (IITMRP). Key focus areas included carbon capture, flow batteries, and the future of electric grids, contributing to ongoing efforts in innovation and sustainability.

PANA Holdings Chairman Daere Akobo Engages with IIT Madras

PANA Holdings recently met the team from The Energy Consortium-IIT Madras to discuss the initiatives being undertaken in collaboration with founding member companies and government partners. The focus was on scaling successful technologies from India for the African market, aligning with PANA Holdings' commitment to enhancing electricity access and promoting economic growth in Africa. The meeting was attended by Daere Akobo, Chairman and GCEO of PANA Holdings, alongside representatives from its subsidiaries PE Energy Ltd and AKD Digital Solutions. This engagement highlights PANA Holdings' ongoing efforts to foster strategic partnerships and drive transformative change in the energy sector.

Celebrating Industry-Academia Collaboration with CPCL

The Energy Consortium-IIT Madras recognizes the valuable contributions of Chennai Petroleum Corporation Ltd. (CPCL) as a Founding Member. We commend Shri Arvind Kumar, former MD of CPCL and current Director (Refineries) at Indian Oil Corporation Limited, for his leadership in fostering industry-academia collaboration and driving research and innovation. This partnership, established nearly a year ago, has expanded with the creation of the CPCL-IITM Research Cell. We look forward to continued collaboration with Shri H. Shankar, MD (in charge) of CPCL.

Shell and IITM announce SICER

The Energy Consortium-IIT Madras hosted a senior leadership delegation from Shell, including Robin Mooldijk, Rebecca Dalton McGarr, Anne O'Halloran, Ajay Mehta, and Dr. Marwa Alansary, to discuss ongoing activities at the Shell IITM Centre for Energy Research (SICER). SICER is dedicated to tackling challenges in the Energy Transition space through bilateral R&D collaboration, participation in the Energy Consortium, and fostering energy start-ups within IIT Madras' start-up ecosystem. As Shell marks its 2nd anniversary as a Founding Member, we highly value the strong and growing partnership in driving impactful energy solutions.

Danish Energy Agency Visits IIT Madras to Discuss Clean Energy

The Energy Consortium-IIT Madras hosted a delegation from the Danish Energy Agency (DEA) to explore collaborative opportunities in clean energy. During the visit, the DEA was introduced to the Consortium's initiatives, with a particular focus on offshore wind power, and discussed areas of mutual interest. The visit highlighted the potential for partnerships in knowledge sharing and research, emphasizing the importance of international cooperation in addressing global energy challenges. It marks a key step towards accelerating clean energy solutions through shared expertise and resources.

Reviewing our CCUS work with Industry Stalwarts

The Energy Consortium - IIT Madras had the special privilege of hosting some of our strongest champions and showcasing the excellent work underway with the collaborative efforts of faculty and industry founding members.

We highly value the time invested by Satish Pai, Thierry Pilenko and Vasu Guruswamy, and their mentorship, as we reviewed work on Carbon Capture, Utilization and Storage underway by Rajnish Kumar and the faculty team and on the green hydrogen initiative by Aravind Kumar Chandiran and faculty team. Discussions on the centrality of the hard-to-abate sectors and the economics of the same towards the energy transition journey were especially motivating.

IITM-Hydrogen Valley Team At DST

A high-powered team led by Prof Aravind Kumar Chandiran has been working on developing a vision of a hydrogen valley cluster that will help assess the potential for hydrogen as an alternate future fuel and a critical element in the nation's decarbonization journey. Pictured here is the group during its review at DST.

Engaging Across Borders

In conversation with the Indian Ambassador to Denmark, HE Manish Prabhat.

The recent visit to Denmark was a significant milestone in strengthening the India-Denmark energy partnership. Engaging discussions with key stakeholders, including the Indian Ambassador to Denmark, HE Manish Prabhat focused on accelerating India's energy transition, particularly in the areas of green fuels and offshore wind. The visit also highlighted the potential for Indian startups to leverage Denmark's innovative ecosystem and the role of IIT Madras in facilitating technology commercialization. By fostering collaboration and knowledge exchange, this visit laid the groundwork for future partnerships and advancements in the energy sector.

INNOWIND Project: Progress and Collaboration

The INNOWIND project marked a significant milestone with discussions centred on hybrid renewable power, hydrogen electrolyzers, battery storage at DTU, as well as power electronics and energy islands research at Aalborg University, organized by Energy Cluster Denmark across Copenhagen, Riso, Aalborg, and Esbjerg. The visit also covered marine governance with the Centre for Blue Governance, green skills academies, and sustainable ports with Port of Aalborg. Special thanks to CS Wind Offshore, Siemens Gamesa, and the Danish Energy Agency for their insights. We appreciate the efforts of Nikoline Bak and Energy Cluster Denmark for facilitating an impactful week that catalyzed key conversations and collaborations for INNOWIND.

FOSTERING INNOVATION BY LEVERAGING THE ECOSYSTEM AT IIT MADRAS

Centre For Innovation

Student Led Teams we support with funding and mentorship

Agnirath

Team Agnirath is a solar car racing team committed to driving innovation in sustainable mobility. The team focuses on designing and building high-performance solar vehicles, with a vision to lead advancements across various engineering disciplines. By competing in premier global solar challenges, Agnirath not only showcases indigenous innovations but also gains valuable exposure to cutting-edge international technologies in the sector. On October 23, the team proudly represented India as the sole Indian participant in the prestigious World Solar Challenge.

Pravahan

Team Pravahan is advancing the design and performance analysis of a hydrogen fuel-cell-powered, high-speed hydrofoiling marine vessel with semi-autonomous capabilities. This pioneering prototype aims to showcase the potential of zero-emission hydrofoiling vessels powered by hydrogen, marking a significant step towards sustainable maritime transport. By integrating hydrogen fuel technology with cutting-edge hydrofoil systems, the initiative addresses the growing global demand for eco-friendly, efficient passenger and cargo transport solutions.

The vessel utilizes hydrofoils to significantly reduce drag, enhancing both speed and efficiency, while its hydrogen propulsion system reflects a strong commitment to clean energy. Currently, the team is building a small-scale prototype to validate key design elements, including the lift and stability provided by the hydrofoils, the performance and safety of the hydrogen powertrain, and the overall operational viability for commercial applications.

Raftar

Team Raftar is a dynamic team of over 40 students from diverse disciplines at IIT Madras, united by a shared passion for automotive engineering and motorsports. Each year, the team undertakes the challenge of designing and building a high-performance Formula Student race car, with the goal of becoming the most skilled and cohesive engineering team in the country. Based at the Centre for Innovation, IIT Madras, Raftar aspires to compete on a global stage and to promote the Formula Student culture in India.

With a strong emphasis on technical excellence and innovation, the team is committed to continuous technological advancement and strives for competitive success at Formula Student events worldwide.

Startups by our affiliated faculty and researchers

TRIGeN Decarbonisation

TRIGeN Decarbonisation is a cutting-edge platform focused on reducing electricity consumption and CO_2 emissions in heating and cooling systems. Backed by research from IIT Madras and supported by INDUS DC, TRIGeN integrates renewable energy and Phase Change Material (PCM) storage to create efficient trigeneration systems. Founded by Ashish Sethi, with Prof. Satyanarayanan Seshadri, Principal Investigator leading the technical team and Dr. Kushant Uppal leading operational strategies, TRIGeN's solutions decarbonize four times faster than traditional methods. The company is committed to innovative, sustainable energy solutions for a cleaner, healthier future.

X2 Fuels and Energy

X2Fuels and Energy Private Limited is a deep-tech start-up dedicated to transforming waste into fuels through cutting-edge hydrothermal liquefaction (HTL) technology. Currently, the company's 5 Ton Per Day (5TPD) pilot plant at Tube Products of India (TPI) Avadi Campus in Chennai stands as a testament to the power of HTL technology, successfully bridging the gap from concept to reality. The team, includes Dr. Vinu R (Co-Founder and PI), Dr. S.R. Chakravarthy (Co-Founder), and Mr. Nallasivam Jeganathan (Chief Technology Officer). With a vision to expand nationwide and globally over the next decade, X2Fuels aims to drive a circular economy, advancing India's low-carbon future under its mission, "Using Waste to Fuel the Economy."

Wankel Energy Systems (WES)

Wankel Energy Systems (WES), an IIT Madras and Forge-incubated startup, is redefining energy efficiency with innovative technology. Their technologies are designed to drive sustainability and energy savings in sectors such as dairy, rubber, pharmaceuticals, textiles, breweries, food & beverages, paper, and petrochemicals. WES's mission is to help industries turn wasted energy into valuable assets, resulting in significant financial gains and improved operational efficiency. Led by Prof. Satyanarayanan Seshadri as the Principal Investigator (PI), the team is committed to pushing the boundaries of energy and sustainability, building the future of energy with versatile solutions.

Susstains Engineering Solutions

Susstains Engineering Solutions is leading the way in sustainable and pollution-controlled biochar production through its patented "Self-Sustained Controlled Oxidative Flash Devolatilization System." The startup, under the leadership of Dr. Muthu Kumar K (Founder & Product Design Lead) and guided by Prof. Varunkumar S (Principal Investigator), offers a cost-effective, high-yield solution to address inefficiencies in traditional biochar production. Targeting industries such as steel, activated carbon, and thermal power, Susstains combines innovation and sustainability to deliver eco-friendly, cost-effective solutions. Co-founders Sowmya G L (Business Strategy) and Karthik Kumar (Supply Chain Management) play key roles in scaling operations and optimizing logistics. Susstains also offers comprehensive EPC services and consulting, leveraging over 7 years of research and expertise in mechanical engineering and energy systems.

Arantree Consulting Services Private Ltd

Arantree Consulting Services, an IIT Madras-incubated startup, specializes in evidence-based decarbonization consulting and advisory services for industries, governments, and agencies. Led by Prof. Anuradda Ganesh (Managing Director & CEO) and supported by experts from IIT Madras—Dr. Nikhil Tambe (Director/Consultant), Prof. Satyanarayanan Seshadri (PI/Director/Consultant), and Prof. Santosh Kumar Sahu (Director/Consultant)—Arantree's approach is rooted in scientific analysis and deep technical expertise. The firm focuses on carbon footprint assessments, tailored decarbonization strategies, and integration of indigenous technologies to drive sustainable growth. Arantree also supports technology startups with personalized guidance, promoting responsible and impactful innovations for a low-carbon future.

Sthyr Energy Private Limited

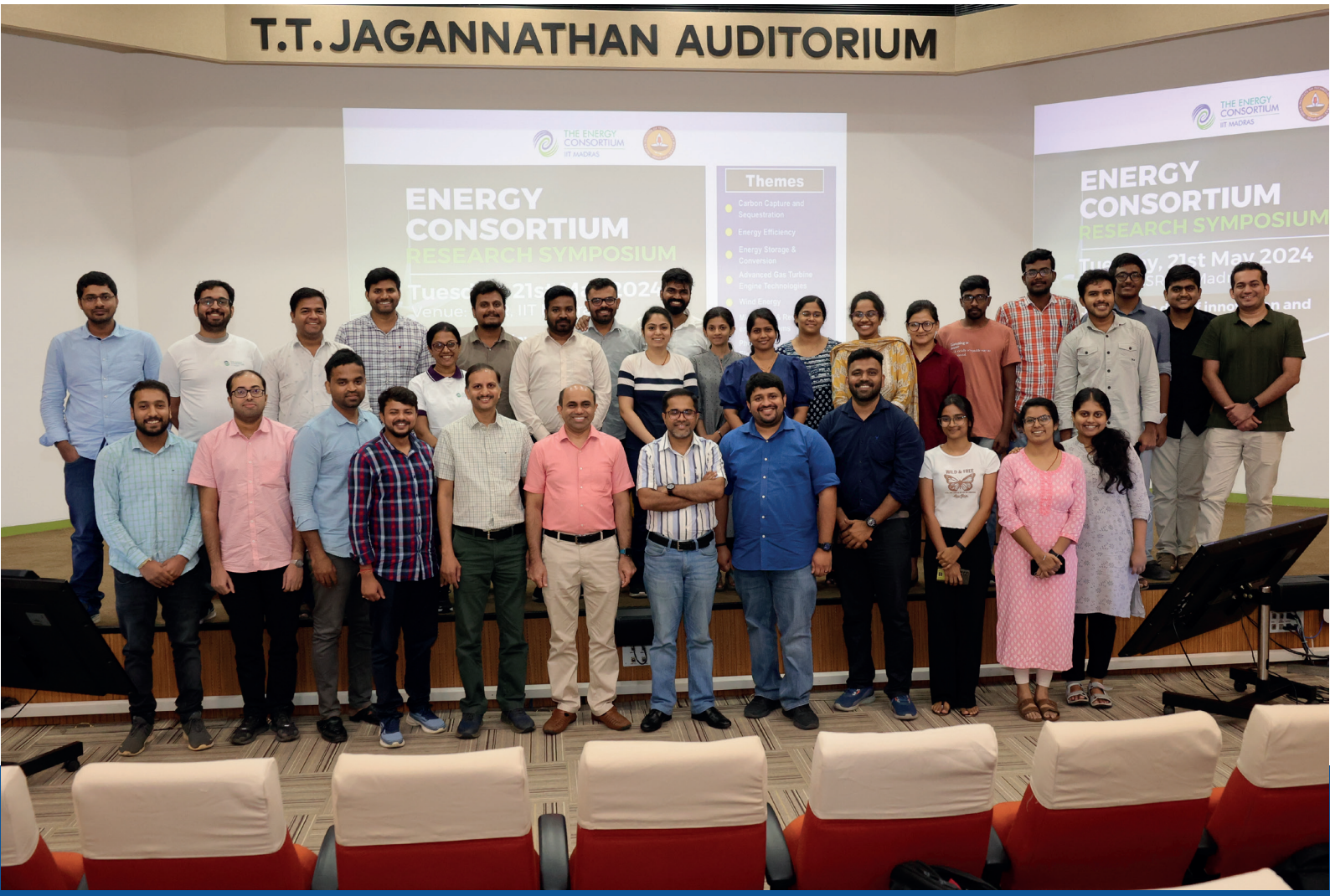
Sthyr Energy Private Limited, a startup initiated at IIT Madras, is pioneering grid-scale energy storage for renewable power through zinc-air batteries as long-duration energy storage systems.

Sthyr Energy is founded by Gunjan Kapadia, Akhil Kongara and Muhammed Hamdan all are Ph.D.s from IIT Madras. Prof. Aravind Kumar Chandiran (IIT Madras) acts as a technology advisor and Mr. Shaaji John (Ohmium) is the market advisor to Sthyr Energy.

The idea is to store excess energy in summer as metallic zinc at an energy density of 6000 Wh/l and then utilise it during monsoon and winter. The solution is low-cost, safe and completely indigenously developed which generated multiple patents. Sthyr Energy develops 200 kWh, 10 kW battery modules combined with 10 kW zinc regeneration units as modular solutions scalable up to GWh. By offering clean, high-quality, and safe energy solutions, Sthyr Energy aims to reduce solar and wind energy curtailment driving sustainability and reducing carbon emissions for a greener future.

CONFERENCES & WORKSHOPS

2024 saw us continuing our efforts towards shaping the global discourse on energy transition through a series of high-impact summits, industry engagements, and international collaborations. These events not only brought together leading experts, researchers, and policymakers but also facilitated groundbreaking discussions on decarbonization, energy storage, and sustainability. Each summit, visit, and dialogue helped refine research priorities, strengthen industry-academia partnerships, and accelerate technology deployment. From global forums on net-zero strategies to hands-on industry workshops, these engagements have set the stage for transformative advancements, ensuring that 2024 was a year of meaningful progress in the clean energy movement.



Research Symposium

The Energy Consortium-IIT Madras hosted a Research Symposium on 21 May 2024, showcasing advancements in energy transition technologies. Discussions spanned renewable energy, next-gen battery innovations, energy efficiency, and emissions reduction. Highlights included a keynote by Prof. Rajnish Kumar, an overview by Prof. Satyanarayanan Seshadri, and insightful sessions chaired by esteemed faculty and researchers. The event fostered collaboration and innovation, driving progress in sustainable energy solutions.

The event was aimed at showcasing the latest research in energy transition technologies, helping researchers explore collaboration opportunities, and connecting with IITM faculty and students who are passionate about these research areas. The symposium featured short talks and poster presentations covering various topics such as
Carbon Capture and Sequestration, Energy Efficiency, Energy Storage & Conversion, Advanced Gas Turbine Engine Technologies, Wind Energy, Microgrids & Resilient energy systems, Photo- and Electro-chemical Energy, Green Hydrogen. We had PIs of all Centers of Excellence present an overall outlook on research direction within their center and it was followed by students and scholars presenting the latest advancements in their respective areas. This served as a seminal platform for all IITM faculty and students to network and learn about each other's areas of focus within the broader energy transition domain.

Industry Day

The Energy Consortium at IIT Madras hosted its 3rd Industry Day on 27 and 28 June 2024, uniting energy leaders, startups, and academia to accelerate net-zero goals. Faculty from the TRENDsetter program and startups presented innovative energy transition solutions. Founding member companies engaged with researchers to align and refine research agendas, fostering collaboration for a sustainable energy future.

The Industry Advisory Board of The Energy Consortium - IIT Madras had, in the presence of Dr. Anita Gupta of India DST, sanctioned eight projects, three in the high-risk high reward track and five in the early career track. The projects are in areas such as Improving energy utilization, Materials for energy transition, Synthetic biology or bio-mining for energy solutions and Niche applications supporting sustainable living. We are conducting the mid-term deliverables progress check discussions this week with our industry members.

Technology Research ENgineering and Development (TREND) Setter program, or simply TRENDSetter program, is Energy Consortium's flagship program initiated in 2023 and is supported exclusively by the industry members that have funded the consortium. The program is aimed towards fostering cross-disciplinary exploratory and collaborative research and enables The Energy Consortium to become one of the key hubs in the area of advancement of decarbonization technologies and innovations. The TRENDSetter program aims to identify a few areas aligned with the long-range research initiatives of the industry and build capability within the consortium that spans the whole spectrum of research in energy generation, storage, conversion, and distribution. The program is not limited only to engineering and basic sciences but also encourages participation in economic sciences and management sciences. This is an unprecedented effort of coordinated activities in energy grand challenge areas in India.

PALS Workshop on Energy Transition Technologies

On 31 August 2024, The Energy Consortium-IIT Madras, in collaboration with PALS, hosted a workshop on Carbon Capture, Utilization, and Storage (CCUS), a key area in mitigating climate change. Over 100 students and faculty participated in this inaugural session of the "Theory to Practice and Lab Visits" series. The event featured talks and lab visits, offering insights into energy transition technologies and career opportunities, bridging academia and industry. PALS is an educational initiative by IIT alumni, supported by the IIT Madras Alumni Charitable Trust. It enhances engineering education through year-long engagements including lectures, industry visits, innovation challenges, and workshops for students and faculty.

Climafix Summit 2024

The Climafix Summit 2024, hosted by The Energy Consortium-IIT Madras and Energy Alternatives India (EAI), was held on 20-21 September 2024 at the IIT Madras Research Park. This global event brought together experts, innovators, and stakeholders to explore solutions to climate challenges. Highlights included impactful talks, pitch fests, VC interactions, and technology transfer sessions, fostering collaboration and knowledge sharing, and creating pathways for advancements in climate technology and sustainability.

The summit showcased cutting-edge innovations in clean energy, decarbonization and circular economy, paving the way for real-world implementation. It provided startups with valuable exposure to investors and industry leaders, facilitating funding opportunities and strategic partnerships. Sessions focused on bridging the gap between research and market adoption, accelerating the deployment of climate tech solutions. Experts and policymakers discussed regulatory frameworks and industry best practices to drive sustainable transformation. The event also inspired young entrepreneurs and researchers, emphasizing the importance of interdisciplinary collaboration in tackling climate change.

ESG Workshops: Building a Sustainable Future

The Energy Consortium-IIT Madras, in collaboration with the School of Sustainability, hosted the 'Industry Dialogue on ESG: Reporting Challenges and the Path Forward' workshop on 24 May 2024, at Chennai. Industry leaders discussed standardized ESG reporting, transparent data collection, and industry-academia collaboration, focusing on decarbonization, green technologies, and sector-specific benchmarks to enhance ESG practices in India.

The ESG workshop, organized by The Energy Consortium-IIT Madras, the School of Sustainability IIT Madras, and Pollution Control India, held on 18 October in Mumbai, focused on improving resource efficiency, climate change mitigation, and decarbonization strategies. Keynote speakers included Ms. Yogita Jadhav from SEBI, Ajay Patil from Cummins India, and Prof. Satyanarayanan Seshadri. The workshop also featured insights from Dr. Nikhil Tambe, Dr. Rahul Muralidharan, Prof. Krishna Malakar, Dr. Mala Singh, Rajesh Vasudevan, Chandrashekhar Chincholkar, Sathvik B, Dr. Anuradda Ganesh, and Prof. Santosh Kumar Sahu.

Summit on Sustainability

The Summit on Sustainability, co-organized by Pollution Control India and The Energy Consortium-IIT Madras, was held on 18 November 2024 in Mumbai. The event featured 25+ expert speakers from academia, industry, and sustainability sectors, engaging in panel discussions on key topics such as empowering sustainable initiatives, corporate responsibility, and circular economy. Highlights included the Sustainability Warrior Awards and presentations on actionable solutions to accelerate sustainability across industries. Participants from startups, academia, and industry contributed to advancing the sustainability agenda.

Energy Summit

The Energy Summit 2024, hosted by Deakin University and co-organized by The Energy Consortium-IIT Madras was held from 26 to 29 November 2024 at Melbourne. The summit brought together about 100 global thought leaders, researchers, and innovators to discuss key issues such as energy storage, sustainability, renewable energy, and policy. Through engaging keynote addresses and technical presentations, the event facilitated impactful discussions on cutting-edge innovations and practical applications in the energy sector. The summit also highlighted the importance of collaboration across industries, academia, and policymakers to achieve global energy goals. It concluded with a shared commitment to Net Zero and climate action, setting a strong foundation for future energy innovation.

BUILDING A LEGACY

The Energy Consortium would not have been possible without the strong patronage and championship of our alumni who were instrumental in helping IIT Madras engage a broad group of stakeholders and develop its unique value proposition that was aligned to its mission of establishing the global hot spot for energy transition research. We are truly grateful and acknowledge the differentiated contributions, especially by Dr Vikram Rao, Dr Ashok Krishna, Vasu Guruswamy and Satish Pai, with a special mention to Seshan Rammohan, who operates out of the US West Coast, helped unlock IIT Madras Foundation's vast alumni network and reaching out to those actively working in the energy industry.

We are also gracious for the guidance and directional inputs available to us from our current and past board members. We highlight a few representative examples.

Ashok Krishna

Seshan Rammohan

Mahesh Panchagnula

The idea of net zero and climate change is a very unique problem that's being posed at us for the first time in our civilizational journey. Never has mankind experienced a global scenario that requires a global solution with survival testing as the downside. It's a very urgent issue because the whole world needs to decarbonize in a hurry, otherwise we're going to hurt this planet in a way that we cannot recover from it. So, achieving net zero should be our number one priority.

Arunkumar Ranganathan

Infosys

Achieving net zero is dependent on choosing the pathways. How we manage the operations, tracking, reporting, controlling the emissions, largely depends on digital maturity and the digital platforms you're ready to implement. Energy Consortium is uniquely positioned in innovating real-life solutions to accelerate net zero strategies. We are walking the talk by identifying and investing in purposeful innovation, leading to industry-scale solutions. Our trendsetter programs have been a great success story.

Ramsubramanian Narayanan

Aditya Birla

There are multiple technology fronts and different expertise would be needed to tackle all of these different challenges. The key to success would be to keep in mind the whole value chain. I think whoever is developing technology in one leg of the value chain, they need to keep in mind the whole sequence that it is meant for and tailor the technologies for those applications. I think there are going to be multiple technologies that is going to be playing the role in making that happen.

ENERGY CONSORTIUM

Affiliated Faculty

SATYANARAYANAN SESHADRI
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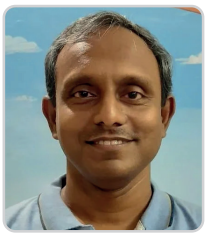
Biomedical Engineering

KOTHANDARAMAN R.
Professor,
Chemistry



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Chemical Engineering

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SWAPNA SINGH RABHA
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Chemical Engineering

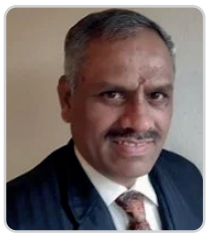
SAGAR SOURAV
Assistant Professor,
Chemical Engineering

RICHA KARMAKAR
Assistant Professor,
Biotechnology

MOHANAKRISHNAN LOGAN
Assistant Professor,
Civil Engineering

GUHAN JAYARAMAN
Professor,
Biotechnology

KRITHIKA RAVI
Assistant Professor,
Biotechnology



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ABDUS SAMAD
Professor,
Ocean Engineering

M S RAMACHANDRA RAO
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Physics

BASAVARAJ M. GURAPPA
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SANKHA KARMAKAR
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SOMNATH CHANDA ROY
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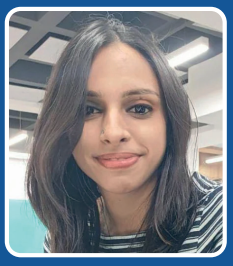

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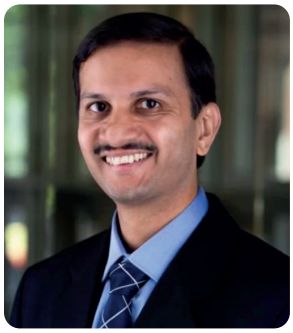

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EPILOGUE

The Energy Consortium has worked very closely with the Office of Global Engagement and the Office of Alumni and Corporate Relations over the three years of its existence. With their help and in conjunction with the strong support of Director Kamakoti V and a few other key offices we have had IIT Madras get inducted as an observer member at the Conference of Parties forum of the United Nations Framework Convention on Climate Change (UNFCCC) and the COP28 in Dubai, UAE was our first presence on inter-governmental panels. It is imperative that we use the collective power behind us via our industry members, academic partners and government agencies in developing and driving future clean energy narratives. We intend to assume Global leadership on energy topics while working with think tanks and policymakers and by putting science based technology inputs. We have already done this on the state level by participating in various policy topics initiated by the State Government of Tamil Nadu, contributing significantly in workshops and symposiums on topics such as CCUS policy making organized by NITI Aayog and US DoE, India Carbon Markets driven by the Bureau of Energy Efficiency, and shaping the hydrogen valley initiative spearheaded by the Ministry of Science & Technology and Ministry of New & Renewable Energy.

There are a number of topics that we are engaging ourselves, thinking beyond just the Sustainable Development Goal #7 which is Clean and Affordable Energy. Following are some of the areas that our faculty are heavily involved in. Here are a few.

Sustainable coastal infrastructure (Energy Consortium is partnering with School of Sustainability and the National Center for Sustainable Coastal Management, Ministry of Environment, Forestry and Climate Change)

The coastal and offshore areas are increasingly becoming central to development of energy infrastructures in supporting India's Nationally Determined Contributions (NDCs) committed at UNFCCC COP gathering in Paris 2015 and more recently at the global stocktake in Dubai in 2023. In India, the Blue Economy, which envisages considerable economic activity in oceans, is identified as one of the ten core dimensions of growth by 2030. We have to address the challenges of implementing an equitable and sustainable Blue Economy in India by building robust environmental and social safeguards for energy infrastructures in coastal and offshore areas. Of broader relevance to the Global South countries, such eco-social safeguards are critical to mitigating potential negative impacts on coastal communities and marine ecosystems already vulnerable to climate change impacts.

The core problems identified that exacerbate susceptibility of the marine ecosystems as well as coastal livelihoods are:

1. Renewable energy infrastructure such as offshore wind, floating solar installations, ocean energy harnessing devices, and desalination plants

2. New sea-ports are envisioned as international hubs for storage and distribution of green fuels such as hydrogen, ammonia and methanol

3. Sea-beds in offshore areas that have been deemed desired locations for sequestration of the captured carbon dioxide in form of hydrates

Role of markets in driving dynamic electricity pricing for grids in India (The Energy Consortium team led by Prof K Shanti Swarup):

Electrical power markets are undergoing a rapid transformation during the digital divide and energy transformation. Smart Power Grids utilizing Information and Commutation Technology (ICT) accelerate the need for the targets towards net zero and de-carbonization. Real Time, Day Ahead, Balancing and Green Energy constitute a major part of Dynamic Electricity Markets that require complex computational calculations for determining various values like market clearing price (MCP), market clearing volume (MCV) required for electric energy trading. Energy internet and energy storage are gaining importance in the era of energy transition. Power exchange for electricity markets uses digital trading methods over short durations. Energy security, sustainability and reliability of power grids are strongly influenced by dynamic electric markets and parameters which are influenced by dynamic pricing.

Application of Block chain-based techniques for energy trading are becoming the need of the hour for efficient dynamic pricing in electricity markets.

Vehicle-to-Grid (V2G) technology offers a promising alternative, leveraging EVs as decentralized energy storage to balance supply and demand. With the current EV battery fleet in India already at 30 GWh—expected to grow to 220 GWh by 2030—V2G integration can reduce reliance on expensive large-scale Battery Energy Storage Systems (BESS). If even 20% of four-wheeler EVs participate in V2G, they could power 1.6 million households, enhancing grid resilience. Widespread adoption of V2G requires policy support, dynamic electricity pricing, and infrastructure enhancements. Time-of-Day (ToD) pricing can encourage off-peak EV charging, optimizing grid stability and minimizing energy costs.

Role of computational tools & AI in material discovery (The Energy Consortium team led by Prof Himanshu Goyal is partnering with the Center for Atomistic Modeling and Materials Design)

For the past century, chemical engineering has played a crucial role in shaping our lives. Developing a chemical process at the lab scale and taking it to the industrial scale is at the heart of chemical engineering. Historically, developing a new chemical process has involved extensive experimentation at various scales, ranging from a catalyst particle to pilot-scale operations, that require significant time and financial investment. There can potentially be millions of possibilities for a new process at the design stage. Given this vast design space, a trial-and-error approach to experimentation is not practical for identifying the optimal design that is both scalable and economical. The transition from empirical toward rational design strategies, however, requires a level of reliability and robustness in the computational models. Selecting appropriate mathematical models to describe the processes occurring inside a chemical reactor is challenging. Typically, these models are in the form of partial differential equations, which require numerical solution using a computer. Solving these equations for real systems become impractical beyond laboratory scale. At the pilot and industrial scales, analyses often rely on simplistic engineering models that neglect the underlying physics. Examples include equilibrium relations and combinations of ideal reactors, such as

continuously stirred tank reactors (CSTR) and plug flow reactors (PFR). In this context, the recent revolution in high performance computing (HPC) and ML/AI tools can be a gamechanger.

- Supercomputers/High-performance computing (HPC): the speed of the top supercomputer has been doubling every fourteen months for the last two decades

- ML/AI tools: a variety of algorithms are freely available in the form of user-friendly and scalable APIs

Addendum

Patents

A complete list of patents is available on our website

Sr No.	Title	Area	Application Number
1	Method for the Preparation of Bilayer Metal Electrocatalyst for Conversion of CO_2 to Formic Acid	CCUS	202341029899
2	Chemogel Superabsorbent Formulation for Carbon Capture	CCUS	202341086640
3	A Process for Manufacture of Hydrogenated Hydroxyl Terminated Polybutadiene (HHTPB) using Pd-Zr-Activated Charcoal as Catalyst.	E-Fuels	202341068679
4	Probe Sonication Converting Nitrates to Ammonia in Water	E-Fuels	202341087398
5	FeS-1 and FeZSM-5 Catalysts for Methanol Synthesis by Aqueous Phase Oxidation of Methane	E-Fuels	202441011306
6	A Method for Extracting High Pure Lignin from Biomass	E-Fuels	202441077134
7	A Method of Converting Waste Plastic Feedstock into Fuels and Chemicals	E-Fuels	202441091002
8	Battery Performance, Lifetime and Safety Testing Device	Energy Storage	202241059308
9	Metal Oxynitride Based Photo- Rechargeable Supercapacitor	Energy Storage	202241074712
10	High-Capacity Redox Flow Battery	Energy Storage	202341005655
11	Electro-Deposition Bath for Recharging the Anode of Mechanically Rechargeable Metal-Air Batteries	Energy Storage	202341051043
12	Electrode for Soluble Lead Acid Redox Flow Battery and Soluble Lead Acid Redox Flow Battery Comprising the same	Energy Storage	202341057222
13	Process for preparing Functionalized and Hydride Inserted Boron/Borophene Nanosheets	Energy Storage	202341057548
14	Mechanically Stable Water-Resistant Layer for Metal-Air Batteries	Energy Storage	202341081761
15	Nafion-Free Hydrocarbon-Based Porous Membrane for Vanadium Redox Flow Battery Application	Energy Storage	202341088792
16	A Battery Cell	Energy Storage	202441048319
17	Low-Cost Zinc-Polyiodide Redox Flow Battery	Energy Storage	202441051658
18	High Energy Dense Mechanically Refuellable Zinc-Air Module Design and Operation Mechanism	Energy Storage	202441061771
19	Battery Having an Organic Electrode: Dual Contributions Amplify Capacity	Energy Storage	202441064313

Sr No.	Title	Area	Application Number
20	System for the Measurement of Polarization-Induced Charge Transfer in Optoelectronic and Photoelectrochemical Devices	Energy Storage	202441067075
21	Rigid and Flexible Parent Coumarin[4]arenes and Method of Preparation thereof	Energy Storage	202441093502
22	Synthesis of Rigid and Flexible Coumarin[4]arenes	Energy Storage	202441093565
23	Process for preparing Tin Coated High Performance Gas Diffusion Electrode (GDE)	Energy Storage	202441096498
24	Packing for Packed Bed Contactor	Renewable Energy	202341065527
25	Blockchain Based Electricity Market Trading Platform	Renewable Energy	202341070142
26	Smart Meter-Based Energy Hubs Performing Energy Interoperability to Improve Consumer Friendly Energy Sector	Renewable Energy	202441002589
27	Accumulator Device for Electric Vehicles	Renewable Energy	202441015526
28	Dsp-Based Apparatus and Method for testing an Electrical Circuit	Renewable Energy	202441021024
29	A Novel Biradial Multiple Entry Mesochannel Heat Sink Using Dielectric Organic Coolant for Electronic Materials Processing	Renewable Energy	202441023684
30	A Guide Vane-Less Bulb Turbine System for Micro/ Mini Hydropower Generation.	Renewable Energy	202441056130
31	A Phase Change Material (PCM)-Based Heat Exchanger System, and a Method Thereof	Renewable Energy	202441078634
32	Unison Duty-Phase Peak Current Control Strategy to Negate DC Bias Current in Dual Active Bridge DC-DC Converters	Renewable Energy	202441090420
33	A System and Method for Electrical Load Management	Renewable Energy	202441099525
34	Model Based Peak Current Estimation using Resonant Capacitor Voltage for Control and Protection	Renewable Energy	202541001269
35	Switch Control Method to Suppress the Effect of Even Order Harmonics in Supply Voltage on ASD	Renewable Energy	17/958,771
36	Blockchain Based Electricity Market Trading Platform	Renewable Energy	PCT/IN2024/052062
37	Smart Meter Based Energy Hubs Performing Energy Interoperability to Improve Consumer Friendly Energy Sector	Renewable Energy	PCT/IN2024/052448

Addendum

Publications

Since our inception, we have over 380 publications in reputed journals. Here is a list of our publications in 2024

A complete list of publications is available on our website

Sr. No	Title of Publication	Name(s) of author(s)	Date of Publication	Journal
Advanced Gas Turbine Engine Technologies				
1	A novel annular slit-type emitter developed for multi-jet electrospray propulsion	Chanearl Kwon, Upasana Priyadarshani Padhi, Pravendra Kumar, Daehong Lim, Sunho Choe, Kybeom Kwon, Jack J Yoh	February 16, 2024	Physics of Fluids 36, 027128 (2024)
2	Transition of Edney shock–shock interactions due to the whipping phenomenon of liquid jet in supersonic crossflow	DS Sebastian, TM Muruganandam	February 13, 2024	Physics of Fluids 36, 026111 (2024)
3	A study on shock-wave/boundary-layer interaction with varying flow deflection angle	SP Baskaran, TM Muruganandam	May 31, 2024	Physics of Fluids 36, 026111 (2024)
Carbon Capture, Utilization & Storage				
4	Decarbonization in Australia and India: Bilateral Opportunities and Challenges for the Net Zero Transformation	Marcello B Solomon, Swapna S Rabha, Gustavo Fimbres-Weihs, Himanshu Goyal, Firouzeh R Taghikhah, Jithin J Varghese, Samuel R Wenger, Weibin Liang, Eleanor R Kearns, Jun Huang, Niket S Kaisare, Deanna M D'Alessandro	January 24, 2024	ACS Eng. Au 2024, 4, 3, 295–311
5	Biodiesel Production: Advance Techniques and Future Prospective	S Chowdhury, R Singh, SK Shrivastava, JS Sangwai	January 05, 2024	Renewable Energy Innovations: Biofuels, Solar, and Other Technologies,
6	Exploring CO_2 sequestration potential as gas hydrates in clay dominated subsea system with and without surfactant	Y Kumar, M Ghoderao, R Sarkhel, J Sangwai	May 01, 2024	Fuel 363, 130990
7	Impact of engineered water in modulating the wettability of oil–brine–rock system for improved oil recovery	US Behera, R Dadhich, JS Sangwai	March 05, 2024	The Canadian Journal of Chemical Engineering, Volume102, Issue8, August 2024, Pages 2786-2804
8	Silica Nanofluids in Low Salinity Water for Wettability Alteration of the Mineral Surface and the Effect of Surface Roughness	GR Seetharaman, DN P, JS Sangwai	January 31, 2024	Energy Fuels 2024, 38, 4, 2830–2843
9	Intermediate Transfer Rates and Solid-State Ion Exchange are Key Factors Determining the Bifunctionality of In2O3/HZSM-5 Tandem CO_2 Hydrogenation Catalyst	Fatima Mahnaz, Jasan Robey Mangalindan, Balaji C. Dharmalingam, Jenna VitoYu-Ting Lin, Mustafa Akbulut, Jithin John Varghese, Manish Shetty	March 18, 2024	ACS Sustainable Chem. Eng. 2024, 12, 13, 5197–5210
10	Molecular Mechanism of Reversible Gas Adsorption and Selectivity in ZIF-90	Rimita Bose, Ashok Yacham, Tarak K Patra, Jithin John Varghese, Parasuraman Selvam, Niket S Kaisare	August 01, 2024	The Journal of Physical Chemistry C, 2024, 128, 31,
11	Metal cation exchange with zeolitic acid sites modulates hydrocarbon pool propagation during CO_2 hydrogenation	Fatima Mahnaz, Balaji C Dharmalingam, Jasan Robey Mangalindan, Jenna Vito, Jithin John Varghese, Manish Shetty	November 13, 2024	Chem Catalysis, 101183
12	Emulsions as Viable Alternative to Conventional Fuels: Current Status and	P Rastogi, NS Kaisare, MG Basavaraj	January 30, 2024	Langmuir 2024, 40, 6, 2800–2808
13	Synthesis and characterization of emulsion fuels–Implications to spray and engine studies	S Gowrishankar, P Rastogi, A Krishnasamy, MG Basavaraj, N Kaisare, Indrapal Singh Aidhen	March 01, 2024	Progress in Energy and Combustion Science, Volume 101, March 2024,
14	Unravelling the Role of Zr–Laponite Supports in Enhancing the Activity of a MnNi Catalyst for the Low-Temperature NH_3 -Selective Catalytic Reduction Reaction	SK Perumal, H Yu, P Aghalayam, HS Kim	February 13, 2024	Energy Fuels 2024, 38, 5, 4516–4525
15	Tuning effect of DIOX on the thermodynamics and cage occupancy of CH_4 /CO_2 + DIOX mixed	Y Yao, Z Yin, R Kumar, X Gao, D Chen	February 15, 2024	Chemical Engineering Journal, Volume 482,
16	Mechanistic insights into C–O bond cleavage in erythritol during hydrodeoxygenation on an Ir–ReO x catalyst	A Rajan, JJ Varghese	July 26, 2024	Reaction Chemistry & Engineering, 2025, 10, 27-37

Sr. No	Title of Publication	Name(s) of author(s)	Date of Publication	Journal
17	Unraveling the Effect of Mo Dopant in Fe_2O_3 Catalyst for Selective Catalytic Reduction of Nitric Oxide with NH_3	T Selvaraj, P Aghalayam, JJ Varghese	April 04, 2024	Industrial & Engineering Chemistry Research 63 (15), 6591-6599
18	Understanding the impact of small vanadia clusters and their coverage effects on undoped and Ni-doped ceria nanorod supports on propane oxidative dehydrogenation	AP Pushkar, JJ Varghese	April 23, 2024	Reaction Chemistry & Engineering, 2024,9, 2050-2065
19	Titania stabilized Pickering emulsion for photocatalytic degradation of o-xylene	NC Maji, NS Kaisare, MG Basavaraj	October 19, 2024	Colloids and Surfaces A: Physicochemical and Engineering Aspects, Volume 705, Part 1, 20 January 2025, 135534
20	Design of microcombustor–thermoelectric coupled device using a CFD-based multiphysics model for power generation	N Yedala, NS Kaisare	May 02, 2024	Reaction Chemistry & Engineering, 2024, 9, 2135-2148
21	Quantification of Degradation of Amine Solvent in CO_2 Capture Process.	AS Khichi, D Sundarrajan, SS Rabha	October 29, 2024	2024 AIChE Annual Meeting
22	An Insight into the CO_2 Adsorption and Temperature Evolution of a Zeolite Bed in a Fluidized Bed Reactor Using a Two-Fluid	P Goel, SS Rabha	May 28, 2024	Industrial & Engineering Chemistry Research, 2024, 63, 23, 10343–10352
23	Prediction of soot for pressurized turbulent kerosene-air diffusion flames using method of moments	S Bhunia, P Aghalayam	December 31, 2024	Energy Sources, Part A: Recovery, Utilization, and Environmental Effects, 46(1),
24	Storage and Transportation of Hythane: Thermodynamics, Kinetics, and Stability Studies Using the Gas Hydrates Process	B Mahant, S CS, OS Kushwaha, R Kumar	September 10, 2024	Energy Fuels 2024, 38, 18, 17586–17607
25	Exploring thermodynamic viable conditions for separation of highly energy intensive H_2O and D_2O mixtures through gas hydrate based	L Paul, JD Lee, P Linga, R Kumar	August 15, 2024	Applied Energy, Volume 368, 2024, 123515
26	Thermodynamic phase equilibria study of Hythane (methane+ hydrogen) gas hydrates for enhanced energy storage applications	B Mahant, OS Kushwaha, R Kumar	July 01, 2024	Fluid Phase Equilibria 582, 114089
27	Partitioning photochemically formed CO_2 into clathrate hydrate under interstellar conditions	G Vishwakarma, BK Malla, R Kumar, T Pradeep	May 22, 2024	Physical Chemistry Chemical Physics 26 (22),
28	A comprehensive review on the recent advances in applications of nanofluids for effective utilization of renewable energy	US Behera, JS Sangwai, HS Byun	September 10, 2024	Renewable and Sustainable Energy Reviews 207, 114901
29	Rheological behavior of deep eutectic solvent promoted methane hydrate formation	PM Shah, SK Prasad, R Sarkhel, PK Naik, JS Sangwai, T Banerjee, Debashis Kundu	October 21, 2024	Journal of the Indian Chemical Society 101 (11),
30	Effect of Clay on the Kinetics of CO_2 Hydrate Relevant for Carbon Capture and Sequestration	Y Kumar, S Kumar, J Sangwai	October 13, 2024	ISOPE Pacific/Asia Offshore Mechanics Symposium, ISOPE-P-24-120
31	Science and Engineering of Functional Coatings Materials Used in Energy Sectors	DP Pathak, AK Prajapati, S Atal, Y Kumar, R Kumar, ASK Sinha, Jitendra Sangwai, Krishna DP Nigam, Deepak Dwivedi	October 04, 2024	Functional Coatings for Biomedical, Energy, and Environmental Applications; Pages 305-
32	Direct Flue Gas Injection into Ocean for Simultaneous Energy Recovery and CO_2 Sequestration in Solid Hydrate Reservoirs	SK Prasad, Y Kumar, DR Bhawangirkar, N Gaikwad, JS Sangwai	August 09, 2024	Energy & Fuels 38 (17), 16622-16637

Sr. No	Title of Publication	Name(s) of author(s)	Date of Publication	Journal
33	Comprehensive Review on the Role of Nanoparticles and Nanofluids in Chemical Enhanced Oil Recovery: Interfacial Phenomenon, Compatibility, Scalability, and	US Behera, S Poddar, MP Deshmukh, JS Sangwai, HS Byun	July 16, 2024	Energy & Fuels 38 (15), 13760-13795
34	Carbon dioxide storage as hydrates in ocean	S Mondal, JS Sangwai	January 01, 2024	Advances and Technology Development in Greenhouse Gases: Emission, Capture and Conversion, 113-135
35	Methane storage underground	R Dehury, Y Kumar, JS Sangwai	January 01, 2024	Advances and Technology Development in Greenhouse Gases: Emission, Capture and Conversion, 251-273
36	Comprehensive review on the recent advancements in nanoparticle-based drilling fluids: properties, performance, and	S Medhi, S Chowdhury, R Dehury, GH Khaklari, S Puzari, J Bharadwaj, Prasenjit Talukdar, Jitendra S Sangwai	July 10, 2024	Energy & Fuels 38 (15), 13455-13513
37	Carbon transportation by pipelines and ships	HD Ansari, JS Sangwai	January 01, 2024	Advances and Technology Development in Greenhouse Gases: Emission, Capture and
38	Recent advances and new concepts in methane conversion and applications	MS Damdhar, P Yogeshwar, JS Sangwai	January 01, 2024	Advances and Technology Development in Greenhouse Gases: Emission, Capture and
39	Dynamics of hydrogen storage in subsurface saline aquifers: A computational and experimental pore-scale displacement study	R Dehury, S Chowdhury, JS Sangwai	June 05, 2024	International Journal of Hydrogen Energy 69, 817-836
40	Study of CO_2 Hydrate Formation in Saline Water for Oceanic CO_2	M Ghoderao, Y Kumar, R Sarkhel, J Sangwai	January 01, 2024	Geoenvironmental Engineering: Proceedings of EGRWSE-23, Volume 1, 271
41	Formation and evolution of particle migration zones for different drilling fluid compositions in	JS Kumar, RK Kandasami, JS Sangwai	April 10, 2024	Acta Geotechnica, 1-20

Energy Storage and Conversion

42	Oxidative Synthesis of 1,3 Diarylphenanthro [9,10 c] thiophenes and Their Aerobic Photoconversion to 9, 10 Diaroylphenanthrenes	S Mahanthi, S Maddala, V Parthasarathy	September 05, 2024	Advanced Synthesis & Catalysis, Volume366, Issue19, Pages 4114-4121
43	Triphenylamine-Appended Carbazole-Based Hole-Transport Layer for Perovskite Solar Cells Fabricated under Low Humidity	N Xavier, K Kollimalaian, P Venkatakrishnan, MS Ramachandra Rao, Soumya Dutta	October 23, 2024	ACS Appl. Electron. Mater. 2024, 6, 11, 7847−7856
44	Tetraphenylethylene tethered 1-(pyridine-2-yl) imidazo [1, 5-a] pyridine: Synthesis, aggregation induced emission, copper (II) ion detection and imaging of latent fingerprint	S Hazarika, B Ilango, V Parthasarathy, M Velusamy, A Kathiravan	December 01, 2024	Dyes and Pigments 231, 112387
45	Selective photoreduction of carbon dioxide to formic acid using $Cs_3Bi_2Cl_9$-Ir/IrO X hybrid	G Pandurangappa, A Kaliyaperumal, R Chetty, AK Chandiran	November 26, 2024	Dalton Trans., 2025,54, 2430-2438
46	Hybrid 1D Titanium Oxide Nanowire–Reduced Graphene Oxide Nanocomposites as Efficient Catalyst Support for PEMFC	R Bhaskaran, SV Selvaganesh, P Dhanasekaran, R Chetty	May 29, 2024	Electrochimica Acta, 144517
47	Insights into the critical materials supply chain of the battery market for enhanced energy security	Marm Dixit, Brett Witherspoon, Nitin Muralidharan, Matthew M Mench, Chol-Bum M Kweon, Yang-Kook Sun, Ilias Belharouak	July 10, 2024	ACS Energy Letters 9 (8), 3780-3789

Sr. No	Title of Publication	Name(s) of author(s)	Date of Publication	Journal
48	Green Synthesis of Magnesium Single Atom Catalyst from Spinacia oleracea-Chlorophyll Extracts for Sustainable Electrocatalytic Nitrate Reduction to Ammonia	K Kumar, P Tripathi, G Raj, D Kalyan, DB Gorle, NG Mohan, SK Makineni, K Ramanujam, AK Singh, KK Nanda	June 01, 2024	Green Chemistry, 2024,26, 7931-7943
49	Advances in Redox Flow Batteries–A Comprehensive Review on Inorganic and Organic Electrolytes and Engineering	M Shoaib, P Vallayil, N Jaiswal, P Iyapazham Vaigunda Suba, S Sankararaman, K Ramanujam, V Thangadurai	June 18, 2024	Advanced Energy Materials, 2400721
50	Facile control of giant green-emission in multifunctional ZnO quantum dots produced in a single-step process: femtosecond pulse	A Sahoo, T Dixit, A Kumari, S Gupta, K Ramanujam, RP Pattathil, MS Ramachandra Rao, Sivarama Krishnan	November 15, 2024	Nanoscale Adv., 2025,7, 524-535
51	Electrocatalysts for Ammonia Synthesis and How Close are We to the Haber-Bosch	NG Mohan, K Ramanujam	April 15, 2024	Current Opinion in Electrochemistry, 101520
52	Selection of solid-state electrolytes for lithium-ion batteries using clustering technique	N Nagappan, GR Kandregula, K Ramanujam	May 20, 2024	Journal of Chemical Sciences 136 (2), 38
53	Quasi-Gel Polymer Electrolyte Interfaced with Electrodes through Solvent-Swollen Poly (ethylene oxide) for High-Performance Lithium/Lithium-Ion Batteries	MP Babu, SB Moodakare, R Vedarajan, K Ramanujam	August 15, 2024	ACS Applied Materials & Interfaces 16 (34), 45399-45410
54	15 Aqueous Acidic Redox	K Ramanujam, C Mirle	August 22, 2024	Advanced Technologies for Rechargeable Batteries: Alkaline Metal Ion, Redox Flow, and Metal Sulfur
55	3 Zinc-Ion Batteries	K Ramanujam, JN Ramavath, LK Nivedha	August 22, 2024	Advanced Technologies for Rechargeable Batteries: Metal Ion, Hybrid, and Metal-
56	Zein protein binder coupled with chitosan-derived carbon for polysulphide trapping in	S Panigrahi, K Ramanujam	August 24, 2024	Journal of Chemical Sciences 136 (3), 62
57	Turning Adversity into Advantage: Investigating the Capacity Decay Mode of Carboxylate Functionalized-Anthraquinone in	R Gupta, K Ramanujam	September 09, 2024	ACS Applied Energy Materials 7 (18), 7737-7744
58	Mechanism of Tin Catalyzed Electrochemical Carbon Dioxide Reduction to Formate	A Naikkath, NG Mohan, K Ramanujam, R Srinivasan	October 09, 2024	PRiME 2024 (October 6-11, 2024)
59	Functionalized graphene nanofiber-based low-cost composite membrane for vanadium redox flow battery applications	H Khan, A Kesh, K Ramanujam, AK Sahu	November 26, 2024	Journal of Chemical Sciences 136 (4), 83
60	From Serendipity to Precision: Decoding the Enigma of Rearrangement in Scholl-Type Reactions for Programmable Cyclization	N Ponugoti, S Maddala, P Venkatakrishnan	February 29, 2024	The Journal of Organic Chemistry, 2024, 89, 6, 4185–4190
61	Crafting diverse tetraphenylthiophene designs through comprehensive 'classical'Suzuki-Miyaura synthesis and electrochemical	S Maddala, K Kollimalaian, A Samal, V Parthasarathy	January 30, 2024	Tetrahedron, 151, 133807
62	Chasing Turns and Twists: Unraveling the One Step Synthesis, Intricate Pathways, and Structural Revelations of N Aryl	S Mallick, K Kollimalaian, P Chetti, V Parthasarathy	January 02, 2024	Chemistry–A European Journal 30 (1), e202302876
63	Pt anchored functionalized graphene nanosheets: A stable oxygen reduction electrocatalyst in alkaline electrolyte	IJR Sarkar, S Kumar, R Koutavarapu, A Bhatnagar, R Chetty	May 20, 2024	International Journal of Hydrogen Energy, Vol 67, 992-999
64	One-Pot Room Temperature Synthesis of Nitrogen-Doped Graphene and Its Application as Catalyst Support for ORR in PEMFCs	R Bhaskaran, R Chetty	January 05, 2024	ACS Applied Energy Materials 7 (2), 390-402
65	Sonochemically synthesized hydride-stabilized boron nanosheets via radical-assisted oxidative exfoliation for energy storage	A Sukeri, S Panigrahi, K Ramanujam	January 01, 2024	Chemical Communications 60 (2), 176-179
66	Mechanism of electrochemical carbon dioxide reduction to formate on tin electrode	A Naikkath, NG Mohan, K Ramanujam, R Srinivasan	February 15, 2024	Chemical Engineering Journal 482, 148972

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67	Improving Pt Utilization and Electrochemical Activity of Proton Exchange Membrane Fuel Cells Through Surface Modification of Carbon Nanotube Catalyst Support	D Ganguly, K Ramanujam, S Ramaprabhu	January 09, 2024	Energy Technology, Vol 12, Issue 4, 2301291
68	Elucidating the role of interface of Cu-Co hybrid metal oxide for oxygen reduction	D Mahato, A Praveen, LK Nivedha, T Gurusamy, K Ramanujam, P Haridoss, T Thomas	March 01, 2024	Surfaces and Interfaces 46, 103924
69	Electrochemical dinitrogen to ammonia reduction at a nickel (II) site: an easy access to	J Kumar, NG Mohan, T Gurusamy, SMNVT Gorantla, P Ravichandran, KC Mondal, K Ramanujam	January 11, 2024	Journal of Materials Chemistry A, 2024,12, 4473-
70	Electrical Equivalent Circuit Model and RC Parameter Estimation for Vanadium Redox Flow Battery by Considering Self-discharge	J Das, R Dasgupta, V Mahanta, K Ramanujam	Mar 07, 2024	Arabian Journal for Science and Engineering, Volume 49, pages
71	An engineered electrode of phenazine with suitable binder and carbon to exhibit excellent energy and power density in an aqueous	P Vallayil, VS Padalkar, C Nandi, K Ramanujam, S Sankararaman	March 30, 2024	Journal of Power Sources 597, 234153
72	A highly conjugated tetrakis-lawsone organic cathode material for enhancing the capacity utilization in the zinc-ion batteries	R Gupta, K Ramanujam	March 11, 2024	Journal of Chemical Sciences 136 (2), 1-11
73	Boron-doped carbon felt electrode on stabilizing cycle life of soluble lead redox flow	Megha Bala, Nandini Jaiswal, Harun Khan, R Kothandaraman	December 20, 2024	Ionics (2024), 1-10
74	Conformal coating of PbO_2 around boron doped diamond coated carbon felt positive electrode for stable and high-capacity operation of soluble lead redox flow battery	Harun Khan, Nandini Jaiswal, C Nikhil, MS Ramachandra Rao, R Kothandaraman	October 10, 2024	Journal of Energy Storage, Vol 99, 113304
75	Robust Sulfonated Proton Exchange Membrane from a Poly(styrene-co-divinylbenzene) melt-Interpenetrated Polyethylene Network for Vanadium Redox Flow	Jeet Sharma, Harun Khan, Prashant Upadhyay, Amit K Rajak, Sarthak Mishra, Nagalakshmi Gayathri M, Ramanujam Kothandaraman, Vaibhav Kulshrestha	August 27, 2024	ACS Appl. Energy Mater. 2024, 7, 17, 7384–7396
76	Enhanced Indoor Perovskite Solar Cells: Mitigating Interface Defects and Charge Transport Losses with Polyarene Based Hole Selective Layers	Zhong En Shi, Kalidass Kollimalaian, Jun Kai Peng, Chi Wei Lin, Wei Tao Peng, Bing Huang Jiang, Yu Hsuan Lin, Lan Yu Yang, Yu Chen Lin, Parthasarathy Venkatakrishnan, Yuan Jay Chang, Chih Ping Chen	November 29, 2024	Advanced Energy Materials, 2404234, Early View

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77	The conundrum of porter hypothesis, pollution haven hypothesis, and pollution halo hypothesis: evidence from the Indian manufacturing sector	P Bagchi, SK Sahu	May 16, 2024	Clean Technologies and Environmental Policy, Volume 27, pages 205–217
78	Controlling Owners and Firm Performance: Empirical investigation from India	R Goswami, AK Gopalaswamy, SK Sahu	November 26, 2024	Studies in Microeconomics, 23210222241277424
79	Comparative study on Multiphase Dynamics of Unsteady Film Condensation over a Vertical Plate in different regimes	N Shiva, N Banerjee, S Seshadri	2024	Proceedings of the 27th National and 5th International ISHMT-ASTFE Heat and Mass Transfer Conference December 14-17, 2023, IIT Patna, Patna-801106, Bihar, India. pages
80	Battery modeling	RK Sankaralingam, M Ravuthan, S Seshadri, J Sunarso	January 01, 2024	Nanostructured Materials Engineering and Characterization for Battery
81	Corrigendum to" Methodology for modeling spray cooling of a cylindrical tube heated in the film boiling regime"[International Journal of Multiphase Flow 171 (2024) 104662]	N Banerjee, C Tropea, S Seshadri	March 01, 2024	International Journal of Multiphase Flow 173, 104699

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82	Methodology for modeling spray cooling of a cylindrical tube heated in the film boiling regime (vol 171, 104662, 2024)	N Banerjee, C Tropea, S Seshadri	March 01, 2024	INTERNATIONAL JOURNAL OF MULTIPHASE FLOW 173 (2024)
83	Hollow-Core Fiber Based Broadband Absorption Spectroscopy With Dual-Wavelength Measurements to Remove the	R Selvaraj, S Seshadri, SMS Nagendra, NJ Vasa	July 12, 2024	IEEE Sensors Letters, vol. 8, no. 8, pp. 1-4, Aug. 2024, Art no. 3502204
84	Climate Action Tool (CAT): Philosophy and Case Studies	Ram Kishore Sankaralingam, Samir Paudel, Nakul Neupane, Sudharshan Saranathan, Dhruv Raghunath, Nishanth Nethaniel Magesh, Sumedh Kulkarni, Shvetha Sivaprasad, Gowri Shankar Navagana, Satyanarayanan Seshadri, Preeti Aghalayam, Raghunathan Rengaswamy	October 30, 2024	2024 AIChE Annual Meeting, 528b
85	Responsible AI for Net Zero: An Australia and India Collaborative Approach Towards Practice, Governance and Ethics in Energy Future	PP Jayaraman, A McCosker, A Banerjee, YB Kang, G Thirunavukkarasu, K Ahmed, R Lundberg, M Seyedmahmoudian, Alex Stojcevski, Vijendran Venkoparao, Narayanan C. Krishnan, Satyanarayanan Seshadri, Balaraman Ravindran	November 19, 2024	Swinburne, https://doi.org/10.25916/sut.26866951.v1
86	Numerical investigation of high temperature heat pump integrated hybrid cooling system	S Koundinya, S Seshadri, A Hafner	December 01, 2024	Journal of Building Engineering, 98, 111037
87	Methodology to compute spray cooling in the nucleate boiling regime	N Banerjee, C Tropea, S Seshadri	June 15, 2024	International Journal of Heat and Mass Transfer 225, 125375
88	Methodology for modeling spray cooling of a cylindrical tube heated in the film boiling regime	N Banerjee, C Tropea, S Seshadri	January 01, 2024	International Journal of Multiphase Flow 171, 104662
89	Access to cleaner cooking fuel in India: the regional and gender disparities	Jayshree Dutta, Santosh Kumar Sahu	January 26, 2024	Environ Dev Sustain, https://doi.org/10.1007/s10668-023-04373-9

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90	Modelling and analysis of a dual-loop current control strategy for grid-tied inverters with LCL filter	Avinash Bhamidipati; Krishna Vasudevan	December, 2024	IEEE International Conference on Power Electronics, Drives and Energy Systems (PEDES), NIT Suratkal
91	Disturbance model for the integrated PSFB and inverter system in grid-tied PV applications	Sri Chaitanya; Krishna Vasudevan	December, 2024	IEEE International Conference on Power Electronics, Drives and Energy Systems (PEDES), NIT Suratkal
92	A Novel Four Level Shared Switch Converter With Buck-Boost Energy Recovery Stage for Switched Reluctance Motor Drive	Arun Chithrabhanu;Krishna Vasudevan	October 21, 2024	IEEE Journal of Emerging and Selected Topics in Industrial Electronics (Volume: 6, Issue: 1, January 2025), 135 - 145
93	An Energy-based Analysis of High Voltage Resonant-based Pulsed Low Power Converter for Water Treatment Application	C Kuldip, N Lakshminarasamma	April 03, 2024	IEEE Access, vol. 12, pp. 49429-49448, 2024
94	Predictive Synchronous Rectification Control Scheme for Resonant DC-DC Converters for Battery Charging and Telecom Application	C Nagesha, N Lakshminarasamma	April 25, 2024	IEEE Journal of Emerging and Selected Topics in Industrial Electronics, vol. 5, no. 4, pp. 1698-1708, Oct. 2024

Sr. No	Title of Publication	Name(s) of author(s)	Date of Publication	Journal
95	LCLC Resonant Converter Modelling in Synchronous Reference Frame	N Chitpadi, N Lakshminarasamma	April 25, 2024	2024 IEEE Kansas Power and Energy Conference (KPEC), Manhattan, KS, USA, 2024, pp. 1-5,
96	An eleven-level self-balancing switched-capacitor based inverter with five-fold voltage gain	AK Upadhiya, N Lakshminarasamma, M Kumar	July 01, 2024	IEEE Transactions on Industry Applications, vol. 60, no. 5, pp. 7138-7155, Sept.-Oct. 2024
97	Frequency Response Measurement and Analysis for Digitally Controlled Power Converters	T Shankar, R Nitheesh, AK Dubey, N Chitpadi, N Lakshminarasamma	July 31, 2024	2024 IEEE 4th International Conference on Sustainable Energy and Future Electric Transportation (SEFET), 1-6
98	Modeling and Control of Single-Input, Multi-Output DC-DC Converters in Port-Controlled Hamiltonian Framework	J Sowmya, AD Mahindrakar, N Lakshminarasamma	July 31, 2024	2024 IEEE 4th International Conference on Sustainable Energy and Future Electric Transportation (SEFET), 1-6
99	A Noniterative Design Method for Output LCL Filter With RC Damping in Grid-Connected Inverters	B Mondal, A Karuppaswamy	June 06, 2024	IEEE Transactions on Industrial Electronics, vol. 71, no. 12, pp. 15768-15779, Dec. 2024
100	Enhancing photovoltaic efficiency through a novel meta-heuristic algorithm for maximum power point tracking	B Rashid, KS Swarup	May 27, 2024	2024 12th International conference on smart grid (icSmartGrid), 226-232
101	Optimal investment by large consumers in an electricity market with generator market power	PP Verma, MR Hesamzadeh, S Rebennack, D Bunn, KS Swarup, D Srinivasan	June 01, 2024	Computational Management Science 21 (1), 1-56
102	Smart Grid Cyber-Physical System: An Overview	A Sreejith, K Shanti Swarup	June 02, 2024	Cyber-Security for Smart Grid Control: Vulnerability Assessment, Attack Detection, and Mitigation, Springer, Singapore, 3-14
103	Attack Mitigation and Recovery in Smart Grid Control	A Sreejith, K Shanti Swarup	June 02, 2024	Cyber-Security for Smart Grid Control: Vulnerability Assessment, Attack Detection, and Mitigation, Springer, Singapore, 119-132
104	Vulnerability Assessment for Multi-area Load Frequency Control	A Sreejith, K Shanti Swarup	June 02, 2024	Cyber-Security for Smart Grid Control: Vulnerability Assessment, Attack Detection, and Mitigation, Springer, Singapore, 43-57
105	MITRE ATT&CK for Smart Grid Cyber-Security	A Sreejith, K Shanti Swarup	June 02, 2024	Cyber-Security for Smart Grid Control: Vulnerability Assessment, Attack Detection, and Mitigation, Springer, Singapore, 59-73
106	Signal Processing-Based Attack Detection	A Sreejith, K Shanti Swarup	June 02, 2024	Cyber-Security for Smart Grid Control: Vulnerability Assessment, Attack Detection, and Mitigation, Springer, Singapore, 77-103

Sr. No	Title of Publication	Name(s) of author(s)	Date of Publication	Journal
107	Smart Grid Control	A Sreejith, K Shanti Swarup	June 02, 2024	Cyber-Security for Smart Grid Control: Vulnerability Assessment, Attack Detection, and Mitigation, Springer, Singapore, 15-25
108	Attack Modeling for Smart Grid Control	A Sreejith, K Shanti Swarup	June 02, 2024	Cyber-Security for Smart Grid Control: Vulnerability Assessment, Attack Detection, and Mitigation, Springer, Singapore, 29-42
109	Machine Learning-Based Attack Detection	A Sreejith, K Shanti Swarup	June 02, 2024	Cyber-Security for Smart Grid Control: Vulnerability Assessment, Attack Detection, and Mitigation, Springer, Singapore, 105-118
110	Quantifying the Performance of Cluster based Anomaly Detection in Smart Grid Control	A Sreejith, B Natarajan, KS Swarup	July 21, 2024	2024 IEEE Power & Energy Society General Meeting (PESGM), 1-5
111	Pattern Recognition Applications in Distributed Systems and Distributed Machine Learning	S Kalyani, KS Swarup, S Avasthi, T Sanwal	July 31, 2024	Decentralized Systems and Distributed Computing, 117-144
112	Cyber Security of Smart-Grid Frequency Control: A Review and Vulnerability Assessment Framework	Amulya Amulya; K. S. Swarup; Ramu Ramanathan	November 11, 2024	ACM Transactions on Cyber-Physical Systems, 2024-10-31 | Journal article, DOI: 10.1145/3661827
113	A novel solution for overcoming conflicts between line protection and LVRT in MV Solar PV interconnections	Anoop V Eluvathingal;K Shanti Swarup	December 02, 2024	IEEE Access, vol. 12, pp. 183038-183059, 2024
114	Maloperation of Zone-3 Distance Relay Prevention Using Distribution Entropy	Upendran Mukundarajan ;K Shanti Swarup	July 04, 2024	IEEE Access, pp. 93171-93184,, Vol. 12, 2024. //ieeexplore.ieee.org/document/10584515
115	Voltage Control in Radial Distribution Systems Using Deep Reinforcement Learning Technique	Rochisnu Dutta, K. Shanti Swarup	November, 2024	IEEE ASIA ISGT Bangalore 10th -13th November 2024
116	Distributed Economic Dispatch in a Microgrid using Proportional- Integral Conesus	P.M.Naina, , K. Shanti Swarup	November, 2024	IEEE ASIA ISGT Bangalore 10th -13th November 2024
117	Approximate Entropy based prevention of third zone distance relay Maloperation	M. Upendran, K. Shanti Swarup,	November, 2024	IEEE ASIA ISGT Bangalore 10th -13th November 2024
118	Value-Based Reactive Power Market in Local Market Areas	D Jay, K Shanti Swarup	January 04, 2024	Market Operation for Reactive Power Ancillary Service: Design and Analysis with GAMS Code, Springer Nature Singapore, 63-80
119	Reactive Power and Network Partitioning	D Jay, K Shanti Swarup	January 04, 2024	Market Operation for Reactive Power Ancillary Service: Design and Analysis with GAMS Code, Springer Nature Singapore, 47-61

Sr. No	Title of Publication	Name(s) of author(s)	Date of Publication	Journal
120	Reactive Power Ancillary Service Markets	D Jay, K Shanti Swarup	January 04, 2024	Market Operation for Reactive Power Ancillary Service: Design and Analysis with GAMS Code, Springer Nature Singapore, 31-44
121	Reactive Power Ancillary Service in Indian Grid Operation	D Jay, K Shanti Swarup	January 04, 2024	Market Operation for Reactive Power Ancillary Service: Design and Analysis with GAMS Code, Springer Nature Singapore, 109-114
122	Market Operation for Reactive Power Ancillary Service: Design and Analysis with GAMS Code	D Jay, KS Swarup	January 03, 2024	Springer Nature
123	Introduction to Electricity Markets	D Jay, K Shanti Swarup	January 04, 2024	Market Operation for Reactive Power Ancillary Service: Design and Analysis with GAMS Code, Springer Nature Singapore, 3-20
124	Inertia monitoring in power systems: Critical features, challenges, and framework	L Lavanya, KS Swarup	February 01, 2024	Renewable and Sustainable Energy Reviews 190, 114076
125	Game Theoretical Analysis	D Jay, K Shanti Swarup	January 04, 2024	Market Operation for Reactive Power Ancillary Service: Design and Analysis with GAMS Code, Springer Nature Singapore, 83-94
126	Energy and Ancillary Service Markets	D Jay, K Shanti Swarup	January 04, 2024	Market Operation for Reactive Power Ancillary Service: Design and Analysis with GAMS Code, Springer Nature Singapore, 21-30
127	Deep Learning Analysis	D Jay, K Shanti Swarup	January 04, 2024	Market Operation for Reactive Power Ancillary Service: Design and Analysis with GAMS Code, Springer Nature Singapore, 95-108
128	Investigation into a Frequency Coupling Matrix of an Adjustable Speed Drive for System Level Harmonic Studies in Sequence Domain	Yadav J.;Vasudevan K.;Meyer J.;Kumar D.	February, 2024	IEEE Journal of Emerging and Selected Topics in Power Electronics (Volume: 12, Issue: 1, February 2024), 815 - 826
129	Analysis of Inverter Output Current Ripple and Design of Inverter-Side Output Filter Inductor for Grid-Connected Applications	Bishal Mondal, Arun Karuppaswamy	October 16, 2024	IEEE Transactions on Industry Applications, vol. 61, no. 1, pp. 686-702, Jan.-Feb. 2025
130	A Comprehensive Multi-stage Validation Approach for Development of Power Electronic Systems	Rajarshi Basu, Chinara Kuldip, Mahesh Kumar, N Lakshminarasamma	November 03, 2024	2024 IEEE 11th International Conference on E-Learning in Industrial Electronics (ICELIE), 1-5

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Photo- and Electro-chemical Energy				
131	Single microbe photoelectrochemical device using scanning electrochemical microscopy	AK Samuel, S Shinde, A Palaniappan, P Bhalla, AK Chandiran	October 10, 2024	Journal of Materials Chemistry C, 2025, 13, 185-192
132	Mixed Tetravalent $Cs_2RumPt_1-mX_6$ (X = Cl-, Br-) Based Vacancy Ordered Halide Double Perovskites for Enhanced Solar Water Oxidation	JS Halpati, N Shanmugam, M Manoj, M Hamdan, AK Chandiran	January 08, 2024	Solar RRL 8 (5), 2300924
133	Bilayer Porous Electrocatalysts for Stable and Selective Electrochemical Reduction of CO_2 to Formate in the Presence of Flue Gas Containing NO and SO_2	YSS Prasad, AK Chandiran, R Chetty	June 04, 2024	ACS Applied Materials & Interfaces, 2024, 16, 24, 31011–31022
134	Direction Dependent Ferroelectricity and Conductivity in a Single Crystal 2D Halide Double Perovskite	SA Rajput, S Antharjanam, AK Chandiran	June 16, 2024	Nano Micro Small, Volume20, Issue42, October 17, 2024, 2403239
135	Above Room Temperature Ferroelectric Two-Dimensional Halide Double Perovskite with Direction Dependent Properties	S Rajput, S Antharjanam, AK Chandiran	June 24, 2024	Chemical Communications, 2024, 60, 7898-7901
136	Mechanically rechargeable zinc-air batteries for two-and three-wheeler electric vehicles in emerging markets	A Kongara, AK Samuel, G Kapadia, AK Chandiran	November 06, 2024	Communications Materials 5 (1), 244
137	Highly Stable $BaZrS_3$ Chalcogenide Perovskites for Photoelectrochemical Water Oxidation	A Das, JS Halpati, V Raj, AK Chandiran	November 12, 2024	Energy Fuels 2024, 38, 22, 22527–22535
Renewable Energy Enhancement				
138	Modelling of chemical kinetics in the presence of hydrodynamic cavitation for wastewater treatment applications	JH Chaudhuri, D Chatterjee	August 05, 2024	Chemical Engineering Science, Volume 295, 2024, 120167
139	Capturing mesoscale structures in computational fluid dynamics simulations of gas solid flows	BK Kumar, S Ganesh, H Goyal	February 26, 2024	AIChE Journal, Volume70, Issue5, e18360
140	Impact of particle-scale models on CFD-DEM simulations of biomass pyrolysis	K Kumar, H Goyal	May 10, 2024	Reaction Chemistry & Engineering, 2024,9, 2552-2568
141	Reaction Chemistry & Engineering	BK Kumar, H Goyal	October, 2024	Reaction Chemistry & Engineering ISSN 2058-9883 Volume 9 Number 10
142	A CFD-DEM Study to Quantify the Influence of Particle Clustering on Catalytic Reactions	BK Kumar, H Goyal	October 28, 2024	2024 AIChE Annual Meeting, 215b
143	Reaction Chemistry and Engineering I: Catalytic Processes	JD Sheehan, H Goyal, B Sarkar	October 31, 2024	2024 AIChE Annual Meeting, 628
144	A Computational Study of Electrically Heated Reactors	T Bhumana, G Mopidevi, S De, AP van Bavel, R Bos, H Goyal	October 31, 2024	2024 AIChE Annual Meeting, 708d
145	Modeling and Analysis of Chemical Reactors I: Managing Heat and Mass Transfer	U Gupta, M Shah, H Goyal	October 31, 2024	2024 AIChE Annual Meeting, 626
146	Capturing Mesoscale Structures in Multiphase Reactor Simulations	BK Kumar, H Goyal	October 31, 2024	2024 AIChE Annual Meeting, AIChE Journal, 671h
147	Pyrolysis characteristics and kinetic investigation of waste groundnut shells using thermogravimetric analyzer, Py-FTIR, and Py-GC-MS	RK Mishra, R Vinu	May 01, 2024	Journal of Analytical and Applied Pyrolysis 179, 106514

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148	Industrial waste to diesel engines: A novel hydrothermal co-liquefaction approach to produce diesel blendstocks	S Harisankar, B Alawa, S Chakma, R Vinu	June 01, 2024	Resources, Conservation and Recycling, Volume 205, 107573
149	Biomass Fast Pyrolysis Kinetics using Curie Point Pyrolysis: Comparison with Pyroprobe and Thermogravimetric Analysis	F Prashanth, RN Sarma, A Jain, S Segar, H Choudhari, R Vinu	June 12, 2024	Journal of the Energy Institute, 115, 101699
150	Hydrogen and Bio-oil Production from Diverse Biomass Through Microwave-assisted Pyrolysis	M Tiwari, MVP Babu, R Vinu	June 15, 2024	Chemical Engineering Transactions, 109, 253-258
151	Microwave-assisted co-pyrolysis of rice straw pellets and plastic packaging wastes for value-added products and energy recovery	M Tiwari, R Vinu	October 01, 2024	Process Safety and Environmental Protection, Volume 190, Part B, 2024, Pages 606-621
152	Experimental Investigation on Atomization of JP-10 Slurry Jets Containing Boron Nanoparticles	A Kumar, A Dilip Ghugare, R Vinu, S Sahu	September 12, 2024	Journal of Propulsion and Power 40 (6), 916-928
153	TEMPO-Assisted Thermal and Catalytic Cracking of 3-Carene and JP-10 to Produce Low-Molecular-Weight Hydrocarbons	S Priyadarshi, S Pal, R Vinu	November 04, 2024	Industrial & Engineering Chemistry Research, Vol 63, Issue 45, 19435-19448
154	Hydrothermal Co-liquefaction of Cellulose and Polypropylene using Co-solvents	D Mahesh, S Harisankar, R Kumar, R Vinu	September 12, 2024	Energy Nexus,Volume 16, 100324
155	Hydrothermal liquefaction of diverse plastics using water and seawater	S Harisankar, MVP Babu, S Srinivasan, R Vinu	November 04, 2024	Chemical Engineering Journal 501, 157365
156	Co-Pyrolysis Studies of Agricultural Residue and Plastics for Process Optimization in a Rotary Kiln Reactor System	S Kakku, N Jonna, AG Chakinala, J Joshi, R Vinu, C Thota, A Sharma	December 04, 2024	Industrial & Engineering Chemistry Research, 2024, 63, 50, 21816−21830
157	Thermal degradation of heterogeneous plastic waste fractions: A hybrid DAEM & parallel reaction approach	S Kartik, HK Balsora, AG Chakinala, J Modi, BCL Fui, A Saptoro, R Vinu, Jyeshtharaj B. Joshi, Abhishek Sharma	December 26, 2024	Chemical Engineering Research and Design, Volume 214, Pages 78-92
158	Biorefinery approach for rhamnolipid production by metabolically engineered Pseudomonas taiwanensis VLB120	V Sivapuratharasan, LM Blank, VS Prabhudesai, R Vinu, G Jayaraman	December 01, 2024	Biomass and Bioenergy 192, 107491
159	The effect of microfluidic chip geometry on droplet clustering in a high throughput droplet incubation platform for single-cell analysis	K Mirkale, D Chatterjee	January 01, 2024	Physics of Fluids 36, 011914 (2024)
160	Steady-state analysis of purge flow passage on the performance of the high-pressure transonic axial turbine at different mass flow ratios	PP SHARMILA, D Chatterjee	February 08, 2024	Sādhanā 49, 59 (2024)
161	Optimal use of glycerol co-solvent to enhance product yield and its quality from hydrothermal liquefaction of refuse-derived fuel	S Harisankar, PF Prashanth, J Nallasivam, R Vinu	February 01, 2024	Biomass Conversion and Biorefinery 14 (4), 4925-4939
162	Microwave-assisted torrefaction of biomass Kappaphycus alvarezii–based biochar and magnetic biochar for removal of hexavalent chromium [Cr(VI)] from aqueous ...	K Govindaraju, R Vinu, R Gautam, R Vasantharaja, M Niranjan, I Sundar	February, 2024	Biomass Conversion and Biorefinery 14 (3), 3643-3653
163	Investigation of anaerobic digested pyrolysis oil and waste derived biodiesel blends as sustainable fuel for marine engine application	V Sharma, AK Hossain, G Griffiths, JC Manayil, R Vinu, G Duraisamy	February 01, 2024	Fuel, Volume 357, Part C, 1 February 2024, 129935

Sr. No	Title of Publication	Name(s) of author(s)	Date of Publication	Journal
164	Hydrodeoxygenation of mixtures of biomass-derived model compound oxygenates over Pt/HY catalysts	VS Prabhudesai, A Yerrayya, L Gurrala, P Castaño, R Vinu	April 15, 2024	Chemical Engineering Science 288, 119800
165	Graphene-Encapsulated Transition Metal@ N/C Catalysts for Catalytic Copyrolysis of Biomass and Waste Plastics: Production of Linear α-Olefins and Aromatics	T Nandakumar, SK Pal, R Vinu, PM Ramar, KK Pant, S Kumar, Ekambaram Balaraman	March 19, 2024	ACS Sustainable Chemistry & Engineering, 2024, 12, 13, 5283−5299
166	Co-pyrolysis of bamboo biomass with polypropylene coverall: Distributed activation energy modeling and pyrolysate composition studies	S Chakraborty, K Mohanty, R Vinu	January 01, 2024	Renewable Energy, Volume 220, January 2024, 119533
167	Catalytic upcycling of post-consumer multilayered plastic packaging wastes for the selective production of monoaromatic hydrocarbons	SK Pal, VS Prabhudesai, R Vinu	February 02, 2024	Journal of Environmental Management, Volume 351, February 2024, 119630
168	Analytical and applied pyrolysis of challenging biomass feedstocks: Effect of pyrolysis conditions on product yield and composition	M Tiwari, MJ Dirbeba, J Lehmusto, P Yrjas, R Vinu	January 01, 2024	Journal of Analytical and Applied Pyrolysis 177, 106355
169	Analytical and Applied Copyrolysis of Mesua ferrea L. and Polyethyelene Terephthalate Plastic for Hydrocarbon-Rich Bio-oil	Janaki Komandur, Ravikrishnan Vinu, Kaustubha Mohanty	December 31, 2024	ACS Omega 2025, 10, 1, 529−540
170	Microwave-assisted rapid pyrolysis of woodblock without adding susceptor and detailed product analysis	B Rajasekhar Reddy, Soham Sarkar, R Vinu	June, 2024	Biomass Conversion and Biorefinery, Volume 14, pages 11941–11950, (2024)
171	On the effect of flow rate on pressure fluctuations and cavitation characteristics in a novel bulb turbine	S Shandilya, SP Das, D Chatterjee	November 11, 2024	2024 IOP Conference Series: Earth and Environmental Science 1411 012008
172	Assessment of synergistic cavitation and silt erosion performance of hydraulic turbine steel	Durga Pechetti, Dhiman Chatterjee, M Kamaraj	November 11, 2024	2024 IOP Conference Series: Earth and Environmental Science 1411 012072

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