Australian Government
Department of Climate Change, Energy, the Environment and Water

AHRN
THE AUSTRALIAN HYDROGEN RESEARCH NETWORK

CSIRO

Australia's National Science Agency

Australian hydrogen research delegation to India

19-24 November 2023

Report compiled by Australian delegates

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Executive summary

The AHRN delegation to India has been our largest delegation taking 14 delegates from eight Australian research organisations, the Australian government and two support crew. It was a prodigious exercise visiting the best of India's energy research laboratories and incubation sites, government departments and industry in Pune, Chennai, Mumbai and New Delhi. The delegation was led by Suresh Bhargava, Director of Centre for Advanced Materials and Industrial Chemistry (CAMIC) at RMIT University, coordinated by Dan O'Sullivan and May Liak from CSIRO, and funded by the Australian Government.

At the end of 2023, India became fourth globally in renewable energy installed capacity, fourth in wind power capacity and fifth in solar power capacity. India recognises that the time has come for them to be a major player in manufacturing clean technology for the globe as well as reducing their own emissions. With large energy demands and significant manufacturing capability, India is seeking to position itself as a global renewable hydrogen hub. India's Hydrogen Mission has articulated preliminary hydrogen-specific targets, which include:[1]

- Five million tonnes of hydrogen produced from renewables annually by 2030; and
- Fertiliser plants and oil refineries to use renewable hydrogen to meet 5% and 10%, respectively, of their total hydrogen requirements in 2023-2024, and increasing this to 20% and 25% respectively within five years.

India aims to develop at least seven national Hydrogen Valleys or Hubs across India to kickstart domestic hydrogen production and commercialisation, to combat climate change. These will be placed in strategic locations with strong solar radiance, abundant water supply, and co-located industrial clusters. Four areas where strong RD&D activity is occurring alongside this clean development push are Mumbai, Delhi, Bengaluru and Chennai, with several demonstration projects completed across India in these regions.

To help meet this vision, India has made strong collaborative networks with many international partners on hydrogen RD&D and commercialisation across the value chain and signalled much more is needed. The Indian government has reinforced its desire to collaborate internationally through existing partnerships and programs – including Mission Innovation, the Quadrilateral Strategic Dialogue, and the International Organisation for Standardisation – and the strategic partnership between the Ministry of Natural resources & Energy (MNRE) and the International Renewable Energy Agency (IRENA) announced in January 2022.

Key Realities

India has substantial global influence attributed to its vast population, democratic governance, cost-effective labour force, and, notably, a substantial market for energy and technologies. In parallel to Australia's commitment to playing a pivotal role in this dynamic market, other nations,

[1] Ministry of Power (2022) Ministry of Power notifies Green Hydrogen / Green Ammonia Policy. <https://pib.gov.in/PressReleasePage.aspx?PRID=1799067>.

such as those in Europe, North America, and the Middle East, are actively engaged in comparable, if not more extensive, initiatives with India.

Australia has considerable opportunity to accelerate our growth with India and implement a thoroughly structured program. The Indian government is actively formulating strategic rules, regulations, and commitments in the realm of green energy and associated technologies. To ensure a comprehensive approach, they seek input and guidance from key stakeholders, including universities, academics, and industry sectors within India. It is imperative for Australia to proactively engage in communication and collaboration with Indian universities, and ideally, establish partnerships with industry sectors.

Suggestions for future funding and engagement

Securing initial funding is a prerequisite for accelerated collaboration. This can proactively be done on two levels: (i) under a structured program such as the $5m Australian government funded program coordinating this delegation and associated fellowship studies, or (ii) use a seed funding methodology as the first crucial step of initial funding.

Both options benefit by joint funding partners under joint or matched pursuits. Energy transition R&D including hydrogen is also in need of defining a set of pivotal research areas, derived from topics identified during stakeholder engagement exercises such as these delegations. This helps refine our work, pool resources, avoid duplicating research, and use our collective talents. Examples of areas that will benefit include

- more efficient manufacturing of electrolysers via alternative membrane development or photocatalysis
- energy storage
- having more widespread emissions sensors where necessary.

Small steps can begin with the provision of seed funding as little as $150,000 to initiate proceedings in a selected area to act as a leverage point for further funding under larger dedicated multi-million-dollar programs.

For effective execution, chosen projects or proposals should involve a collaborative effort between a minimum of two research entities—one from Australia (university or research institute) and one from India (university or research institute); focus on a topic of mutual interest; and be of value to industry, policy and society. To perform this plan, the Indian project partner could seek to match funding, such as a 1:1, 1:2, or even a 1:3 ratio, under options between cash contributions but could also take the form of labour equivalents.

Proposed project durations are recommended to be set at least at 12-18 months, with the flexibility to extend to 3 years contingent upon a justified rationale. A primary objective is ‘rapid innovation’ on selected areas of great need. To quickly initiate a collaborative effort and establish trust among the project partners. It is anticipated that a robust collaboration will evolve among the participants throughout the project's duration. This collaborative synergy is crucial as it empowers project participants to leverage the knowledge, and insights gained from the initial funding as a solid foundation. This, in turn, positions researchers and their industry and government partners to strategically pursue additional research grants from various funding schemes offered by both the Indian and Australian governments, as well as other potential funding sources.

As frequently mentioned during our week in India, three governance themes are necessary to lay the foundations for future research agreements:

a) *Training*: Incorporating short-term exchange students, early-career, and mid-career researchers in selected areas serves the dual purpose of facilitating knowledge exchange, training, and fostering future collaborative research endeavours between Australian and Indian universities, industry, and government departments.

b) *Knowledge sharing*: the skills and knowledge needed for all agents in the energy transition is large. We must create and use online tools, decision making tools and governance tools in a much more collective way.

c) *Intellectual Property (IP)*: Any IP arising from this collaborative venture can be jointly shared among the project partners, with the distribution contingent upon their respective contribution percentages.

After our travels we believe such an approach could be influential for creating meaningful energy research partnerships with India both in academic and industrial sectors.

The table below summarises a areas of mutual interest discussed in our meetings with government departments and universities.

Research areas highlighted for early collaboration
Green H2 technologies commercialization and business planning
Biomass/gasification to produce green H2
Type 4 cylinder manufacture. Currently there is no Type 4-cylinder manufacturer in India.
Development of Type 4 and 5 H2 storage – Additive manufacturing of intermetallic alloys for Hydrogen storage cylinders
Assistance to industry to improve their cooling systems to reduce water usage
Protonic batteries: Electrochemical hydrogen storage using carbon adsorbents
Mimic Nafion membrane
Development of suitable/durable sea water electrolyser for hydrogen production
Development of cost effective green ammonia, and using ammonia directly as fuel
Development of more cost effective and sustainable battery recycling
Claim validation testing centre. Help to validate the technologies developed in India
Carbon capture/sequestration using eco-sustainable carbon-based adsorbents
User safety – tailored infrastructure designs with hydrogen sensors available for specific applications

Australian delegation

Name of Delegate	Role	Institution
Behdad Moghtaderi (Prof.)	Laureate Professor, School of Engineering (Chemical Engineering)	University of Newcastle
Breandan Skinner (Mr.)	Australian policy development	Department of Climate Change, Energy, the Environment and Water
Ian Macgill (Prof.)	Professor, School of Electrical Engineering and Telecommunications; Joint Director (Engineering) Centre for Energy and Environmental Markets (CEEM).	University of New South Wales
Jafar Zanganeh (Dr.)	Research Associate, School of Engineering	University of Newcastle
Ken Baldwin (Prof.)	Professor, Research School of Physics; Inaugural Director, former ANU Energy Change Institute; founding Director, ANU Grand Challenge: Zero-Carbon Energy for the Asia-Pacific	Australian National University
Nolene Byrne (Assoc. Prof. (Ms.))	Associate Professor - Circular Design, Institute for Frontier Materials	Deakin University
Patrick Hartley (Dr.)	Leader, CSIRO Hydrogen Industry Mission	CSIRO
Paul Medwell (Prof.)	Professor, School of Electrical and Mechanical Engineering, Faculty of Sciences, Engineering and Technology	University of Adelaide
Petros Lappas (Dr.)	Director - Aerosol & Green Engines Laboratory, Program Manager - Master of Engineering (Sustainable Energy)	RMIT University
Sally McArthur (Prof. (Ms.))	Director, Institute for Frontier Materials	Deakin University
Sarb Giddey (Dr.)	Senior Principal Research Scientist	CSIRO
Suresh Bhargava (Prof.) - MISSION LEAD	Distinguished Professor, AM, KIA Laureate and QPM Chair, Dean, Research & Innovation, Research partnerships (India), Director for CAMIC, STEM College, RMIT University	RMIT University
Dan O' Sullivan (Mr.) - CSIRO Coordinator	Program Manager, Hydrogen RD&D International Collaboration, CSIRO Energy	CSIRO
May Liak (Ms.) - CSIRO Coordinator	India Program Partnership Manager - Global, Strategic Partnerships Group, Growth - CSIRO	CSIRO
Sanjiva D'Silva (Mr.)	Counsellor (Industry, Science and Resources), India; Australian High Commission, New Delhi	Australian High Commission
Shireen Ardeshir (Ms.)	Program Officer & Coordinator, AustralianH2Research Mission: India	Study Networks, Mumbai, India

Monday, 20 November 2023

India-Australia Joint Interaction (Symposium) on Green Energy to Develop 3rd Gen Technologies

Hosted by Dr. Mahesh Sharma and Ms. Deepti Sharma and Ms. Avni Khatkar, CSIR - National Physical Laboratory.

Location: Taj Mahal Hotel, New Delhi

The Australian delegation was welcomed by Dr Vibha Sawhney, Outstanding Scientist CSIR, and a reply given by Prof Suresh RMIT, the Australian Mission Lead. The delegates from India and Australia then introduced themselves and their research areas to the audience, which comprised both academic and industry participants.

The symposium started with an opening ceremony in which candles representing enlightenment were lit by the lead delegation members. The candle ceremony is shown in figure 1 below.

Figure 1. Opening ceremony for the Symposium on Green Technology, 20 November 2023.

After several presentations from both sides the symposium participants split up into roundtable discussion groups and generated the following joint R&D initiatives.

Leadership

Create a Scientific Leadership in Energy and Environment Program to identify emerging leaders focusing on rapid innovation. A successful program like this needs a process to find the right leaders, a process to train them, and institutions willing to drive the program and support them.

Skill development programs

Many new skills are required across research, industry and policy in H2 technologies that will benefit from (i) real and virtual learning and share exchange programs (ii) online and digital platforms that vastly extend information and data exchanges, including industry players so that research is applied and demonstration seen in action and practice; and (iii) timely development of standards and regulations.

Markets

Sellers need buyers. Gas blending infrastructure is likely to be a major first mover in large scale projects across steel, cement, plastics and other hard to abate areas. This will be more challenging and unlikely without large government inputs and coordinated efforts. Green ammonia was also identified as another early market requiring:

- low pressure ammonia synthesis (consider: CSIRO, CSIR-Indian Institute of Chemical Technology (IICT), Bharat Petroleum Corporation Limited (BPCL), and Indian Institute of Technology IIT Kanpur)
- high efficiency ammonia cracking/oxidation (consider: CSIRO, IICT, BPCL, CGCRI, CUMI and IIT Kanpur)
- direct use of ammonia (consider: direct ammonia use in internal combustion engines: RMIT, CSIRO, HPCL, IICT. For direct ammonia use in solid oxide fuel cells were identified: CSIRO, CGCRI and CUMI).

Generation

Highlighted areas include:

- Alternative novel non fluorinated membrane materials for replacement of nafion with non-noble metal catalysis with possibilities of recycling (CSIRO-Melbourne; CSIR-NCL)
- Next Generation High Performance SOE cell & stack with lowering operational temperature and high endurance (CSIRO-Melb, CSIR-CGCRI).
- Biomass & municipality waste-based materials with CO2 capture (CSIRO- to identify, TERI-India, CSIR_ IICT)
- Solar Thermal based water splitting for H2 generation (IIT-Kampur, CSIRO-Solar, ASTRI)

Storage

Highlighted areas include:

- Novel Double plateau-based metal hydride storage materials for two-wheeler applications.
- Material development (innovative material)
- Hardware development (3D printing)
- Novel process development and process intensification
- Carbon Capture, storage & utilisation

Tuesday, 21 November 2023

KPIT Technology Limited

Hosts: Mr. Tejas Kshatriya and Mr. Deepesh Gujarathi
Location: Hinjawadi IT Park, Hinjawadi, Pune

KPIT Technologies Ltd is a global partner to the automotive and mobility ecosystem for making software-defined vehicles a reality. KPIT is a private company with a strong focus on technology innovation founded on software development for the automotive industry (25 large customers), particularly engine control unit (ECU) software. More than 10m vehicles use KPIT software. The company has more than 12000 staff and operates in 13 countries. The company's mission is 'Reimagining mobility with you for creation of a cleaner smarter and safer world'. More recently they have diversified into energy technologies, including batteries (inc. sodium ion) and hydrogen from waste.

The company has been active in hydrogen fuel cells since 2016, working with NCL Pune (Dr. Lele) on low temperature PEM fuel cell development. In 2020, they demonstrated a retrofit BEV car with a fuel cell range extender, and have scaled up this technology for buses and a 20 person twin hull catamaran ferry will be commissioned in December 2023. Their fuel cells range in power from 25kW to 200kW, and 500kW and MW systems are in development. KPIT has developed the systems 'from the bottom up' using their own stack components, membrane electrode assemblies, balance of plant etc. Research is underway to look at in situ catalyst contamination reversal.

Other areas of development are high altitude (4,500m) defence applications for low partial pressure of O2 (compressor modification). They can accept solar, wind, battery and fuel cells to replace diesel gensets. Their components are defence rated. They are thinking about different catalysts to reverse electrolysis for hydrogen storage. During the tour of the warehouse facility, the delegation saw a 15kW demonstration unit and test station. Some technical notes on the range extended bus are:

- 32kWh battery with 20-40kW fuel cell. The fuel cell can charge a battery in 45 minutes from empty
- Four cylinders containing 7.7kg hydrogen @ 350 Bar gives an extended lifetime of 600 kms, or around 5 times the range of the bus with just the battery.
- Hydrogen tanks and fuel cell weigh 1.1 tonnes, battery weighs 1.6 tonnes.
- Magic number is 400kWh per day for FC extension to make sense (rather than just adding extra batteries).

Reliance Innovation Council India

https://www.ril.com/Innovation-R-D/Innovation.asp

Hosts: Mr. Sushil Borde and Shrikant Deo
Mr. Borde presented Reliance's history and innovation philosophy, which is driven by their Chairman Mukesh D. Ambani (a chemical engineer by training). The core element of Reliance's strategy is to deliver what India needs. Initially this was through textiles, new textile materials (polyester) then back up through the value chain to refining.

The company has become highly diversified with activities in desalination and irrigation for arid zone agriculture. The company doubles revenue every 5-6 years (75% of revenues are based on fossil fuels). To address India's needs for telecommunication connectivity, the company created the Jio mobile fibre network which it built across the nation in 3 years. It achieved 50m subscribers in just 83 days from launch. India now has more data usage than US and China put together with access equality outcomes at $2/month basic access. The company deploys devices, network, content, apps, services (including financial) and has over 500 million customers.

Reliance sees energy as its next frontier with a balanced outlook of 50% electricity/ 50% green molecules. Chairman Ambrani's target is to be net zero by 2035 and generate 100GW of solar by 2030, to reach US$1/kg hydrogen in one decade. The company is manufacturing 20GW PV per year on government wasteland – a Battery Energy Storage System (BESS) Gigafactory 50GWh per year (Li and Na in modular flexible factory as chemistry changes).

Reliance aims to produce green hydrogen and hydrogen derivatives (e.g. methanol) and downstream processes (e.g. methanol to olefins) based on verifiable renewables, with assistance from government in the transmission system (which is unified, relatively new, and expanding – may invest there also). They are investigating hydrogen mobility, yet they are unsure of this area given the recent debate around BEV dominating even the heavy vehicle sector. They are already producing 4 million tonnes of grey hydrogen per year.

Council of Scientific and Industrial Research – Central Electrochemical Research Institute

CSIR Madras Complex

Mr David Eggleston (Deputy Consul General for South India) arranged a comprehensive agenda and accompanied the Australian delegates on this visit. A welcome address was received by Dr N Anandavalli, Coordinator Director of CSIR Madras Complex (CMC); with introductory remarks by Dr K Ramesha, Director of CSIR-CECRI; and Dr Mahesh Kumar, CSIR-HQ. An introduction of the Australian delegates and CECRI presenters was made by Dr Vishal Dhavale, Senior Scientist, CSIR-CECRI.

CSIR has 37 institutes, about one-third involved with hydrogen. Material was shared showing the list of CSIR institutes involved with various parts of the hydrogen value chain. Figure 2 shows the areas of high RD&D activities in India. The major institutes where hydrogen related work in south of India is carried out are Central Electrochemical Research Institute (CECRI) and IIT Madras.

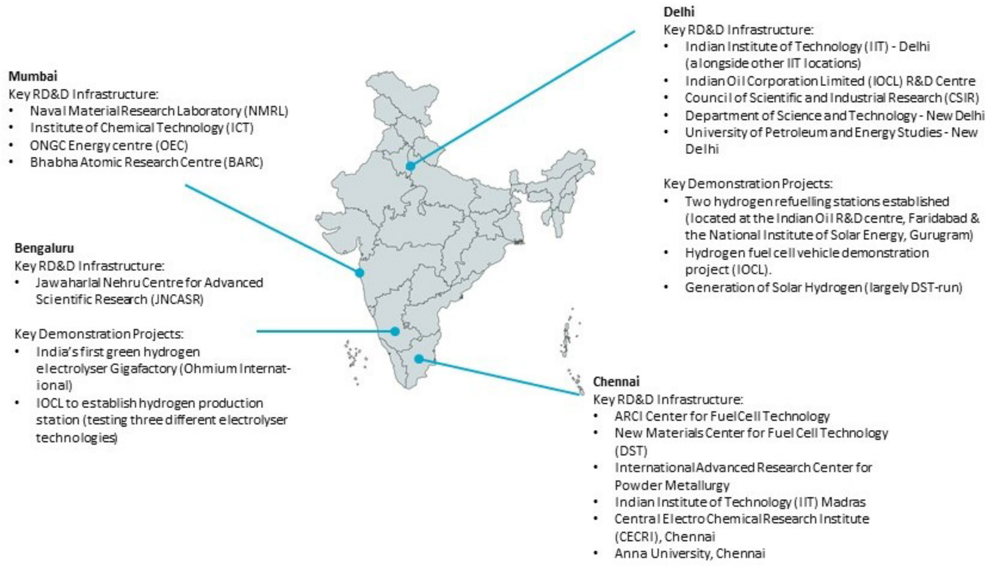

Fig. 2: Areas of high RD & D activities in India.

Fig. 3 Photograph of the attendees taken during the meeting / symposium at CSIR Madras Complex.

CSIR-CECRI is involved in following R&D areas related to renewable fuels like hydrogen and ammonia, and battery technologies:

- slectrochemical generation: PEM electrolysis and seawater electrolysis
- hydrogen utilisation: PEM fuel cells
- Li- and Na-batteries
- Redox flow battery
- CO2 capture and conversion

- photocatalysis
- biosensors
- corrosion.

The possible collaborations proposed by CECRI are: efficient and low cost polymeric and ceramic membranes for electrolysers; electrocatalysts for electrolysers; light-weight, low-cost composite monopolar / bipolar interconnects for electrolysers; photo-electrochemical water splitting and alternative approaches for seawater electrolysis.

The presentation by Dr S Vengatesan, Principal Research Scientist (CECRI) related to hydrogen generation. The major areas of his work are PEM and alkaline water electrolysis; seawater electrolysis and hydroxide exchange membrane (HEM) electrolyte. The group is working on all the three low temperature electrolysis technologies and have built prototypes. Some important technology / prototypes achievements include:

- 5 kW PEM electrolyser (1Nm^3 H_2/h) consumes 57-61 kWh/kg H_2. Target is: lower the catalyst loadings; improve current density and achieve <53 kWh/kg H_2 power consumption.
- 5 kW Alkaline electrolyser (1 Nm^3 H_2/h) consumes 54-63 kWh/kg H_2.
- Alkaline anion exchange membrane (AAEM) water electrolysis cells; lower current densities – 350 mA/cm^2; and membrane conductivity is low (10^{-3} – 10^{-2} S/cm)
- Seawater electrolysis: The concept is based on electrochemical cum electro-osmotic system that selectively oxidises the anions/cations in the seawater. The challenges of lower current density and life of the membrane are still being resolved. This is CSIR's patented process.
- CSIR is developing its own anion exchange (AEM) and cation exchange (CEM) polymer membranes, including non-noble metal catalysts based on titania support.
- Current collectors for PEM electrolysis: CSIR is developing 3D – printed titanium current collectors, and the fabrication process reduces the costs by 50%.

The presentation by Dr Santoshkumar D Bhat (CECRI) was on hydrogen utilisation. The group is working on fuel cells and batteries, technology indigenisation, direct methanol fuel cells (~250 W demonstration scale) and electrolytic production of NH3. The group has advanced the technologies for applications of fuel cells for the automotive applications, and is working with TVS Motor Company and Reliance, and have participated in operating a first indigenous fuel cell bus. The areas of collaboration suggested were: open cathode PEM fuel cells; component development (catalyst, membrane, electrodes, and MEAs for fuel cells); ammonia production via electrochemical route; and a hydrogen ecosystem through the combination of electrolyser, fuel cell, H2 storage.

The presentations by Dr A S Prakash, Dr P Ragupathy and Dr Ravi Babu were respectively on Li / Na- batteries, flow batteries and CO_2 capture / utilisation.

Areas identified for collaboration between Australia and India are as follows:

- CO_2 capture under flue gas conditions (power stations, steel, cement, incineration)

- Direct air capture (open, closed, and semi-open environment)
- Bio-gas enrichment (Nio-CNG) – upgraded by CO_2 capture.
- CO_2 capture from automotive sector
- Next gen carbon capture technologies
- Scale-up of technologies for real time applications.
- Carbon utilisation: cement carbonisation process, carbon nanotubes, oxalic acid, methanol.

Wednesday, 22 November 2023

Australian Consulate-General, Chennai

A briefing on Chennai economic development and surrounding southern regions was provided by Mr. David Eggleston, Deputy Australian Consul-General in Chennai at the Australian Consulate-General Office. For additional information see, https://www.dfat.gov.au/publications/trade-and-investment/india-economic-strategy/ies/index.html

Items to follow up include: a Memorandum of Understanding (MOU) signed between Australian universities and IIT Madras, and the Australia-India Centre for Energy (AICE). These activities show positive signs for Australian companies and researchers to be more involved with government pushes under opportunities such as the Hydrogen Valley Innovation Clusters (IITM TIDCO). See also Tamil Nadu in Clean Energy and Green Hydrogen.

IIT Madras Research Park

Prof. V. Kamakoti – Director IIT Madras

The first meeting at IIT Madras (IITM) was held with Prof. V Kamakoti. The 300-hectare campus is luscious and green housing wild deer, monkeys, and pythons and pursuing strong sustainability plan led by a team from Australia. The campus recycles 100% of its water used on campus. Incinerators are used for waste conversion to heat, and electricity, and they expect more jobs in recycling than in IT to occur within the next decade. Carbon capture from steelmaking and technologies is to be explored. The campus is part of the Green Hydrogen Valley Innovation Cluster (30 firms). IITM is looking to establish a separate campus to be a test bed for validating claims about sustainability. IITM is looking for more joint degree programs – twin programs at bachelor's degree level (PhD level already happens) and they are offering a course on sustainability in the bachelor's degree program. There is a strong push for start-up companies as India offers cheaper design costs (estimated at 1/10th of Australian cost), and there is a strong desire to pursue patents and startups. They are very proud and showed us several industry-student joint projects that have led to the formation of startups. They have several international joint programs and could extend to Australia. They are amenable to have IITM outposts in Australia and vice versa.

IITM Research Park

Hosts: Anson Sando and Reema Saha

This centre leverages IITM academic and engineering skills. The focus is on technology commercialisation, incubation and technology leadership training. The current technology focus is on batteries, green buildings and electric mobility. The mid-term focus of the centre is on green hydrogen, cement / steel decarbonisation and energy storage. The major focus is on solar PV panel efficiencies and effectiveness, cleaning, and recycling. The centre plays a pivotal role of marrying three sectors – industry, academia, and start-ups. The centre is run as a not-for-profit organisation and funding looks healthy. The companies involved currently are Reliance – PV modules; Shell – EV mobility; Total Energy, Daimler.

Tour of IITM Incubation Cell

IITM Incubation Cell is India's leading deep-tech startup hub (http://rtbi.in/incubationiitm/home.html). IITM Incubation Cell coordinates and leverages the synergies in various strands of excellence driving innovation and entrepreneurship at IIT Madras, consisting of cutting-edge research, industrial interactions, India's first university-driven IITM Research Park and a stellar record of incubation in rural, social and industrial technologies. The incubation cell is responsible for 233 startups, and has 88 startups currently in the market. It is registered as a not-for-profit company, and is recognised as a Technology Business Incubator by Startup India, DIPP and NSTEDB, Department of Science & Technology, Government of India. IITMIC supports students, faculty, staff and alumni of IITM and external entrepreneurs in creating successful deep tech startups, disrupting industries & translating benefits to the society at large.

Fig. 4 IITM Incubation Cell. Right: non-motorised and motorised versions of a wheelchair).

IITM – Energy and Emissions Research Group

The Energy and Emissions (EnERG) Laboratory was established in 2016 under the Department of Applied Mechanics, IITM. At EnERG lab, the primary focus is on applied research in the areas of energy and emissions. Members are actively involved in development and testing projects in areas of waste heat recovery, solar energy, aerosol, and emission. There is an increasing need for efficient energy utilisation and low environmental impact within the work, and there is a global need for improving the energy efficiency with existing power production processes coupled with a reduction in emissions. People at EnERG are interested in finding effective means to tap energy such as solar-powered cycles, and waste heat recovery from processes using organic Rankine cycles. The research also focuses on niche component developments such as expanders used in steam/ organic Rankine cycles and performance improvement of heat pumps in the industry. Another research focus area noted is on emission monitoring and control, where different methods to differentiate the various components in industrial emissions are tested. People at EnERG are also involved with R&D works on emission measurement and control devices.

The group has facilities on electrochemical diagnostics, gas sensing and analysis, steam characterisation and particle size analysis. The major collaborators are: ISRO, DRDO, BHEL, DST.

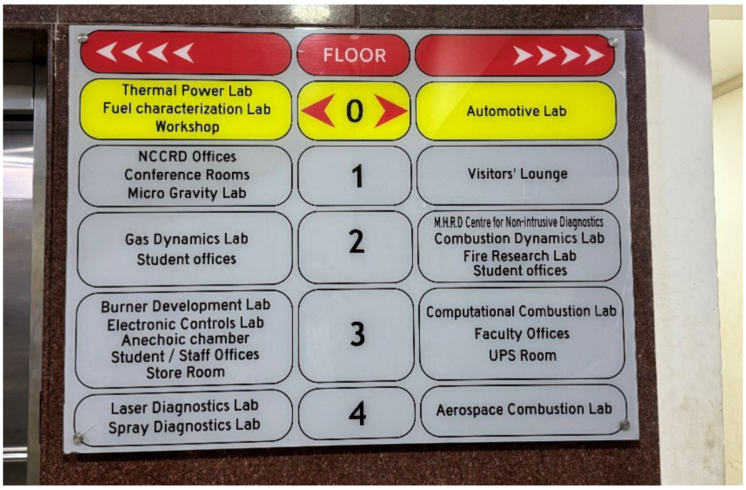

Fig. 5 The different labs of Energy and Emissions Research Group at IITM.

IIT Madras – The Energy Consortium (Towards decarbonisation)

https://energyconsortium.org/

Host: Prof. Satyanarayan Seshadri, Head, Energy Consortium, Energy CoE and IEAC.

The Energy Consortium was founded in Dec 2021 to enable India's journey towards a low carbon energy future. The consortium has an impressive ten global energy majors in partnership covering research in hard to abate sectors and hard to electrify sectors as well as those at the forefront of leveraging digital means for energy transition. They are participating heavily in two major alliances: one on energy storage and another on green fuels. The consortium is also actively partnering and advising government agencies on topics of national and international importance and represented at the COP28 in Dubai. They are leaders on collective action at scale and hope to contribute more assertively to the net zero India agenda.

The consortium has a revised strategy to advance research in clean energy sources, including offshore wind, green hydrogen, green fuels, and large-scale industrial electrification, while intensifying efforts in carbon capture, utilisation and storage. The Energy Consortium is an umbrella initiative at IIT Madras that spans the whole spectrum of research in energy generation, storage, conversion, and distribution. This is an industry-academia-government collaborative effort established with the aim of accelerating the development of technologies to enable the energy transition towards a low-carbon future.

The core expertise in the consortium includes carbon capture and storage, gas hydrates, coal and biomass conversion to useful chemicals, renewable energy systems including applications in electrolyser technologies for CO_2 conversion and green hydrogen, energy storage technologies both lithium and beyond, and distributed energy management including for resilient AC and DC microgrids. These are organised in centres of excellence (https://energyconsortium.org/centers-of-excellence/) as shown in Fig.5.

Fig. 6 Energy Consortium Technology Centres of Excellence at IITM.

Prof T.M. Murugandandam – Combustion lab tour

Prof. Murugandandam oversees the Advanced Gas Turbine Engines lab at IITM. The ongoing increase in aviation travel is driving research into reducing carbon emissions worldwide. The group has facilities and capability in Advanced Gas Turbine Engine Technologies, H2/ H2-HC blend/ SAF combustion, Next-gen Thermal Management, Advanced Fluid Based Heat Exchangers, Seals and Rotor Dynamics, Hybrid Electric Components. The centre has four verticals with the immediate goals:

1. futuristic fuel-based combustion - combustor technology for H2/ H2-HC blends and SAF
2. thermal management – Innovative, compact, high performance next-gen heat exchangers
3. seals and rotor dynamics - developing architectures for future engines
4. Hybrid electric components - high power to weight ratios and efficient core gas turbine air usage and design flexibility.

The group use the following labs for their R&D works and engagement with industry: Thermal Power Lab, Fuel Characterization Lab, Automotive Lab, Microgravity Lab, Gas Dynamics Lab, Combustion Dynamics Lab, Fire Research Lab, Burner Development Lab, Electronic Controls Lab, CFD lab, Laser Diagnostics Lab, Spray Diagnostics Lab, and Aerospace Combustion Lab.

Council of Scientific and Industrial Research - National Chemical Laboratories (CSIR – NCL), Pune

https://www.ncl-india.org/

Dr Ashish Lele

The delegation was greeted by current institute director Dr. Ashish Lele, and Dr. Swaminathan Sivaram who was NCL director 2002-2010. NCL has around 550 staff and 350 PhD students and was founded during the final years of British rule. National Chemical Laboratories sits amongst green and luscious gardens in an area of innovation institutes / companies to the northeast of Pune's city centre.

Following a candle lighting ceremony (symbolising enlightenment), the delegation settled down to a large workshop with staff at NCL and other invited organisations (including KPIT and Reliance). The workshop commenced with an address from Dr. Sivaram, who discussed the hope and hype of hydrogen, and urged the application of cautionary principles in rolling out hydrogen and other potentially disruptive energy transition technologies. Amongst many other reflections, he noted that 'The Principles of Economics often do not pull in the same direction as the Laws of Thermodynamics'. This provides food for thought, particularly when the delegation consider that round trip efficiency is often cited as the sole 'make or break' figure of merit for hydrogen technologies.

Dr. Lele followed Dr. Sivaram and gave an overview of India's hydrogen strategy and hydrogen activities in Pune. India currently produces 5Mt per year of grey hydrogen and has only 2 refuelling stations. India is aiming for a carbon intensity of 2 tonnes CO2/ tonne of hydrogen (c.f. EU 4.4 TCO2-e/TH2). Its goal is to produce 5MT/y green hydrogen by 2030, needing:

- 32GW electrolysers (60-100GW according to IIT Bombay)
- 330ML water
- 90GW PV,
- 38 GW wind,
- 560 GWh storage – not requiring 100% duty cycle
- 340,000 hectares
- US $154Bn.

Activities are coordinated through the Ministry of Natural resources & Energy (MNRE) who are developing a number of initiatives such as

- Mission mode Projects (industry partnerships / consortia)
- Grand Challenge Projects (critical technology focus)
- Blue Sky projects (longer term, global IP development)

CSIR is developing a hydrogen technology (H2T) program which will focus on improving the lifetime of electrolyser technologies through materials innovations. The program is funded with INR 100 Crore (US$9.7m). Dr Lele has considerable experience in fuel cell research. Pune is developing the Pune Hydrogen Valley Innovation Cluster (P-HVIC) covering the entire hydrogen value chain, and a Mumbai-Pune hydrogen bus corridor is being proposed.

Dr Lele's presentation was followed by science presentations from NCL group leaders and scientists.

Dr Bhagwat and Dr Dhakephalkar spoke about work on biohydrogen production using agri-waste. Biological hydrogen production is a priority for India and is being investigated in a number of the institutes the delegation visited. A motivation for this work is the wasteful and polluting use of stubble burning by Indian farmers. This is because Artesian water mining is now banned, so planting has to be delayed into the monsoon and the winter crop sowing window is reduced since summer harvesting is pushed back into September leading to widespread burning as the only option to remove waste over only 15 days of the year.

The stoichiometry for glucose to hydrogen is 1M glucose -> 3.4M H_2

An anaerobic bacterium, Clostridium hydrogenum, and bacterial isolates from waste sources are being studied. Isolates from termite guts which can use cellulose in rice straw as a feedstock are being developed as proof of concept.

Dr Vikas Mathe from Pune University is studying thermal plasma pyrolysis of methane to produce carbon black, various graphenes, and hydrogen. The process uses an Argon plasma torch, and the outlet gas composition (which includes ethyne (C_2H_2) is being analysed using GCMS. Hydrogen yield is 70-90%.

Dr SS Thipse from the Automotive Research Society of India (ARAI) spoke about certification agency and an R&D institute which looks at alternative fuels, e-mobility and fossil fuel use in mobility. The objectives of the association are R&D in automotive engineering for industry, product design and development, evaluation of automotive equipment and ancillaries, standardisation, technical information services, execution of advanced courses on the application of modern technology and conduct of specific tests. India has developed a roadmap for alternative fuels and is implementing stringent emissions standards.

Indian genset emission standards are most stringent in the world. The new CPCB IV and emission standards will cover all fuel types for engine power output of up to 800 kWh. It is a single standard for both prime and standby usage of gensets. https://www.business-standard.com/companies/news/cummins-india-receives-cpcb-iv-norm-compliance-certification-from-arai-123061300478_1.html

The institute works on Compressed Natural Gas (CNG, which is a major mobility fuel in India) biodiesel, ethanol, synthetic fuel DME, h2. They consider all 'colours' of hydrogen.

Standards for CNG include for storage cylinders which are very safe. The standard requires bullets being fired at the tanks. They are developing hydrogen fuels standards for every part of Hydrogen fuelling stations, and a hydrogen cylinder test facility.

Research relating to hydrogen includes:

- H2 ICE, where simple replacement of the engine head allows adoption of different fuels. They look at PFI (port fuel injection), DI (direct injection), HP (high pressure). DI appears optimal – higher pressures (100-600 Bar) to come
- H2-CNG blended fuels for engines.
- ARAI will develop H2 bus engine for hydrogen valley project.
- H2 engine test cell.
- Developing H2 bowser.
- Small tractors and motor mowers (~1 kW) – a niche area not considered by large players (Dr Mulik) using 300 bar tanks and a hybrid battery system.

Thursday, 23 November 2023

Symposium on Green Technology, IIT Bombay

Location: IIT Bombay, Powai, Mumbai

Led by Ms Tanvi Mehta

The delegation attended a Symposium on Green Technology held at IIT Bombay, welcomed by Prof. KVK Rao and Prof. Ravinda Gudi. The symposium consisted of a mix of presentations from IIT Bombay researchers and the Australian delegation.

IIT Bombay summarised India's National Hydrogen Mission announcement in January 2023 of a 19,744 Cr ($4B) commitment through to 2030. This includes 500 GW of non-fossil fuel capacity by 2030. A recurring theme throughout the various presentations has been an emphasis on indigenous technological development to help meet India to be carbon neutral by 2070.

Within the National Green Hydrogen Mission there are two phases:

- Phase 1 (2022-2026): creating demand, incentivising supply, increasing electrolyser manufacturing, scale up production and use.
- Phase 2 (2026-2030): Cost competitiveness, pilot projects, scale up R&D, enhance penetration across sectors.

The actions initiated through the National Green Hydrogen Mission include:

- Policy initiatives
- Standards
- R&D
- Demand aggregation
- Pilot Projects
- International cooperation

There is a key objective of "demand creation" for hydrogen, coordinated across many government departments. There is recognition that research drives cost reduction to support demand creation. The vision for 2030 is at least 5 million metric tonnes per annum of green hydrogen production.

Across IIT Bombay, some of the key hydrogen research activities include:

- Hydrogen production (Prakash Ghosh, Sandeep Kumar, Sanjay Mahajani, Arnab Dutta, C. Subramaniam).
- Hydrogen storage (Pratibha Sharma, Sankar Sarma V T , Asim Tewari, Abhijit Chaterjee)
- Hydrogen utilisation (Prakash Ghosh, Asish Sarangi, Manoj Nergat)

Some specific examples of hydrogen activities include:

- Prof Pratibha Sharma — metal hydride storage
- Prof Sandeep Kumar — hydrogen production via biomass-plastic oxy-steam gasification
- Prof Arnab Dutta — bio-inspired catalysts for electrolysis, potentially with impure water
- Prof Anirban Guha — hydrogen storage in composite materials, pressure vessel design
- Prof Manoj Neergat — batteries (including flow redox), fuel cells, electrolysers
- Prof Zakir Rather — balance of plant and grid integration

Following the Symposium on Green Technologies, the delegation toured Prof Sharma's laboratory. Across the breadth of activities at IIT Bombay, there are many potential opportunities for collaboration with Australian research institutions. IIT Bombay is deeply linked with India's National Hydrogen Mission, which gives them some unique insight into the long-term aspirations for India.

Friday, 24 November 2023

Meeting with CSIR Director General

Meeting with Professor N. Kalaiselvi, Director General, CSIR, and Vice Chairman, Board of Governors, AcSIR
Location: Nilgiri Meeting Room, Australian High Commission, New Delhi
Coordinated by Mr Sanjiva De Silva, DFAT
Supported by Rama Swami Bansal, Chief Scientist and Head, CSIR

Prof Kalaiselvi spoke to the delegation about sharing our visions and installing better processes to meet our vision. We need to collectively understand what TRLs all the many different technologies and R&D subject areas are at. We can then allocate our skills and expertise more efficiently. And once TRL levels of 5-8 are obtained we need to come together even more as it can still take many years to commercialise. Many of the technologies needed to develop a hydrogen industry are in these early stages breaking into 4-7 levels and need nurturing. India is very ready for increased synergies with Australia and suggested we could start by sharing research planning exercises such as a TRL analysis, joint dashboards, and needed research management between Australia and India.

Priority topics:

- Replace Nafion
- Type 4 and 5 storage cylinders (carbon fibre?)
- Seawater electrolysis
- Green ammonia and chemicals
- Green steel

Ministry of New and Renewable Energy

Meeting with Mr. Jagdale, Joint Secretary, Ministry of New and Renewable Energy (MNRE) https://mnre.gov.in/

Location: Atal Akshay Urja Bhawan, CGO Complex, New Delhi

India already has strong collaborative networks with international partners on hydrogen RD&D and commercialisation across the value chain and signalled much more to be done. Key developments include the strategic partnership between the MNRE, and the International Renewable Energy Agency (IRENA) announced in January 2022. The Indian government has reinforced its desire to collaborate internationally through existing partnerships and programs – including Mission Innovation, the Quadrilateral Strategic Dialogue and the International Organisation for Standardisation. Key areas of focus include the development of regulatory codes, technical specifications and market frameworks which are necessary to scale-up hydrogen utilisation.

India and Australia are also partners through a number of agreements: the Letter of Intent (LoI) on New and Renewable Energy Technology (February 2022); the India-Australia Comprehensive Strategic Partnership (June 2020); and the Memorandum of Understanding (MoU) on New and Renewable Energy Cooperation (February 2010).

MNRE committed to a reciprocal fellowship program with CSIRO to focus on building the resiliency of supply chains. Green technology focus areas are:

- Battery storage
- Offshore wind
- Green hydrogen

H2 Priorities are storage, electrolyser manufacturing (which will be heavily subsidised); fertilisers, refineries, steel and cement; and a H2 export import market.

India's domestic hydrogen landscape

At the governmental level, there are several regulatory bodies that administer, promote and develop India's hydrogen policies.

The primary government body driving India's hydrogen strategy and RD&D policies is the MNRE, which established the Hydrogen Energy and Fuel Cells Steering Committee to publish strategic documents and effect high-level strategic priorities. Other Indian ministries and departments support the implementation of these strategic priorities. For example, the Department of Science and Technology (DST) establishes mission-based programs, and the Ministry of Petroleum and Natural Gas (MoPNG) has oversight for hydrogen policies and demonstration projects which overlap with India's existing energy grid. Hydrogen RD&D funding sits across several departments with respect to their sector mandate. For example, the MoPNG's 'Hydrogen Corpus Fund' provides project funding relevant to the oil-industry whilst the DST's 'Advanced Hydrogen and Fuel Cell Programme' is focussed on hydrogen fuel cell, storage and electrolysis technologies and materials. Additionally, the MRNE's budget has allocated INR 20 Crore for hydrogen energy and fuel-cell R&D more broadly.

India has a well-structured science, technology and innovation (STI) policy landscape. Government ministries formulate and fund RD&D policy initiatives, which are then implemented and overseen by several different departments – including the Department of Scientific & Industrial Research (DSIR), DST, Department of Biotechnology (DBT), and the Defence Research Development Organisation (DRDO). In December 2020, India announced the New Science, Technology Policy (STIP) which identifies India's current STI policy focuses. The MRNE is responsible for hydrogen and energy-specific policy in India.

India also has active consortia and industry associations which support India's transition to a hydrogen economy, including the Indian Hydrogen Alliance (IH2A) and the Hydrogen Association of India. The IH2A is working with members to inform India's *National Hydrogen Policy Roadmap*.

Indian Government Departments & Industry Roundtable discussion

Roundtable: Technological needs of India in the Green Hydrogen space and Value Addition by Australia - strengths and scope for involvement

Location: Murray – Harris meeting room, Australian High Commission, New Delhi

Mr Sanjiva De Silva from the DFAT, Australia, facilitated a roundtable discussion between the Australian delegates and the following attendees:

Andrew Carter, Investment attraction, Austrade – introduce Indian investors to Aust

Dr Sneha Malhotra, Chief Technology Officer, Office of Principal Scientific Advisor

Dr Anita Gupta, Advisor, DST

Dr Piyali Das, Senior Fellow (Scientist), TERI

Dr R K Malhotra, President, Hydrogen Association of India

Ms Shuva Raha, Head – New Initiatives, CEEW

Mr S Bharathan, Director-Refineries, HPCL

Prof Ashutosh Bhardwaj, Department of Physics and Astrophysics and Dean, International Relations (S&T), Delhi University

Prof Sasank Deka, Department of Chemistry, Delhi University

Ms Ankita Bhatnagar

Prof Sudhir Kumar Barai, Director, BITS Pilani

Ms Nisha Jayaram, Principal Counsellor, Confederation of Indian Industry

Nishaanth Balashanmugam, Country Director, GH2

Anuraag Nallapaneni, Manager (Hydrogen and E-Mobility), World Resources Institute

Sanjiva de Silva, Counsellor, Counsellor, DISR and DCCEEW, Australian High Commission

Caitlin Searle, Counsellor (Science &Technology), DISR, Australian High Commission

Steven Connolly, First Secretary (Economic), Australian High Commission

Andrew Carter, Trade and Investment Commissioner (South Asia), AUSTRADE

To date, industry has been playing a leading role in hydrogen RD&D collaboration, with Indian state-owned and private enterprises announcing expressions of interest for international private-sector companies to partner and establish pilot projects. The India Hydrogen Alliance (IH2A) has led this approach and now represents a coalition of industry partners – both in India and globally – that seek to accelerate hydrogen RD&D and commercialisation, with a particular focus on hydrogen production, storage, industrial clusters and end-use applications.

The following key points and offers were raised:

- India's Hydrogen Roadmap needs R&D to meet the targets and vision. There are very underdeveloped areas like biomass and waste management.
- DST is running the Hydrogen Valleys program and recognises the risks and the need for solid planning and meaningful timeframes. There is a great need for international collaboration.
- Many of the people and organisations at this table could help facilitate necessary and impactful research. This needs funding, leadership, and momentum.
- We need joint testing facilities and complementary standards and regulations.
- Life cycle assessment will be best served if done across countries and set standards. See the WRI example of emissions intensity.

A strong leadership group could be picked from this roundtable. This group could drive the necessary levers that arose from the roundtable which are:

1. More supply chain knowledge is needed and requires data, thinking and planning
2. Skills development across industry, policy and research, requires facilitating more mobility and skills transfer
3. Knowledge sharing (e.g. standards and regulations, safety)
4. Creating decision making tools (e.g. Lifecycle analysis, Guarantee of Origin)
5. Scaling up technology and manufacturing which requires large amounts of capital, technology adoption and transfer between our countries.

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For further information

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