indus TOWERS

IMPACT ASSESSMENT REPORT

RESEARCH LAB ON HYDROGEN WITH SOLAR INTEGRATION

IMPLEMENTING PARTNER: IIT MADRAS

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Path to Sustainability

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TABLE OF CONTENTS

ABBREVIATIONS

AEM	Anion Exchange Membrane
BMS	Battery Management System
BOP	Balance of Plant
CAN	Controller Area Network
CHL	Chemical Engineering Laboratory
CO_2	Carbon Dioxide
CSR	Corporate Social Responsibility
DAQ	Data Acquisition (System)
DC/AC	Direct Current / Alternating Current
DOT	Department of Telecommunications
GX	Graphic Experience (Victron Energy controller)
H_2	Hydrogen
IP	Infrastructure Provider / Intellectual Property
IPR	Intellectual Property Rights
IIT	Indian Institute of Technology
IITM	Indian Institute of Technology Madras
kW	Kilowatt
kWh	Kilowatt-hour
L&T	Larsen & Toubro
LFP	Lithium Iron Phosphate
Li-ion	Lithium-ion
MCA	Ministry of Corporate Affairs
MoU	Memorandum of Understanding
MPPT	Maximum Power Point Tracker
MSB	Main Science Block
MWh	Megawatt-hour
NA	Not Applicable
Nm^3/h	Normal Cubic Metres per Hour
PEM	Proton Exchange Membrane
PG	Post Graduate
PU	Polyurethane
R&D	Research and Development
SOC	State of Charge
SOH	State of Health

01. EXECUTIVE SUMMARY

PROJECT OVERVIEW

This report presents an independent assessment of the Corporate Social Responsibility (CSR) initiative funded by Indus Towers Limited and implemented by the Indian Institute of Technology Madras (IIT Madras). The project, titled "Research Lab on Hydrogen with Solar Integration," supported the design, construction, and operationalisation of a green hydrogen microgrid at a premier academic institution, under the CSR provisions of Section 135 of the Companies Act, 2013.

The initiative was structured purely as a research and prototype-development grant, aimed at advancing India's green hydrogen ecosystem through public academic infrastructure. The project ran over five quarters, from November 2022 to March 2024, with a total CSR contribution of INR 1,20,00,000/- (Rupees One Crore and Twenty Lakhs only). The infrastructure created is owned exclusively by IIT Madras and serves academic, research, and public demonstration purposes.

The project culminated in the successful commissioning of a fully operational Green Hydrogen Microgrid at the Chemical Engineering Laboratory (CHL) Building of IIT Madras, inaugurated on 23rd February 2024. The microgrid integrates a 20kW rooftop solar array, a 6.2kW Anion Exchange Membrane (AEM) electrolyzer, a 30kWh Lithium Iron Phosphate (LFP) battery bank, and a 3kW Proton Exchange Membrane (PEM) fuel cell, which together generate, store, and utilise green hydrogen to power common areas of the building.

INR 1.2 Cr	33,000 L	2.7 MWh	2.43 T
CSR Investment	Green H_2 Generated	Electricity Saved	CO_2 Avoided
Nov 2022 – Mar 2024	As on Apr 2024	Grid offset	Environmental saving

PROJECT DETAILS

CSR Contribution

INR 1,20,00,000/-

Project Period

01.11.2022 to 31.03.2024

CSR Category

Schedule VII – R&D / Environment

ABOUT THE RESEARCH PROJECT

The project — "Research Lab on Hydrogen with Solar Integration" — was conceived to address a critical gap in India's clean energy research infrastructure: the absence of an end-to-end, integrated solar-to-hydrogen-to-power demonstration and data-generation facility at an academic institution. India's National Green Hydrogen Mission, launched in 2023, underscores the national imperative for building exactly such research capacity. This project delivers precisely that, in prototype form, at one of India's premier institutions.

Technical Architecture

The prototype microgrid was built at the Chemical Engineering Laboratory (CHL) building of IIT Madras and integrates the following components into a unified, data-monitored system:

- 20kW rooftop solar photovoltaic array (Vikram Solar) installed on the CHL building rooftop
- Smart Solar MPPT charge controllers (Victron Energy, 450V/200A) for maximum power point tracking
- 30kWh Lithium Iron Phosphate (LFP) battery bank for excess solar energy storage
- 6.2kW Anion Exchange Membrane (AEM) electrolyzer (Enapter) producing 1 Nm^3/h of green hydrogen at 99.5% purity
- Hydrogen dryer (Enapter Dryer 2.1) upgrading purity to 99.999% — meeting PEM fuel cell grade requirements
- Hydrogen storage cabinet at 35 bar pressure (1.4 kg H_2 capacity)
- 3kW PEM fuel cell (Horizon Fuel Cell Technologies) for electricity generation from stored hydrogen
- 15kW DC/AC inverter and 5kW inverter for load distribution
- Keysight Data Acquisition System (DAQ 970A) for real-time monitoring of all system parameters
- Hydrogen leak sensor (TS21I-CAT-H2) for operational safety

The system powers the common walkways, corridors, entrance areas, parking, and select rooms of the CHL building entirely through solar-derived green hydrogen — demonstrating a complete, emission-free stationary power cycle. All system outputs, including solar generation, hydrogen production rates, battery state of charge, fuel cell performance, and load profiles, are continuously logged to build a comprehensive techno-economic dataset.

RESEARCH OBJECTIVES

The project was designed to achieve the following primary objectives:

Design, procure, and construct an integrated solar-hydrogen microgrid as a working prototype at an Indian academic institution, filling a critical infrastructure gap in the country's clean energy research ecosystem.

Generate and validate end-to-end operational data correlating solar irradiance, hydrogen production, storage behaviour, fuel cell output, and electrical load — producing a replicable dataset for future research.

Demonstrate the technical and functional feasibility of solar-to-hydrogen-to-electricity conversion for stationary power applications under Indian climatic and grid conditions.

Create a permanently accessible research, teaching, and demonstration facility for students, faculty, government bodies, and industry professionals working in the green hydrogen and renewable energy domain.

Contribute to the development of skilled human capital in green hydrogen technology by training B. Tech, M. Tech, and PhD students through hands-on engagement with the microgrid

Establish a modular, upgradeable research platform that can serve as the foundation for larger sponsored research projects, government grants, and academic collaborations in hydrogen energy.

KEY FINDINGS

The assessment of the project against its stated objectives and the CSR mandate yields the following key findings:

Technical Performance

The Green Hydrogen Microgrid was successfully commissioned and operationalised by February 2024, fully meeting the project's scope and timeline.

The AEM electrolyzer achieved a production rate of 1 Nm^3/h of green hydrogen at 99.5% purity, which when processed through the dryer reaches 99.999% — sufficient for direct fuel cell use without additional treatment.

The integrated system demonstrated stable and reliable performance across multiple quarters of data collection, validating the technical architecture for Indian conditions.

Environmental Outcomes

A total of 33,000 litres of green hydrogen was generated as of 3rd April 2024 — hydrogen produced entirely from solar energy with zero fossil fuel input.

The system achieved a grid electricity offset of 2.7 MWh — energy displaced from the conventional grid and replaced by solar-green hydrogen power.

Carbon dioxide emissions of 2.43 tonnes were avoided as a direct result of the microgrid's clean energy supply to the building.

Research and Academic Impact

A rich, multi-parameter operational dataset has been generated, covering solar generation, hydrogen production, battery behaviour, fuel cell output, and load profiles — a first-of-its-kind dataset from an Indian academic installation.

The microgrid serves as a live teaching platform for students across multiple departments, including Chemical Engineering, Electrical Engineering, and Energy Sciences.

The facility attracted visits from 20 plus senior industry leaders, research professionals, renewable energy experts, and representatives from leading public and private sector organisations, demonstrating its growing recognition as a national-level demonstration and knowledge-sharing platform for green hydrogen technologies.

KEY IMPACT

The CSR investment has generated measurable, verifiable impact across four dimensions:

ENV

Environmental Impact

33,000 L of green hydrogen generated from solar energy; 2.7 MWh of grid electricity offset; 2.43 tonnes of CO_2 emissions avoided — all through clean, renewable-sourced energy.

EDU

Educational Impact

A permanent, hands-on teaching and research facility created at IIT Madras; B. Tech, M. Tech, and PhD students engaged in real-world hydrogen energy systems; researchers trained in cutting-edge AEM and PEM technologies.

SCI

Scientific & Knowledge Impact

First integrated solar-hydrogen-fuel cell dataset generated at an Indian academic institution; modular infrastructure established for long-term research continuity; scientific foundation laid for techno-economic assessments of green hydrogen viability in India.

POL

Policy & National Mission Alignment

Directly supports India's National Green Hydrogen Mission; provides academic evidence and demonstration capability aligned with India's decarbonisation goals; accessible to government bodies and policymakers as a live proof-of-concept facility.

In summary, the CSR project funded by Indus Towers has successfully catalysed the creation of a unique, public-good research infrastructure at IIT Madras. The investment has the potential to yield tangible environmental outcomes, significant educational value, and enduring scientific contributions — all fully aligned with the intent and spirit of Schedule VII of the Companies Act, 2013. The detailed findings, methodology, and impact analysis are presented in the chapters that follow.

02. INTRODUCTION

BACKGROUND AND CONTEXT

India's transition to a clean energy economy is among the most consequential national undertakings of the twenty-first century. As the world's third-largest emitter of greenhouse gases and a country with rapidly expanding energy demand, India has committed under its Nationally Determined Contributions (NDCs) to achieving 500 GW of non-fossil fuel-based electricity capacity by 2030 and net-zero carbon emissions by 2070. Within this strategic framework, green hydrogen — hydrogen produced by electrolysing water with renewable electricity — has emerged as a transformative energy carrier capable of decarbonising hard-to-abate sectors such as industry, heavy transport, and long-duration energy storage.

Despite growing recognition of green hydrogen's potential, India has historically faced a significant gap in academic and research-level infrastructure dedicated to hydrogen production, storage, and utilisation. During the early stages of the country's green hydrogen journey, opportunities for researchers and students to work with integrated, real-world hydrogen systems remained limited. This constrained the generation of indigenous techno-economic data needed to design cost-effective systems suited to Indian climatic conditions, operational realities, and energy requirements. It also hindered the development of a skilled talent pipeline to support the emerging hydrogen economy.

It is against this backdrop that the "Research Lab on Hydrogen with Solar Integration" project was conceptualised and implemented. Supported by CSR funding from Indus Towers Limited and executed by the Department of Chemical Engineering at IIT Madras, the initiative aimed to establish a fully integrated green hydrogen research and demonstration facility at a leading academic institution. The project represents an important contribution to India's evolving clean energy ecosystem by creating infrastructure for research, experimentation, capacity building, and knowledge generation in green hydrogen technologies.

Its significance extends beyond the infrastructure itself. By enabling hands-on learning, operational research, technology validation, and stakeholder engagement, the facility contributes to strengthening the scientific, technical, and institutional foundations required for the long-term growth of India's green hydrogen sector.

PROJECT OVERVIEW

The project, formally titled "Research Lab on Hydrogen with Solar Integration," was implemented by the Department of Chemical Engineering at the Indian Institute of Technology Madras (IIT Madras), under the principal investigator ship of a senior faculty member and 4 research assistants. The project was funded through a CSR contribution of INR 1,20,00,000/- (Rupees One Crore and Twenty Lakhs only) by Indus Towers Limited, pursuant to a formal Memorandum of Understanding (MoU) executed between the two parties effective 1st November 2022, with a project term extending to 31st March 2024.

The primary aim of the project was to design, procure, construct, commission, and operationalise an integrated green hydrogen microgrid at the Chemical Engineering Laboratory (CHL) Building of IIT Madras. The microgrid was designed to demonstrate the complete technological cycle of: (i) solar electricity generation; (ii) water electrolysis for green hydrogen production; (iii) hydrogen storage; and (iv) re-conversion of hydrogen to electricity via a fuel cell for powering building infrastructure. The project was structured as a five-quarter phased programme, with quarterly reporting and utilisation certification submitted to the donor.

Project Title

Research Lab on Hydrogen with Solar Integration

Donor Organisation

Indus Towers Limited (formerly Bharti Infratel Limited)

Implementing Body

IIT Madras – Dept. of Chemical Engineering

CSR Contribution

INR 1,20,00,000/- (One Crore Twenty Lakhs)

Project Duration

01 November 2022 – 31 March 2024 (5 Quarters)

Location

CHL Building, IIT Madras Campus, Chennai

ABOUT THE DONOR ORGANISATION — INDUS TOWERS LIMITED

Indus Towers Limited, formerly known as Bharti Infratel Limited, is one of the largest telecom tower infrastructure companies in the world and India's leading provider of shared passive telecommunications infrastructure. Registered as a Category-1 Infrastructure Provider (IP-1) by the Department of Telecommunications (DoT), Ministry of Communications and Information Technology, Government of India, the company operates under Section 4 of the India Telegraph Act, provisioning passive infrastructure including towers for use by licensed mobile telecom operators across the country.

Indus Towers has maintained a steadfast commitment to corporate social responsibility, operating in consonance with Section 135 of the Companies Act, 2013 and the Companies (Corporate Social Responsibility) Rules, 2014. The company's CSR philosophy extends to benefiting socially and economically disadvantaged communities through targeted interventions in education, environmental sustainability, scientific research, and skill development — all areas recognised under Schedule VII of the Companies Act.

For this project, the CSR contribution was channelled exclusively towards the creation of academic research infrastructure and the advancement of knowledge in green hydrogen technology — a domain of clear and pressing national interest. Indus Towers holds no intellectual property rights over the research outputs generated under this project; all foreground IPR vests solely with IIT Madras as stipulated in Clause 13 of the MoU. The company's contribution is thus a pure CSR grant, directed at public good through academic institution-building.

ABOUT THE IMPLEMENTING INSTITUTION — IIT MADRAS

The Indian Institute of Technology Madras (IIT Madras) is one of India's foremost institutions of higher education and research, constituted by the Government of India under the Institutes of Technology Act, 1961. IIT Madras has consistently ranked as the No. 1 engineering institution in India under the National Institutional Ranking Framework (NIRF) and is globally recognised for excellence in science, engineering, technology, and management education. The institution hosts over 600 faculty, approximately 10,000 students, and 150+ research and academic departments, centres, and interdisciplinary programmes.

IIT Madras is a gazette-notified CSR implementation agency as per the MCA gazette notification of 2019, making it a legally recognised and fully compliant partner for corporate CSR engagements. The institution administers CSR-funded projects through the Centre for Industrial Consultancy and Sponsored Research (ICSR) and the Office of Alumni and Corporate Relations (ACR), ensuring robust governance, financial accountability, and quarterly programmatic reporting standards.

The Department of Chemical Engineering at IIT Madras, which led the implementation of this project, has a distinguished record in cutting-edge research spanning electrochemical systems, energy materials, process engineering, and environmental technology. The department is home to internationally recognised faculty and research groups working at the frontiers of clean energy science, including hydrogen production, fuel cell technology, and battery materials — disciplines directly pertinent to this initiative.

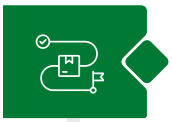
PROGRAMME ACTIVITIES

The project was implemented over five quarters spanning November 2022 to March 2024. Each quarter was defined by specific deliverables, milestones, and reporting obligations. The programme unfolded in a logical progression from planning and design, through procurement and civil works, to installation, commissioning, and operationalisation. The table below summarises the key activities and outcomes across all five quarters:

Quarter	Period	Key Activities & Outcomes
Q1	Nov–Dec 2022	Project initiation, design finalisation, site assessment, and identification of the Chemical Engineering Laboratory (CHL) building as the host facility. Preliminary civil work planning and vendor identification commenced.
Q2	Jan–Mar 2023	Detailed engineering design of the microgrid system. Procurement processes initiated for all major components. Revision of site plan: solar panels relocated from MSB building to CHL rooftop for better integration with the hydrogen console room.
Q3	Apr–Jun 2023	Continued procurement and vendor finalisation. Structural assessment of CHL rooftop completed. Console room layout finalised in consultation with IIT Madras Dean (Planning) and Engineering Unit.
Q4	Oct–Dec 2023	Installation of 20kW rooftop solar PV array (Vikram Solar) on CHL building completed. All major components procured and delivered on-site including AEM electrolyzers, PEM fuel cell, battery bank, MPPT controllers, inverters, gas analyser, DAQ system, hydrogen storage cabinet, and water purification system. All electrical wiring from solar panels to MPPT and load completed. Console room modifications finalised.
Q5	Jan–Mar 2024	Completion of civil and electrical modifications to the hydrogen microgrid room. Installation and commissioning of AEM electrolyzer and PEM fuel cell system with hydrogen leak detection safety measures. Inauguration of the Green Hydrogen Microgrid on 23rd February 2024. Commencement of continuous data collection across all system parameters. Total of 33,000 L green hydrogen generated and 2.43 tonnes of CO_2 emissions avoided.

PROGRAMME OBJECTIVES

The programme was designed to achieve a set of interlinked technical, educational, environmental, and national-interest objectives. These are articulated below:



To design and construct a fully operational, end-to-end solar-powered green hydrogen microgrid at IIT Madras, creating unique academic research infrastructure that did not previously exist at any Indian premier institution at this scale and integration level.

To demonstrate the technical feasibility of the complete solar-to-hydrogen-to-electricity cycle for stationary power applications under real Indian climatic and grid conditions, generating empirical performance data of national scientific value.

To produce and validate a comprehensive, multi-parameter operational dataset — covering solar irradiance, electrolyzer performance, hydrogen generation and storage, fuel cell output, and load profiles — suitable for techno-economic analysis, future research, and policy guidance.

To create a permanent, publicly accessible teaching, training, and demonstration facility at IIT Madras, enabling hands-on education for B. Tech, M. Tech, and PhD students across multiple departments, and serving as a demonstration platform for industry, government bodies, and other academic institutions.

To build skilled human capital in green hydrogen technologies by engaging students and research scholars in the practical operation, data analysis, and optimisation of a working hydrogen energy system — contributing to India's national pipeline of clean energy professionals.

To establish a modular, upgradeable research infrastructure that can serve as the foundation for future government-funded research grants, international collaborations, and expanded experimental programmes in hydrogen and renewable energy integration.

STUDY OBJECTIVES OF THE CSR IMPACT ASSESSMENT

This CSR Impact Assessment Report has been prepared to independently evaluate the outcomes and impact of the CSR-funded project. The specific study objectives of this assessment are:

To assess the extent to which the project has achieved its stated programme objectives within the agreed project period and budget.

To quantify and document the measurable environmental outcomes of the project, including green hydrogen generated, electricity saved, and carbon dioxide emissions avoided.

To evaluate the educational and human capital impact of the project in terms of students and researchers trained, institutional capacity built, and knowledge disseminated.

To assess the quality, reliability, and future utility of the scientific data generated through the microgrid's operation, and its significance for India's green hydrogen research ecosystem.

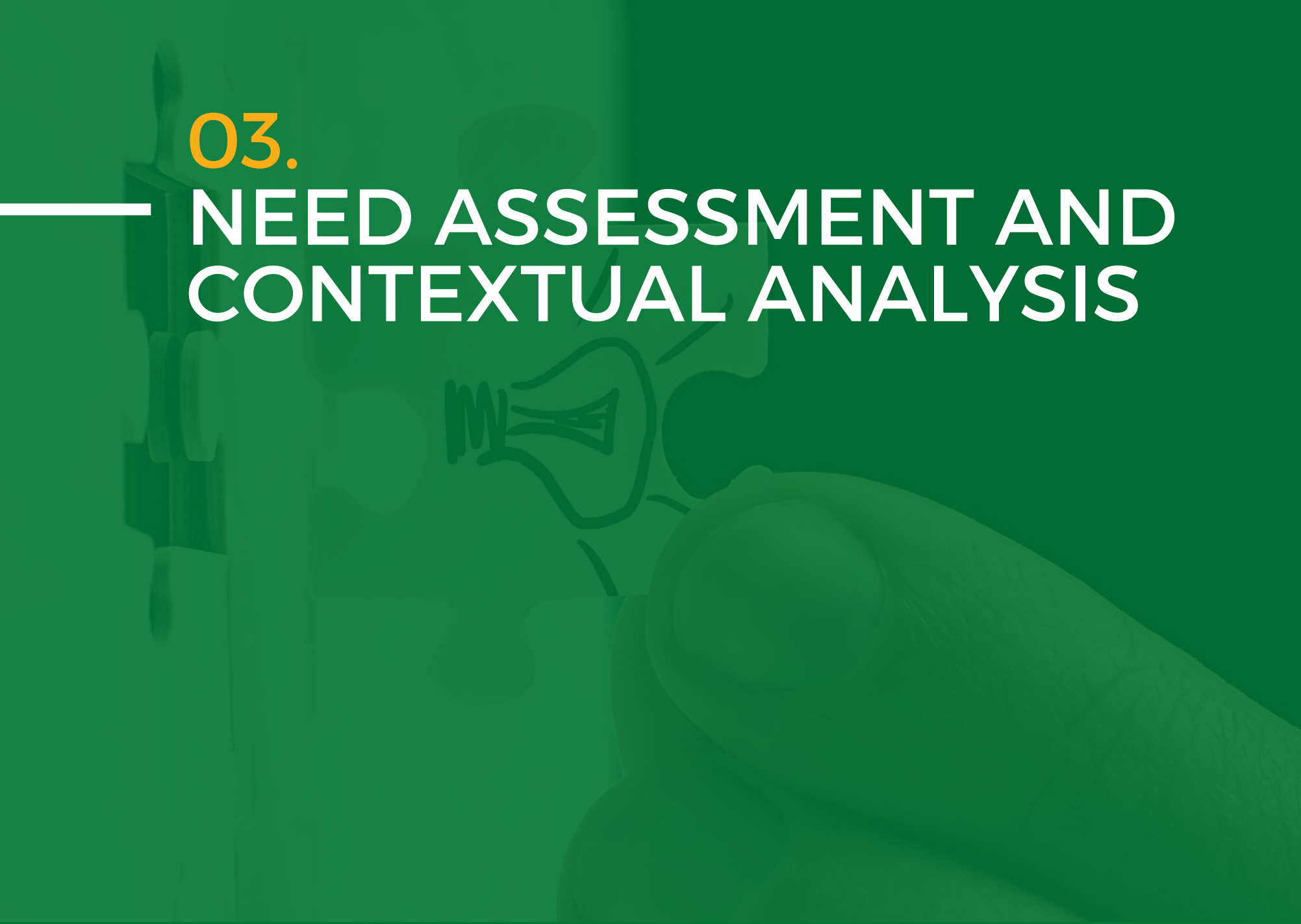
To document the broader knowledge-sharing and public demonstration impact of the facility, including outreach to industry, government bodies, and academic institutions.

To verify that all CSR funds were utilised strictly in accordance with the MoU, for the purposes of research infrastructure creation and prototype development, with no commercial benefit accruing to the donor organisation.

To identify lessons learned and forward-looking recommendations for the long-term sustainability, utilisation, and expansion of the green hydrogen microgrid facility at IIT Madras.

This assessment draws exclusively on semi-structured interviews with the research team, programme documents, quarterly progress reports, the final technical report, the MoU between Indus Towers and IIT Madras, and available operational data from the microgrid. It is conducted with the objective of presenting a fair, evidence-based, and donor-neutral evaluation of the project's public good outcomes.

03.
NEED ASSESSMENT AND CONTEXTUAL ANALYSIS



INDIA'S GREEN HYDROGEN IMPERATIVE

India's energy landscape is at a pivotal inflection point. With a population exceeding 1.4 billion and an economy growing at approximately 6–7% annually, energy demand is projected to more than double by 2047. At the same time, India has made binding international commitments under the Paris Agreement to reduce the emissions intensity of its GDP by 45% from 2005 levels by 2030 and achieve net-zero emissions by 2070. Meeting these dual imperatives — of energy security and decarbonisation — requires a fundamental transformation of India's energy system.

While solar and wind energy are central to India's renewable transition, they are intermittent by nature and cannot independently satisfy the energy needs of hard-to-abate sectors such as steel, cement, fertilisers, heavy-duty transport, and long-duration storage. Green hydrogen — produced by splitting water using renewable electricity through electrolysis — is recognised globally and by India's NITI Aayog as the most promising energy carrier to bridge this gap. It is storable, transportable, and versatile as both a fuel and a chemical feedstock.

India's National Green Hydrogen Mission (2023) aims to make India a global hub for green hydrogen production and export, targeting 5 MMTPA production, 125 GW of associated renewable energy capacity, and over 8 lakh jobs by 2030. The mission has identified the following priority areas: development of domestic electrolyzer manufacturing, piloting of hydrogen in industrial applications, research and development in cost reduction, and creation of a skilled workforce. The present project, conceived prior to the formal launch of the mission, independently anticipates and directly contributes to these priority areas.

National Need	How This Project Responds
No academic-level integrated solar-hydrogen demonstration facility in India	Created India's first AEM electrolyzer + PEM fuel cell microgrid at IIT Madras
Shortage of primary techno-economic data on hydrogen systems under Indian conditions	Generating continuous multi-parameter operational data from a real-world installation
Critical gap in trained researchers and engineers in hydrogen technologies	Hands-on training platform for Beach, M.Tech, and PhD students at a premier institution
Limited public-sector demonstration capacity for Green Hydrogen Mission	Open-access facility used by government bodies, PSUs, industry, and academic visitors

STATE OF GREEN HYDROGEN RESEARCH IN INDIA — THE GAP

At the time of project conception (2022), India's green hydrogen research landscape was characterised by several structural gaps. While individual laboratory-scale experiments on electrolysis and fuel cells were being conducted at various institutions, no integrated pilot-scale facility existed that demonstrated the complete solar-to-hydrogen-to-electricity cycle in a single, continuously monitored system. This is significant because system-level integration introduces complexities — in power electronics, gas handling, safety protocols, and data acquisition — that cannot be understood from component-level studies alone.

Furthermore, most research in this domain relied on imported components without assessing their performance and degradation under Indian conditions of temperature, humidity, water quality, and solar irradiance variability. There was no publicly available dataset on long-duration AEM electrolyzer performance, hydrogen storage pressure behaviour, or PEM fuel cell output stability under Indian ambient conditions. Such data is essential for techno-economic modelling of green hydrogen systems, which in turn is required for policy design, investment decisions, and standards development.

The absence of this infrastructure also had a downstream impact on human capital formation. Engineering students across India had limited or no access to hands-on training in hydrogen energy systems, creating a knowledge gap in the very workforce that would be needed to implement India's Green Hydrogen Mission. This project directly addresses this systemic deficit by creating a permanent, accessible, and scientifically rigorous training and demonstration facility at one of India's most influential engineering institutions.

CSR AS A CATALYST FOR PUBLIC RESEARCH INFRASTRUCTURE

The utilisation of Corporate Social Responsibility funding to create academic research infrastructure represents an important and increasingly recognised modality of public good investment. Under Schedule VII of the Companies Act, 2013, contributions to institutions of national importance and to projects promoting environmental sustainability are explicitly eligible for CSR expenditure. IIT Madras, as both a national institution of eminence and a gazette-notified CSR implementation agency, represents precisely the kind of entity that can translate corporate CSR investment into durable, high-leverage public value.

In this project, a CSR contribution of INR 1.2 crore has created infrastructure with a functional lifespan of multiple years, generating environmental, educational, and scientific benefits that far exceed the initial investment in scope and duration. The modular design of the microgrid ensures that the infrastructure will continue to be upgraded and expanded, multiplying the impact of the original CSR investment through subsequent government grants, academic projects, and institutional support.

Critically, the CSR funding model employed here is structured to ensure clean separation between the donor's commercial interests and the research outcomes. No intellectual property, proprietary data, or business advantage flows to Indus Towers from this project. The entire output — physical infrastructure, operational data, and academic knowledge — is the exclusive property of IIT Madras and is available for public good purposes. This model represents a best-practice template for CSR-funded academic research in India.

The project exemplifies a well-governed CSR-academic partnership where corporate funding catalyses the creation of public research infrastructure of national relevance — with full compliance to statutory CSR requirements, transparent financial accountability, and zero commercial benefit to the donor.

ALIGNMENT WITH NATIONAL POLICY FRAMEWORKS

The project's objectives and outcomes are aligned with multiple national policy frameworks and priorities, reinforcing its significance as a CSR investment:

National Green Hydrogen Mission (2023)

The project directly contributes to the mission's objectives of building domestic research capability, generating techno-economic data, and developing a skilled workforce in green hydrogen technologies.

National Education Policy (NEP 2020)

The facility supports the NEP's vision of experiential, research-integrated learning by providing students with live industry-grade equipment and real-world data for project-based learning.

India's Nationally Determined Contributions (NDCs)

By demonstrating solar-powered green hydrogen as a viable stationary power source, the project contributes to India's NDC commitment of achieving 500 GW renewable energy capacity and reducing carbon intensity.

Atal Mission for Rejuvenation and Urban Transformation (AMRUT) / Smart Cities

The microgrid's concept of clean, decentralised energy for building infrastructure is directly relevant to India's smart city and urban energy resilience goals.

Make in India – Clean Energy

The project builds India's domestic technical knowledge base in assembling, operating, and optimising green hydrogen systems – a prerequisite for developing indigenous manufacturing and deployment capabilities.

Across five distinct national policy frameworks, the project's outputs are directly relevant and contribute measurable advancement — underscoring the high leverage value of the CSR investment and its alignment with India's strategic development priorities.

04. RESEARCH **METHODOLOGY**

This CSR impact assessment employs a qualitative research design, grounded in an interpretivist paradigm. Qualitative inquiry is the most appropriate approach for assessing the impact of a research and prototype-development CSR project, where outcomes are multidimensional — spanning scientific knowledge creation, educational value, environmental contribution, and institutional capacity building — and cannot be fully captured through quantitative metrics alone. The assessment is structured as a single-case study of the Green Hydrogen Microgrid project at IIT Madras, using multiple data sources to triangulate evidence and build a comprehensive, credible impact narrative.

01
Key Informant Interviews
Faculty PI + 4 Research Students

02
Document Review
MoU, Progress Reports, Final Report

03
Physical Observation
On-site facility inspection

04
Research Paper Analysis
Published & unpublished outputs

DATA COLLECTION METHODS

Key Informant Interviews (KII)

Semi-structured interviews were conducted with the principal research team comprising the faculty member who led the project and four research students directly involved in the microgrid's design, installation, operation, and data collection. The interview protocol was designed to elicit: (i) the research intent and conceptual framework of the project; (ii) technical challenges encountered and adaptations made; (iii) perceived educational and skill-development value; (iv) observed environmental and operational outcomes; and (v) the researcher's assessment of the project's long-term significance. Interviews were conducted in-person at IIT Madras and recorded with prior consent for accuracy of transcription.

Review of Project Documents

A systematic review of all primary project documentation was undertaken, covering the full documentary lifecycle of the CSR engagement. Documents reviewed include: the Memorandum of Understanding (MoU) between Indus Towers Limited and IIT Madras; quarterly progress and financial reports (Q1 through Q5); the Final Technical Report on the Green Hydrogen Microgrid; fund utilisation certificates; and operational data logs from the Keysight Data Acquisition System. This review provided the evidentiary basis for verifying milestone achievement, financial compliance, and quantitative impact metrics.

Physical Observation of the Facility

A structured physical observation of the Green Hydrogen Microgrid facility was conducted at the Chemical Engineering Laboratory (CHL) Building, IIT Madras. The observation protocol covered: (i) physical condition and completeness of all installed components; (ii) operational status of the solar array, electrolyzer, battery bank, fuel cell, and hydrogen storage systems; (iii) safety infrastructure including hydrogen leak detection sensors; (iv) data acquisition and monitoring equipment; and (v) the condition of common areas powered by the fuel cell. Photographic documentation and observational field notes were recorded as part of the evidence base.

Review of Research Papers and Academic Outputs

Published and in-preparation research papers, conference presentations, and academic outputs arising from or related to the project were reviewed to assess the scientific contribution of the initiative. This review situates the project within the broader academic literature on AEM electrolysis, PEM fuel cell stationary applications, and solar-hydrogen integration, and establishes the originality and significance of the data generated by the IIT Madras microgrid.

DATA TRIANGULATION AND VALIDATION

The assessment adopts methodological triangulation, cross-referencing findings from KIIs, document review, physical observation, and research literature to ensure validity and reliability of conclusions. The triangulation matrix below summarises how each data source contributes to and validates the assessment findings:

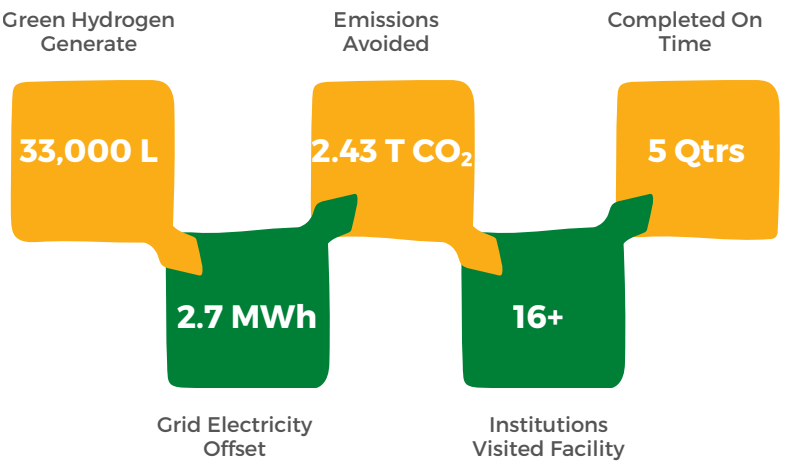
Data Source	Nature of Evidence	Validation Role
KII – Faculty PI	Interpretive / Expert	Primary source of research intent and outcomes
KII – Research Students	Experiential / Operative	Operational ground-truth; day-to-day performance
Project Documents	Documentary / Quantitative	Financial compliance and milestone verification
Physical Observation	Empirical / Sensory	Infrastructure existence and condition assessment
Research Paper Review	Scholarly / Analytical	Scientific validity and academic contribution

ETHICAL CONSIDERATIONS AND LIMITATIONS

All interview respondents provided informed consent and were assured that their individual responses would be reported in aggregate. The assessment adopts a strictly donor-neutral posture: no business benefit to Indus Towers is attributed or inferred from the research findings. Findings are based solely on evidence from primary sources. A key limitation of the assessment is that the microgrid had been operational for approximately six weeks at the time of the final report; longer-term performance data and techno-economic conclusions will require continued monitoring over subsequent years, as planned by the research team.

05 KEY FINDINGS AND KEY IMPACT

This chapter presents the consolidated findings of the CSR impact assessment of the Green Hydrogen Microgrid project at IIT Madras, funded by Indus Towers Limited. The findings are organised across five thematic domains: (i) infrastructure and prototype delivery; (ii) technical and operational performance; (iii) environmental outcomes; (iv) educational, research, and human capital impact; and (v) knowledge dissemination and public demonstration. Each domain of findings is followed by an assessment of its corresponding impact. The chapter concludes with a consolidated impact scorecard and an integrated synthesis of the project's overall significance.



FINDING DOMAIN I: INFRASTRUCTURE AND PROTOTYPE DELIVER

The first and most foundational finding of this assessment is that the project achieved complete, on-time delivery of the Green Hydrogen Microgrid prototype, within the agreed project term of November 2022 to March 2024. All five quarterly milestones were met, with no reported challenges in any quarter — an exceptional execution record for a complex, multi-technology research infrastructure project.

Full Scope Delivery Within Project Timeline

The Green Hydrogen Microgrid was conceptualised, designed, procured, constructed, and commissioned within the five-quarter project term. The system was inaugurated on 23rd February 2024 at the Chemical Engineering Laboratory (CHL) Building, IIT Madras, three weeks before the project's final deadline of 31st March 2024. All civil works, electrical modifications, and system integrations were completed as planned.

A total of 18 distinct major capital components were procured and installed across two phases, including a 20kW solar array, dual AEM electrolyzers, a hydrogen dryer, 30kWh LFP battery bank, 3kW PEM fuel cell, hydrogen storage cabinet at 35 bar, water purification system, gas analyser, Keysight data acquisition system, and hydrogen leak detection sensors. Every component was successfully integrated into a single operational microgrid.

Adaptive Site Planning and Design Flexibility

During the second quarter, the research team demonstrated strong adaptive management by relocating the solar panel installation from the originally proposed MSB building rooftop to the CHL building rooftop. This decision was taken in consultation with the IIT Madras Dean of Planning and the Engineering Unit, and was motivated by the superior integration potential of the CHL rooftop with the hydrogen console room below. The decision required no additional budget and caused no delay — reflecting the team's technical competence and institutional responsiveness.

Further room layout modifications were carried out in Q4 in coordination with institutional authorities, demonstrating that the project's execution model was collaborative, transparent, and fully embedded in IIT Madras's institutional processes

Permanent, Publicly Owned Research Infrastructure Created

The physical infrastructure created by this project — the Green Hydrogen Microgrid — is permanently owned by IIT Madras and is not subject to any commercial claims, IP transfer, or proprietary restriction. Clause 13 of the MoU between Indus Towers and IIT Madras explicitly states that "the ownership of all results of the Project under this Agreement shall solely vest with IITM." This ensures that the infrastructure is, and will remain, a public good accessible to students, researchers, government bodies, and the broader academic community.

FINDING DOMAIN II: TECHNICAL AND OPERATIONAL PERFORMANCE

The microgrid demonstrated strong technical performance across all major subsystems within its operational period from late February to early April 2024. The system's architecture — solar generation, electrolyzer, hydrogen storage, and fuel cell — functioned in integrated, data-monitored operation, validating the design assumptions that informed the project's technical scope.

Metric	Value	Significance
Solar PV System	20 kW	Installed on CHL rooftop; powers electrolyzer with excess stored in LFP battery bank
AEM Electrolyzer Output	1 Nm^3/h H_2	6.2kW peak; generates hydrogen at 99.5% purity from solar-powered electrolysis
Post-Dryer H_2 Purity	99.999%	Enapter Dryer 2.1 upgrades purity to PEM fuel cell grade requirement
H_2 Storage Pressure	35 bars	1.4 kg H_2 stored in cabinet; enables decoupling of generation and power delivery
PEM Fuel Cell Output	3 kW	Powers corridors, entrance, parking areas and select rooms of CHL building
Battery Bank Capacity	30 kWh (LFP)	Stores excess solar energy; ensures continuity during low-irradiance periods
Total Load Served	2.5 kW (avg.)	Corridors, stairways, parking area and common rooms — all emission-free supply
Data Acquisition	Continuous	Keysight DAQ 970A logging solar, battery, electrolyzer, and fuel cell parameters

Successful System Integration — End-to-End Solar-Hydrogen Cycle Demonstrated

The most significant technical finding is the demonstrated operability of the complete solar-to-hydrogen-to-electricity chain in a single, continuously monitored system under Indian ambient conditions. Solar irradiance data from the pyranometer was correlated with battery voltage, electrolyzer stack voltage and current, hydrogen generation rate, hydrogen purity, storage pressure, fuel cell output, and building load profile — creating an end-to-end performance dataset that is first-of-its-kind in Indian academia.

The system's modular architecture, with each subsystem independently operable but jointly monitored through the DAQ system, also demonstrated sound engineering design judgement that will enable component-level upgrades without requiring system-wide shut down.

Zero Operational Challenges Across All Five Quarters

A particularly notable technical finding is that across all five quarterly progress reports, the challenges column was recorded as 'No challenges faced' — a remarkable outcome for a pilot-scale, multi-technology integration project that involved civil modifications, electrical works, gas handling systems, safety infrastructure, and real-time data acquisition. This reflects both the quality of pre-project planning and the competence of the research team in managing system integration risks proactively.

FINDING DOMAIN III: ENVIRONMENTAL OUTCOMES

The Green Hydrogen Microgrid generated measurable, verifiable environmental outcomes during its initial operational period from commissioning (23rd February 2024) to the assessment date (3rd April 2024) — a period of approximately six weeks. These outcomes, while reflecting only the early operational phase of a system designed for multi-year service, are significant as proof-of-concept environmental achievements and will scale materially as the system continues to operate.

33,000 Litres	2.7 MWh	2.43 Tonnes
Green H_2 Generated (Feb–Apr 2024)	Grid Electricity Displaced	CO_2 Emissions Avoided

1 33,000 Litres of Green Hydrogen Generated from Zero-Emission Source

As of 3rd April 2024, the microgrid had produced 33,000 litres of green hydrogen, generated entirely through solar-powered water electrolysis with no fossil fuel input at any stage of the production chain. This represents a meaningful pilot-scale demonstration of solar-to-hydrogen conversion under real-world Indian conditions, and establishes a baseline production rate that can be extrapolated to project multi-year system performance.

At an average production rate of approximately 1 Nm^3/h from the 6.2kW AEM electrolyzer, the system is generating hydrogen at the purity levels (99.999% post-dryer) required for direct use in PEM fuel cells without additional treatment — a technically demanding standard that the system has consistently met.

MWh of Grid Electricity Displaced

The microgrid has offset 2.7 MWh of electricity that would otherwise have been drawn from the Tamil Nadu grid, which has a carbon intensity that reflects India's current coal-heavy generation mix. This grid offset is attributable entirely to the solar-hydrogen system's supply of clean electricity to the CHL building's common areas.

The significance of this finding lies not in the absolute quantum — which is modest given the early operational stage — but in the demonstration that solar hydrogen can displace grid electricity in a reliable, infrastructure-integrated manner over a sustained period, under the variable irradiance conditions of the Chennai coastal climate.

Tonnes of CO_2 Emissions Avoided

The displacement of 2.7 MWh of grid electricity has resulted in the avoidance of 2.43 tonnes of CO_2 emissions. This is calculated based on the emission factor of the Tamil Nadu / Southern Regional Grid. Over the full multi-year operational life of the microgrid — which the research team has committed to continuing — this avoided emission figure will grow substantially, reinforcing the long-term environmental value of the infrastructure investment.

Importantly, the entire hydrogen production cycle is carbon-free: the solar array produces electricity without combustion, water electrolysis produces hydrogen and oxygen without by-products, and the PEM fuel cell reconverts hydrogen to electricity with water as the only output. The system demonstrates a completely closed, zero-emission energy cycle at the building scale.

FINDING DOMAIN IV: EDUCATIONAL AND HUMAN CAPITAL IMPACT

Beyond its technical and environmental outcomes, the Green Hydrogen Microgrid has generated substantial and durable educational value by creating a unique, hands-on learning environment for students and researchers at IIT Madras. This finding domain assesses the project's contribution to human capital formation in the green hydrogen sector — a domain of critical national importance for India's clean energy transition.

Creation of a Unique Experiential Learning Platform

The Green Hydrogen Microgrid is the only operational, fully integrated solar-hydrogen-fuel cell research facility at any Indian academic institution at this scale. Students across multiple departments — Chemical Engineering, Electrical Engineering, Energy Systems, and Materials Science — now have access to a live, industry-grade installation where all system parameters are monitored and logged in real time.

The pedagogical value of such a facility is significant. Unlike laboratory-scale experiments with bench-top equipment, this microgrid exposes students to the full engineering complexity of a real energy system: procurement decisions, civil and electrical integration, safety protocol design, gas handling, data acquisition architecture, and operational monitoring. These are skills that no classroom or simulation can adequately replicate.

Research Scholar Capacity Building Across Hydrogen Technologies

Four research scholars — two M. Tech and two PhD students from the Department of Chemical Engineering — were directly involved in the project's design, procurement, installation, commissioning, and operation. Each scholar developed specialised competency in a distinct technical domain: AEM electrolyzer performance characterisation; solar PV system integration and MPPT optimisation; PEM fuel cell operation and load management; and system-level data acquisition and energy balance analysis.

This depth of specialisation, developed through direct engagement with operational equipment rather than theoretical study alone, represents a significant human capital investment. These researchers will carry this expertise into future academic, industry, and government roles — directly contributing to India's green hydrogen workforce pipeline.

Multi-Year Teaching and Demonstration Mandate Established

The research team has formally committed to using the microgrid infrastructure for teaching and demonstration purposes for students from various institutions, industry personnel, and government bodies for the foreseeable future. The modular design of the system enables continued upgrades — adding new electrolyzer modules, expanding storage, or integrating additional renewable sources — ensuring that the facility remains at the frontier of available technology for ongoing teaching purposes.

The inauguration of the facility was attended by faculty and students from multiple departments across IIT Madras, marking the beginning of cross-disciplinary engagement that extends the educational reach of the project well beyond the Chemical Engineering department.

FINDING DOMAIN V: KNOWLEDGE DISSEMINATION AND PUBLIC DEMONSTRATION

The Green Hydrogen Microgrid rapidly established itself as a nationally significant demonstration facility, attracting senior industry leaders, researchers, government officials, and academics within weeks of its inauguration. This finding domain documents the breadth and quality of the facility's outreach and assesses its significance as a public knowledge platform.

Senior Professionals from 9 Industry Sectors Visited the Facility

Within the initial operational period, the Green Hydrogen Microgrid was visited by more than 16 senior executives and professionals representing organisations across nine distinct industry sectors. The range of organisations represented — from a public sector power utility (NTPC) to automotive OEMs (Hyundai Motors India), defence-space research (VSSC/ISRO), heavy engineering (L&T Construction), metals and mining (Hindalco, Aditya Birla Science & Technology), renewable energy developers, electrolyzer OEMs, and venture capital — reflects the cross-cutting national relevance of the facility.

Significantly, the seniority of visitors (Managing Directors, Chief Operating Officers, Executive Directors, Senior Vice Presidents, and Lead Scientists) indicates that the facility is being engaged at a strategic, decision-making level — not merely as a curiosity. This strongly suggests that the research output of the microgrid will influence investment decisions, technology adoption choices, and policy positions in the hydrogen sector.

The table below categorises the visiting organisations by sector and documents the significance of each sector's engagement with the facility:

Visitor Sector	Significance
Public Sector Enterprises	Demonstrates alignment with national priorities and growing interest in green hydrogen as part of the energy transition agenda.
Engineering, Procurement & Construction (EPC) and Industrial Infrastructure	Highlights the potential applicability of the technology for large-scale renewable energy and infrastructure projects.
Automotive and Sustainable Mobility	Reflects industry interest in the convergence of hydrogen technologies with future mobility and clean transportation solutions.
Metals, Manufacturing and Advanced Materials	Indicates the relevance of green hydrogen for industrial decarbonisation and low-carbon manufacturing processes.
Renewable Energy Developers	Validates the viability of integrated solar-hydrogen systems as a pathway for clean energy generation and storage.
Space, Defence and Strategic Research Institutions	Underscores the strategic importance of hydrogen fuel cell technologies for advanced scientific and mission-critical applications.
Hydrogen Technology and Electrolyzer Manufacturers	Demonstrates peer recognition of the facility as a technologically relevant and contemporary hydrogen innovation platform.
Venture Capital and Emerging Technology Investors	Signals growing investor confidence in the commercial potential and scalability of hydrogen-based energy solutions.
Academic and Research Institutions	Facilitates knowledge dissemination, capacity building, and technology transfer to the next generation of engineers and researchers.

Knowledge Transfer to Regional Academic Institutions

The facility has attracted visits from members of the academic community representing engineering colleges and higher education institutions, highlighting its role as a catalyst for knowledge dissemination beyond premier research centres. This is particularly significant from an educational equity perspective, as many regional institutions may not possess the resources required to establish comparable green hydrogen infrastructure independently. Such engagements create valuable pathways for the transfer of practical, equipment-level knowledge and real-world exposure to green hydrogen technologies, extending learning opportunities beyond theoretical classroom instruction. Through these interactions, students and faculty from regional institutions gain insights into emerging clean energy technologies, thereby strengthening the broader ecosystem of hydrogen awareness, research, innovation, and workforce preparedness across the state and beyond.

Original Scientific Dataset of National Value Under Generation

The continuous data collection system — logging solar irradiance, battery state, electrolyzer stack parameters, hydrogen generation rate, hydrogen purity, storage pressure, fuel cell output, and building load profile — is generating a first-of-its-kind operational dataset from an integrated solar-hydrogen facility operating under Indian conditions. This dataset has the potential to underpin multiple academic publications, techno-economic analyses, and policy submissions.

The research team has committed to continuing microgrid operation 'for a few years' to build a longitudinal dataset of sufficient duration to draw statistically robust conclusions about system efficiency, degradation rates, and maintenance requirements. Such data is precisely what India's National Green Hydrogen Mission requires to inform realistic project feasibility assessments and cost reduction roadmaps.

KEY IMPACT: CONSOLIDATED ASSESSMENT

Drawing together the findings across all five domains, this section presents the consolidated impact of the CSR investment in four structured dimensions: Environmental Impact, Educational and Human Capital Impact, Scientific and Knowledge Impact, and Institutional and Policy Impact. Each impact statement is directly evidence-grounded in the findings above.

ENV Environmental Impact

Measurable Carbon Avoidance and Clean Energy Demonstration

The microgrid has generated 33,000 litres of green hydrogen from solar energy, displaced 2.7 MWh of grid electricity, and avoided 2.43 tonnes of CO_2 emissions — all within approximately six weeks of commissioning. These outcomes are entirely attributable to the CSR-funded infrastructure and are independently verifiable through the continuous data logs of the Keysight DAQ system.

The environmental impact will multiply over the multi-year operational life of the facility. Extrapolating conservatively, a five-year operational lifespan would yield approximately 250,000+ litres of green hydrogen, 20+ MWh of grid electricity displaced, and 18+ tonnes of CO_2 avoided from the same infrastructure investment.

EDU Educational & Human Capital

Skilled Researchers and a Permanent Training Platform Created

Four research scholars have received deep, hands-on training in hydrogen energy systems — AEM electrolysis, PEM fuel cells, solar integration, and system-level data analytics — through direct engagement with the operational microgrid. The facility has been formally designated as a teaching and demonstration platform, available to students across departments, institutions, and disciplines.

The educational leverage of this investment extends well beyond the four directly trained scholars. Every student cohort that uses the facility, every visiting faculty member who returns to their institution with experiential knowledge, and every PhD thesis that emerges from this platform represents a return on the original CSR investment in human capital terms.

SCI Scientific & Knowledge Impact

First Integrated Solar-Hydrogen Dataset Generated at Indian Premier Institution

The microgrid is generating a first-of-its-kind, multi-parameter, continuous operational dataset from an integrated solar-to-hydrogen-to-electricity system under Indian ambient conditions. This dataset is of direct relevance to India's National Green Hydrogen Mission, providing empirical performance data to inform techno-economic modelling, standards development, and investment decisions.

The modular, upgradeable architecture of the facility means it will remain scientifically current as technology evolves. Future expansions — additional electrolyzer capacity, higher-pressure storage, integration of wind energy, or testing of indigenous electrolyzer components — can build on the foundation created by this CSR investment, amplifying its scientific impact over time.

POL Policy & Institutional Impact

National-Level Demonstration Capacity and Cross-Sector Knowledge Exchange

The facility's rapid emergence as a destination for senior industry, government, and academic visitors — across nine sectors and 16+ organisations within weeks of inauguration — establishes IIT Madras as a nationally recognised centre of competence for green hydrogen research and demonstration. This positions the institution to play an active role in policy advisory, standard-setting, and technology road mapping for India's green hydrogen ecosystem.

The visits from NTPC, VSSC, L&T, Hyundai, and Aditya Birla Science & Technology signal that the private and public sectors are looking to this academic facility for evidence and inspiration. This influence on national-level technology decisions and investment strategies represents an institutional impact that far exceeds the monetary value of the original CSR contribution.

CSR IMPACT SCORECARD AGAINST PROGRAMME OBJECTIVES

The following scorecard maps each of the six programme objectives (as stated in Chapter 1) against the assessment's findings, providing a structured evaluation of objective-level achievement:

#	Programme Objective	Status	Evidence Base
01	Design, construct and commission an integrated green hydrogen microgrid at IIT Madras	Fully Achieved	System commissioned 23 Feb 2024; all 18 components installed; CHL building powered by green H_2
02	Demonstrate technical feasibility of solar-to-hydrogen-to-electricity cycle under Indian conditions	Fully Achieved	Continuous operation confirmed; 33,000 L H_2 generated; end-to-end DAQ data collected
03	Generate comprehensive multi-parameter operational dataset	Achieved — Ongoing	Keysight DAQ logging all parameters; long-term dataset collection committed for several years
04	Create permanent teaching and demonstration facility	Fully Achieved	16+ institutional visits; multi-departmental student engagement; formal teaching mandate established
05	Build skilled human capital in green hydrogen	Fully Achieved	4 research scholars trained in AEM, PEM, solar integration, and data analytics
06	Establish foundation for future research grants and collaborations	Substantively Achieved	Modular design enables upgrades; national-level visibility positions lab for future funded projects

The assessment concludes that the CSR project funded by Indus Towers Limited and implemented by IIT Madras has fully achieved its programme objectives, generated measurable and independently verifiable environmental outcomes, created durable educational and research infrastructure of national significance, and established IIT Madras as a nationally recognised centre of competence in green hydrogen technology. The project exemplifies the highest standards of CSR investment in academic research — transparent, donor-neutral, publicly owned, and aligned with India's most pressing strategic priorities.

06. OECD FRAMEWORK

Relevance | Coherence | Effectiveness | Efficiency | Impact | Sustainability

★★★★★

RELEVANCE

The project demonstrated high relevance to India's emerging green hydrogen ecosystem and directly addressed critical gaps in academic research infrastructure, practical hydrogen training, and generation of indigenous techno-economic data. The initiative aligns strongly with the National Green Hydrogen Mission, India's decarbonisation commitments, and the need for skilled human resources in clean energy technologies.

★★★★★

COHERENCE

The project was well aligned with national policy frameworks, including the National Green Hydrogen Mission, National Education Policy (NEP 2020), Nationally Determined Contributions (NDCs), and broader clean energy transition goals. It complemented existing academic research efforts while creating synergies among academia, industry, government agencies, and research institutions.

★★★★½

EFFECTIVENESS

The project successfully achieved all major planned objectives. The integrated solar-hydrogen-fuel cell microgrid was commissioned within the stipulated timeframe, operationalised successfully, and demonstrated the complete solar-to-hydrogen-to-electricity cycle. It generated operational data, created a teaching and demonstration platform, trained research scholars, and attracted significant stakeholder engagement.

★★★★½

EFFICIENCY

The project demonstrated strong implementation efficiency, with all milestones completed within the approved project period and budget. Adaptive design modifications were undertaken without additional financial implications or delays. The absence of major implementation challenges and the successful integration of multiple advanced technologies indicate effective utilisation of CSR resources and institutional capabilities.

★★★★½

IMPACT

The project generated measurable environmental, educational, scientific, and institutional impacts. Environmental outcomes include green hydrogen production, grid electricity displacement, and carbon emission avoidance. Educational impacts include hands-on training for students and researchers. Scientific impacts include creation of a first-of-its-kind operational dataset, while institutional impacts include positioning IIT Madras as a recognised demonstration and knowledge hub for hydrogen technologies.

Index : 5 Points - Very High ; 4 Points - High ; 3 Points - Moderate ; 2 Points - Low ; 1 Point - Very Low

★★★★½

SUSTAINABILITY

The project's sustainability prospects are strong due to the creation of permanently owned research infrastructure within IIT Madras, long-term commitment by the research team for continued operation, modular system design enabling future upgrades, and growing interest from industry, government, and academic stakeholders. The facility is well positioned to attract future research funding, collaborations, and technology expansion opportunities, ensuring benefits continue beyond the CSR funding period.

07. RECOMMENDATIONS

The following recommendations are drawn from the assessment findings and the project's technical reports, MoU commitments, operational data, and the research team's stated way-forward plans. They are organised across five thematic domains and addressed to distinct stakeholders: IIT Madras as the implementing institution, the Department of Chemical Engineering as the immediate research custodian, and the broader academic-policy community that this facility serves. They are structured to build upon the strong foundation already created by the project rather than to correct deficiencies.

A priority implementation matrix summarising all ten recommendations is presented at the close of this chapter for ease of reference by all stakeholders.

INFRASTRUCTURE AND OPERATIONAL CONTINUITY

INF Recommendations on Infrastructure Sustainability and Operational Continuity

The microgrid was operationally new at the time of the final project report, having been commissioned just six weeks before the reporting date. Sustained, uninterrupted operation over several years is essential to realise the full scientific, educational, and environmental value of the investment. The following recommendations address operational continuity and infrastructure stewardship.

Activate the Modular Upgrade Pathway to Expand Capacity and Research Scope	
Addressed to: Department of Chemical Engineering / IIT Madras Research Office	
Rationale	**Recommended Actions**
The research team has noted that the system was built in a modular fashion specifically to enable future upgrades in performance, safety, and capacity. This architectural foresight creates a significant opportunity: the existing infrastructure can serve as a launchpad for expanded research by adding electrolyzer capacity, higher-pressure storage, additional solar input, or wind energy integration — without requiring a ground-up rebuild.	Prepare a costed upgrade roadmap within one year, identifying the two or three highest-priority capacity additions based on the techno-economic data collected from the current system.
	Explore integration of a second AEM electrolyzer module to double hydrogen production capacity, drawing on the existing gas handling and storage infrastructure.
	Apply for funding from the National Green Hydrogen Mission's R&D component, the DST's SERI programme, or other government grant schemes to finance the upgrade phase.

RESEARCH OUTPUT AND DATA UTILISATION

RES Recommendations on Research Publication, Data Sharing, and Techno-Economic Analysis

The microgrid's most enduring contribution to India's green hydrogen ecosystem lies in the quality and continuity of the research data it generates. The following recommendations address how this data should be managed, analysed, and disseminated to maximise its scientific and policy impact.

R3 [Research] Develop and Publish a Comprehensive Techno-Economic Assessment of the Microgrid

Addressed to: Principal Investigator, Department of Chemical Engineering

Rationale	Recommended Actions
The research team has committed to operating the microgrid for several years to build a dataset sufficient for techno-economic analysis. The value of this commitment is contingent on the dataset being analysed rigorously and the findings published in peer-reviewed journals and policy-relevant formats. A techno-economic assessment (TEA) will quantify the levelized cost of hydrogen produced, the energy efficiency of the solar-to-hydrogen-to-power cycle, and the payback metrics of the system — data of direct relevance to India's National Green Hydrogen Mission.	Conduct a formal Techno-Economic Assessment (TEA) after at least two full years of operation, quantifying the levelized cost of hydrogen (LCOH) from this solar-integrated system under Chennai conditions.
	Publish the system's performance data — including degradation curves, efficiency trends, and maintenance costs — as an open-access dataset to support the broader Indian research community and reduce duplication of effort by other institutions building similar systems.
	Submit findings to relevant government bodies, including the Ministry of New and Renewable Energy (MNRE) and the National Hydrogen Mission secretariat, to inform policy and standards development.

Establish a Structured Data Governance Framework for the Microgrid's Operational Dataset

Addressed to: Department of Chemical Engineering / IIT Madras Data Office

Rationale	Recommended Actions
The Keysight DAQ 970A system continuously logs multi-parameter operational data. Over a multi-year operational lifespan, this will accumulate into a substantial longitudinal dataset of national scientific value. Without a structured data governance framework — covering storage, backup, version control, access protocols, and retention policy — there is a risk that valuable long-term data could be lost due to equipment failure, personnel transitions, or institutional reorganisation.	Define a data retention policy specifying the format, frequency, and metadata tagging of logged parameters for a minimum period of ten years.
	Establish a clear data access protocol that enables qualified researchers from other institutions to request access to the dataset for collaborative research, under appropriate agreements.
	Consider developing a real-time public dashboard — displaying current solar generation, hydrogen production, and CO_2 savings — to enhance the facility's visibility and public engagement value.

EDUCATION, TRAINING, AND HUMAN CAPITAL DEVELOPMENT

EDU Recommendations on Structured Academic Programming and Outreach to Regional Institutions

The facility's designation as a teaching and demonstration platform is a commitment that requires active programming to realise its educational potential. The following recommendations provide specific structures for translating this commitment into measurable educational impact.

Design and Deliver a Structured Training Programme for Students from IIT Madras and Partner Institutions	
Addressed to: Department of Chemical Engineering, IIT Madras	
Rationale	**Recommended Actions**
At present, the microgrid serves as an informal teaching platform through research scholar engagement and ad hoc visits. Formalising this into a structured training programme — with defined learning objectives, hands-on lab modules, and assessable outcomes — would dramatically increase the number of students who derive educational benefit from the facility and strengthen IIT Madras's position as India's leading academic centre for green hydrogen education.	Design a modular 3-day 'Hydrogen Energy Systems' training programme covering solar integration, AEM electrolysis, hydrogen safety, fuel cell operation, and energy data analytics, offered to B. Tech, M. Tech, and PhD students.
	Extend the programme to students from partner engineering institutions, including regional colleges with whom IIT Madras has existing academic collaborations, at subsidised or no cost.
	Offer at least two intensive workshop cohorts per academic year, with structured lab sessions at the microgrid and case-study analysis of real operational data.
	Document the training programme as a replicable model that other IITs or NITs planning similar infrastructure can adapt, contributing to India's national green hydrogen skilling ecosystem.

Establish a Formal Knowledge-Sharing Network with Regional Engineering Colleges	
Addressed to: IIT Madras / Department of Chemical Engineering	
Rationale	**Recommended Actions**
The visits by representatives from regional academic institutions highlighted the facility's growing importance as a knowledge hub for emerging clean energy technologies. Many engineering colleges across Tamil Nadu and neighbouring states produce graduates who are likely to enter the energy, manufacturing, and technology sectors but have limited opportunities for practical exposure to hydrogen energy systems. As a leading centre of excellence in engineering and research, IIT Madras is uniquely positioned to bridge this gap through structured outreach and knowledge-sharing initiatives. Such efforts can significantly expand awareness and understanding of green hydrogen technologies among students and faculty, helping build a future-ready workforce without requiring substantial additional investments in infrastructure or resources	Establish an annual 'Green Hydrogen Open Day' at IIT Madras, inviting faculty and students from up to ten regional engineering colleges in Tamil Nadu for a full-day structured visit to the microgrid. Create a repository of open-access educational materials — lab manuals, system schematics, safety guides, and data analysis exercises — derived from the microgrid, available for use by faculty at regional institutions. Propose a collaborative research arrangement with two or three regional colleges to co-supervise M.Tech or PhD projects that use the IIT Madras microgrid data as a primary research resource. Explore the National Hydrogen Mission's Skill Development component as a funding source for formalising and scaling this outreach programme.

INSTITUTIONAL POSITIONING AND POLICY ENGAGEMENT

POL Recommendations on Institutional Strategy, Government Engagement, and National Mission Alignment

The Green Hydrogen Microgrid has established IIT Madras as a nationally visible centre of green hydrogen competence. The following recommendations provide a strategic pathway for the institution to leverage this positioning for maximum impact on India's clean energy transition.

Document and Share This Project as a Replicable CSR-Academic Research Model	
Addressed to: IIT Madras / Indus Towers Limited (for sharing within the CSR community)	
Rationale	**Recommended Actions**
The project represents a best-practice case study in CSR-funded academic research: a legally compliant, donor-neutral, publicly owned, well-governed, and high-impact engagement between a corporate CSR programme and a premier academic institution. India's CSR ecosystem would benefit significantly from the wider sharing of this model — particularly with other large corporates who are currently fulfilling their CSR obligations through lower-impact interventions, and with other academic institutions that could replicate this model for other emerging technology domains.	Prepare a concise case study document (8–10 pages) describing the project's governance model, implementation approach, impact outcomes, and lessons learned, suitable for circulation in the CSR practitioner community. IIT Madras should proactively share the model with the Indian Institutes of Technology and National Institutes of Technology network, enabling other institutions to adapt it for CSR-funded infrastructure projects in emerging domains such as carbon capture, bioenergy, advanced materials, or quantum computing.

The Green Hydrogen Microgrid at IIT Madras is more than a completed CSR project — it is the beginning of a long-term national scientific resource. With deliberate governance, sustained operation, structured educational programming, and active policy engagement, a one-time CSR investment of INR 1.2 crore can generate decades of environmental, educational, scientific, and institutional impact. The recommendations in this chapter constitute a practical roadmap for realising that potential in full.

08. CONCLUSION

The CSR-supported Research Lab on Hydrogen with Solar Integration at IIT Madras represents a pioneering investment in India's emerging green hydrogen ecosystem and demonstrates how corporate social responsibility can be effectively leveraged to create long-term public research infrastructure of national significance. Through a CSR contribution of INR 1.20 crore from Indus Towers Limited, the project successfully established a fully operational Green Hydrogen Microgrid integrating solar photovoltaic generation, hydrogen production through electrolysis, hydrogen storage, and electricity generation through fuel cells. The project was completed within the stipulated timeline and achieved all major technical, operational, educational, and environmental objectives envisaged at the time of its conception.

The assessment finds that the project has generated measurable environmental outcomes within a short operational period, including the production of 33,000 litres of green hydrogen, displacement of 2.7 MWh of conventional grid electricity, and avoidance of 2.43 tonnes of carbon dioxide emissions. While these outcomes represent only the initial phase of operations, they provide tangible evidence of the technical viability of integrated solar-hydrogen systems under Indian conditions and establish a strong foundation for future scaling and replication.

Beyond its environmental contribution, the project has created substantial educational and scientific value. The facility has emerged as a unique experiential learning platform, enabling students and research scholars to gain hands-on exposure to advanced hydrogen technologies, including electrolyzers, fuel cells, energy storage systems, and real-time performance monitoring. The continuous operational data being generated by the facility constitutes a first-of-its-kind integrated solar-hydrogen dataset from an Indian academic institution and has significant potential to inform future research, techno-economic assessments, technology development, and policy formulation.

The project has also demonstrated its broader institutional relevance by attracting interest from stakeholders across government, industry, academia, renewable energy, manufacturing, mobility, and strategic research sectors. The facility is increasingly serving as a platform for knowledge dissemination, technology demonstration, and cross-sector dialogue, thereby extending the impact of the CSR investment beyond the boundaries of IIT Madras. As the infrastructure continues to operate and evolve, its value as a national resource for capacity building, research collaboration, and evidence generation is expected to increase substantially.

Importantly, the project exemplifies a model CSR-academia partnership in which corporate resources have been translated into publicly owned scientific infrastructure that generates enduring societal benefits without creating commercial advantage for the donor. The initiative is fully aligned with the objectives of the National Green Hydrogen Mission, India's climate commitments, and the broader national agenda of fostering innovation-led sustainable development.

In conclusion, the assessment finds that the Green Hydrogen Microgrid project has not only achieved its stated objectives but has also created a strategic platform capable of generating long-term environmental, educational, scientific, and policy value. The project stands as an example of how targeted CSR investments in research and innovation can contribute meaningfully to national priorities while creating durable public assets that continue to deliver benefits well beyond the project period. With continued utilisation, expansion, and stakeholder engagement, the facility is well positioned to play an important role in supporting India's transition towards a clean energy and green hydrogen future.

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