Implemented by

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

On behalf of:

Federal Ministry for Economic Affairs and Climate Action

of the Federal Republic of Germany

SCOPE Promoting Excellence 50

Initiatives towards building a low-carbon economy

Compendium of innovative climate change mitigation technologies and practices by Indian Public Sector Enterprises

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Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), a federally owned enterprise of the German Government and Standing Conference of Public Enterprises (SCOPE).

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About SCOPE

Standing Conference of Public Enterprises (SCOPE), being the apex body of public sector enterprises (PSEs) in India aims at promoting excellence and facilitating the public sector fraternity to create a cohesive environment for PSEs. With recent novel initiatives of SCOPE, the organization has developed into an impactful, innovative and inspiring apex body expanding its horizon to four pillars – Policy Advocacy, Programmes and Workshops, Capacity Building and Skill Development and Brand Building. Nationally, SCOPE is closely associated with the Ministry of Labour and Employment , Government of India and interfaces with statutory and regulatory bodies to highlight issues of concerns to the public sector fraternity. Internationally, SCOPE has engagement with organizations like the International Labour Organization (ILO); United Nations (UN); Organization for Economic Co-operation and Development (OECD); International Organization of Employers (IOE), besides being actively engaged with internationally acclaimed institutes like the IIM. SCOPE has also collaborated with international partners on joint research projects on women empowerment, climate change, leadership, skills advocacy, digitisation.

For more information, please visit www.scopeonline.in

About GIZ

The Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH is a federally owned enterprise supporting the German Government in achieving its objectives in the field of international cooperation for sustainable development. For over 60 years, GIZ in India has been working on behalf of the Federal Ministry for Economic Cooperation and Development (BMZ), the German Federal Ministry of Environment, Conservation, Nuclear Safety and Consumer Protection (BMUV) as well as the Federal Ministry for Economic Affairs and Climate Action (BMWK) as main commissioning parties and together with partners in the country for sustainable economic, ecological, and social development. The thematic areas are Energy, Environment, Climate Change and Biodiversity, Sustainable Urban and Industrial Development as well as Sustainable Economic Development.

In the thematic area of Environment, Climate Change and Biodiversity, GIZ implements several projects supporting communities, as well public and private institutions to improve and conserve natural resources, minimise risks from climate change and enhance rural livelihoods in four priority areas:

- Climate Change and Circular Economy,
- Agriculture,
- Natural Resource Management and Agroecology, and
- Biodiversity

More details are available at www.giz.de/india.

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Abbreviations

API	American Petroleum Institute
ATF	Aviation Turbine Fuel
BEDP	Basic Engineering Design Packages
BECCS	Bioenergy With Carbon Capture and Storage
BEL	Bharat Electronics Limited
BES	Bio Electrochemical System
BESS	Battery Energy Storage System
BF	Blast Furnace
BFG	Blast Furnace Gas
BHEL	Battery Energy Storage System
BOF	Basic Oxygen Furnace
BPCL	Bharat Petroleum Corporation Limited
BRON	Blending Research Octane Number
CAFÉ	Corporate Average Fuel Economy
CBG	Compressed Biogas
CBM	Coal Bed Methane
CCEA	Cabinet Committee on Economic Affairs
CCS	Carbon Capture and Storage
CCU	Carbon Capture and Utilisation
CCUS	Carbon Capture Utilisation and Storage
CDCP	Coke Dry Cooling Plant
CDQ	Coke Dry Quenching
CHP	Combined heat and Power
CNG	Compressed Natural Gas
CO	Carbon Monoxide
CPP	Captive Power Plant
CPV	Concentrator Photovoltaic
DAC	Direct Air Capture
DCFS	Double Contact Flow Scrubber
DCU	Delayed Coker Unit
DHDT	Diesel Hydrotreater
DIMTS	Delhi Integrated Multi-Modal Transit System
DM water	Demineralised Water
DNI	Direct Normal Irradiation
DPCC	Delhi Pollution Control Board
DRA	Drag Reducing Additive
DSIR	Department of Scientific and Industrial Research
EAF	Electric Arc Furnace
EIA	Environmental Impact Assessment
EIL	Engineers India Limited
EOR	Enhanced Oil Recovery
EV	Electric Vehicle
FCC	Fluidised Catalytic Cracking
FG	Flue Gas
FGD	Flue Gas Desulphurisation
FW	Formation Water
GDP	Gross Domestic Product

GHG	Greenhouse Gas
GNIDA	Greater Noida Industrial Development Authority
GoI	Government of India
HAL	Hindustan Aeronautics Limited
HCL	Hindustan Copper Limited
HCNG	Hydrogen CNG
HGU	Hydrogen Generation Units
HPCL	Hindustan Petroleum Corporation Limited
HWOG	Hot-Well-Off-Gas
IEA	International Energy Agency
IGL	Indraprastha Gas Limited
IREDA	Indian Renewable Energy Development Agency Ltd
MLP	Multi layered Plastic
MSW	Municipal Solid Waste
NALCO	National Aluminium Company Limited
NAPCC	National Action Plan on Climate Change
NDC	Nationally Determined Contributions
NFL	National Fertilizers Limited
NHPC	National Hydroelectric Power Corporation Limited
NLC	Neyveli Lignite Corporation
NMDC	National Mineral Development Corporation
PCK	Pipeline Compatible Kerosene
PEGS	Plasma Enhanced Gasification System
PNG	Piped Natural Gas
PSA	Pressure Swing Adsorption
PSE	Public Sector Enterprise
PV	Photovoltaic
RDF	Refuse Driven Fuel
RE	Renewable Energy
RFO	Residual Fuel Oil
RON	Research Octane Number
SAE	Society of Automotive Engineers
SAIL	Steel Authority of India Ltd.
SAPCC	State Action Plan on Climate Change
SATAT	Sustainable Alternative Towards Affordable Transportation
SCR	Selective Catalytic Reduction
SIAM	Society of Indian Automobile Manufacturers
SJVN	Satluj Jal Vidyut Nigam Ltd
SRU	Sulphur Recovery Units
THDC	Tehri Hydro Development Corporation
TRL	Technology Readiness Level
ULSD	Ultra-Low Sulphur Diesel
UNFCCC	United Nations Framework Convention on Climate Change
VAM	Vapour Absorption Machine
VFD	Variable Frequency Drive
VOC	Volatile Organic Compounds
WHR	Waste Heat Recovery

Foreword

Atul Sobti
Director General, SCOPE

Climate Change Mitigation is one of the most pressing concerns for the World so much so that the global development targets are being linked to the minimisation of negative impact on environment. The horizon of environmental concern has moved beyond contributing to the green cover and is focussing on integrating the mitigation practices in the organisational processes so as to create a link between reduction in carbon footprint and commercial prudence.

As the world unites to contribute effectively towards combating climate change, India has exhibited unparalleled commitment and courage to take concrete steps in the form of tough decisions so as to bring about changes in the country and move towards a greener and cleaner environment.

Given the global commitment to the subject, corporates become key players in balancing commercial prudence and green environment. Further, with the positive approach of the Governance, it becomes imperative for corporates to explore the critical role of technology in reducing greenhouse gas emissions and building resilience to the impacts of climate change. Hence, companies across the world are adopting new technologies not only for increasing automation and efficiency of work but also to navigate ways to reduce carbon footprint.

In this endeavour, Public Sector Enterprises (PSEs), contributing significantly to the Indian GDP (over 13% in 2021-22) and having presence in all strategic sectors of the economy (coal, oil, gas, transportation, power, metals & minerals, defence etc.), have led the path of technological innovation for moving steadily towards lowering the emission norms. Not only have they adopted the technologies in commercial aspects but also integrated them with their townships so that need for environment conservation can be inculcated in every individual of the country. In the process, PSEs have developed some very unique technologies which are helping them mitigate the carbon footprint without compromising on commercial aspects.

Given the significant contribution of PSEs in the socio-economic development of the country and their inherent nature of operation in hard to abate sectors, **it is imperative that in order to meet the national agenda to climate change mitigation, PSEs have to play an active and vital role. With this perspective, SCOPE and GIZ thought it pertinent to bring to light the innovative technologies, practices and processes that the PSEs across the country are following so as to continue their performance while being sensitive to climate.** This endeavour of SCOPE & GIZ is one of the many initiatives undertaken to enhance capacities of the PSEs on climate change, carbon markets, Sustainable Development Goals (SDGs) and climate finance through a focussed approach of creating knowledge through seminars and webinars, assessing capacities, build capacities and share best practices in PSE.

The Compendium is a repository of unique technological initiatives of PSEs as they continue to achieve performance milestones while being mindful of climate change. The Compendium reflects and analyses technological, product and process innovations of twenty-six '*Ratna*' PSEs. I would like to express my heartfelt gratitude to the PSEs for sharing the information transparently with us which today is likely to form benchmark and also provide direction to many organisations in re-inventing the wheel of commercial prudence in light of climate sustenance.

We sincerely hope that you find this Compendium useful while we work together for furthering sustainability in PSEs as they continue to play a vital role as the country embarks on a growth trajectory.

Atul Sobti
Director General, SCOPE

Foreword

Climate crisis is an existential threat in today's world. The crisis affects every facet of human society, and demands every stakeholder in society to contribute to its mitigation and adaptation actions. Ambitious climate action from all actors is the need of the hour.

Dr. Shailendra Dwivedi
Director – Climate Change and Circular Economy
GIZ India

The Government of India has been proactive in implementing climate action. Several ambitious targets and policies at the national level around renewable energy, landscape restoration, circular economy and alternative energy technologies like green hydrogen are being introduced to fast-track the country towards a low-carbon economy and achieve the long-term net-zero target of 2070.

Public Sector Enterprises (PSEs), known for its remarkable efforts in the socio-economic development of the country since its independence, is going to play a critical role in realising India's ambitious climate goals. Their presence in critical sectors of the Indian economy make them indispensable in a just transition towards a low-carbon economy. Several PSEs have already embarked on this transition with vigour and are spearheading innovations that will benefit their sector in the country and across the globe. In addition, they are adopting proven technologies at scale.

This compendium is a first-of-its-kind effort of SCOPE and GIZ to document the innovative climate change mitigation technologies developed and implemented by the PSEs of the country. The compendium also highlights other climate change mitigation and environmental conservation initiatives of the PSEs. The intention of this compendium is to facilitate knowledge exchange amongst players within important, hard-to-abate economic sectors to support a faster low-carbon transition.

GIZ is pleased to collaborate with SCOPE on this initiative as part of its wider partnership to support climate action of PSEs. We sincerely hope that the compendium will be an interesting and informative read, providing a starting point for greater knowledge exchange and collaboration among the PSEs as well as other actors in achieving India's net-zero goal.

Dr. Shailendra Dwivedi
Director – Climate Change and Circular Economy
GIZ India

Executive Summary

Unchecked, the climate crisis can lead to catastrophic consequences for the world. By the end of 21st century, the Earth's global average temperature is projected to rise by 4°C[1] compared to pre-industrial levels if mitigation efforts are not scaled up. Greenhouse Gas (GHG) emissions need to be drastically reduced across all sectors of the economy to prevent the crisis from getting worse. Given the implications of this crisis, the Government of India has recognised the need to adopt climate adaptation and mitigation strategies. The government has, in line with this, committed to several ambitious targets at the national and international levels.

PSEs, being an important component of the Indian economy (over 13% of India's GDP) and a vital pillar in India's development, play a crucial role in supporting the Indian Government in addressing the challenges of the climate crisis. Their role becomes even more critical given their presence in several hard-to-abate sectors.

The PSEs, on their part, are leading from the front in this challenge. They have taken significant steps to enact internal environment-friendly and low-carbon policies. They have also spearheaded several low-carbon innovations in their sectors while they continue to examine how innovative climate technology can help implement the national climate action plans and help achieve the NDCs under the Paris Agreement. Given their commitment to the national agenda of climate change mitigation, they are vital players in supporting the country to achieve its long-term goal of becoming net-zero by 2070.

As they dedicate themselves to the nation's growth while being sensitive to the carbon footprint, they have designed and implemented many projects and processes that curtail GHG emissions. These innovative products and processes exceed the corporate social responsibility of planting trees and using LED and portray the technological maturity of the PSEs in optimising science to promote climate action.

Given the multitude levels of these innovations, SCOPE and GIZ conceptualised Compendium of "Initiatives towards building a low carbon economy" (referred to as 'technology compendium') to highlight the dedicated efforts of PSEs to combat climate change. The technology compendium is a collation of innovative technologies implemented by PSEs in India for the climate change mitigation. The compendium is divided into four sections:

1

Innovative Climate Change Mitigation Practices

This section describes innovate climate mitigation technology developed by PSEs in India. This is further categorised as technologies that:

a) reduce GHG emissions and

b) reduce critical gases

2

Recognised Technologies and Environmental Initiatives adopted/modified to combat climate change

This section focuses on existing, commercially available technology(ies) that have been adopted by several PSEs.

3

Initiatives for environmental improvement and sustainable development adopted by PSEs

The section reflects and discussed environmental initiatives adopted by the PSEs so as to promote good climate practices.

1 https://www.greenfacts.org/en/impacts-global-warming/l-2/index.htm

4 Global Technologies

The final section discusses global technologies that are being developed for climate change mitigation universally. This section has been incorporated with the intent of describing the global outlook and practices towards technology intervention for reducing the carbon footprint.

For this purpose, 26 major PSEs were identified based on their energy intensity, emissions intensity, secondary data available for their low-carbon activities and projects undertaken by them for reducing carbon emissions. Data and information collection has been done for the identified PSEs through:

- Primary data collection i.e., engaging in stakeholder consultations with the PSEs and;
- Secondary data collection i.e., obtaining information from secondary sources available in public domain including Sustainability Reports, Annual Reports, etc.

Based on the above data collection and information analysis, the technology compendium reflects and aims to summarise the innovative climate and environmental initiatives of the PSEs and initiate knowledge exchange among PSEs and other stakeholders to accelerate the low-carbon transition.

However, despite our best efforts, the technology compendium may not reflect all the technical details or all the technologies due to commercial confidentiality constraints.

1

Introduction

1.1 Climate change

The augmented burning of fossil fuels, and rising land use changes have continued to emit increasing quantities of greenhouse gases into the Earth's atmosphere. The rise in these greenhouse gases with a major share of carbon dioxide (CO_2), methane (CH_4) and nitrogen dioxide (N_2O), have intensified the amount of heat from the sun withheld within the earth's atmosphere, heat that would normally be radiated back into space.

This increase has led to the greenhouse effect, resulting in climate change. The main characteristics of climate change are measured against the increase in average global temperature (global warming); changes in cloud cover with varied precipitation ratio particularly over land; melting of ice caps and glaciers thereby reducing snow cover, and an increase in ocean temperatures and ocean acidity due to seawater absorbing heat and carbon dioxide from the atmosphere.

1.2 Need for climate change mitigation actions

Given the implications of climate change, the Government of India has recognised the need to adopt climate adaptation and mitigation strategies to combat rising temperatures. The Government recognises the urgency and importance of the actions that needs to be taken collectively and is party to the United Nations Framework Convention on Climate Change (UNFCC). The ultimate objective of the Convention is to stabilise greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Climate change is recognised as a key global and national challenge by the Government of India, as also evident in the National Action Plan on Climate Change (NAPCC), the State Action Plans on Climate change (SAPCC), as well as Nationally Determined Contributions (NDCs) submitted as part of its commitment to the Paris Agreement.

India has been ranked as one of the top six countries within the G-20 countries in line to meet its Nationally Determined Contribution (NDC) targets. India's updated NDC targets include reducing the emissions intensity of its GDP by 45% by 2030 compared to 2005 levels (revised from the previous target of 33-35% reduction in emissions intensity over the same timeline), achieving 50% of its installed electricity capacity from renewable resources by 2030 (as compared to the previous target of 40% by 2030. Additionally, India has committed one target against increasing carbon sink, which reads "creating an additional carbon sink of 2.5-3 billion t CO_2 equivalent through additional forest and tree cover by 2030".

1.3 Role of Public Sector Enterprises (PSEs)

In tandem with the Government's commitments at international forums and conventions, there lies now a significant focus on PSEs to act as frontrunners in India's climate change actions. For decades, PSEs have played a significant role in India's socio-economic development through their contribution to the industrial development, upliftment of backward regions, environment protection, promotion of green, energy-efficient technologies, capacity building, and promotion of social infrastructures such as education and healthcare. PSEs have catered to our country's energy and food security needs and have supported in the implementation of various Government schemes and policies. In the post-independence period, the public sector provided the required thrust to the economy and was synonymous with creating a strong industrial base for India. After independence, the Government introduced a public-sector led industrial development (the Feldman Mahalanobis) model, which focused on developing a strong capital base through PSEs in sectors such as railways, steel, power, oil, telecommunications, mining, and transportation. The Government of India awarded enhanced financial autonomy to the PSEs for comparative advantages to help them compete in the global market. Based in various parameters including performance, size of operation, domain etc., presently, there are 12 Maharatna, 12 Navaratna, and a total of 74 Miniratna (including two categories) PSEs present in India.

Therefore, for deeper climate action, and achievement of India's NDC targets, it is vital to position PSEs and build capacities to address climate change, considering their strategic importance in the Indian economy, and their contribution towards capital formation, employment generation, balanced regional development, and promotion of research and development in the country.

PSEs are significant stakeholders in the Indian economy, contributing nearly 13% to the Indian GDP in terms of turnover. **Despite having a presence in hard-to-abate sectors where emissions are inherent, PSEs have taken significant steps toward reducing GHG emissions. Several PSEs have adopted an "Environmental Policy Statement" as a part of their corporate strategy, thereby integrating climate change mitigation and other environmental initiatives into their operations.** Apart from this, mass awareness campaigns across various levels have been organised by PSEs in various sectors to contribute to the national commitment towards climate change mitigation. Additionally, the power sector has made rigorous efforts toward increasing the proportion of renewable power generation, **thereby reducing the need to use fossil fuels for power generation. Such PSEs are focusing to expand grid storage capacities for renewable sources of power generation, thereby ensuring enhanced use of renewable power**.

As highlighted during the UN Climate Change Conference 2022 at Bonn, Germany, technologies can play a critical role in reducing greenhouse gas emissions and building resilience to the impacts of climate change. Hence, technology is key to raising climate ambition. New upcoming technologies like Hydrogen Fuel, Carbon Capture and utilisation, Solar Concentrator, and Artificial Intelligence will lead the way towards climate action in the nearby future.

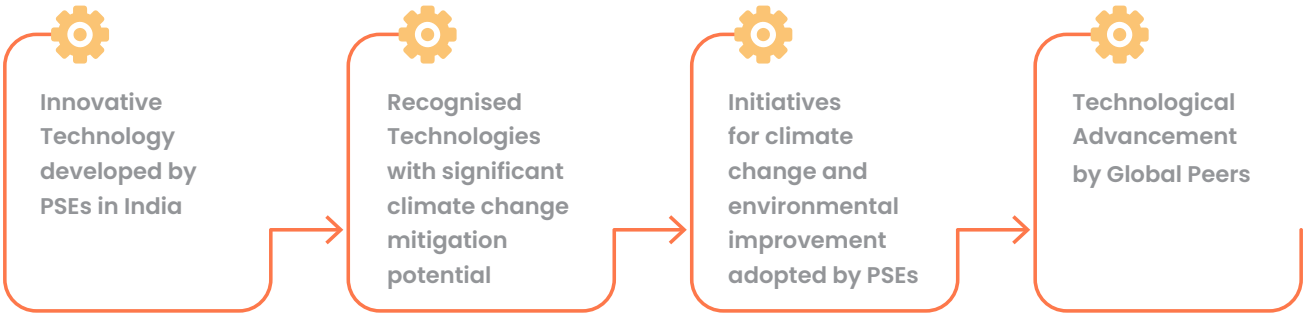
Start-ups, R&D facilities, academic institutions, and even established private and public players are continuously working on the development of new technologies, and upgradation of existing technologies such as decarbonisation technologies for clean, green, reliable energy solutions as well as zero-emissions manufacturing.

PSEs in India have already embarked on their journey to lead India's climate change commitments by fostering the use of innovative climate technology to reduce greenhouse gas emissions and adapt to the impacts of climate change. PSEs are examining how innovative climate technology can help implement the national climate action plans, and help achieve the NDCs under the Paris Agreement. The current level of ambition set out in these plans is, in aggregate, still far too low for the international community to meet the temperature goals of the Paris Agreement.

1.4 About the Compendium

This technology compendium document is a collation of innovative technologies implemented by PSEs in India for the climate change mitigation. The data collation is included majorly through stakeholder consultations with the PSEs of India and secondary research. This compendium aims to give a brief overview of the technologies developed and/or adopted by PSEs to address greenhouse gas emissions. The technologies collated in this compendium also provide a brief analysis based on specific aspects like GHG reduction potential, feasibility and, potential for replicability and scalability.

The compendium is divided into four parts:



This knowledge compendium is jointly published by the Standing Conference of Public Enterprises (SCOPE) and the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH India under the Global Carbon Markets (GCM) Project. The GCM Project is a global development cooperation project, implemented in India by GIZ India, on behalf of the German Federal Ministry for Economic Affairs and Climate Action (BMWK).

2

Scope, Approach, and Methodology

2.1 Scope

Climate change mitigation is imperative, especially for the energy-intensive and emission-intensive private and public sector entities. The PSEs are not just drivers of economic development in India but have traditionally been rooted in the problems confronting society at large. They play a crucial role in supporting the Government, in achieving its nationally determined contributions, the climate targets, or even the sustainable development goals.

Understanding the impending climate change risks and the transformation that is required to address the issue, some PSEs have innovated and/or adopted existing technologies, thereby supporting the Government of India's commitments to the Paris Climate Accord. This document intends to compile these innovative technologies used by the PSEs of India, for the mitigation of Climate Change.

The compendium is not restricted to any one sector but attempts to cover PSEs operating in different sectors and have adopted innovative technologies for the mitigation of climate change. Along with the unique enterprise-specific innovative technologies, the compendium also covers common technologies adopted by multiple enterprises that may have a high climate change mitigation potential. The compendium also Illustrates a list of selected global best available technologies for climate change mitigation in the global technologies chapter.

The information in the compendium is limited to compiling specific data based on its availability either through secondary sources or through the consultations conducted with the respective public sector enterprise.

2.2 Approach & Methodology

The major objective of this compendium is knowledge dissemination to support the capacity building of PSEs on climate change mitigation-related issues. This compendium can be used as a reference for the PSEs to understand various ongoing and upcoming initiatives of their peers for climate change mitigation and consider collaborations. With this objective, it was necessary to collate details of selected innovative technologies with respect to its functioning, climate change mitigation potential, the funding requirements of respective technologies, the status of its implementation as well as replicability and scalability. This compendium adopts different approaches to research including secondary research, one-on-one consultation with selected PSEs and stakeholder feedback. The methodology adopted from each of these approaches is illustrated below:

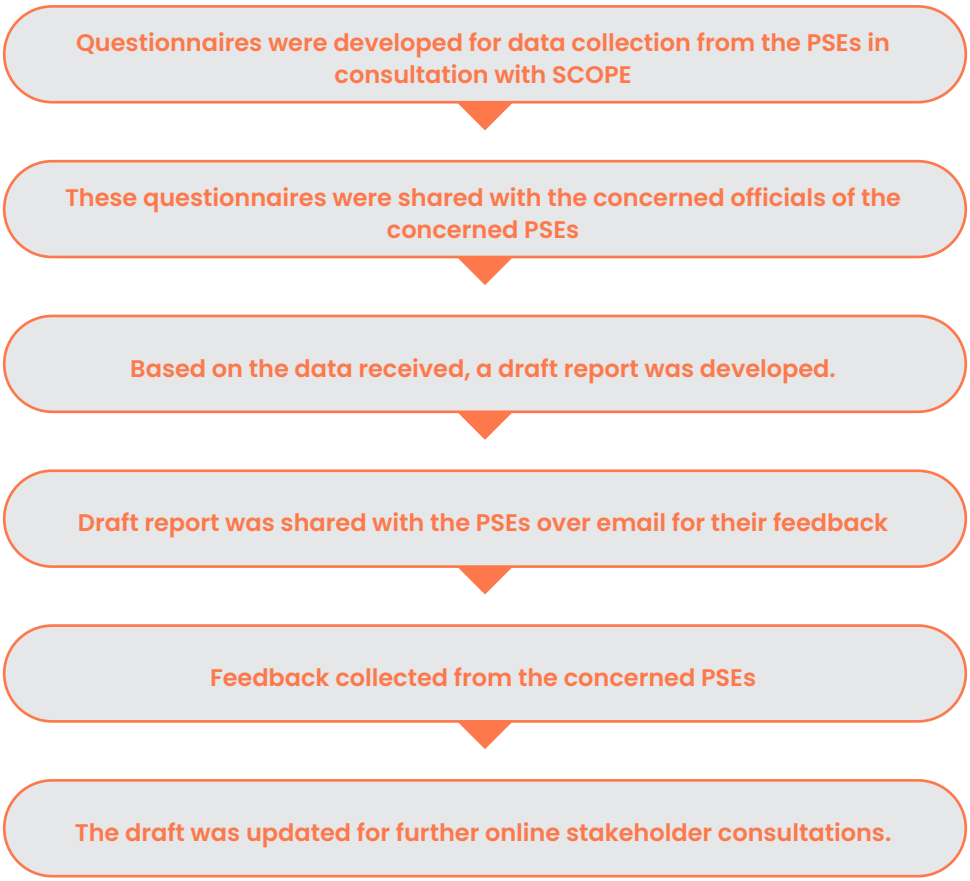
2.2.1 Secondary Research

Secondary research was conducted as an integral approach for three major aspects:

- To identify the strategic PSEs in the country that are implementing climate change mitigation technologies. This was further validated through direct consultations with all relevant PSEs of India.
- To understand the implication of various industrial and non-industrial processes on climate change at a national and global level and how different technologies are helping towards mitigation of climate change impacts.
- To understand and compile the global best practices on technologies that are adopted or piloted for mitigation of climate change.

2.2.2 Stakeholder Consultations

Relevant PSEs were shortlisted through secondary research for either their innovative technologies or their emissions intensity. Respective officials from selected PSEs were consulted to understand and collate details of the technologies adopted to mitigate climate change. This approach gave an in-depth understanding and details as required to fulfil the objectives of this compendium. The steps are as follows:



Stakeholder Feedback

Based on the secondary research and individual stakeholder consultations, a draft compendium was prepared. This draft was further reviewed by the PSEs during online consultations. These consultations were one-on-one consultation held with the nodal officers and their extended team to validate the draft document and seek further information, if any. The feedback received from all stakeholders has been incorporated into this compendium.

3

Innovative Climate Change Mitigation Practices

Climate change mitigation, especially in the hard-to-abate sectors, is a growing challenge due to non-availability of easily adaptable technologies, affordability, and supply chain barriers. While national and international policies along with financial aids and incentives from national and multinational sources act as key drivers towards adoption of climate change practices, adaptability/transferability, technical know-how and financial viability deters the pace of adoption. Captive research & development may facilitate the solution to this concern; collaborative research and knowledge sharing coupled with collaborated technology implementation may further help negate the current gap.

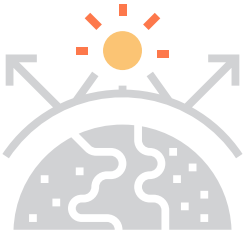
This chapter is a collation of technologies, processes or products researched, developed, or innovatively modified by the PSEs either to abate GHG emissions or that of other critical gases, to help improve the micro and macro climate. Thereby the chapter is divided into two sections:

a. Technologies, processes, or products developed for climate change mitigation through GHG emission reduction, and

b. Technologies, processes, or products developed for emission reduction of critical gases

GHG here refers to carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N20) as major gases and hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF6) as less prevalent but very powerful greenhouse gases[1] (as defined by UNFCCC). Other critical gases include aerosols, CO, NOx, SOx, particulate matter, water vapour and volatile organic materials. The list of technologies, products and process collated the respective sections is limited to the data available through secondary research and stakeholder consultations with PSEs and are hence non-exhaustive.

The chapter is structured to give a brief understanding of the need for developing the respective technology/process/products and with the details of how the technology helps in climate change mitigation. It was attempted to statistically quantify the GHG emission reduction through CO_2 equivalent emissions and approximately scales its 'ease of replicability' and 'challenges for scalability' as low, medium, and high. The considerations adopted for low medium and high are as follows:



GHG here refers to carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_20) as major gases and hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6) as less prevalent but very powerful greenhouse gases

1 Sourced from https://unfccc.int/process-and-meetings/the-convention/glossary-of-climate-change-acronyms-and-terms#g

a. Challenges for Scalability is analysed as the financial barriers and technical barriers

Graphical representation adopted	Low | Medium | High		**Green** – most easy **Yellow** – moderate **Red** – difficult
Consideration for financial barriers	**Low**	Low capex and maintenance cost incurred to adopt the respective technology, or by adopting the respective technology/process the operation cost of the conventional process is further reduced (lesser use of fuel/ electricity/raw materials, etc)	
	Medium	Capex may be required but the adoption of the technology will eventually reduce the operational cost. Does not require huge investments for complete replacement of current operational systems/machinery. Can be modified with systems easily available within accessible supply chain.	
	High	Requirement of high investments for its R&D, complete modification of plant specifications (retrofitting not possible/costly), will increase the cost of the product.	
Consideration for technical barriers	**Low**	Given technology can be adopted in the existing setting with minimum modifications	
	Medium	Retrofitting/modifications to the current approach required	
	High	Where the technology can be adopted only in a completely new setting and/or where modifications require specialised instruments/land/buying patents/import of base materials etc.	

b. Ease of Replicability is analysed for its adaptability within the same sector and other sectors

Graphical representation adopted	Low | Medium | High		**Green** – most easy **Yellow** – moderate **Red** – difficult
Consideration for same/ similar and other sectors	**Low**	Difficult to adopt the given technology into other industries	
	Medium	Can be adopted with minor modifications/if similar conditions prevail (for e.g., availability of raw materials/land/machinery/etc.)	
	High	Easily replicable with no/minor modifications	

3.1 Technologies, processes, or products developed for climate change mitigation through GHG reduction by PSEs in India

This section with the collation of technologies, processes, or products developed for climate change mitigation through GHG emission reduction by PSEs in India can be further categorised into:

a. Reduction in usage fossil fuel for thermal energy (Crude oil/coal)
b. Capture and conversion of thermal losses to captive power/feed fuel
c. Efficient Management of off gases
d. Enabling Decarbonisation
e. Alternative Fuels

Table 1. Technologies, processes, or products developed for climate change mitigation through GHG emission reduction

	Technology	Organisation (in alphabetical order)
A	**Reduction in usage fossil fuel for thermal energy (Crude oil/coal)**	
1	Advanced Ultra Super Critical Technology	BHEL
2	Anode Grade Coker Technology	IOCL
3	Ultra-super critical Technology for Coal based power Plants	NTPC
4	Coke Oven Battery (7m) with Coke Plant Automation and Process Control System and Coke Dry Cooling Plant (CDCP)	RINL and SAIL
B	**Capture and conversion of thermal losses to captive power/feed fuel**	
1	Top Pressure Recovery Turbine based large volume (>4000 m3) BFs	RINL and SAIL
2	Waste Heat Recovery from Blast Furnace Stove	RINL and SAIL
3	Waste heat Recovery from Sinter Coolers	RINL and SAIL
C	**Efficient Management of CO_2 and other off gases**	
1	Caustic Effluent Neutralisation Technology using CO_2 enriched streams	EIL
2	Recovery of Ammonia	EIL
3	Process: CO_2 for EOR project at Koyali Refinery	IOCL
4	Refinery off-gas to ethanol plant at Panipat refinery (33,500 TPA)	IOCL
5	CO_2 to Lipid CCU Technology	IOCL
6	Enzymatic Solvent based CCS Technology	IOCL
7	Electro-biocatalytic CO_2 to Ethanol CCU Technology	IOCL
8	BOF Gas Recovery with Gas Holders	SAIL
D	**Enabling Decarbonisation**	
1	K Model – Software for predicting crude blend compatibility & optimisation	BPCL
2	High Performance Domestic LPG Cooking Stove	BPCL
3	R&D for CO_2 to valuable chemicals	GAIL
4	HP Gas Flame Plus	HPCL
5	HP-Razor	HPCL
6	HP THERMOPRO	HPCL
7	SprayMax FCC Feed Nozzle	HPCL

	Technology	Organisation (in alphabetical order)
8	Technology: 2G Ethanol Enzymatic Technology Demo Plant at Panipat	IOCL
9	Technology: Octamax®: technology for conversion of cracked C4 Streams to high Octane Gasoline	IOCL
10	Drag Reducing Additive (DRA) Technology	IOCL
11	Demonstration of HCNG in Delhi	IOCL
12	Boric Acid treatment of Anodes	NALCO
13	Slotted Anodes and Increased Stub-hole depth of Anode for energy efficiency	NALCO
14	Low Energy Cell Technology	NALCO
15	Coal Dust Injection	RINL and SAIL
E	**Alternative Fuel and Battery Technology**	
1	Development of commercially viable hydrogen fuel cell buses	IOCL
2	Plasma Enhanced Gasification System (PEGS) for refuse driven fuel (RDF)	IOCL
3	Compressed Biogas (CBG) under SATAT Scheme	IOCL
4	Green Hydrogen Microgrid	NTPC
5	Green Hydrogen Mobility at Leh, Ladakh	NTPC
6	Green Hydrogen Blending in PNG network	NTPC
7	Green Methanol with carbon capture from flue gas – Vindhyachal, Madhya Pradesh	NTPC
8	Battery Energy Storage System	NTPC

BHEL

A. REDUCTION IN USAGE FOSSIL FUEL FOR THERMAL ENERGY (CRUDE OIL/COAL)

Advance Ultra-Super Critical Technology

PROJECT BACKGROUND

Development of Advanced Ultra Supercritical (AUSC) Technology for Coal based Thermal Power Plants was identified by Government of India (GoI) as a mission project under the National Mission for Development of Clean Coal (Carbon) Technologies. This was a part of the NAPCC. A consortium of BHEL, NTPC and Indira Gandhi Centre for Atomic Research (IGCAR) was formed to pursue this Mission. The Research & Development Phase of AUSC project was approved by the Cabinet Committee on Economic Affairs (CCEA).

Key Benefits – GHG emission reduction

- ~20% reduction in CO_2 emissions compared to?
- With AUSC technology, the thermal power plant efficiency will improve to 46%.
- Reduction in coal consumption & CO_2 emission by 11% as compared to Super Critical parameters thermal power plants

DETAILS OF TECHNOLOGY/PRODUCT/PROCESS

The AUSC R&D project is primarily focussed on the design, design review by external experts, manufacturing technology on full-scale prototype, indigenous materials development, materials evaluation programme by the three consortium partners, reputed academic institutes and R&D organisations, and establishing unique experimental facilities for validating the materials selected and turbine design.

ADVANTAGES

- The development of the AUSC technology has allowed the development of core knowledge within the country for possible technological advancements in the following aspects:
- Designing of large steam turbine designs, turbine blading, governing systems etc. for improved efficiency
- Supply Chain Development for advanced nickel-based forgings/castings of steam turbines & boiler tube materials
- Advancements in dissimilar material welding
- Development of new non-destructive testing techniques & radiography testing suitable for the inconel materials
- Establishment of automated manufacturing & fabrication technology for machining of super alloy
- Advancement in technology development for welded rotor & welded casing designs for steam turbine
- Development of advanced material data generation, manufacturing & fabrication technologies, which can be applied in automobile & aerospace industries

Current Status

The AUSC technology has completed all milestones of the R&D phase by December 2020.

Implementing Organisation

Consortium of BHEL, NTPC & IGCAR

Challenges for Scalability

Financial barrier	Low	Medium	**High**
Technical barrier	Low	Medium	**High**

Ease of Replicability

Same/Similar Sectors	Low	Medium	**High**
Other Sectors	Low	Medium	**High**

Future Outlook:

Replacement of old subcritical thermal power plants with advanced supercritical AUSC technology will lead to possible reduction of ~20% in CO_2 emissions. All new thermal power plant should be based on AUSC technology in future. Implementation of 800MW TDP AUSC plant is planned to be completed within four and half years from Government of India's approval.

IOCL

Anode Grade Coker Technology

PROJECT BACKGROUND

Worldwide, 'Anode grade delayed coker units' are operated at high recycle ratios with high furnace heat loads resulting in CO_2 emissions. Energy Efficient and Eco-friendly Anode Coker grade Technology was developed in-house in Indian Oil R&D Centre with better energy efficiency.

Key Benefits - GHG emission reduction and step for "Atmanirbhar Bharat"

At 0.6MMTPA Coker-A unit, Barauni Refinery, IOCL:

- Reduction of CO_2 emissions due to reduction of fuel oil consumption in Coker furnace - 27830 Tonnes/year
- Reduction of SOx emissions: 177 Tonnes/year
- Reduction of NOx emissions: 27 Tonnes/year.

DETAILS OF TECHNOLOGY/PRODUCT/PROCESS

This technology enables production of Anode grade Coke at low recycle with substantial reduction in Furnace heat load. Implementation of the technology causes reduction of CO_2 and SO_2 emissions with reduced fuel requirement. Energy Efficient & Eco-friendly Anode Coker grade Technology maximizes the distillates yield and reduces the coke yield without compromising the product quality. This technology can be easily implemented in Anode grade Delayed Coker Units operating at high recycle ratios and low energy efficiency. The technology employs very low recycle ratio (5-10%) and requires low furnace heat load. It does not require use of 'Quench Column', thereby eliminating residual fuel oil (RFO) production thereby reducing emissions.

Current Status

The AUSC technology has completed all milestones of the R&D phase by December 2020.

Implementing Organisation

Consortium of BHEL, NTPC & IGCAR

Challenges for Scalability

Financial barrier	Low	**Medium**	High
Technical barrier	**Low**	Medium	High

Ease of Replicability

Same/Similar Sectors	Low	Medium	**High**
Other Sectors	**Low**	Medium	High

Future Outlook:

Feasibility of implementation of Anode grade Coker technology in various refineries is being scouted by IOCL's Engineering partner, EIL.

Ultra-super critical Technology

NTPC

PROJECT BACKGROUND

NTPC has adopted Ultra-Super Critical (USC) Technology with steam parameters of 270 kg/cm2(a)/600 °C /600 °C in its coal-based power plants. USC Plants can achieve about 42% efficiency as compared to 40% and 38% efficiency achieved in super critical units and sub-critical units respectively, leading to a reduction in CO_2 emissions.

Key Benefits - GHG emission reduction and step for "Atmanirbhar Bharat"

USC Plants have a CO_2 emission intensity of 800 g/kWH, as compared to 840 g/kWH and 880 g/kWH respectively for super critical and sub critical plants

DETAILS OF TECHNOLOGY/PRODUCT/PROCESS

A Power Plant of 2x660 MW operating at an average Plant Load Factor (PLF) of 85% shall lead to a reduction of 0.4 MT of CO_2 in a year, as compared to a power plant of same capacity based on Super Critical Technology and 0.8 MT of CO_2 in a year, as compared to a power plant of same capacity based on Sub Critical Technology.

Current Status

The technology is already under commercial scale. NTPC has successfully commissioned Khargone Super Thermal Power Project (2x660 MW). Other projects based on this technology are under commissioning stage at Khurja (2x660 MW), Telangana (2X800 MW) and Patratu (3x800 MW).

Implementing Organisation

The technology is implemented in-house by NTPC. It is being used by NTPC, THDC (a subsidiary of NTPC) and PVUNL (a Joint Venture Company of NTPC).

Challenges for Scalability

Financial barrier	Low	Medium	High
Technical barrier	Low	Medium	High

Ease of Replicability

Same/Similar Sectors	Low	Medium	High
Other Sectors	Low	Medium	High

Future Outlook:

This technology can be scaled up by adopting Advanced Ultra Super Critical (AUSC) parameters 310Ksc/710°C/720°C, which is under development by a consortium of NTPC, BHEL, and IGCAR, with a targeted efficiency of 46%. The AUSC Plants will have an estimated emission intensity of 730 g/kWH.

The Technology Demonstration Plant (TDP) of a 1x800 MW unit at Sipat is proposed to be executed by a JV of NTPC and BHEL. The challenges are in the R&D phase and high costs.

RINL

Coke Oven Battery (7m)

with Coke Plant Automation and Process Control System and Coke Dry Cooling Plant (CDCP)

PROJECT BACKGROUND

Coke oven battery is used to convert coal into coke for use in a blast furnace. In the coke making process coal is heated in an oxygen deficient atmosphere. In conventional system, the red-hot coke extruded from the coke oven is cooled by spraying it with water. The water used for cooling is vaporised and released into the atmosphere which is still in high temperatures. This conventional system does not capture the untapped energy of the red-hot coke. It also poses serious environmental hazards by way of polluting atmosphere and water. This system is thus being replaced by Coke Dry Quenching (CDQ) system.

Key Benefits - GHG emission reduction and step for "Atmanirbhar Bharat"

The technology has a potential of reducing

3,01,344 tonnes of GHG emission per year.

Other Co-benefits:

- High energy recovery
- Decreased dust, CO_2, and SOx emissions.
- Increased water efficiency

DETAILS OF TECHNOLOGY/PRODUCT/PROCESS

In the CDQ system, the red-hot coke is cooled by gas circulating in an enclosed system, thereby preventing the release of airborne coke dust. The thermal energy of the red-hot coke, which is lost in the conventional system, is conserved, and reused to make steam in the CDQ system, which is utilised for power generation and other uses. This technology uses less fossil fuel and results in lower CO_2 emissions, thereby contributing to the prevention of global warming.

Image 1 Coke oven battery with CDCP Plant.

Credits: RINL

Current Status

RINL is a pioneer in installing this technology (CDQ1 to 3) along with 3 MT Integrated steel plants in 1989-91 and other Integrated steel Plants installed CDQs to recover sensible heat.

Implementing Organisation

The technology was adopted as a proven energy efficient state-of-the-art technology during the Modernisation and Expansion programme of RINL plants. The facility was installed in RINL plants with the help of international technology providers.

Challenges for Scalability

Financial barrier	Low	Medium	**High**
Technical barrier	Low	Medium	**High**

Ease of Replicability

Same/Similar Sectors	Low	Medium	**High**
Other Sectors	Low	**Medium**	High

Future Outlook:

Retrofitting of the technology in the existing old installations is not feasible. However, all new units of coke oven battery designed and installed during next phase of modernisation and expansion programme in RINL, and its subsidiaries is planned to be equipped with this technology.

SAIL

Coke Oven Battery (7m)

with Coke Plant Automation and Process Control System and Coke Dry Cooling Plant (CDCP)

PROJECT BACKGROUND

The coke oven battery converts coal into metallurgical coke for use in a blast furnace. In the coke making process, coal is heated in an oxygen deficient atmosphere and all volatile matter is distilled from the coal mass to form high quality metallurgical coke. In conventional system, the red-hot coke extruded from the coke oven chambers is cooled by spraying it with water. The water used for cooling is vaporised and released into the atmosphere which is still in high temperature. This conventional system does not capture the untapped energy of the red-hot coke. It also poses serious environmental hazards by way of polluting atmosphere and water. This system is thus being replaced by Coke Dry Cooling Plant (CDCP).

Key Benefits - GHG emission reduction and step for "Atmanirbhar Bharat"

The technology has a potential of reducing

3,01,344 tonnes of GHG emission per year.

Other Co-benefits:

- High energy recovery
- Decreased dust, CO_2, and SOx emissions.
- Increased water efficiency

DETAILS OF TECHNOLOGY/PRODUCT/PROCESS

In the CDCP, the red-hot coke is cooled by gas circulating in an enclosed system, thereby preventing the release of airborne coke dust. The thermal energy of the red-hot coke, which is otherwise lost in the conventional system, is conserved, and reused for making steam in the CDCP and further utilised for power generation. With CDCP, about 0.5 tonne steam/tonne coke can be recovered and used for electricity production. Nowadays, CDCP plants have gathered a lot of attention from the world due to its efficient energy recovery and the characteristic of reducing the environment pollution. They are being regarded as an essential facility for the countermeasure against environmental problems like global warming by CO_2 and air pollution. In a study, in which the energy saving calculation has been carried out based on the operation of an existing CDCP process, it has been shown that 85 % of the waste heat generated during coal carbonisation is being recovered by the CDCP process.

Capacity utilisation of the facility or ramping up of its production within the scheduled time period was one of the challenges.

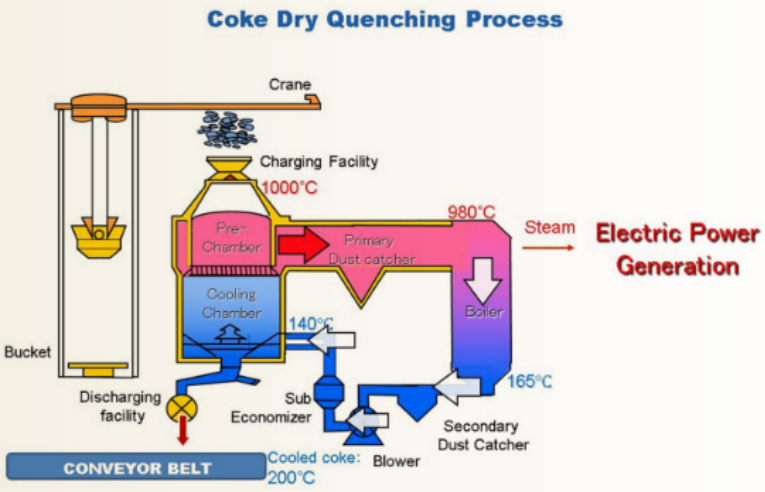


Figure 1 Schematic diagram of Coke Dry Cooling Plant.

Current Status

Coke Dry Cooling Plant (CDCP) along with 7m tall Coke Oven Battery with Coke Plant Automation and Process Control System facilities installed at Bhilai Steel Plant (BSP) in October 2014, Rourkela Steel Plant (RSP) in April 2013 and IISCO Steel Plant (ISP) in February 2013 during last modernisation cum expansion programme of SAIL and under operation.

Implementing Organisation/Service Provider

The facility adopted as a proven energy efficient state-of-the-art technology and installed with the help of technology/Service providers: GIPROKOKS, Consortium Agroindustry (CUI)/KB Koksokhimmash (KBK), CUI/ SOY and Bhilai Engineering Corporation.

Challenges for Scalability

Financial barrier	Low	Medium	**High**
Technical barrier	Low	Medium	**High**

Ease of Replicability

Same/Similar Sectors	Low	Medium	**High**
Other Sectors	Low	**Medium**	High

Future Outlook:

Retrofitting of the technology in the existing old installations is not feasible. However, all new units of coke oven battery designed and installed during next phase of modernisation and expansion programme in RINL, and its subsidiaries is planned to be equipped with this technology.

B. CAPTURE AND CONVERSION OF THERMAL LOSSES TO CAPTIVE POWER/FEED FUEL

Top Pressure Recovery

Turbine based large volume (>4000 m3) BFs

PROJECT BACKGROUND

In conventional practice, the energy of blast furnace gas is wasted by pressure reduction at a septum valve. This technology aims to recover this blast furnace gas to produce electric power, realising significant energy saving.

Key Benefits – GHG emission reduction

The technology has a potential of reducing 98,112 tonnes of GHG emission per year.

Other Co-benefits:

- Fuel less power generation thus no GHG emission
- Less noise
- Decreased CO_2 emissions

DETAILS OF TECHNOLOGY/PRODUCT/PROCESS

A top-pressure recovery turbine plant is installed in the downstream of gas-cleaning equipment of a blast furnace. After dust is collected by gas cleaning equipment, blast furnace gas is led to the turbine and drives it while expanding from the furnace top pressure to atmospheric pressure. The power generated by the turbine is transferred to the generator and converted to electric power. A BF top-pressure recovery turbine plant comprises of dust collecting equipment, a gas turbine, and a generator. It generates less noise in compared to a conventional septum valve, contributing to the improvement of the environment around a blast furnace. It also decreases CO_2 emissions.

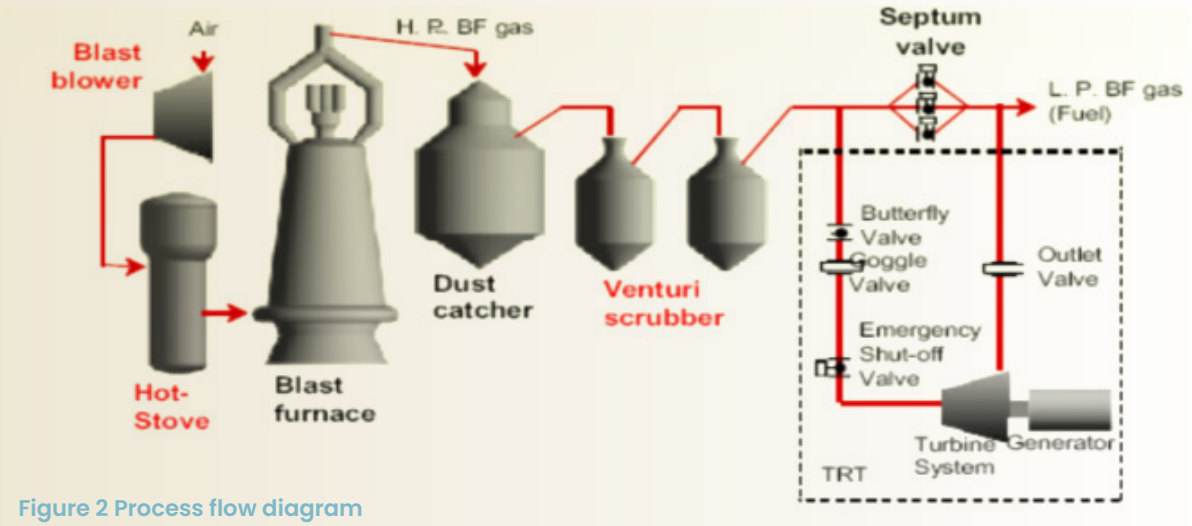


Figure 2 Process flow diagram

Current Status

RINL is a pioneer in installing this technology (GETs-1&2) along with 3 MT Integrated steel plants in 1989-91 other Integrated steel Plants installed GETs to recover pressure energy.

Implementing Organisation

These facilities are installed along with an integrated steel plant by external agencies. GETS 1&2 are installed along with Blast Furnace 1 &2 as part of an expansion of Blast Furnace-3, TRT is installed.

Challenges for Scalability

Financial barrier	Low	Medium	High
Technical barrier	Low	Medium	High

Ease of Replicability

Same/Similar Sectors	Low	Medium	High
Other Sectors	Low	Medium	High

Future Outlook:

This technology has contributed to the reduction of CO_2 emissions and all integrated steel plants are gradually adopting it through brown field and green field expansion. MOEF stipulates that this technology is to be adopted mandatory while issuing Consent for Establishment (CFE).

RINL

Waste Heat Recovery

from Blast Furnace Stove

PROJECT BACKGROUND

Modern blast furnaces work with very high temperatures and very high-pressure blasts. To heat this blast to the required temperature the hot stoves are fed with highly enriched blast-furnace gas. This produces high thermal energy making it important to capture and utilize the thermal losses by the waste gas. The efficiency of the hot stoves can be improved by recovering the heat from the flue gases of the stoves and using this energy to pre-heat the combustion fuel and/or the air entering the stoves. Thus, saving fuel and reducing GHG emissions.

Key Benefits - GHG emission reduction

The technology has a potential of reducing 72,010 tonnes of GHG emission per year.

Other Co-benefits:

- High energy recovery
- Decreased CO_2 emissions.

DETAILS OF TECHNOLOGY/PRODUCT/PROCESS

The heat energy of waste energy carrying medium (hot combustion products) of Blast Furnace Stoves is recovered by installing waste heat recovery system. The waste heat recovery system recovers the heat from waste gases and preheats the combustion air and fuel gas to Blast Furnace Stoves. With the result, the fuel gas input (Blast Furnace gas) is reduced to Blast Furnace Stoves.

This system recovers the sensible heat of the flue gas generated in heating the hot stoves which supply hot blast to the blast furnace and uses this heat in preheating fuel and combustion air for the hot stoves. Installation of this device improves the combustion efficiency of the hot stoves, thereby saving energy and reducing GHG emissions. The exit temperature of the flue gases, approximately 3280°C, shall be recovered. This device consists of counter current heat exchanger wherein outgoing flue gases sensible heat is recovered by the incoming fuel gas and combustion air. The fuel gas and combustion air are pre-heated and supplied to the Blast Furnace stoves.

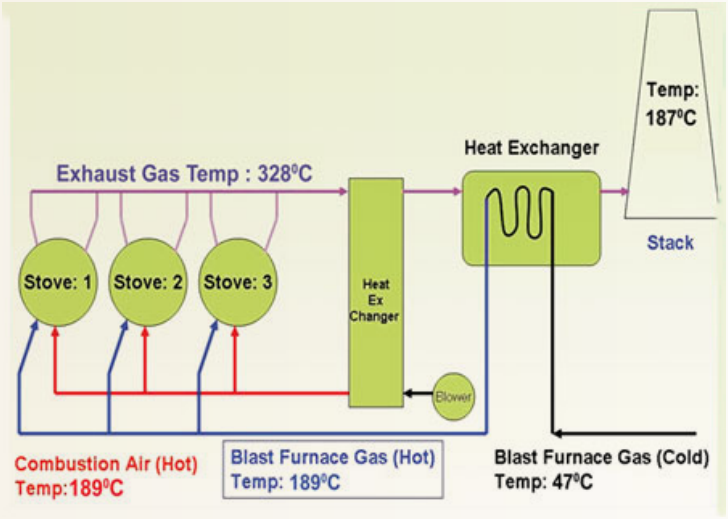


Figure 3: Process flow diagram
Process flow diagram – Waste Heat Recovery

Current Status

RINL installed this technology (WHR) and other Integrated steel Plants to installed WHR in BF to recover sensible heat of waste gas.

Implementing Organisation/Service Provider

These facilities are installed along with integrated steel plant by external agencies. WHR installed along with Blast Furnace-3 at Vijag Plant.

Challenges for Scalability

Financial barrier	Low	Medium	**High**
Technical barrier	Low	Medium	**High**

Ease of Replicability

Same/Similar Sectors	Low	Medium	**High**
Other Sectors	Low	**Medium**	High

Future Outlook:

This technology has contributed to the reduction of CO_2 emissions and all integrated steel plants are gradually adopting it through brown field and green field expansion. MOEFCC stipulates that this technology is to be adopted mandatory while issuing CFE.

RINL

Waste Heat Recovery

from Sinter Coolers

PROJECT BACKGROUND

Conventionally, the heat from the sinter cooler is wasted. Heat recovered from the sinter cooler can be recirculated to the sinter machine or can be used for preheating the combustion air in the ignition hood, for pre-heating of the raw mix to the sinter machine. Therefore, reducing fuel consumption and CO_2 emission.

Key Benefits - GHG emission reduction

The technology has a potential of reducing 1,44,365 tonnes of GHG emission per year.

Other Co-benefits:

- Fuel less power generation thus no GHG emission
- Less noise
- Decreased dust, CO_2, and SOx emissions

DETAILS OF TECHNOLOGY/PRODUCT/PROCESS

The hot sinter at the sinter machine outlet is about 800-8500C and the rate of production of the sinter is 450- 500 t/hr. In the present system, the hot sinter is cooled by blowing air through sinter blower fans and cooled sinter (600C) is sent to blast furnace and available heat energy is recovered by waste gas from two sinter coolers is heated by red hot sinter, captured by a hood, dedusted by a pre-duster, and then routed to a boiler to generate superheated steam, which is converted to electricity by a turbine connected to a generator. The exhaust gas from the boiler is re-circulated into the respective sinter coolers by the circulating fans to reuse the remaining sensible heat to increase the recovery of waste gas from the sinter cooler.

Image 2 Site Image Waste Heat Recovery

Current Status

RINL is a pioneer installing in this technology (SHRPP) in sinter plants other Integrated steel Plants installed SHRPP to recover sensible heat of hot sinter.

Implementing Organisation

The technology was adopted as a proven energy-efficient state-of-the-art technology during the Modernisation and Expansion programme of RINL plants.

RINL installed SHRPP at Sinter Plant-1 under the Japan Green aid plan.

Challenges for Scalability

Financial barrier	Low	Medium	**High**
Technical barrier	Low	Medium	**High**

Ease of Replicability

Same/Similar Sectors	Low	Medium	**High**
Other Sectors	Low	**Medium**	High

Future Outlook:

This technology has contributed to the reduction of CO_2 emissions and all integrated steel plants are gradually adopting it through brown field and green field expansion. MOEFCC stipulates that this technology is to be adopted mandatory while issuing CFE.

RINL

BF Gas based captive power plant -2

PROJECT BACKGROUND

During the process of iron making BF, gas is generated, and it is expected that 4,40,000 Ncum/hr of BF gas at the calorific value of 715 kcal/Cum shall remain unutilised. The purpose of this practice is to utilise the surplus BF gas to generate electricity that otherwise would have been flared.

Key Benefits - GHG emission reduction

The technology has a potential of reducing 8,40,960 tonnes of GHG emission per year.

Other Co-benefits:

- High energy recovery
- Reduced emissions

DETAILS OF TECHNOLOGY/PRODUCT/PROCESS

The project comprises of installation of Boiler, Turbine, Generator, and all other facilities required for the generation of 120 MW of electricity. BF gas has low calorific value and therefore, the use of BF gas is a challenge. To overcome this challenge RINL installed a 120MW BF gas-based power plant with specially designed boilers.

The boilers are designed in such a way that a low volumetric heat release rate with a larger boiler furnace results in higher residence time & higher heat surface area to enable flue gas temperature as low as possible.

The boilers are envisaged with Scroll type burner which provides spin to the BFG at the point of air-fuel mixing and adequate refractory lining on water wall tubes of the furnace heat surface which will reradiate heat into the flame. The steam turbine system is of a water-cooled, condensing type. The turbine is coupled with an AC generator giving a rated output of120MW. This project doesn't use any fossil fuels and contributes to the reduction of GHG emissions.

Image 3 Site Image Captive Power Plant. Credits: RINL.

Current Status

RINL installed 120MW power plant to utilise the surplus BF gas.

Implementing Organisation

The technology has been adopted as a proven energy efficient state-of-the-art technology in RINL plants.

Challenges for Scalability

Financial barrier	Low	Medium	High
Technical barrier	Low	Medium	High

Ease of Replicability

Same/Similar Sectors	Low	Medium	High
Other Sectors	Low	Medium	High

Future Outlook:

To utilise surplus blast furnace gas for power generation, this technology helps in minimising wastage of BF gas.

SAIL

Top Pressure Recovery Turbine based large volume (>4000 m3) BFs

PROJECT BACKGROUND

Larger volume modern blast furnaces in the steel plants operate at a high-top gas pressure. The BF gas leaving the BF at the top still maintains a pressure of around 1.6 kg/sq cm (g) to 3 kg/sq cm (g) and has a temperature of around 200°C. This BF gas which is coming out at the top of a BF is cleaned to remove dust and the cleaned gas is used in the steel plant as fuel for the heating purpose at relatively low pressure. In conventional practice, a large amount of pressure energy is lost across the valve.

Key Benefits - GHG emission reduction

The technology has a potential of reducing 3,42,345 tonnes of GHG emission per year.

Other Co-benefits:

- Fuel less power generation thus no GHG emission
- Less noise
- Reduced dust, CO_2, and SOx emission

DETAILS OF TECHNOLOGY/PRODUCT/PROCESS

BF gas top pressure recovery turbine (TRT) is an energy-saving mechanism that utilizes the BF gas heat and pressure energy to drive a turbine. The work generated by the turbine is transferred to a generator and converted to electric power. TRT generates power by exploiting a known property of all gases which is the expansion of gas volume with the reduction of its pressure. The system comprises dust collecting equipment, a gas turbine, and a generator.

The TRT unit is normally installed downstream of gas cleaning equipment for a blast furnace, which can produce power around 15 to 60 kWh/t of hot metal. The BF gas leaving the TRT unit is still used as fuel in the steel plant. Capacity utilisation of the facility or ramping up of its production within the scheduled time period was one of the challenges.

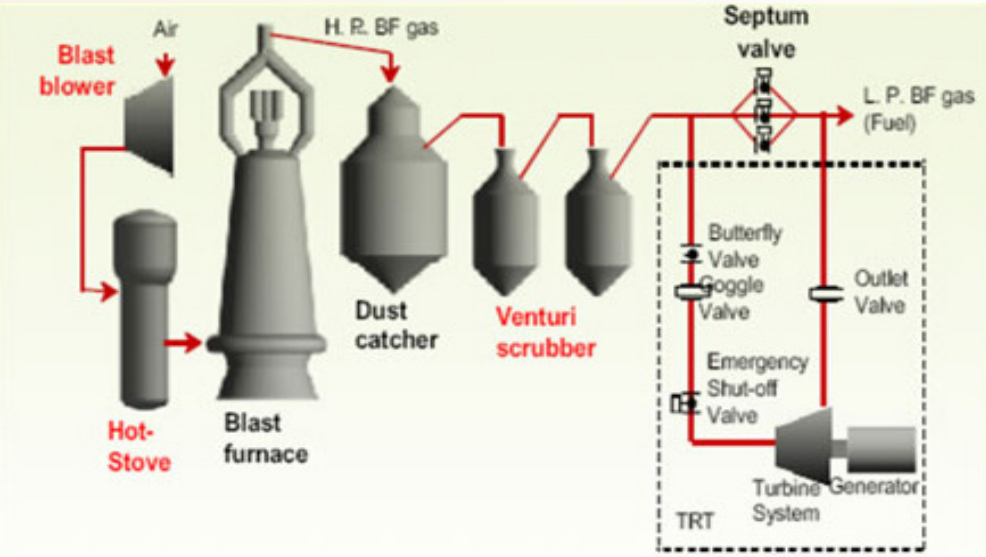


Figure 4 Schematic diagram of Top Pressure Recovery Turbine

Current Status

The facility was installed at Bhilai Steel Plant in February 2018, Rourkela Steel Plant in August 2013, and IISCO Steel Plant in November 2014 during the last modernisation cum expansion program of SAIL and under operation.

Implementing Organisation

The facility was adopted as a proven energy-efficient state-of-the-art technology and installed with the help of technology/Service providers: Paulwurth, L&T for BSP/Danieli Corus, TATA Projects for RSP/ POSCO, Nagarjun Construction, Mitsui (L), NICCO Corporation for ISP.

Challenges for Scalability

Financial barrier	Low	Medium	**High**
Technical barrier	Low	**Medium**	High

Ease of Replicability

Same/Similar Sectors	Low	Medium	**High**
Other Sectors	Low	**Medium**	High

Future Outlook:

All new modern Blast Furnaces are planned to be equipped with this technology during the next phase of the modernisation and expansion program in SAIL. Retrofitting the technology in the existing installations is quite difficult due to logistic constraints. However, considering the advantages, the possibility to be explored for retrofitting existing setups by engaging experts in the area.

SAIL

Waste Heat Recovery from Blast Furnace Stove

PROJECT BACKGROUND

Modern blast furnaces work with very high temperatures and very high-pressure blasts. To heat the blast to the required temperature the hot stoves are fed with highly enriched blast-furnace gas. The temperature of the waste gas leaving from the hot blast stoves is around 4000 C. Without this heat-saving technology, the sensible heat of the exhaust gas goes wasted.

Key Benefits - GHG emission reduction

The technology has a potential of reducing 81,019 tonnes of GHG emission per year.

Other Co-benefits:

- High energy recovery.
- Reduced CO_2 emission.

DETAILS OF TECHNOLOGY/PRODUCT/PROCESS

The hot blast stoves of modern Blast Furnaces are designed in such a way to supply of adequate hot blast temperature at 12000 C to the blast furnace. The waste gas having temperature of around 4000C coming out from the hot blast stoves is passed through the heat exchangers for the recovery of heat entrapped in it. The thermic fluid is heated in the heat exchanger by the waste gas and the heated thermic fluid passes through two heat exchangers to impart the heat to combustion air and fuel gas. The thermic fluid is thus cooled and the cycle repeats. On the other hand, the temperature of exhaust gas is reduced from 4000C to 1500C.

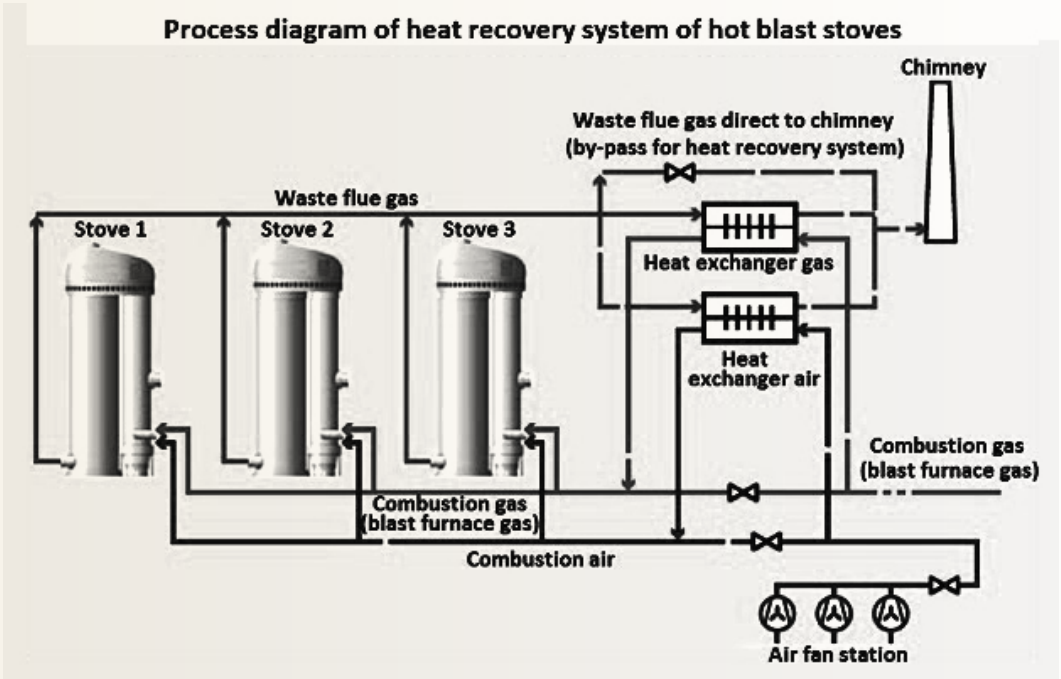


Figure 5 Process flow diagram of Waste Heat Recovery System from Blast Furnace Stove

Current Status

The system was installed at Bhilai Steel Plant in February 2018, Rourkela Steel Plant in August 2013, and IISCO Steel Plant in November 2014 during the last modernisation cum expansion program of SAIL and under operation. The same was also installed at Bokaro Steel Plant (BSL) during the up gradation of Blast Furnace stoves in July 2010 and under operation.

Implementing Organisation

The facility was adopted as a proven energy-efficient state-of-the-art technology and installed with the help of technology/Service providers: Paulwurth, L&T for BSP & BSL/ Danieli Corus, TATA Projects for RSP/POSCO, Nagarjun Construction for ISP.

Challenges for Scalability

Financial barrier	Low	Medium	**High**
Technical barrier	Low	**Medium**	High

Ease of Replicability

Same/Similar Sectors	Low	Medium	**High**
Other Sectors	Low	**Medium**	High

Future Outlook:

All new modern Blast Furnaces are planned to be equipped with this technology during the next phase of the modernisation and expansion program in SAIL. Retrofitting the technology in the existing installations is quite difficult due to logistic constraints. However, considering the advantages, the possibility to be explored for retrofitting existing setups by engaging experts in the area.

SAIL

Waste heat Recovery from Sinter Coolers

PROJECT BACKGROUND

In the sintering technology, the raw materials such as green feed are charged to the strand of the sinter machine to form the 'sinter bed'. This bed passes through the ignition furnace (hood) to initiate the chemical reaction, which is propagated between the carbon and the air sucked through the sinter bed by the exhaust fans. The sinter burns through vertically while the bed moves horizontally towards the discharge end. The sintered material is discharged through a hot sinter crusher onto a sinter cooler, where ambient air is blown through the crushed sintered hot material from below. As a result, the hot sinter gets cooled, and the circulated air gets heated up by absorbing the sensible heat trapped in the sinter. Conventionally it is allowed to vent out through the stack, without utilising the heat carried by the waste gas.

Key Benefits - GHG emission reduction

The technology has a potential of reducing 87050 tonnes of GHG emission per year.

Other Co-benefits:

- High energy recovery.
- Reduced CO_2 emission.

DETAILS OF TECHNOLOGY/PRODUCT/PROCESS

The waste heat recovery system with the Sinter Cooler recovers the high-temperature waste heat (part of waste heat with the temperature of 250-450°C) from the cooler used to cool high-temperature sintered ore (500-700°C) produced by the sintering furnace and recovers this heat for preheating the combustion air. The system comprises mainly combustion air fans, hot air fans, multi-cyclone, piping & valves, instruments & controls, electrics, etc. for effective recovery of waste heat coming out from the cooler bed. Piping/Ducting work from cooler to ignition furnace including post ignition hood is complete with fixed/sliding supports & compensators, valves, and instruments. Capacity utilisation of the facility or ramping up of its production within the scheduled time period was one of the challenges.

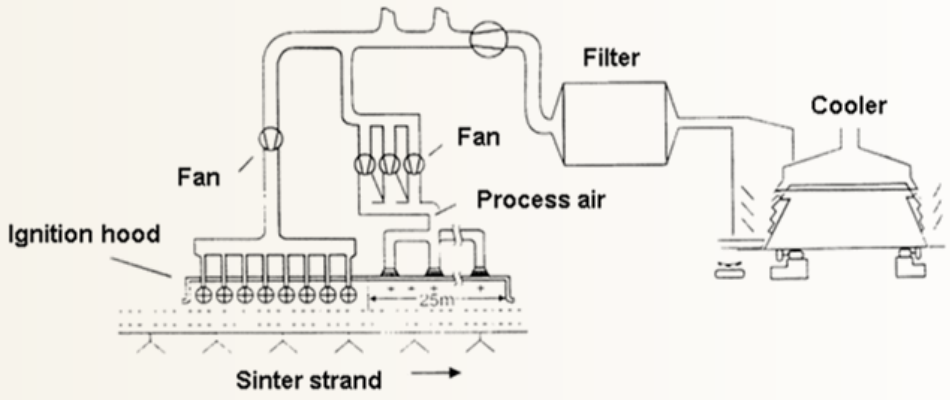


Figure 6 Schematic diagram of Waste Heat Recovery Facility with sinter Cooler

Current Status

The facility was installed at Bhilai Steel Plant in December 2016 and IISCO Steel Plant in January 2013 and is under installation at Bokaro Steel Plant.

Implementing Organisation

The facility adopted as a proven energy-efficient state-of-the-art technology and installed with the help of technology/Service providers:

Primetals Tech for BSP/BEC, UKRG, PROMEZ, Trafalgar, Uralmash for BSL/Autotech, L&T for ISP.

Challenges for Scalability

Financial barrier	Low	Medium	**High**
Technical barrier	Low	**Medium**	High

Ease of Replicability

Same/Similar Sectors	Low	Medium	**High**
Other Sectors	Low	**Medium**	High

Future Outlook:

All new sinter plants are planned to be equipped with this technology during the next phase of the modernisation and expansion program in SAIL. Retrofitting the technology in the existing installations is quite difficult due to logistic constraints. However, considering the advantages, the possibility to be explored for retrofitting existing setups by engaging experts in the area.

C. EFFICIENT MANAGEMENT OF CO_2 AND OTHER OFF GASES

EIL

Caustic Effluent Neutralisation Technology using CO_2 enriched streams

PROJECT BACKGROUND

Carbonation Process is a jointly developed technology of EIL and GAIL R&D for the caustic effluent neutralisation using waste CO_2 streams. Carbon dioxide (CO_2) is considered one of the main contributors to the greenhouse effect and is currently a key challenge throughout the world.

A novel optimised process has been developed for neutralisation of caustic effluent using CO_2 rich streams such as off gas from gas processing unit and flue gases. This is a green process that obviates a myriad problem associated with conventional acid treatment such as high carbon footprint, risk of water contamination with toxic metals like mercury (Hg), imparting permanent hardness to the water, and frequent maintenance necessitated by the highly corrosive acids. This innovative process can bring down the pH of the spent caustic stream from 13-14 to around 7.5 to 8.5 in a benign manner.

Key Benefits - GHG emission reduction

For a typical unit of capacity 205 TPD

Other Co-benefits:

- CO_2 reduction: 750 MT/annum

DETAILS OF TECHNOLOGY/PRODUCT/PROCESS

This innovative technology is an alternate method for efficient and cost-effective alternate method for neutralisation of caustic effluent using carbon dioxide enriched stream having impurities like hydrocarbon, amine etc.

The technology comprises a carbonation reactor having a first section consisting of packing or tray and providing low pressure drop. A second section consisting of gas sparger for bubbling carbon dioxide enriched stream through the pool of wastewater. It also includes a skimming facility installed across the highest liquid level of pool of wastewater at the interface of liquid hydrocarbon and liquid water to remove foam from the system.

Current Status

Lab studies have been completed and Implementation is under progress.

A patent has been filed in the name of "an apparatus and process for neutralisation of alkaline wastewater using CO_2 enriched stream" on 04.02.2019. (Application No: 201911004300).

Implementing Organisation

EIL and GAIL R&D have jointly developed an alternate method to the conventional and complex chemical system for caustic effluent neutralisation using Carbon Di Oxide (CO_2) gas.

The technology has been tested at EIL R&D facility and Basic Engineering Design Package (BEDP) for the carbonation unit submitted to GAIL for implementation at PATA.

Challenges for Scalability

Financial barrier	Low	**Medium**	High
Technical barrier	Low	**Medium**	High

Ease of Replicability

Same/Similar Sectors	Low	Medium	**High**
Other Sectors	Low	Medium	**High**

Future Outlook:

Carbon dioxide (CO_2) is considered one of the main contributors to the greenhouse effect and is currently a key challenge throughout the world. Since this technology utilizes waste CO_2 released to atmosphere by other process units it is expected that this technology would be adopted by various refineries petro-chemical, textile, paper & pulp units. For any client company, this technology translates to OPEX savings and helps reduce their carbon footprint.

EIL

Recovery of Ammonia

PROJECT BACKGROUND

NH3-rich sour gas generated in refinery SWSU (Sour Water Stripper Unit) is typically processed in either of 2 ways: (i) processing in Claus-based SRU (Sulphur Recovery Unit) along with amine acid gas and other sour gases or (ii), processing in reduction furnace/incinerator. While the former option faces the risk of severe operational issues in SRU, the latter option demands additional fuel gas as well as power, not to mention higher CAPEX. Further, any disturbance in operating conditions may lead to higher NOx emissions that are detrimental to the environment. As such, there is a need to explore alternative processes for better utilisation of NH3-rich sour gas.

Key Benefits - GHG emission reduction

The ammonia recovery unit has the potential to save 520 tonnes of direct CO_2 emissions in the form of reduced fuel gas consumption in the Reduction Furnace/ incinerator. Indirect emission benefits include the reduced power consumption for combustion air blower and BFW pump.

DETAILS OF TECHNOLOGY/PRODUCT/PROCESS

To address the challenges mentioned above, EIL has an indigenously developed process for the recovery of ammonia from refinery sour gases. The process takes the NH3-rich sour gas stream and treated water stream from SWSU as feed streams and can provide either anhydrous ammonia gas or aqueous ammonia solution of desired concentration as main products, depending upon the client's requirement, while sour water generated is routed to SWSU. Regarding utilities, the process mainly requires DM water, while the caustic solution is required on a need basis. H2S content in the products is negligible/ extremely low.

The major equipment involved in the process is 3 columns, 1 compressor, and several heat exchangers and pumps. The average life span of the equipment may be considered as ~20 years.

Environmental benefits:

- Lower-zero NOx emissions in SRU (considering the processing of entire NH3-rich sour gas from SWSU)
- Lower CO_2 emissions (due to lower fuel gas requirement)

Financial/economic benefits:

- Reduction of CAPEX in the form of the requirement of a new Reduction Furnace or a bigger incinerator for the destruction of NH3-rich sour gas
- Reduction of OPEX as fuel gas savings
- Saleable product (aqueous ammonia/anhydrous ammonia)

Other benefits:

- The improved operation, lower manpower requirement, etc.

Overall benefits:

- All the above advantages combine to provide a very attractive IRR/ payback period. As per our estimates, IRR for a plant capacity of 16 TPD of aqueous ammonia is ~14%.

Current Status

Implemented in one of the refineries at Northeast Region of India

Implementing Organisation

EIL had implemented this process technology at an Indian refinery.

Challenges for Scalability

Financial barrier	Low	Medium	**High**
Technical barrier	Low	Medium	**High**

Ease of Replicability

Same/Similar Sectors	Low	**Medium**	High
Other Sectors	Low	**Medium**	High

Future Outlook:

EIL is trying to implement similar cases in other industries as well.

IOCL

CO_2 for EOR project at Koyali Refinery

PROJECT BACKGROUND

The project involves sequestration of CO_2 into dormant oil fields for enhanced oil recovery (EOR) in Gujarat Region. CO_2 for the project will be captured from PSA tail gases of SMRs at Indian Oil's Koyali Refinery and then transported via CO_2-Pipeline to oil fields of ONGC in Gandhar region of Gujarat. Project will also lead to recycle of CO_2 into beverage industries which otherwise would have been produced from fossil fields.

Key Benefits - GHG emission reduction

Total 1650 TPD of CO_2 will be captured at Indian Oil Gujarat Refinery out of which 1500 TPD will be used for CO_2-EOR while the balance 150 TPD will be used to produce Food and Beverage (F&B) Grade CO_2 for Beverage industries.

DETAILS OF TECHNOLOGY/PRODUCT/PROCESS

Carbon capture facility at Indian Oil Koyali Refinery will have chiller and membrane systems for CO_2 capture. For compressing the captured CO_2 to 100 bar pressures for transferring the same to ONGC, a compressor package will also be installed. Carbon capture facility will be installed for an average life span of around 20 years. This project is India's first demonstration project for CO_2 for EOR jointly being taken-up by Indian Oil and ONGC. At higher capacities, capture cost can be reduced significantly. Koyali Refinery has a total CO_2 capture potential of around 5000 TPD which can be tapped by identifying additional suitable sinks near Koyali Refinery.

Current Status

The feasibility studies at both the ends have been completed by respective consultants. Joint proposal and business model is being prepared towards seeking grant/ assistance/funding from the government and other possible agencies.

Implementing Organisation

The project was jointly conceptualised by Indian Oil and ONGC by mapping the source (Koyali refinery) with the sink (Gandhar oil fields).

Challenges for Scalability

Financial barrier	Low	Medium	High
Technical barrier	Low	Medium	High

Ease of Replicability

Same/Similar Sectors	Low	Medium	High
Other Sectors	Low	Medium	High

Future Outlook:

Based on Techno-Commercial feasibility of Indian Oil-ONGC CO_2 EOR project, the concept can be replicated in the other refinery locations where suitable sink options can be mapped. With rising focus on reduction in GHG emissions, such projects will need to be considered by industries as power, refining, steel etc. Hence, a proper mechanism of carbon credit and VGF will help in faster adoption across various sectors and will incentivize the businesses to create domestic capacities around such requirements.

Refinery off-gas to fuel ethanol plant

IOCL

PROJECT BACKGROUND

Indian Oil is setting up a World's First refinery off-gas to Fuel conversion ethanol plant at Panipat based on gas fermentation technology, which essentially converts refinery off-gases containing CO_2, CO & slipped hydrogen to fuel grade ethanol for blending with methylated spirit (MS). Commissioning of Ethanol plant is expected by July'2022.

Key Benefits - GHG emission reduction

The plant is expected to reduce CO_2 emissions of ~ 34 Kilo Tonnes/annum (considering power source from renewable grid).

DETAILS OF TECHNOLOGY/PRODUCT/PROCESS

M/s LanzaTech, USA has developed a bio catalyst (microbe) based technology to convert the mixtures of Carbon monoxide (CO) and Hydrogen to Ethanol. The process also generates approximately 130-140 kg/h of dry biomass, which has potential of high nutrition value, and can be valorised.

Indian Oil is setting up refinery off-gas to ethanol plant at Panipat refinery with capacity of 33,500 TPA i.e., 128KL/Day. The Unit mainly comprises of the PSA off gas compression system, Gas Fermentation system, Distillation and Dehydration system and Bio-Mass separation system. Apart from utilising off gases from PSA in Hydrogen Generation Units (HGU) at refineries, this technology can be also utilised for producing ethanol using CO from steel mill blast furnaces.

Current Status

- The plant is expected to be commissioned by July 2022.
- M/s LanzaTech has also developed Commercial Scale Ethanol Plant at Beijing, China for production of Fuel Grade Ethanol from Steel Mill Off gases based on LanzaTech Gas Fermentation Technology. This plant was commissioned in 2018 and is operating successfully.

Implementing Organisation

Refinery Off gases to ethanol plant at Indian Oil Panipat Refinery is based on Gas Fermentation technology by M/s LanzaTech, Distillation and Dehydration section for the Ethanol plant has been designed by Indian Oil's Process Design and Engineering Cell (PDEC) under global partnership.

Challenges for Scalability

Financial barrier	Low	Medium	High
Technical barrier	Low	Medium	High

Ease of Replicability

Same/Similar Sectors	Low	Medium	High
Other Sectors	Low	Medium	High

Future Outlook:

Based on Techno-Commercial feasibility studies such ethanol plants can be replicated in other refinery locations that have waste gases comprising mainly of CO_2, CO and H2. The Biomass produced during the gas fermentation process has high nutrient value and can also be sold as feed to cattle and fish.

IOCL

CO_2 to Lipid CCU Technology

PROJECT BACKGROUND

In line with GoI focus to reduce GHG emissions, DBT-IOC Centre for Advanced Bio-Energy Research at Indian Oil R&D (IOC R&D) has developed a novel Bio-fuel technology to convert carbon dioxide into highly valuable Omega 3-fatty acids (DHAs) and biodiesel.

The process has demonstrated a tremendous potential for carbon recycling. The technology shall create a platform that can produce sustainable food and fuels economically and at scale, dramatically altering how we approach the issue of food vs fuels. This is a remarkable technology for carbon dioxide capture and conversion to high value products.

Key Benefits - GHG emission reduction

The process is still under development but has good potential of CO_2 sequestration / carbon recycling. This technology shall create a platform that can produce sustainable food and fuels economically and at commercial scale.

DETAILS OF TECHNOLOGY/PRODUCT/PROCESS

DBT-IOC Centre for Advanced Bio-Energy Research at Indian Oil R&D (IOC R&D) has developed this novel Bio-fuel technology by integrating the LanzaTech USA anaerobic gas fermentation technology to convert carbon dioxide into acetic acid and IOC (R&D) aerobic fermentation technology to convert acetic acid to lipids (algal oil) including highly valuable Omega 3-fatty acids (DHAs).

The lipids are then trans-esterified to esters followed by separation of Omega 3-fatty acids (DHAs) esters as high value product & remaining lipid esters are used as biodiesel fuel. DHAs esters are essential components of nutrient formulation for children, adults and shall help in combating childhood malnutrition. For the research in this area DBT-IOC centre has put up world's first pilot facility at IOC R&D, Faridabad to sequestrate about 10 kg/day of CO_2 in 2018.

Current Status

The feasibility studies at both the ends have been completed by respective consultants. Joint proposal and business model is being prepared towards seeking grant/assistance/ funding from the government and other possible agencies.

Implementing Organisation

DBT IOC Centre for Advanced Bioenergy Research, Indian Oil R&D Centre, Faridabad & LanzaTech USA

Challenges for Scalability

Financial barrier	Low	Medium	**High**
Technical barrier	Low	Medium	**High**

Ease of Replicability

Same/Similar Sectors	Low	Medium	**High**
Other Sectors	Low	**Medium**	High

Future Outlook:

The process has demonstrated high potential of carbon recycling while producing sustainable food and fuels economically and at scale. The Technology once proven at pilot scale has a potential for diverse opportunities for IOC & Lanza Tech.

Enzymatic Solvent-based CCS Technology

PROJECT BACKGROUND

Solvent-based CO_2 capture is a key technology for the deployment of near-zero-emission strategies. It is one of the commercially ready options for the decarbonisation of oil refineries, particularly in a post-combustion mode. Conventional carbon capture techniques using amines are considered expensive and energy intensive, and like in all processes, it is desired to minimize capital and operating costs.

Key Benefits - GHG emission reduction

The technology can be used for capture of CO_2 from flue gas of power plants and from biogas. This can lead to significant reduction to GHG emission.

DETAILS OF TECHNOLOGY/PRODUCT/PROCESS

Indian Oil R&D has developed a patented enzyme and amine combination-based process for improving conventional amine-based CO_2 capture technology. The enzyme improves the efficiency of the solvent-based CO_2 capture process and lowers the regeneration energy, leading to overall low energy requirement for better economics. The enzyme mediated solvent based CO_2 capture requires biocompatible solvent composition and thermotolerant industrially relevant immobilised enzymes. IOC R&D has developed proprietary solvent system, enzyme and developed the process for capture of CO_2 from flue gas and biogas.

Current Status

Pilot scale studies completed. Technology has been patented. Development of Basic Engineering Design Packages (BDEP) for large scale commercial implementation underway.

Implementing Organisation

This technology was developed by Research and Development Centre, Indian Oil Corporation Ltd.

Challenges for Scalability

Financial barrier	Low	Medium	**High**
Technical barrier	Low	Medium	**High**

Ease of Replicability

Same/Similar Sectors	Low	Medium	**High**
Other Sectors	Low	Medium	High

Future Outlook:

Indian Oil intends to commercialise the enzyme assisted CO_2 capture technology in a grassroots unit at an identified Indian Oil Refinery from flue gas stream. After successful implementation, the technology is planned to be commercialised at Indian Oil refineries at a larger scale.

IOCL

Electro-biocatalytic CO_2 to Ethanol CCU Technology

PROJECT BACKGROUND

Conversion of CO_2 into fuels and alcohols is one of the potential options for carbon recycling and mitigate climate change. IOC R&D is working on development of electro-biocatalytic process for the CO_2 transformation into alcohols as methanol, ethanol, butanol etc. IOC R&D has developed a unique process and reactor design to carry out the CO_2 conversion to alcohols from flue gas/off gas.

Key Benefits - GHG emission reduction

This technology is under development and anticipated to be useful in direct conversion of CO_2 to alcohols from any flue gas source. This can lead to significant reduction to GHG emission.

DETAILS OF TECHNOLOGY/PRODUCT/PROCESS

The electro-biocatalytic route of CO_2 conversion is a hybrid process combining the benefits of both electrochemistry and biotechnology. In this process, the energy required for the CO_2 conversion is lower than the electrochemical process, but the yield is higher than the biotechnological process. Selectively enriched/developed microbial blend forms electro-active biofilm on the electrode (customised cathode) and creates a CO_2 transformation platform under low external potentials in bio electrochemical system (BES). Energy required for the reduction of CO_2 can be supplied through renewable sources like solar.

Current Status

The technology has been established at lab-scale with dominant production of alcohols. Based on the lab result three different types of pilot scale bio-electrochemical stacks (BES) have been designed, installed and are operation for establishing the process at pilot scale and to derive cost economics of the optimised process.

Implementing Organisation

This technology has been developed by Research and Development Centre, Indian Oil Corporation Ltd., in collaboration with M/s VITO (Flemish Institute for Technological Research), Belgium for developing and supplying electrode components.

Challenges for Scalability

Financial barrier	Low	Medium	**High**
Technical barrier	Low	Medium	**High**

Ease of Replicability

Same/Similar Sectors	Low	Medium	**High**
Other Sectors	Low	Medium	**High**

Future Outlook:

Currently, the pilot scale design operating at IOC R&D is first of its kind and has huge potential, if established. The performance data of the pilot scale studies can be used for scaling up of the technology. After successful up scaling, the technology may be commercialised at Indian Oil refineries on larger scale.

BOF Gas Recovery with Gas Holders

PROJECT BACKGROUND

During the process of steelmaking in the basic oxygen furnace (BOF), oxygen is blown in the charge mix and due to the chemical reactions taking place in the converter vessel, a large amount of gas at high temperature and rich in carbon mono oxide is ejected through the mouth of the converter. This gas is known as BOF gas. Conventionally, after cleaning, the BOF gas was flared.

Key Benefits - GHG emission reduction

The technology has a potential of reducing 6,04,800 tonnes of GHG emission per year.

Other Co-benefits:

- High energy recovery.
- Reduced pollutant emission

DETAILS OF TECHNOLOGY/PRODUCT/PROCESS

The process equipment which is installed above the converter mouth has functions to cool down, clean up, and recover the converter gas with the help of suppressed combustion. With suppressed combustion of the converter gas, 70 cum to 100 cum of converter gas per tonne of crude steel with a calorific value ranging from 1,600 kcal/N cum to 2,000 kcal/N cum of gas is recovered. The converter gas recovered is mixed with other by-product gases (coke oven gas, and blast furnace gas) and used in the steel plant as fuel, therefore, increasing energy efficiency and reducing GHG emission. Capacity utilisation of the facility or ramping up of its production within the scheduled time period was one of the challenges.

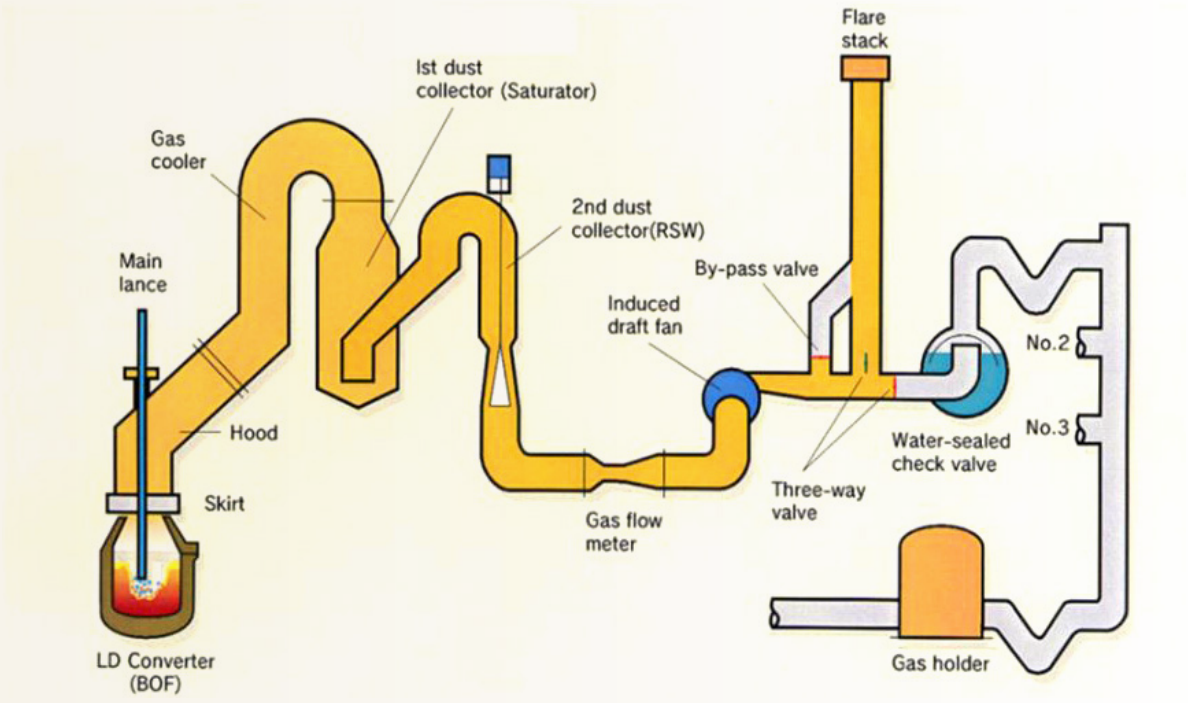


Figure 7 Schematic diagram of BOF Gas Recovery with Gas Holder Facility

Current Status

BOF gas recovery systems with gas holders installed at all steel plants.

Implementing Organisation

The facility adopted as a proven energy-efficient state-of-the-art technology and installed with the help of technology/Service providers:

Seimens VAI for BSP/Beijing Shanghai Corporation Group (BSCG) for DSP/SMS Siemag for RSP/MICCO for BSL/SMS Demag, Bridge & Roof for ISP.

Challenges for Scalability

Financial barrier	Low	Medium	**High**
Technical barrier	Low	**Medium**	High

Ease of Replicability

Same/Similar Sectors	Low	Medium	**High**
Other Sectors	Low	**Medium**	High

Future Outlook:

All new BOF converters are planned to be equipped with a Gas Recovery system during the next phase of the modernisation and expansion program in SAIL. However, retrofitting the technology in the existing installations may be a viable option.

K Model – Software for predicting crude blend compatibility & optimisation

BPCL

PROJECT BACKGROUND

Crude involves 85-90% of refining cost and in refinery operation, profitability increase when heavy/opportunity crudes are blended with light crude without affecting its process ability. High asphaltene content in heavy oils can affect the Desalter operation by strong water emulsions with asphaltene, fouling in heat exchangers. Thereby requiring increased fuel firing and thus, increased CO_2 emissions, and/or coking issues due to incompatibility. This leads to refineries losing more rather than gaining advantage of purchasing heavy crudes. Thus, the accurate prediction of crude compatibility is an indispensable tool that refinery operators would like to use before starting any process. Current benchmark processes to evaluate the processability are based on experiments and takes weeks' time to complete.

Adhering to K Model to maintain the crude compatibility framework helps in keeping good health of refinery equipment, avoid heat exchanger fouling & excess fuel firing and thus, reduces CO_2 emissions.

Key Benefits - GHG emission reduction

For 35 million barrel/annum refinery, 10C improvement in heat exchangers network (HEN) of crude distillation unit is accounted as about $1 million / Annum. Also, to compensate for this, extra fuel firing is required which typically generates 90000 tons/Annum CO_2 per Deg C in HEN. The adherence to K Model recommended solutions can lead to significant fuel savings and reduction in CO_2 emission for a healthy environment.

DETAILS OF TECHNOLOGY/PRODUCT/PROCESS

BPCL has developed and patented 'K model' a web-based software for quick and accurate prediction of compatibility of numerous crude oils within minutes. K Model enables to arrive at an optimum blend based on economics, availability, and processing feasibility on real time basis, thereby promoting simultaneous evaluation of multiple crude mix options in quick time and take more informed decisions, especially for refineries who have large crude mix parcels. K Model can also guide refiners on fuel oil blending and crude oil blending for bitumen potential. Most importantly, this will assist refiners to go for crude mix parcels with a greater number of constituents and increase profitability. K Model also adds a new dimension to the entire crude oil sourcing process.

Current Status

Patented and implemented in BPCL refineries.

Patent Grants:

1. IN Pat. # 328119 / 26.12.2019
2. US Pat # 10365263 B1 / 30.07.2019
3. US Pat # 10,317,325 A1 / 11.06.2019
4. US Pat # 9846147 B2 / 19.12.2017
5. EP Pat # 1201400138 / 13.02.2019
6. OAPI Pat #1201400138 / 30.04.2015

Patent applications under examination:

1. EP Pat # 18164352.9
2. IN Pat # 201821003341
3. IN Pat # 201621015432
4. IN Pat # 64/MUM/2015
5. US Pat # 14/989,159

Implementing Organisation

K Model is a BPCL's patented technology which is now in continuous use in BPCL group refineries.

Challenges for Scalability

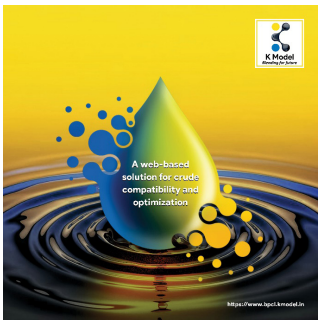
Financial barrier	Low	Medium	**High**
Technical barrier	Low	**Medium**	High

Ease of Replicability

Same/Similar Sectors	Low	Medium	**High**
Other Sectors	Low	Medium	**High**

Future Outlook:

The software product is live on cloud https://www.bpcl.kmodel.in and is available for commercial sale. Business collaboration with software selling organization for international customers is under way.



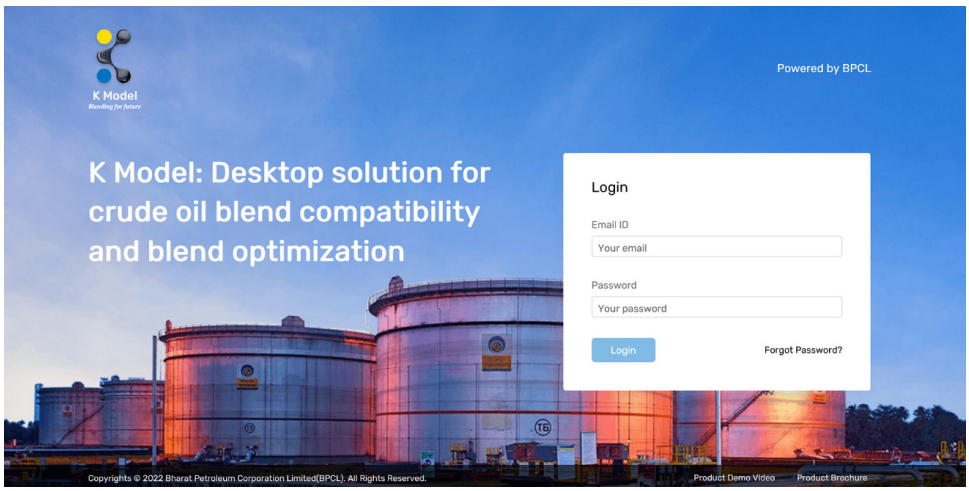


Figure 8 Implementation – Mumbai Refinery, India (Top left) Kochi Refinery, India (Bottom left)

Figure 9 : K Model: A web-based software for crude compatibility and optimization (Right)

High Performance Domestic LPG Cooking Stove

BPCL

PROJECT BACKGROUND

Extensive research has been carried out in fuel conservation and alternative fuels by the petroleum industry to meet the impending fuel crisis. Liquefied Petroleum Gas (LPG) is the most convenient and clean fuel for domestic use and is very popular today. The LPG stove industry is about 60 years old and is mainly concentrated in the small-scale sector. With some improvements in the existing LPG cooking stoves, a small saving in its consumption per family will lead to an enormous saving nationwide. Moreover, considering the limited fossil fuel resources and increased demand for LPG in near future, it is necessary to explore opportunities to further improve the thermal efficiency and emission reduction of the combusting fuel.

Key Benefits - GHG emission reduction

For 35 million barrel/annum refinery, 10C improvement in heat exchangers network (HEN) of crude distillation unit is accounted as about $1 million / Annum. Also, to compensate for this, extra fuel firing is required which typically generates 90000 tons/Annum CO_2 per Deg C in HEN. The adherence to K Model recommended solutions can lead to significant fuel savings and reduction in CO_2 emission for a healthy environment.

DETAILS OF TECHNOLOGY/PRODUCT/PROCESS

A domestic LPG cooking stove with improved thermal efficiency of 74% plus (BEE Star 2 rating) has been developed which is the highest among all available burners in the market in India and internationally. The newly designed LPG cooking stove is 5-6% more efficient compared to the commercially available stoves in the market. The developed cooking stove is estimated to save one cylinder per family of 5 members per year.

The newly developed high-performance LPG cooking stove has the following unique features:

- Burner Top has optimised flame orientation which is easy to retrofit in the existing burner of similar dimensions.
- Mixing Tube has an innovative design for primary air entrainment and better air-fuel mixing.
- Pan Support has a unique design to prevent heat loss also easy to retrofit in existing stoves with minor modifications.
- Cover Plate is with optimised secondary air supply

To ensure accurate, reliable, and consistent results, BPCL (CRDC) has established an automated state-of-the-art test setup as per BIS protocol for the evaluation of the thermal efficiency of the cook stove. Design of experiments (DOE) based Computational Fluid Dynamics (CFD) Analysis of LPG Domestic Cooking Stove Gas was carried out. Multiple prototypes of various components were fabricated based on extensive CFD simulation studies. Based on experimental validation and analysis, the final design was firmed up.

Current Status

BPCL had filed four patents and four design registrations. Total Indian (IN) Patent Applications Filed - Four (4)/ Grant – (1)

1. IN Pat # 201921048624 dated 27.11.2019
2. IN Pat # 201921048625 dated 27.11.2019
3. IN Pat # 201921048626 dated 27.11.2019
4. IN Pat # 201921048627 dated 27.11.2019 (Grant)

Total Indian (IN) Design Registrations Filed - Four (4)/ Grant (3)

1. IN Design No. 324046-001 dated 27.11.2019 (Grant)
2. IN Design No. 324047-001 dated 27.11.2019
3. IN Design No. 324048-001 dated 27.11.2019 (Grant)
4. IN Design No. 324049-001 dated 27.11.2019 (Grant)

Also, launched on 20th Foundation Day – 4th July 2021 Bharat Hi-Star stove has licensing agreement signed with 7 LPG stove manufacturers.

LPG stove launched commercially on 17th December 2021, and it will be available with the BPCL LPG distributors soon.

Implementing Organisation

BPCL had implemented this process technology at one of their refineries.

Challenges for Scalability

Financial barrier	Low	Medium	High
Technical barrier	Low	Medium	High

Ease of Replicability

Same/Similar Sectors	Low	Medium	High
Other Sectors	Low	Medium	High

Future Outlook:

It can be easily replicated to all the LPG cooking gas sector. The product can be exported as well as per the market study conducted by BPCL.

Image 5 Launch of the High-Performance Domestic LPG Cooking Stove & Receiving first runner-up award for Frost and Sullivan Prep 2020 in Environment Leadership Category, Manufacturing Sector. Credits: BPCL.

R&D for CO_2 to valuable chemicals

PROJECT BACKGROUND

Presently GAIL releases CO_2 to atmosphere at its natural gas sweetening units at Pata and Vijaipur posing an environmental concern for the organisation's GHG reduction commitments. As the Pata & Vijaipur plants are standalone petrochemical projects far removed from the Oil & Gas fields and Coastal or Mineral bearing areas, the widely established CO_2 utilisation methodologies such as CO_2 for Enhanced Oil Recovery, CBM recovery, CO_2 mineralisation etc. cannot be used. However, there are emerging technologies for the direct or indirect conversion of CO_2 to valuable chemicals and energy products that have high market potential and promising environmental benefits. In this context GAIL is pursuing various R&D projects for bulk utilisation of CO_2.

Key Benefits - GHG emission reduction

This project estimates a potential CO_2 reduction as follows: (ton CO_2/tonne of Product)

- CO_2 to Methanol-1.375 – TRL level 3 – Lab scale
- CO_2 to Polycarbonate-0.5 – TRL level 3
- CO_2 to Syngas- 0.35 – TRL level 4

DETAILS OF TECHNOLOGY/PRODUCT/PROCESS

The following processes for valorisation of CO_2 to valuable chemicals/ fixing of CO_2 for environmental mitigation are being pursued by R&D department in association with various research institutes:

- CO_2 to Methanol & DME (Dimethyl ether): GAIL in association with IIT-Delhi is developing novel catalysts for direct hydrogenation of carbon dioxide to methanol.
- CO_2 to Polycarbonate Diol: GAIL in association with IISER, Tirupati is developing novel and cost-effective catalyst for production of carbon dioxide-based poly carbonate diol polymers by incorporating ~ 45 - 47% CO_2 in the polymeric backbone (product).
- CO_2 to Syngas: GAIL in association with IIP, Dehradun developed a robust catalyst for tri-reforming CO_2 with methane and steam.
- CO_2 fixation using Microalgae: GAIL is also implementing a pilot project for fixing CO_2 (1TPD) using Microalgae in an Open Raceway Ponds at the Pata petrochemical complex in association with CIMFER, Dhanbad. Suitable microalgae strains have been already screened and identified in lab scale photobioreactors for its potential application in the large-scale ponds.

Figure 10. CO_2 capturing using microalgae at Pata. Credits: GAIL.

Current Status

CO_2 to Methanol:	TRL (Technology readiness level) -3 Catalysts being developed at lab scale
CO_2 to Polycarbonate Diol:	TRL-3, Catalysts being developed, and process conditions are being optimised at lab scale
CO_2 to Syngas:	TRL-4, bench scale study completed
CO_2 fixation using Microalgae:	TRL-4, Raceway Ponds constructed, trial run will be started soon

Implementing Organisation

GAIL in collaboration with IIT's and CSIR units is involved in the research and development.

Three Indian patents filed for the above processes

Challenges for Scalability

	Low	Medium	High
Financial barrier			
Technical barrier			

Ease of Replicability

	Low	Medium	High
Same/Similar Sectors			
Other Sectors			

Future Outlook:

Successful implementation of above processes and catalysts for the bulk utilisation of CO_2 for production of fuels and valuable chemicals can replace fossil fuels, thereby reducing dependence on conventional fuel for transport and other uses. Moreover, growing Microalgae using CO_2 shall lead to competitive source of biofuel production.

HP Gas Flame Plus

PROJECT BACKGROUND

The novel additive for Liquified Petroleum Gas (LPG) was developed to improve combustion kinetics, flame profile and temperature. The additive LPG, HP Gas-Flame Plus, showed substantial reduction in cooking time up to 17% and fuel savings up to 9%. It was launched in the year 2021.

Key Benefits - GHG emission reduction

- Approx. 3600 tonnes of CO_2 reduction per annum (for 15 TMT Flame Plus; considering 9% reduction in fuel consumption)
- Reduction in CO_2 : Approx. 240 g/KG of LPG combusted

DETAILS OF TECHNOLOGY/PRODUCT/PROCESS

HP Gas-Flame Plus, an improved cooking LPG, was developed indigenously at HP Green R&D Center. This additive LPG significantly improves the combustion kinetics, flame profile and temperature. It showed substantial reduction in cooking time and results in considerable savings in fuel. The additive has improved stability compared to contemporary nano-additives. The additive LPG would significantly reduce carbon footprint in the domestic/commercial cooking process.

Development of volatile catalyst for LPG is a significant challenge as most combustion catalysts are metal-based and are insoluble in non-polar LPG. Moreover, even modified homogenous/nano catalysts are non-volatile and rarely combusts along with LPG. Although kinetics of the combustion can be modulated, reduction of fuel combustion requires more intricate analysis of the combustion process

Current Status

The additive LPG, branded as HP Gas Flame Plus, was launched in Feb 2021 and went into production since Jun 2021. Indian Patent filed in Dec 21 (Application number 202141061004).

Implementing Organisation

The product was developed by HP Green R&D and dosing of additive into LPG is being carried out at HPCL's various LPG bottling plant locations across India.

Challenges for Scalability

Financial barrier	Low	Medium	High
Technical barrier	Low	Medium	**High**

Ease of Replicability

Same/Similar Sectors	Low	Medium	**High**
Other Sectors	Low	**Medium**	High

Future Outlook:

The Catalyst formulation is being modified by the company to further improve LPG combustion efficiency.

HP – Razor

PROJECT BACKGROUND

HP-Razor additive is an in-house developed, import substitute additive for LPG which is specially developed for metal cutting, brazing, and several other thermal applications with performance comparable to or even better than acetylene. It was launched in the year 2018.

Key Benefits – GHG emission reduction

- Approx. 270 tonnes per annum of CO_2 reduction for 500 MT Razor; considering 20% reduction in fuel consumption.
- CO_2 was reduced by approximately 540 g per KG of LPG, compared to unadditized base LPG reduced during trials.

DETAILS OF TECHNOLOGY/PRODUCT/PROCESS

HP-Razor can efficiently catalyse oxidation of both fuel & metal while maintaining proper stoichiometry and reaction rate which in turn decreases metal loss, reduces fuel & oxygen consumption during the cutting process. The additive does not contain any aromatics & is environmentally benign.

As the additive formulation is completely soluble in LPG, it provides superior performance compared to contemporary nanoparticle dispersion used in various other commercial products. Also, unlike in case of dispersions, precipitation and deposit formation is negligible, resulting in improved shelf life. The advantages include:

- Faster pre-heating, cutting travel speed, piercing rates, reduced slag formation and narrower heat affected zone as compared to Acetylene
- Reduction in fuel consumption of up to 20 -30% and oxygen consumptions up to 20%.
- Cheaper by about 27% than traditionally used acetylene
- Enhanced safety due to its narrower flammability limit as compared to Acetylene and negligible risk of back-fire in the torch.
- Better shelf-life and better catalytic performance compared to contemporary nanoparticle dispersion due to homogeneity.
- Single product for cutting, brazing, gouging, glass blowing and heating applications

Current Status

- The Product has been certified by BHEL, Lloyds Inspection Agency and SGS.
- The product has been commercialised in 2018.
- Indian Patent No:372034 granted in April 2021.

Implementing Organisation

- HP – Green R&D center has developed the homogenous additive for HP-Razor.
- The additive LPG was commercialised in 2018.

Challenges for Scalability

Financial barrier	Low	Medium	High
Technical barrier	Low	Medium	**High**

Ease of Replicability

Same/Similar Sectors	Low	Medium	**High**
Other Sectors	Low	Medium	**High**

Future Outlook:

Further improvements are currently being made to improve efficiency of the cutting gas.

HP THERMOPRO

PROJECT BACKGROUND

Fouling of process equipment is a common problem resulting in severe economic losses in refineries due to energy and throughput loss. Typical problem areas include preheating exchangers and furnaces. HP Thermopro was developed to mitigate the fouling in preheat exchangers of refinery units to reduce preheat loss. It also reduces maintenance of preheating exchangers, minimising safety concerns and enhances service time leading to improved throughput, reduced fuel oil burning, and minimised greenhouse gases emission and savings on the novel product (~50% savings) as well as the chemical cost. It was launched in the year 2020. HP THERMOPRO was awarded "FICCI-Product Innovator of the Year (Petrochemicals)" in 2021.

Key Benefits - GHG emission reduction

- Absolute emission reduction - tonnes of CO_2 equivalent: 3 kilo tonnes per annum (for 8 MMTPA refinery)
- Relative emission reduction (% reduction compared to the baseline): 0.4%

DETAILS OF TECHNOLOGY/PRODUCT/PROCESS

Antifoulants for preheat exchangers in refineries are specific to the crude/crude blend/ short residue processed in the refinery. There is no single antifoulant working effectively for all types of crudes (high Sulphur, low Sulphur, waxy, etc.) and short residue at the same time. HP THERMOPRO is a novel antifoulant formulation was developed at HP Green R&D Centre to mitigate fouling issues and sustain preheat temperatures through efficient heat transfer. It is equally efficient for all types of crudes and residues. This reduces consumption of fuel significantly and in turn, decreases greenhouse gas emissions.

The field trials were conducted for one year to evaluate the sustainable performance against different types of crudes and short residues processed in HPCL Visakh Refinery. HP THERMOPRO has shown improved performance on both Low Sulphur & High Sulphur crudes and short residue. Similar field trials conducted in HPCL Mumbai refinery demonstrated its efficiency with waxy crudes and showed improved performance compared to contemporary additives

Current Status

- HP-ThermoPro was launched in 2020
- Indian patent no 377730 granted in 2021

Implementing Organisation

- HPGRDC has developed the antifoulant additive, HP-Thermopro
- The product was commercialised in 2020

Challenges for Scalability

Financial barrier	Low	Medium	High
Technical barrier	Low	Medium	**High**

Ease of Replicability

Same/Similar Sectors	Low	Medium	**High**
Other Sectors	Low	**Medium**	High

Future Outlook:

Presently, majority of antifoulant formulations are being imported in India. HPCL offers HP THERMOPRO as an improved, cost-efficient, in-country substitute.

SprayMax FCC Feed Nozzle

PROJECT BACKGROUND

Fluidised catalytic cracking (FCC) is a well-known conversion process in petroleum refineries which converts low value heavy petroleum fractions into high value products like LPG, propylene, gasoline, and diesel. The process uses a set of feed injection nozzles to atomise the FCC feed into fine droplets and spray inside the riser. Fine atomisation of liquid feed helps in its quick vaporisation and catalytic cracking over a fluidised stream of catalyst. Performance of feed nozzles is critical for maximising conversion and yields of valuable products in FCC process.

Key Benefits - GHG emission reduction

SprayMax nozzles help reduce dry gas and coke in FCC process thereby indirectly reducing CO_2 emissions from the FCC unit. The nozzles installed at Visakh, and Mumbai refineries have resulted in dry gas reduction by 10%.

DETAILS OF TECHNOLOGY/PRODUCT/PROCESS

HPCL has designed, fabricated, and installed efficient and cost-effective SprayMax FCC feed injection nozzles in FCC units of HPCL refineries. SprayMax nozzles are designed to provide multi-stage atomisation of the FCC feed aided with the efficient utilisation of steam. With optimum steam to oil ratio, the droplet size can be minimised while controlling the tip velocity to avoid the attrition of catalyst particles. SprayMax nozzles have helped in increasing conversion by about 1% at both Mumbai and Visakh refinery FCC units. The nozzles have been in operation for more than 5 years and are cost-effective (SprayMax nozzle cost is about one-tenth of commercially available nozzles). HPCL has demonstrated its capability of in-house development of FCC feed nozzles for its own use, which has helped reduce HPCL's dependency on foreign licensors and resulted in significant time and cost savings.

Current Status

The nozzles have been fully developed and deployed in FCC units of HPCL Visakh and Mumbai refineries. HPCL has received Indian and European patents on the design of these nozzles.

Implementing Organisation

The SprayMax nozzles were developed at HP Green R&D Centre, Bangalore and implemented in HPCL refineries

Challenges for Scalability

Financial barrier	Low	**Medium**	High
Technical barrier	Low	**Medium**	High

Ease of Replicability

Same/Similar Sectors	Low	Medium	**High**
Other Sectors	Low	Medium	**High**

Future Outlook:

HPCL has commercialised SprayMax nozzles in its own refineries and achieved significant performance improvement in terms of product yields and conversion. HPCL is ready to offer SprayMax nozzles to other Indian refineries.

2G Ethanol Enzymatic Technology Demo Plant

IOCL

PROJECT BACKGROUND

Indian Oil R&D Centre has developed 2G Ethanol technology for energy security through local production with substantial environmental benefits. It does not compete with the feed or fodder and is therefore considered ideal for a country like India. With use of 2 G Ethanol, the net reduction of GHG emission is about 75% of CO_2 vis-à-vis gasoline.

Key Benefits - GHG emission reduction

1.73 Kg CO_2 Reduction potential in GHG emission intensity Per Liter of ethanol used.

DETAILS OF TECHNOLOGY/PRODUCT/PROCESS

DBT IOC Centre has developed an indigenous technology for conversion of lignocellulosic biomass to 2G ethanol. The Centre has optimised pre-treatment process at 250 kg/day pilot plant-based on acid technology to minimise the cost of chemical w.r.t similar acid-based technologies. For this, the Centre has developed a cost effective and high-performance enzyme technology tailored for a given biomass pre-treatment. The Centre has integrated its pre-treatment followed by patented simultaneous scarification and co-fermentation (SSCF) process using indigenously developed low cost and efficient enzyme cocktail with low HRT (reaction time) of 60 Hrs vs conventional 120 hrs for separate hydrolysis and fermentation.

Current Status

DBT-IOC Centre has put up India's first pilot facility at 250 kg/day scale at IOC R&D, Faridabad in 2012.

Indian Oil is putting up an integrated 2G ethanol demonstration plant of 10TPD scale (dry biomass basis) with onsite enzyme production at Panipat for conversion of lignocellulosic biomass to 2G ethanol to establish the patented technology at commercial scale.

Implementing Organisation

DBT IOC Centre for Advanced Bioenergy Research, Indian Oil R&D Centre, Faridabad.

Indian Oil has applied for patents in India and globally.

Challenges for Scalability

Financial barrier	Low	Medium	**High**
Technical barrier	Low	Medium	**High**

Ease of Replicability

Same/Similar Sectors	Low	Medium	**High**
Other Sectors	Low	**Medium**	High

Future Outlook:

Ministry of Petroleum & Natural Gas (MoP&NG) has taken a major initiative of setting up 12 2G ethanol commercial plants from agriculture waste (lignocellulosic biomass) across eleven states at an estimated cost of Rs. 14,000 crore (US$1.9 billion). The first four 2G ethanol commercial plant of 100 KL/day ethanol production by Indian Oil, BPCL, HPCL & NRL are expected to be commissioned by 2022-23. To meet the capex, MoP&NG has initiated Pradhan Mantri JI-VAN (Jaiv Indhan- Vatavaran Anukool fasal awashesh Nivaran) Yojana, which aims to provide Viable gap funding/ financial support to Integrated 2G ethanol Projects commercial and demo plants (Rs. 5000 crore or US $ 675 million) using lignocellulosic biomass and other renewable feedstock.

Octamax®:

Technology for conversion of cracked C4 Streams to high Octane Gasoline

PROJECT BACKGROUND

Environmental regulations on fuel specifications mandates refiners to adopt greener technologies. Presently, Indian refineries are producing Bharat Stage (BS) VI quality fuels rolled out in 2020. While moving from BS IV to BS VI, there was a need to enhance the octane number of existing gasoline/naphtha streams in refineries due to adverse effects of deep desulfurisation to meet Sulphur 10 ppm requirement. It was first-of-its-kind R&D project execution model where all activities from concept to developing the technology, preparation of BDEP, cost estimation, start up and commissioning were done in-house by IOCL.

Key Benefits - GHG emission reduction

Reduces vehicular GHG emission considerably.

DETAILS OF TECHNOLOGY/PRODUCT/PROCESS

IOCL R&D has developed Octamax® process for conversion of C4 streams from Cat Cracker and/or Naphtha Cracker to produce high-octane stream (blending RON > 110), which can be directly blended into gasoline pool using low octane naphtha thus providing desired flexibility to meet BS VI Gasoline Specification with higher RON.

The first Octamax® unit with a product capacity of 55 kTA was successfully commissioned in Mathura Refinery (MR) in January 2018. The Average Blending RON (BRON) of Octamax® product obtained since commissioning is > 120 enabling MR to augment their gasoline pool for both quality and quantity. This process employs simple configuration with environmentally safe solid catalyst operating under moderate conditions.

Octamax® played a pivotal role in introduction of niche products with high Octane number (like XP95 and XP100 grade gasoline) in Delhi NCR area, which improves the efficiency and emission reduction. Octamax® will continue to play the key role across India in the upcoming scenario of CAFÉ-II implementation and stringent emission standards, which will reduce GHG through vehicular emissions.

Current Status

The technology has been demonstrated at commercial scale at Mathura refinery.

Implementing Organisation

The technology has been developed, commercialised, and currently being licensed by IOCL.

Challenges for Scalability

Financial barrier	Low	Medium	**High**
Technical barrier	Low	**Medium**	High

Ease of Replicability

Same/Similar Sectors	Low	Medium	**High**
Other Sectors	**Low**	Medium	High

Future Outlook:

With a proven success of first unit at Mathura Refinery, 2nd, and 3rd Octamax® units (110 kTA each) are already under advanced stage of implementation. 4th unit at 45 kTA is under active consideration. The technology has been patented in India and other foreign countries. (Patent grant: France: 2949636, GB: 2949636, Germany: 2949636, Italy: 2949636, Netherland: 2949636, Saudi Arabia:5472, Spain:2949636). USA:10131589 The technology bagged two coveted awards, 'FIPI Innovator of the year Team Award' and Centre for High Technology, MoPNG 'Best Indigenously Developed Technology' Award in 2018.

Drag Reducing Additive (DRA) Technology

PROJECT BACKGROUND

DRAs are added in ppm levels in pipeline transportation of petroleum products and crude oils, enabling energy savings with increased flow throughput. These DRAs are Ultra High Molecular Weight Polymers (having Molecular Weight more than 10-20 Million). Less usage of input energy has direct benefit in reducing GHG emissions. Usage of DRA technology reduces operational costs, thereby saving on cost of energy (Power & Fuel) per tonne of hydrocarbon transported through pipeline. Considering pre-covid year i.e., 2019-20 as a base case, for a total pipeline throughput of ~83 MMTPA (crude and product), ~68 MMTPA was transported with DRA addition by Indian Oil. For a cumulative average pipeline throughput enhancement of 25% achievable using DRA, there is potential of ~₹80 Cr per annum OPEX saving where addition of DRA is practiced currently within Indian Oil.

Key Benefits - GHG emission reduction

~86000 tCO_2 equivalent per annum for 68 MMT for hydrocarbon transport through pipeline by Indian Oil (2019-20 base).

This in-house developed product has performance in line with commercially available imported products.

DETAILS OF TECHNOLOGY/PRODUCT/PROCESS

Indian Oil-R&D has developed a complete DRA technology package starting from catalyst, polymer designing & process to obtain ultra-high mol weight polymer (>10-20 million Dalton). No additional hardware is required for usage of DRA. The product has been evaluated for meeting claims by third party in Germany and subsequently performed successfully during commercial trials at par with the imported commercial alternatives.

Current Status

Fully developed and systemwide integration completed i.e., commercialised. DRA is being fully used in Indian Oil pipelines from Nov 2021.

Awarded FIPI Award 2021- Innovator of the year-Team. Patented & granted in 5 major jurisdictions i.e., India, US, Saudi Arabia, Korea, and Russia.

Implementing Organisation

The technology developed by Indian Oil has been licensed to M/s Dorf Ketal Chemicals India Pvt Ltd, for manufacturing in India and global supply against royalty to Indian Oil.

Challenges for Scalability

Financial barrier	Low	Medium	High
Technical barrier	Low	Medium	High

Ease of Replicability

Same/Similar Sectors	Low	Medium	High
Other Sectors	Low	Medium	High

Future Outlook:

There is a rising demand in line with planned expansion of pipeline network in country both by Indian Oil and other players. Indian Oil is also exploring usage of DRA for transportation of LPG and ATF. It is also exploring possibility of export through M/s Dorf Ketal which has global presence in countries like USA, China, Brazil, Argentina, Netherlands, U.A.E., Bahrain, Singapore, and Malaysia.

Demonstration of HCNG in Delhi

PROJECT BACKGROUND

Indian Oil along with Society of Indian Automobile Manufacturers (SIAM) and 5 OEMs undertook demonstration project, 'Use of hydrogen (up to 30%) as fuel blended with CNG in internal combustion engines.' Vehicle performance and emission tests were conducted with different Hydrogen-CNG blends (12 to 25% v/v) on 7 vehicles. Based on performance and emission results, 18% (v/v) Hydrogen-CNG blend (HCNG) was finalised and its benefits with respect to emissions, mileage and durability were observed and reported.

Indian Oil R&D has patented a single step controlled compact reformer technology by which the HCNG blends can be produced directly from NG and hence, replacing physical blending of hydrogen in CNG. With this background, Hon'ble Supreme Court of India directed MoP&NG and Indian Oil Corporation Ltd. to undertake the project "Demonstration of HCNG fuel mixture in 50 numbers of Delhi Public buses" to establish the utility of HCNG for reduction of emissions along-with the advantages of in-situ methane reforming technology of Indian Oil developed by its R&D Centre.

Key Benefits - GHG emission reduction

The CO_2 equivalent emissions reduced by 39127 MT/year and 776284 MT/Year for DTC+DIMTS buses (~3700 no) and entire CNG fleet of Delhi respectively with the usage of HCNG.

DETAILS OF TECHNOLOGY/PRODUCT/PROCESS

The project involved setting up of 4TPD HCNG compact reformer plant and HCNG dispensing station jointly by Indian Oil and IGL at Rajghat Bus Depot, Delhi. Field trials for Delhi Public Buses for six months were conducted at DIMTS Bus Depot, Rajghat, Delhi, where emissions and fuel economy were measured. Indian oil observes that the results are in line with the claims.

Current Status

Indian Oil & IGL commissioned 4 TPD HCNG plant at Rajghat Depot and conducted field validation in 50 BSIV buses of DIMTS / ARTSPL with CNG and HCNG fuels for six months. The study report is submitted to MoPNG.

Implementing Organisation

- Indian Oil Corporation Limited (IOCL),
- Indraprastha Gas Limited (IGL)
- Delhi Integrated Multi-Modal Transit System (DIMTS) Ltd.
- Antony Road Transport Solutions Pvt. Ltd. (ARTSPL) – Bus concessionaire.

Supported by: Transport Department, GNCTD; CHT, MoPNG, GoI; OIDB; iCAT Manesar; Ashok Leyland; IIT Delhi; DPCC; MorRTH, GoI

Challenges for Scalability

Financial barrier	Low	Medium	**High**
Technical barrier	Low	**Medium**	High

Ease of Replicability

Same/Similar Sectors	Low	Medium	**High**
Other Sectors	**Low**	Medium	High

Future Outlook:

HCNG can be implemented in the buses of State Transport Undertakings (STU) where CNG is used as fuel. HCNG can be easily replicated to metropolitan cities and throughout country. It is immediate to medium-term solution towards hydrogen economy, though it may require additional financial support.

Boric Acid treatment of Anodes

PROJECT BACKGROUND

Aluminium is produced conventionally by the Hall Heroult process, by the electrolysis of alumina dissolved in cryolite containing molten electrolytes at temperatures around 955-960 . In these Hall Heroult cells, the anodes are usually prebaked carbon blocks which are electrochemically consumed. Prebaked anodes are made of a mixture of calcined petroleum coke and coal tar pitch. The theoretical consumption of carbon as per the reaction is 334 kg per tonne of aluminium produced. However, the actual carbon consumption is 400-450 kg per tonne of aluminium produced. The extra carbon consumption is due to the current efficiency of pots and various secondary reactions occurring during the process such as:

- Oxidising reaction with oxygen from air on the upper part of anodes if the anodes are not protected.
- Carbon oxidation reactions with CO_2 at the surface of the anode bottom immerse in liquid bath.
- Selective oxidation of binder pitch coke.

The carbon consumed accounts for 20-25% of Aluminium production cost. Smelter plant of National Aluminium Company Ltd (NALCO), is located at Angul, Odisha and has an installed capacity of 0.46 million tonnes of aluminium per year. The smelter has 960 electrolytic cells in four AP18 potlines, The AP18 Electrolytic cells use prebake carbon anodes, manufactured in two captive carbon plants. There are two green anode paste plants, three baking furnaces and two rodding plants operating on latest technologies.

Key Benefits - GHG emission reduction

18kg CO_2/tonne of metal produced

Installed capacity at NALCO - 0.46 million tonnes of aluminium per year.

Approx. Total CO_2 reduction – 8280 tonnes of CO_2 per annum.

DETAILS OF TECHNOLOGY/PRODUCT/PROCESS

It has been observed from the studies carried out at smelter plant of NALCO that boric acid addition in anodes leads to improvement mainly the air reactivity residue of anodes; this will help reduce net carbon consumption keeping the boron content of metal within acceptable limits. Simultaneously there will be a reduction of greenhouse gas (CO_2) emission and thus carbon footprint of smelter plant. Air reactivity dust of anodes has also decreased by 8.9%. This will help lower the carbon dust and mushroom generation in the pots and thus, improve current efficiency of pots. Controlled R&D Trial has shown reduction of approx. 5 kg carbon consumption per tonne of Aluminium produced and accordingly 18kg CO_2/tonne of metal produced. This process also helps reduce the reactivity related problems in potline such as mushrooms, dusting etc. as mentioned above along with reduction of net carbon consumption per tonne of Aluminium.

Current Status

Fully Implemented in Green Anode Plants of NALCO. The technology is patented in 2017 (Patent No:289807).

Implementing Organisation

NALCO in-house R&D.

Challenges for Scalability

Financial barrier	Low	Medium	High
Technical barrier	Low	Medium	High

Ease of Replicability

Same/Similar Sectors	Low	Medium	High
Other Sectors	Low	Medium	High

Future Outlook:

Many aluminium smelters in the world are facing the problem of deteriorating CPC quality mainly due to increased levels of Vanadium, Nickel & Sulphur. The addition of Boric Acid can be adapted in any aluminium smelter for lowering the air reactivity of anodes. However, it is applicable only for aluminium manufacturing process.

Slotted Anodes and Increased Stub-hole depth of Anode for energy efficiency

NALCO

PROJECT BACKGROUND

Aluminium is produced conventionally by the Hall Heroult process. Hall Heroult aluminium production is a highly energy-intensive process where 35% of the cost of production is accounted for by electrical energy. Primary producers all around the world are striving to minimise energy use. During the electrolysis process, gases such as carbon dioxide, carbon monoxide, Al-O-F complex, and C-F gas are formed. These gases tend to form highly resistive bubble film between the anode bottom and bath, leading to an increase in bath voltage drop. Bath voltage drop is the largest component of the total pot voltage. Thus, NALCO piloted studies to reduce the bath voltage drop with the introduction of slots in the anode that can allow the gases formed during electrolysis to escape. Similarly, NALCO piloted studies to reduce the contact drop between carbon anodes & metallic stubs with the increased stub-hole depth in the anode which reduces the overall anode drop.

Key Benefits - GHG emission reduction

18kg CO_2/tonne of metal produced

Installed capacity at NALCO - 0.46 million tonnes of aluminium per year.

Approx. Total CO_2 reduction – 8280 tonnes of CO_2 per annum.

DETAILS OF TECHNOLOGY/PRODUCT/PROCESS

The limited pilot study demonstrates that slots on the bottom part of anodes help to expel the gases out of the pot easily thereby reducing bubble voltage drop to the tune of 50~70mv. This thereby shall reduce specific DC energy consumption by around 150 KWH/tonne during the electrolysis process used for the production of aluminium resulting in the reduction of an equivalent quantity of coal consumed for power generation and reduction in CO_2 emission from CPP.

Apart from the introduction of the sotted anodes, another study on higher stub hole depth in anodes demonstrates a reduction in pot voltage. This reduces the specific DC electricity consumption by around 100 KWH/tonne during the electrolysis process used for the production of aluminium resulting in a reduction of the equivalent quantity of coal consumed for power generation and a reduction in CO_2 emission from CPP.

Current Status

Slotted Anode - Full implementation in progress higher Stub holder on Anode – Fully Implemented.

Implementing Organisation

NALCO's in-house R&D had developed.

Challenges for Scalability

Financial barrier	Low	Medium	High
Technical barrier	Low	Medium	High

Ease of Replicability

Same/Similar Sectors	Low	Medium	High
Other Sectors	Low	Medium	High

Future Outlook:

NALCO looks forward to 100% scaleup of Slotted anodes withing the NALCO facility. The technology can be easily adopted by other Aluminium manufactures.

Image 6 Site Image Captive Power Plant and Normal anode

Low Energy Cell Technology

NALCO

PROJECT BACKGROUND

The Hall Heroult process is an energy intensive process. The low energy cell technology is being developed to improve energy efficiency.

Key Benefits - GHG emission reduction

284 Tonnes CO_2 equivalent/ annum can be mitigated (considering equivalent amount of coal being replaced for producing green power).

DETAILS OF TECHNOLOGY/PRODUCT/PROCESS

AP2XN0 Technology is being researched and developed through 15 pot trials. The trials have demonstrated reduction of specific DC energy consumption by around 150 KWH/ tonne during electrolysis process used for production of aluminum resulting in reduction of equivalent quantity of coal consumed for power generation and reduction in CO_2 emission from power generated at captive power plant (CPP). The pot lining material is modified to the specification of the technology and its design.

Current Status

Trial in limited pots have been successful. Thus, systemwide integration is being planned.

Implementing Organisation

International partnership with Rio Tinto Alcan, France.

Challenges for Scalability

Financial barrier	Low	Medium	High
Technical barrier	Low	Medium	High

Ease of Replicability

Same/Similar Sectors	Low	Medium	High
Other Sectors	Low	Medium	High

Future Outlook:

NALCO plans to implement the technology in 60 pots and further scale it up to the complete facility. The technology can be easily replicated; however, it is applicable only for aluminium manufacturing process.

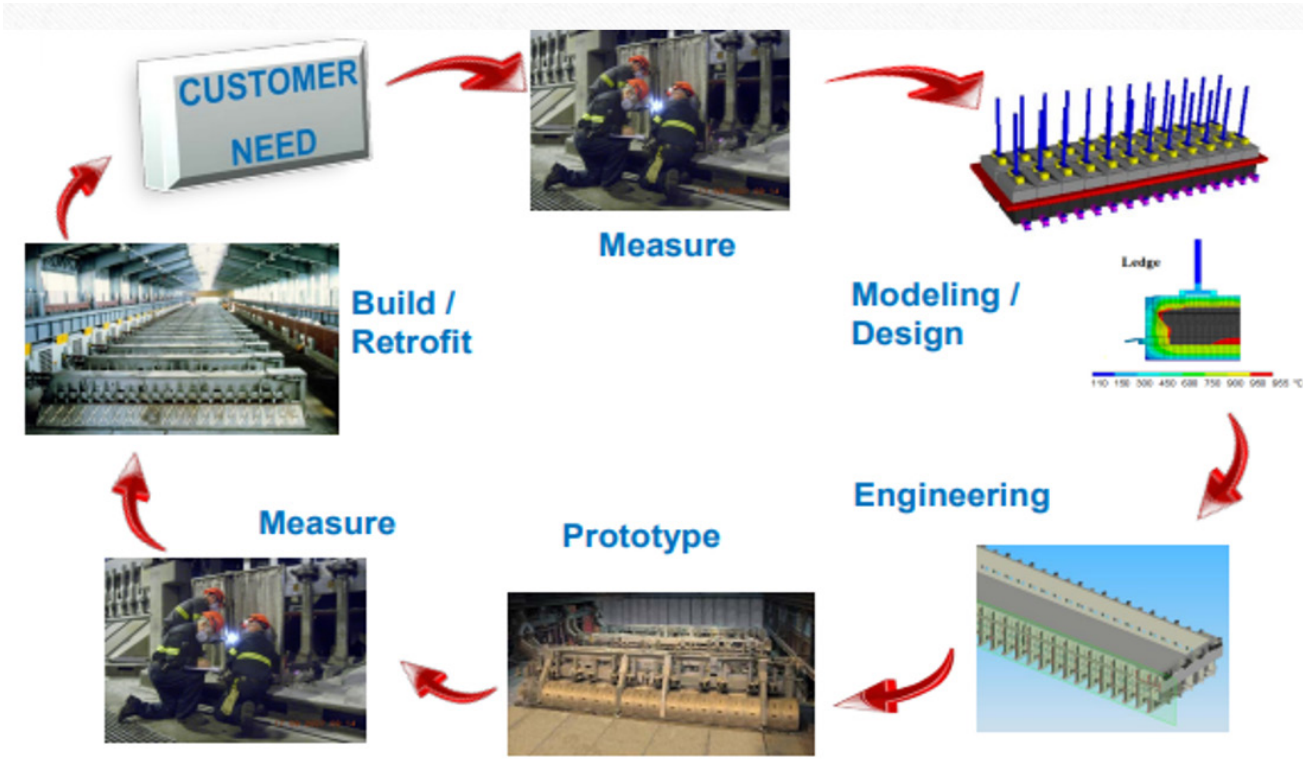


Image 7 AP2XN0 low energy cell technology development – trial in 15 pots in Smelter Plant (completed on 31.01.2021.)

Coal Dust Injection facility (CDI) in Blast Furnaces

PROJECT BACKGROUND

Direct injection of reducing agents into Blast Furnace means replacing part of the metallurgical coke with another hydrocarbon source injected at the tuyere level. These hydrocarbons may be in the form of heavy oil, oil residues, recovered waste oil, granular or pulverised coal, natural gas or coke oven gas, and waste plastics. Coal and oil are the most commonly used tuyere injections. By reducing the need for metallurgical coke, overall pollution, and energy demand decrease.

Key Benefits - GHG emission reduction

The technology has a potential of reducing 12,12,527 tonnes of GHG emission per year.

Other Co-benefits:

- Higher fuel efficiency.
- Reduced CO_2 and SOx emission.

DETAILS OF TECHNOLOGY/PRODUCT/PROCESS

Coal Dust injection (CDI) is a well-established technology today for the production of hot metal (HM) in a BF. It is practiced in most of the BFs and all the new BFs are normally built with CDI capability. CDI provides auxiliary fuel for partial coke replacement and has proven both economically and environmentally favorable. CDI is a process that involves injecting a large volume of fine coal particles into the raceway of the blast furnace through blowpipes and tuyeres. Here the pulverised coal acts as a source of heat as well as a reductant because of the reactions of devolatilisation, gasification, and combustion and the formation of unburned char. It can result in substantial improvement in BF efficiency and contributes to the reduction in energy consumption and emissions. Capacity utilisation of the facility or ramping up of its production within the scheduled time period was one of the challenges in implementing this technology.

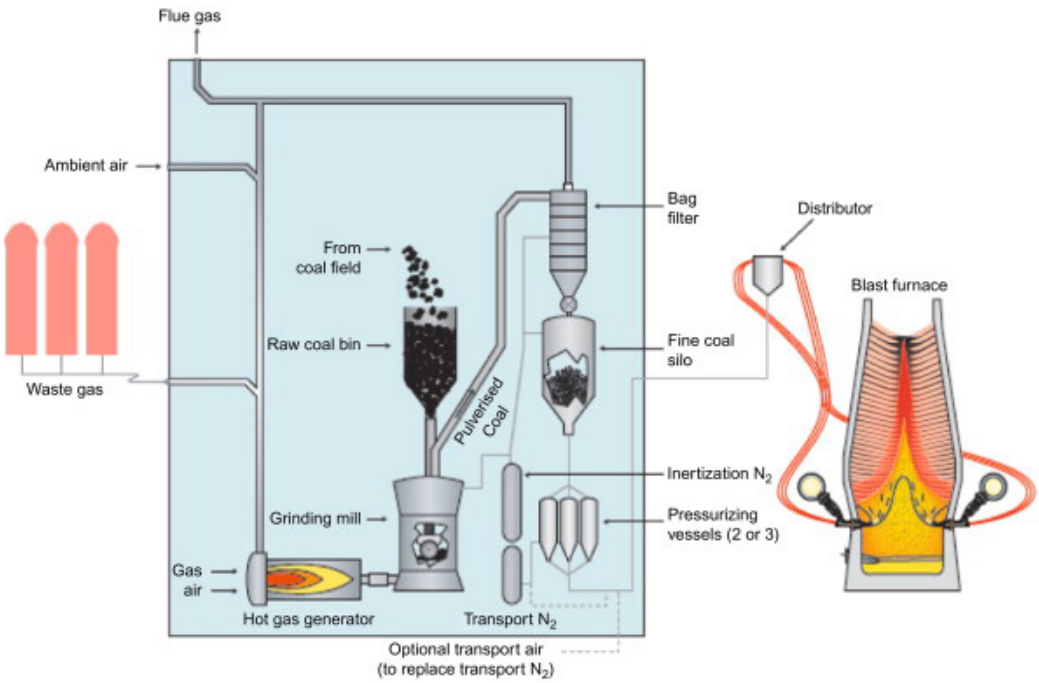


Figure 11 Coal Dust Injection (CDI) system at Blast Furnace

Current Status

All the blast furnaces in the SAIL Plants are equipped with the CDI facility and under operation.

Implementing Organisation

The facility adopted as a proven energy efficient state-of-the-art technology and installed with the help of technology/Service providers:

Paulwurth, L&T for BSP/ Sino-Steel Industry & Trade Group Corporation (SSIT) & Shriram EPC for DSP /Danieli Corus, TATA Projects for RSP/ SSIT & China Iron & Steel Research Institute Group (CISRI) & Shriram EPC for BSL/ POSCO, Nagarjun Construction for ISP.

Challenges for Scalability

Financial barrier	Low	Medium	**High**
Technical barrier	Low	**Medium**	High

Ease of Replicability

Same/Similar Sectors	Low	Medium	**High**
Other Sectors	Low	Medium	**High**

Future Outlook:

All new modern Blast Furnaces are planned to be equipped with this technology during the next phase of the modernisation and expansion program in SAIL. However, retrofitting the technology in the existing installations may be a viable option.

C. EFFICIENT MANAGEMENT OF CO_2 AND OTHER OFF GASES

Development of commercially viable hydrogen fuel cell buses

PROJECT BACKGROUND

Electric mobility based on either battery based Electric Vehicles (EVs) or hydrogen-based fuel cell EVs is a promising and sustainable alternative to traditional fossil fuel-based mobility to decarbonise the transport sector. Considering the potential of hydrogen-based fuel cell technology in providing the sustainable mobility solutions, Indian Oil initiated a project for development and demonstration of commercially viable fuel cell buses based on hydrogen produced from multiple pathways.

Key Benefits - GHG emission reduction

- Solar powered green hydrogen - No CO_2 emissions
- Biomass based hydrogen -net-zero CO_2 emissions.
- Hydrogen fuel cell vehicles - no tailpipe emissions

Study conducted by Indian Oil R&D for heavy duty fuel cell vehicles, WTW CO_2 emission is least for those fuelled by biomass gasification hydrogen

DETAILS OF TECHNOLOGY/PRODUCT/PROCESS

This project aims to assess the viability of different hydrogen production pathways. The project covers the entire value chain of hydrogen and fuel cell technology from hydrogen production to end use in fuel cell systems for heavy duty mobility application. Extensive field trials on 15 fuel cell buses for a cumulative running distance of 20,000 kms has been proposed.

Indian Oil has planned for the following hydrogen production demo plants:

- Biomass gasification-based hydrogen generation
- Solar PV powered electrolyser-based hydrogen generation
- Bio-CNG and natural gas reforming-based hydrogen generation

Hydrogen produced from the above production units will be integrated with downstream infrastructure comprising of high-pressure compressors, high pressure hydrogen storage and dispensers for refuelling the fuel cell vehicles at 350 bar pressures. Fuel cell technology will be demonstrated in 15 buses, which will be refuelled by hydrogen produced by above hydrogen production demo plants. Wide scale trials are also planned for cumulative distance of 20000 kms will be undertaken in Delhi NCR to establish the efficacy and durability of the systems under Indian operating conditions.

Current Status

Design, research and development phase by Indian Oil and respective collaborators for each identified aspects for production of hydrogen and fuel buses.

Implementing Organisation

- Hydrogen from Biomass gasification – Jointly by Indian Oil and Indian Institute of Science (IISc), Bangalore
- Hydrogen from Solar-PV powered electrolyser, and bio-CNG and natural gas reforming- Agencies being identified
- Fuel cell buses - jointly by Indian Oil and M/s Tata Motors, Pune

Challenges for Scalability

Financial barrier	Low	Medium	**High**
Technical barrier	Low	**Medium**	High

Ease of Replicability

Same/Similar Sectors	Low	Medium	**High**
Other Sectors	Low	Medium	**High**

Future Outlook:

Hydrogen is expected to play a key role in low-carbon energy pathways. For building the hydrogen ecosystem in India and build momentum, robust standards and regulatory systems are required to support the development of low-cost and low-carbon hydrogen on a large scale. This will also help position hydrogen to be ready to compete and seize longer-term opportunities.

Plasma Enhanced Gasification System (PEGS) for refuse driven fuel (RDF)

IOCL

PROJECT BACKGROUND

The Plasma Enhanced Gasification System (PEGS) technology shall be used to produce energy from waste material. This shall reduce landfill emissions from landfill sites. This process shall also produce Green Hydrogen from waste which can be used as a 'zero-emission' fuel in fuel cells or used for production of H-CNG (CNG mixed with Hydrogen) which improves emission profile as well as mileage of CNG vehicles.

The PEGS technology has been developed by EnerSol Technologies, Inc., a USA based Company. EnerSol Technologies, Inc had built a 5 tonnes per day (TPD) Pilot Plant, based on PEGS technology, in Virginia, USA for processing RDF produced from organic and inorganic portion of MSW (excluding inerts and debris) to Syngas in 2010.

Key Benefits - GHG emission reduction

As PEGS produces green hydrogen from waste, the fuel Green Hydrogen is effectively zero emission. Hence entire emission from petrol vehicle can be reduced.

DETAILS OF TECHNOLOGY/PRODUCT/PROCESS

The PEGS technology can process feedstocks including Municipal Solid Waste (MSW), biomass, petcoke, etc. to produce synthesis gas (Syngas). The Syngas can be used to generate electricity or further processed through catalytic or biological conversion technology to produce Alcohols, Synthetic Natural Gas, Green Hydrogen, etc. The key benefits of PEGS technology are:

1. Feed flexibility: The technology is feed agnostic and can process different kind of wastes such as MSW/ RDF, Industrial wastes, biomass, Petcoke, Bio-medical waste, and hazardous waste generated by industries. Additionally, there is no requirement to co-feed pet-coke, shredded tyres or other high calorific value waste and PEGS technology can process waste as received.
2. Environment friendly: The technology produces more net power (high quality Syngas) per tonne of waste compared to other competing technologies with zero pollution (including hazardous pollutants like furans and dioxins) and zero landfill. There shall also be reduced water requirement through this technology.
3. Syngas quality: PEGS achieves optimal Syngas quality, without the formation of tar, required for downstream technologies for producing alcohols like Ethanol, Methanol, and other fuels like Hydrogen, etc.
4. Emission reduction: The feedstock is waste and thereby the process reduces landfill emission and produces a net-zero fuel for the future.

Current Status

Indian Oil is exploring deployment PEGS technology in various Municipal Corporations for processing of Refuse Derived Fuel (RDF) produced from Municipal Waste to produce Green Hydrogen.

Implementing Organisation

The PEGS technology has been developed by EnerSol Technologies, Inc., a USA based Company.

Challenges for Scalability

Financial barrier	Low	Medium	High
Technical barrier	Low	Medium	High

Ease of Replicability

Same/Similar Sectors	Low	Medium	High
Other Sectors	Low	Medium	High

Future Outlook:

IndianOil is exploring to implement the technology at various Municipal Corporations to process waste to generate energy. Production of useful Syngas from wastes like RDF and biomass, shall reduce landfill emissions and produce energy from waste materials. Considering the benefits, various State Governments have requested IndianOil to set up Waste to Energy Plants for management of waste and reduction of landfills.

Compressed Biogas (CBG) under SATAT Scheme

IOCL

PROJECT BACKGROUND

Waste and Bio-mass sources like agricultural residue, cattle dung, sugarcane press mud, distillery spent wash, municipal solid waste, sewage treatment plant waste, etc. produce Biogas through the process of anaerobic decomposition/ digestion. The Biogas is purified to remove hydrogen sulphide (H2S), carbon dioxide (CO_2), water vapor and compressed as Compressed Biogas (CBG), which has methane (CH4) content of more than 90%.

'SATAT' (Sustainable Alternative Towards Affordable Transportation) scheme on Compressed Biogas (CBG) was launched by Ministry of Petroleum & Natural Gas on 1.10.2018. The scheme envisages targeting production of 15 MMT (million tonnes) of CBG, from 5000 Plants.

Key Benefits - GHG emission reduction

Approximately, 60 MMTPA CO_2e of GHG emission can be mitigated through production of 15 MMTPA of CBG under SATAT scheme. Of this IOCL will be putting up 2500 plants. Against this, till date more than 2100 LOIs have been issued.

DETAILS OF TECHNOLOGY/PRODUCT/PROCESS

Indian Oil R&D Centre has developed IBG-Max, IBG-Plus and BioXeed technologies on CBG. IBG-Max and IBG-Plus are CBG Plant configurations. Bioxeed is an inoculum developed to increase methane yield in biogas. Indian Oil is finalising offering of technology for setting up of CBG Plants, inoculums for enhancing CBG production from CBG Plants and additives for enhancing quality of Fermented Organic Manure. This shall increase the viability of CBG Plants.

Current Status

Under SATAT scheme, 17 CBG Plants have been commissioned. CBG sales has been initiated through 27 Retail Outlets and 2 Industrial Customers. CBG is also being injected in the CGD network. Many more CBG Plants are under various stages of commissioning. For IOCL 13 CBG plants are now operational and for 17 numbers there is work in progress.

Implementing Organisation

Ministry of Petroleum and Natural Gas (MoP&NG) and Oil & Gas Marketing Companies including Indian Oil, HPCL, BPCL, GAIL and IGL.

Challenges for Scalability

Financial barrier	Low	Medium	**High**
Technical barrier	Low	Medium	**High**

Ease of Replicability

Same/Similar Sectors	Low	Medium	**High**
Other Sectors	Low	**Medium**	High

Future Outlook:

Utilising technology developed by Indian Oil R&D Centre, a 200 tonnes per day (TPD) paddy straw to CBG Plant is under construction in Gorakhpur, UP and a 100 TPD cattle dung based CBG Plant is under construction in Jaipur, Rajasthan. This is being scaled up from 5 TPD organic waste to CBG Plant commissioned at Faridabad through Indian Oil technology. CBG Plants produce valuable by-products including Fermented Organic Manure and Liquid Fermented Organic Manure. This can usher in an era of organic farming through replacement of chemical fertilisers.

Green Hydrogen Microgrid 25 kWe – Greater Noida

NTPC

PROJECT BACKGROUND

Solar Power is limited to the available solar hours and storage of solar power for longer hours is challenging. Green hydrogen aims to overcome this challenge by providing green power using a hydrogen-driven fuel cell. This pilot project at Greater Noida shall help in storing the intermittent RE in the form of hydrogen and then converting it into electricity in the non-RE hours.

Key Benefits - GHG emission reduction

97 Tonnes CO_2eq/annum can be mitigated (considering equivalent amount of coal being replaced for producing green power)

DETAILS OF TECHNOLOGY/PRODUCT/PROCESS

The technology envisages the generation of hydrogen using Solar PV and compressing and storing it during solar hours and utilising the stored H2 to produce electricity using fuel cells during the off-solar period. This system will include a PEM electrolyser, hydrogen compression, and storage system, fuel cell system, associated auxiliaries, and integrated control system to feed the power to the grid. All required components for the hydrogen technology are commercially available, however, their cost is higher than the components for other renewable technology. To overcome this, NTPC-NETRA has developed the system design package and integrated different components to achieve optimum efficiency from the integrated plant.

Hydrogen is a very light and flammable, thus, the system is designed with special features for hazard detection and control systems. The integration of the hydrogen grid with the existing NETRA grid shall be done using an intelligent control system to achieve stable grid operation.

Current Status

The system is a pilot stage. The demonstration stage is under construction at:

- 25 kWe – Greater Noida
- 50 kWe - Visakhapatnam

Implementing Organisation

The system configuration was designed in-house by NTPC-NETRA and the implementing Agency is Spirare Noida

Challenges for Scalability

Financial barrier	Low	**Medium**	High
Technical barrier	**Low**	Medium	High

Ease of Replicability

Same/Similar Sectors	Low	Medium	**High**
Other Sectors	Low	Medium	**High**

Future Outlook:

NTPC-NETRA envisages the system to provide green power during the off-solar period, i.e., 24X7 green power and reduction in CO_2 emission. This system will be commercially viable provided cost reduction in electrolyser, H2 compressor, and fuel cell components and their increased life.

Green Hydrogen Blending in PNG network

NTPC

PROJECT BACKGROUND

In the mission to minimise climate change effects and reduce the usage of natural gas, hydrogen blending is being investigated as a potential solution across the globe. Very few pilot projects have been carried out across the globe and in India, this project of NTPC is the first-of-its-kind. This involves supplying blended PNG to 200 households in the NTPC Kawas colony near Surat, Gujarat. When the project is completed, it will have 20% vol/vol hydrogen blending to 100 SCMD of PNG.

Key Benefits - GHG emission reduction

When full scale pilot is made operational in six months' time in 200 households, CO_2 equivalent from cooking is reduced by 6% i.e., 200 kg CO_2 equivalent/year.

DETAILS OF TECHNOLOGY/PRODUCT/PROCESS

Major components of the project are:

Hydrogen blending skid and all required accessories for blending hydrogen into natural gas at different levels (5-20%)

1 Nm3/hr (5kW) output electrolyser

Storage capacity of 16 hours of hydrogen supply

Current Status

Design phased completed. Tendering and construction of pilot project is under implementation.

Implementing Organisation

The system configuration was designed in-house, and the implementing agency is being selected through a tendering process.

Challenges for Scalability

Financial barrier	Low	Medium	High
Technical barrier	Low	Medium	High

Ease of Replicability

Same/Similar Sectors	Low	Medium	High
Other Sectors	Low	Medium	High

Future Outlook:

NTPC anticipates the technology to mature in 2 – 5 years which will help achieve cost parity with natural gas. The successful implementation of these pilot projects can help scale up hydrogen blending in the entire PNG network of the country within two years.

NTPC

Green Methanol Pilot Project – Vindhyachal

PROJECT BACKGROUND

In the mission to minimise climate change effects and reduce the usage of natural gas, hydrogen blending is being investigated as a potential solution across the globe. Very few pilot projects have been carried out across the globe and in India, this project of NTPC is the first-of-its-kind. This involves supplying blended PNG to 200 households in the NTPC Kawas colony near Surat, Gujarat. When the project is completed, it will have 20% vol/vol hydrogen blending to 100 SCMD of PNG.

Key Benefits - GHG emission reduction

Enables the extraction of CO_2 emission from flue gas and converting into fuel.

DETAILS OF TECHNOLOGY/PRODUCT/PROCESS

The 10 TPD Flue Gas - CO_2 to Methanol Plant (FG-CTM) Plant shall comprise the following 3 units:

- Carbon Capture Unit: For capturing 20 TPD CO_2 from thermal plant flue gas through an energy-efficient amine absorption process.
- Hydrogen Generation Unit: For generating 2 TPD Hydrogen through the electrolysis of water, hydrogen is another ingredient for methanol production.
- Methanol Production Unit: For the conversion of CO_2 to Methanol through the catalytic hydrogenation process

Current Status

Design phased completed. Tendering and construction of pilot project is under implementation.

Implementing Organisation

The system configuration was designed in-house, and the implementing agency is being selected through a tendering process.

Challenges for Scalability

Financial barrier	Low	Medium	High
Technical barrier	Low	Medium	High

Ease of Replicability

Same/Similar Sectors	Low	Medium	High
Other Sectors	Low	Medium	High

Future Outlook:

Currently, this pilot project is under implementation, full-scale plant option is to be explored based on actual data of the pilot plant after its completion. This technology will help in mitigating GHGs emissions and provide financial and social benefits.

Battery Energy Storage System – Ramagundam

PROJECT BACKGROUND

This project of Battery Energy Storage System (BESS) at Ramagundam is one of the largest in India that integrates with a solar plant. This BESS would help to demonstrate and study different technical aspects such as the implementation of different solar plant generated power, smoothening algorithm and ramp-rate control strategy, grid frequency control, battery state-of-charge control strategy, round-trip efficiency under different loading conditions, automated scheduled-based solar plant generation dispatch, battery cycle utilisation, etc.,

Key Benefits - GHG emission reduction

Enables to store renewable energy for its usage during non-productive period.

DETAILS OF TECHNOLOGY/PRODUCT/PROCESS

List of major Equipment:

- Battery
- Battery Management System, SCADA etc.,
- Inverter (bi-directional)
- MV Transformer

Plant Life: 10-15 years

Current Status

Pilot project of (10 MW/40 MWh) at Ramagundam, Telangana has completed research and development stage. Tendering and Implementation phase is in progress.

Implementing Organisation

The system configuration was designed in-house by NTPC and implementing agency would be selected through bidding process.

Challenges for Scalability

Financial barrier	Low	**Medium**	High
Technical barrier	**Low**	Medium	High

Ease of Replicability

Same/Similar Sectors	Low	Medium	**High**
Other Sectors	Low	Medium	**High**

Future Outlook:

Currently, the technology needs financial investment along with the need to import batteries. However, in 5-7 years the technology is anticipated to mature and achieve cost parity with the existing system. This will help the technology to be scaled up to larger capacities for grid management, RE integration, backup power supply, etc.

3.2 Technologies, processes, or products developed for emission reduction of critical gases by PSEs in India

This section with the collation of technologies, processes, or products developed for emission reduction of critical gases by PSEs in India can be further categorised into:

- Reduction of CO, NOx, and SOx
- Treatment of water vapor for reduction in heat emission
- Other practices for emission reduction

Table 2. Technologies, processes, or products developed for emission reduction of critical gases

Technology		Organisation (in alphabetical order)
A	Reduction of CO, NOx, and SOx	
1	Flue Gas Desulphurisation (FGD) System using DCFS Technology	BHEL
2	Selective catalytic reduction SCR DeNOx system	BHEL
3	EngHOG- Desulphurisation of low pressure Hotwell Off Gases	EIL
4	Sulphur Recovery-Oxy Enrichment	EIL
5	HP WMA (Warm Mix Additive)	HPCL
6	Technology: Ind-CokerAT – Delayer Coker Technology	IOCL
7	Refining Processes Technologies and Catalysts for meeting BS-VI/ EURO-VI Gasoline & Diesel fuel	IOCL
8	Modification of Nitric Acid Plant for reduction in NOx emissions	NFL
B	Treatment/Efficient management of Steam/ water vapour/ thermal heaters	
1	EngCHP - Combined Heat and Power optimising software	EIL
2	EngRT-Htr- Real Time Optimisation of Heater Performance	EIL
C	Other practices for emission reduction	
1	Electrostatic precipitator (ESP)	BHEL
2	Vapor Recovery System for retail outlets	BPCL
3	Waste Plastic to Fuel - INDEcoP2F Technology	IOCL
4	MSW or RDF to Power	NTPC

Flue Gas Desulphurisation (FGD) System using DCFS Technology

PROJECT BACKGROUND

Ministry of Environment and Forest and Climate Change (MoEFCC) through a gazette notification dated 8th December 2015, limited the SO_2 emission to be 100 mg/Nm3 for all thermal power plants with effect 1st January 2017. This mandated the development of desulphurisation of the flue gas emitted from the thermal power plants. The Flue Gas Desulphurisation (FGD) is a process of removal of sulphur dioxide (SO_2) from flue gases emitting from thermal power plant. BHEL is presently providing Double Contact Flow Scrubber (DCFS) technology based FGD system to its customers using one of the two types of processes: Wet Limestone process and Sea Water process.

Key Benefits - GHG emission reduction

Typically, thermal power plant burning coal that contains 0.5 percent sulphur by weight emits SO2 of range 1500 - 2000 mg/Nm^3.

Installation of FGD system with DCFS technology, would enable to achieve permitted emission level of below 100 mg/ Nm^3.

DETAILS OF TECHNOLOGY/PRODUCT/PROCESS

Wet Limestone based FGD process: In a wet limestone process, Flue gas is treated with limestone slurry, which is sprayed on the gas in the FGD absorber towers. The flue gas is brought in contact with the absorber to remove not just SO_2 but also particulate matter, mercury etc. This system consists of four major components including flue gas unit, absorber unit, the limestone grinding unit and the gypsum dewatering unit respectively.

Chemical reaction involved:

$$SO_2 + CaCO_3 \text{ (Limestone)} + ½\ O_2 + 2\ H_2O = CaSO_4.2H_2O \text{ (Gypsum)} + CO_2$$

Seawater based FGD process: In seawater FGD alkalinity of seawater is used to remove SO_2 from the flue gases; the by-product is water, which is then treated and discharged back into sea. This process is used in thermal power plant located near coastal areas thereby taking full advantage of the cooling water circuit downstream of the condenser. Sulphur dioxide is absorbed and subsequently oxidised to sulphate, which is a native constituent of seawater. Prior to discharge, the acidified seawater effluent undergoes neutralisation using the natural alkalinity present in seawater.

Chemical reaction involved:

$$SO_2 + H_2O + 1/2O2 = SO_4\ 2- + 2\ H+$$

$$HCO_3- + H+ = CO_2 + H_2O$$

Current Status

Implementation is ongoing in 60 thermal plants of major power producers like NTPC, TSGENCO, MAHAGENCO, NALCO, UPRUVNL etc.

Implementing Organisation

BHEL has an ongoing technology license agreement with Mitsubishi Heavy Industry, Japan for Wet limestone based, and Seawater based FGD process.

Challenges for Scalability

Financial barrier	Low	Medium	High
Technical barrier	Low	Medium	High

Ease of Replicability

Same/Similar Sectors	Low	Medium	High
Other Sectors	Low	Medium	High

Future Outlook:

BHEL strives to develop energy and emission efficient technologies and collaborate with international agencies pioneering in such technological innovations to help Indian entities to efficiently reduce emissions.

Selective Catalytic Reduction (SCR) DeNox Technology

BHEL

PROJECT BACKGROUND

MoEFCC GoI through a gazette notification dated 8th December 2015, specified the permissible upper limit of NOx emission to be 100 mg/Nm3 for thermal power plants installed from 1st January 2017. To meet this requirement, Selective Catalytic Reduction (SCR) systems are used in Thermal Power Plants.

Key Benefits - GHG emission reduction

SCR DeNOx system is capable of reducing NOx emissions in flue gas <100 mg/Nm3 in thermal power plants.

DETAILS OF TECHNOLOGY/PRODUCT/PROCESS

The selective catalytic reduction (SCR) system removes nitrogen oxides (NOx) from flue gas emitted by power plant boilers and other combustion sources, and the catalyst is the key component of this system. The SCR System can be arranged in three basic locations in the flue gas path as per the requirement in thermal power plant for removing NOx from flue gas (high dust, low dust, or tail end) The sub systems of the complete SCR system broadly consist of:

- Flue Gas System (including SCR reactor)
- Dedusting systems including auxiliary steam/compressed air
- Reagent systems from unloading to storage to vaporisation for anhydrous ammonia
- Aqueous ammonia (between 9% and 29%)
- Urea based ammonia systems
- Dilution air system
- Potable water system
- Firefighting water system
- Industrial water system
- Service/compressed air system
- Instrument air system
- Condensate water system
- Ammonia system

Current Status

First commercial scale SCR Project is under execution for 660 MW Unit in Maharashtra.

Implementing Organisation

BHEL entered a technology collaboration agreement (TCA) with Babcock Power Environmental Inc., USA in 2018 for Selective Catalytic Reduction (SCR) System.

Challenges for Scalability

Financial barrier	Low	Medium	High
Technical barrier	Low	Medium	High

Ease of Replicability

Same/Similar Sectors	Low	Medium	High
Other Sectors	Low	Medium	High

Future Outlook:

BHEL is working towards developing energy and emission-efficient technologies and collaborating with international agencies to help Indian entities efficiently reduce emission

EngHOG - Desulphurisation of low pressure Hotwell Off Gases

PROJECT BACKGROUND

EngHOG™ process is EIL's patented technology for desulfurisation of low-pressure gases such as hot well off-gases (HWOG), flue gases, landfill gases, Biogas, etc. The off gases released from the hot well of the vacuum distillation unit of a refinery are referred to as hot well-off gases (HWOG). These are low-pressure off-gases containing C1-C6 hydrocarbons, and impurities like H2S, etc. These gases can be utilised as fuel gas due to their high calorific value but due to significantly high sulfur content (10-20 wt.% H2S), it also creates corrosion problems in furnaces and increases SOx levels in flue gases which is detrimental to the environment. The best utilisation of these off-gases is possible after desulphurisation.

EIL has developed an optimised process called "EngHOG" that removes H2S from hot well off-gases and improves its utility as a fuel in the heater, and also mitigates environmental damage.

Key Benefits - GHG emission reduction

This project estimates a potential CO_2 reduction as follows: For BORL Case

- CO_2 Reduction - 50000 MT/Annum
- SO_2 reduction- 5000 MT/ Annum
- SOx emission to environment also decreases by 96%

DETAILS OF TECHNOLOGY/PRODUCT/PROCESS

One of the major challenges of the existing technologies for desulfurisation of off gases are high pressure absorption processes. To overcome this challenge, the absorber column and column internals are optimised to achieve desired H2S removal at very low pressure through the design of the absorber.

The absorber is designed with two sections, the amine section, and the caustic section. The amine section is designed with very low pressure drop internals to achieve H2S in sweet gas to 800-1000 ppmw. In this section aqueous solution of Methyl diethanolamine (MDEA) is used as a solvent. The second section is the Caustic Section, where H2S concentration in sweet gas is brought down to nil. Amine flow and caustic flow are also optimised aptly hence very low spent caustic is generated.

Confederation of Indian Industry (CII) awarded the EngHOG in Innovations in Energy Efficiency by "3rd Energy Circle National Energy Circle Competition 2019"

Manufacturing Process Innovator of the year award by "FICCI Chemicals and Petrochemicals Awards 2017"

Image 8 - Awards

Current Status

It is a commercialised technology as well implemented by different organisations such as Bharat Oman Refinery Limited, Hindustan Petroleum Corporation Limited Vishakhapatnam, HPCL Rajasthan Refinery (HRRL) and IOCL Panipat.

Implementing Organisation

It is a Patented Technology of EIL, patented under the title of "An apparatus and a process for low pressure Hydrogen Sulphide absorption." (Indian Patent No - 342730).

Challenges for Scalability

Financial barrier	Low	Medium	High
Technical barrier	Low	Medium	High

Ease of Replicability

Same/Similar Sectors	Low	Medium	High
Other Sectors	Low	Medium	High

Future Outlook:

The EngHOG technology has direct savings on fuel as it utilises low pressure off gases as fuel, thereby reducing the need for additional fossil fuel and its associated CO_2 emission. The technology is already adopted by numerous refineries. Further, the technology can be implemented to new and revamp projects with required customisation.

Sulphur Recovery-Oxy Enrichment

PROJECT BACKGROUND

Whenever there is change in fuel specifications or increase in the capacity of existing process units of refinery, the capacity of SRU generally needs to be enhanced. Having additional units, increases utility requirements as well. Instead, existing SRUs can be revamped and augmented with oxygen enriched air to increase the SRU capacity by up to 35 percent.

Key Benefits - GHG emission reduction

In a typical refinery of 15 MMTPA, around 16,000 MTOE is saved which accounts for around 48,000 Tonnes of CO_2 equivalent

DETAILS OF TECHNOLOGY/PRODUCT/PROCESS

A Revamp of existing Sulphur Recovery Units (SRUs) can be carried out with oxygen enriched air to increase the capacity by up to 35%. In this process, the main combustion chamber of SRU is operated at higher temperature due to replacement of part of nitrogen in combustion air with oxygen. Besides capacity enhancement, the process improves sulphur recovery. Oxygen enrichment of SRU can be done using waste nitrogen from air separation unit. Thus, it helps in reduction of GHG emissions as the need for steam, fuel etc. comes down by having a single unit in place of multiple units of smaller capacity.

EIL has implemented this technology in SRUs having original capacity ranging from 14.7 TPD up to 336. 8 TPD. EIL has been granted a patent (jointly with CPCL) for its oxygen enrichment technology (patent no. 291293). Thereafter, a separate patent for high level capacity enhancement of SRU (patent no. 305758) has also been granted to EIL, which is a further modification of the process technology.

Current Status

The technology has been developed and is being implemented across multiple SRUs across India.

Implementing Organisation

Oxygen enrichment is EIL's in-house developed process technology. The first commercial demonstration/ implementation was done in partnership with CPCL.

Challenges for Scalability

Financial barrier	Low	Medium	High
Technical barrier	Low	Medium	High

Ease of Replicability

Same/Similar Sectors	Low	Medium	High
Other Sectors	Low	Medium	High

Future Outlook:

Presently, the technology is successfully implemented in various refineries. It can similarly be extended to other industries also.

HPCL

HP WMA (Warm Mix Additive)

PROJECT BACKGROUND

Conventional Hot Mix Asphalt (HMA) is mixed and compacted at temperatures between 150°C and 190°C during the pavement construction, which lead to high fuel consumption and emission of greenhouse gases. The asphalt industry worldwide is making a concerted effort to reduce emissions by lowering the mixing and compaction temperatures of the asphalt mixes without significantly affecting the properties.

A possible alternative is to use warm mix asphalt (WMA) infused with an additive, which is mixed and compacted at 20–40°C lower than the conventional Hot Mix Asphalt (HMA). In WMA technology, decreasing temperatures during the production of asphalt mixes not only lowers fuel usage, but also leads directly to reduction in emissions of greenhouse gases (CO_2 and NOx) and other critical air pollutants (CO, VOCs, particulate matter and SO2). HPGRDC developed cost-effective warm mix asphalt additives for asphalt applications. The product will be commercially launched in a year.

Key Benefits - GHG emission reduction

- Significant CO_2 emission reduction during the pavement construction.
- Improve the asphalt performance.

DETAILS OF TECHNOLOGY/PRODUCT/PROCESS

There are two types of additives associated with WMA production, namely, chemical/ organic additives and foaming additives (water-containing). The in-house developed additive possesses dual functional (wax and surfactant) properties. This work has successfully completed the end-to-end activities in terms of research, development of commercially viable product and field trials. All oil marketing companies, manufacturing and distributing Bitumen can benefit from the product.

Current Status

Field trials have been conducted and based on the results Indian (reference number 202141008203) was filed in Feb 2021.

Implementing Organisation

The field trials have been conducted by Hincol and HPCL Bitumen SBU.

Challenges for Scalability

Financial barrier	Low	Medium	High
Technical barrier	Low	Medium	High

Ease of Replicability

Same/Similar Sectors	Low	Medium	High
Other Sectors	Low	Medium	High

Future Outlook:

WMA additive applications in pavement construction are increasing in the Europe/USA and expected to grow In India. The HP-WMA additive is an import substitute and is environmentally benign.

Ind-Coker^{AT} Delayer Coker Technology

IOCL

PROJECT BACKGROUND

Delayed Coker Unit (DCU) is a key refining unit for enhancing refinery profitability by conversion of bottom of the barrel residues to distillates. High Sulphur pet coke is a by-product produced from Fuel grade DCUs, which is used as a fuel for burning in boilers resulting into emissions of CO_2 and SOx.

Key Benefits - GHG emission reduction

CO_2 & SOx emissions reduction by ~5% compared to conventional DCU, which amounts to 139,645 & 5017 Tonnes/MMTPA of residue feed capacity, while burning of high sulfur pet coke in pet coke boilers.

DETAILS OF TECHNOLOGY/PRODUCT/PROCESS

Ind-Coker^{AT} is a novel process technology developed and patented by IOCL to reduce the menace of air pollution caused by high sulphur pet coke burning and improving refinery margins by using a modified cracking methodology. This technology was validated in a 1 bbl./day pilot plant at IOCL R&D. Based on encouraging results, the technology was commercially demonstrated through batch-mode operation in DCU of Panipat Refinery (PR) resulting in reduction of coke yield by ~5 wt.% with corresponding increase in distillate yield by ~4 wt.%. The technology has been patented (India, USA, Japan, and Russia). The technology has also been internationally recognised by means of presentation of a paper in Word Petroleum Congress – December 2021, Houston, USA.

Current Status

The technology has been commercially demonstrated in batch mode for a period of two weeks in DCU of Panipat Refinery of IOCL in Nov 2016. For commercial implementation of the Ind-CokerAT technology, locations are being scouted.

Implementing Organisation

Ind-Coker^{AT} was developed completely in-house by IOCL R&D Centre, Faridabad.

Challenges for Scalability

Financial barrier	Low	Medium	High
Technical barrier	Low	Medium	High

Ease of Replicability

Same/Similar Sectors	Low	Medium	High
Other Sectors	Low	Medium	High

Future Outlook:

IOCL R&D through Technology Implementation Cell, is scouting for potential locations and customers for implementation of Ind-CokerAT technology. However, for commercialisation, there is a requirement of commercial reference unit in continuous operation and space availability in the existing DCU battery limit for the add-on hardware which needs to be evaluated on a case-to-case basis. There are no upcoming grassroot DCU installation planned in India, where the technology could be considered for implementation.

Refining Processes Technologies and Catalysts for meeting BS-VI/ EURO-VI Gasoline & Diesel fuel

IOCL

PROJECT BACKGROUND

Presently, Indian refineries are producing Bharat Stage (BS) VI quality gasoline & diesel fuels rolled out in 2020. While moving from BS-IV to BS-VI, there is a need to reduce sulphur levels with improved engine performance in both gasoline and diesel in refineries for meeting stringent BS-VI fuel specifications. IOCL R&D has developed two process technologies (INDAdeptG and indDSN®) for gasoline desulfurisation, an ultra-low sulphur diesel production technology (indeDiesel®) for meeting BS-VI specifications, and indDSK® technology for use of kerosene as a plug required for pipeline transportation of BS-VI fuels. All these technologies employ best in class proprietary in-house catalyst systems.

Key Benefits - GHG emission reduction

INDAdeptG, indDSN®, indeDiesel®, and indDSK® technologies and catalysts have been developed for various fuels meeting BS-VI specifications, thus contributing towards improvement of climatic conditions in terms of lower SOx, NOx, and PAH (Poly-Aromatic Hydrocarbons) emissions.

DETAILS OF TECHNOLOGY/PRODUCT/PROCESS

INDAdeptG: INDAdeptG Technology employs novel proprietary in-house adsorbent for producing low sulfur, BS-VI compliant gasoline and is based on reactive adsorption principle. The conventional hydrotreating for removal of sulphur requires substantially high hydrogen.

indDSN®: indDSN® Technology removes sulfur from Naphtha stream to ultra-low levels (S ≤ 0.2 p.m.) and produces feed for hydrogen generation/isomerisation/ catalytic reforming units. For this technology, in-house developed catalyst (Indictable) has been deployed.

indeDiesel®: Introduction of ultra-low-sulfur diesel (ULSD) necessitated quantum improvements in performance of Diesel Hydrotreating technology. indeDiesel® technology employing innovative proprietary catalysts is developed for production of BS-VI/Euro-VI quality Diesel. The technology offers the flexibility to upgrade middle range straight run distillates, Coker gas oil streams and light cycle oil from Catalytic Cracking units to ultra-low sulfur (< 10 ppm), high cetane diesel suitable for meeting ULSD specification.

indDSK®: This innovative technology based on hydrotreating platform is for the production of Pipeline Compatible Kerosene (PCK) meeting < 8 ppm product sulfur employs in-house proprietary catalyst. The technology has been developed for transportation of BS-VI fuels by pipeline, in which PCK is used as product plug.

Current Status

INDAdeptG: A 35 kTPA unit based on the technology is operating successfully at Guwahati Refinery and producing < 10 ppm sulfur product as per BS-VI requirement consistently.

indDSN®: A 235 KTPA capacity grass-root indDSN® commissioned at Bongaigaon Refinery in May 2021 employing indigenously developed indDSN® technology. This unit is producing feed for isomerisation unit.

indeDiesel®: 5 indeDiesel® units (grass-root & revamp) have been successfully commercialised and 1 unit is under implementation stage. The capacities of these units are in the range of 1.2 to 2.86 MMTPA.

indDSK®: 300 kTPA grass-root unit is under implementation at Paradip Refinery.

INDICAT Catalysts: Indian Oil's in-house DHDT catalyst INDICA Prime was successfully deployed in DHDT unit (0.43 MMTPA) of Digboi Refinery in 2019. In 2021, 377 MT of this catalyst was supplied for deployment in DHDT unit (2.86 MMPTA) of Gujarat refinery. indeDiesel® technology is being offered with INDICATPrime catalyst. Indian Oil is setting-up a Catalyst Manufacturing Plant at Panipat Refinery (PR) suitable for captive consumption of diesel hydrotreating catalysts.

Implementing Organisation

Technologies and respective in-house proprietary catalyst systems for meeting BS-VI gasoline and diesel fuel specifications of < 10 ppm sulfur have been developed and commercialised in several units of IOCL and being licensed by IOCL.

Challenges for Scalability

Financial barrier	Low	Medium	High
Technical barrier	Low	Medium	**High**

Ease of Replicability

Same/Similar Sectors	Low	Medium	**High**
Other Sectors	Low	Medium	**High**

Future Outlook:

With a proven success of these technologies at various IOCL refineries, many more units of varying capacities are under implementation at various refineries in India.

These technologies have been well protected by various patents in both India and abroad and all these technologies employ novel special purpose catalysts/ adsorbent also developed and protected by patents. With know-how of processes, catalysts, and Basic Design & Engineering capabilities, IOCL is now in position to license/offer these technologies globally.

Modification of Nitric Acid Plant for reduction in NOx emissions

NFL

PROJECT BACKGROUND

The NOx emissions from the Nitric Acid Plants as that of NFL consist of Nitrogen Oxide (NO) and Nitrogen dioxide (NO2) in the range of 2000ppm. Nitrogen dioxide has sufficiently high solubility and reactivity with water or with aqueous alkaline solutions, and as such, it can be absorbed in solutions. Thus, to limit the emission levels to less than 888ppm (permissible limits up to March 2019), NFL used the technology of washing NOx gases with 25% concentrated Caustic Lye (NaOH). This process limited the emission to less than 888ppm. However, the permissible limits of NOx emissions were reduced to be less than 195 ppm effective from 1st April 2019. To limit the NOx emissions below 195ppm (Initially it was 888 ppm), Selective Catalyst Reduction was a proven technology but required high financial investments. To overcome this economic barrier, NFL modified and innovated the conventional process of washing with NaOH to achieve emission levels of less than 195ppm. The project was initiated by the internal team NFL in February 2019, and it was implemented in April 2019 with help of the in-house equipment.

Key Benefits - GHG emission reduction

Reduce NOx emissions levels to less than 100 ppm.

DETAILS OF TECHNOLOGY/PRODUCT/PROCESS

The convention process includes washing NOx gases with 25% concentrated NaOH. A pilot study of washing the NOx gases by varying concentration of alkali was conducted. The pilot plant consisted of two packed vessels in series that was designed to inject alkali in the concentration between 2% to 26%. The tail gas containing NOx content in the range of 400ppm – 600ppm was allowed to pass through these vessels. The best results indicated that when concentration of alkali (scrubbing medium) was 1.75% to 2.5%, the NOx content in the outlet gas was in the range of 87-138ppm. Based on this pilot study, NFL converted two idle towers of 2nd stream for alkali washing. The tail gas with NOx when treated with 2% NaOH, the outlet gas had reduced to less than the permissible limits of NOx emissions. This technology not only allows limiting the NOx levels to permissible limits but also to continue production of caustic wash by-products namely sodium nitrite and sodium nitrate.

* Execution time and cost of execution were low for NFL as they had reused much in-house equipment. The execution cost and timeline may be high for other entities if they have to procure the equipment from external sources. The new equipment's may cost 10-15 crore

Current Status

Fully Implemented in NFL Nangal Unit.

Implementing Organisation

National Fertilizers Limited, Nangal Unit.

Challenges for Scalability

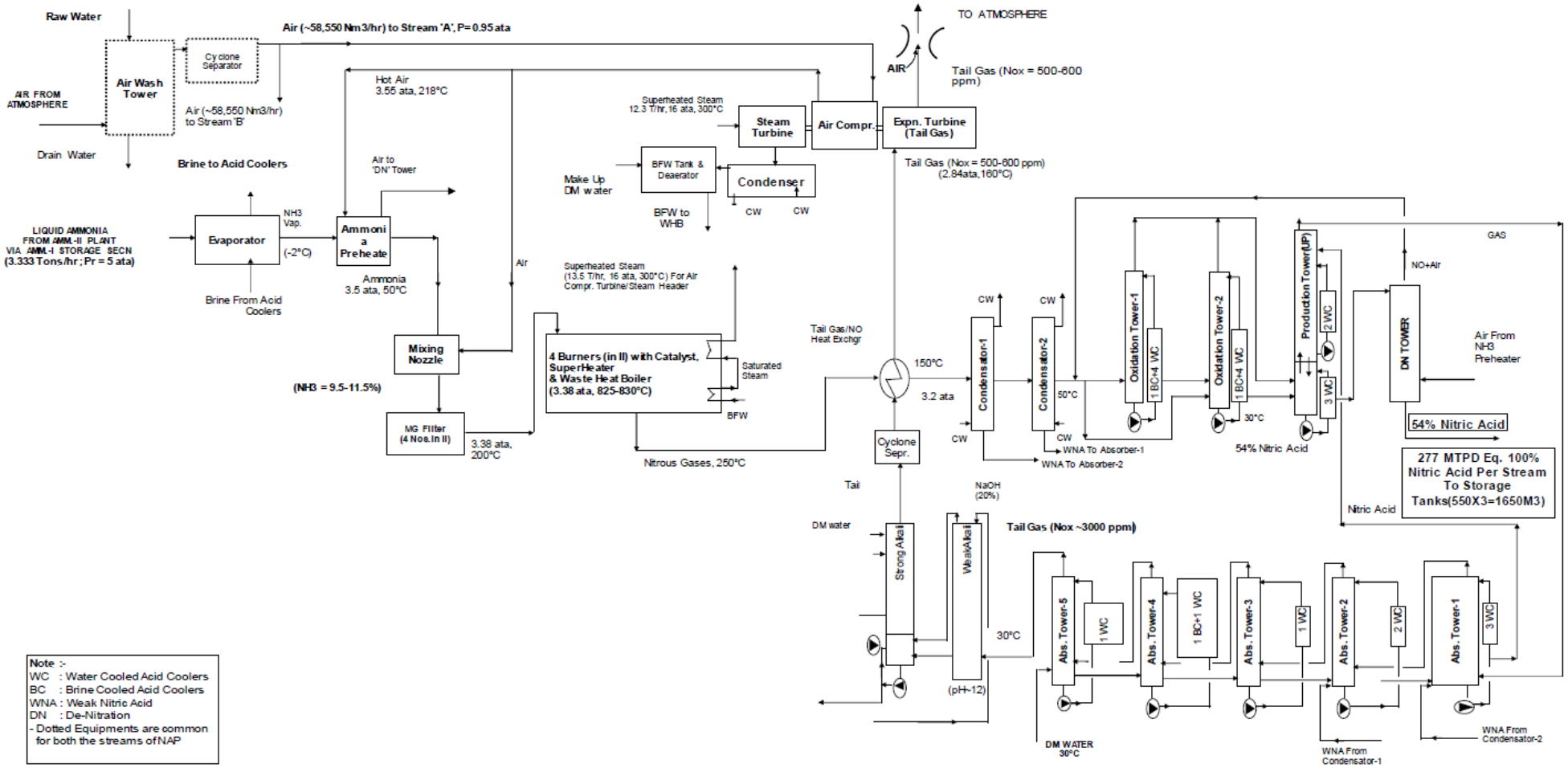
Financial barrier	Low	Medium	**High**
Technical barrier	Low	**Medium**	High

Ease of Replicability

Same/Similar Sectors	Low	**Medium**	High
Other Sectors	Low	**Medium**	High

Future Outlook:

Presently the technology is being used for single stream of Nitric acid plant of design capacity of 277 MTPD (54% Conc. Of NA). NFL is reviving its second stream of Nitric acid with similar technology for reduction of NOx in effluent gases.



NITRIC ACID PLANT (Double Stream For 554 MTPD of Nitric Acid)

Figure 12 Process flow diagram - Nitric Acid Plant

EIL

B. TREATMENT/EFFICIENT MANAGEMENT OF STEAM/ WATER VAPOUR/ THERMAL HEATERS

EngCHP – Combined Heat and Power optimising software

PROJECT BACKGROUND

EngCHP software is an online optimiser which enable to optimise the use of utilities such as steam and power in Refineries & other process industries and thus reduces the fuel being used in generation of these utilities, thereby, reducing in CO_2 emissions.

Key Benefits - GHG emission reduction

The absolute GHG emissions depend upon the operating conditions, and it varies from refinery to refinery. For a typical 3 MMTPA refinery, the CO_2 emissions are reduced by ~20,000 TPA.

DETAILS OF TECHNOLOGY/PRODUCT/PROCESS

CHP system of a typical refinery/process units are complex, and it consists of:

- Steam generation sources: Utility boilers, Waste Heat Boilers like HRSG, Extraction Steam, PRDS etc.
- Steam Consuming Sources: Stripping, process heating, jacketing, Turbines, and miscellaneous uses like Soot blowing, Safety Steam etc.
- Power generation sources: GT, STG etc.
- Power consuming sources: Pumps, Compressors, lighting, HVAC etc.

EngCHP software evaluates performance of all these equipment and recommends action for best combination to enable minimum fuel consumption.

Award received for Combined Heat & Power Optimisation of a Refinery using EngCHP software in Confederation of Indian Industry (CII) National Energy Efficiency Circle Competition for Best Energy Efficient Case Study

Current Status

The software has been developed and system-wide integration is completed. The software is already tested/ validated in operating refineries. It is ready for commercial use.

Implementing Organisation

EngCHP is an in-house online optimizer, developed by EIL.

A patent application has also been filed under the title "Method for Optimising Energy in A Process Carried Out Using a System" (Application Number: 201811011933)

Challenges for Scalability

Financial barrier	Low	Medium	High
Technical barrier	Low	Medium	High

Ease of Replicability

Same/Similar Sectors	Low	Medium	High
Other Sectors	Low	Medium	High

Future Outlook:

Presently, the EngCHP software is tested in Refineries. The software may be implemented in other industries also as the utility network is quite similar.

EIL

EngRT-Htr-Real Time Optimisation of Heater Performance

PROJECT BACKGROUND

Energy Efficiency Improvement remains an important factor for refineries for increasing operating profitability. Around 50% of refinery fuel is consumed in fired heaters. Further, fired heaters safety is very critical for sustainable operating plants. So, there is a need for monitoring and optimising fired heaters. EngRT-Htr enables energy efficient operation and thus leads to fuel savings and CO_2 emission reduction.

Key Benefits - GHG emission reduction

In a typical study using this software, a 1% improvement in efficiency of an 80 MMKcal/hr crude heater, GHG emission reduction of 2700 TPA (CO_2 equivalent) is envisaged. Thus, based on the number of heaters and their performance, the value can be many folds.

DETAILS OF TECHNOLOGY/PRODUCT/PROCESS

In fired heaters, after prolonged operation, reduction in actual efficiency occurs due to:

- Ageing of equipment / deterioration of Heat transfer surface / auxiliaries
- Changes in fuel specifications
- Changes in process conditions

EngRT-Htr is a real time optimisation technique will help fuel savings by fine tuning the control parameters corresponding to existing conditions. It will enable:

- Modulating parameters/Set Points according to deviated condition to improve efficiency
- Status of current/improved efficiency level
- Protecting equipment/auxiliaries (longer equipment life)
- Identifying hardware limitation for further improvement

EngRT-Htr also allows equipment protection, identification of other heat losses, and improved safety & heater availability which is not quantified conventionally.

Current Status

The software development and system wide integration is completed. The software can be implemented in any operating plant.

Implementing Organisation

EngRT-Htr is an EIL in-house developed optimisation tool.

Challenges for Scalability

Financial barrier	Low	Medium	High
Technical barrier	Low	Medium	High

Ease of Replicability

Same/Similar Sectors	Low	Medium	High
Other Sectors	Low	Medium	High

Future Outlook:

Presently, the EngRT-Htr software is tested in Refineries. The software may be implemented in other industries also.

C. OTHER PRACTICES FOR EMISSION REDUCTION

Electrostatic precipitator (ESP)

PROJECT BACKGROUND

Electrostatic precipitator (ESP) is used to remove particulate matters from flue gases in thermal power plant.

Key Benefits - GHG emission reduction

For gas flow up to 49,00,000 m3/hour, emission level lower than 17 mg/Nm3 and collection efficiency of 99.9% and above can be achieved.

DETAILS OF TECHNOLOGY/PRODUCT/PROCESS

An electrostatic precipitator (ESP) removes particles from a gas stream by using electrical energy which charges particles either positively or negatively. The charged particles are then attracted to collector plates carrying the opposite charge. The collected particles may be removed from the collector plates as dry material (dry ESPs) or they may be washed from the plates with water (wet ESPs). ESPs are capable of collection efficiencies greater than 99%.

An ESP is primarily made up of the following four components: gas distribution plates, discharge electrodes, collection surfaces (either plates or pipes) and rappers. The gas distribution plates consist of several perforated plates which help maintain proper flow distribution of the entering gas stream. The discharge electrodes are divided into fields. Most ESPs have three or four fields in series; however, very large units may have as many as fourteen fields in series. Discharge electrodes are energised by a single transformer-rectifier (T-R) set power supply. The energised electrodes create ions that collide with the particles and apply the electrical charge to the particles contained in the incoming gas stream. The collection plates or pipes provide the collection surfaces for the charged particulate matter. The rapping system is responsible for removing the collected particulate matter from the collection surfaces.

ESPs are generally classified as dry ESPs (the most used) and wet ESPs. The primary difference between the two classifications is the method by which the collector plates are cleaned. In dry ESPs, the collector plates are cleaned by applying mechanical impulses or vibration to the plates, which knocks loose the collected particulate matter (referred to as rapping). In wet ESPs, the collector plates are cleaned by rinsing with water. Wet ESPs are typically employed when gas streams contain sticky particles with low resistivity.

Current Status

ESP technology is fully developed, and system wide integration has been completed.

Implementing Organisation

After initial hand holding by OEMs in 1970s, BHEL has developed capability for state-of-the-art ESP for various coal-based power plants range up to 800 MW, Industrial application for cement, steel, fertilizer industries, sugar, biomass, chemical recovery etc.

Over 1000 ESPs are currently in operation in various sectors.

Challenges for Scalability

Financial barrier	Low	Medium	High
Technical barrier	Low	Medium	High

Ease of Replicability

Same/Similar Sectors	Low	Medium	High
Other Sectors	Low	Medium	High

Future Outlook:

BHEL is working towards developing energy and emission-efficient technologies and collaborating with international agencies to help Indian entities efficiently reduce emission

Vapor Recovery System for Retail Outlets

PROJECT BACKGROUND

Volatile organic compound (VOC) emission at Retail Outlets (RO) are becoming a significant environmental concern due to the higher volatility and wide applications of Motor Spirit (MS). The majority of VOC emission generated at RO, mainly during the unloading of MS (Stage IB). A vapor recovery system (VRS) is the equipment for recovering MS vapor, so that they do not escape into the atmosphere during unloading operations. VRS not only curbs the release of toxic organic compounds, but it also reduces the evaporative losses of fuel.

Key Benefits - GHG emission reduction

- CO_2 emission reduction: 8-10 tonnes per year (capacity of petrol sale of 300-350 KLPM)
- VOCs reduction is 2-2.5 tonnes per year
- Reduction of harmful gases > 97%

DETAILS OF TECHNOLOGY/PRODUCT/PROCESS

Corporate Research & Development Centre (CRDC) has developed a technology for reducing the MS (gasoline) vapor emission through detailed experimental and modelling & simulation studies. A ddemonstration unit (capacity: 500 LPM) is successfully commissioned at BPCL-COCO RO, Greater Noida. The technology makes use of refrigeration and membrane-based systems to recover harmful hydrocarbons gases and thereby reduces the fuel loss and VOC emissions. The volumetric recovery is consistently achieved >0.1 vol% of MS. The recovered gasoline product can be available for immediate sale after blending with gasoline pool at petrol station. The payback period of this technology is about 3-4 years. The life of the equipment is about 7 to 8 years.

Image 4 Inauguration of Vapor Recovery System

Current Status

The proposed technology has been successfully demonstration at commercial scale at the Retail Outlets.

Implementing Organisation

BPCL had implemented this process technology at one of their refineries.

Challenges for Scalability

Financial barrier	Low	Medium	High
Technical barrier	Low	Medium	High

Ease of Replicability

Same/Similar Sectors	Low	Medium	High
Other Sectors	Low	Medium	High

Future Outlook:

The technology can be easily replicated to all the petrol stations in India. About 20,000 tonnes of CO_2 emission can be reduced by implementing this technology at 2,000 units at RO, which has equivalent financial benefit of about 72 Crores per year.

Waste Plastic to Fuel - INDEcoP2F Technology

IOCL

PROJECT BACKGROUND

Waste plastic pollution is one of the most prevailing global threats to the sustainability of the environment. Prevailing disposal methods like land filling and incineration cause groundwater contamination and air pollution. Waste plastic pollution is also a threat to the marine ecology. There is a pressing need to develop technologies for effective disposal of all types of waste plastics, including MLP plastic waste. By recycling waste plastic and integrating with refinery operations, the purpose of GHG emission reduction associated with plastics can be effectively achieved.

Key Benefits - GHG emission reduction

During demonstration of IndEcoP2F technology, 65MT polymer was recycled, which is equivalent to 1664 MT of CO_2

DETAILS OF TECHNOLOGY/PRODUCT/PROCESS

Indian Oil's Eco-friendly Waste Plastic to Fuel Technology 'INDEcoP2F' is a novel technology developed and demonstrated commercially by Indian Oil R&D Centre for conversion of single use waste plastic to fuels by leveraging existing Delayed Coker Unit (DCU) of the refinery.

INDEcoP2F technology was conceptualised & developed in pilot scale at Indian Oil R&D Centre in 2019-20. Complete Process design of the Unit including BEDP, Detailed Engg etc. were carried out in-house. Successful commissioning and demonstration of INDEcoP2F technology was conducted and MLP waste plastic (~54 MT) was processed in the INDEcoP2F Demo Unit at Digboi Refinery, in Aug 20 and Feb 21. During demonstration, all features of the process were successfully demonstrated. Moreover, all DCU plant hardware operation found normal. The technology has demonstrated that >95wt% waste plastic to Naphtha (~35-45 wt.%) and Middle Distillates (~55-65 wt.%) and the GRM improvement over DCU ~2 million USD per 1000 kTA DCU per year for processing 1.5 wt.% waste plastic.

Current Status

The technology patents have been filed in Indian and Europe, USA, China, Japan, and Saudi Arabia markets and is available for licensing.

Implementing Organisation

Fully developed in house by Indian Oil R&D along with Refining Team

Challenges for Scalability

Financial barrier	Low	Medium	High
Technical barrier	Low	Medium	High

Ease of Replicability

Same/Similar Sectors	Low	Medium	High
Other Sectors	Low	Medium	High

Future Outlook:

Currently, the total capacity of DCUs in Indian refineries is ~51.6 MMTPA. Considering future implementation of INDEcoP2F technology in all the DCUs of India, considering 1.5 wt.% waste plastic processing, potential saving is projected to be 19.8MMTPA CO_2 equivalent.

MSW or RDF to Power

NTPC

PROJECT BACKGROUND

The process will gasify Refused Derived Fuel (RDF) i.e., combustible portion of Municipal Solid Waste (MSW) from Greater Noida Industrial Development Authority (GNIDA) and waste generated at NETRA to produce power which otherwise would have gone for landfilling. Using RDF to generate power reduces use of fossil fuel and reduces the load on landfills thus preventing environmental degradations.

Key Benefits - GHG emission reduction

Considering CO_2 emission from Coal Power generation @0.950 kg CO_2/kwh, the RDF gasification-based power will reduce (on equivalent coal basis) CO_2 emission by 3.3 million tonne/year (0.950*500 kwh*24 hrs*365 days*80%)

DETAILS OF TECHNOLOGY/PRODUCT/PROCESS

The combustible portion of MSW (RDF) will be sourced, dried, and fed into the MSW gasifier to generate producer gas, a mixture of (H2, CO, CO_2, N_2, CH_4, H_2S, NH_3). The combustible waste generated at NETRA (horticulture waste, dry waste, oil waste) shall also be used as feed in the gasifier. The producer gas shall be first cooled and cleaned using various filters and fed into a gas engine to produce electricity. The gas engine shall be suitably designed for burning producer gas. In this technology, enriched air and steam shall be used for gasification resulting in higher H2 concentration in syngas. Study is going on to use the syngas produced shall be used to produce Methanol/ethanol in the second phase of the project.

Current Status

Demonstration plant under construction

Implementing Organisation

The technology is implemented by in-house NETRA -NTPC.

Challenges for Scalability

Financial barrier	Low	Medium	High
Technical barrier	Low	Medium	High

Ease of Replicability

Same/Similar Sectors	Low	Medium	High
Other Sectors	Low	Medium	High

Future Outlook:

The current facility sizing was designed as per the power requirement at NETRA. The same can be scaled up for higher power provided sufficient quantity of MSW/RDF is available. Setting up higher sized plant in Urban Municipalities is the best option due to availability of RDF and demand of power. Higher capacity gasifier will reduce the heat losses, also the gas engines can be sized optimally, thus increasing efficiency. This can be replicated easily in all municipalities, industries with large townships and major establishments which produces sufficient waste.

4

Recognised Technologies and Environmental Initiatives adopted/ modified to combat climate change

Under the provisions of India's NAPCC, which was launched in 2008, several missions promoted the adoption of activities and technologies that can reduce our impact on the climate. Further, over the last decade, several missions, programmes, and subsidies aimed at combating climate change were launched with specific targets. National emission reduction targets, together with these missions and programmes encourage businesses to embrace climate change mitigation strategies. They have, thus, facilitated the adoption of the fast maturing and flexible technologies on a large scale. The technologies and initiatives adopted can be broadly classified into:

The recognised and commonly adopted technologies for climate change mitigation can be classified into:

a. Use of Renewable Energy – (Solar and Offshore wind)
b. Carbon Capture utilisation and storage (CCUS)
c. Biofuel and Enhancing fossil fuel efficiency
d. Waste and flue gas heat recovery
e. Waste to fuel

4.1 Use of Renewable Energy for Captive Power

Adopting renewable energy for captive power by industries is growing in India. With government policies encouraging this move, most Indian PSEs have also adopted increased usage of renewable energy to meet their industry needs and achieve GHG emission targets. The country has set an ambitious target to achieve an installed capacity of 175 GW worth of renewable energy by the end of 2022, which expands to 500 GW by 2030 as highlighted in the Hon'ble Prime Minister's speech at CoP26 in Glasgow.

PSEs have adopted renewable energy technologies in different forms. The share of captive energy production by most PSEs in India predominantly utilises roof-top and ground-mounted solar photo-voltaic panels for off-grid and grid-based electricity production. These technologies are followed by usage of solar water heaters, solar water pumps, solar streetlights, and wind farms. The estimated capacity of all such installations is approximately 12000 MW.

List of PSEs using renewable energy (Solar PV and Wind power) for captive power via rooftop solar, ground-mounted solar, solar heaters, solar street lights, wind farms, etc.

- BHEL
- BPCL
- HPCL
- GAIL
- IOCL
- NTPC
- ONGC
- SAIL
- BEL
- EIL
- NALCO
- NLC
- OIL
- SCI
- IREDA
- SJVN
- HAL
- HCL
- NFL
- NHPC
- NMDC OIL
- THDCIL

Some PSEs have innovatively adopted existing renewable energy-based technologies. These examples are highlighted in the box items below.

Solar Hybrid thermal Power Plant

Hybrid applications using solar energy have the potential to be an important, low-cost option for adding green power to the existing conventional practices that uses fossil fuel. In this solar hybrid thermal plant, NTPC has developed a process to integrate solar power with the existing coal-based generation fleet, allowing utilities to meet renewable energy targets, reduce plant emissions and lower fuel costs.

In this process, controlled quantity of feed water is tapped from inlet of HP Heater-6 to be passed through solar heat exchanger and again looped back at the exit of HP Heater-6. This process helps to reduce the extra steam extraction from HP turbine and will help to reduce coal consumption or produce extra units of electrical energy by the plant. The system uses Linear Fresnel Reflector (LFR) technology and achieves a heat output of 5.2812 X 1013 J/Annum (@DNI=1169 kWh/m2/Year). The project was developed on a budget of INR 74 crores which was co-finance by NCEF (NTPC-60% and NCEF-40%)

Solar thermal sea water desalination (STSW-Desal)

This project is envisaged by NTPC to utilise solar heat to de-salinate and produce drinking water in coastal regions. NTPC has developed the thermal desalination process using solar heat directly through non-tracking solar heat collectors. These are compound parabolic collector, which collects solar heat to de-salinate water through multiple effect distillation process. The process was designed, developed, and implemented at NTECL Vallur by NETRA (DSIR recognised R&D of NTPC Ltd.).

In comparison to the conventional desalination plant that requires sweet water, which is converted to demineralised water, the STSW-Desal system can convert sea water to demineralised water or even to drinking water. Also, the STSW-desal system consumes minimal quantities of chemicals as it operates at temperature of 65^{0}C which is below the solubility temperature of carbonates (70^{0}C) and sulphates (67^{0}C).

This project with its capex approximated to INR 11.5 Crore enables to produce drinking water at a rate of INR 0.18/litre (18 paise/litre), and this capex can be further reduced with increase in plant size. However, the land requirement for the solar collector is directly proportional to the plant capacity. Further it is operational only during sunny hours.

Floating Solar Photovoltaic (PV) Installations

Harnessing solar power using photovoltaic panels as roof mounted and ground mounted systems is now well implemented technology. One of it constrains being land intensive, there is an emerging option of installing solar PV on water bodies like lakes, reservoirs, canal, etc. This has attracted large hydro electricity generating companies and having large reservoirs including NTPC. Apart from land conservation, floating PV installations have many other benefits like increase in performance of solar panels due to cooling effect, water conservation, reduction in algae growth, quicker installation etc.

The main component of floating solar PV system is the floating platform or floaters on which solar modules are installed. The cost of imported floaters is presently very high posing constraint for large scale installations. NETRA and Central Institute of Plastic Engineering & Technology (CIPET) has jointly developed low-cost indigenous floaters for installation of solar PV panels. These floaters were designed and developed considering important design criteria including lifespan, durability, scalability, ease of maintenance, high wind speed etc. Presently, three version of this technology is deployed with 5kWP and 100kWP at NTPC Kayamkulam, Kerala and 1Mwp at NTPC Kawas, Gujrat. The NTPC Kayamkulam installation demonstrates floater cost of INR 4.35crore/MWp and that at NTPC Kawas, Gujrat at a breakthrough cost of INR 1.02 crore/MWp. Apart from the above mentioned inhouse installations, NTPC in collaboration with BHEL and Tata power have installed floating PV at NTPC-Ramagundam, Telangana and NTPC- Simhadri, Andhra Pradesh.

This system can be easily replicated by any company like power, refineries, municipalities, or any government authorities who have large reservoirs.

Solar HVAC

Solar HVAC is a technology developed by NTPC to produce bulk air conditioning using solar radiation as the major fuel. The technology is developed as an integration of solar thermal with vapour absorption machine to produce air conditioning along with cold energy storage that can address air conditioning requirements during lean solar time. The plant is designed for 50TR where 40 TR is for peak load and 10 TR for storage. The technology and the plant are designed, developed, and implemented by NETRA who also has patented the technology. The auxiliary power consumption is reduced to 20 percent as compared to conventional air conditioning plant. While the technology needs less maintenance and discharges no effluent to the environment, it is feasible to operate only in areas with high solar radiation (DNI). Cost of producing solar thermal energy being high, the feasibility of the technology for full scale implementation is low and can be implemented only in areas with easy access to demineralised hot water and high DNI throughout the year.

Renewable Energy & Battery Energy storage system

Energy generation from Renewable Energy (RE) projects depends on day-to-day weather conditions and, therefore, the energy produced is highly variable and intermittent in nature. To deal with the intermittency of RE supply, adequate balancing resources need to be developed and deployed to provide clean, affordable, reliable, and sustainable power. A Battery based Energy Storage System (BESS) is proposed in addition to roof top solar plants termed as "Solar plus storage" was planned as a Proof of concept (POC) demonstration. In order to assess options to integrate distributed energy storage and evaluate the associated benefits and cost, a 100 kWh Battery based Energy Storage System (BESS) was established. Subsequently 200KW, 100 kWh is installed in BAE premises as an alternate to 250 KVA DG set. There by 250 KVA DG set installation avoided and burning of fossil fuel avoided.

The BESS is primarily envisaged to be used for Ramping Control and Power Firming applications. The additional expenditure on increasing Electrical Maximum demand will be reduced through this system due to the advantages of peak-load control, load balancing, and emergency power backup for critical loads.

A total capacity of 5MWh capacity Battery Energy Storage System (BESS) is planned as per Road map drawn to reduce dependency on DG sets for short duration power failures and peak load shifting to control Maximum demand.

Key Features

- Micro-grid Control System (MCS) based Battery Energy Storage System (BESS) consisting of batteries.
- Battery Management System (BMS) inclusive of Power Conditioning System (PCS).
- Energy Management System and Monitoring & Control System.
- Protection System and associated components in a Container based solution.
- Provision for controlling & monitoring remotely from local control Center.
- Integration with existing Solar PV power plant.

Key Functions

- Ramping Control: To fill in the gap of 15- 20min between the power outage and start of DG sets installed.
- Power Firming: To smooth the output and controls the ramp rate to eliminate rapid voltage and power swings on the electrical grid.
- Energy time shift: To schedule the BESS Charge & Discharge operation up to maximum power limited to ratings defined.
- Peak Saving: To control Maximum demand on EB grid.

Image 9 Renewable Energy & Battery Energy storage system

Site image - Solar panel at Maritime Training Institute, Shipping Corporation India, Powai, Mumbai

Solar PV panels installed at EIL Complex, Gurugram

Site image from HCL

Image 10 Adoption of solar panels

Apart from these innovative uses of the available renewable energy technologies, the share of captive energy production by most PSEs in India predominantly utilises roof-top and ground-mounted solar photo-voltaic panels for off-grid and grid-based electricity production. These technologies are followed by usage of solar water heaters, solar water pumps, solar streetlights, and wind farms. The estimated capacity of all such installations is approximately 12000 MW.

Role of Indian Renewable Energy Development Agency Limited (IREDA)

IREDA is a specialised public sector financial institution dedicated for financing renewable energy (RE) projects in India. It has facilitated financing of RE projects for past 35 years and has been developing several innovative financial schemes/solutions for meeting the market requirements from time to time. As on 30th May 2022, IREDA has financed close to 3,000 RE loan accounts in the country with cumulative loan sanctions and disbursements of Rs.1,21,061 Crores and Rs. 79,994 Crores respectively, supporting green power capacity addition of 18,700 MW. The total loan book as on 31st March 2022 stands at Rs.33,931 Crores.

IREDA has been successfully financing renewable energy and energy efficiency sectors for more than 35 years. Taking a cue from the successful business model created by IREDA, other financial institutions have been increasingly coming forward to finance the RE Projects. Over the years, IREDA has introduced several Innovative financing schemes/mechanisms like structured/flexible repayments linking with seasonal generation, longer door-to-door repayment periods of more than 20 years and higher Debt-Equity ratio for Projects. IREDA has been offering competitive rate of interest for financing renewable energy projects and acting as a trend setter for other FIs.

IREDA is amongst the largest 'Green Energy Financier' in India & this has greatly supported the shaping of renewable energy sector in India. IREDA has been a focal point of attracting international finance in the Indian RE sector; many multilateral/bilateral lending agencies such as the World bank, JICA, ADB, KFW, AFD & EIB etc. prefer to route their funds through IREDA for supporting the Indian RE sector.

Solar Energy Sector

- Initially in the 90s, IREDA was involved in various Solar Water Pumping programmes, Small Solar thermal applications and created awareness of the technologies.
- During 2010-11, in initial phase of "National Solar Mission", IREDA has financed significant no. of solar projects, which paved the way for future financing of Solar Projects.
- IREDA was designated as "Programme Administrator" by MNRE for administering of GBI programme for Rooftop PV and Small Solar Power Generation Programme (RPSSGP).
- The sector has evolved from small scale solar systems to Large Scale projects and Solar Parks of hundreds of MW Capacity. There have been continuous improvements in technology and processes. IREDA has been continuously supporting the development of the sector through financing.
- IREDA financed projects under co-financing/consortium mode, which further paved the way for financing of large projects
- As on 30th May 2022, IREDA has sanctioned and disbursed cumulative amount of Rs. 33,294 crores and Rs. 19,354 crores respectively. IREDA funded projects have resulted in Solar Power capacity addition of around 6334 MW, which is contributing significantly towards CO_2 emission reduction.

Wind Energy Sector

- In the early 2000s, IREDA started funding Independent Power Producers (IPPs) in the wind energy sector, with the IREDA's funding support initially, the Financing of wind power projects evolved. Banks / FIs were initially hesitant to finance wind projects, so taking a cue from IREDA's models, they have opened their financing to the Wind sector.
- IREDA is administering Generation Based Incentive (GBI) scheme of GoI for Wind Projects, which has proved to be an extremely successful scheme for the RE Sector.
- The sector has evolved from installation of kW size machines to bigger MW size machines now.
- IREDA financed projects under co-financing/consortium mode, further paved the way for financing of large size projects.
- As on 30th May 2022, IREDA has sanctioned and disbursed cumulative amount of Rs. 29,701 crores and Rs. 20,966 crores respectively to Wind Energy Projects. IREDA funded projects have resulted in Wind Energy capacity addition of around 7525 MW, which is contributing significantly towards CO_2 emission reduction.

IREDA owned 50 MW Solar Power Project at Kasargod, Kerala

IREDA funded 60 MW Solar Power Project at Haridwar, Uttarakhand developed by EDEN Renewables

IREDA funded 108 MW Wind Energy Project at Dewas, Madhya Pradesh developed by Vena Energy

Image 11 Adoption of renewable energy by IREDA

4.2 Carbon Capture Utilisation and Storage (CCUS)

India has stated that it will attain net-zero emissions by the year 2070. It has also pledged to decrease expected emissions by 1 billion tonnes from now until 2030, with a carbon intensity reduction of 45 percent above 2005 levels by 2030[1]. Government of India had updated their NDC targets in August 2022 and it will be communicated to the United Nations Framework Convention on Climate Change (UNFCCC).

As per the updated NDC, India now stands committed to reducing the Emissions Intensity of its GDP by 45 percent by 2030, from the 2005 level, and achieving about 50 percent cumulative electric power installed capacity from non-fossil fuel-based energy resources by 2030. This demonstrates India's commitment at the highest level to the decoupling of economic growth from greenhouse gas emissions.

Decarbonisation of 'hard-to-abate' industries including oil and gas, power, steel, and metal refineries will necessitate extraordinary efforts. To achieve the decarbonisation goals, CCUS could play an essential role for such industries, in addition to the use of renewable technologies. Based on the evaluation of various GHG mitigative technology, it is anticipated that CCUS holds a great potential to mitigate the emissions from fossil fuel consumption between 2018 and 2100 especially in the hard-to-abate industries.

The CCUS technology in terms of its research and adoption has gained momentum in India since its collaboration with Mission Innovation, a global initiative of 24 countries and EU launched alongside the Paris agreement in 2015[2]. Mission Innovation aims to catalyse action and investment in research, development, and demonstration to make clean energy affordable, attractive, and accessible to all this decade[3]. CCUS is one of the eight challenges of mission innovation, which in India is being implemented through the Department of Science & Technology, Department of Biotechnology and Council of Scientific and Industrial Research. The two Centres, namely the National Centre of Excellence in Carbon Capture and Utilization (NCoE-CCU) at Indian Institute of Technology (IIT) Bombay, Mumbai and the National Centre in Carbon Capture and Utilization (NCCCU) at Jawaharlal Nehru Centre for Advanced Scientific Research (JNCASR), Bengaluru have been set up with support from the Department of Science & Technology, Govt. of India[4]. In collaboration with these centres, industries are increasing momentum towards CCUS technology. According to the MoEFCC, leading companies in the iron, steel, and cement industries are keen to follow the path to explore CCUS technologies to stay carbon-neutral[5]. Government owned corporations such as NALCO have commissioned a pilot-cum-demonstration CO_2 sequestration plant. In 2018, ONGC signed a memorandum of understanding (MOU) with ILFS Energy and Tamil Nadu Power Company (ITPCL) to inject CO_2 captured at the ITPCL plant into oil fields of ONGC Cauvery Asset.

1 Sourced from https://www.ceew.in/news/cop-26-ceew-unpacks-indias-2070-net-zero-target-and-other-climate-mitigation-measures
2 Sourced from https://pib.gov.in/Pressreleaseshare.aspx?PRID=1706083
3 Sourced from http://mission-innovation.net/about-mi/overview/
4 Sourced from https://dst.gov.in/india-have-two-national-centres-excellence-carbon-capture-utilization-iit-bombay-jncasr-bengaluru
5 Sourced from https://auctusesg.com/increasing-the-uptake-of-ccus-to-reach-indias-net-zero-target/

The box items below provide a snapshot of pilots undertaken by some of the PSEs.

CO_2 sequestration from thermal power plant by biological process

NLCIL, to minimise CO_2 emissions from its thermal power plant, carried out a pilot study to sequester CO_2 in a photo-bio reactor. The bioreactor was designed to culture micro-algae using CO_2 and further the algae biomass was converted to biodiesel. The technology along with its system was designed in collaboration with Pondicherry Engineering college. Based on the study conducted for four years (2013-2017).

It was done in two steps, first at lab level in 100 litre capacity Photobioreactor and next at pilot scale with 1000 litres capacity of Photo bioreactor in the area of about 70 M2 area.

Concept of the study

The experimental work was carried out by Biological mode of sequestration of CO_2 from flue gas of thermal power plants. Photobioreactor (PBR), a specially designed reactor for culturing Microalgae of capacity 1000 litres is used for the study. The flue gas which contains 11-12% of Carbon dioxide after reducing temperature, removal of SOx and NOx, etc., using bubbling reactor operated in day light is fed into the micro algal culture period, where Microalgae consumes CO_2 by photosynthesis reaction.

Outcome of the study

Based on the assessment of the pilot scale Photobioreactor the outcome of the study is detailed below:

- Flue gas contains 11-12% of Carbon dioxide. The daily absorption rate of Carbon dioxide by 1000 litres reactor is in the range of around 2 kg per day.
- It is assessed that algal photobioreactor technology is responding and reducing carbon footprint to some extent for the sequestration of $CO_2$from flue gas. However, the need of more space, water, cleaning of flue gas is considered as the limitations.
- It was found that in a micro algae pho bio-reactor of 1000 litre capacity two kilograms of CO_2 sequestration was achieved per day.

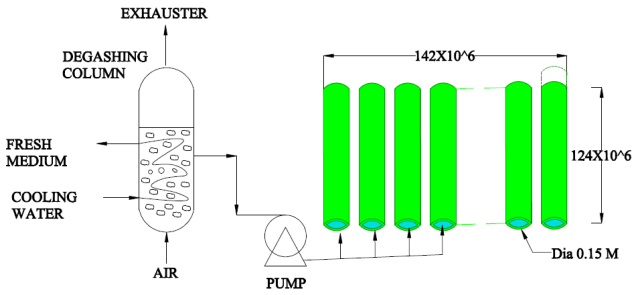


Figure 13 Bioreactor adopted by NLCIL

Image 12 Photo bioreactor of 1000 litres capacity

Enhanced Oil Recovery by Carbonated Water Injection

OIL in a joint industry project (JIP) with Heriot- Watt University, Edinburg, UK is investigating the process of oil recovery by CO_2-enriched (carbonated) water injection in oil reservoir. The objective of this technology is utilisation of CO_2 emitted from the process industry for pre-mixing Formation Water (FW) and use the Carbonated Formation Water (CWI) injection for enhanced oil recovery purpose.

Enhanced Oil Recovery by CO_2 Injection

OIL together with an MoU with IOCL is developing CO_2 injection for enhanced oil recovery along with CO_2 storage. The initial sub-surface study for this technology has been completed and operational feasibility study for pilot stage is planned. In this technology the CO_2 from the process industry is captured and injected to the in underground oil reservoir through injector well which thereby enables to enhance oil recovery by increasing mobility of oil. During this process part of CO_2 will be stored in the reservoir. This project is currently studied and developed in OIL's Upper Assam Fields.

4.3 Fuel Efficiency and Biofuel

For India, being one of the fast-growing economies of the world, energy is a crucial element and its dependence on fossil fuel will continue to remain dominant for the next few decades[6]. However, owing to the increasing global oil prices and the environmental concerns, ensuring fuel efficiency for fossil fuel and development of alternate fuel is crucial. National targets to develop efficiency in fuel, automobiles, alternative fuel like natural gas, hydrogen fuel and biofuels have been initiated through various national policies. Through the national policy on biofuel, government targets 20% blending of ethanol in petrol by 2030 and 5% blending of biodiesel in diesel by 2030. To achieve the nation targets of fuel efficiency, industries including PSEs have developed technologies and process that enable efficient biofuel blending and catalyst/additives for improving fuel efficiency. The box items below highlight initiatives of some PSES in adopting biofuel and/or fuel efficiency measures.

Premium gasoline fuel with RON 95 and 100

To meet the needs of racing enthusiasts who need to add octane boosters to raise octane levels while using normal gasoline, IOCL has developed and launched first domestically developed fuel with 95 and 100 Research Octane Number (RON) as XP95 and XP100 respectively. While XP100 specifically in its quality exceeds IS 2796 specifications with low olefinic content, better oxidation stability, low aromatic content and reduced particulate. XP100 is designed to give faster acceleration, boosts engine performance and provides better drivability.

XP95 fuel is launched with higher octane rating for 2-wheeler/3-wheeler/4-wheeler vehicles to achieve better Fuel Economy (3.95%), Power boost (3.68%), faster acceleration (20.15%) and significant reduction in emissions.

Indian Oil's latest XTRAGREEN diesel, launched on 1st of July 2021, utilises 7% Biodiesel, blended in normal diesel and fortified with in-house developed multifunctional fuel additives, offers an eco-friendly energy solution for the increasingly environment-conscious Indian market. This premium grade fuel exhibited fuel economy benefits between 5-6% in trucks/buses as tested by an accredited third-party laboratory. The product is fully compliant with IS1460-2017 specifications. Xtra-green diesel provides fuel economy of 5-6%, The PAH content in the PM decreases by 2-3%, thus reducing carcinogenicity of diesel exhaust emissions. Carbon monoxide emissions decreases by 12%. Oxides of nitrogen emissions reduces by 5%.

6 Sourced from the National policy on Biofuels http://164.100.94.214/sites/default/files/uploads/biofuel_policy_0.pdf

Green Combo Lubricant

All the countries including India have introduced strict CAFÉ norms to restrict the CO_2 emissions from the vehicles. The green combo lubricant developed by IOCL R&D centre is a combination of optimised engine oil, gear and axle oil for heavy duty segment which has proven to reduce vehicle fuel consumption thus reducing CO_2 emissions as well.

The green combo lubricants use extreme and cutting-edge lubrication technology to reduce friction by reducing viscous drag and other performance attributes resulting in incremental fuel economy improvements. Their adoption does not need any hardware changes in the vehicle.

- Engine Oil - The viscosity grade of the engine oil is SAE 10W-30 meeting API CK4 performance level which is the highest heavy duty API diesel engine oil specification as on date with excellent engine durability and long oil drain potential. The oil has been tailored to reduce internal friction along with enhancing durability.
- Transmission oil – It is an SAE 75W-80 meeting API GL4 Plus specification and has long oil drain capability.
- Axle Oil is an SAE 80W-90 Axle meeting API GL5 Plus specification and provide long oil drain capability.

Green Combo Lubricant Solution has been tested for 4-5% fuel economy performance in heavy duty vehicles by field trial at various STUs.

Differentiated LPG products (Xtra-Tej and Nanocut)

Differentiated LPG products are developed by doping performance improving nano additives with normal LPG, improving combustion efficiency, and reducing harmful emissions of NOx and CO. IOCL has developed and commercialised two LPG differentiated products using nanotechnology namely Indane Nanocut and Indane Xtra-Tej.

- **Indane Nano cut:** LPG with special additives with a use-case for metal cutting and other high temperature applications. The product was launched during March 2015 and appreciated by premier customers as Indian Railways, L&T, BHEL etc. The product gives fuel saving of ~15% and thus reducing emission.
- **Indane XTRA TEJ:** A differentiated commercial LPG with enhanced flame temperature. The product gives fuel saving of ~5%. The product was launched in September 2020.

The additive for both the products is being produced by a Toll processor, dosed at IOC bottling plants and products are available Pan India through Indian Oil LPG retail network.

Thermol-D Diesel Additive for improved fuel efficiency

THERMOL-D is an eco-friendly, multifunctional diesel additive which is developed in association with Indian Institute of Technology, Bombay. The additive improves efficiency through the complete consumption of Diesel. It also helps in maintaining cleanliness of the components in the entire fuel system. NMDC conducted trials for the efficiency of the additive through M/s Abhitec Enerycon Ltd., Mumbai. Based on the studies, the proposed benefits of Thermol-D Diesel additive are as follows:

- Improves combustion efficiency
- Reduces diesel consumption by 3-6%
- Reduces harmful emission and smoke
- Reduces engine noise
- Reduces maintenance costs
- Improves life of fuel injection system and diesel pump
- Enhances smoother engine operation and reliability

Dynamic Gas Blending in large Diesel Engines

Dynamic Gas Blending is a dual fuel technology which enables to run diesel engines on a mix of diesel and gas. The method was first implemented in three Drilling Rigs of Ankleshwar Asset (E-1400-VII, E-1400-III & EV-2000-II rigs) and observed about 45% reduction in diesel consumption has been recorded, with significant reduction in stack emissions.

After successful implementation of Dynamic Gas Blending (DGB) on three drilling rigs of Ankleshwar Asset, it is being implemented in other existing rigs of different Assets and all 27 new drilling rigs being procured.

4.4 Waste/Flue Gas, heat recovery technologies

Waste heat recovery (WHR) is the use of thermal energy to accomplish a useful function using heat that would otherwise be lost to the environment. In many cases, WHR avoids or reduces the need for additional fuel energy input. While the most used technology includes heat recovery for captive power production or to redirect into the same function as a fuel to reduce fossil fuel consumption[7], few technologies utilise waste heat and flue gas for varied function/utilities. The box items below highlight waste heat recovery measures of some of the PSEs.

Flue gas-based sea water desalination system (FGSW- Desal)

Desalination of sea water is a requirement for the efficient running of coastal thermal plants and for the production of drinking water which is low in coastal areas. Conventional desalination plant requires around 360 kJ/Kg of thermal energy which is invariably sourced from process steam. In case of FGSW-Desal system, entire thermal energy is drawn from waste flue gas. Therefore, cost of producing Demineralised water (DM)/ Drinking water through a FGSW-Desal system is substantially lower compared to any other competing technology.

FGSW-Desal system produces DM/drinking water directly from sea water as compared to conventional DM plant that essentially require sweet water which is converted to DM water. In FGSW-Desal system, chemical consumption is small as its operating temperature (65°C) is below the solubility temperature of carbonates (70°C) and sulphates (67°C). FGSW-Desal system is envisaged as a continuous operating system. There is no intermittency of operation like de-mineralisation, softening plant etc. Therefore, plant availability & yield is high. However, flue gas-based desalination plant is useful if flue gas heat is easily available and is the only thermal energy source for desalination. The current cost of the project developed, designed, and implemented by NETRA – NTPC is about Rs. 6.94 crore, with the cost of drinking water produced at 6.5 paise/ litre. With increase in plant size this cost is expected to reduce to 3 paise/litre.

Flue gas waste heat-based air conditioning (FGWH- AC)

This technology utilises low grade heat energy of flue gas to produce air conditioning effect. Flue gas is tapped from ID fan outlet and drawn in a slip stream where gas-to-water heat exchanger is provided. In the heat exchanger, heat is transferred from flue gas to generate hot water. A booster "flue gas fan" (FG Fan) with variable frequency drive (VFD) is also provided in the slip stream duct. The VFD regulates the FG fan speed and controls hot water temperature by modulating the flue gas flow. Vapor Absorption Machine (VAM) is connected to hot water loop. This hot water heat is utilised in VAM to generate chilled water. The chilled water is circulated through AHUs to produce air-conditioning.

7 Sourced from https://www.energy.gov/sites/default/files/2016/02/f30/QTR2015-6M-Waste-Heat-Recovery.pdf, https://www.ispatguru.com/waste-heat-recovery-technologies/, https://www1.eere.energy.gov/manufacturing/intensiveprocesses/pdfs/waste_heat_recovery.pdf

This technology and its process is developed, designed, and implemented by NETRA at NTPC Ramagundam and Talcher-Kaniha with 100TR and 400TR FGWH-AC system respectively. These systems have proved power saving of 0.8-1.0 kW-Hr/TR-Hr compared to conventional compression system and 100% steam saving compared to steam-based vapour absorption system. The 100 TR plant at Ramagundam and 400 TR plant at Talcher-Kaniha cost around 4.19 crore and 8.88 crore respectively. The technology is replicable in existing power plants where R&M of air conditioning system is due and in new plants.

HP FurnoKare – to reduce heat loss within furnace

Furnaces are the major energy consumers of any refinery. Due to the inorganic metal impurities present in fuel oil, scales are deposited on the external tube surface of the fired heater. These scales hamper the heater transfer efficiency of the tubes which in turn increases the furnace load leading to high energy losses. In the long run, this can also lead to throughput reduction.

HPCL developed an in-house process cum additive (HP FurnOKare) for online cleaning of external scale depositions on the heater tubes. The proprietary chemical is injected into the furnace even while it is in operation. The chemical reacts with the scales to clean it and leaves along with the flue gases. Injection of HP FurnOKare has shown significant improvement in the heater bridge wall temperature thereby improving the furnace efficiencies and heater run length. The process and additive were commercialised in 2016 and implemented at HPCL refineries, MRPL, OMPL, and IOC-Mathura. It is developed and patented by HPGRDC. (Patent no:325373).

Waste heat recovery to Steam generators

Recovery of waste heat is one of the main energy efficiencies improving measure deployed in ONGC. All the gas turbines in Hazira, Uren, Ankleshwar and HPHT Kakinada has heat recovery steam generators. In Uran, Hazira and HPHT steam is used for process heating. In Ankleshwar, steam is used to run 12 MW steam turbine for power generation.

WHR in Hazira plant and Uran plant results into gas saving of about 120.0 MMSCM/annum and 80 MMSCM/annum respectively. Gas turbines in Mumbai offshore and EOA Kakinada gas turbines are equipped with WHR units for heating of process fluid.

In OTPC Tripura, exhaust from gas turbines is used to generate steam, which is, in turn used to run steam turbines 2 x 140 MW for power generation. WHR from hot effluent from heater-treater is being implemented under revamping of 4 no CTFs in Mehsana Asset. ONGC office at Delhi and Mumbai are equipped with gas engine WHR units for VAM air conditioning system.

Micro Turbines Generators for Flare Gas Reduction

Micro turbines are basically very small gas turbines, ranging from 25 KW to 500 KW, which can use low-pressure natural gas to generate power. A successful pilot project was done for flare gas reduction by installing a 65 KW micro turbine generator at Linch GGS in Mehsana. The turbine utilises about 20,000 SCMD of low-pressure gas, for power generation, which was otherwise being flared. This success story was emulated in Geleky GGS-I, Nazira, Assam Asset, by installing a 200 KW Micro Turbine for captive power generation. Also, two Micro Turbines are being installed in MH Asset & three micro turbines are being installed in Mehsana Asset.

4.5 Waste to fuel

The most common technologies adopted for waste to fuel include conversion of organic waste to biogas, predominantly for cooking or for boilers. This is followed using organic waste to biofuels. However, industries and PSEs are developing in-situ technologies and process based on the availability of their process waste or locally accessible waste. A unique example of using waste-to-fuel concept in thermal power plants is highlighted below.

Bio-mass co-firing in coal based thermal plants

Biomass co-firing is a near-term, low-cost option for efficient and clean conversion of biomass to electricity by adding biomass as a partial substitute fuel in high-efficiency coal boilers. In this process, using agricultural residue-based biomass pellets, an equivalent amount of CO_2 emitted from combustion gets absorbed in the next crop cycle through the process of photosynthesis which makes agricultural residue-based biomass pellets a carbon neutral fuel. UNFCCC has recognised biomass co-firing using agricultural residue-based pellets/waste as technology to reduce GHG emissions. The government of India has also developed a supporting policy framework and regulation for its wider implementation across India. Further, biomass co-firing will provide the farmers a commercial option to better utilize their agri-waste.

Biomass co-firing has been achieved by co-milling biomass and coal together in a conventional coal mill with minor modifications. Biomass is fed through an emergency hopper in a coal yard and coal is fed from a track hopper or stacker reclaimer both get mixed at Transfer Point (TP) after crusher and fed to the coal bunker from where this blend goes to the feeder.

NTPC-NETRA, using advanced characterisation techniques, have established safe O&M procedures for co-firing raw biomass pellets up to 10% in a coal fired boiler The procedure has been established after successful trial in NTPC Dadri 200 MWe coal fired power plant. The high alkali and chlorine content in agriculture residue-based pellets are limiting the co-firing ratio to 10%. Studies are going on to increase the co-firing ratio using torrefied biomass pellets and to make it financially feasible from its current high pellet creation cost.

4.5.1 Adoption of electric vehicle

One of the most common measures taken up worldwide is to make travel greener and cleaner. In accordance with the Government of India's electric vehicle policy, many PSEs had started to adopt and promote electric vehicles among their employees. This includes electric bikes, cars, e-carts, etc. One example is highlighted below.

EIL

EIL had taken up an initiative to promote the electric vehicle. They have introduced e-bikes and e-carts within their premises to promote EV adoption.

Image 13 Site Image -e-Bicycles for eco-friendly transport within the complex

Image 14 Site Image -e-Kart for eco-friendly transport within the complex

5

Initiatives for climate change and environmental improvement adopted by PSEs

All PSE responded have adopted or have planned to adopt mandatory and recommended practices for sustainability and environmental improvement such as large-scale tree plantation, water treatment using STP and ETP, replacement of conventional lighting systems with energy efficient lighting fixtures, and phased adoption of paperless procedures. In addition, the box items below highlight some environmental/sustainability initiatives that work towards improving the environment and provide climate co-benefits.

BEL

Rejuvenation of lakes

Bharat Electronics Limited has taken up rejuvenation of Doddabommasandra Lake by setting up a 10 MLD Sewage Treatment Plant (STP) with a project cost of 13.5 crores under the BEL Corporate Social Responsibility (CSR) scheme. The project intends to augment evaporation losses in the lake during the summer by supplementing treated sewage in the upstream area as a source of water.

Beginning in the late 1990s, with a change in the rain pattern and no runoff from Thindlu and Narasipura Lake to Doddabommasandra Lake, this lake became dry around 2002. The scale of the problem was beyond imagination, the wells in and around the area were slowly running out of water. Water scarcity was the major problem faced by around 3 lakh residents of the Doddabommasandra watershed region in the Vidyaranyapura, Govindayyanpalya, Thindlu, and BEL areas. Doddabommasandra Lake is one of the main lakes in cascading series of Lake Narasipura, Lake Tindlu, which overflows to Lake Hebbal, and finally forms the Dakshina Peenakini River, which flows towards Malur and joins into the Kaveri River.

To address this issue, BEL took up the lake rejuvenation project by setting up 10MLD STP to improve the flora and fauna and restore the lake water to become perennial again. The project has been taken up in collaboration with the Karnataka Lake Conservation and Development Authority (KLCDA), the Bruhath Bengaluru Mahanagara Palike (BBMP), and the Revenue Department.

The STP is designed on "Sequential Batch Reactor (SBR)" Technology using PLC/SCADA control, a process in which the sewage is fed into the SBR units for biological treatment and advanced treatment using "Activated Sludge Process (ASP)". This plant will be maintained by BEL for 20 years.

The benefit of the above project is promoting flora and fauna, increasing the groundwater level by ground water recharging, encouraging the birds and mammals to breed, improving the environment, and reduction in Pollution by preventing the disposal of sewage water into the lake.

Following are some of the benefits to the society of the lake rejuvenation project:

- Positive impact on society due to lake rejuvenation:
  - About 3 Lakhs citizens were benefited with better access to water.
  - Recharging of groundwater about 2000 ML at the rate of 5.5MLD
  - Improved groundwater table in and around the area of Vidhyaranyapura, Govindayyanapalya, and Tindlu, and the BEL factory area
  - Reduction of sewage load on BWSSB Hebbal treatment plant
- Flood and disease control:
  - Indirect health advantage as it will prevent water-borne diseases associated with waterlogging and flooding such as typhoid, dysentery, malaria, etc.
  - The excess water of about 30 ML from these areas during the rainy season will be diverted into the lake preventing flooding and water logging in these areas as well as in the downstream areas of Hebbal.
- Ecological Importance and diversity:
  - Varieties of birds and other fauna and flora have increased.
  - Improved micro-climatic condition resulting in a balanced ecological system.
- Social and Recreational benefits:
  - Fishing activities and other recreational activities like boating.
  - Education spot for school children and other academicians.
  - Visiting spot for bird watching.

Bio-Methanation plant for Handling of Food Waste

Up flow Anaerobic Sludge Blanket (UASB) based Biogas Plant in one among other sustainable renewable energy system. The UASB Biogas Plant at BEL, Bengaluru Complex has a capacity to digest 2 MT of food waste generated in canteen and produce a minimum of 160 cum of gas per day, which is equivalent to 70 Kg of LPG. This replaces the older KVIC (Khadhi and Village Industrial Commission) model.

The UASB technology has high gas production and better process control system, such as a flame arrester, pH/Temperature monitoring systems, Scrubbers for removal of Hydrogen Sulphide gas and carbon dioxide gas, alarms, etc.

The gas is supplied to canteen at 0.4 Kg/cm2 pressure to commensurate LPG burning effect. The capital Cost of the project is 40 Lacs INR. The plant was commissioned in October 2015. About 1800 Kg of LPG per month is replaced with biogas. This amounts to potential savings of rupees 11.70 Lakhs per annum in addition to achieving an environmentally sound disposal of food waste.

Image 15 Bio-Methanation plant for Handling of Food Waste

BHEL

Fabric Filters for removing particulate matter from contaminated gas stream

With initial phase technology collaboration since the 1990s, BHEL has indigenously developed this technology with three types of bags (shaker bag, reverse air filter, reverse pulse, or pulse jet collectors) that differ in methodology adopted for cleaning the filters for removing particulate matter from contaminated gas stream. In each bag, the contaminated gas stream enters the hopper, flows into and through the bag, and leaves the dust cake on the inside which is removed either by gently shaking, or reversing the gas flow, or compressing into few rows for shaker, reverse air filter and pulse jet bags respectively.

Air Pollution Control Tower

BHEL has indigenously designed and developed a state-of-the-art Air Pollution Control Tower (APCT) to deal with air pollution problem in urban areas, The APCT operates by pulling polluted air through its base. Filtration is carried out by three types of media viz. demister, PM 2.5 filter and activated carbon filter for cleaning mist, dust & harmful gaseous substance. Clean air is released from the top of the tower.

An automatic pulse jet type dust cleaning system is provided to clean the PM 2.5 filter at regular intervals. The dust gets collected at the bottom in drum/receptacle and is to be removed & disposed periodically. Expected dust collection rate is about 1.5 to 2 Kg/day.

NTPC

Adoption of Dual Condenser in series

Based on in-house study and analysis by running the Heat and Mass Balance Software, NTPC customised the technology to improve turbine cycle heat rate and in turn, the cycle efficiency. The concept of 'Dual condenser' in series has been adopted in recent water-cooled condenser based thermal projects, which has optimised condenser pressure, and resulted in higher efficiency and lower CO_2 emissions.

Oil & Natural Gas Corporation Limited (ONGC)

Clean Development Mechanism (CDM) projects

ONGC has so far registered 15 CDM projects with the UNFCCC with an emission reduction potential of 2.1 million T CO_2 equivalent/year. The 728 MW capacity ONGC Tripura Power Company (OTPC) natural gas-based combined cycle power plant is one of the largest CDM projects in the world, with an emission reduction potential of 1,612,506 T CO_2 equivalent/year. Despite the declining carbon market, the company is continuing CDM route in the interest of authentic emission reductions and environment protection. Registration of three new CDM projects are underway.

Global Methane Initiative (GMI) Programme

Fugitive emissions are those emissions, which cannot be detected by the naked eye and is a major contributor to GHG emissions in oil and gas industry. The Global Methane Initiative (GMI) is an action-oriented initiative from the United States Environment Protection Agency (US-EPA) aimed at reducing global methane emissions to enhance economic growth, promote energy security, improve the environment, and reduce GHG emissions. ONGC was the first non-American oil company to enter a collaboration (MoU) with the US-EPA. Under this program, fugitive methane emission detection survey is conducted at production facilities/plants and remedial actions are initiated to arrest the leakages if any into the atmosphere

Gas Flare Reduction

Flaring of natural gas is common in oil and gas industries when it cannot be processed for sale or due to technical and economic reasons. Reducing the gas flaring is another thrust area for ONGC. Gas compressors are installed for compressing the low-pressure gas and feed them to sale line or for gas injection in artificial lift wells. Various measures like installation of low-pressure compressors, revamping of existing compressor plants and pipelines, installation of gas-based generator sets, etc. are taken up across work centres for reducing the flaring of gas. Through these measures, ONGC has brought down the gas flaring to less than 2% of its production. Overall, the gas flaring has reduced from 648 MMSCM IN 2015-16 to 487 MMSCM in 2020-21. ONGC has also endorsed World Bank Initiative to reduce global gas flaring: "Zero Routine Flaring by 2030" prior to COP 21 Conference in Paris.

Energy Efficiency Motors/equipment's

New-technology electronic diesel engines and hundreds of high-vintage electrical motors, which out-lived their lives, have been replaced with energy-efficient motors such as Variable Frequency Drives (VFD). Old air conditioners have been replaced with new energy efficient air conditioners, etc. these have together contributed to substantial reduction in electricity consumption and emission reductions.

Green Buildings

ONGC has set up LEED certified platinum rated Green Buildings for its office complex at Delhi, Dehradun, and Mumbai. The fourth one is under implementation at Kolkata. Green Buildings are expected to save 30-40% of energy and they are equipped with rainwater harvesting system and efficient lighting and electrical equipment system.

State-of-the-art fuel-efficient, Diesel Engines

In a major energy efficiency improvement drive, ONGC has replaced inefficient and outdated diesel engines of onshore drilling rigs with state-of-the-art fuel-efficient, diesel engines. It has resulted in substantial saving in diesel consumption, to the tune of 15-20 litres/hr/engine. After replacing 266 engines, the approximate diesel savings being achieved is 9,855 kilo litres per annum.

Natural Gas based Generator sets for captive power generation

Every permanent installation had a standby diesel generator set for producing power in case of non-availability of power from the grid, which is very common. Over a period, most of the production installations/ permanent installations were fitted with Natural Gas based Generator sets for their captive/stand by power generation. This reduces gas flaring as well as emissions.

Pit-less Drilling – A new initiative in Water Management

One of the most promising emerging drilling technologies is pit-less drilling. The land footprint required for exploratory/development drilling activities is reduced significantly by this method leading to less land related challenges. ONGC had implemented pit-less drilling in Well# BKAA in KG-PG Basin (E-2000-I Rig). It was found that apart from significant savings accrued from less land use, land filling, restoration and other related costs, the freshwater consumption was reduced by about 3 times when compared to other comparable wells.

The cost saved due to water was INR 2,51,944. By eliminating the use of mobile ETP, ONGC was benefited by Rs. 9,28,700/- The cost saved on drilling fluid was INR. 74,04,406.

NALCO

Graphitisation of Cathode Blocks

Graphitisation is an established national and international practice of the present time for reduction of specific energy consumption and improving productivity. It is a process of replacing semi-graphite cathode block by graphitised cathode carbon block in aluminium smelting pot. Approximate lifespan of cathode block is 2500-3000 days. Graphitisation of Cathode increase the pot productivity in term of hike in amperage of operation and decrease specific DC energy consumption since graphitised cathode has a characteristic of low voltage drop in comparison to semi-graphite cathode. Graphitisation of pot at NALCO started in Dec 2009 and as on 18.01.2022, 863 out of 960 (89.90%) pots are graphitised.

Modification of existing Air Pre-heater

Selected existing air-preheater were renovated & modernised with advanced profile heating element and double sealing arrangement. This will result in increase in boiler efficiency by 1.14% due to reduction in air leakage and increased heat transfer thereby coal saving of 7639 tonne /unit/year.

OIL

Retrofitting of Dynamic Gas Blending System in diesel engine used in drilling operation

Diesel engines are widely used in drilling operations because of better torque, transient response, and higher power density. The objective of this intervention is to explore the use of cleaner fuel and optimise fuel costs in Drilling Operations. The Caterpillar Dynamic Gas Blending System (DGB) allows ECM-controlled CAT 3512 B Diesel engines to operate in diesel or diesel and natural gas fuel, simultaneously reducing environmental impact and operational cost. A DGB engine, or a Caterpillar engine with the DGB retrofit kit installed, will be able to operate on 100% diesel or a combination of diesel and natural gas, safely and successfully with a maximum natural gas percent substitution of 70[SR1]%.

Field information is yet to be collated. This technology is verified by other pilots tested by other organisations in the oil sector. It is a proven technology & verified by OIL. OIL is planning to take it forward as a pilot project.

Retrofitting conversion kit in petrol/diesel vehicles for using CNG as fuel

OIL has taken up a pilot project for retrofitting conversion kits in a few of the existing fleet of vehicles to run on CNG. At present, all the vehicles running under OIL, Duliajan either runs on diesel or petrol. For petrol engines, conversion kits are retrofitted so that engines can be run on dual fuel systems, and in the case of diesel engines, the entire engines have to be modified to run on CNG.

CNG-fuelled engines will emit 5-10% less CO_2 than the business-as-usual situation. The NOx and SOx emissions of CNG-powered vehicles are substantially lower than that of diesel-powered vehicles. This conversion has other advantages as well, such as:

- The low operational cost of the vehicle
- Increased life of the engine oil with low contamination
- CNG is the safest fuel with a high auto-ignition temperature
- CNG is also considered a greener option due to its lead and Sulphur free character

This is a pilot project, hence, an ecosystem for CNG is yet to be developed in and around Duliajan. Also, cylinder hydro testing is required at regular intervals.

Enhanced Oil Recovery by Carbonated Water Injection

It is a Joint Industry Project (JIP) between OIL and Heriot-Watt University, Edinburg, UK. It is being conducted to investigate the process of oil recovery by CO_2-enriched (carbonated) water injection in the oil reservoir.

The objective of the technology is to use CO_2 for pre-mixing Formation Water (FW) and use the Carbonated Formation Water (CWI) injection for Enhanced Oil Recovery purposes. CO_2 emissions from the process will be used in the project.

Carbon Capture, Transpiration, Storage, and Injection of CO_2 for Enhanced Oil Recovery

CO_2 will be injected into an underground oil reservoir through an injector well to enhance oil recovery by increasing the mobility of oil. Part of injected CO_2 will be stored in the reservoir supporting carbon footprint reduction and simultaneously enhancing oil recovery from the matured reservoir and thus financial benefits.

This initiative is taken up by OIL in collaboration with IOCL. OIL signed MoU with IOCL for collaboration on the above project on 12.01.2020.

The initial study was carried out jointly by Oil India Ltd & University of Houston. The initial sub-surface study has been completed and an operational feasibility study for the pilot stage is planned. It will be piloted in the reservoir in OIL's Upper Assam Fields.

Image 16-Site image from PHILLOBARI-1 (EA)

Image 17- OIL initiative -The process of reclaiming the drilling well locations

RINL

Afforestation:

During the expansion of their existing plant, RINL had taken a motto of **"one tree per every tonne of steel"**. To achieve the same RINL had planted more than 5.478 million trees and is moving towards 6.3 million trees with the motto of one tree per every tonne of steel capacity. These trees are absorbing about 1,20,516 tonnes of Carbon dioxide annually.

Image 18 Impact of lush green man-made forest by RINL

Waste water treatment plant:

To reduce freshwater consumption and wastewater generation during steel production RINL had adopted one of the common best practices, which is a wastewater treatment plant. This initiative has the potential to recycle 473 million gallons of waste per year.

Two treatment plants have been implemented:

- Appikonda Wastewater Treatment Plant (WWTP) (Capacity: 220 million gallons)
- Wastewater Treatment Plant at Balacheruvu (Capacity: 253 million gallons)

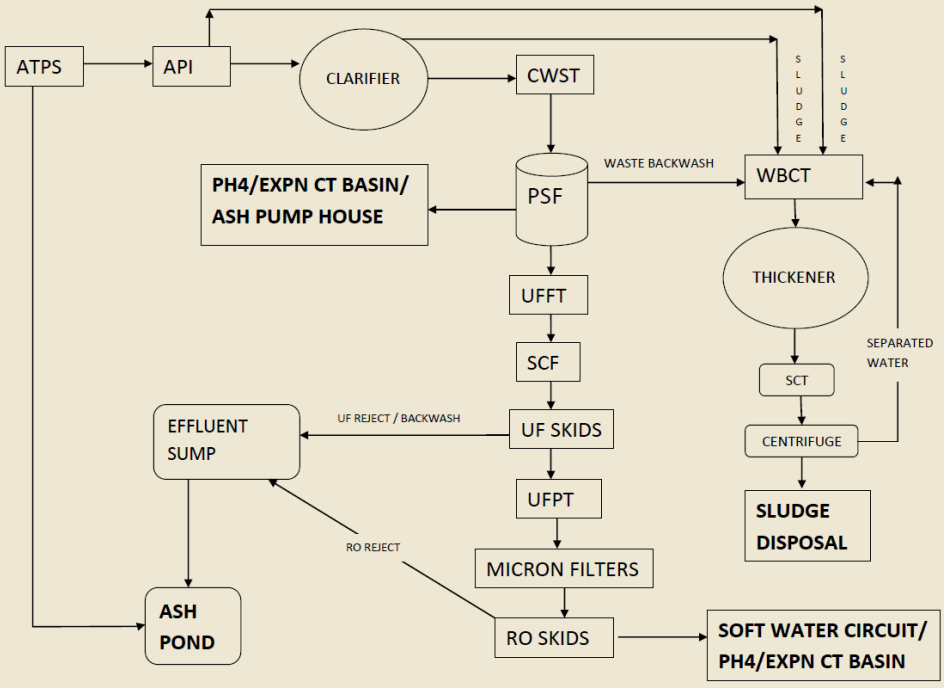


Figure 14 Process flow diagram of the wastewater treatment plant implemented by RINL

Shipping Corporation of India

International Maritime Organisation (IMO) has set ambitious goals of halving GHG emissions by 2050, compared to 2008 levels, while at the same time reducing CO_2 emissions intensity up to 40% by 2030 and 70% by 2050.

In adherence to the regulations and mandates of the Government of India and the IMO, the Shipping Corporation of India has adopted various environmental initiatives that promote climate change mitigation.

The organisation started working from June 2021 onwards to ensure to comply with mandatory IMO guidelines from January 2023 started with many energies' efficient measures. Processes such as underwater hull cleaning, propeller polishing, and hull coating are adopted which will help in reducing total resistance thereby reducing fuel consumption and carbon emissions. The use of shore power for ships drastically reduces the noise, vibration, and emissions in ports. Fitting energy-saving devices on the ship's underwater portion of hull improves propulsive efficiency thereby helping reduce fuel consumption and CO_2 emission. The organisation is also planning to use Biofuel to reduce GHG emissions.

Balmer Lawrie & Co. Ltd

Use of PNG in place of LDO in baking ovens of Drum manufacturing Plant

The conventional LDO in baking oven drums have been replaced with PNG gas fire ovens, imported from M/s KBA Metal Prints Germany. These PNG gas fire ovens have very high efficiency in terms of their calorific value. The Ovens were installed in the year 2013 & have an average life span of 20-25 years.

Recycle and Reuse of Hazardous waste in the manufacturing process of Leather Chemicals

While the manufacturing of leather chemicals was supported by a net zero emission-based process design, the operational cost was high. Hence the company's in-house R&D modified the kettle type reaction to series type reaction system thereby improving efficiency from 55% to 85%. The newly developed process does not generate any effluent from the primary reaction. Acidic effluents are converted to usable products, cleaning chemicals and alkali effluents are converted to saleable leather chemical product. Another advantage of this new process is the liquid by-product discharged from this reaction, which forms the feed for another plant – syntan plant, resulting overall higher plant capacity utilisation. Now, scrubbers and effluent handling equipment are being used for producing new products.

The process began implementation in 2021.

Image 19 Site image: Zero Liquid Discharge Plant of Balmer Lawrie SBU Chemicals located at Manali, Chennai

SJVN

Muck management and Use of Geo Green erosion control blanket

Muck management is being done in line with the approved Muck Management Plan proposed in the EIA/EMP Report and in line with MOEF&CC guidelines.

Generally, the muck which is excavated is inert and does not support any vegetation. There is no nutritional value. The muck gets eroded very fast during rains (25–30-degree slope). This creates a blanket to augment water retention.

The restoration of muck dumping sites in all SJVN projects are planning to use geo-green erosion control blankets (coir-geo textiles) which will enable vegetation to establish early. Geo-textiles are permeable fabrics which, when used in association with soil, can separate, filter, reinforce, protect & drain. Geo-textiles can be used concurrently with bio-engineering structures for slope stabilisation of dumping sites. Geo-textiles made of coconut or jute are biodegradable, and hence they promote fast growth of vegetation by providing nutrients, creating a micro-climate, and by preventing loss of soil in steep slopes. They absorb five times their own weight of water by firstly attenuating the run-off into the drainage system and then releasing it gradually to soak into the adjacent soil for the nourishment of plants.

The phase wise development are as follows:

- During 2008-2009 the technology was conceptualised to increase moisture retention for muck management.
- Pilot projects were implemented in Rampur in Hydro Power Station which is under operation since 2014. Muck was made of jute or coir as it doesn't erode quickly. Restoration for muck dumping was done at the site.

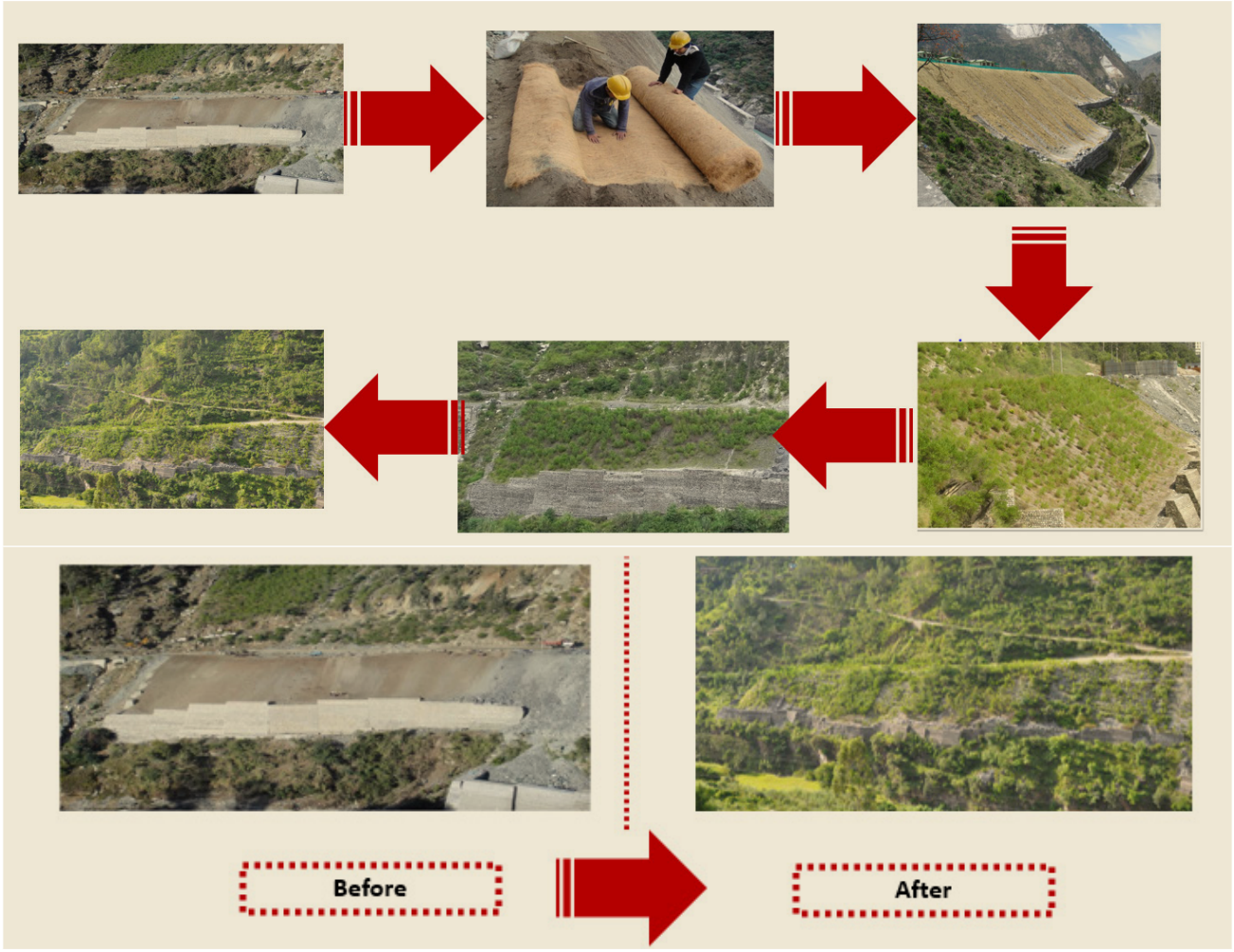


Image 20 Site Image - Muck Dumping Sites

IREL

Thermal Barrier Coating (TBC)

IREL has developed a process technology to produce TBC materials such as Yttria zirconia, Lanthanum zirconate/Gadolinium zirconate. The TBC material from rare earths such as Yttria zirconia, Lanthanum zirconate/Gadolinium zirconate reduces CO_2 emissions. The TBC improves the efficiency of combustion engine by increasing the internal turbine inlet temperature. TBC is applied to the exterior surface of the turbine blades.

Production of Rare- Earth based compounds:

Rare Earth based catalytic converter

IREL has taken an active role to develop three-way catalyst by collaborating with NCL, Pune using Cerium material derived from monazite of beach placer. The rare earth based catalytic converter used in catalytic combustion yields improved economic benefits, due to low concentration of methane in its emissions. It also avoids the formation of by-products in traces like formaldehyde, which may be more harmful than methane itself.

About 35% of CO, 30% of HC and 25% percent of NOx produced into the atmosphere is from just the transportation sector. The catalytic converter is an effective and consistent option for reducing the noxious tailpipe emissions of automobile vehicles and helps to reduce emissions. Cerium is used in automotive vehicles pollution control catalysts for its satisfactory oxygen storage properties and is an extremely active catalyst in Carbon monoxide oxidation, water–gas shift reaction and hydrocarbon conversion.

THDCIL

Revival of old Gharat's by way of renovation and mechanical improvements for higher efficiency

THDCIL focused on the Revival of Traditional ecological knowledge. These interventions, taken up under CSR, created multiple livelihood opportunities and capacity-building opportunities for the local people.

Water mill or locally known as "Gharat" is an eco-friendly, "zero" emission, locally evolved technology used by the rural people for meeting their grinding needs. The basic principle on which the water mill runs is the same as that of a hydroelectric project to produce power. However, in the absence of appropriate technology, water mills were never used for any purpose other than grinding.

THDCIL engaged "Mandakani Waterpower Systems" in Rudraprayag, Uttarakhand, a pioneer organisation in the field of Gharat Modernisation, to modernise the Gharat to produce electricity along with its conventional purpose of grinding.

A total of 15 such Gharats were renovated. Generally, penstock and runner are made of wooden logs, which have been replaced with PVC pipes and metal blades, which reduces pressure on nearby forest and enhances grinding efficiency to almost double the previous rates.

Water Intake- before Modernization

Water Intake- after Modernization

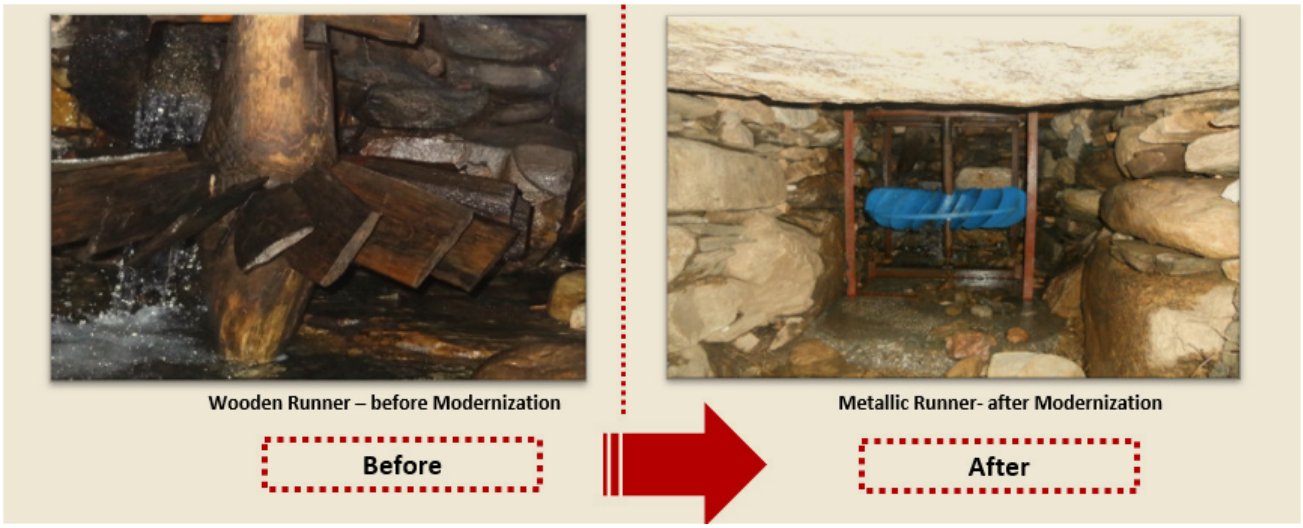


Image 21 Site Image - Experience from Village Pancakki

Strengthening of fragile and dry catchment areas through traditional technique of Chal-Khal to mitigate the climate change impacts on the Basin

Traditionally, rural Uttarakhand, used to dig chal-khal for storing/intercepting runoff due to rainfall over the mountains. The rainwater thus intercepted remains stored in the khal (or small ponds), trickles down to recharge groundwater that fuels the drinking water resources and helps reduce incidences of forest fires. Indirectly this intervention reduces the GHG emissions by reducing the risks of forest fires as well as the soil erosion in the uphill**.**

THDCIL has tried to improve and fund projects for making chal-khal and other water recharge structures in Tehri, Uttarakhand. This intervention started in the year 2011.

Image 22 Experience from Tehri, Uttarakhand

WCL

Development of Mine Eco-Park and introduction of first Eco-mine Tourism in India

WCL has developed an eco-park in Nagpur, which is presently part of the ECO-MINE tourism circuit developed by WCL. This circuit involves a visit to Eco-Park along with two operational coal mines - Saoner Underground Mine- 1 and Gundogan Open Cast Mine, 38 km, and 30 km away, respectively, from Nagpur, Maharashtra. WCL has an MOU with Maharashtra Tourism Development Corporation (MTDC), which brings tourists to visit the Eco-Park along with working mines. The idea of an Eco-Park is to connect fragments of open unused land into a comprehensive network of local ecology conservation and recreational and learning environment.

Image 23 Site image of Gundogan Sand segregation plant

Sand Segregation Plan

River sand is a depleting commodity and natural sand and gravel pose an expensive extraction procedure. Coal fields are required to manage the overburdened soil and reclaim them through backfilling during mine closure. This overburden (OB) soil however due to a 20% swell, can be safely extracted from OB dumps even after re-handling the dump for mine closure. Studies show that processed sand from OB dumps can be the best alternative to river sand. If overburden is processed, it generally yields 60-65% sand, 25-30% clay, and 5% pebbles. WCL has initiated pilot plants for sand segregation and has secured permission from the Government of Maharashtra (GoM) in 2019, for the commercial selling of sand through e-auction for private organisations and without e-auction for government organisations (exclusive of Royalty, Levies, Applicable taxes, and transportation).

Image 24 Site image of Gundogan Sand segregation plant

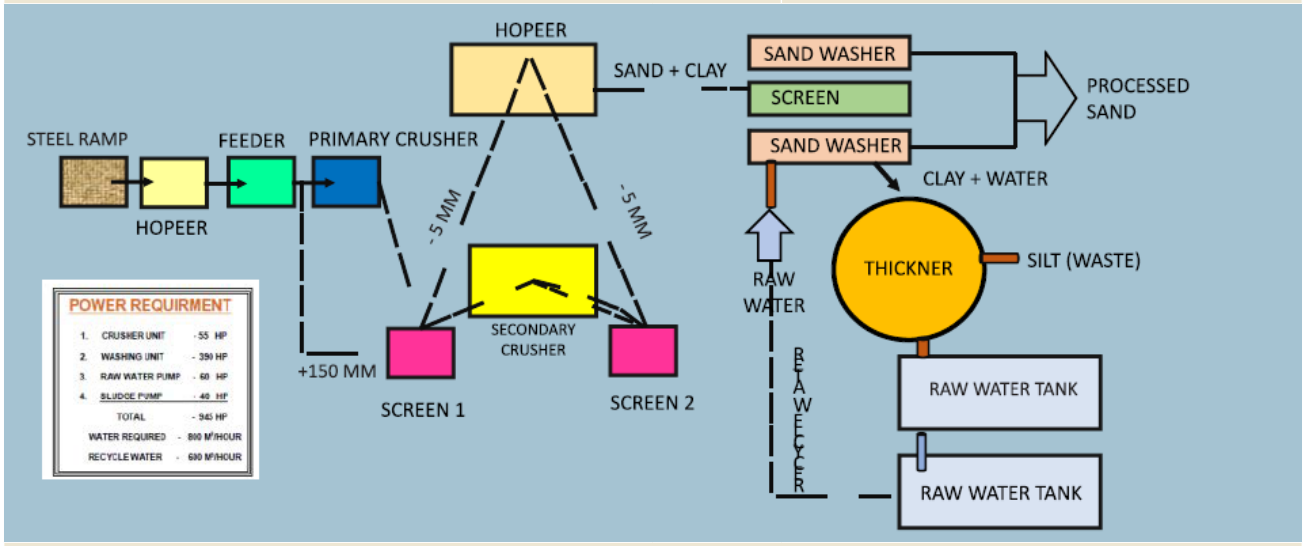


Figure 14 Process flow diagram of Sand Segregation Plan

Coal NEER at Patansaongi – efficient reuse of mine water

The mine water is pumped out from internal mining activities and is transported to the nearby community after proper treatment to use as potable, domestic, and irrigation water. WCL, in line with the Jal Shakti Abhiyan for water conservation campaign initiated by the Government of India, has installed an RO Plant of capacity 2.5 lakh liters/day in Patansaongi village catering to the drinking water needs of around 1,00,000 local citizens.

WCL signed an MOU with women Self-Help Groups (SHGs) in six villages (i.e., Chicholi, Silewara, Rohana, Walni, Ishapur, Dahegaon). Additionally, a bottling plant has been installed as a revenue model for a local SHG.

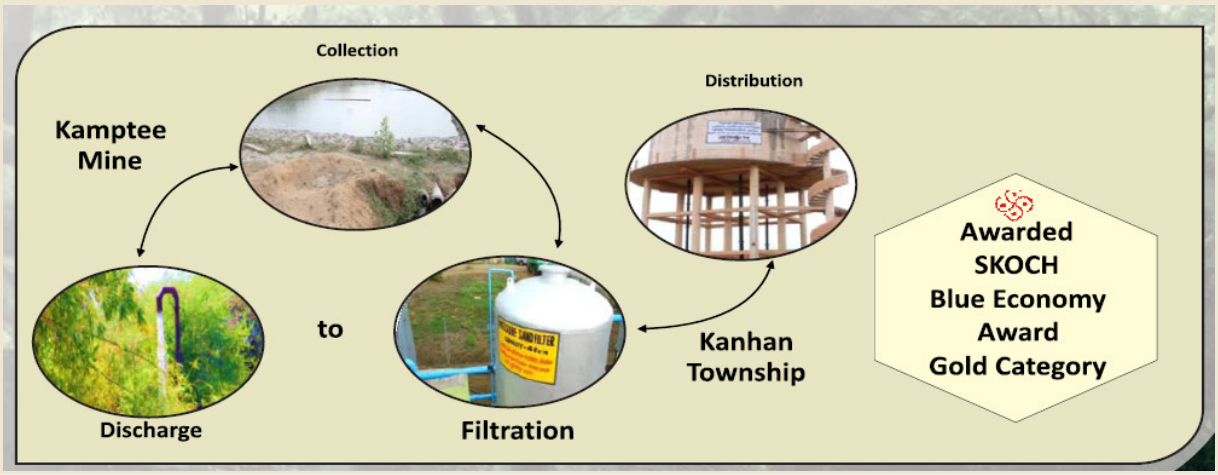


Figure 15 Using the mine water for irrigation purpose -Borgaon Village

Process flow diagram – Reuse of the Mine water

Image 25 WCL's inititive with the Women SHG

Image 26 Using the mine water for irrigation purpose -Borgaon Village

Global Technologies

6.1 Renewable Energy/alternate to Traditional Energy Technology

As per the International Energy Agency (IEA)[8], the energy sector, which contributes more than 75% of global emissions, holds the key to tackling climate change. This makes decarbonisation of the energy system the top-most priority for most countries and stakeholders.

Considering the global GHG scenario and diminishing coal/fossil fuel supply, the world is working towards exploring more areas in the renewable energy sector. As per the International Renewable Energy Agency (IRENA)[9], at the end of 2020, global renewable generation capacity amounted to 2799 GW i.e., a 10.3% rise in the installed capacity. According to the Energy Information Administration (EIA), in 2020, electricity generation was 834 billion kWh from renewable sources. This was about 21% of the total electricity generated in the US, coming in second to the electricity generated from natural gas at 1,617 billion kWh (EIA report).

Worldwide multiple innovative technologies are getting tested and implemented every day. The report identifies a few innovative technologies which are relevant to this study and have an implementation potential in India as per the national policies.

As per the updated NDC, India now stands committed to reducing the Emissions Intensity of its GDP by 45% by 2030, from the 2005 level, and achieving about 50 percent cumulative electric power installed capacity from non-fossil fuel-based energy resources by 2030. The new targets were developed based on the Hon'ble Prime Minister's vision of sustainable lifestyles and climate justice to protect the poor and vulnerable from adverse impacts of climate change.

Considering India's target for 2030 and the initiative taken up by PSEs, this report illustrates a few global innovative technologies which make renewable energy more accessible, efficient, and cheaper.

6.1.1 Solar energy

6.1.1.1 Concentrator photovoltaic - Broad Spectrum solar

Concentrator photovoltaic (CPV) technology is an innovative high-efficiency system in the world of photovoltaic solar technologies. CPV technology uses optical instruments such as curved mirrors or lenses to focus a large amount of sunlight onto a small area of multi-junction (MJ) solar cells (photovoltaic panels) to generate electricity.

6.1.1.2 Concentrated solar system

The innovative concentrated solar system uses the sun's heat directly to generate electricity even during the night, which makes it different from the photovoltaic system. Heliostats (mirrors) focus the sunlight onto a heat receiver on a tall tower. Molten salts circulate through this receiver at a temperature of 560°C and transfer the heat to a circuit that drives a steam turbine to produce electricity. One distinctive feature of the system is the molten salts can be stored for up to 17.5 hours, enabling it to keep operating even without direct sunlight. This system ensures electricity production reliably, 24 hours a day.

Cerro Dominator project located at the Atacama Desert in northern Chile inaugurated in June 2021. The project costed EUR 113 million, funded by The European Union (EU), KfW Development Bank and KfW IPEX-Bank - grant from the EU's Latin America Investment Facility (LAIF) and loans from the International Climate Protection Initiative (IKI) of the German Federal Ministry for the Environment, which are implemented by KfW Development Bank. This project will be replacing the expected emissions of 640,000 tonnes of CO_2 per year by installing a 210MW hybrid concentrated solar power (CSP) and photovoltaic (PV) power complex.

8 Net Zero by 2050, IEA
9 https://www.irena.org/newsroom/pressreleases/2021/Apr/World-Adds-Record-New-Renewable-Energy-Capacity-in-2020

6.1.2 Offshore energy

6.1.2.1 Modular floating wind arrays

Offshore wind power or offshore wind energy is the deployment of wind farms sites in water bodies. Higher wind speeds are available offshore compared to on land, so offshore farms' electricity generation is higher per amount of capacity installed. Till now most of the offshore wind projects have been installed near coastlines. But the ability to install turbines in deeper waters where winds tend to be stronger, opens up a great opportunity to generate renewable wind power. Close to 80% of the potential offshore wind power is found in deep waters. In addition, positioning floating turbines much further off the coast helps avoid conflicts with those who object to their impact on coastal views.

In Scotland, five **floating offshore wind turbines** stretch 574 feet (175 metres) above the water. The world's first floating windfarm, a 30-megawatt facility run by the Norwegian company Equinor.

Interior Bureau of Ocean Energy Management approved Vineyard Wind 1, America's first commercial-scale offshore wind farm, near Martha's Vineyard, which is projected to generate 800 megawatts (MW).

6.1.2.2 Tidal energy

Tidal energy is one of the oldest forms of energy harnessed from the naturally occurring phenomena of rise and fall of ocean water level due to gravitational attraction between sun, moon, and the earth. It is non-polluting, reliable, and predictable.

Tidal stream turbines (TSTs) are Axial turbines and tidal stream generators draw energy from water currents in much the same way as wind turbines draw energy from air currents.

The Orbital O2, a floating 2MW tidal turbine began generating power for the UK grid in July 2021. It was designed and built by Orbital Marine Power Ltd. This is the basis for accelerating commercial use of floating tidal energy. The European Union supported this effort with a EUR 20.5 million grant from the Horizon 2020 program.

6.2 Clean Transportation technology

Indian transport sector is responsible for 13.5% of India's energy-related CO_2 emissions, with road transport accounting for 90% of the sector's total final energy consumption followed by rail and domestic aviation (both at 4%) (IEA, 2020). Thus, focusing on cleaner transportation is very important to reduce the India's GHG emissions. Around the world, major initiatives towards making cleaner and greener transport systems focus on two things:

6.2.1 Adaptation of Electric Vehicle and making them more efficient and cost effective

6.2.1.1 New battery technology

Battery cost is one of the major issues preventing wider adoption of electric vehicles. However, new battery technologies are poised to solve this issue at once. Lithium-ion batteries have become the industry standard over the two decades of EV development. These innovations will shape the future of EV charging, accelerating EV adoption. The new technologies will be game-changers from an EV charging experience perspective, ensuring support of new business models for EV charging, and generating new business opportunities for e-mobility industry players.

New technologies such as **graphene-based technologies**, which charge in 15 seconds are being developed and tested by Skeleton Technologies and Karlsruhe Institute, Germany. These are expected to supplement, not replace, traditional EV batteries.

Toyota is working on sulphide-based, solid-state batteries that are projected to last almost 30 years. Other companies are trying to eliminate cobalt, one of the most expensive components in existing batteries, which will significantly reduce the price.

6.2.1.2 Innovation in charging infrastructure for EVs

The absence of an efficient EV charging facility is one of the hindrances towards EV adoption. Multiple innovations are going on to make EV charging infrastructure more easily accessible, effective, and efficient.

Wireless EV Charging:

Wireless EV charging may be the catalyst for the mass adoption of electric vehicles. With a high-powered wireless EV charging system, vehicles can automatically charge while parked in selected pick-up/drop-off locations – an ideal solution to keep taxis or autonomous vehicles perpetually charged. The system requires no physical charger-vehicle connection; it consists of multiple charging plates installed underground that engage automatically. No charging station will be present on the ground, delivering more convenience and less clutter in the public space.

The state of Michigan has unveiled a first of its kind wireless charging pilot program in the US, one of two key announcements to improve EV charging infrastructure in conjunction with the Office of Future Mobility and Electrification.

Ultra-fast charging:

Ultra-fast charging is the logical next step in satisfying EV drivers' demand for charging on the go. A fill-up at the pump with a traditional internal combustion engine vehicle takes only a few minutes, and EV drivers are demanding the same time for charging their EVs. Ultrafast chargers are delivering 32 km (20 miles) of range in one minute, removing driver range anxiety, one of the major barriers that limits the adoption of EVs.

Australia is working to create a countrywide national ultrafast EV charging network. The charging stations will be spaced to enable EV drivers to confidently drive between Australia's major cities, with convenient, ultra-fast charging sites enabling them to charge in minutes.

6.2.2 Developing rail network as a net-zero sector

Rail being one of the major contributors to the transport industry is one of the low GHG emitting sectors. The world is working towards making it a net zero sector. Optimising the operation and infrastructure will be key to achieving net zero. A key part of this strategy involves the IT sector. Different softwares can be harnessed to make railway operation and infrastructure more optimised and climate friendly.

Researchers at the Department of Energy's (DOE's) National Renewable Energy Laboratory (NREL) are collaborating with leading industry and research partners, including the University of Illinois Urbana-Champaign (UIUC), BNSF Railway, and Southwest Research Institute, on a new modelling framework that can be used to analyse and plan net-zero-emission and hybrid freight train systems. Soon, Advanced Locomotive Technology and Rail Infrastructure Optimization System (ALTRIOS) software will offer the first fully integrated package to optimise deployment of locomotive technologies, railway energy supply infrastructure, and train operating practices for cost-effective deep decarbonisation.

6.3 Carbon capture, utilisation, and storage

CCUS plays a diverse role in meeting climate goals by capturing carbon from large point sources and facilities which use either fossil fuels or biomass for fuel such as steel production. As rightly observed by the IEA, the momentum for CCUS is increasing. CCUS facilities, if successfully implemented, can capture 130Mt of CO_2 per year.[10]

CCUS adoption is increasing globally with applications being piloted in the production of chemicals, fertilisers, hydrogen, natural gas processing, power generation, cement, steel making, etc. However, this technology is expensive, and costs can be wide ranging, depending upon the application and availability of storage/ utilisation opportunities. Carbon consciousness and an effective carbon price, driven by carbon taxes, quota, public sentiment, and other regulations, would be the key drivers for accelerating adoption.

The Alberta Carbon Trunk Line (ACTL) system is the world's newest integrated, large-scale CCUS system. The ACTL system captures industrial emissions and delivers the CO to mature oil and gas reservoirs for use in enhanced oil recovery and permanent storage. As the world's largest capacity pipeline for CO from human activity, the ACTL is capable of transporting up to 14.6 million tonnes of CO per year. This represents approximately 20% of all current oil sands emissions or is equal to the impact of capturing the CO from more than 3 million cars in Alberta. The future of a lower carbon economy relies on key infrastructure like the ACTL system to provide sustainable solutions to global energy requirements.

6.3.1 Direct Air Capture

Direct Air Capture (DAC) technology capture CO_2 by pulling in atmospheric air, then through a series of chemical reactions, extracts the carbon dioxide (CO_2) from it and returns the rest of the air to the environment. This is what plants and trees do every day as they photosynthesise, except DAC technology does it much faster, with a smaller land footprint, and delivers the carbon dioxide in a pure, compressed form that can then be stored underground or reused.

DAC technology works by using giant fans to draw in air, with the CO_2 (roughly 0.04% of the content of air) bonding to chemicals known as sorbents. When the sorbent is saturated, it is heated to 80-100C to release the captured carbon dioxide. Though it is a well-known technology, energy consumption is high. Technological advancement is required to make it more efficient and commercially viable.[11]

Hinwil DAC plant, Switzerland, the world's first commercial DAC plant inaugurated in 2017, operated as a three-year demonstration project in co-operation with the partners Gebrüder Meier and KEZO, a Swiss municipal waste disposal company with a contribution towards non-amortisable costs by the Swiss Federal Office of Energy (SFOE). The plant nominally captured 900 tonnes of CO_2 per year from the air and delivered the CO_2 to a nearby greenhouse.

6.3.2 Bioenergy with carbon capture and storage

Bioenergy with carbon capture and storage (BECCS) is the most scalable negative emissions technology available today to remove CO_2 from the atmosphere. Biomass (organic material) is converted into heat, electricity, or liquid or gas fuels (the "bioenergy" step), and the carbon emissions from this bioenergy conversion are captured and stored in geological formations or embedded in long-lasting products (the "carbon capture and storage" step). Because the biomass draws carbon from the atmosphere as it grows, BECCS can be a negative emissions technology when it is implemented well.

10 Carbon capture, utilisation and storage, IEA
11 https://www.rechargenews.com/energy-transition/the-amount-of-energy-required-by-direct-air-carbon-capture-proves-it-is-an-exercise-in-futility/2-1-1067588

Though BECCS can be a negative emissions technology when it is implemented well, it also has some concerns[12]. Unplanned application of BECCS can lead to biodiversity loss, water scarcity, soil carbon loss, hazards from the geological storage (CO_2 leakage, seismic activity, and water pollution), etc. Many of these issues would arise only from a very large-scale adoption of BECCS. Smaller scale applications using agricultural residues or marginal agricultural land generally pose fewer risks.

Bonanza CCS (USA): 100,000 tonnes per annum (TPA) of CO_2 is compressed and piped from an ethanol plant in Kansas to the nearby Stewart Oil field for Enhanced Oil Recovery (EOR).

Husky Energy CO_2 Injection (Canada): 250 tonnes per day (TPD) of CO_2 is compressed and trucked from an ethanol plant in Saskatchewan to nearby Lashburn and Tangleflags oil fields for EOR; the fields are shallow (~500m) and comprise heavy oil.

Drax Power Plant (UK):

Biomass power generation pilot in North Yorkshire with the potential to develop CO_2 capture and storage. Drax BECCS pilot (with C-Capture) started capturing CO_2 in world first with 100% biomass feedstock.

6.4 Hydrogen Fuel

In the quest to develop safe and environment-friendly energy, hydrogen is gaining fast recognition despite its current non-viability due to high production cost. The IEA reports that "there is a growing international consensus for clean hydrogen to be playing a key role in the world's transition to a sustainable energy future. Hydrogen will be crucial to help reduce carbon emissions from industry and heavy transport, and also to provide long-term energy storage at scale."[13]

Hydrogen is a versatile energy carrier that can be produced from a wide range of sources and used in many ways across the entire energy sector. Currently, hydrogen is available majorly through three sources: grey, blue, and green hydrogen. The grey and blue hydrogen are those produced from natural gas where carbon-di-oxide is a bi-product. While grey hydrogen releases CO_2, blue hydrogen captures and stores CO_2. The most efficient of the three types are green hydrogen produced by electrolysis of water using renewable energy without any CO_2 emissions. It could hence become a game-changer in its low-carbon form, but its widespread adoption faces challenges.

Japan's Hydrogen Initiatives[14]

Japan was the first country in the world to draw up a hydrogen strategy in 2017. It aims to cut emissions by 46% by 2030 and achieve carbon neutrality by 2050. As part of Japan's transition to 'hydrogen society' the city of Kobe, produces heat and electricity from hydrogen for a hospital, sports center, and trains.

Japan is researching extensively on green hydrogen especially at the Fukushima Hydrogen Energy Research Field - FH2R - one of the world's largest facilities of its type. Japan has also set a goal to reduce the cost of hydrogen to that of the current rates of fossil fuel by 2050. One of the key strategies adopted for this is to empower the supply chain majorly through the mass transport of hydrogen by sea and huge storage facilities.

12 https://www.american.edu/sis/centers/carbon-removal/fact-sheet-bioenergy-with-carbon-capture-and-storage-beccs.cfm
13 IEA (2019), *The clean hydrogen future has already begun*, IEA, Paris https://www.iea.org/commentaries/the-clean-hydrogen-future-has-already-begun
14 Euronews. (Nov 2021.). *Japans Hydrogen Power Play*. Retrieved from: Japan's hydrogen power play | Euronews

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Conclusion

A low-carbon transition is critical for the world to limit warming to below 2°Celsius by the end of the century – the target set for the world under the Paris Agreement. India has committed ambitious targets as part of its first and second NDCs and has also declared a long-term net-zero target of 2070. To achieve net-zero, every sector of India's economy must first reduce emissions as much as possible before compensating for residual emissions through removals. Given PSEs' role in the Indian economy – both in terms of economic output and significant presence in hard-to-abate sectors – it is important for them to innovate and adopt low-carbon technologies for India to meet its net-zero target.

PSEs are uniquely placed to lead India's low-carbon transition. The government ownership structure provides an opportunity for steering the implementation of national climate policy preferences and being a leader for the country in the journey to net-zero by 2070. Leading this transition is also key for many PSEs from the climate risk and competitiveness perspectives. PSEs need to avoid overinvesting in high-carbon assets that may become stranded in the long-term, and at the same time ensure competitiveness with other companies that are prioritising low-carbon investments to improve public image and reduce business risks.

Many of the technologies highlighted above have been developed in-house through R&D by the PSEs, while many others are in pilot stages and require a proof-of-concept before scaling. This demonstrates the immense technical capacities within Indian PSEs to explore, innovate, and scale low-carbon opportunities within their business sectors. There is a lot of potential for knowledge exchange among PSEs within the same sectors to facilitate a faster low-carbon transition of the global industrial sector. Such collaborations will enable overcoming some key barriers, including access to finance and achieving commercial viability faster. Descriptions of the technologies and process interventions in this document also includes an estimate of the ease of replicability and scalability; this is an attempt to kick-start knowledge exchange by providing some information for the interest reader on how these technologies may be adopted into their own firms wherever applicable. As described in Chapter 6, several companies around the world are also pioneering low-carbon technologies and processes. Showcasing Indian innovations on global peer exchange platforms will also open new business opportunities for the PSEs. At the same time, globally mature technologies can be brought into India through dedicated, sectoral knowledge sharing channels. A more exhaustive review of global technologies and relevant actors could be the next step in facilitating international knowledge transfer.

An exhaustive description of the initiatives with technical details on the technologies and processes was beyond the scope of this document. Developing such a document, within the boundaries of trade secrets, could be a next step in sharing information on the excellent climate and environmental action undertaken by PSEs as it may greatly improve the possibilities for replication, accelerating the low-carbon transition. Further, a biennial update on this document will ensure regular knowledge dissemination on PSEs' initiatives and continue to foster collaborations that may develop as a result of this publication.

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