



C2CNG

**R&D
PROJECT**

JUNE 2023

annexure

I

PROJECT
BACKGROUND

BUILDING COAL2CNG

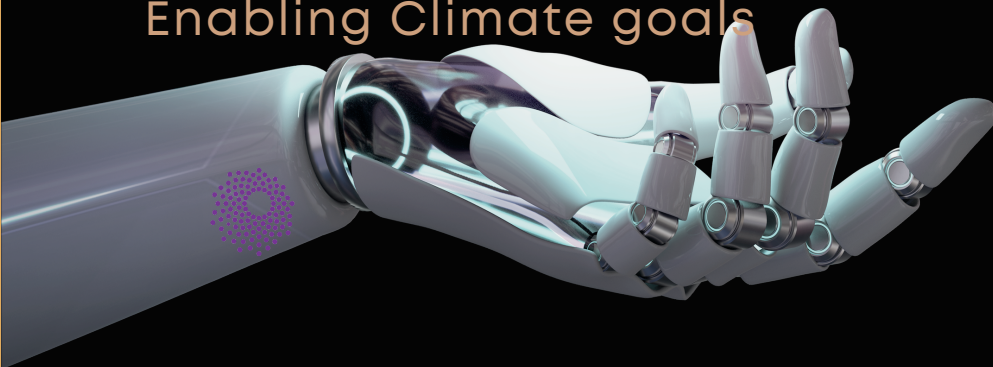
for

Energising transport &
cooking

Eliminating Imports

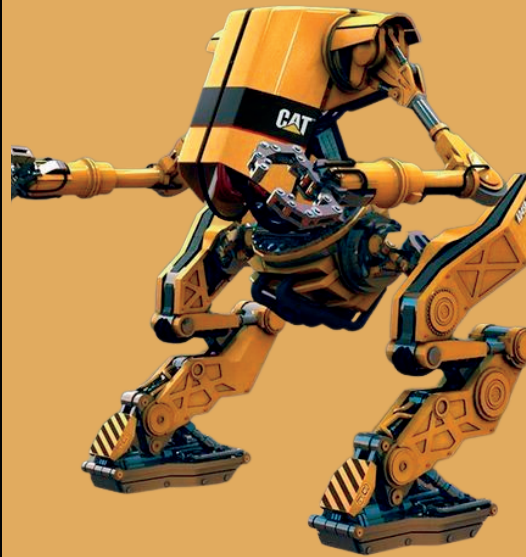
Expanding biogas capacity

Enabling Climate goals



Underground coal to natural gas

Natural gas as digital fuel for data, transport & cooking





The Coal Technology Task Force was created by the IIT Alumni Institute in 2018. The task force was mandated to evaluate coal gasification options including syngas production by underground gasification and coal to chemical technologies based on conventional high pressure, high temperature technologies such as the Fisher Topsch reaction. The task force rejected syngas based options in 2020.



As part of the MegaLab mission, the task force studied the fifteen year work of one of its volunteers - Prof Prasad Dhurjati, an alumnus of IIT Kanpur. This work related to microbial conversion of underground coal deposits directly into methane. Unfortunately Prof Prasad passed on in June 2020, a victim of covid. The task force recommended microbial conversion as the only known viable and practical option for coal utilisation in January 2022.



The Forum, Institute and Incubator initiatives of the IIT Alumni Council worked with the three mission organisations - MegaLab, MegaFund and MegaReach - to configure a scaleable solution for massive scale conversion of underground coal directly into methane using microbial conversion. This approach has the potential for 10x improvement in the overall conversion cost compared to the coal to syngas to methane conversion.



There is no short cut for transformation of India to an Atma Nirbhar Bharat.

Radical transformation needs technology first. Subsidies and public policy is then just an enabler to accelerate mass deployment. However, without appropriate technology to back - subsidies can end up as vanity projects, eventually achieving no real purpose.

One of our drivers as a philanthropic body is the realisation that the global IIT alumni network can deliver technology solutions which no commercial player or incumbent can do. The radical findings of the Coal Technology Task Force are yet another example. What started off as an initiative to evaluate coal gasification technology of 1850 vintage (which was practically implemented by Sasol in 1950) - not only led to the rather obvious conclusion that conventional coal gasification was an obsolete, unviable and unscaleable proposition - but more importantly, it led to the discovery of the microbial process as an unexpected innovation from the MegaLab platform which was addressing the Covid pandemic.

Ravi Sharma
President & Chief Volunteer

IIT Alumni Council
Chief Volunteer
Retired Corporate Leader

IIT Roorkee Distinguished Alumnus



Executive Summary

The final report of the Coal Technology Task Force concluded that commercialisation of the in-situ underground microbial methanation process was the only viable, scaleable and suitable technology to use the vast underground coal deposits of India.

One of the findings of the task force is that annual CNG imports would top USD 100 billion a year (at current levels of indigenous CNG production) to meet the demand from just four segments - fuel for public transport vehicles, piped cooking fuel, mission critical data centres and non solar hours power generation. The primary driver for electrification of transportation is the lower fuel cost per km even if electricity is generated onboard - using fossil fuel such as CNG - via internal combustion engines or fuel cells. The task force noted that a Maruti Ertiga CNG engine could power a full sized DTC bus leading to substantial saving in fuel consumption.

There is a need for a concerted national effort across public and private enterprises, which could lead to global leadership for India in the area of microbial conversion of underground coal directly into methane. This methane can complement biogas, directly mined natural gas and coal bed methane (CBM). CBM, by itself is undesirable for environmental reasons.

India already has substantial infrastructure to distribute CNG to all three key segments – power generation, transportation and cooking gas. The primary problem is the reliance on imported CNG, which has led to thousands of MW of gas-based power plants lying unused.

Presentation Objectives

1

The core objective of this presentation is to get the buy-in of all stakeholders in India to support a technology development initiative for microbial methanation of coal which has the potential of saving Rs 80 lac crores (USD 1 trillion) in forex over its useful life.

2

The MegaFund initiative of the IIT Alumni Council is catalysing a Rs 2,000 crore technology development program. This will facilitate the indigenous development of two key technologies:

- 1.1 Biomethanation of coal in underground coal mines to produce methane
- 1.2 Production of hydrogen in a moving vehicle from water using thermolysis.

3

Being an introductory presentation, the slides are configured to address the macro business issues. This is not a technology presentation.

4

The target outcome from this presentation is support and suggestions for bringing these projects to life as early as possible.

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Chapter. A

Background

of the project

A Background

of the project

1

The IIT Alumni Council (Forum/MegaLab/Institute) approached the MegaFund mission to consider an investment in three related technology development projects:

1. Autonomous underground drilling to create insitu bioreactors in underground un-mined coal seams.
2. Direct microbial conversion of coal into methane underground.
3. Low cost thermolyser powered by CNG for onboard production of hydrogen from water.

2

The MegaFund evaluation team constituted an Investment Committee to look into the project. The following slides contain an overview of the recommendations.

Original proposal evaluated

Financials

India coal

Strategic imperatives

Autonomous

Methane

Sequester



Financial Overview : Mining Automation

Methane Capacity: 10 million tons pa
Operation: 24/7, 365 days

Workflow: Underground drilling to create bioreactors where in-situ coal is used to produce methane based on nutrient feed from the ground level.

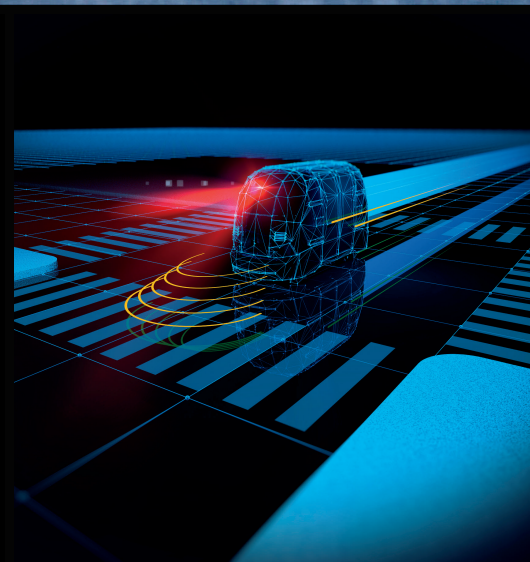
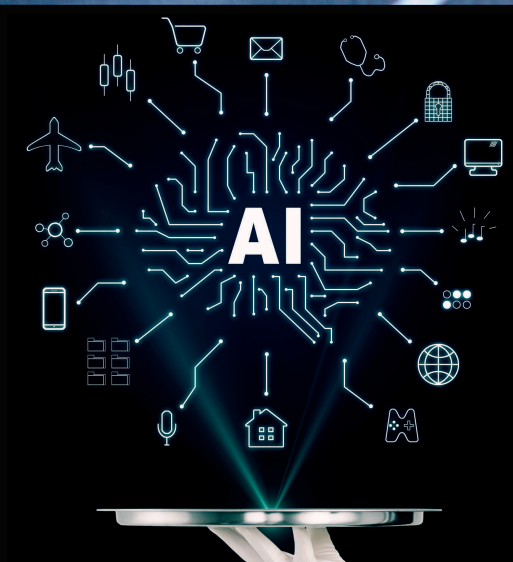
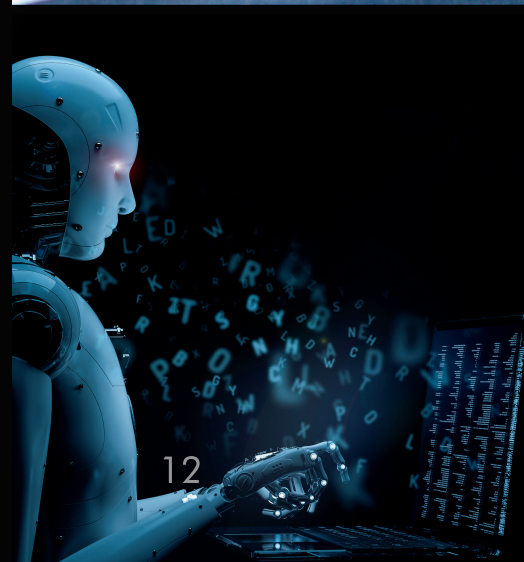
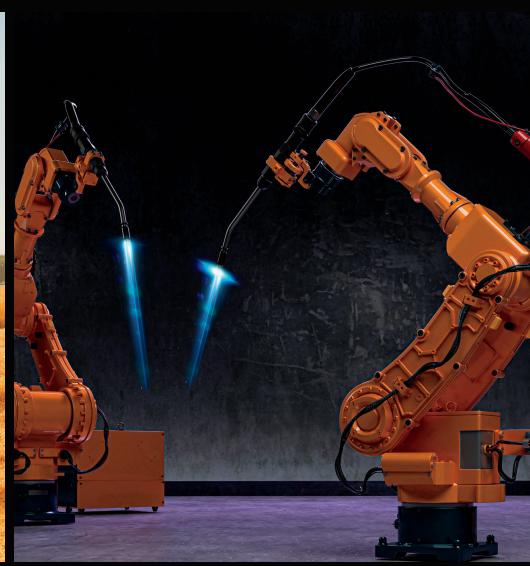
Automation: Completely autonomous operation

Surveillance: Hyperspectral imaging of the bioreactors to continuously monitor microbial density and conversion rates for the purpose of nutrient feed regulation.

Capital cost estimate: Rs 30,000 crores for drilling to create the initial bioreactor capacity. This is only the initial drilling cost

Total number of mine locations: Twenty with each mine having a capacity of 0.5 million tpa.

Useful life of mine: Ten years with one year gestation between bioreactor creation and start of production.



Biomethanation

Methane capacity	0.5 million tpa per mine (on 100% methane basis)
Total mine heads	20
Annual production	10 million tons
Distribution	Compressed gas pipeline or cylinders
Alternate use	Excess gas fed into 75 MW gas engines for power generation
Expected gas revenue	Rs 450 Billion (Rs 45K crores) pa
Capital cost estimate	Rs 60,000 crores.* (excludes drilling capcost of Rs 30K crores)

Thermolyser Fuel Cell

Power capacity	75 KW to 75 MW
Annual production	10 GW at Rs 15/W
Expected revenue	Rs 150 billion (Rs 15,000 crores)
Technology dev cost	Rs 500 crores*

**subject to detailed project report final findings.
Figures are indicative and tentative*

India Coal Overview

Coal is the primary fossil fuel of India and constitutes 55% of India's energy basket. Coal based power generation accounts for around 70% of electricity produced in India. Coal is abundant, available and affordable. About 85% of India's coal is mined by Coal India, a listed corporate controlled by the Government of India under the Coal Ministry. Coal India produces around 600 million tpa of coal, a lot of it is high ash and low calorific value.

Around 95% of output is from open pit mines. Coal India plans to substitute the 200+ mtpa import through mine developers and operators who would produce 160+ mtpa. Most of the Indian coal deposits are underground and unviable for mining.

Coal prices in India are among the lowest in the world. So is the cost of production. As a result, Coal India makes an annual profit of over USD 2 billion inspite of selling coal at very low prices.



Capacity expansion projects with a total outlay of over Rs 100,000 crores are underway. Annual revenue net of taxes is around Rs 100,000 crores – and over 50% of the costs are manpower costs.

Contracting and outsourcing costs are around 33% of the direct manpower cost. CIL has about 250,000 blue collar staff and nearly 15,000 officers. Annual reduction is an indicative 5% pa.

Strategic Imperatives

Increase production and reduce imports through the use of four basic concepts:

Conversion of underground coal deposits into methane using microbial conversion. Autonomous bioreactor management on a 24/7 basis using hyperspectral imaging and deep learning.
(disruptive innovation)

Onboard conversion of methane into hydrogen using thermolysis of water using CNG as a fuel.
(disruptive innovation)

Electrification of drive trains in public vehicles. This helps realise the benefits of electrification without the need for electric charging points and the downtime taken by charging.
(already existing technology)

Production of hydrogen from CNG using reforming at hydrogen filling and production centres.
(already existing technology)



Total Capcost Estimate

Rs 90,000 crores

Implementation Time

48 months

Annual Import Substitution

Rs 45,000 crores



Climate Change Objective

To replace gasoline in transportation, coal in power generation, LPG in cooking gas and diesel generators in data centres.

Production Objective

To monetise unused underground mines.

Technology Objective

To produce CNG indigenously from unmined underground coal by microbial conversion.



Biomethanation



India has several underground coal mines which are either unviable or out of service for other reasons. There are over 200 such mines in India. These mines have rich coal reserves, which are difficult to excavate and bring to the surface. In areas like Meghalaya, rat hole mining has been banned for various reasons, including the risk to the miners.

India has an established end to end ecosystem for compressed natural gas. However, India is a large importer of natural gas for a variety of applications -

from transportation to power generation to fertiliser production. Natural gas can also be feedstock for hydrogen production.

The IIT Alumni Council's engineered biomolecule incubator has developed bacteria-based enzymatic solutions which can convert underground coal into methane.

This methane can be pumped out and used as a CNG replacement. Using a thermolyser, the methane can power conversion of water into green hydrogen.



Autonomous Operations

Unlike conventional underground mining, the current proposal envisages creation of unmanned bio reactors in coal seams which are fed with nutrients for sustenance of microbial colonies which use engineered microbes for rapid conversion of coal into methane.

Nutrient regulation requires continuous monitoring of the underground reactors. This is achieved by using hyperspectral cameras that monitor the composition and density of the microbial colonies.

The real time information is used to control and regulate the nutrient feed required to sustain the microbial processes.

The drilling process uses low diameter cylindrical reactors which are upto one km long and set up in a horizontal form factor emanating radially from a central stem for nutrient delivery.

Coal is a hydrocarbon with 3% hydrogen content whereas methane has 25% hydrogen content.





Sustainability Overview

Coal India is enhancing sustainability through water recovery, plantations, solar power and surface mining. It spends over Rs 500 crores on CSR projects. They include Rs 250+ crores of covid relief and Rs20 crores for Thalassemia screening.

Underground mines, which account for under 10% of the production and over 40% of the workforce, are being phased out. Wage costs are high because of continuous increases driven by the Pay Commissions.



In order to pivot focus onto the blue economy and green chemistry paradigms, the MegaLab initiative which has developed significant competencies in the creation and propagation of micro-organisms was brought into the project.

This helped to view the problem from the lens of biotechnology rather than from a thermochemical perspective.



Chapter. B

Findings

of the investment committee

B1 Findings

of the investment committee

The Investment committee teams carried out a detailed study of the following from April 1, 2022 till June 30, 2022:

- a The approach adopted by key industry players in India like Netra at NTPC
- b Global trends in the sector
- c Available technologies that could be optimised for India
- d Available incentives and carbon credit framework
- e UN framework on meeting climate change targets
- f The blue economy and green chemistry developments
- g Learnings from the MegaLab initiative of the IIT Alumni Council
- h Inputs from MegaLab partners such as CSIR, ICT University and CII Groups

B2

Findings

of the investment committee

The MegaFund evaluation team constituted an Investment Committee to relook into the project from June 2022 to March 2023.

The investment committee members interacted with Board level leaders from various companies in related fields such as mining, power production, CNG distribution. They also met up with companies like Lanzatech who have microbial systems for conversion of carbon dioxide and carbon monoxide.

Based on inputs from various stakeholders, the investment committee suggested an alteration of the proposed project to the following:

- a Replace open cast mining with underground mining. 40% of Coal India's workforce is employed in extracting 10% of the output. Several underground coal mines were either used sub-optimally or not used at all.
- b Alter the coal to methane conversion process from a mix of bioconversion and thermochemical conversion to 100% bioconversion
- c Catalyse the development of CNG based thermolysers for onboard production of green hydrogen from water. Complement this with PEM type fuel cells for the production of electricity in non peak hours and for usage in public transportation including shipping, trucking, passenger transport etc.

Revised proposal approved

India coal

Strategic imperatives

Autonomous

Methane

Thermolyser

Capacity

Investment

This approach reduced the project cost from Rs 1,40,000 crores to Rs 90,000 crores (on an indicative pre-DPR basis).

The altered project had the following installed capacities:

Autonomous mining restricted for application in undersea and space mining for now.

Biomethanation: 10 million tpa of CNG (Rs 45,000 crores pa at Rs 45 per kg).

Project cost: Rs 90,000 crores

Thermolyser fuel cells: Create 10 GW capacity through technology licensing.

Technology development cost: Rs 500 crores



Rationale for changes in strategy

Original proposal

Challenges foreseen

Committee conclusions

Opportunities identified

Imperatives for
revised strategy

The Research Arm of the IIT Alumni Council had approached the MegaFund mission in 2020 to consider an investment in three related projects:

1. Autonomous open cast mining
2. Coal bed methane
3. Carbon sequestration

The total investment envisaged in the three ventures was Rs 140,000 crores.

The project has since been altered to:

- a. Autonomous underground reactors
- b. Insitu microbial conversion
- c. Thermolyser based fuel cells using CNG and water for power production.

The total investment for 10 million tpa of CNG is now pegged at Rs 90,000 crores.

For a minute, lets step back to what was proposed and why it was altered.

Broad challenges going forward

The broad Challenges identified by the Investment Committee were as follows:

- 1 Global leadership in microbial conversion is possible and highly desirable.
- 2 Using thermolysers for onboard production of hydrogen using solar thermal, CNG burning or nuclear power is more efficient than any other option.
- 3 Global warming and electrification are leading to new challenges
- 4 Hydrogen is not yet there, and batteries need more development.
- 5 The thermolyser based fuel cell is suitable not just for road transportation but also for shipping and naval use.

Challenge 1

Global leadership in microbial conversion of coal.

The bulk of India's coal is now produced from open pit mining. India a large importer of coal for two reasons - insufficient production and poor quality of domestic coal.

The production issue can be solved by increasing production from existing and new open pit mines.

The unmined underground coal can be used by converting the same into CNG by microbial conversion. There is no proven existing player in this field. The underlying science of microbe amplification and genetic alteration is now well understood.

India has little chance for global leadership in highly automated open pit mining. However, global leadership is possible in creation of underground bioreactors which are created using advanced methodologies used in fracking and the coal bed methane industry.



Challenge 2

Domestic coal needs upgradation of calorific value.

India is a net importer of coal to meet demand from existing users. It would thus not be advisable to divert existing or proposed/ work in progress open pit mining capacity for CNG production.

Indian coal is of poor quality in terms of calorific value. Thus the challenge is to replace imported coal by increasing the calorific value of Indian coal complementing it with CNG.

This approach could take the calorific value of the coal to match the best quality imported coal (and at a substantially lower cost)

Challenge 3

Peak power and base load power continue to be a challenge

Power on the go (transportation, for example) costs 3x of stationery power (powering a car vs powering a stationery Aircon).

Similarly, the cost of time-shifted solar power is around 3x the cost of real time solar power.



Challenge 4

Global warming and electrification are leading to new challenges.

GDP growth in India will lead to an improvement in quality of life which in turn will lead to higher energy requirement per capita. The energy mix is shifting towards electricity. A large chunk of this electricity demand could be met by rooftop solar.

Telecommunications and the electrification of transportation will lead to new demand profiles. Global warming will increase power consumption for air conditioning. This would put new kinds of pressure on the electric grid.

The fastest growing energy needs are transportation, Aircon and cooking fuel. The cost of batteries (and import requirements for lithium and cobalt) and peculiar needs of Indian cooking have made it challenging to replace gas-fired, flame-based cooking systems with electric/ induction systems.

Challenge 5

Hydrogen is not yet there and batteries need more development.

The universal fuel emerging is electricity. But not yet for transportation and cooking. Batteries need to be made cost effective and produced at 10x or 100x current volumes.

The raw material supply chain is a challenge, and new chemistries like lanthanide are still in development. H₂ is still futuristic. Interestingly, most of the world's hydrogen is produced from methane / CNG



The conclusions

The revised conclusions of the Investment Committee were as follows:

- 1 Coal is a hydrocarbon and not just carbon.
- 2 The reality is that we do not have wind, crude oil, natural gas or lithium/cobalt. We only have solar, coal and thorium.
- 3 We need at least three energy sources – coal, CNG and nuclear – besides solar.
- 4 India has adequate reserves for thorium and micro nuclear reactors are now safe and practical. They adhere to net zero. CNG can be replaced by nuclear heat sources for thermolysers.
- 5 The bio-methanation process has direct applications for several other raw materials, including biomass.

Conclusion 1

Coal is a hydrocarbon and not just carbon.

Indian coal is low in calorific value but is ideal for in-situ bio-methanation in underground mines. India has the biotech ability to manage the micro-organism cultures and the skills in hyperspectral imaging to use long wave infrared based imaging to track the methane from the ground level.



Conclusion 2

The reality is that we do not have wind, crude oil, natural gas or lithium/cobalt. We only have solar, coal and thorium.

The only way to navigate the expected increase in energy needs and the shift in energy mix towards electricity is to strengthen rooftop solar, produce CNG and base load from thorium.

India has tens of billions of tons of underground coal, which will, in all probability, never be mined using conventional mining techniques – whether manned or autonomous.

These offer the most attractive raw material possibilities for in-situ bio-methanation



Conclusion 3

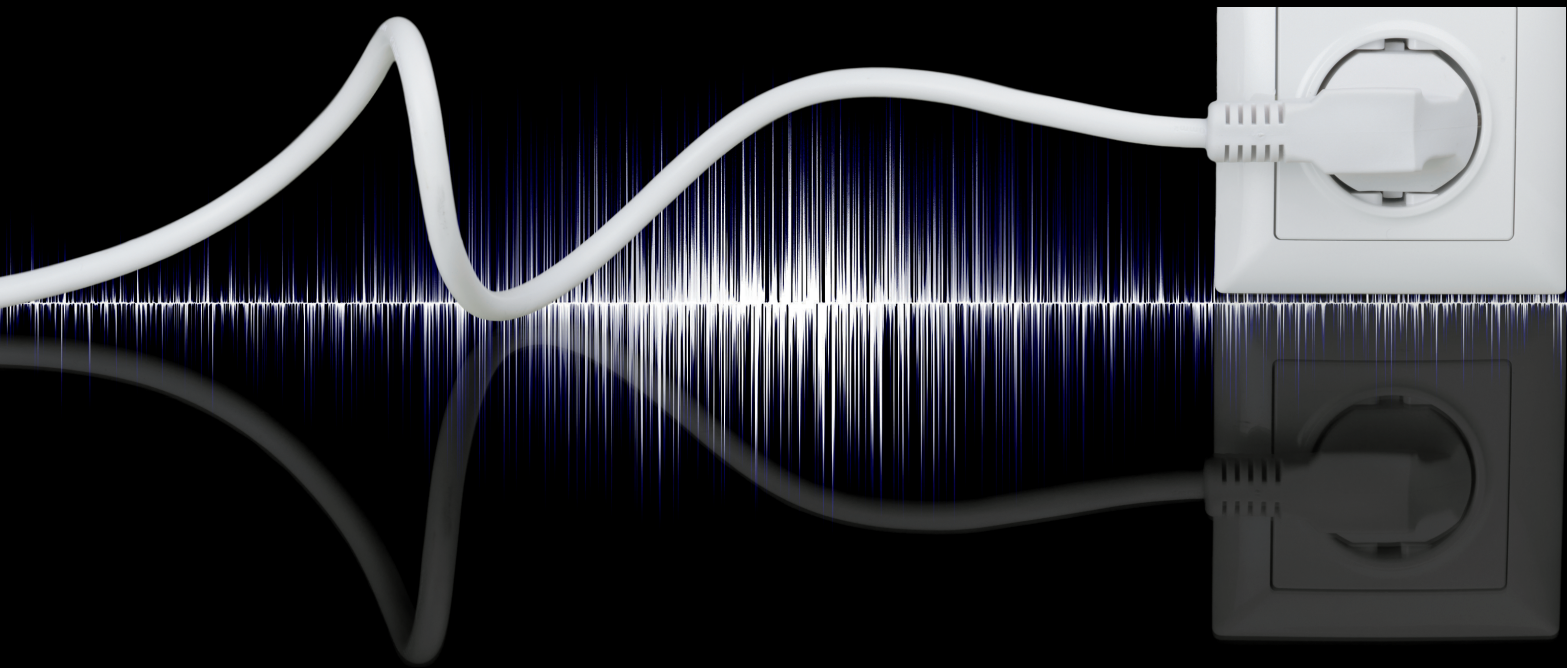
We need at least three energy sources – coal, CNG and thorium – besides solar.

Electricity could cater to growth in air-conditioning and industry. CNG can drive transportation and cooking gas. Nuclear can drive underwater installations, base load of electricity etc.

The last couple of decades has seen substantial shifts in natural gas production. Prime examples are the shale revolution in USA and coal bed methane in Australia. Both countries now export more gas than Qatar.

Hydrogen, as and when required to meet demand, can be generated from renewables or CNG using hydrogen production or by thermolysis.

At some stage, hydrogen could power fuel cells for demand-responsive power generation.



Conclusion 4

India has adequate reserves for thorium and micro nuclear reactors are now safe and practical. They adhere to net zero. CNG can be replaced by nuclear heat sources for thermolysers.

The Reliance plant already converts 5 million tpa of petroleum coke into syngas has highlighted the challenges - primarily cost - of the coal to syngas type of approach.

Recent advances in thorium reactors - mainly the LFTR type molten salt reactors have great potential for India.

A proven process already exists for production of heat from thorium using nuclear fission.



Conclusion 5

The bio-methanation process has direct applications for several other raw materials including biomass.

The production of ethanol from cellulosic waste has not been commercially successful anywhere in the world, even though billions of dollars have been invested in the sector.

The bio-methanation process has now been proven with underground coal. It can now be extended to other biomass including crop waste as a superior alternative to cellulosic ethanol.



Case Study

IOCL is implementing a rice paddy to 2G ethanol project with Praj Industries and Novozyme.

800 tons of rice paddy are expected to generate 100 tons of ethanol for petrol blending. India needs 10 billion litres per annum of ethanol for 20% blending.

61% of the variable cost of production is expected to be the cost of the imported enzyme used for disintegration of cellulosic fibre.

Membrane separation is used for purification.

Ethanol has lower calorific value than methane.

IOCL is also implementing a microbial conversion process based on Lanzatech enzymes. The business model of Lanzatech is to continuously sell enzymes like raw material. This makes the process import intensive. The enzymes are not suited for Indian weather.

Chapter. C

Additions

to conventional wisdom

The Investment committee team found five specific opportunities in existing national and global policy gaps which could be exploited to national benefit.

These are:

- 1 Methane instead of ethanol, methanol and hydrogen
- 2 Extending bioconversion
- 3 Zero emission methane to hydrogen
- 4 Hybrid in place of battery only electric vehicles
- 5 Nuclear in place of other liquid fossil fuels

In addition the team found five other peripheral opportunities:

- 1 Hyperspectral imaging for bioconversion enhancement
- 2 Underground gas storage for continued methanation
- 3 Fuel cells for power generation using low cost electrodes
- 4 CNG thermolysers for green hydrogen production
- 5 Using nuclear forces for high quality heat production

Opportunity 1

Methane instead of ethanol,
methanol and hydrogen

Methane is a smaller molecule compared to ethanol and methanol. Whilst methane cannot be used to blend with liquid fuels like petrol, it is far easier to produce.

Fuels like petrol are themselves on the way out and therefore it may not make long term commercial sense to invest in ethanol production capacity.

The other source of ethanol is food material such as grain or molasses - all of which involve diverting food material towards ethanol production.

Hydrogen can be manufactured from water by electrolysis using renewable energy such as solar panels. However, this is currently not yet cost effective.

**Compelling argument: Methane has higher calorific value than ethanol or methanol.
And is heavier than hydrogen.**

Methane instead of ethanol, methanol and hydrogen ...

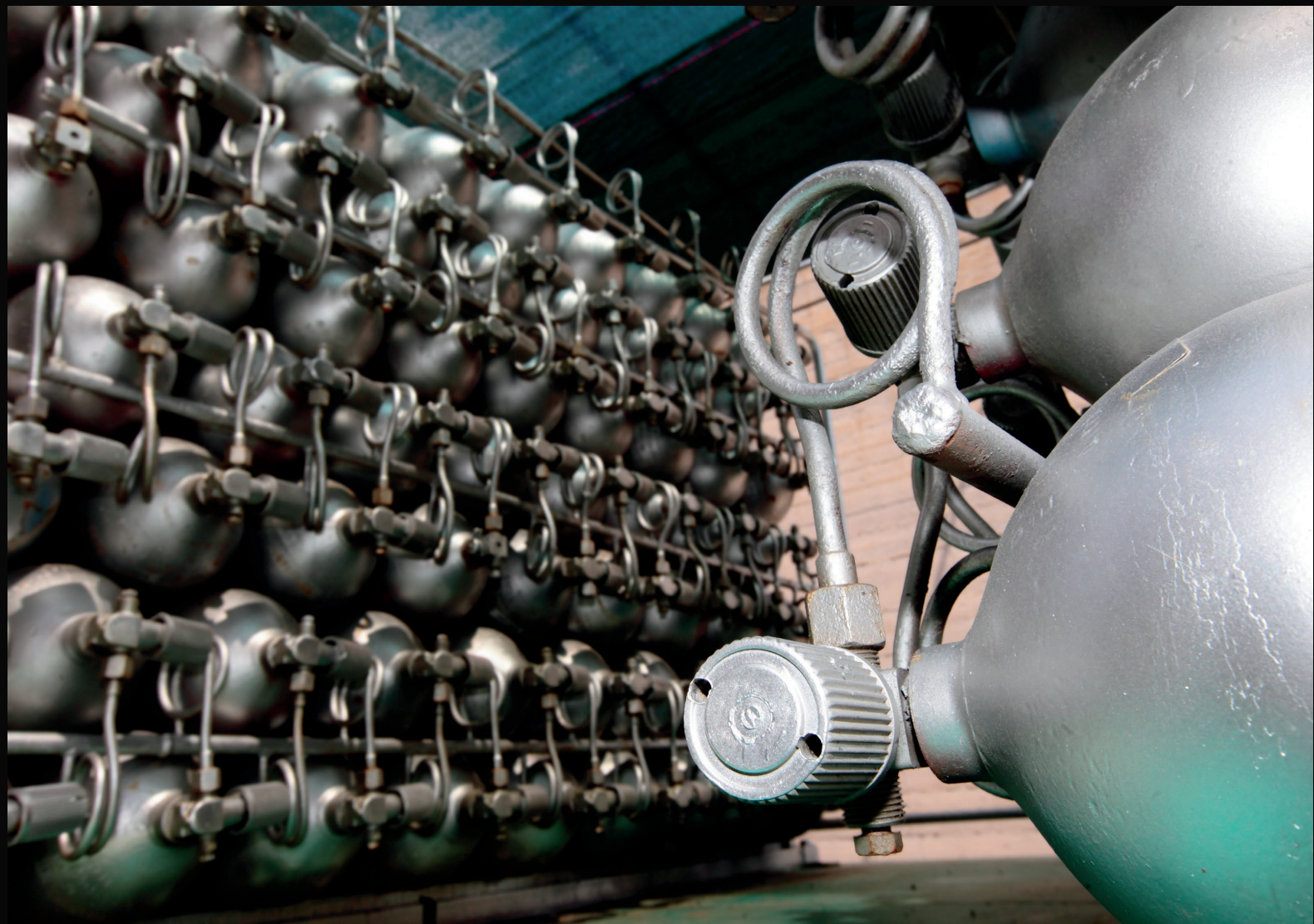
The primary superiority of methane stems from the fact that there are multiple sources and multiple pathways to get to methane. At the most fundamental level, it is found in oil wells to be used directly as CNG or converted into LNG for transportation.

For over four decades, India has been pursuing a program to produce biogas from organic waste.

Methane can also be produced from carbon dioxide and hydrogen using methanation bacteria supplemented by electric power or thermal energy. It is also possible to produce methane from underground coal deposits by in-situ bio-methanation.

It is important to note that adequate infrastructure already exists in India for the distribution of CNG/ methane for applications such as transportation fuel and cooking gas.

A spate of recent regulatory changes pertaining to licensing for retail and paradigms for transportation through pipelines have made the sector attractive for investors.



Opportunity 2

Extending bioconversion

Once the process for bio-methanation is proven, it can almost completely replace thermochemical conversion in a wide range of applications. The top five applications for bioconversion could be:

- Biomass /cellulosic or organic waste to methane
- Power from renewable sources to methane for storing hydrogen
- Fertiliser production as a replacement for high temperature high, pressure processes for the production of ammonia/ urea
- Electro synthesis based applications where conversion energy is provided by electrolysis type systems to alter yield and rate of production
- Carbon sequestration and removal of greenhouse gases from the atmosphere

Opportunity 3

Zero emission methane to hydrogen

Most conversion processes to extract hydrogen from methane such as steam reforming will yield carbonaceous by products like carbon monoxide or carbon dioxide. These have the potential to damage noble metal types of fuel cells such as PEM fuel cells.

There have been several innovative approaches to extracting hydrogen such that carbon gets sequestered.

One such approach is to use a liquid metal molten nickel and bismuth so that the surface area available does not reduce as carbon sequestration proceeds = and the collected carbon floats on the metal for removal.

The use of liquid metal forces deployment of high temperature conditions.

Zero emission methane to hydrogen...

Emerging bioconversion paradigms could enable two way reactions - production of hydrogen by cracking hydrocarbons or just water on one side - and the production of hydrocarbons from hydrogen.

The conventional heat of combustion approach does seem to be a limiter for many real world reactions - though yield and rate of production will continue to be challenges, to be overcome.



Opportunity 4

Hybrid in place of battery-only electric vehicles

Electric drivetrains are far more efficient than internal combustion engine based transportation.

However a full electric drivetrain will need onboard battery capacity proportional to the range in addition to needing charging infrastructure and downtime for the charging.

The best social return is from public vehicles such as taxis, trucks and buses since they clock substantial average kilometres per day compared to private vehicles.

The current cost of lithium cobalt batteries is an indicative USD 200+ per KWH. Even if we were to build the battery manufacturing capacity in India, we would be dependent on imported raw materials.



The largest component of capital cost are the batteries. And in any case, because most of our power is coal derived, charging is not going to be based on green power.

Rooftop solar have not yet taken off in a big way. For use cases like intercity buses and trucks, charging downtime is a drain on transport capacity per annum.

Thus the best option for India till the hydrogen economy takes off is to use electric vehicles with onboard charging infrastructure based on CNG.

India already has the ability to manufacture some of the worlds most cost effective small engines powered by CNG.

To give an example, a bus carrying 30 passengers in airconditioned comfort can be charged by a CNG engine from Maruti similar to the one used by the Ertiga car (40 KW continuous charging).

In terms of fuel efficiency, it would imply that a passenger bus would consume the same amount of CNG as an Ertiga car (which typically seats six passengers).

Because the battery pack is smaller, the capital cost and dead weight would be substantially lower than a full electric bus



Opportunity 5

Nuclear in place of other liquid fossil fuels

There is no known way to fuel aircraft and ships with renewable power. A fully electric or solar option does not currently exist. Planes currently use a form of kerosene as their primary fuel. This is supplemented by Nickel-cadmium batteries (which are carcinogenic but do not cause fires). Ships are unlikely to have charging stations on the high seas.

There is thus no escape from fossil fuels for these two categories in transportation. In addition, electric heating has not found much favour with Indian homemakers who prefer a naked flame for their cooking (think brinjal bharta and fresh chapattis).

Nuclear based on thorium is an excellent medium term solution. This would be especially useful for underwater mining and other underwater applications.



Peripheral opportunity 1

Hyperspectral imaging for bioconversion enhancement

The primary challenges in bioconversion are yield and rate of production.

These could vary substantially depending on the type of fossil deposit. The historical challenge has thus been the methodology to characterise the deposit.

Breakthrough technologies such as hyperspectral imaging can now facilitate real time tracking of underground coal seams.

Underground robotic cameras could complement these to create a digital twin of the deposit.

Similar approaches have been used successfully for shale gas in the USA. And can be used in India.



Peripheral opportunity 2

Underground gas storage for continued methanation

Underground reservoirs have been used for almost a century to store gas. These could be unused mines, depleted gas wells, water aquifers or salt caverns.

Many of these gas storage options will continue to be used to store gas for time shifted delivery or simply for storage.

As electricity markets shift to rooftop solar and geothermal, the utility grids will primarily be used for load balancing, peak load and nighttime use.

The electricity grid will thus need to be far more responsive to demand changes. This will necessitate a smart generation which closely follows demand changes.

Such generation is possible by using gas engines with highly variable output levels and fuel cell based systems.



Peripheral opportunity 3

Fuel cells for power generation using low cost electrodes

Current fuel cell technologies rely on hydrogen as the primary fuel and platinum as the primary electrode material. Platinum is susceptible to poisoning by carbon. Several approaches are currently being tried, including ammonia based fuel cells and esoteric methods wherein the fuel cell absorbs carbon dioxide.

None of the alternate approaches has been successful commercially as yet. At the same time, large volumes for PEM-type fuel cells have led to a reduction in cost for a large variety of applications, from onboard power generation in transportation to drones and mainline power generation.

The next possible innovation in fuel cells is using CNG as the primary fuel to power thermolysers that split water into pure hydrogen and oxygen. Some early movers like BloomEnergy already produce over 2 GW of power in mission-critical applications like Data Centres using CNG as the primary fuel (through a reformer that produces hydrogen)

Peripheral opportunity 4

CNG thermolysers for green hydrogen production

Over the last few decades, several policy frameworks have emerged for production of green energy. Various projects range from using solar electricity to drive electrolysis at one end of the spectrum to producing hydrogen from methane.

The most economic way to produce green hydrogen is to split water by thermolysis using heat generated by nuclear fission or fusion.

Thermolysers do not have any moving parts. Similarly fuel cells do not have any moving parts. A thermolyser requires water as fuel and some source of heat.

The source of heat can be solar thermal, lasers, CNG or nuclear.

Thermolysis generates 100% carbon free hydrogen. The chances of contaminating the noble metals in the fuel cell are minimal even if we use CNG as the energy source.

This is a far better approach than generating hydrogen from the CNG

Peripheral opportunity 5

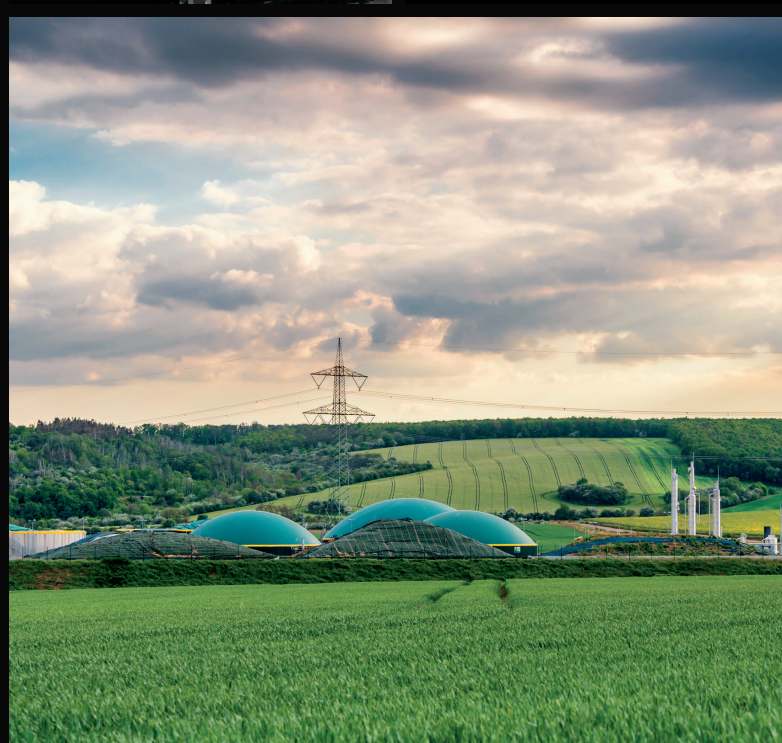
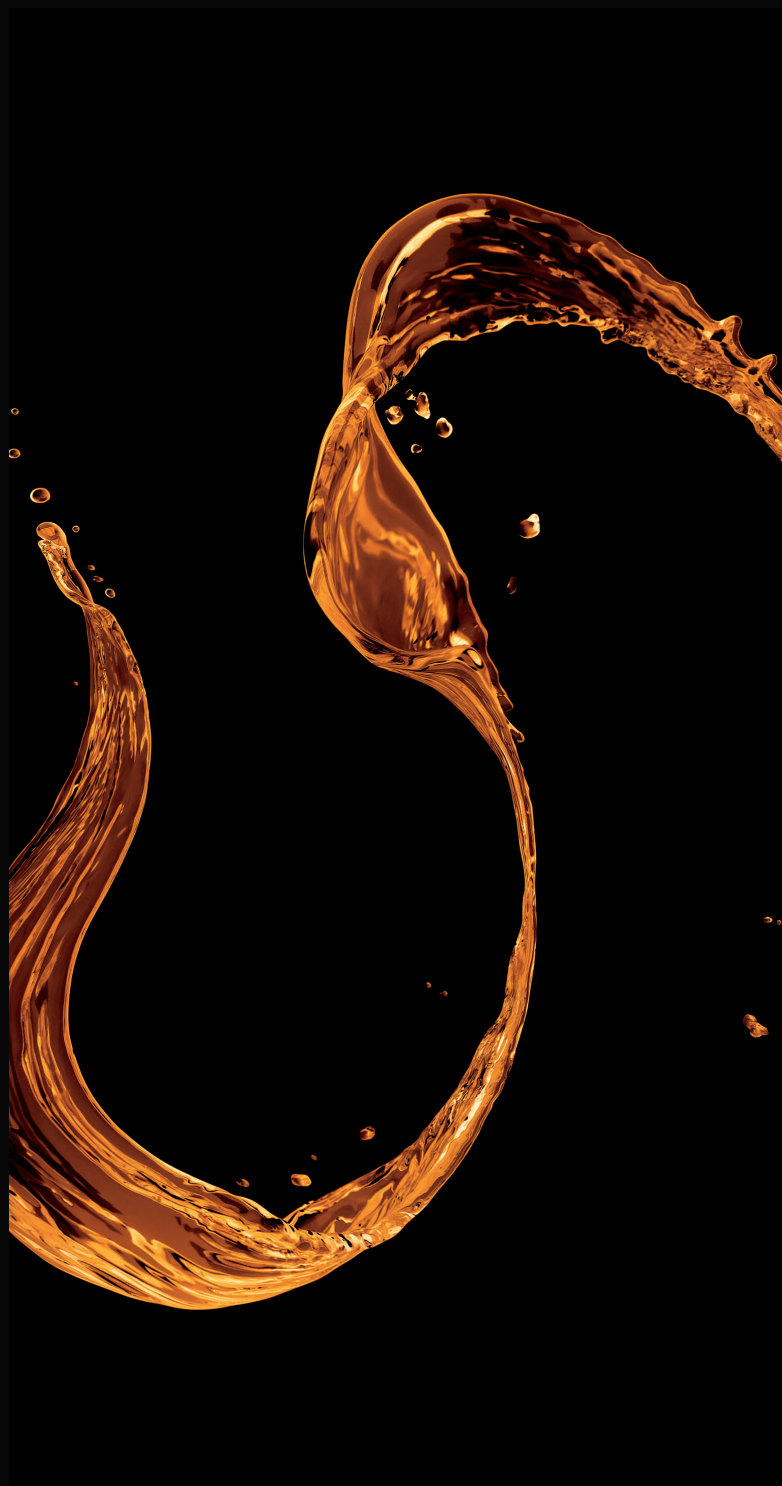
Using nuclear forces for high quality heat production

Almost all processes which involve the conversion of greenhouse gases to usable hydrocarbons need a large amount of energy in the form of high quality heat.

This heat needs to be produced cost effectively as waste heat is rarely of the desired quality.

One approach to do that is to use concentrated solar thermal assisted by nuclear heaters based on thorium fuel abundantly available in India.

Thorium-based reactors can be produced in very compact forms, do not produce nuclear grade uranium as a by-product, have lower half life and do not have the risk associated with conventional nuclear reactors. In the last decade, driven by funding by foundations, substantial progress has been made.



Chapter. D

Imperatives

for a project of such nature

Our reliance on imported CNG will be a colossal forex bleed.

If we restrict crude oil imports to existing levels or lower levels, we will need to import kerosene for aviation and shipping.

A disruptive plan along the lines of that proposed will need an ecosystem approach for global leadership.

This requires a collaborative framework, suitable public policy, supporting regulations and



In the absence of an initiative such as the proposed one, we will end up relying on imported CNG to meet our need for clean fuel to supplement renewables.

The methane proposed to be produced will be ready for use as a CNG replacement for baseload/ peak load power generation, transportation fuel (for IC and hybrid electric public vehicles) and piped cooking gas.

The thermolyser fuel cell approach can radically improvise on the design for electric vehicles which will now need 90% lower capacity of batteries. This would make electric vehicles viable without subsidy.



Once the project meets all its objectives,

India will be able to reduce its dependence on imported crude /petroleum products for use in power generation, transportation fuel and cooking gas.



In keeping with our approach, we would like to include as many entities as possible in the project on both – the supply side, intermediation side as well as on demand side.

On the supply side, these include underground coal mine concession owners, microorganism developers and equipment suppliers.

On the demand side, all user segments, especially power generators.

On the intermediate side, transmission pipeline companies, retail distributors and local piped gas delivery entities.



Chapter. E



CNG

market & demand

CNG

Market and demand 2030

Hybrid vehicle fuel, cooking gas,
balancing power generation

Hybrid vehicles: 5 million @ 500 kg per
annum = 2.5 million tpa

Cooking gas: 100 million @ 200 kg per annum
= 20 million tpa

Balancing power: 50 GW @12 hours per day



Chapter. F

Biomethanation

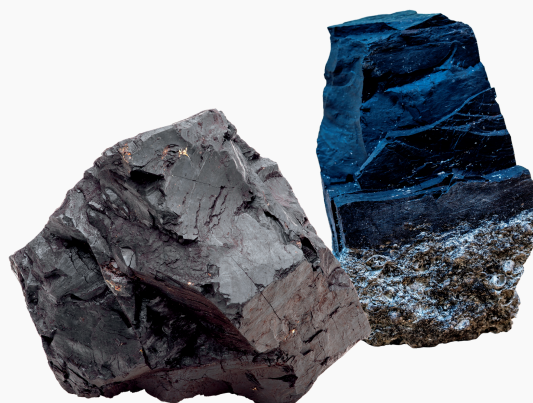
technology issues

Approximately 71.4% of the world's total fossil fuel reserves are in the form of coal.

The mineable coals are less than 10% of a total global reserve of over six trillion tons.

Approximately 58% of all coal reserves are categorised as low ranked lignite and sub-bituminous coals, which have lower calorific values but can be degraded biologically much more quickly.

Proven thermochemical technologies exist for converting low-rank coals in syngas (a mix of methane, carbon oxides, hydrogen and water vapour). These are used in India in both the steel and oil/gas sector.



These processes require high temperature (1350 degC and 20 to 140 atm pressure). In addition extensive clean up and purification is required.

It is possible to achieve gasification in more ambient conditions by means of microbial degradation, also coined as bio gasification as observed in biogenic coal bed methane.

CBM is contributed by two processes, geological (thermogenic) and biological (methanogenic).

Microbial production of CBM can happen at under 100 degC. CBM currently accounts for over 10% of total natural gas production in the US. Microbial CBM accounts for 40% of total CBM in the US.



The two broad approaches for enhancing the production of methane from coal are:

Bioaugmentation:

Adding external microbial sources and

Biostimulation:

Adding supplementing chemicals and nutrients.

Best practices from the shale gas industry can be applied to microbially enhanced coalbed methane for making full use of coalbeds as methane reservoirs.



Bioconversion of Coal

Coal is generally not a favourable microbial substrate.

Approximately 85% of dry coal is comprised of organic material called macerals - which reflect the properties of the precursor biological material - while the remainder is in the form of aluminosilicates and sand pyrites.

CBM formation through microbial processes requires the collective actions of microorganisms comprising three major metabolic groups:

1. hydrolytic and fermentative bacteria
2. acetogenic bacteria and
3. methanogenic archaea.



Chapter. G

Nuclear

market & demand

Nuclear Market and demand 2030

Base load, strategic equipment, shipping fuel etc where fossil fuels need to be eased out.

Addressable market of 25 million tons equivalent fossil fuels per annum.

Shipping fuel has to be supplied based on competitive international pricing to incentivate local sourcing.



Chapter. H



USG

market & demand

Underground storage of CNG

It is not practical to always evacuate methane from point of production in real time. Thus some storage is required.

The best way to store methane is to store it in an unused coal mine or gas well or aquifer.

It is also possible to facilitate further methanation in the storage well. And to incorporate membrane purification just prior to evacuation by pipeline. If a pipeline is not available, methane can be converted into kerosene.



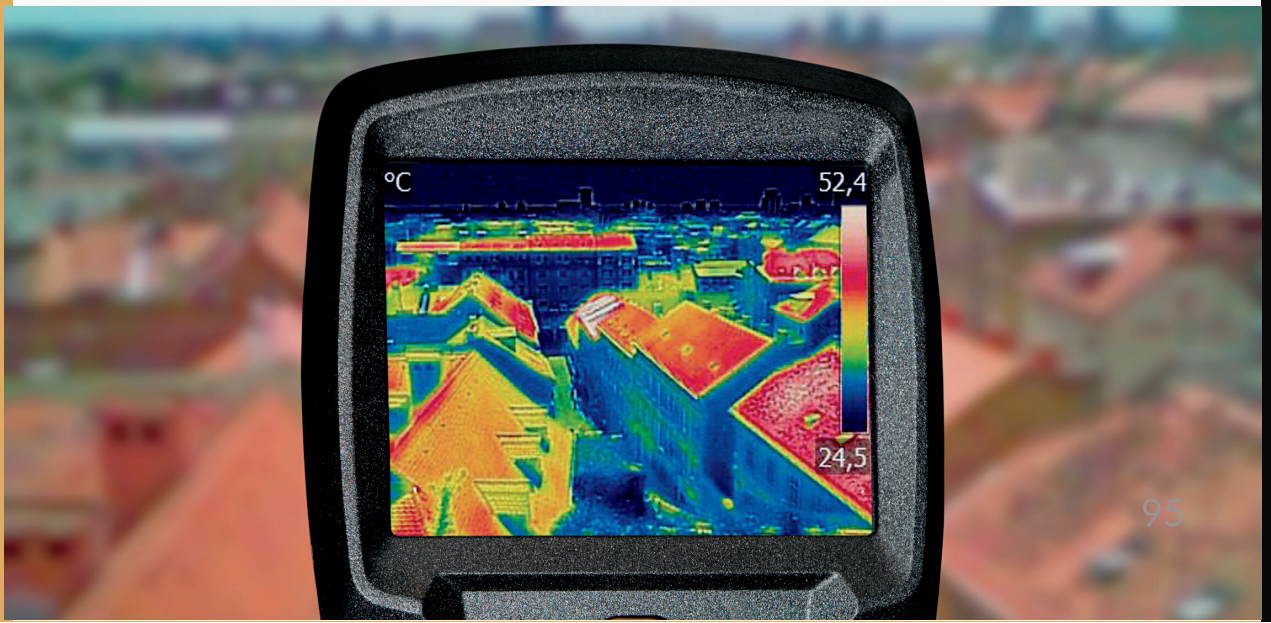
Chapter. I

USG
technology issues

USG Technology issues

A two stage bioreactor is achieved in practice by using underground storage in an unused coal mine.

This approach requires accurate understanding of the topology, geology and composition of the underground coal seams. It also requires real time tracking of methane production from the surface or through robotic cameras underground using long wave infrared.



Chapter. J

Conclusions

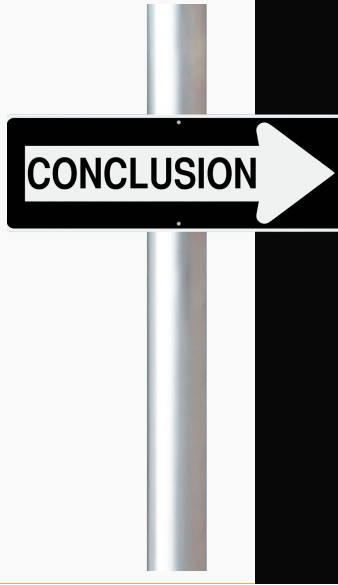
for action to be taken on
technology development front

Conclusions

The imperatives for India are self sufficiency in renewables, CNG and kerosene.

An initial deployment will have a project cost of Rs 90,000 crores. Initial capacities proposed are 10 million tpa of CNG. Biotechnology development cost is estimated at Rs 1800 crores.

This will use biomethanation in underground coal mines. This technology project will substitute Rs 45,000 crores pa of imported CNG/LNG



CONCLUSION

Conclusions

continued...

These will help meet the national need for:

A more "demand responsive" grid.

Net Zero power plants.

Revive gas based power plants which are currently unviable and thus closed.

Provide fuel for transportation and cooking.

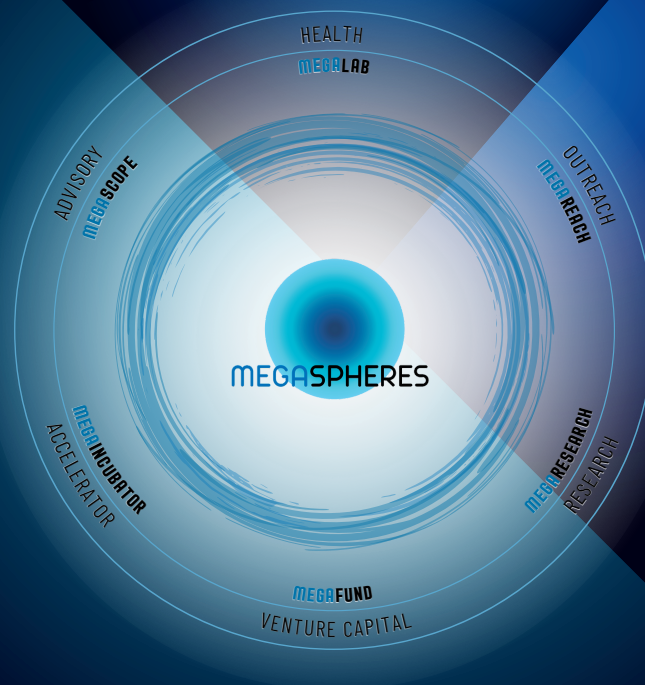
Annexure

Sponsors of the project



MegaSpheres is the quality of life initiative of the IIT Alumni Council.

MegaSpheres initiative comprises six synergistic missions that complement one another to address national challenges using paradigms from venture funding and startups. The current project addresses climate change and energy security as a quality of life challenge.





How it all began...

As an emergency response to the covid pandemic, the IIT Alumni Council set up the C19 Task Force in March 2020.

Over 25,000 IIT Alumni contributed to the activities of this task force.

The C19 Task Force morphed into the MegaLab mission on August 15, 2021.

During the interaction with members of the MegaLab mission, several engineer groups from sectors like oil and gas realised that bioconversion could be done for green chemistry and blue economy applications using bioconversion. MegaLab partners like CSIR and ICT Mumbai accelerated this learning.

All of this was not put together by rational intent. It emerged from serendipity. Locked at home because of covid restrictions, the current project is one of several that emerged as a positive fallout of covid.

Glide path

The Alumni Council is pursuing a technology intensive model which uses paradigms from the startup and venture capital world to disrupt the social sector. For the supported entities to be self sustaining and internally fuelled in the long term - the focus is on ventures where benefit created is captured in the long term revenue - either as profitability or as valuation in the startups.

Videos



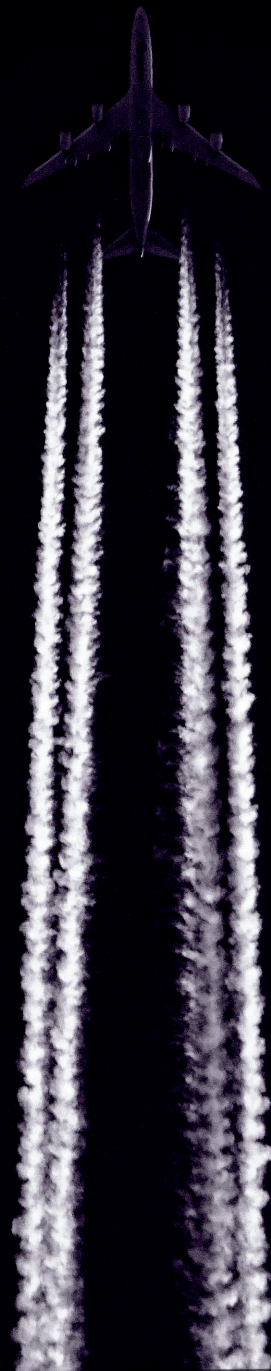
[The United States imports smart people from India](#)

YouTube · Dia Asmar
31-May-2018



[Indian Institutes of Technology - IITs on CBS 60 Minutes](#)

Facebook · Indian Institutes of Technology
07-Dec-2008





IIT Alumni Council is now the largest global body of alumni across all the twenty-three IITs and partnering Universities. The IIT Alumni Council aspires to align Alumni resources towards catalysing India's technological renaissance for a digital society. The member alumni actively participate in social ventures that are configured to solve key national challenges through the deployment of appropriate technologies using the well-proven venture capital funded start-up format.



Ravi Sharma
President &
Chief Volunteer

Forum refers to PanIIT Forum, an Indian non-profit company registered under Section 8 of the Companies Act, its network of member firms, and their related entities. Forum and each of its member firms are legally separate and independent entities. The forum does not provide direct paid services to clients.

Please see www.megascopes.in for a more detailed description of the Forum and its member firms.

This material is prepared by the Coal Technology Council appointed by the Forum. The Council was manned by a group of alumni drawn from various mission organisations of the IIT Alumni Council. The group included experts in the area of AI/ML, robotics, coal gasification, biotechnology, mining, civil engineering, chemistry, geology, finance, regulation, public policy etc. None of the Council members has received any remuneration for the services rendered. No sponsorship or fee has been received for the same.

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