Hydrogen From Waste

Rajan Varshney

Introduction

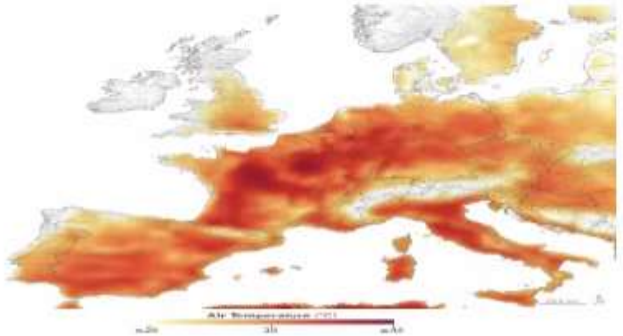
Climate change : GHG effect : Making Human Survival Difficult?

Climate Change Impact

Australian Wildfires

Polar Vortex: -46°C as Chicago River turns to Ice

London Floods

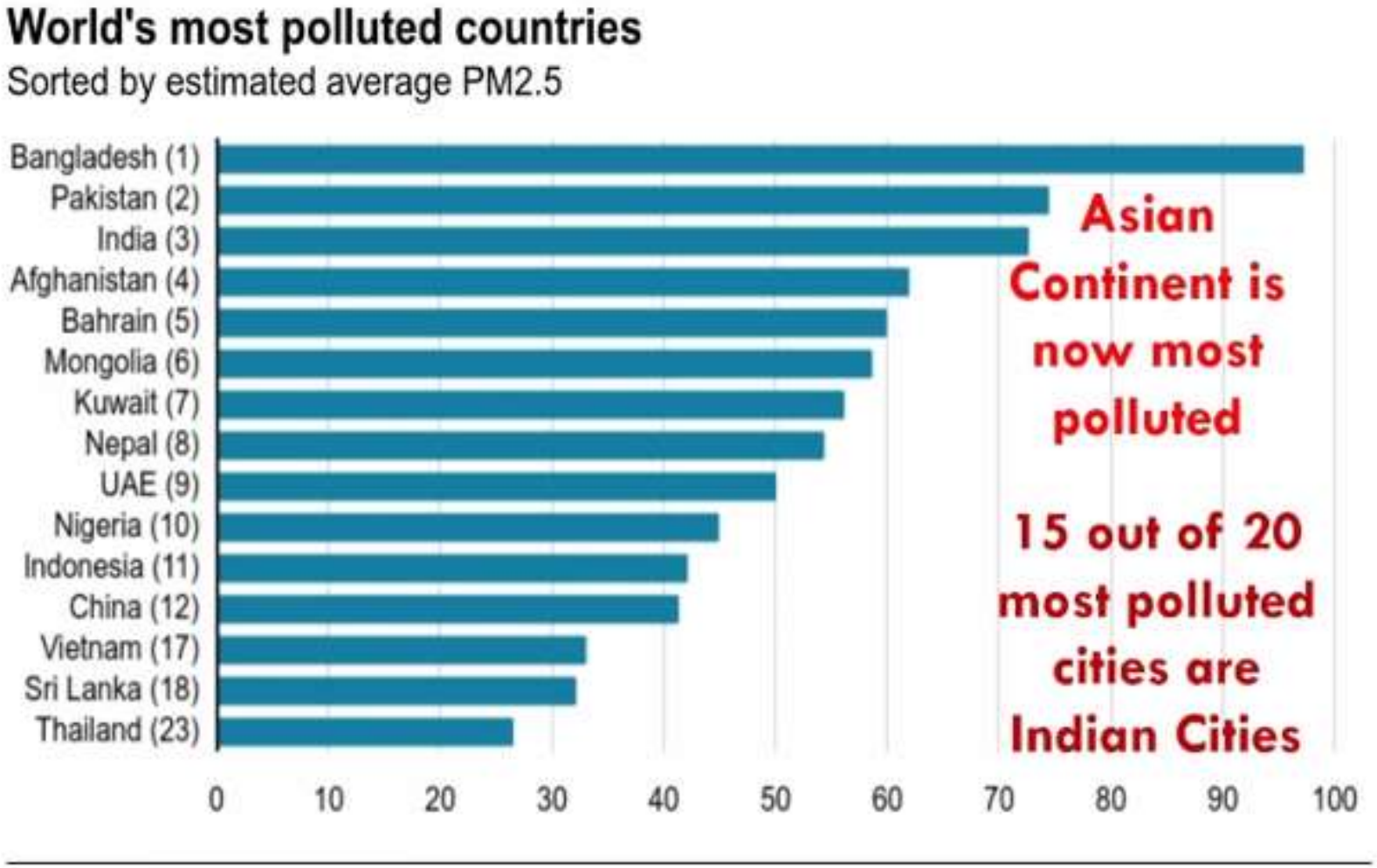


Heat Wave in Europe

Drought in Africa

Glacier Burst & Flash Floods
in Uttarakhand

India has some of the World's Most Polluted Cities



Deloitte Report :India : $11 Trillion Opportunity or $35 Trillion Risk

Climate Change $11-Trillion Opportunity and $35-Trillion Risk for India: Deloitte

Country can add $11 trillion if it properly handles the challenge, may lose $35 trillion if it doesn't: Deloitte

Sachin.Dave@timesgroup.com

Mumbai: Climate change is both a momentous opportunity and significant threat for India – and New Delhi's choices will determine how the country fares.

A Deloitte report has said that around $11 trillion – or more than three times the current size of gross domestic product – could be added to India's economy if it properly handles climate change. At the same time, India faces the biggest risk too – of losing $35 trillion – if its crisis response falls short of what's required, said the report titled India's turning point: How climate action can drive our economic future.

That is the potential economic loss over the next half a century.

Deloitte researchers said that the country could end up gaining $11 trillion in economic value over the same period by limiting the rise in global temperatures and realising its potential to 'export decarbonisation' to the world.

"We have a narrow window of time — the next 10 years — to make the decisions needed to alter the trajectory of climate change," said Atul Dhawan, chairperson, Deloitte India. "As India aspires to be a $5-trillion economy, it is not just foreign and domestic investments that will be key in driving growth; we must also take this opportunity to 'align our ambitions with climate choices."

If no action is taken on climate change, average global temperatures could rise by 3°C or more by the end of this century

The report added that if no action is taken on climate change, the average global temperatures could rise by 3°C or more by the end of this century.

"Deloitte's research also shows that if governments, businesses, and communities act boldly and rapidly in the next decade to address climate change, average global temperature rises can be limited to around 1.5°C by 2050 – a scenario that will minimise the impact of climate change for India and the rest of the world. At the same time, India can achieve significant economic growth by supplying the products, services, and financing the world will need to limit temperature increases," it said.

India could be at the vanguard of the global climate-change initiatives.

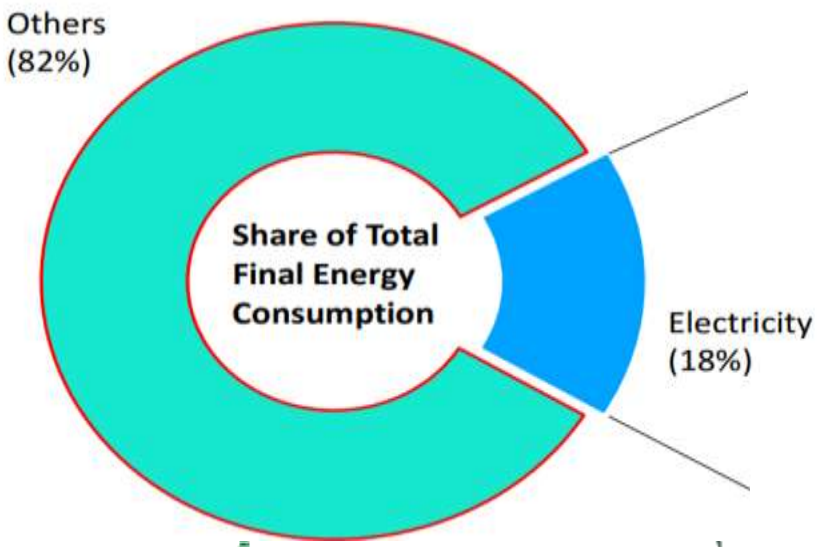
"We need to transform the world's economies toward new, low-emission pathways and India is well positioned to play a leading role in this process globally," said Viral Thakker, Partner and Sustainability Leader, Deloitte India.

Urgency

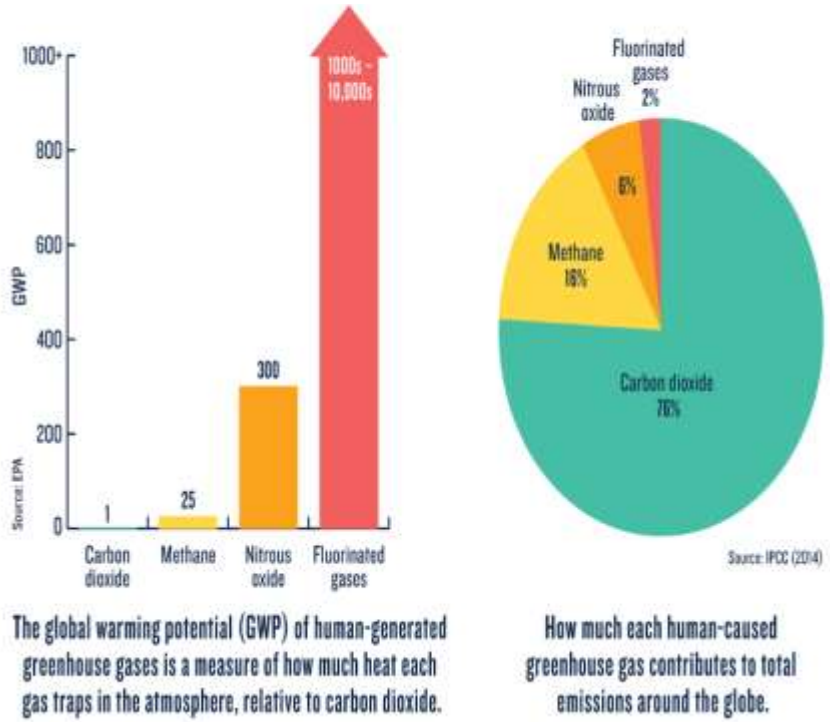
Urgent requirement of Decarbonization

- India is the third largest emitter of Green house gases.
- Country has pledged 50% reduction in emission intensity of its economy by 2030, compared to 2005 levels.

Electricity Contributes only 18% of Energy needs



Why CO_2 needs attention



The global warming potential (GWP) of human-generated greenhouse gases is a measure of how much heat each gas traps in the atmosphere, relative to carbon dioxide.

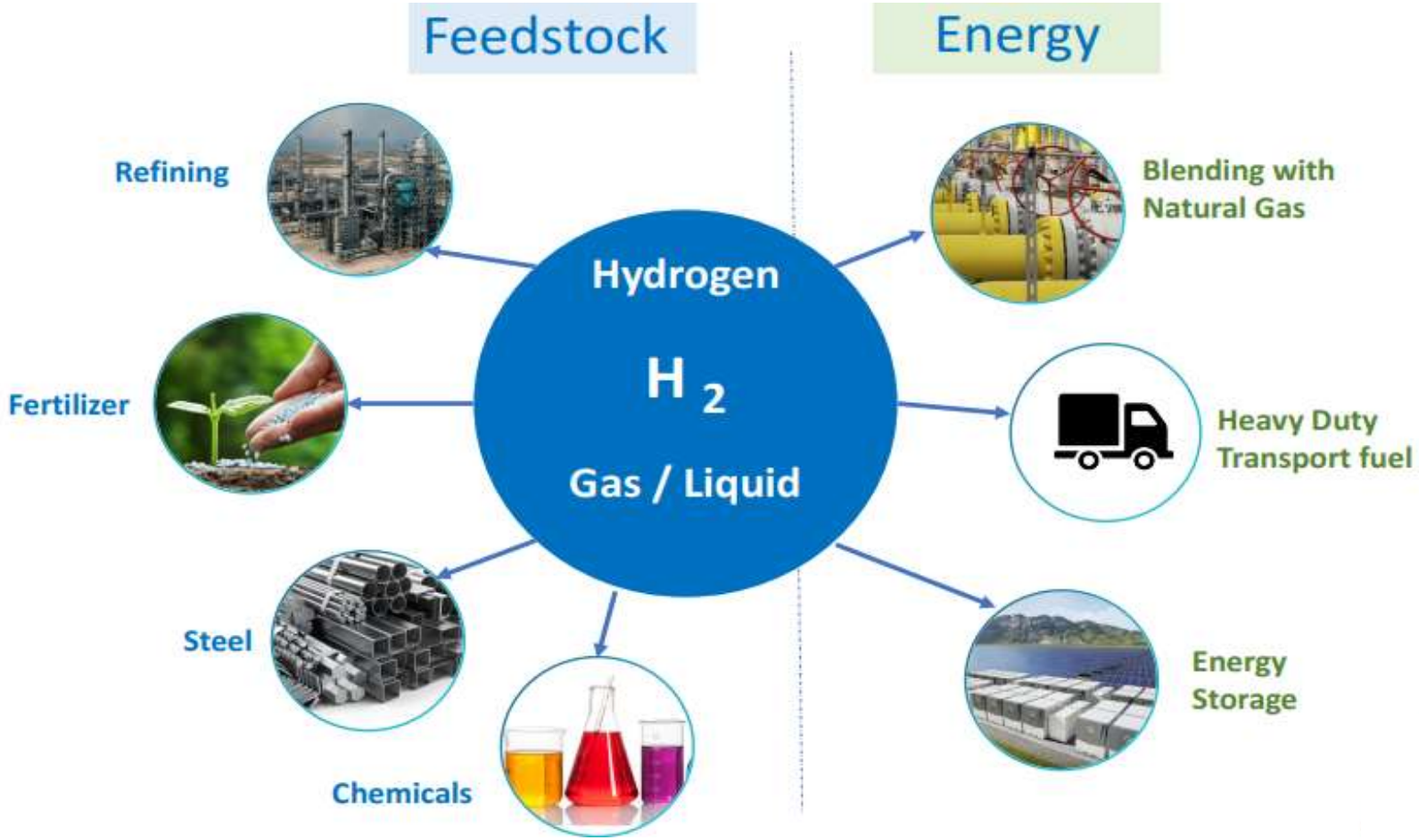
How much each human-caused greenhouse gas contributes to total emissions around the globe.

Global Waste to Hydrogen to Mobility Potential

India has Lot of waste round the Year for Producing H2

MSW(62 MMT) + **Agri-waste(150 MMT)** + Animal Dung + Sludge +Poultry+Agro-forestry… Bioenergy Crops like Napier grass shown in Photos

H2 is versatile energy Carrier interconnecting various sectors



Tokyo Olympics 2020(23Jul-04Aug 21) & Paralympics(24 Aug - 05 Sep 21) & China Winter Olympics (4 -22Feb 22)

- Completely Hydrogen Based
- Hydrogen refueling stations
- Fuel cell vehicles and buses
- Power supply through fuel cells
- Stable hydrogen fuel supply
- Increased social acceptance

Waste goes to Landfills or is burnt or left as it is

- Burning Plastics say by Incineration causes Air Pollution, Dioxins.Furans,Heavy Metals

https://www.nationalgeographic.com/environment/article/should-we-burn-plastic-waste

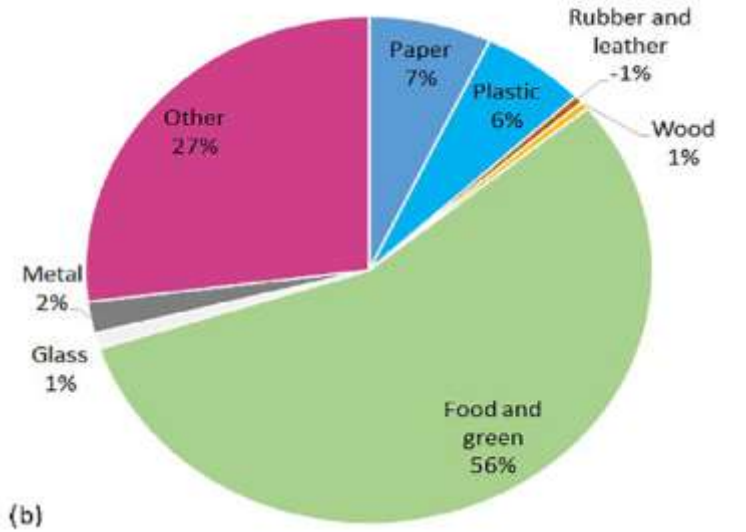
- Pyrolysis also concentrates these in the products and when used say as fuel on Combustion release these into air https://www.lowimpact.org/posts/pyrolysis-not-solution-plastics-problem
- Harmful to Marine Life and Humans

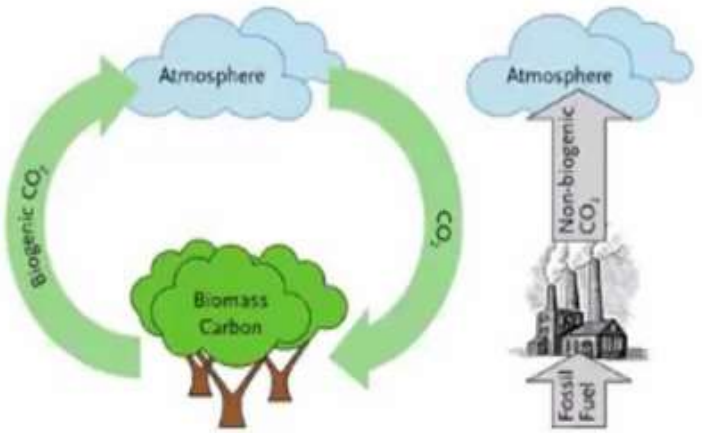
Reimagine Waste and Produce H2 – Greener Solution

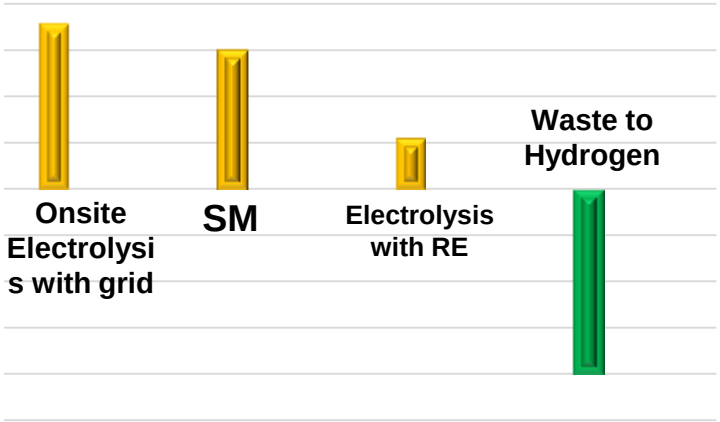
Criteria for Ideal Solution

- **GHG Reduction**
- **Energy Security**
- **Clean Air,water,Soil**
- **Waste Management**
- **Cut Imports**

Hydrogen From Waste fits the bill







Waste Generation Profile

2019 – Over 2.0 Billion Tons

2050 – 3.4 Billion Tons

India Produces > 1.4 lakh tons of waste/Day

Some Companies in Waste to H2

- IPR has developed Plasma Gasification
- Pennsaco, US: Pennsaco technology heats biomass in absence of Oxygen and produces H2 and Biochar through its patented Process without any external electricity
- ThermoChem Recovery International Gasification of Waste to Syngas from which H2 and Biodiesel
- Standard Hydrogen (Waste+Sulphur: H2S to H2 and recirculating S)
- SGH2 (Gasification)
- Ergostech converts sewer-waste into bio-H2
- Shell : IH2: INTEGRATED HYDROPYROLYSIS AND HYDROCONVERSION
- Revaluo
- Chinook Sciences' patented RODECS gasification and pyrolysis
- Polycrack (Catrogen Unit)
- CAC-H2 is also utilising its carbon-negative biomass-gasification technology to produce H2 and Biochar
- Mote: uses proprietary integration of proven equipment in a novel process: Biomass is heated in a limited-oxygen environment to above 815°C converting it to a mixture of gases which produce hydrogen & CO2 and the resultant Ash is used as additive for Fertiliser
- HOPE Resources using Vaccum reforming produces Hydrogen from Organic Carbon and Ash

Pennsaco: waste to BioChar + H2

- **Carbon negative H2 & renewable electricity made from recycling biomass, agricultural, plastic, MSW, and other wastes avoids & offsets emissions of hundreds of thousands of MT CO2e from the atmosphere per facility per year.**
- Tens of thousands of MT CO2 permanently removed from the atmosphere per facility per year through biochar. 3 MT of CO2 permanently removed per MT of biochar produced and sequestered.
- 6+ MT CO2e offset per MT of feedstock recycled.
- Carbon Intensity Score: -209 and higher
- Collaborating with complimentary blue carbon technologies to permanently remove all biogenic CO2 per MT of biomass recycled.
- Biochar is the solid carbon product of biomass pyrolysis & captures 3 MT CO2 per MT.
- When biochar is land applied in agriculture, incorporated as an additive in cementitious products, or otherwise permanently sequestered, this CO2 is permanently removed from the biogenic carbon cycle and the atmosphere

World's Largest Net-Negative CO2 Biomass-To-Energy Facility

Babcock & Wilcox and Kiewit Industrial have teamed up to build a biomass power plant in the Port of Greater Baton Rouge in Louisiana. The 200-megawatt Project Cyclus power facility will be the largest of its kind.

The projected facility will create aviation fuel, green hydrogen, bio-plastic feedstock, and renewable diesel with no carbon emissions. Biomass fuels will be used in the Cyclus project, including wood waste, wood chips, and bagasse, etc., with carbon capture technology that will isolate the CO_2 emissions underground.

Babcock & Wilcox. (2022). *B&W, Kiewit partner to deliver 200 MW biomass plant in Louisiana*. [Online]. Available at: https://biomassmagazine.com/articles/18852/bw-kiewit-partner-to-deliver-200-mw-biomass-plant-in-louisiana (April 24 2022).

Ontario's Hydrogen Strategy

The Government of Ontario released its first Low-Carbon Hydrogen Strategy on April 7, 2022, outlining the province's vision and expectations for the developing hydrogen sector.

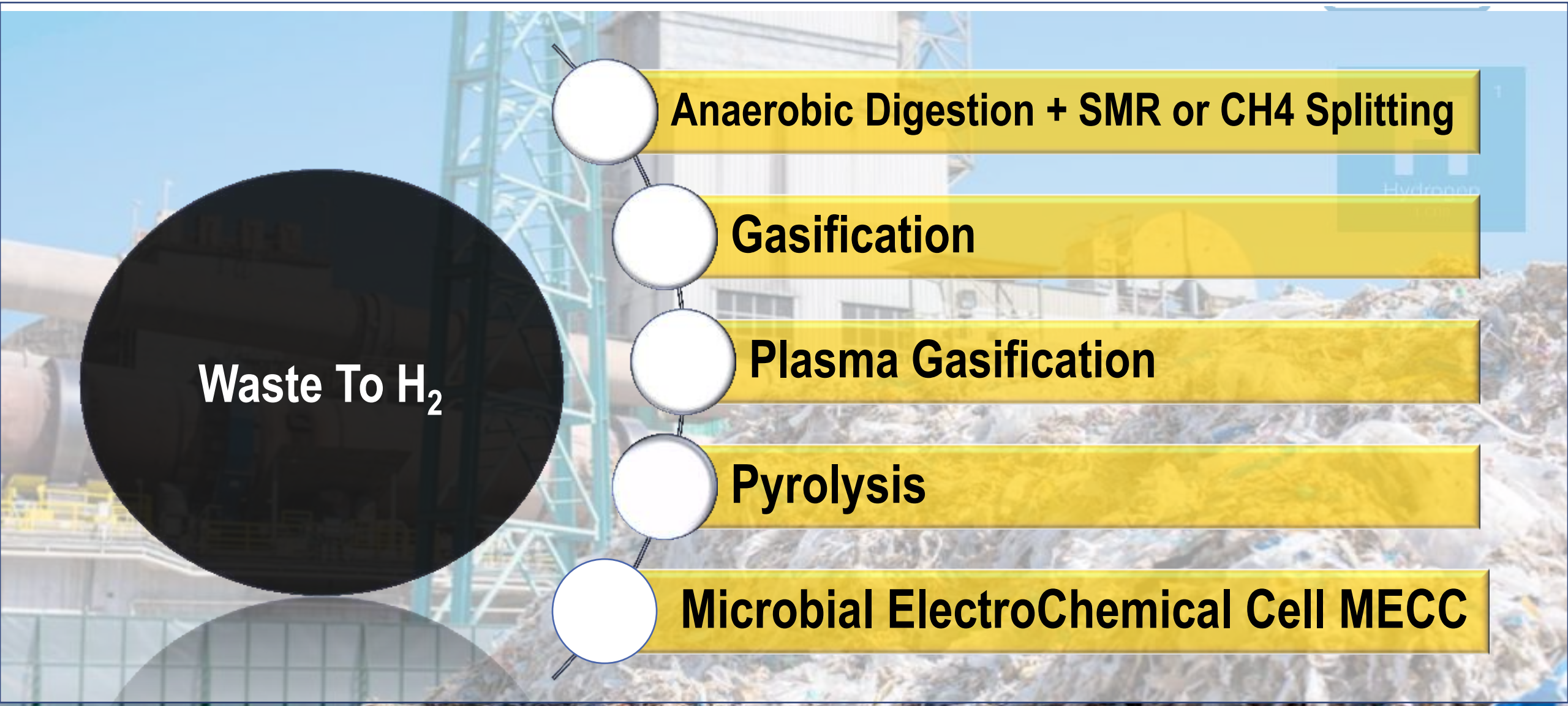
H2 Industries: Waste to H2 two Big Projects

Egypt: $3bn Plant to convert
4MMT of organic waste and non-recyclable plastic into 300,000 tonnes of H2 per year — roughly the amount that would be produced by a 4GW renewable H2 electrolysis facility.

Oman: $1.4bn plant to Convert
1 MMT MSW (fresh waste plus waste from Landfills) — into 67,000 tonnes of H2

It involves an “integrated thermolysis plant”. Thermolysis means chemical decomposition by heating.
The waste heat from the process can be used to generate power

Methods for Hydrogen Production from Waste



Anaerobic Digestion + SMR/Methane Splitting

Anaerobic Digestion : Waste to B

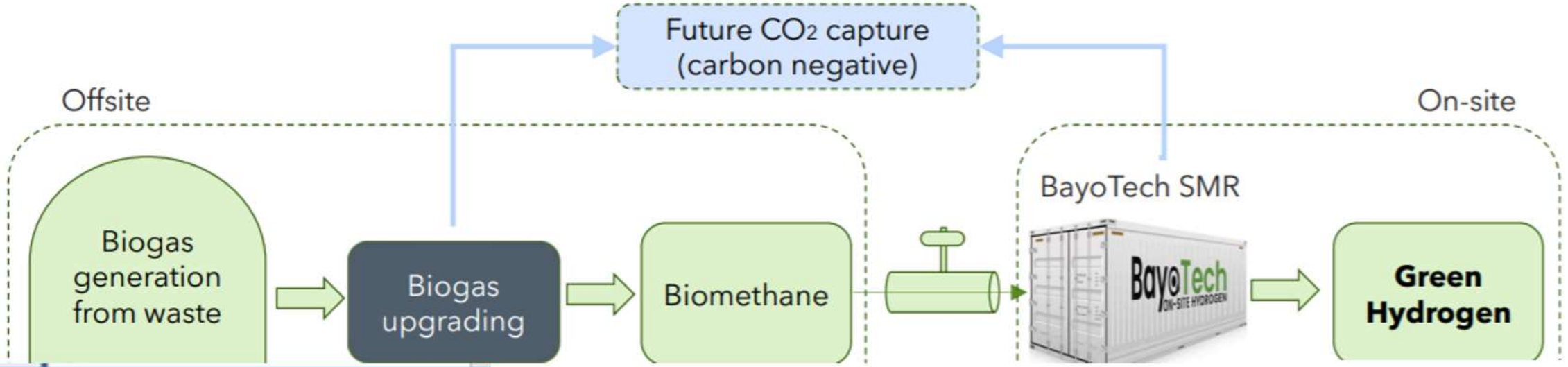
Scrubbin g

Methane Splitting or

Decentralised H2 from Bio-Methane: for Remote off grid /Industry/ H2 Filling Station

- **Many vendors supply SMRs for Conversion of Methane to H2. CO2 can be captured and can be used for various uses or mixed with H2 to make SAF, e-fuels etc.**
- **BayoTech USA offers Decentralised H2 at reqd site @$2/kg** (Biomethane,Water & Electricity to be provided by Customer) and **authorized H2-Zest** in India
- **HyGear**(Netherlands/Singapore) offers small scale H2 generation systems at the end user's site. On-site hydrogen supply by the HyGEN increases the reliability of supply and decreases the costs. Authorised Vendor in India: GPS renewables
- Ranging from 10 Nm3/h up to 1000 Nm3/h (20kg to 2000kg/day)
- Turnkey selling of equipment to full-service contracts or supply of gases "GaaS" or "Gas-as-a-Service"

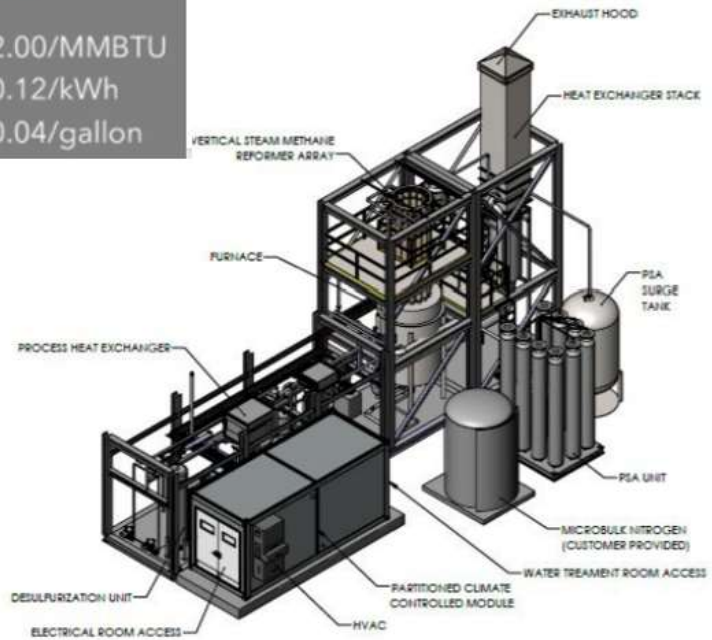
Onsite-H2 Production from Biogas



Hydrogen produced using BayoTech has the lowest cost of ownership – as low as $1.69 per kilo

Assumed utility costs

- Natural Gas Cost: $2.00/MMBTU
- Electricity Cost: $0.12/kWh
- Potable Water Cost: $0.04/gallon



Carbon Capture Technologies

Amine Separation	2 TPD CO_2 $TBD/MT	Gaseous CO_2 Purity TBD
Solvent Separation	1 &10 TPD CO_2 $TBD/MT	Gaseous CO_2 Purity TBD
Mineralization	1-10 TPD CO_2 $TBD/MT	Limestone $CACO_3$

Some SMRs

- Hy.GEN Steam Methane Reformers
- Natural gas or BioCNG at a pressure of 11 bar(g) is the inlet requirement which allows
- the system produces high purity hydrogen gas suitable for the Fuel Cell industry
- Hy.GEN 50 can prorduce a maximum hydrogen flow of 42 Nm3/h based on a 5.0 (99.999%) purity
- Fits into 20 ft container
- 100kg/day : Rs 7 crore

- 200Nm3/h NG-SMR HYDROGEN PLANT
- 500kg/day H2
- US$1,000,000 FOB China Port
- or Rs 8 Crore

Chengdu TCWY
New Energy Technology Co., Ltd.

SMR Designed by NANOSOL India (H2:10kg/day)

A. Summary

A1	Project Title	Development of SMR reactor for hydrogen production capacity of 10 kg per day for commercial applications
A2	Project Cost ***(Amount in INR)***	**₹. 25,00,000.00** (Rupees Twenty-Five Lakhs Only)
A3	Duration	12 months
		Dr K. Naga Mahesh, CEO / Director

H2 from Waste – Biomethane Splitting

Conversion of waste to Bio-methane and subsequently to Hydrogen production generates various valuable byproducts

Waste – 50TPD

Compost – 20 TPD

Liquid manure – 1 lakh Litre/Day

Pyrolysis

500 Kg/Day

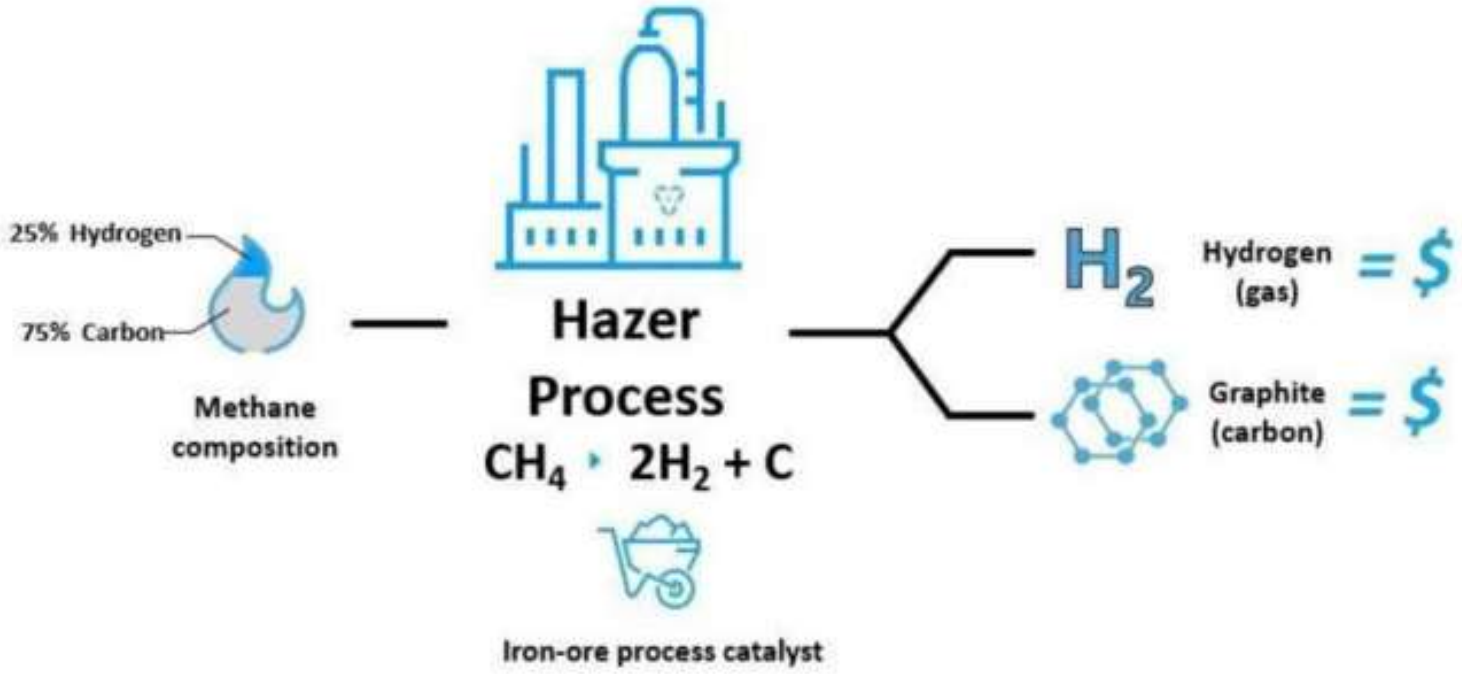
Solid Carbon uses:

- Coke Steel refining
- Tyres, Plastics
- Graphite electrodes
- Carbon nanofibres
- Diamond
- Increase fertility

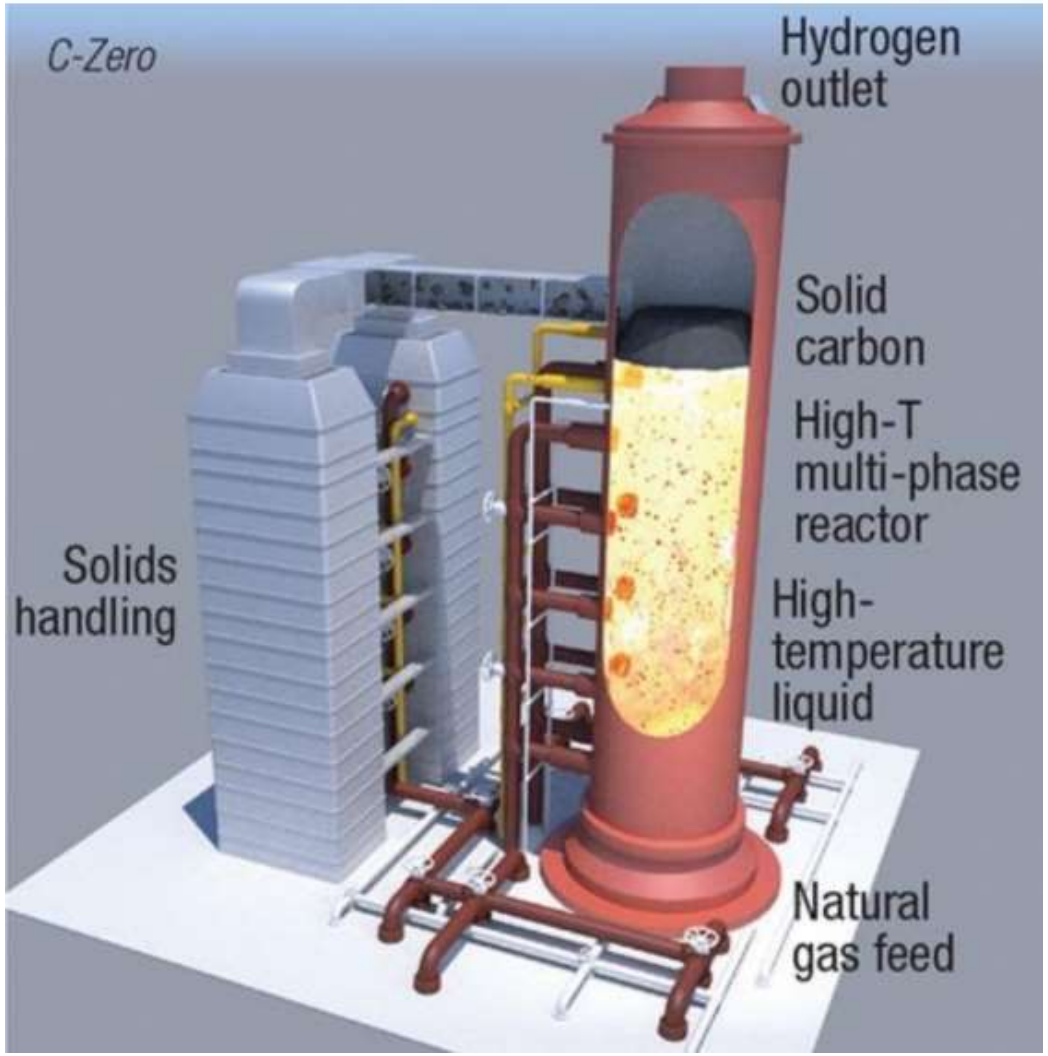
Biomethane – 1.7 TPD

PLASMA METHANE PYROLYSIS: Monolith USA

FeO Catalysed Methane Pyrolysis: Hazer, Australia



Molten Salt Methane Pyrolysis, C-Zero, USA



APVentures
ADVANCE & PIONEER

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Breakthrough Energy

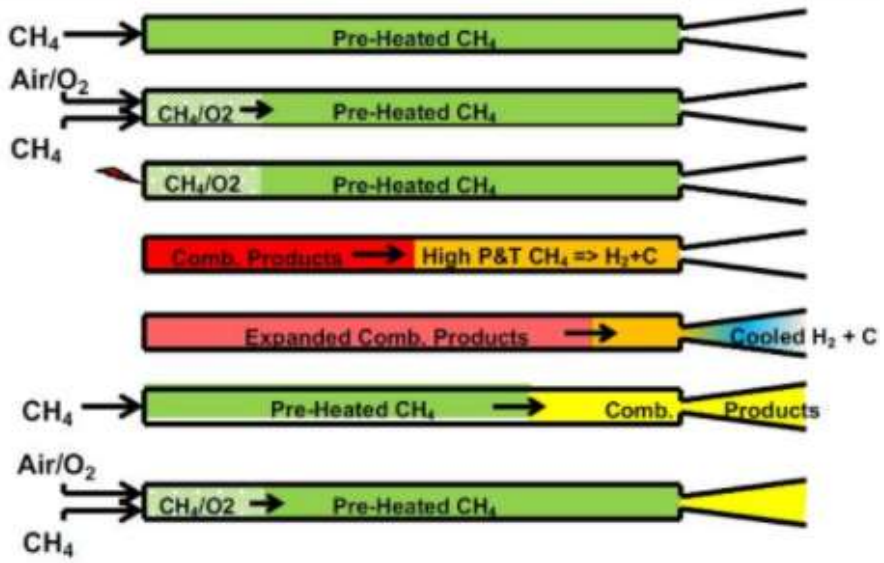
MITSUBISHI HEAVY INDUSTRIES

SoCalGas

PG&E

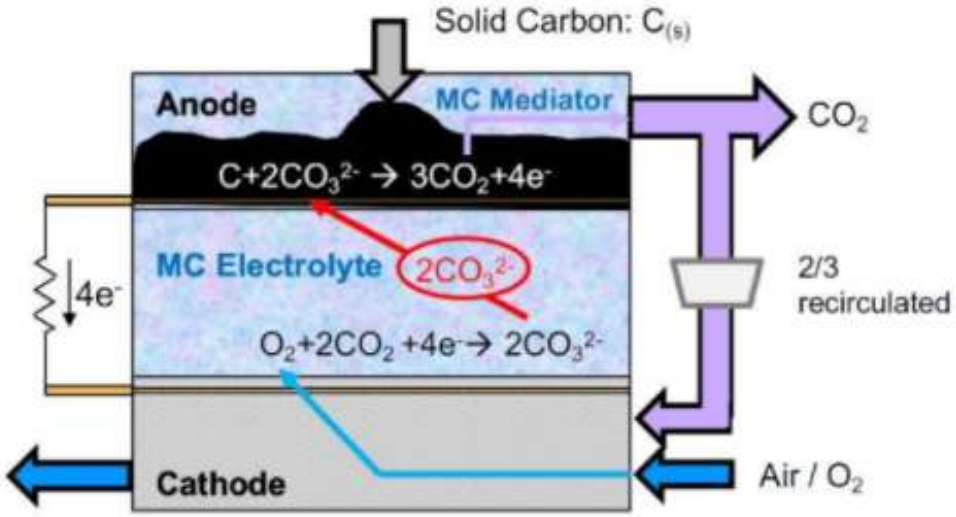
Pulse Methane Pyrolysis : Ekona Power, Canada

Pulse Methane Pyrolysis (PMP)



- Pulsed injection of thermal & mechanical energy
- Automatic removal of C-buildup due to unsteady flow
- Fast kinetics quenching via unsteady expansion
- Prototype reactor presently being assembled & tested
- PI Partners: Geminus Technologies, U of W, NRC

Direct Carbon Fuel Cell (DCFC)

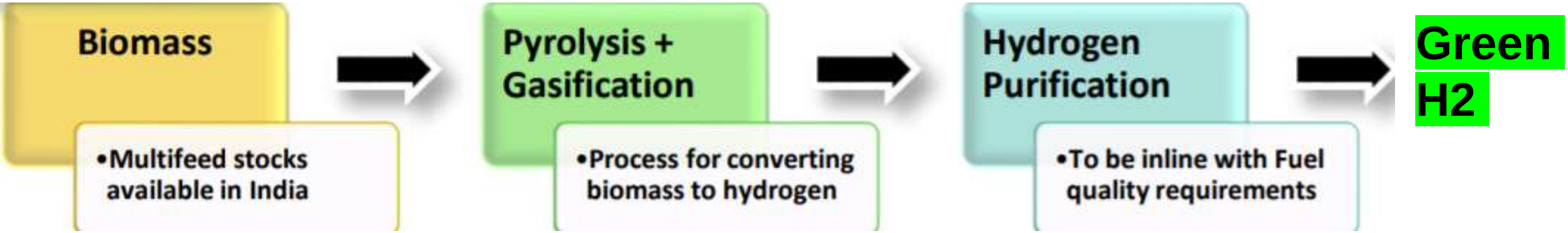


- Fuel: solid carbon in a MC mediator
- Advantages: high efficiency + pure CO2 byproduct
- Challenges: carbon delivery to anode
- Prototype *button cell* is presently being assembled & tested
- PI Partners: NRCan-Canmet Energy, NRC

Levidian Loop50 Shipping container: CH4 Pyrolysis

- LOOPs can be deployed in standard shipping containers or into permanent infrastructure as single units or larger arrays. Levidian is currently scaling up LOOP technology to deploy LOOP1000+.
- The device uses a patented low temperature, low pressure process to crack methane into its constituent atoms, hydrogen and carbon, without the need for catalysts or additives.
- The carbon is locked into high-quality graphene and the hydrogen can either be used as a hydrogen-rich blend or separated and stored for use in its pure form.
- A single LOOP50 device utilising Bio-CH4 reduces CO2 equivalent (CO2e) by 100 tonnes per year.

Biomass/Waste to H2 by Gasification



- IOC and IISc. working to Scale up the Tech
- Sentient Labs(KPIT Research) is also working on it
- "Inst. For Plasma Research"(IPR) has developed Gasification Technology

Plasma Gasification: Boson Energy

BEH2X Wood - Hydrogen from Biomass Residue | Göttingen, Germany

- **Project Purpose**
  - Gasification of biomass, forest-residue to produce renewable 24/7 Hydrogen with with X set of options
  - Demonstrate scalable roll out model across Europe with a global aim
  - Hydrogen compliant with ISO 19880:2020-1
  - Zero Emission transition: Strive to eliminate emissions CO_2, NOx, PM and other
  - Set up a Distributed commodity model with minimal infrastructure stress (fits also to local H2 storage model)
  - Target 100% availability, 100% stability and 100% repeatability of complete system
- **Partners**
  - **Stadtwerke Göttingen:** Feedstock, site, utilities, Hydrogen offtake
  - Local Authorities
  - TU Freiberg, IEC, KTH Stockholm
- **How does it work?**
  - Thermochemical recycling of woody biomass to Hydrogen
  - High Hydrogen yield through integration of gasification, steam reforming and WGS
- **Project description**
  - Biomass input: 700kg/h
  - Hydrogen output target: 70+ kg H2/h for local dispensing
  - Offtake: Stationary Fuel Cell for speed charging of BEV and/or peak load and FCEV
  - **Siemens Energy Supplier:** Fabrication of Boson's reactor system, Instrumentation, Electric & Controls, Compressors, Storage. Partner in SCM, Erection, Balance of Plant

SIEMENS energy

1 ton of waste wood =
100 kgs of H2 =
1250 kms of bus =
600 litres of diesel saved
Minimum 4 tons of CO_2 saved

BEH2X Waste - Hydrogen from Non-Recyclable Mixed Waste | Oslo, Norway

- **Project Purpose**
  - Gasification of non-recyclable mixed waste to produce renewable 24/7 Hydrogen with X set of options
  - Proprietary technology. Demonstrate scalable roll out model across Europe with a global aim
  - Hydrogen compliant with ISO 19880:2020-1
  - Zero Emission transition
  - Strive to eliminate emissions CO_2, NOx, PM and other
  - Set up a Distributed commodity model with minimal infrastructure stress (fits also to local H2 storage model)
  - Target 100% availability, 100% stability and 100% repeatability of complete system
- **Partners**
  - **Norsk Gjennvinning:** Feedstock, site, Hydrogen offtake
  - Local Authorities
  - TU Freiberg, IEC, KTH Stockholm
- **How does it work?**
  - Thermochemical recycling of waste to release Hydrocarbons – clean and efficient
  - High Hydrogen yield through integration of gasification, steam reforming and WGS
- **Project description**
  - Waste input: 35k tons waste per year
  - Hydrogen output target: 3 500 tons H2
  - Offtake: Stationary Fuel Cell for speed charging of BEV and/or peak load and FCEV
- **Suppliers - committed**
  - **Siemens Energy Supplier:** Fabrication of Boson's reactor system, Instrumentation, Electric & Controls, Compressors, Storage. Partner in SCM, Erection, Balance of Plant
  - Plasma Torches by Pyrogenesis
  - Refractories by RHI Magnesita

NG Norsk Gjenvinning

SIEMENS energy

Boson Energy (High temperature Plasma torches): Implementing 18TPD Plant in Germany (commg Q3)
Ways2H - (Gasification after mixing waste with Ceramic)Sewage sludge to H2(1T Sewage to 50kg H2)

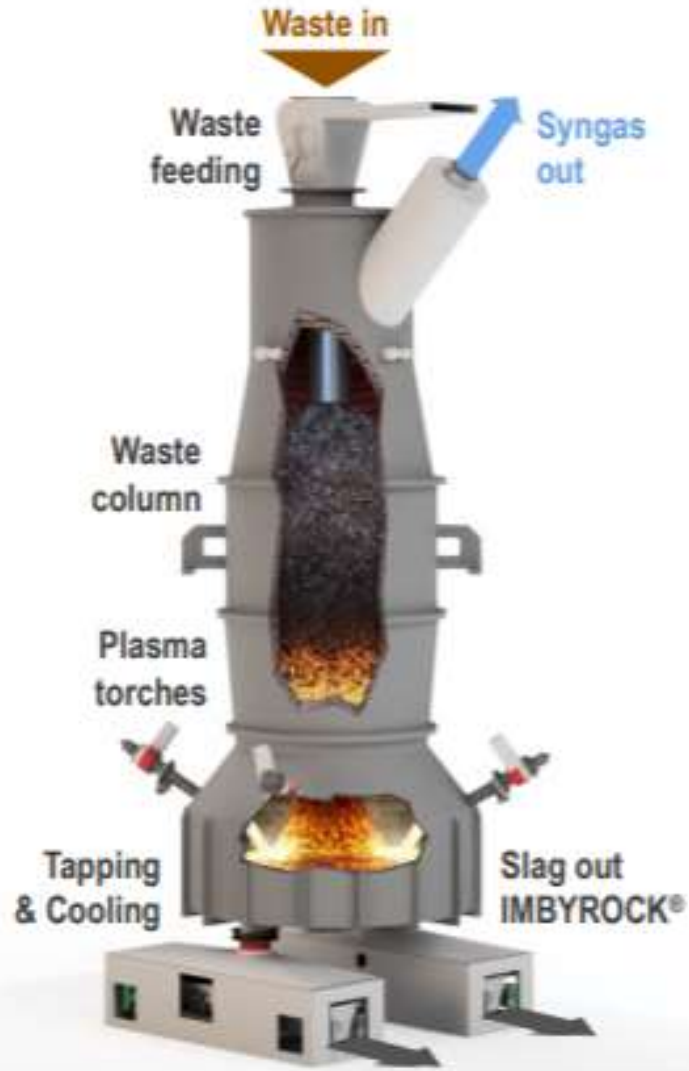
- Biezel Green Energy (TAD:Thermally accelerated Anaerobic Digestion):Implementing at Khandva

Waste To H2 by Boson Energy

A waste pile and the corresponding inert glass aggregate after treatment (close-up above)

BOSON ENERGY

- Core technology proven at full commercial scale
- Complete elimination of wide range of wastes
- Net CO_{2e} negative. Zero toxic ash. Zero emissions.
- High energy efficiency and Hydrogen output
- High execution capacity through global partners
- Turn-key 'as-a-Service' business model



Financial Analysis

Typical 50TPD waste to Hydrogen plant

Waste	50 TPD	Annual Revenue
Project Cost	13.50	Cr
Raw material cost	1.65	Cr
Electricity Cost	0.19	Cr
Other Variable charges	0.50	Cr
Total Variable Cost	**2.34**	Cr
Total Revenue (Except Biomethane Revenue)	**9.44 (**6.89)	Cr
Annual Revenue from Compost	2.64	Cr
Annual Revenue from Liquid Manure	2.25	Cr
Annual Number of Carbon Credits earned	2	Cr (180000CoU)
Revenue from Biomethane at 55	2.55	Cr

Cost of converting Bio-methane to H_2 → SMR Leasing Cost $2/Kg =Rs 150/Kg of H_2

Revenue forgone (sale of Bio-methane) Rs 180 (for 4 Kg @Rs 45/Kg)

Other Misc expenses Rs 25/Kg

4 Kg methane will produce 1 kg of H2

Prod. Cost of 4 Kg Methane = (-)324 INR

Hence,

Cost of 1 Kg of H2 = INR 30/kg of H2

(From III yr onwards)

Raw Material INR 1/ kg (330 days)

Net Profit per year: 7.1 Cr (9.44 - 2.34)

Payback period:1.5 yrs~2yrs

Total Capacity: Bio-Methane=550 Ton pa

OR Hydrogen 150 Ton pa

Lot of Energy and resources reqd for H2 by Electrolysis using RE

Energy
- ~ 50 – 60 BU/ MT Green Hydrogen
- ~ 30 – 40 GW of Installed Capacity

Land
- ~ 4-5 acre / MW for RE
- ~ 10 acre / GW for Electrolyzer

Water
- ~ 9-10 litre/Kg of Hydrogen
- ~Raw water – 3 to 4 times

Material
- Nickle
- Platinum, Iridium
- Zirconium, Yttrium

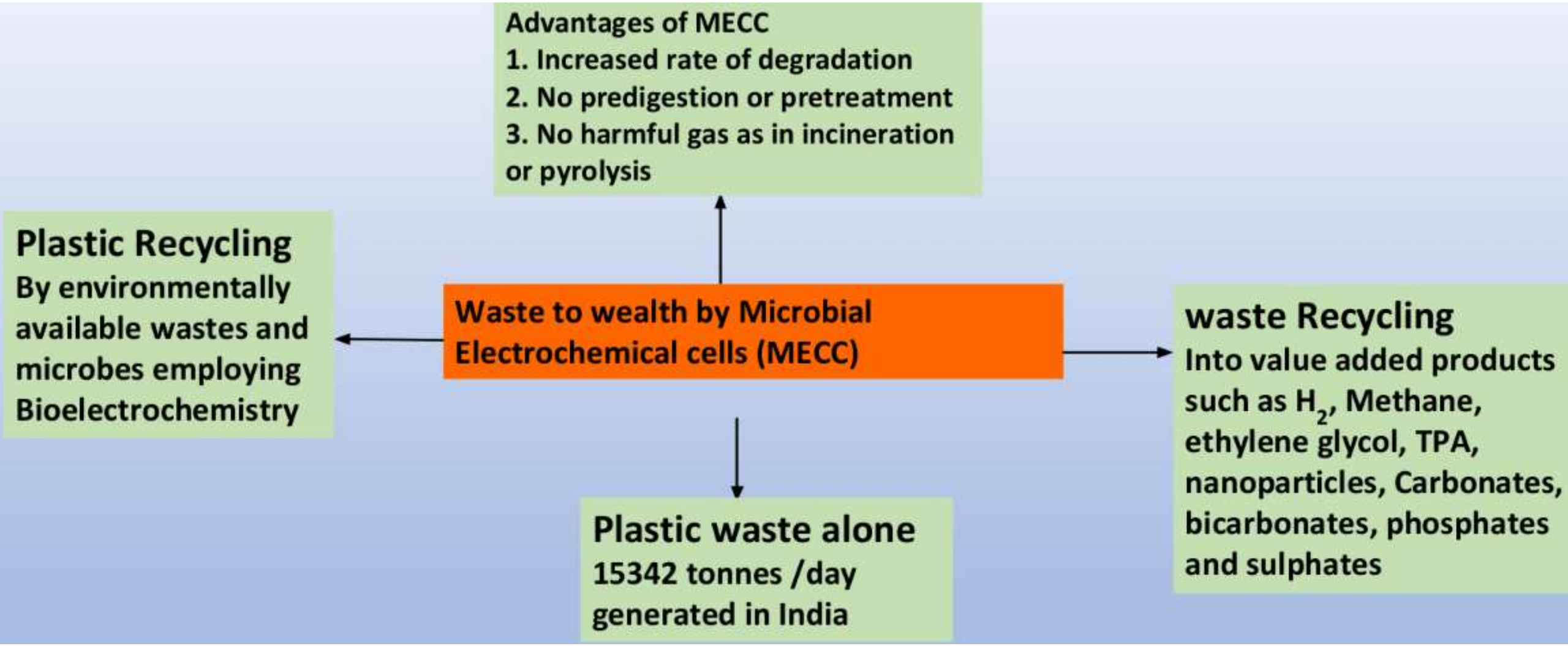
Min. Cost of Green H2 using Electrolysis by RE ~ Rs 300/Kg

Soundness of Business Plan for Waste to H2

System	Source	TRL Tech Maturity L	Cost of H2/Kg (INR)
Steam methane Reforming	Fossil NG	9	110
Coal Gasification	Fossil Fuel	9	140
Water Electrolysis	Water with grid electricity	9	313
Pyrolysis or AD+ Methane Pyrolysis	Waste/Biomass	7	140
MECC	Unsegregated Waste	5	40
Clear Hydrogen	Abandoned Gas Well	7	110
Biomass Gasification from waste/Biomass	Waste	9	200

Chosen Method: AD +SMR: Waste to Biomethane to H2+Manure+Compost

MECC (Microbial ElectroChemical Cell)



MECC thru Microbes

waste eating Microbes!!!
Gram negative, non pathogenic

Hydrolyse ester bonds with enantiospecificity

Releases enzymes such as PETase and MHETase

Degrade waste into desired product based on the rate of release of chemicals by bacterium elecrochemically

No control over the metabolic rate as it is a natural process

Takes millennium to degrade the tonnes of plastic waste generated every day

Novel Concept to Convert waste into H2,EG &TPA

In MECC as biofilms to degrade unsegregated waste including plastic

Hydrolyse ester bonds with enhanced enantiospecificity

Release rate of enzymes such as PETase and MHETase increases

Enhanced degradation of waste including plastic into desired products (H2, Methane, methanol, ethanol, carbonates, bicarbonates, sulphates, nanoparticles etc

Advantages of MECC over natural/biotechnology/pyrolysis or incineration of plastic

- Simulating bacterium to release the enzyme at higher rate via electrochemical perturbations
- Control over the experimental conditions such as current density, potential, pH, partial pressure of oxygen to control formation of Ethylene glycol and Terephthalic acid
- Inhibit the absorption of ethylene glycol and TPA by the outer membrane and stops further metabolism by bacteria via electrical impulses on the electrode
- Takes hours to days to degrade the tonnes of plastic waste generated every day
- Environmental friendly, no harmful pollutants, complete conversion of plastics to value added products

Techno-Economics with MECC

Considering 50 kg per day waste capacity

Product	Rate (INR)	Qty	Revenue (INR)
H2	40 /kg	20	800
Ethylene Glycol	50/lit	10	500
TPA	65/kg	20	1300
Fertilisers			400

Revenue per day = Rs 3000/-

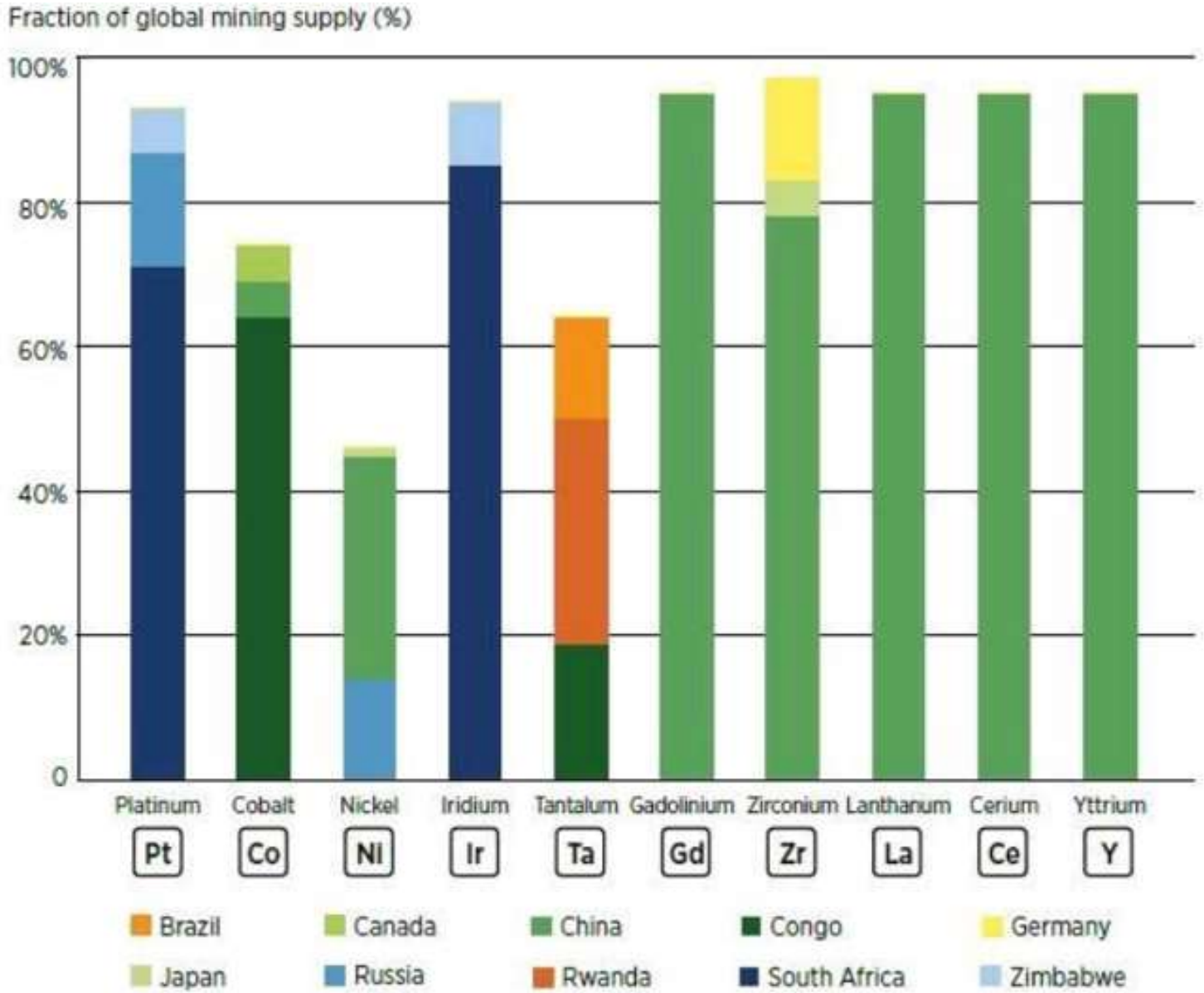
Annual revenue from a 50 kg per day plant = Rs 10 lac

Waste capacity per day	Annual Revenue (INR)	Cost +AMC INR Crore	Payback Period
50 kg	10 lac	1Cr	
500 kg	1Cr	2 Cr	2.5 yr
5 TPD	10 Cr	4 Cr	5 months
50 TPD	100 Cr	8 Cr	1 month

S. No	Capacity Per Day (Patented Technology)	***Cost per quantity (INR) (including, OPEX, 18%GST and AMC)***	AMC charges (INR)	Timeline for product installation, commissioning
1.	50 kgs	***1,18,00,000***	10,00,000	4 months
2.	500 kgs	***2,36,00,000***	20,00,000	4 months
3.	Five ton	***4,72,00,000***	40,00,000	6 months
4.	50 ton	***9,44,00,000***	50,00,000	12 months

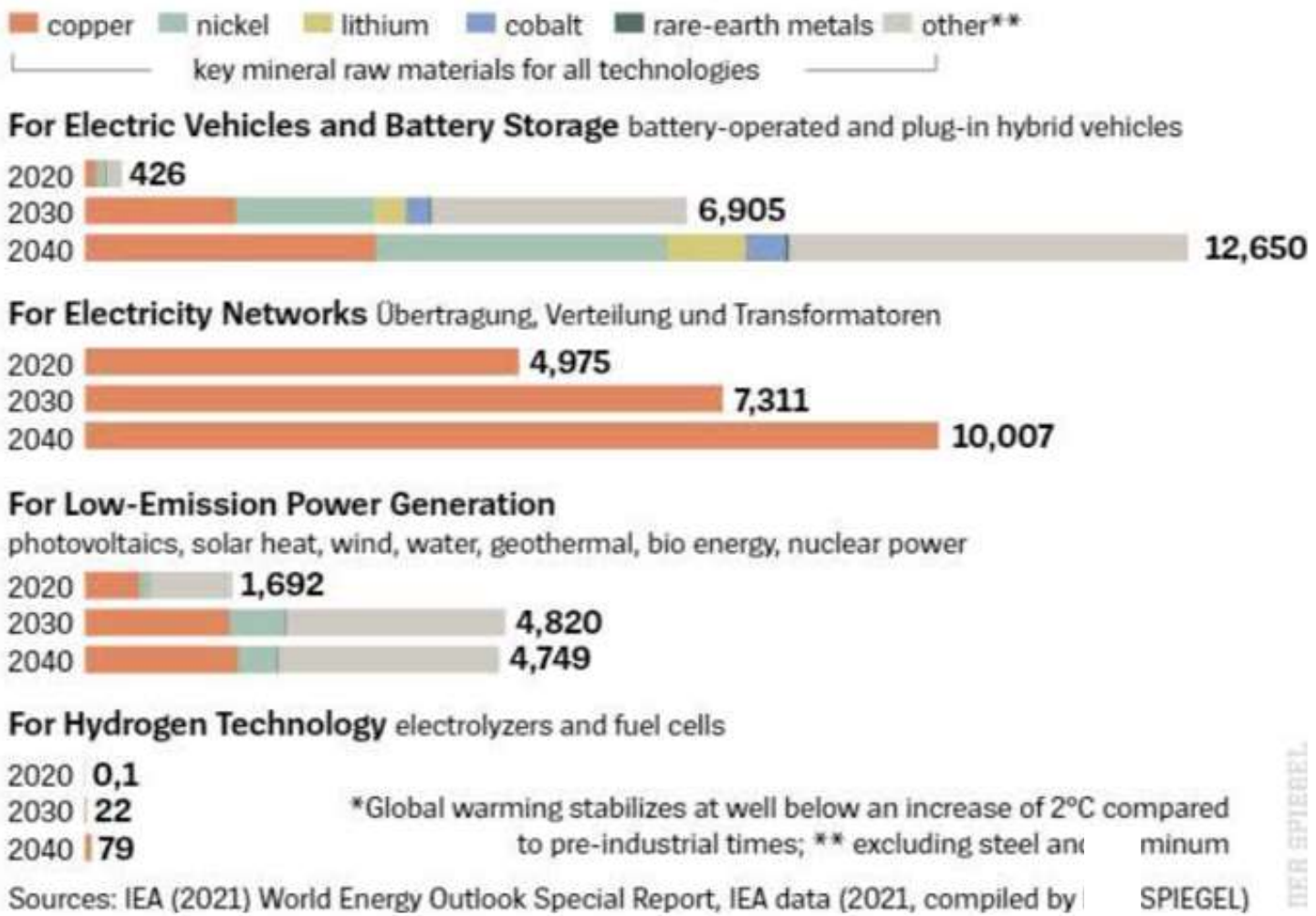
Country generates 62 MMT MSW and more than 150 MMT spare agri-waste and other wastes. Thus there is enough scope of revenue generation. If 200 such plants could be set up for treating 50x200= 10000 TPD waste an Income of INR 20000 Cr per annum is possible

Top Producers of Critical Materials



Global demand of materials for Clean Energy Tech

It is clear that H2 has minimal Imported MATERIAL Requirement and so least dependence of Imports for India



New Totyota Mirai

H2 in CNG pipeline:

Economical notifications:

HCNG 585(E) dtd25/09/20 &

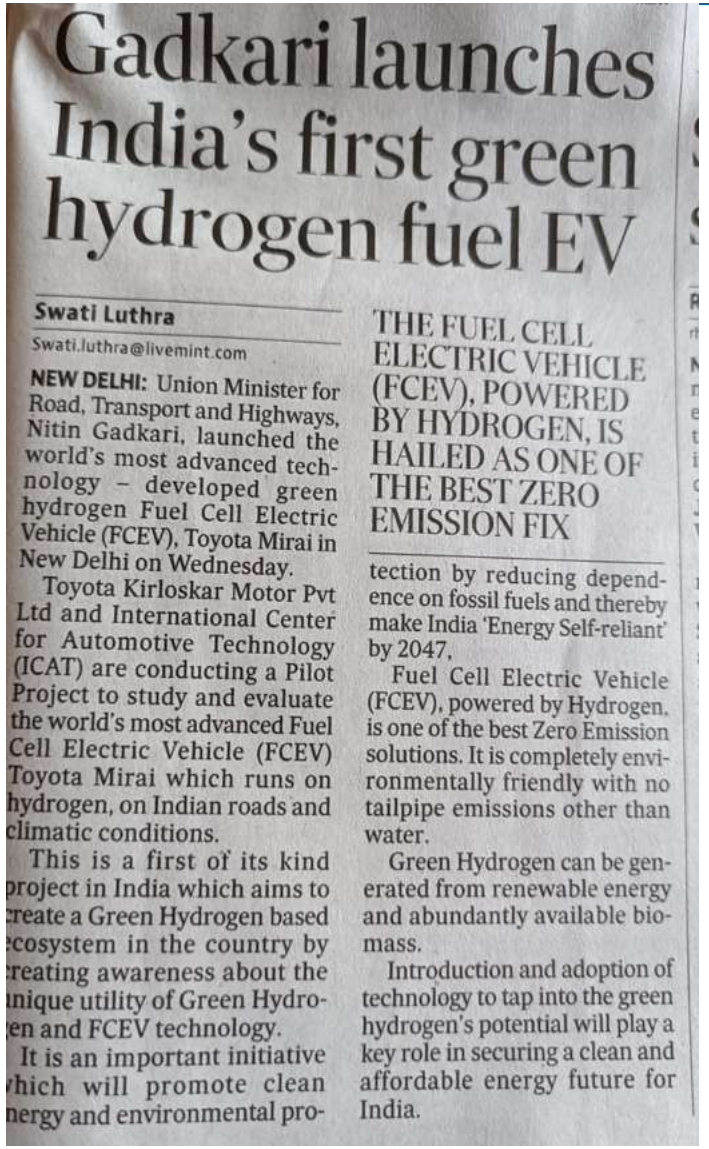
FCEVs safety & Type

approval Eequirements GSR

579E

180HPM		
Range 650 km or 400Miles		
Cost:$50,000 to $70,000		

H2 Mirai Launched on 16th March 2022



Gadkari launches India's first green hydrogen fuel EV

Swati Luthra
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NEW DELHI: Union Minister for Road, Transport and Highways, Nitin Gadkari, launched the world's most advanced technology – developed green hydrogen Fuel Cell Electric Vehicle (FCEV), Toyota Mirai in New Delhi on Wednesday.

Toyota Kirloskar Motor Pvt Ltd and International Center for Automotive Technology (ICAT) are conducting a Pilot Project to study and evaluate the world's most advanced Fuel Cell Electric Vehicle (FCEV) Toyota Mirai which runs on hydrogen, on Indian roads and climatic conditions.

This is a first of its kind project in India which aims to create a Green Hydrogen based ecosystem in the country by creating awareness about the unique utility of Green Hydrogen and FCEV technology.

It is an important initiative which will promote clean energy and environmental protection by reducing dependence on fossil fuels and thereby make India 'Energy Self-reliant' by 2047.

THE FUEL CELL ELECTRIC VEHICLE (FCEV), POWERED BY HYDROGEN, IS HAILED AS ONE OF THE BEST ZERO EMISSION FIX

Fuel Cell Electric Vehicle (FCEV), powered by Hydrogen, is one of the best Zero Emission solutions. It is completely environmentally friendly with no tailpipe emissions other than water.

Green Hydrogen can be generated from renewable energy and abundantly available biomass.

Introduction and adoption of technology to tap into the green hydrogen's potential will play a key role in securing a clean and affordable energy future for India.

HCNG Buses : DTC: 70% reduction in Emissions

Mass Emission Results – Certifying Lab

Emission species	% benefit achieved with HCNG over CNG	% reduction claimed in Hon'ble Supreme Court
CO	-77.97	70
THC	-68.15	15

Raw Emission Results

Idle Emission Species	Idle Emissions		
	CNG	HCNG	% reduction achieved
CO (%)	0.13	0.07	-50.63
NMHC (ppm)	96.16	40.08	-58.32
NOx (ppm)	112.45	85.71	-23.78
O_2 (%)	6.64	6.75	+1.68
CO_2 (%)	7.12	6.69	-6.15

Fuel Economy Benefits

Fuel	Avg. FE (Km/Kg)	% Fuel saving with HCNG
HCNG	3.07	+4.77 (against 4-5% claimed)
CNG	2.93	

Repowering Coal Fired Plants with Gas/H2

Shift from Coal to Gas-fired reduces 50% of the CO2 emissions, and also lowers other pollutants like Hg, NOx, SOx and PM

Blending with H2 reduces pollution drastically

- China: **GE(using** GE 9HA.01 Turbine) **commercial operations started Junliangcheng 661 MW plant in Tianjin City, :** 50% H2 by volume blended with natural gas

- Capital Power a **Canadian utility has ordered two Mitsubishi Power natural gas-fired turbines(**M501JAC) **to repower its combined cycle plants in Alberta,** as it converts from coal-fired generation Expected repowering completion of Unit 1 in 2023 and Unit 2 in 2024.
- The repowered plant will provide 1,360MW of electricity capacity.

Co-firing Coal with H2/NH3

https://www.ammoniaenergy.org/articles/ihi-first-to-reach-20-ammonia-coal-co-firing-milestone/

- The Japanese manufacturer IHI Corporation **announced** on March 28,2018 successfully demonstrated 20% NH3 co-firing with coal (% energy content)

https://www.powermag.com/jera-planning-to-shift-coal-power-fleet-to-100-ammonia/

- Japan: JERA plans to shutter its entire 2.2 GW supercritical coal plant by 2030, and then gradually co-fire coal with ammonia and hydrogen

Utah Power Plant :H2 adoption/transition from Coal

- CA Delta(Utah): **Coal** power plant (1900MW) is transitioning to **840 MW Hybrid (30% H2/NG fuel) in 2025 and** later in 2045 to switch to 100% H2

https://www.greenbiz.com/article/you-say-old-coal-plant-i-say-new-green-hydrogen-facility

- 1000 Electrolysers (Siemens Energy's Silyzer technology) and H2 storage
- The scope also includes hydrogen compression, storage and intelligent plant controls.

SWOT Analysis Biomass to H2

Strengths

Decentralized; Strengthens self-reliance ,
Environmentally sound;

Locally available fuel, ability to meet the fossil fuel applications/replacement

- Indigenous technology
  - Directly from biomass to hydrogen
- Hybridization with other renewables for firm power
  - To support other renewable hydrogen
- Employment potential

Weakness

- No level playing field
- Fuel dispersed;
- Not many players in the sector
- Low visibility
- Completely indigenous technology

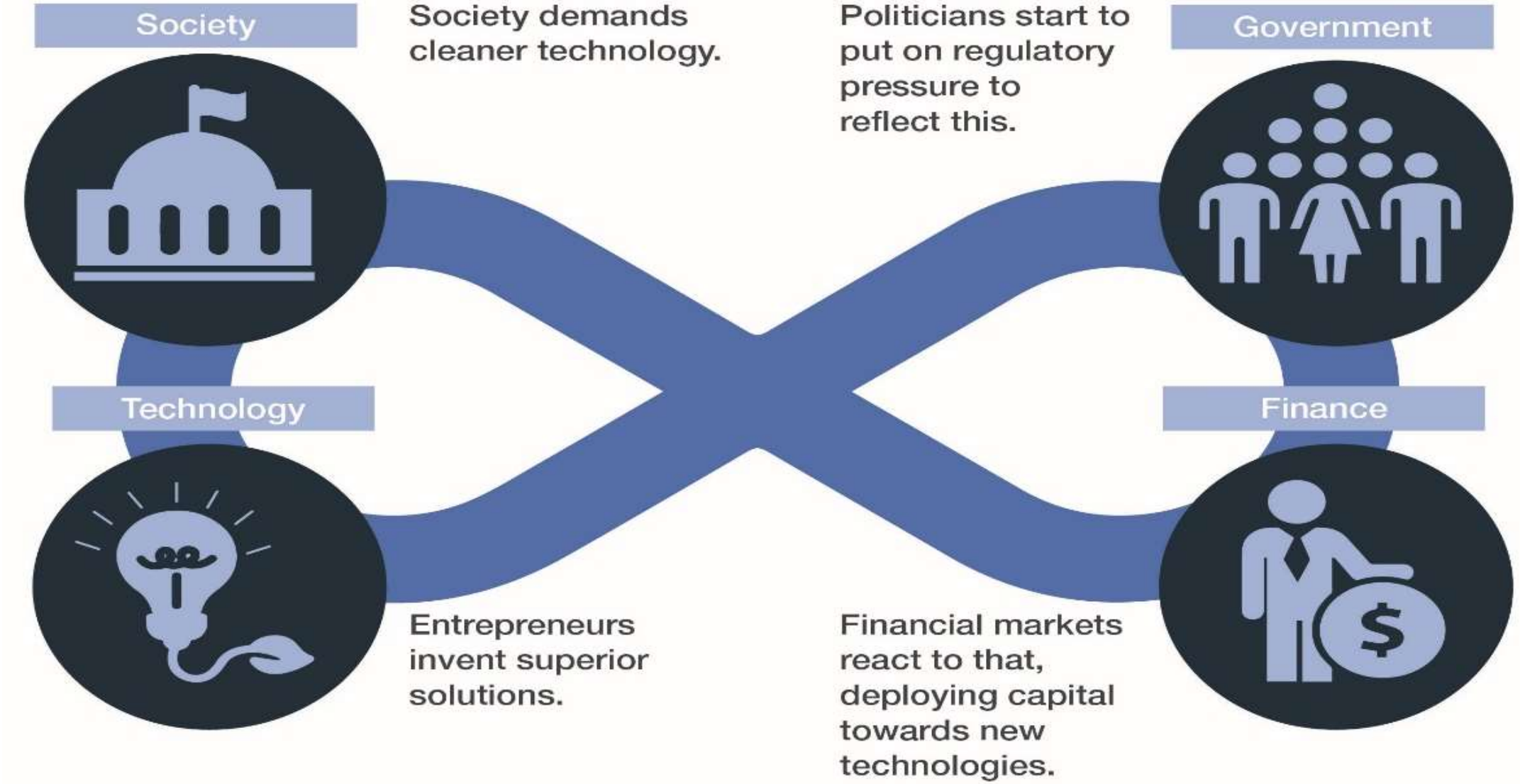
Opportunities

- ATMA Nirbar
- Potential very high
- Distributed concept
- Gestation period nearly zero;
- Hydrogen generation costs are comparable to that of fossil fuel system;
- Supports GoI's initiative on Green NH3 and Urea

Threats

- Reforms under-emphasize biomass-based systems;
- No access towards level playing field,

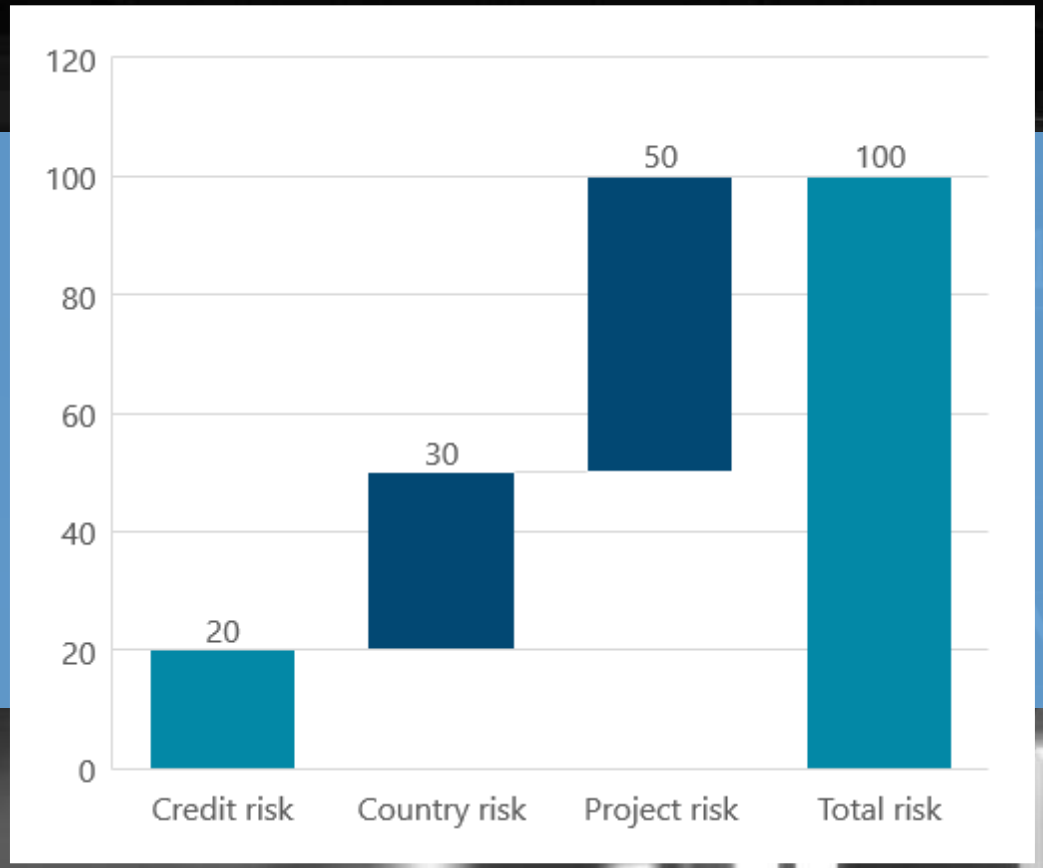
Stakeholder's engagement



Policy Recommendations

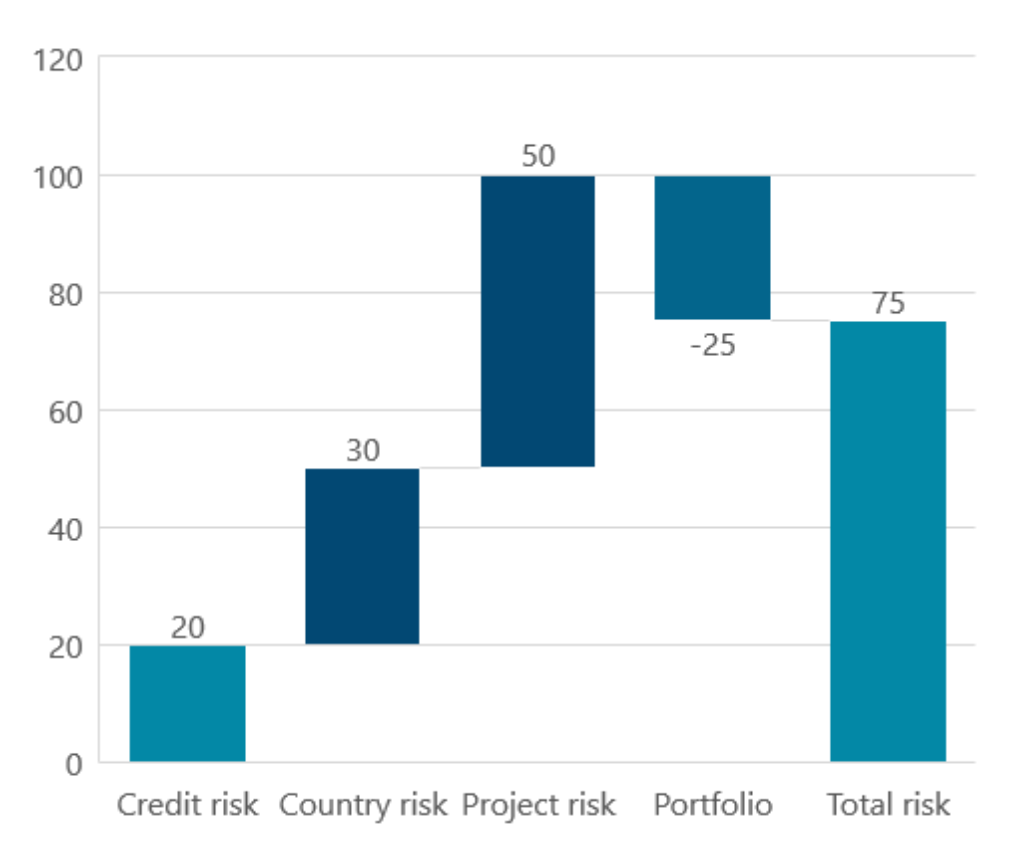
- Carbon intensity should be measured instead of colours
- If pilot/ demo plants are set up by govt/ PSU, the success will create change and more and more entrepreneurs will come in.
- Derisked and Long term Finance by Banks / Institutions/ Agencies
- Carbon mkt regulator/ regulations/ trading established ASAP. Carbon credits will help financing green economy
- Policies supporting decentralised waste to H2 : reducing transportation of waste/H2 and the waste accumulation
- Just like RE: Bankink and Different Points of Injection and withdrawal should be permitted for Bio-H2 and for Bio-CH4
- Certified Carbon Intensity for H2 and bio-CH4

PROJECT FINANCE DOES NOT WORK FOR NON-TRADITIONAL RENEWABLE ENERGY PROJECTS



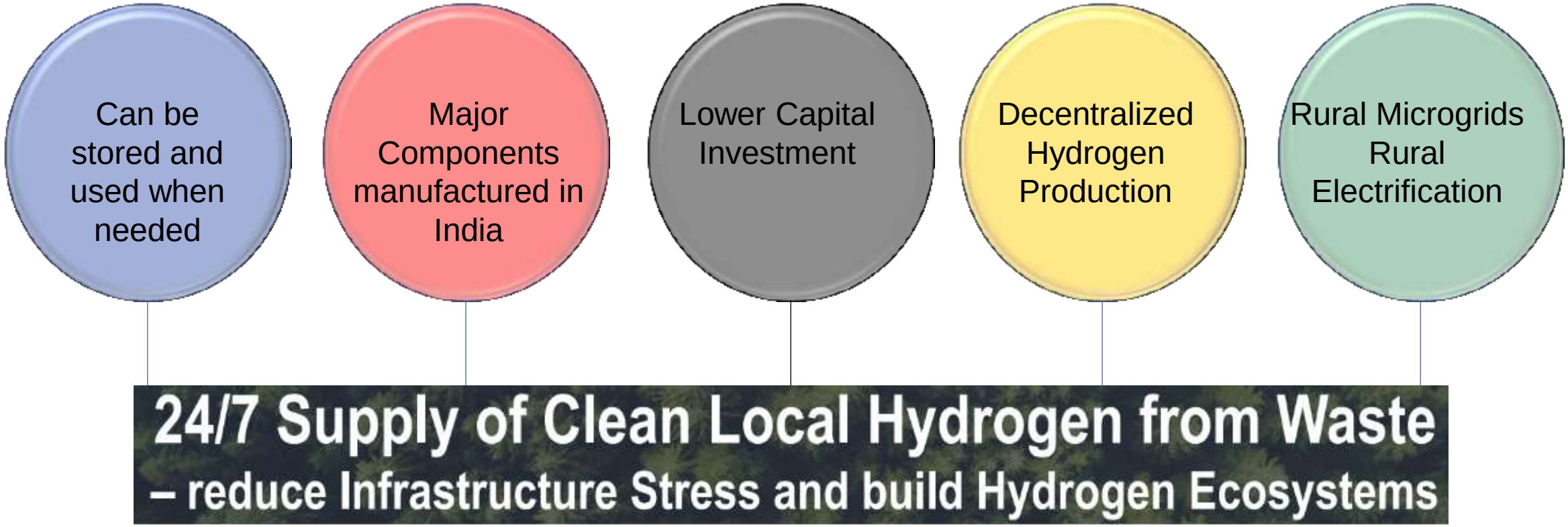
- Project finance is about the Total Risk
- In which country risk is high
- Project risk is not understood / no specialists on board
- Without benefit of portfolio risk reduction

EXPORT FINANCE CAN BE LAYERED AND MAKES IT EXCELLENT FOR NON-TRADITIONAL RENEWABLES



- Bank only exposed to Credit risk
- Ext Fin Agency exposed to country risk
- Guarantor is exposed to the net of individual project risk and portfolio risk mitigation measurements
- Total risk is lower
- Individual parties only take partial risk

Hydrogen from Waste – Advantages



Summing up

- Hydrogen from Waste would be a key driver in the triad of energy, economy and environment.
- Meeting the requirements for Grid Stability, Energy storage Transport and utiliziation in Micro-grids.
- @ Rs 30/Kg as against Rs 313/Kg of Hydrogen from Electrolysis it is economic and sustainable.
- Hydrogen from waste is greener than the green because it prevents contamination of soil, water and air, mitigates GHG and returns carbon to the soil improving fertility, preventing soil erosion and land slide.

All SDG Goals can be addressed Direct and Indirect Impacts

Conclusion

- **Waste to H2 is Greener than green**
- **Green H2 is Multi-Decade opportunity**
- **Green H2** can integrate RE sustainably and thus Provide Energy across Sectors
- Additional benefits being :
  - Cleaner Environment, Avoid Methane Flaring, Waste Treatment, Clean Energy, Free Prime Lands being locked by Landfills
  - More Jobs/Lesser Migration
  - Lesser imports
  - Higher Exports (Lo Carbon produce like Steel,Green NH3)
- **PPP (Planet, People & Prosperity) [100]**
- **Win-win for all**

Thank You,

Questions ?