13th WORLD PETRO COAL CONGRESS
INTERNATIONAL CONFERENCE & EXPO
15-16 February 2023 | New Delhi
International Confernece on Petroleum-Coal-Gas-Hydrogen

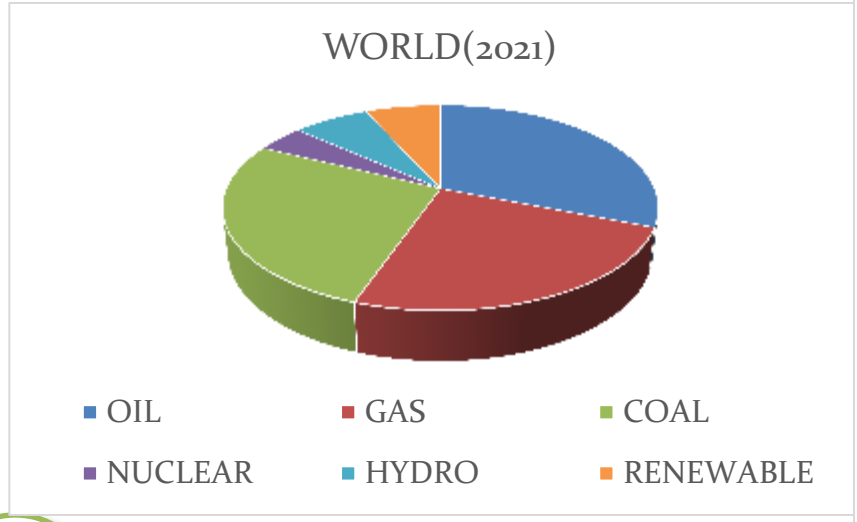
Future Fuels and Green Energy Transition

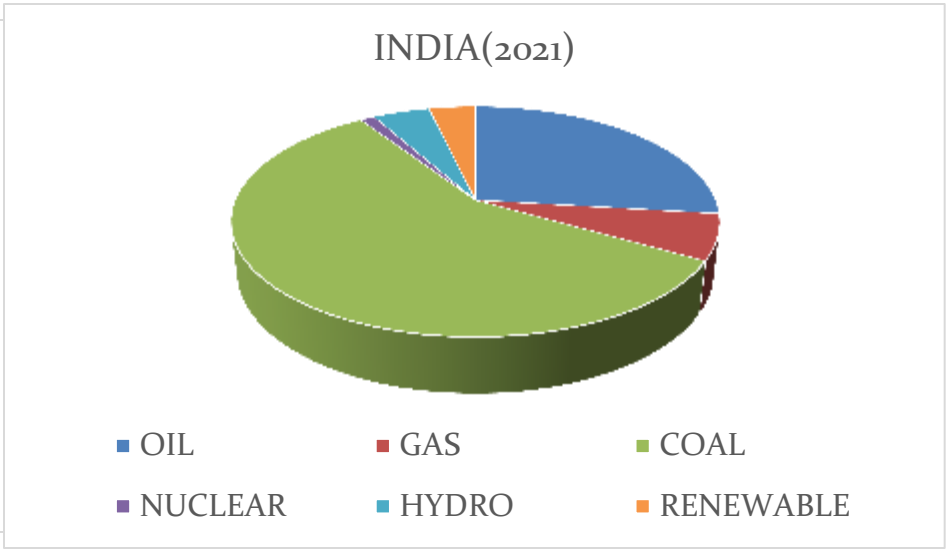
Dr BS Negi
Former Member, PNGRB (India)

Primary Energy Consumption

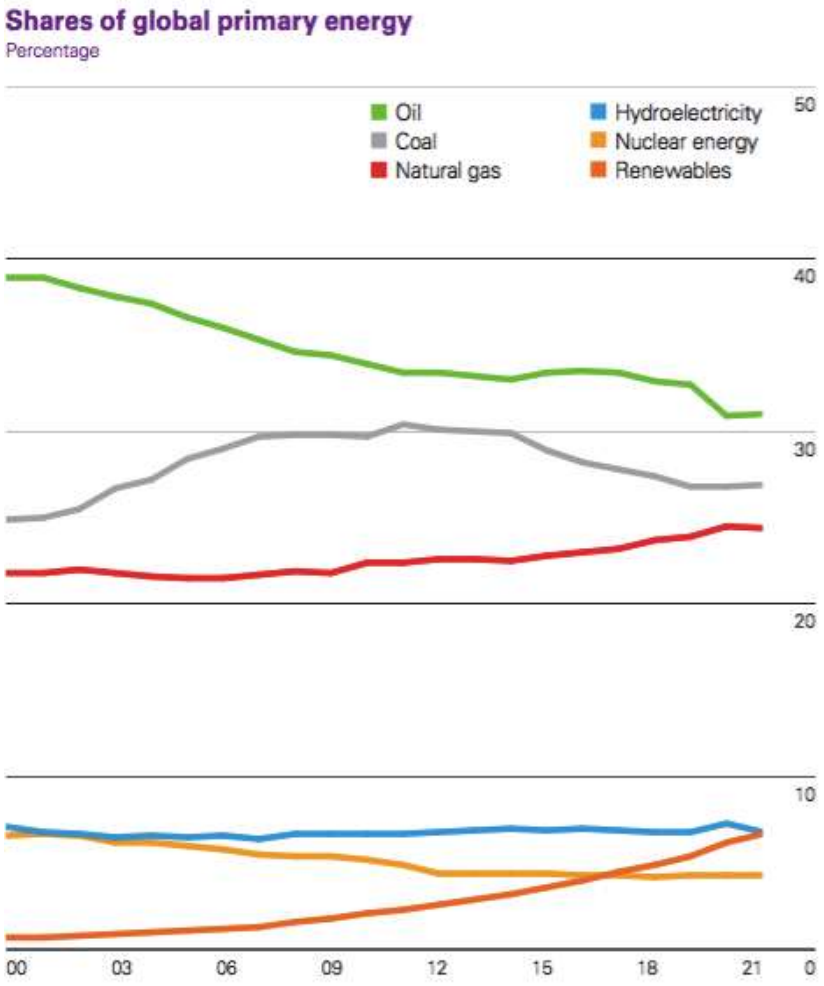
BP Statistical Review-2022

Energy	Oil	Gas	Coal	Nuclear	Hydro	Renewables	Total (Exaj)
World	184.21	145.35	160.10	25.31	40.26	39.91	595.14
%	31	24.4	26.9	4.25	6.75	6.7	100
India	9.41	2.24	20.09	0.40	1.51	1.79	35.44
%	26.6	6.3	56.69	1.11	4.26	5.05	100





Primary Energy Decadal trend



Challenge to Energy Transition

- Energy used in India has doubled in last 20 years and will further increase by 25% by 2030
- World Fossil fuel consumption **82.3%** with Natural Gas **24.4%** (**57.9%** Oil and Coal)
- India Fossil fuel consumption **89.59%** with Natural Gas **6.3%** (**83.29%** Oil and Coal)

Global Concerns

- Green House Gas emissions
- Global Temperature rise 1.5°C (Limiting)
- Consequences:
  - Global warming
  - Melting of Ice, rise of sea levels, floods, draught
  - Submergence of islands

Efforts to combat Global Warming

- Conference of Parties (COP) of 197 countries, Under UN
- Koyoto (Japan) Protocol
- Paris Agreement: Consensus to limit Temp. rise to 1.5 ^{o}C
- COP-26 in Glasgow-"world last chance to stop catastrophic global warming"
- Outcome-
  - Net Zero by 2050/2070(India)
  - Financial Support from developed countries/ more polluting countries
  - Phasing out of Coal

In search of More Benign Fuels

- Renewables (13.45% with Hydro)
- Natural Gas (24.4%)
- Hydrogen (also as energy storage)

❖ Present fuel mix will not achieve Net Zero

❖ Share of renewables to increase fast

❖ Natural Gas will continue to play significant role till 2050

❖ **Hydrogen** is emerging Fuel/energy storage

Continuity for energy supply from Solar/Winds

- PSP- Pump Storage Plants: use reversible turbine, which become pump, for pumping water from sump to up stream storage and produce electricity as turbine
  - Example: Purulia (WB), Tehri Hydel Plant
  - Greenko is developing a round the clock renewable electricity through PSP in Seemandhra along with RE
- CSP-Concentrated Solar Plants, using molten salt Batteries and H2. CSP is new technology, where the sun rays are concentrated through an array of mirrors to a point where the heat is stored in molten salt and later the stored heat is used to run a conventional thermal steam turbine to generate electricity

Hydrogen Mobility

- H2 mobility represents an alternative to reducing CO2 emissions in transport sector

- H2 stored in vehicle is converted to electricity by a fuel cell, which in turn drives an electric motor
- H2 fuel cells are also used in Trucks, Ships and Trains

Hydrogen Mobility History

- 200 years ago H2 was used in IC engine
- First fuel cell made in 1839 but commercialized in 1970 (*Study by Deloitte and Ballard 2020*)
- 2014 world first fuel cell vehicle launched by Toyota
- H2 fuel cells are also used in Trucks, Ships and Trains

Hydrogen Production Process

- Fossil Fuel based:
  - Reforming Natural Gas with super heated steam
  - Gasification of Coal, Charcoal- partial oxidation at high temperature
  - Pyrolysis

Hydrogen Production Process

- Renewable Energy based:
  - ➢ Water splitting
    - ✓ Electrolysis process (Alkaline, PEM-Polymer Electrolysis, SOEC-Solid Oxide Electrolyzing Cell)
    - ✓ Thermochemical (Sulfur- Iodine Cycle, Copper -Chlorine cycle)
    - ✓ PEWS (Photo Electric Water Splitting)
  - ➢ Bio Mass Process
    - ✓ Biological(Bio photolysis, Dark fermentation, Photo fermentation, microbial electrolysis)
    - ✓ Thermochemical(Bio Mass gasification)

Production based Color Code

- **White H2-** Naturally occurring in universe
- **Brown/Black H2-** Produced from Coal gasification
- **Grey H2-** Produced from Natural Gas without capturing CO_2
- **Blue/Turquoise H2-** Produced from Natural Gas with CO_2 sequestration (this is carbon neutral energy source)

Production based Color Code

- Pink H2- Produced by electrolysis of water from the electricity produced from Nuclear Power Plant
- **Red H2**- Produced using thermal energy of Nuclear Power Plant for high temperature catalytic splitting of water
- **Purple H2**- Produced using electric power and heat (both) for splitting water in combined Chemo-Thermo hybrid electrolyzer
- **Green H2**- Produced by electrolysis of water using electricity generated from renewables

❖ France is pitching for naming nuclear power based H2 as Green

H2 Properties

- H2 is lightest element (Molecular weight 2.016 gm/mole), its transportation posed big problem
- H2 needs be pressurized to 500 Bar to 700 Bar to store in cylinder. A fill of 4.5 Kg enables a light vehicle to cover about 800 Km.
- In liquid form it has a temp. of (-) 253° C and cost of liquefaction consumes 30% of the H2 energy
- liquid density of H2 is 70.85 gm/lit i.e. it reduces in volume by 787 times

Green Ammonia for Mobility

- NH_3 is liquid at 20° C and 8.6 Bar
- NH_3 contains 17.8% of H_2 by weight i.e. 121 Kg/m^3
- NH_3 can be decomposed at 360- 600 ° C in an endothermic reaction using Ni or Ru (Ruthenium) as catalyst
- This property makes NH_3 very useful for long haul transport vehicles, ships and trains application as the refueling station can be regionalized where NH_3 decomposers are established
- Therefore NH_3 is good alternative to achieve H_2 mobility

H2 Mission- Indian Prospective

- Government of India has approved "National Green H2 Mission" NGHM with objective of:
- To make India the Global hub for production, usage and export of Green H2 and its derivatives, this will contribute to India's aim to become AATMNIRBHAR through clean energy and serve as an inspiration for global clean energy transition
- MNRE is the nodal ministry to implement NGHM

NGHM will result in

- Development of Green H2 capacity of 5 mmtpa with an associated renewable capacity of 125 GW
- Investment of Rs 8 lac Cr
- creation of 6 lac jobs
- Cumulative reduction in fossil fuel import of > 1 lac Cr
- Abetment of nearly 50 mmtpa GHG emission
- mission will facilitate demand creation, production, use and export of Green H2
- Under Strategic Intervention for Green H2 Transition (SIGHT) two distinct financial incentives for manufacturing of electrolysers and Production of Green H2 will be provided

H2 Applications- Indian Prospective

- Indian Govt. ramping up measures to increase green H2
- Rajasthan to first state to implement green H2 policy
- India's first green hydrogen fuelling station, being set up at **Leh** in the Union Territory of Ladakh, is all set to be commissioned before May next year. The first-of-its-kind project is being set up by state-run NTPC.
- Ladakh to become Carbon Neutral by 2050
- Kerala Government has allocated Rs 200 Cr for Green H2

H2 Applications Indian Prospective

- India's first H2 powered train to be ready by next year.(*Minister of Railways*)
- **Private initiative**: Ohmium and Amp Energy India to develop 400MW (@25MW modules) green H2 in 3 years. Ohmium has PEM electrolysers (easy to install and flexible modal)
- **RIL in association with Cummins India** unveils India's first H2 combustion engine technology for Heavy duty trucks

H2 Mobility Indian Prospective

- Hythane has been successfully used for automotive application
- H2 Mix in NG has been transported through NG pipeline
- ONGC and GreenKo signed an MOU to jointly pursue opportunities in renewable, green H2, green NH3 ant other derivatives.
- India and Egypt signed MOU to set up 220,000 mtpa H2, at an investment of $8Bn at Suez Canal economic zone

H2 Mobility Global Experience -US

- First country to establish H2 and fuel cell technology as a part of its National Energy Strategy in 1970
- Government support
- Public Private partnership
- Till 2019, FC based cars sold 7271
- California highest number of commercial FC vehicles (6830), planned for 2030, 1 million FC and 1000 Fuelling Station
- US earmarks $8B for establishing 6 to 10 regional clean H2 hubs *(reports DOE)*

H2 Mobility Global Experience -China

- First vehicle in 1999
- Highest H2 producing country (25mtpa)
- 3000 FCEV from 2017 to 2019
- Government initiative (Declassification of H2 as part hazardous chemical category, simplified approval procedure, subsidy on FCEV and fuelling stations)
- H2 vehicles running at par with ICE in operating cost
- Fusan is most active city in H2

H2 Mobility Global Experience -Europe

- In 2003, 25 EU nations launched combined R&D efforts
- 2008 public- private partnership begin
- Plans for 2030-2050 released (Regulator and Industry to join hands, invest in H2 and FC)
- H2 to replace 7% of NG for heating by 2030 and 32% by 2040
- Germany has successfully rum H2 fueled Train developed by Alstom. 3000 such train are planned
- Siemen has developed a prototype for H2 Train
- Britain plans for 35% primary energy to come from H2. They have plans to transport 5% blended H2 Through Natural Gas pipeline grid by 2024 and to raise it to 100% by 2028 *(Antony Green, Hydrogen Director, National Gas Grid)*

H2 Mobility Global Experience -Japan

- Government support ($260m allocated for R&D in H2 and Fuel cell)
- Fuel cell based CHP for household established in 2009 (now 20,000such units are operative)
- 2014 first commercial FCEV Mirai by Toyota
- As of June 2019, FCEV sold- 3219
- In 2018 consortium of 11 companies including Toyota, Nissan, established “Japan H2 Mobility” aimed at making 80 H2 refueling stations by 2021 and by 2020, 127 stations are in operation.

H2 Production bottlenecks

- Polluting H2 production other than Green H2
- H2 Pipeline transportation not yet proven
- Cascade transportation needs high pressure (500-700 bar)
- Water requirement to produce green H2: chemically about 10 lit of potable water is required to produce 1 Kg of H2, but in practice, 60-95 lit of water is required *(Engg consultant GHD)*
- Terry Kallis cancelled development of 6GW green H2 project in south Australia in May'22, due to water shortage

JAIHIND