# Future of Fuel and Propulsion Technologies

for

# Indian Railways

## Way to low cost sustainable traction

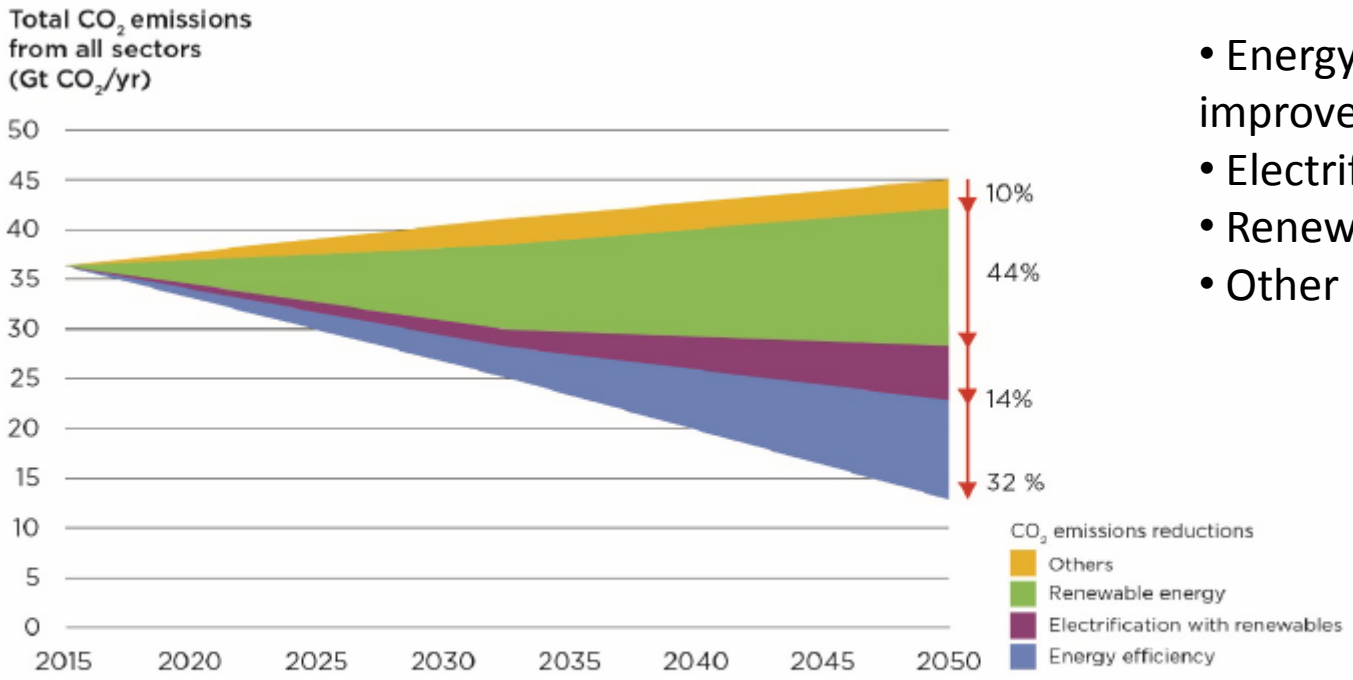
## A different Perspective

Indian Railways

# Traction Vision of IR

- Ultra-low emission railways
- Sustainable
- Low cost
- Reliable
- Supports security and strategy of India
- Geared up for natural calamities and disasters
- Futuristic

# International Efforts to reduce Carbon footprint



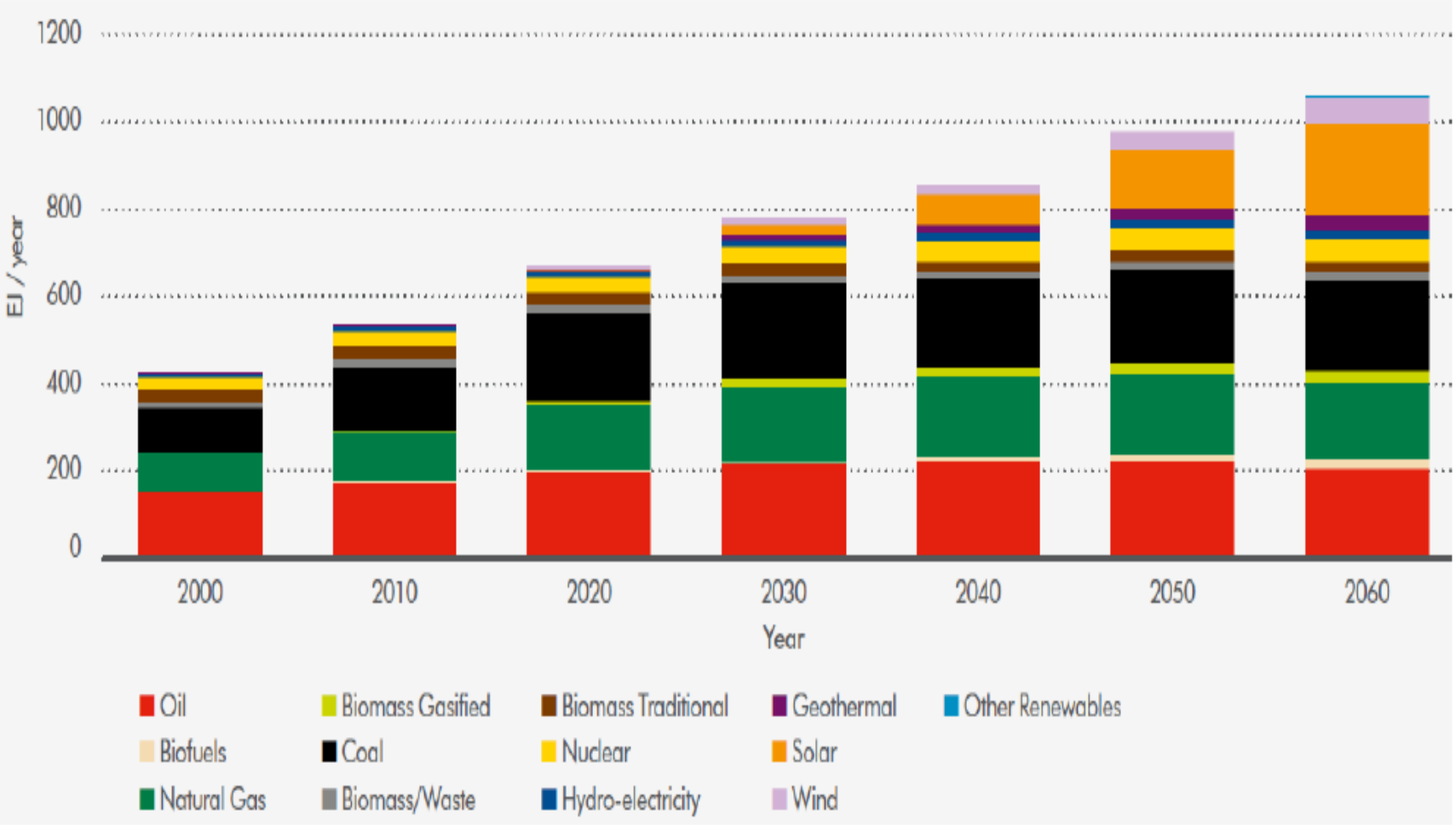

- Energy & material efficiency improvements – 32%
- Electrification of drives – 14%
- Renewable energy - 44 %
- Other measures – 10%

Notes: $CO_2$ emissions include energy-related emissions (fossil fuel, waste, gas flaring) and process emissions from industry. If only fossil fuel emissions were displayed in this figure, $CO_2$ emissions would start from 33 Gt in 2015 and would reach 40.5 Gt and 9.5 Gt per year in 2050 in the Reference Case and REmap, respectively.

# Some Perceptions

- Perception of electrification with wire
- Notion about centralised electricity production and distribution the only way
- Renewables will replace fossil fuels for electricity generation by 2050
- Tailpipe emissions form the only emissions
- Indian Railways traction is not 100% electrified

# Primary energy sources of various sources of power Shell - 2016



# Some answers

- Electrification of vehicles refers to electrification of drives
- Indian Railways traction is already 100% electrified- all type of locomotives use electric drives
- Indian Railways is already using healthy mix of renewables/ alternate fuels – Biodiesel and CNG
- Working towards developing 100% renewable technologies

# Indian Railways – Biodiesel initiative

- Largely responsible for mandating B5 biodiesel diesel blends on all diesel locomotives of Indian Railways
- Plan to increase this to B10 depending on availability of biodiesel
- Reinvigorated biodiesel industry, Zonal railways have started procuring biodiesel locally
- Has set up biodiesel production plants in India using local feedstocks
- Considering use of green diesel from wood and cellulosic material

# IR – CNG initiative

- Converted 20 Diesel Power Cars to run partially on natural gas
- Diesel substitution 20-25% achieved
- Proved in-port injection technology with 40% diesel substitution
- Working on 100% natural gas engines on DPCs with horizontal engines below underframe with hybrid concept with Cummins
- Tendered for LNG carriage of NG with lower fuel storage footprint

# IR – Solar Initiative

- Worlds first solar train launched by IROAF
- Working on solar PV set-ups in workshops, all railway stations, railway buildings etc.
- Considering investments in solar parks with Concentrated Solar Power in Gujarat and Rajasthan
  - For grid electricity generation
  - For methanol production with CO2 sequestration

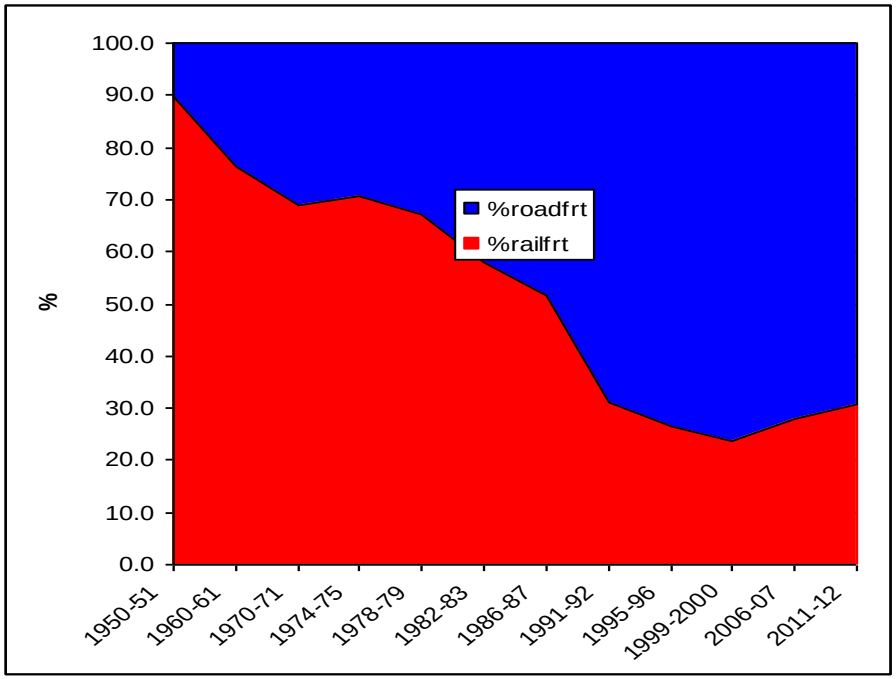
# IR LNG initiative

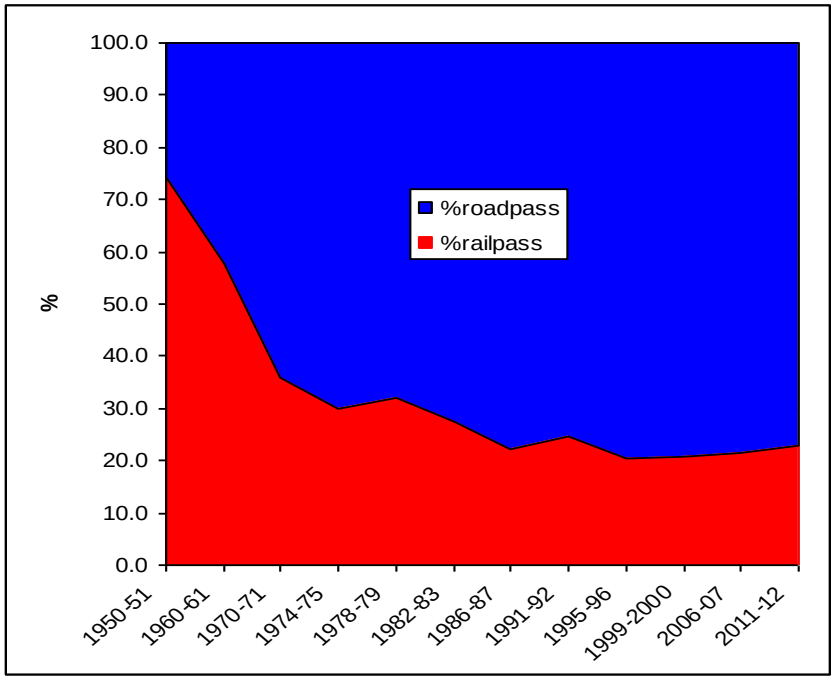
- Tendered for LNG DEMU trains
- Working on developing the first LNG locomotive conversion – project sanctioned
- Sanctioned project on design and manufacture of first Gas Turbine Locomotive with LNG carrier (similar to the Russian LNG train)- 12000 hp locomotive cost effective solution for heavy/ long haul
- Use of LNG in place of furnace oil in the workshops

# IR – Methanol and future traction initiative

- Working with NITI Ayog, DST and RDSO to convert HHP locomotives to run on methanol, expected savings – Rs. 81 K Crore in next ten years
- Working to develop hybrid methanol, battery DEMUS
- Introduction of methanol in the production units in place of oil based fuels

# Existing Situation in India – root cause of problem




- Modal share of freight and road traffic shifting in favour of road, which is highly capital intensive and polluting
- Due to lesser budgetary support to IR and social obligations
- Inefficiencies in the IR logistics systems
- In spite of both traction systems electrified

# Tank to wheel analysis step towards Life Cycle Assessment (LCA)

Diesel Electric Locomotives

- 2.8 billion liters diesel/ year
- Diesel fuel bill Rs. 16 K Cr/ year
- 353.6 Kt NOx, 15.9 Kt PM, 25 Kt HC / year
- Efficiency – 33%

Electric Locomotives

- 14.8 billion liters eq. of diesel energy (coal)
- Electricity bill Rs.11.5 K Cr/ year
- Investment cost of electrical catenary systems, power generation and distribution systems and interest accrued on them extra3
- 483.2 Kt NOx, 80.5 Kt PM, 485 Kt Sox, 24 t Hg / year
- + Pollutants emitted for setting up and maintaining over head and other structures
- Efficiency – 19%

# GHG Emission Facts

| India | Total | Coal | Oil | Gas | Other | Total | Coal | Oil | Gas | Other |
|---|---|---|---|---|---|---|---|---|---|---|
| **Total sectors (Mt $CO_2$)** | **1,869** | **1,348** | **447** | **72** | **1** | **100%** | **72%** | **24%** | **4%** | **0%** |
| Power and heat generation * | 945 | 886 | 25 | 32 | 1 | 51% | 47% | 1% | 2% | 0% |
| Other energy industry own use | 43 | 3 | 31 | 10 | | 2% | 0% | 2% | 1% | |
| Manufacturing industry ** | 493 | 410 | 66 | 17 | | 26% | 22% | 4% | 1% | |
| Road transport | 206 | | 203 | 4 | | 11% | | 11% | 0% | |
| Other transport *** | 16 | | 16 | | | 1% | | 1% | | |
| Residential sector | 87 | 14 | 66 | 8 | | 5% | 1% | 4% | 0% | |
| Other buildings **** | 78 | 36 | 40 | 2 | | 4% | 2% | 2% | 0% | |

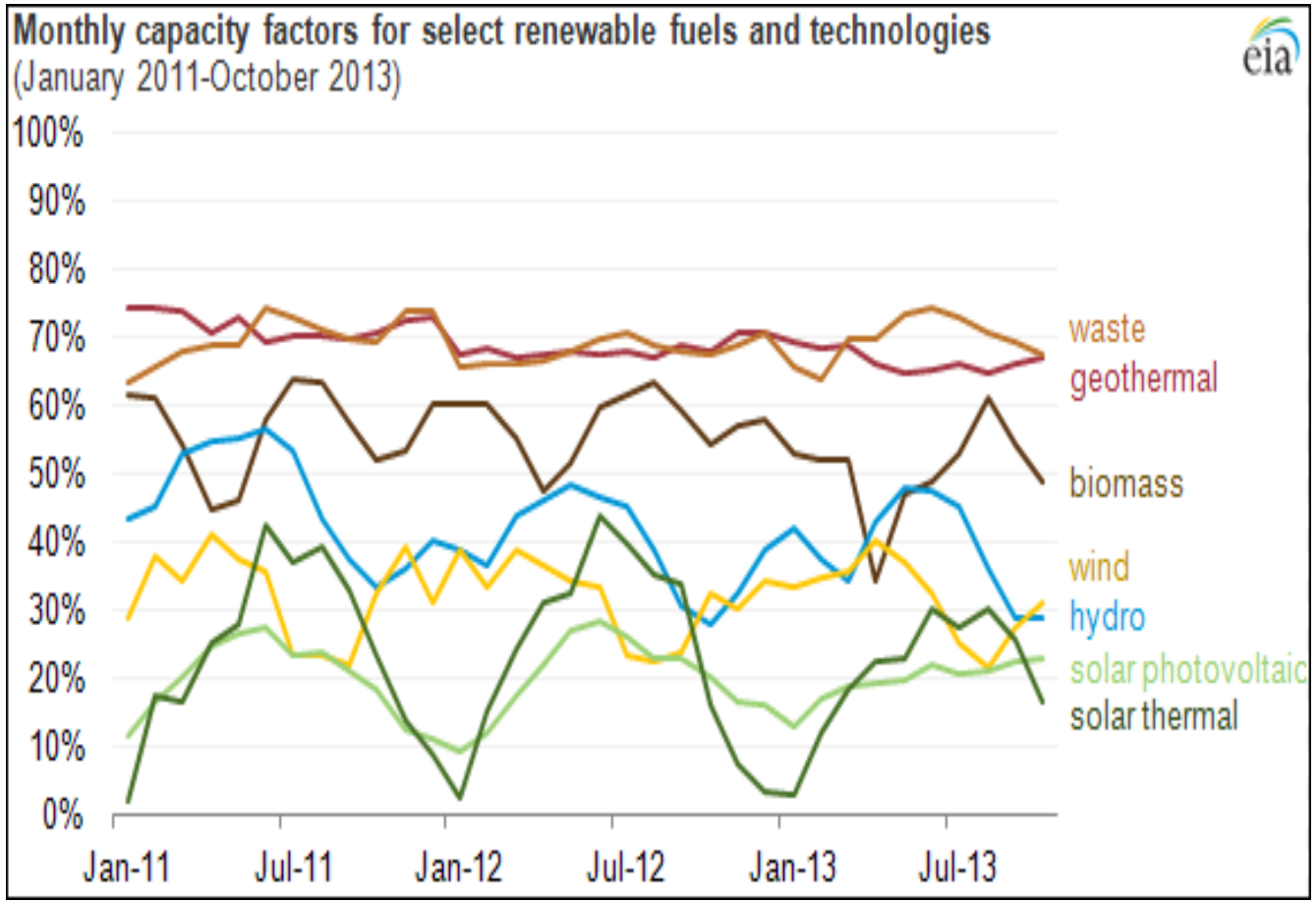
* Includes public power and heat production

** Excludes emissions from non-energy use and feedstock use of fuels

*** Excludes international marine and aviation bunkers

**** Service sector; includes agriculture and forestry

# Renewables and their limitations

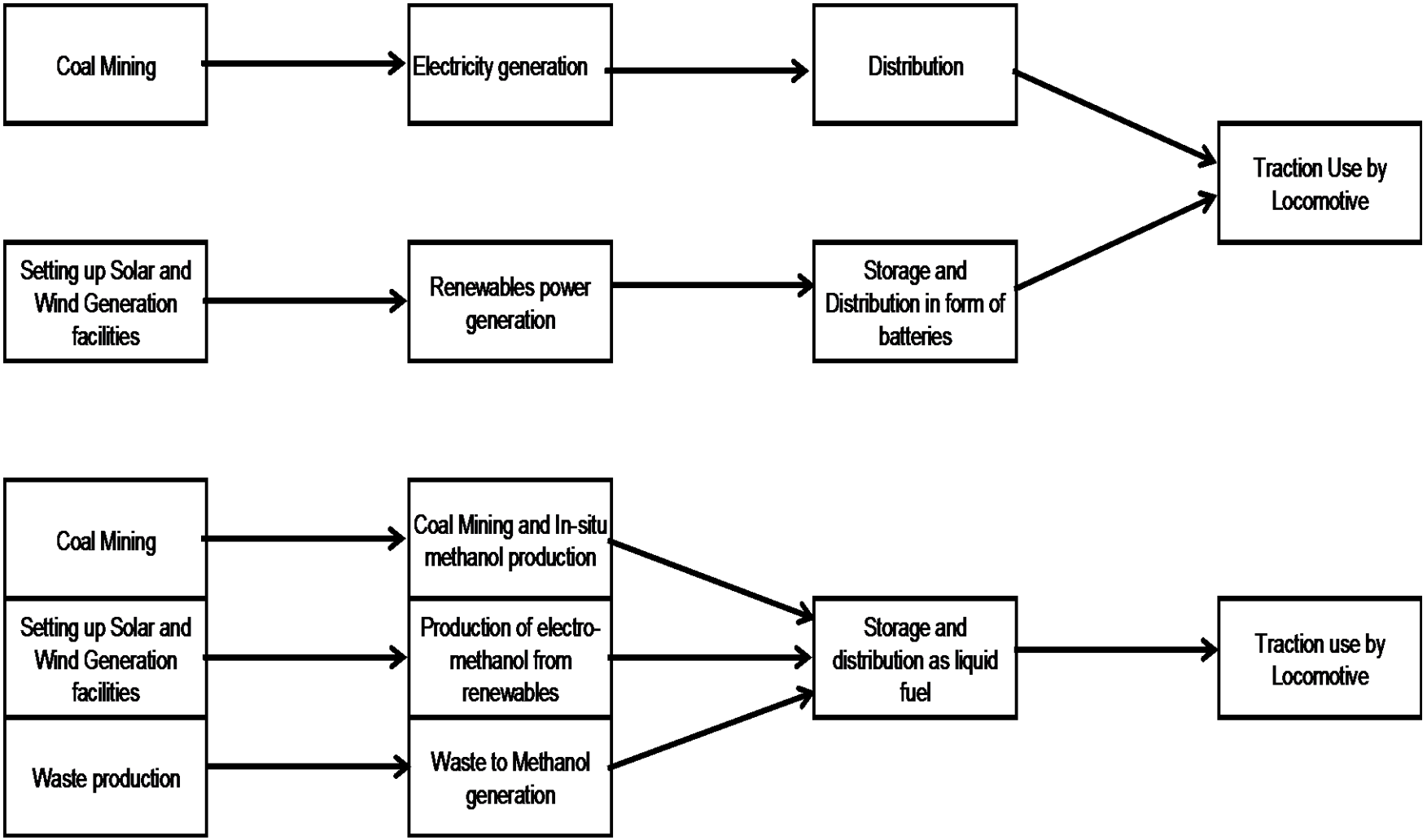



- Low capacity factor of renewables
- Capacity of 200 GW of Solar and Wind can generate peak 50 GW
- Energy storage required
- **Electrofuels like methanol best way to store renewable energy**

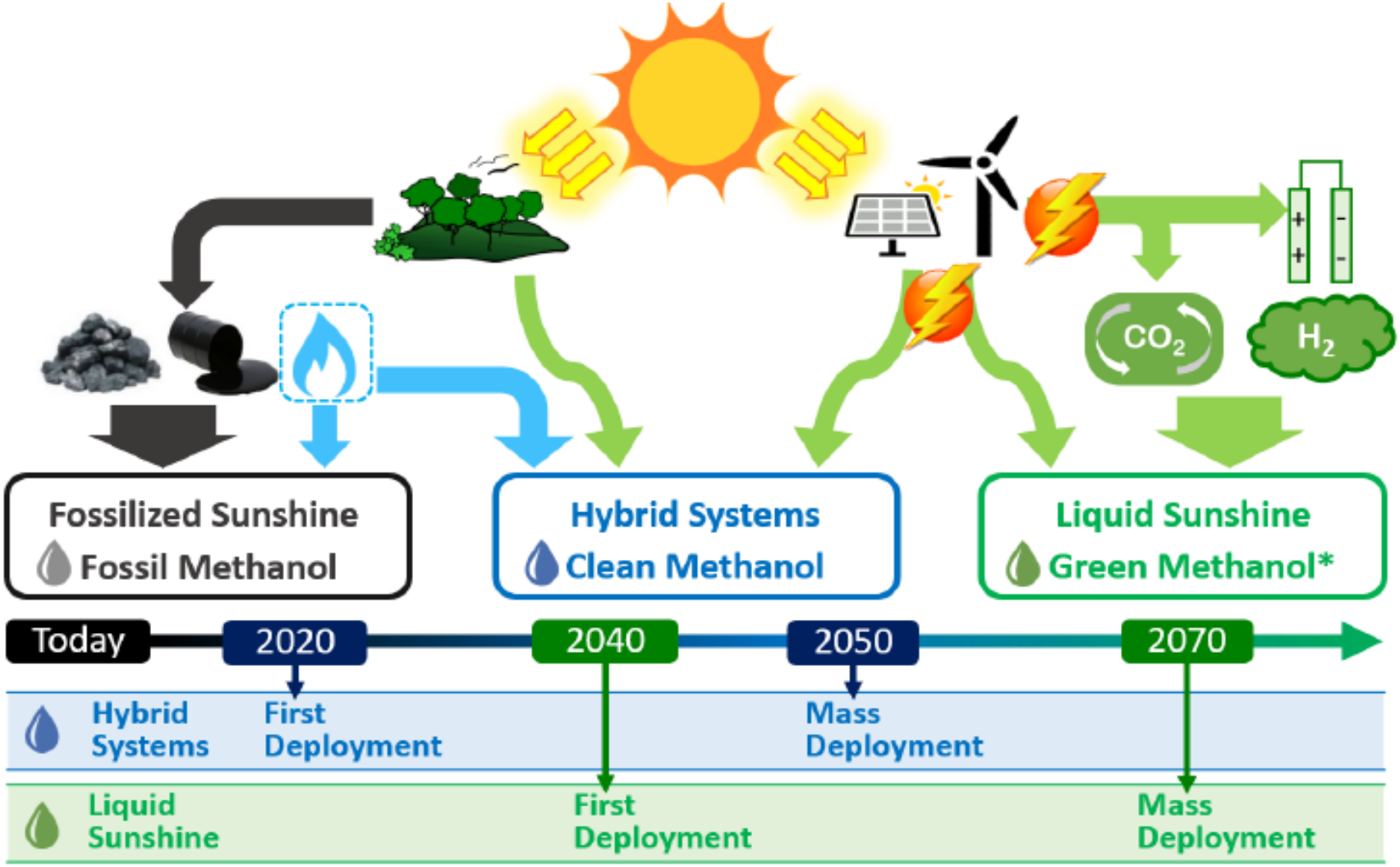
# Renewable – installed capacity and actual generation

| Renewable | Installed capacity as % of the total installed capacity | Generated power as % of the total generated power |
|---|---|---|
| Solar + wind + biomass + bagasse + small hydro | 14% | 6.90% |
| Hydro* | 14% | 11.10% |

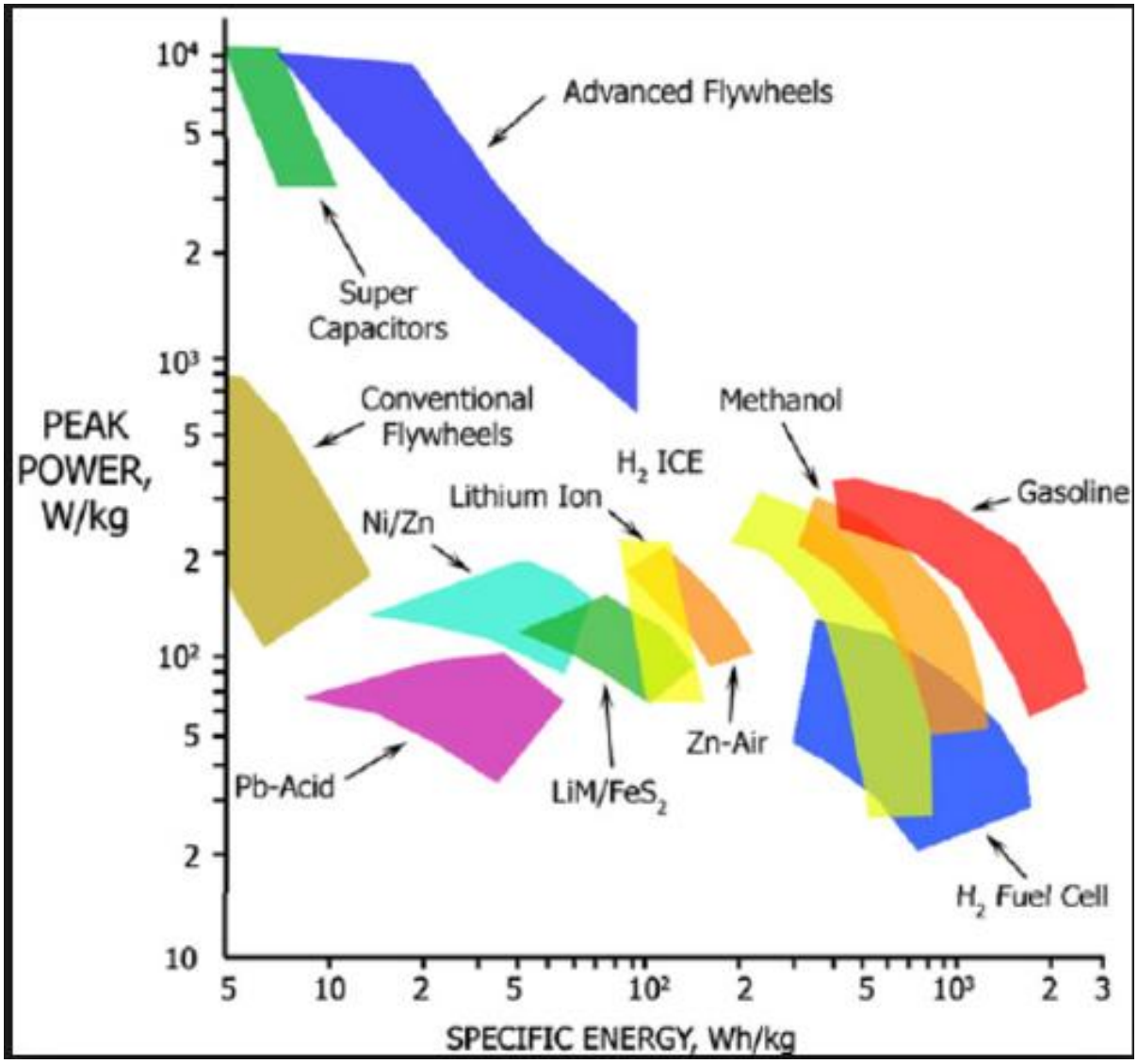
# Reliability Considerations – Single Mode vs Dual mode traction



# Methanol – Liquid Sunshine fuel



# Ragone Plot  comparing different energy devices/fuels



# Methanol – Experience in other countries

## China

- 114.5 billion tons coal reserves (12.8% of Global)
- Coal to methanol playing dominant role
- Clean Carbon Energy – "To echo the key points and tasks of fundamental research program in 13th 5YP, emphasizing the clean conversion of carbon based energy under energy saving and new energy aspects, researching on promotion and application of effective utilization of methanol fuel in ICE in clean and effective coal.
- 2 million vehicles, cars, trucks, buses plying on methanol

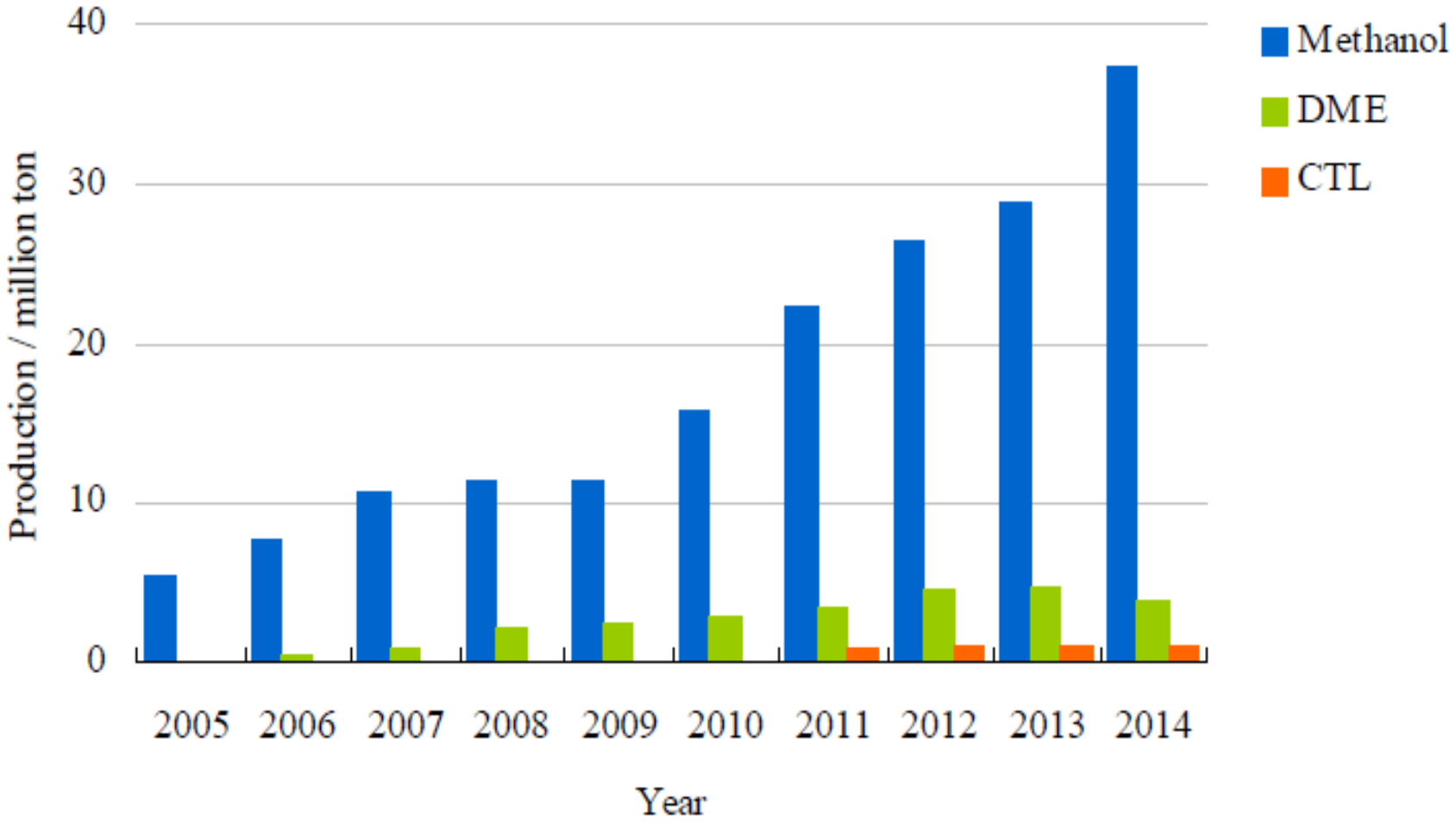
# China – Methanol vehicles








# Production of Methanol in China



# Coal In India

- A Total of 306.60 billion tonnes of **coal reserves** estimated by GSI as on 01.04.2015
- Prime coking **coal** 5.313 billion tonnes
- Medium and semi coking **coal** are 29.09 billion tonnes
- Non- Coking **Coal** 270.70 billion tonnes
- Tertiary **coal** (High Sulphur) 1.49 billon tonnes
- Large amount of Indian coal is high ash content (30-40%) – can be gasified to produce methanol
- The production of methanol from coal gasification is a mature technology
- United States, - Eastman Chemical produces methanol from coal gasification at a plant in Kingsport, Tennessee from coal for as little as Rs. 10 per liter.
- China, production costs from coal are generally RMB$800-1,200 per metric ton of methanol (US$110-165/metric ton, or Rs. 7-10 per liter).
- China coke furnaces in China generate 80 billion cubic meters of waste gas each year to produce 40 million metric tons of methanol, significantly reduce pollution in the coal-producing regions
- In India we can do the same

# Sweden

VärmlandsMetanol AB

- Convert 1000 tons of wood biomass per day
- 4 Lakh liters of biomethanol per day

# Iceland

- George Olah Renewable Methanol Plant in Svartsengi
- Worlds largest $CO_2$ to Methanol plant
- Uses hydro and geothermal energy to split water and uses hydrogen to produce methanol from atmospheric $CO_2$
- Capacity – 5 million litres of methanol per year
- Recycles 5.5 thousand tons of $CO_2$ per year

# Ghazipur Landfill Delhi

# MSW to Methanol – Edmonton Canada Plant

Enerkem Alberta Biofuels

## A global game-changing facility!

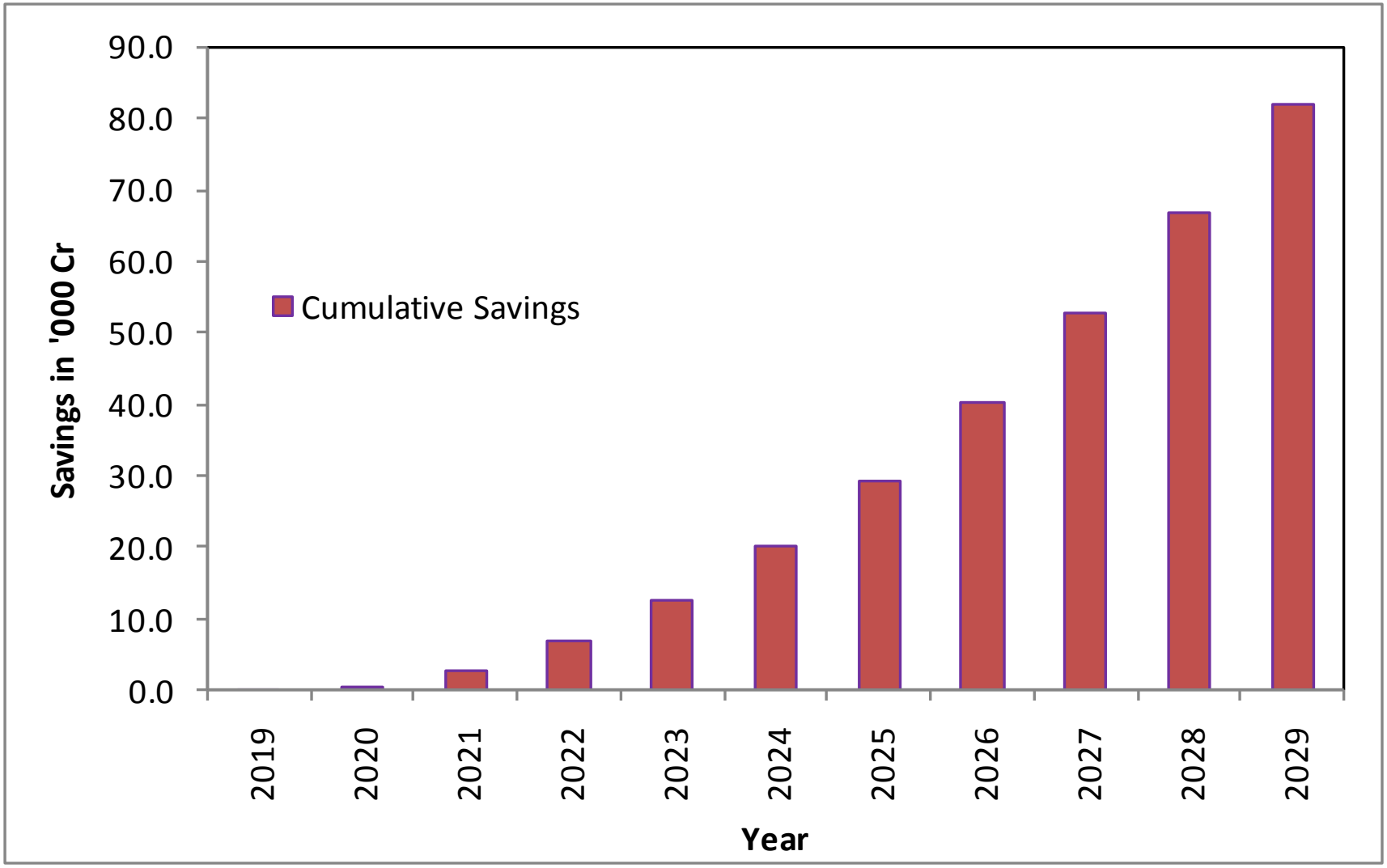
The Enerkem Alberta Biofuels facility is helping the City of Edmonton increase its waste diversion from 50% to 90%.

# Rise of Electrofuels – Latest issue of ASME magazine

# Economics of methanol on IR

- Saving – Rs. 2.5 Crore per locomotive per year
- Conversion of 6000 diesel locomotives will save Rs.81 K Crore in ten years
- Modest investment of Rs. 10 K Crore for conversion
- In first phase Methanol will be made from Indigenous coal along with $CO_2$ sequestration to reduce carbon fooprint fulfilling Hon'ble PMs vision of 10% reduction in petroleum import
- NITI Ayog in talks with State Governments to convert Methanol from Waste, Canada set up first commercial waste to methanol plant. Is being taken up in parallel to coal to methanol initiative
- In second phase Methanol will be made from renewable solar and wind energies by sequestration of $CO_2$ - carbon neutral methanol

# Savings due to Methanol Switch on IR



# Savings due to efficiency Improvements

| | **Energy efficiency increase measure** | **Yearly savings (Rs. Cr)** |
|---|---|---|
| 1. | Common rail fuel injection system | 960 |
| 2. | Variable Geometry Turbocharger | 160 |
| 3. | High effectiveness aftercooler | 160 |
| 4. | Cast engine block | 120 |
| 5. | Separate after cooling for the locomotive | 180 |
| 6. | Auxiliary Power Unit | 320 |
| 7. | Guided Optimised Locomotive Driving (GOLD) | 640 |
| | **Total** | **2540** |

# Future – Methanol Fuel-Cell powered trainsets

- Made by ALSTOM for German Railways
- Future of Rail Traction

# Methanol Fuel Cell Technology Fast maturing

## Honda begins Clarity Fuel Cell deliveries in Europe, California

The first deliveries of the Honda Clarity Fuel Cell saloon (sedan) were made to European customers at the end of November, with the first six vehicles based in London and Copenhagen as part of the EU-supported Hydrogen for Innovative Vehicles (HyFIVE) demonstration project. And in mid-December Honda began deliveries of the car at selected dealerships across southern California.

## Just Eat delivers food in Denmark using methanol fuel cell car

The world's first road-registered methanol fuel cell car has successfully completed a seven-week test in Denmark with online takeaway ordering service Just Eat. The vehicle – based on a Fiat 500 city car – features a range-extender that uses a methanol reformer with a high-temperature

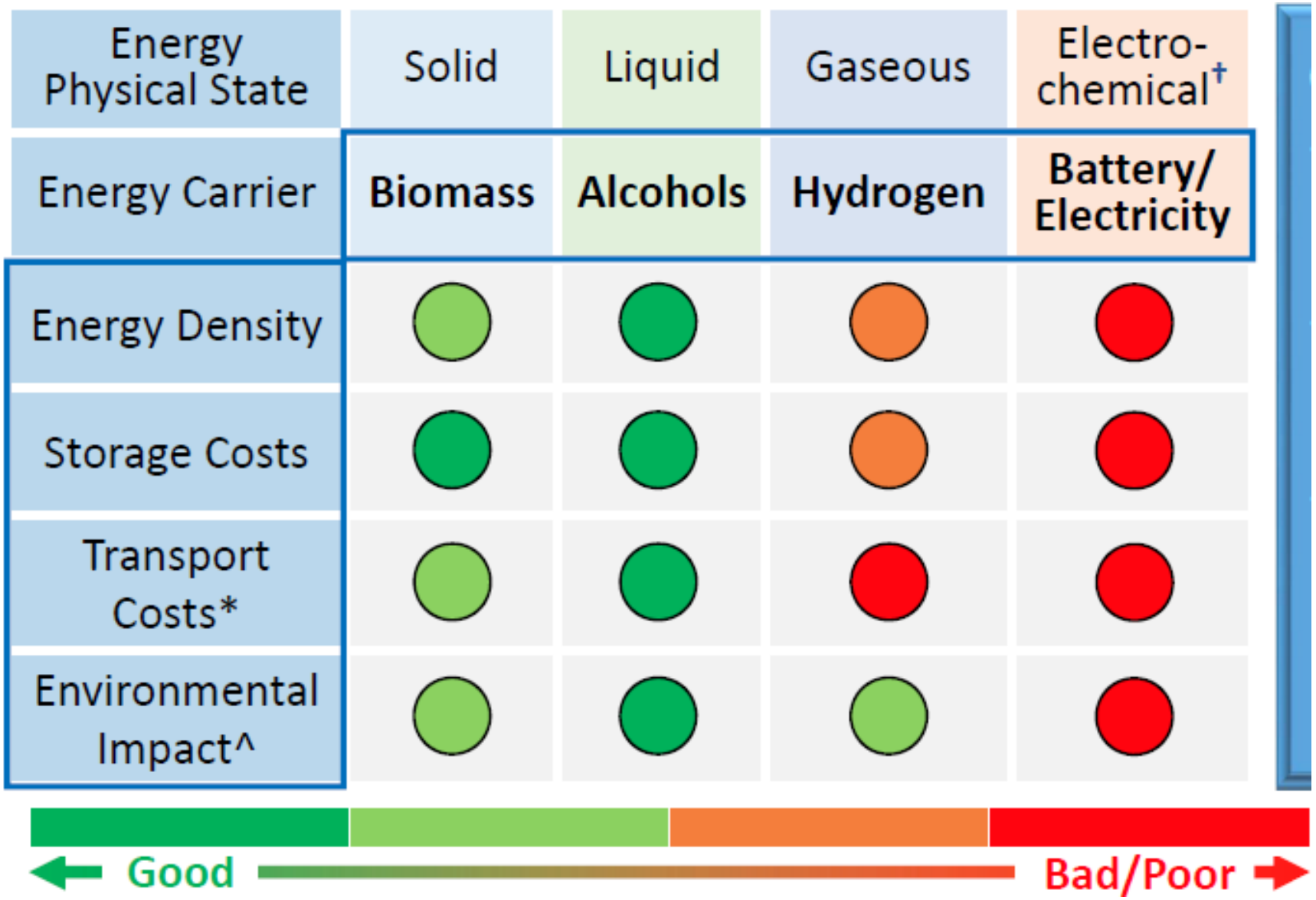
## SerEnergy unveils new methanol fuel cell vehicle in Denmark

Danish methanol fuel cell manufacturer SerEnergy has launched its commercial next-generation, reformed methanol fuel cell vehicle, which it says offers a range up to 800 km (500 miles) on a tank of methanol.

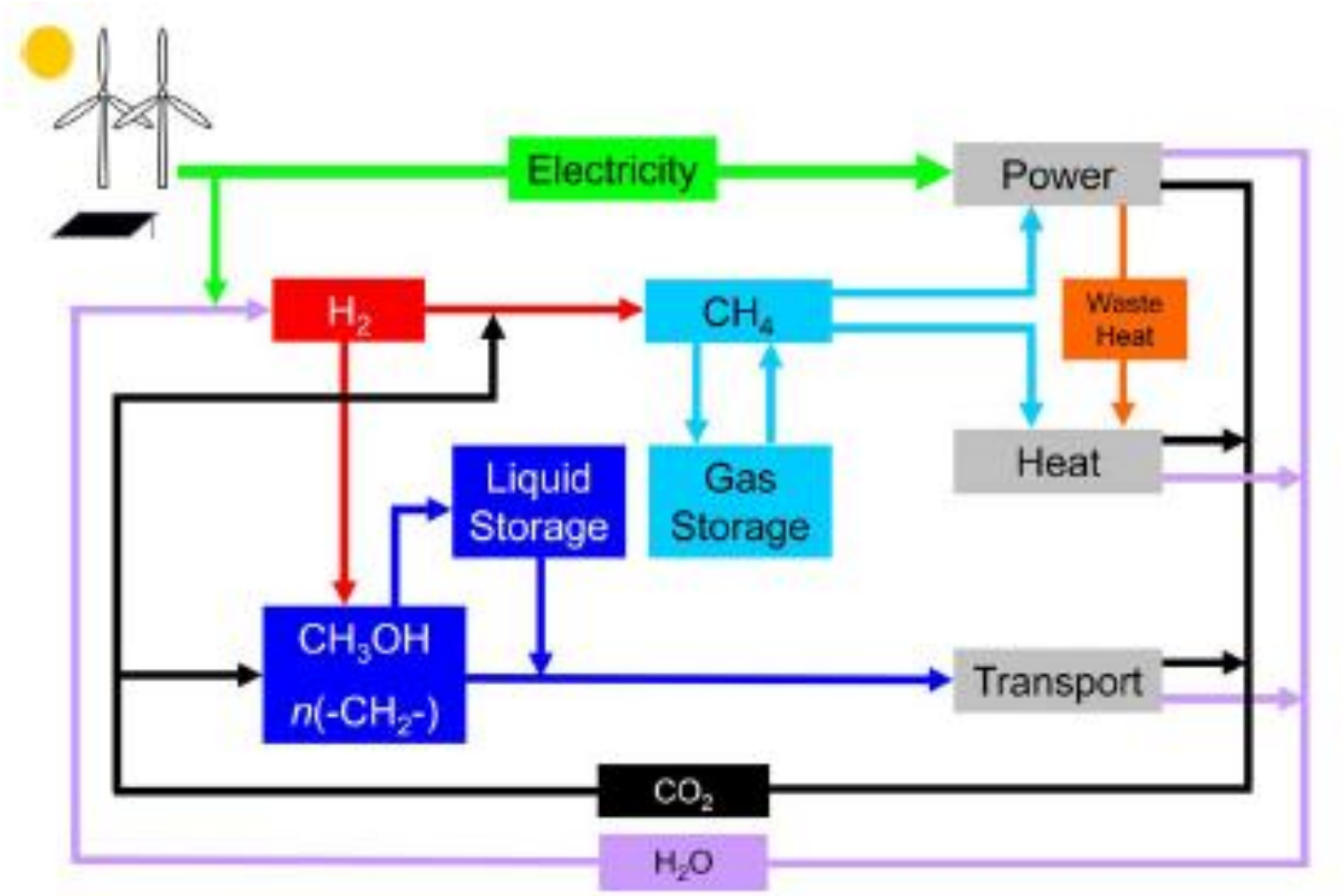
# Comparison of four modes of traction

| | Economy | Environment | Overall energy conversion Efficiency | GHG equivalent |
|---|---|---|---|---|
| Diesel locomotive fleet | Rs. 16 K Crore/annual expense ~ 2.8 billion liters of diesel | NOx – 353.6 kton/year<br>PM – 15.9 kton/year<br>HC – 25 kton/year | 33% | 95 g $CO_2$ eq./ MJ of fuel energy |
| Electric Locomotive fleet | Rs. 11.5 K Crore/ annual expense and Rs. 3.5 Lakh Crore invested in existing electrification infrastructure ~ 14.8 billion liter of diesel | NOx – 483.2 kton/year<br>PM – 80.5 kton/year<br>SOx – 483.2 kton/year<br>Hg – 24 ton/year | 19% | 120 g $CO_2$ eq./ MJ of fuel energy |
| Methanol locomotive equivalent fleet with IC engine | Rs. 10 K Crore/ annual expense ~ 2.2 billion liters of diesel | NOx – 75 kton/year<br>PM - NIL<br>HC - Minimal | 38% | 50 g $CO_2$ eq./ MJ of fuel energy with coal to methanol and 20 g with green methanol |
| Methanol fuelcell hybrid trainset with equivalent horsepower as that of diesel locomotive fleet | Rs. 8 K Crore/ annual expense ~ 2 billion liters of diesel | NOx – NIL PM – NIL HC – NIL | 70% | 10 g $CO_2$ eq./ MJ of fuel energy |

# Comparison of different fuels- India/ China



# *Future will be electrified but not as we think*….Integrated power, heat and transport system with renewable and synthetic fuels



# Conclusion & Recommendations

- For reliability of traction necessary to have multiple modes of traction
- Basket of fuels and traction technologies should be adopted by Indian Railways since situation is fluid at the moment
- Indian Railways should invest in Methanol Economy and traction. Methanol best form of electro-fuel to store renewable energy
- Li-Ion batteries two orders of magnitude less than liquid fuels like methanol in energy density and power density . Multiple times expensive also.
- Savings of Rs. 81 K Crore over ten years by switching to methanol
- Government of India has take up Methanol Economy as a Mission area
- Methanol based fuel cell based train sets future of traction
- Life cycle assessment must be done before adopting any fuel/ technology. Methanol LCA shows best economy and lowest environmental degradation
- India and Indian Railways  must embrace Sunshine and Liquid Sunshine

Science Based Decision Making…

Thank You