Renewable Energy Arm
Of The Hero Group

HERO FUTURE ENERGIES®
planet positive power

INTERNATIONAL CONFERENCE ON GREEN HYDROGEN 2023

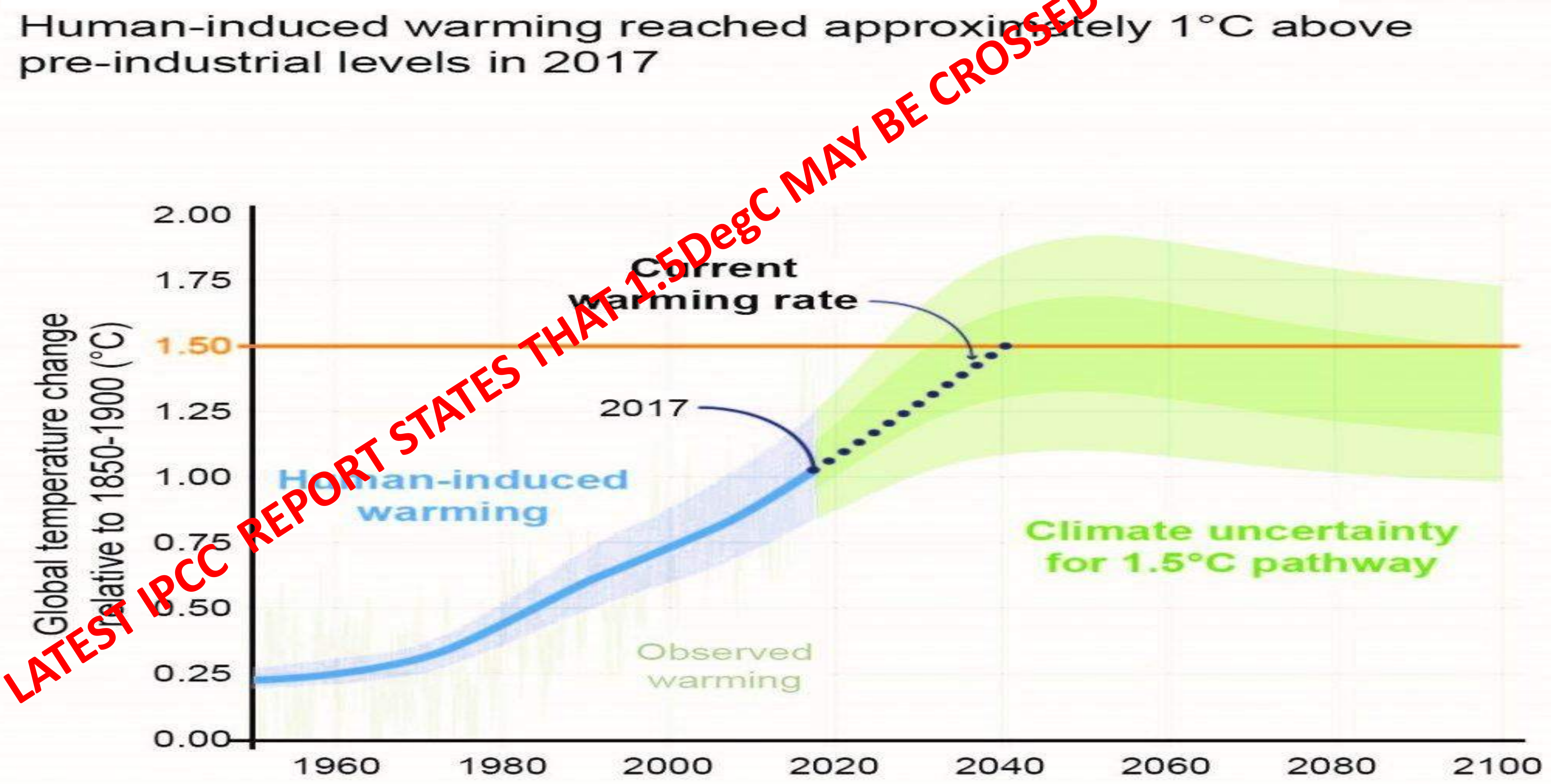
HYDROGEN IN INDUSTRIES…..

05.07.2023

SUDHIR PATHAK
Head (Engg/QA/Green Hydrogen)

MOTHER EARTH IS FEVERISH…….

LATEST IPCC REPORT STATES THAT 1.5DegC MAY BE CROSSED BY 2030-35



NATURE IS HOLDING OUR "NECQ"

Man-kind has never been so "Kind" to the nature

↓

C.E.Q.- " Sick": the quest for fulfilling the needs in the Cheapest, Easiest, Quickest

↓

Now "N"ature is holding our "N.E.C.Q." : **Nature Enabled Checks and Questions**

↓

Directed Sons and Daughters to be "N.I.C.E.": Nature Inclined Cost-Effective Strategy

SONS AND DAUGHTERS DEVISED THERMOMETER….

GLOBAL TEMP RISE LIMIT(IPCC REPORT)

RCPs	Global Temp (°C) Rise Limits	Target
RCP 1.9	1.5	Aspirational
RCP 2.6	2	1. CO_2 emission start declining by 2020 and zero by 2100. 2. Methane (CH_4) emissions go to approximately half the CH_4 levels of 2020, 3. Sulphur dioxide (SO_2) emissions decline to approximately 10% of those of 1980–1990. 4. Negative CO_2 emissions (such as CO_2 absorption by trees).Those negative emissions would be on an average 2 Gigatons of CO_2 per year ($GtCO_2$/yr)
RCP 4.5	2~3	1. CO_2 Emissions peak around 2040, then decline. 2. Methane emissions stop increasing by 2050 and decline somewhat to about 75% of the CH_4 levels of 2040, 3. Sulphur dioxide (SO_2) emissions decline to approximately 20% of those of 1980–1990. 4. Requires negative CO_2 emissions (such as CO_2 absorption by trees). Those negative emissions would be 2 Gigatons of CO_2 per year ($GtCO_2$/yr)
RCP 6.0	3~4	1. CO_2 Emissions peak around 2080, then decline. 2. It uses a high greenhouse gas emission rate and is a stabilisation scenario where total radiative forcing is stabilised after 2100 by employment of a range of technologies and strategies for reducing greenhouse gas emissions.
RCP 8.5	~5	1. Emissions continue to rise throughout the 21st century. 2. It's generally taken as the basis for worst-case climate change scenarios, was based on what proved to be overestimation of projected coal outputs

Source : IPCC AR5 and AR6 Report

RCP: Representative Concentration Path

Impact of Climate Change:

1. PHYSICAL:

A. Glaciers, snow, ice,permafrost
B. Rivers, lakes, floods, drought
C. Coastal erosion, seal level effects

2. BIOLOGICAL:

A. Terrestrial Ecosystems
B. wildfires
C. Marine Ecosystems

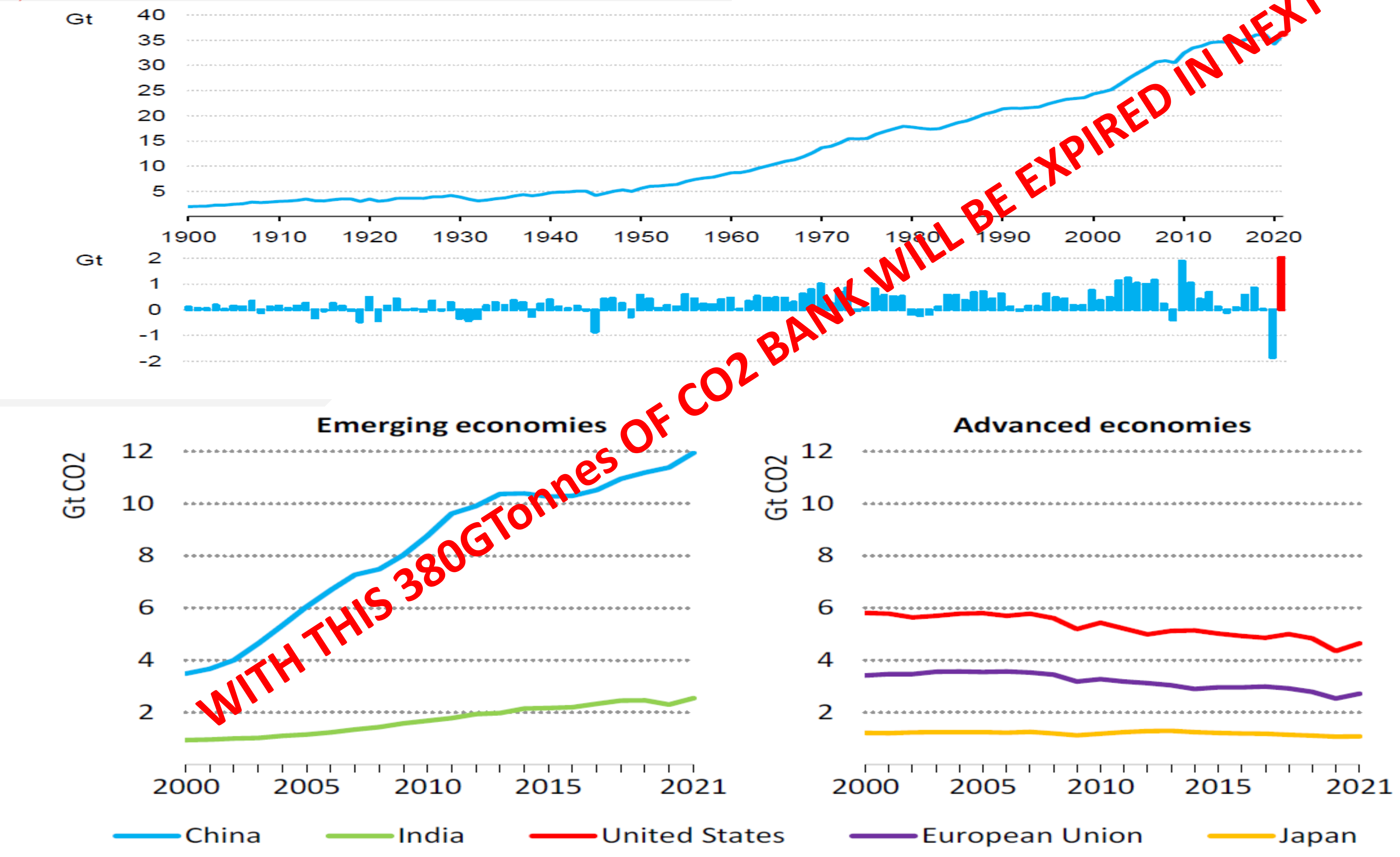
3. HUMAN & MANAGED SYSTEM

A. Water Scarcity and Food Production
B. Health And Wellbeing
C. Cities, Settlements And Infrastructure
D. Economics

BLEEDING CO2….

POOR CO2 BALANCE LEFT TO SAVE MOTHER EARTH

WITH THIS 380GTonnes OF CO2 BANK WILL BE EXPIRED IN NEXT 10 YEARS



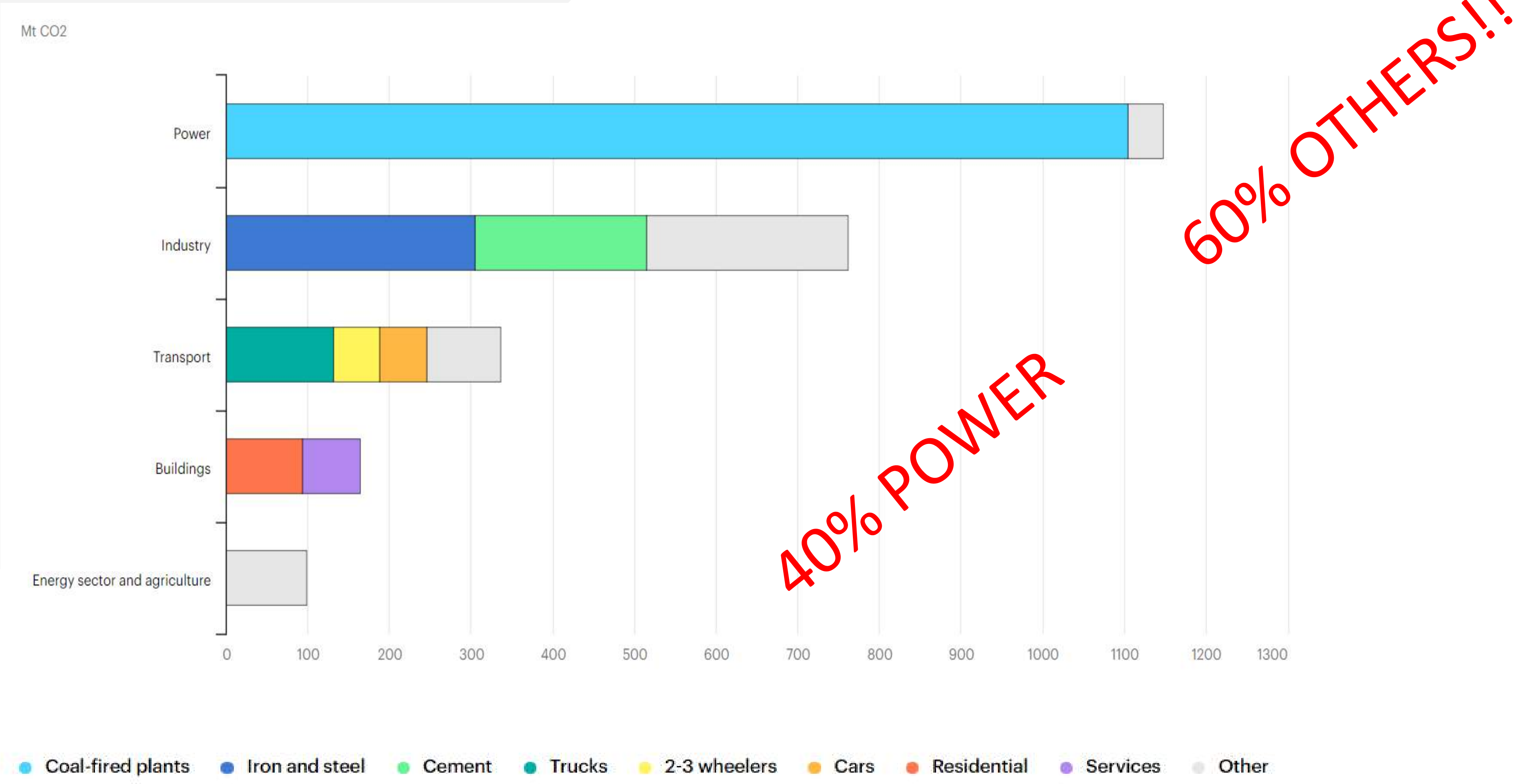
Source: IEA

ALARM TO WORLD

1. According to the IPCC’s 2018 special report “Global Warming of 1.5 °C,” we had 580 gigatons of CO2 in our remaining carbon budget if the globe were to have a 50–50 chance of keeping global warming to 1.5 °C compared to pre-industrial levels. Bring that forward from 2018 to 2020, and if we continue on our current path of emissions, we have only 15 years left before the budget runs out.

OFFENDERS….

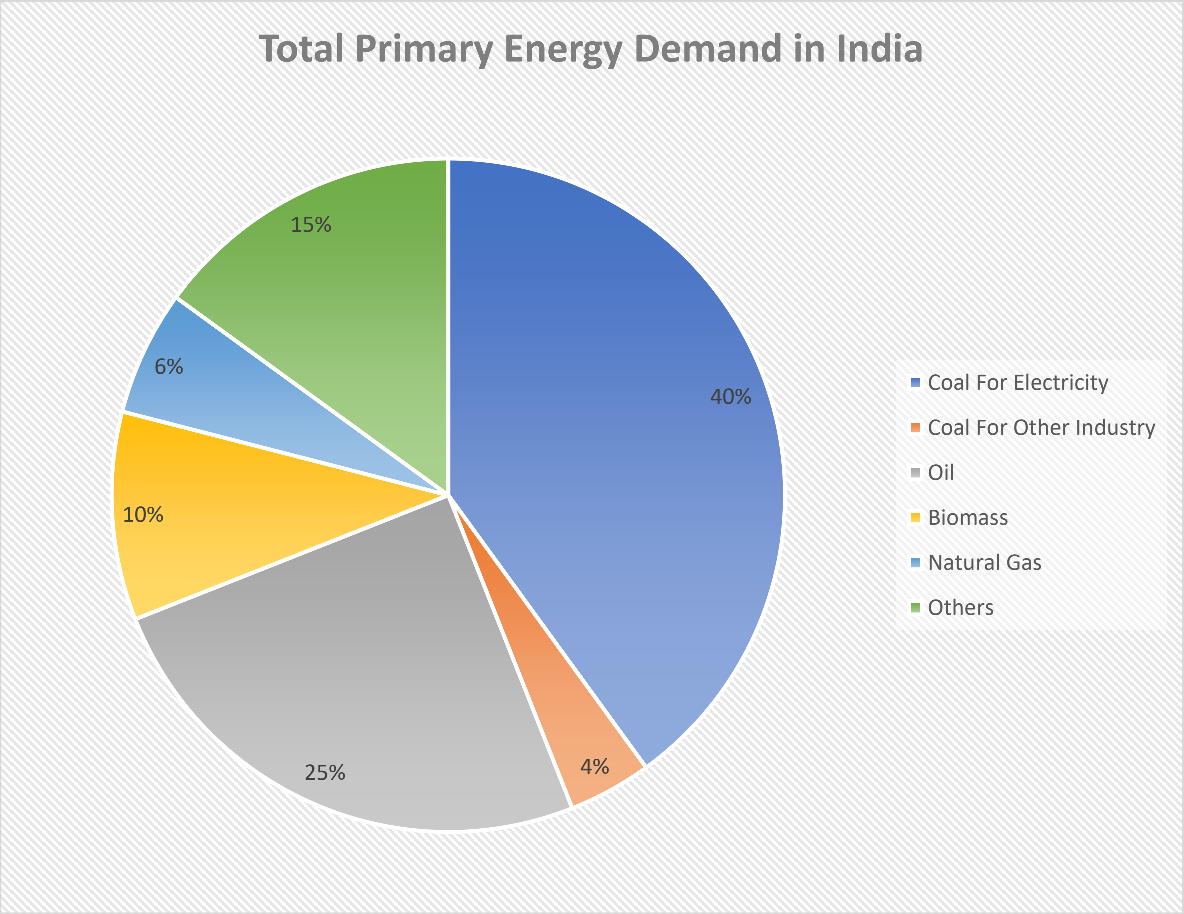
CO2 Emissions In India From Different Sector



Source: IEA

PIE OF DIRTY FUEL….

Indian Energy Mix



Source: IEA

1.India is the world's third-largest energy consuming country, thanks to rising incomes and improving standards of living.

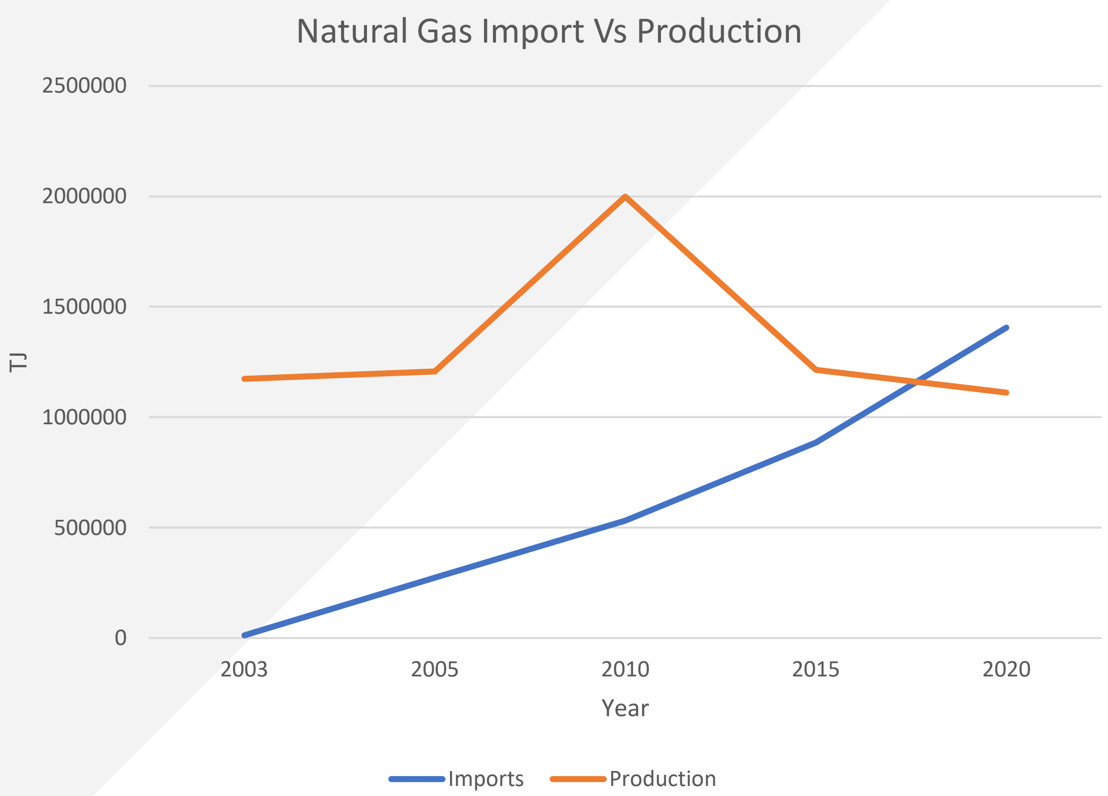
2. Energy use has doubled since 2000, with 80% of demand still being met by coal, oil and solid biomass.

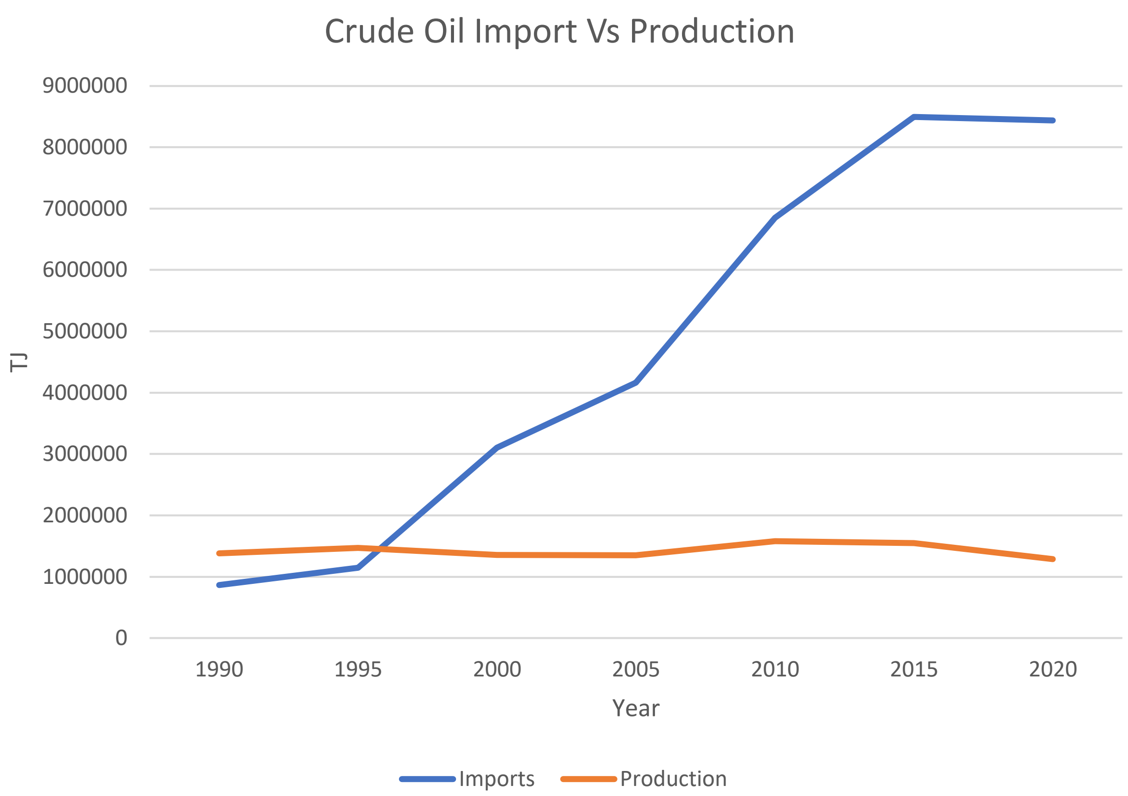
3. On a per capita basis, India's energy use and emissions are less than half the world average, as are other key indicators such as vehicle ownership, steel and cement output.

4. As India recovers from a Covid-induced slump in 2020, it is re-entering a very dynamic period in its energy development.

HERO FUTURE ENERGIES

COST OF DIRTY FUEL IMPORTS...





India paid $7.9 billion in 2020-21 and $9.5 billion in 2019-20 for the import of gas.

India, the world's third biggest oil consuming and importing nation, spent USD 119.2 billion in 2021-22 (April 2021 to March 2022), up from USD 62.2 billion in the previous fiscal year, according to data from the oil ministry's Petroleum Planning & Analysis Cell (PPAC).

During the current fiscal, it has produced 23.8 million tonnes of crude oil so far as compared to 24.4 million in the first 10 months of 2020-21. The target for 2021-22 is 26.1 million tonnes, the PPAC data showed.

Source: IEA & PPAC, Read more at:
https://economictimes.indiatimes.com/industry/energy/oil-gas/indias-oil-import-bill-doubles-to-usd-119-bn-in-fy22/articleshow/91049349.cms?utm_source=contentofinterest&utm_medium=text&utm_campaign=cppst

WAY FORWARD → Energy Transition to Decarbonisation → Carbon Neutralism

STEP-1:

- Any Entity/enterprise/industry/consumer must:
  - Measure
  - Monitor
  - Mitigate

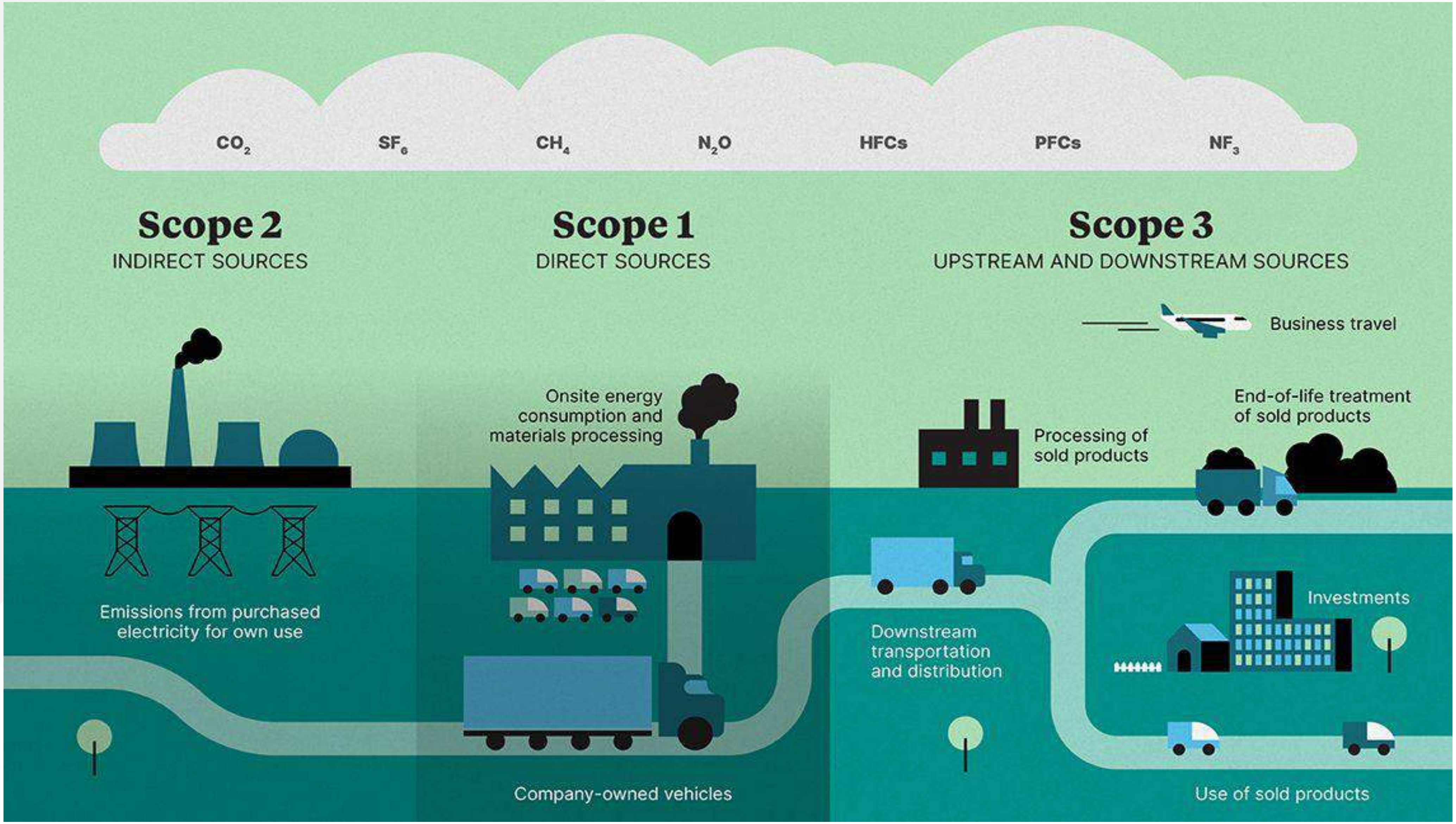
} *CARBON FOOTPRINT*

STEP-2:

Carbon Emissions are typically Classified into three categories.

SCOPE-1 | SCOPE-2 | SCOPE-3

SCOPE EMMISSION???



Source: https://climateactionnavigator.oliverwymanforum.com/

SCOPE MITIGATION APPROACH BOUNDARIES

STEP-3:

RE-0 → RE-40 → RE-70 → RE-100

SOLAR + WIND + Banking/Exchange + Storage

SCOPE 2

Scope 1
Scope 3

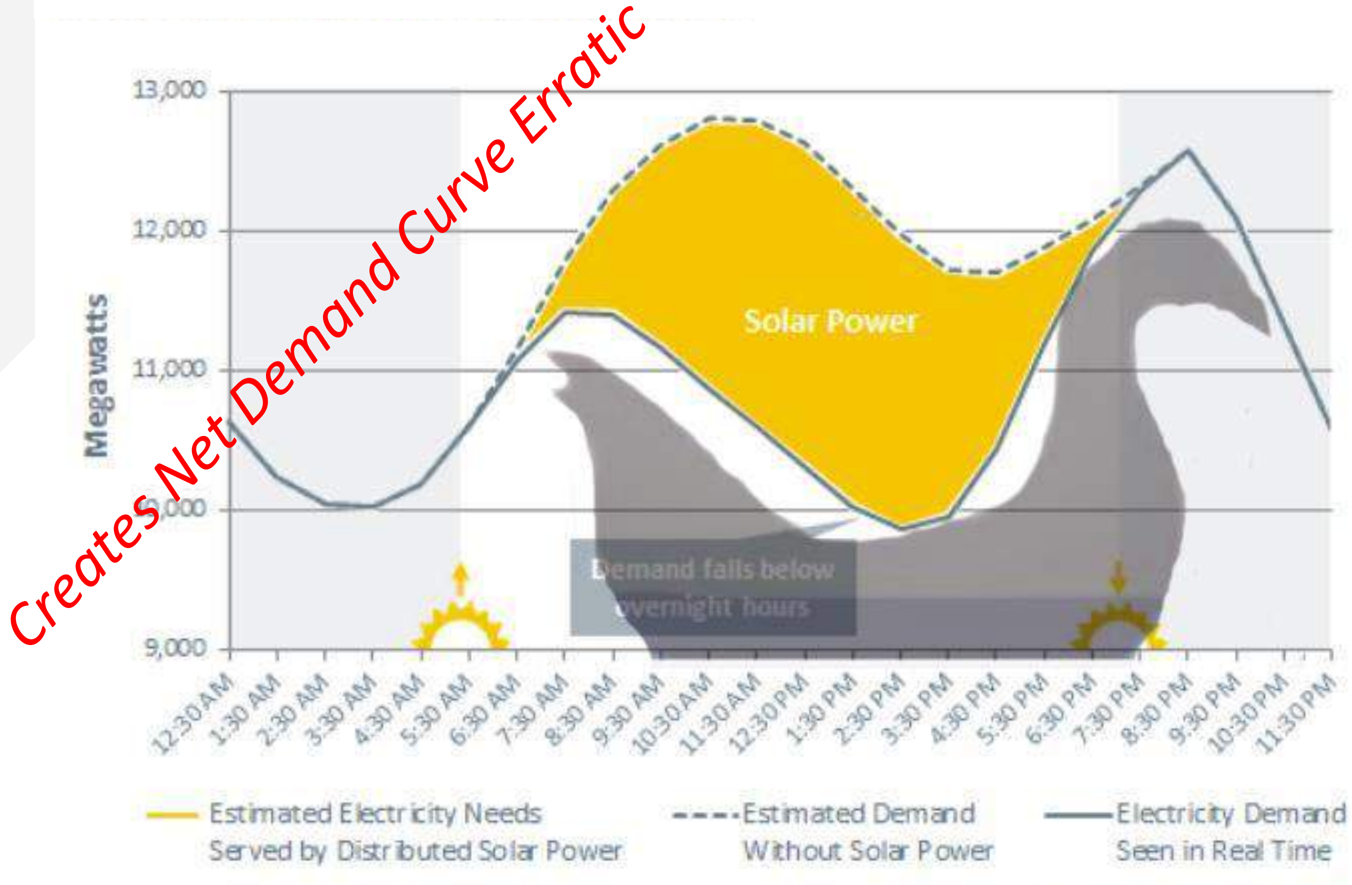
Path to Net Zero
(100% Decarbonization)

DECARBONISATION: OOPS TOLL ON GRID STABILITY !!!

1. STEADY STATE ACTIVE POWER ISSUES
2. STEADY STATE REACTIVE POWER ISSUES
3. TRANSIENT STABILITY ISSUES

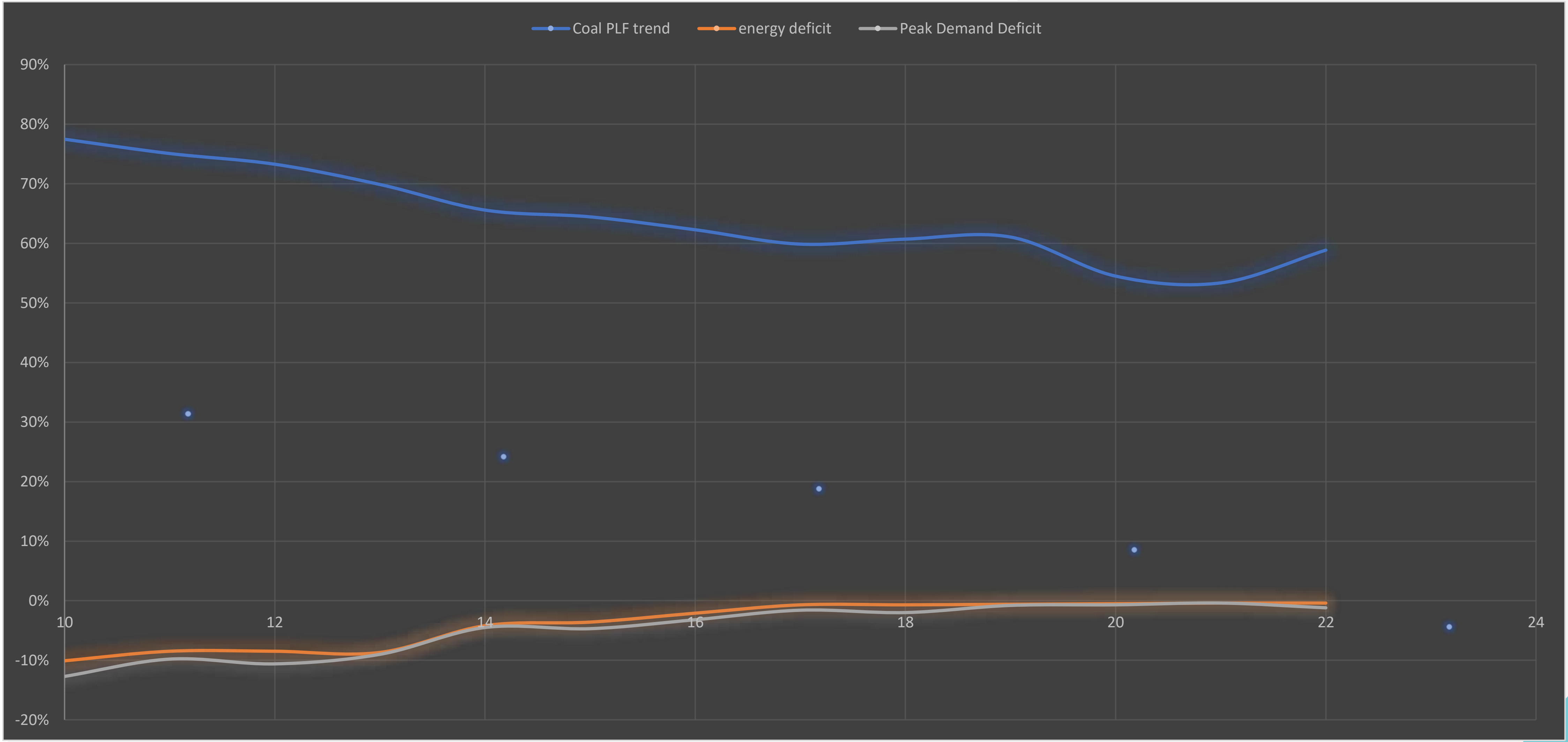
DUCKING THE GRID REALITY…..

In-famous Duck Curve!



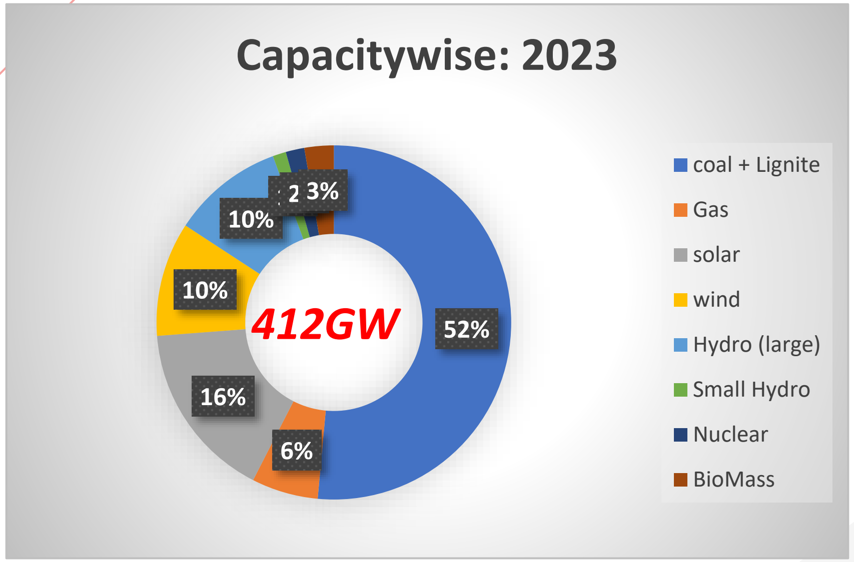
Source: ISO New England.

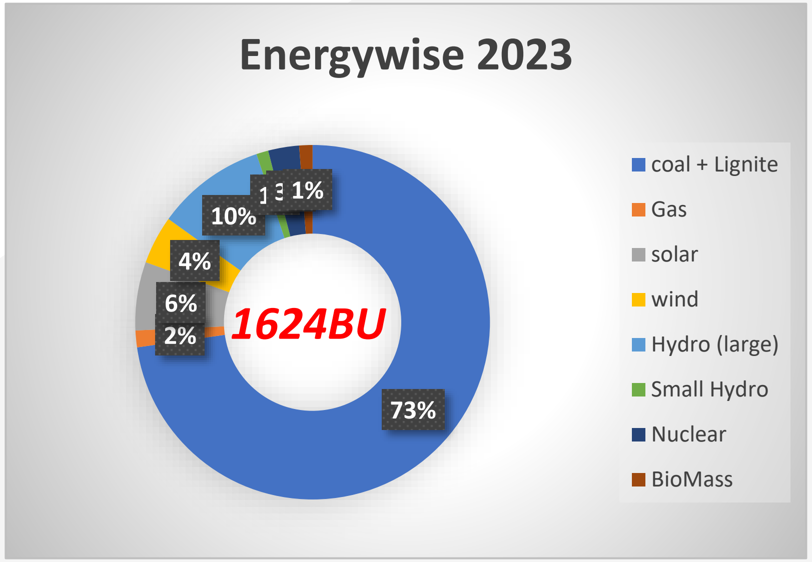
STEADY STATE ACTIVE: RESOURCE IN-EFFICIENCY PRESENTLY

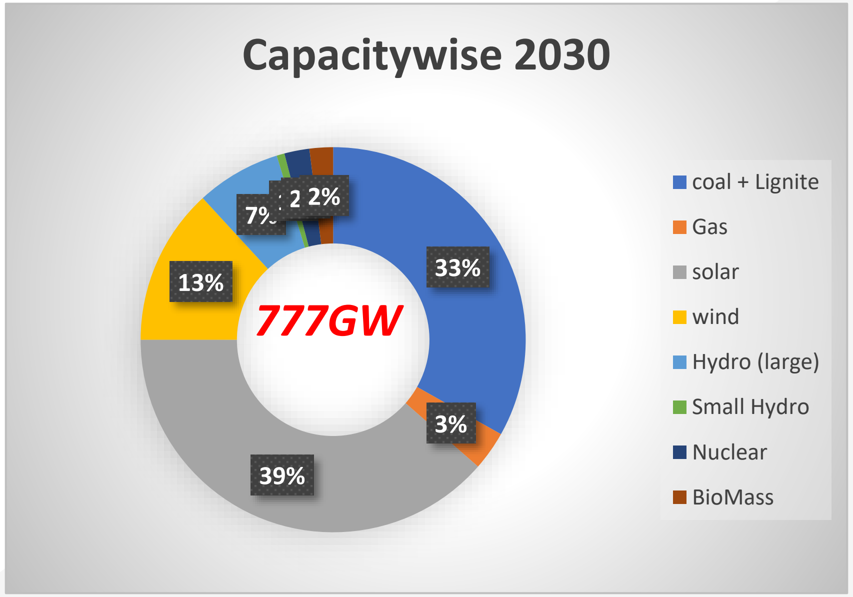


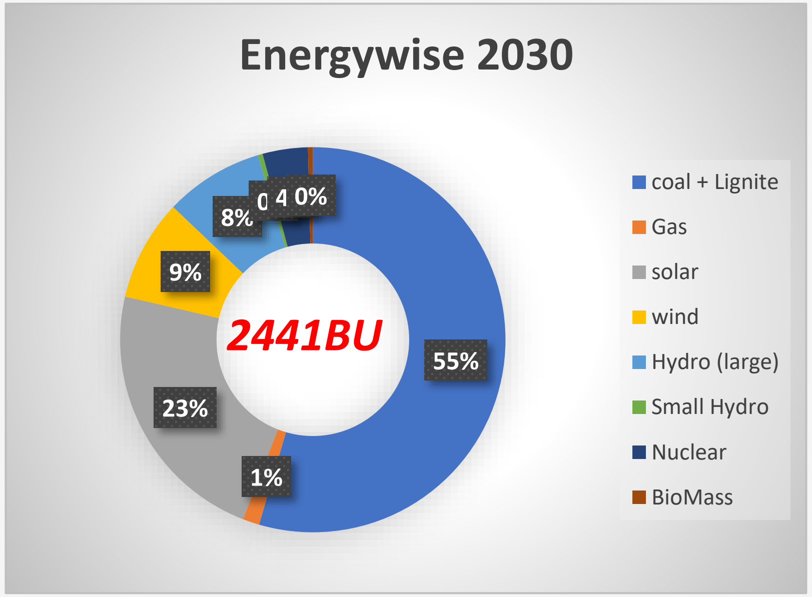
Data Source: Powermin website

STEADY STATE ACTIVE: RESOURCE IN-EFFICIENCY IF FUTURE IS NOT CORRECTED







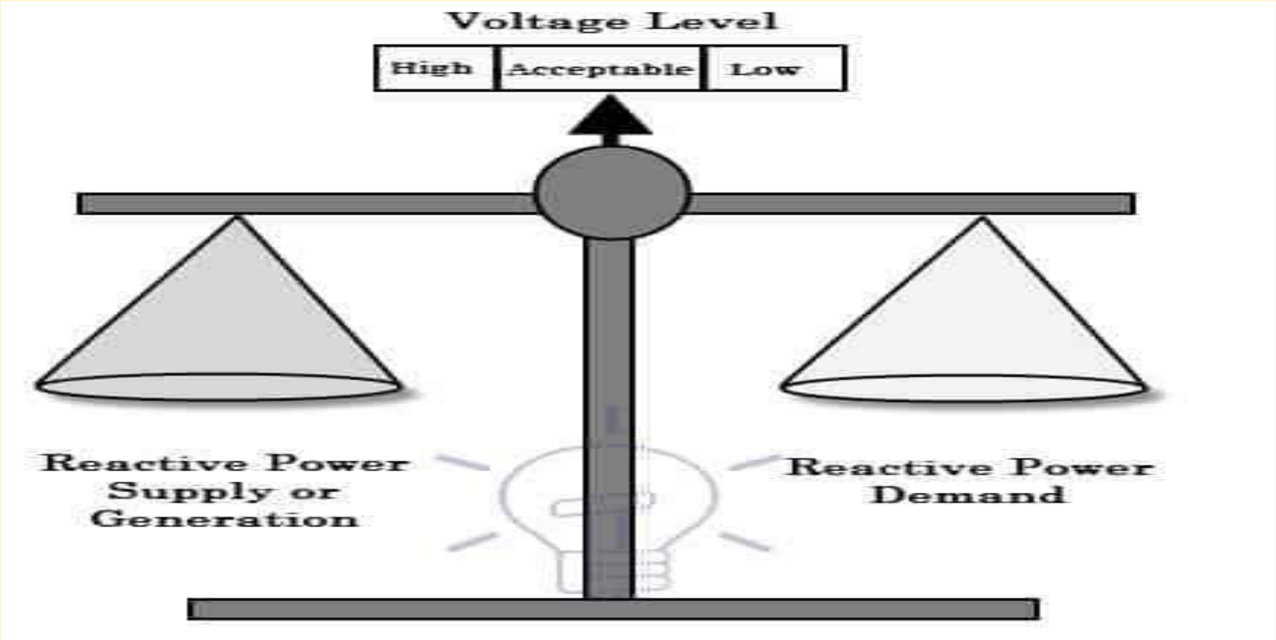


Data Source: CEA Optimal mix report

STEADY STATE REACTIVE: VOLTAGE ROLLER COASTER RIDE

❑REACTIVE POWER

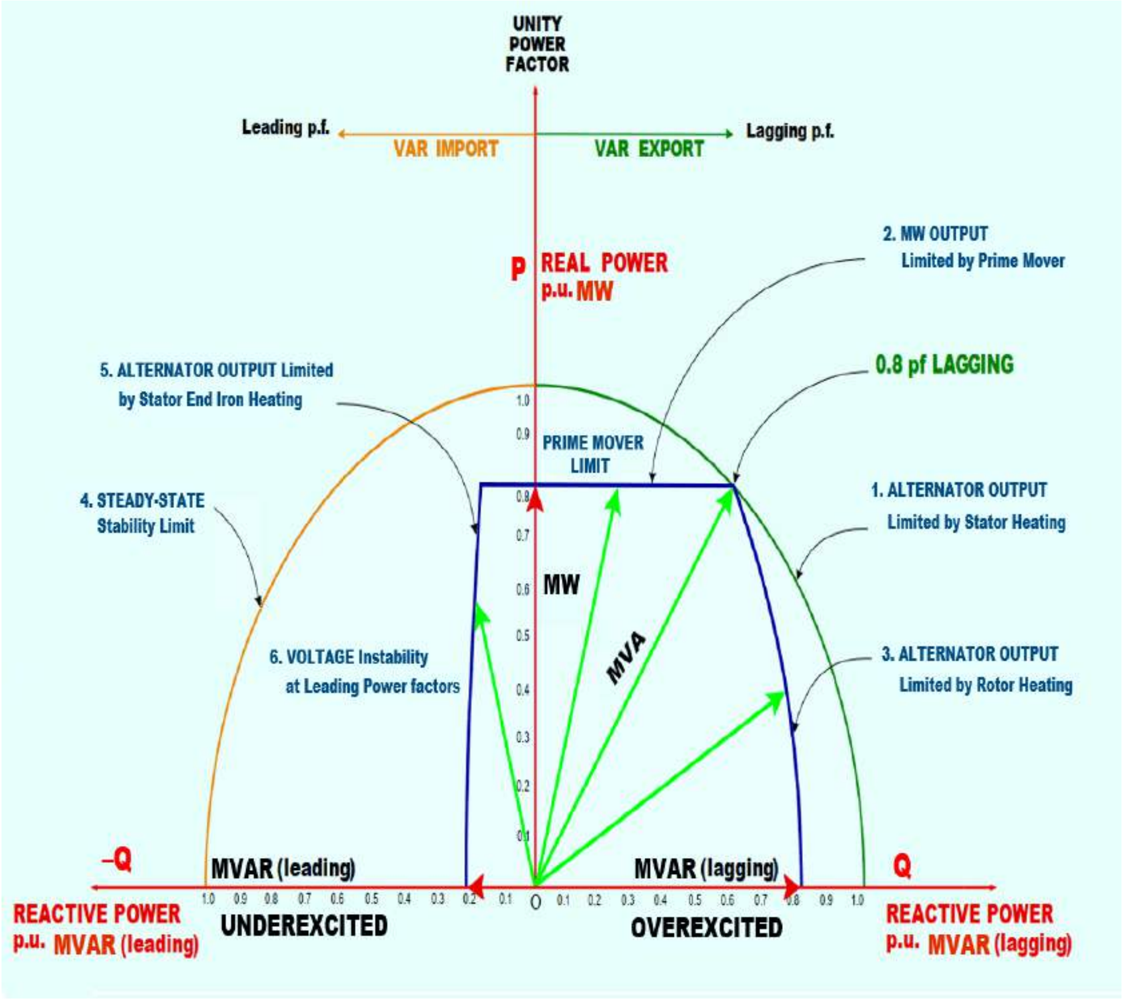
- Supply and absorption of Reactive Power leads to Voltage Stability in the Grid.



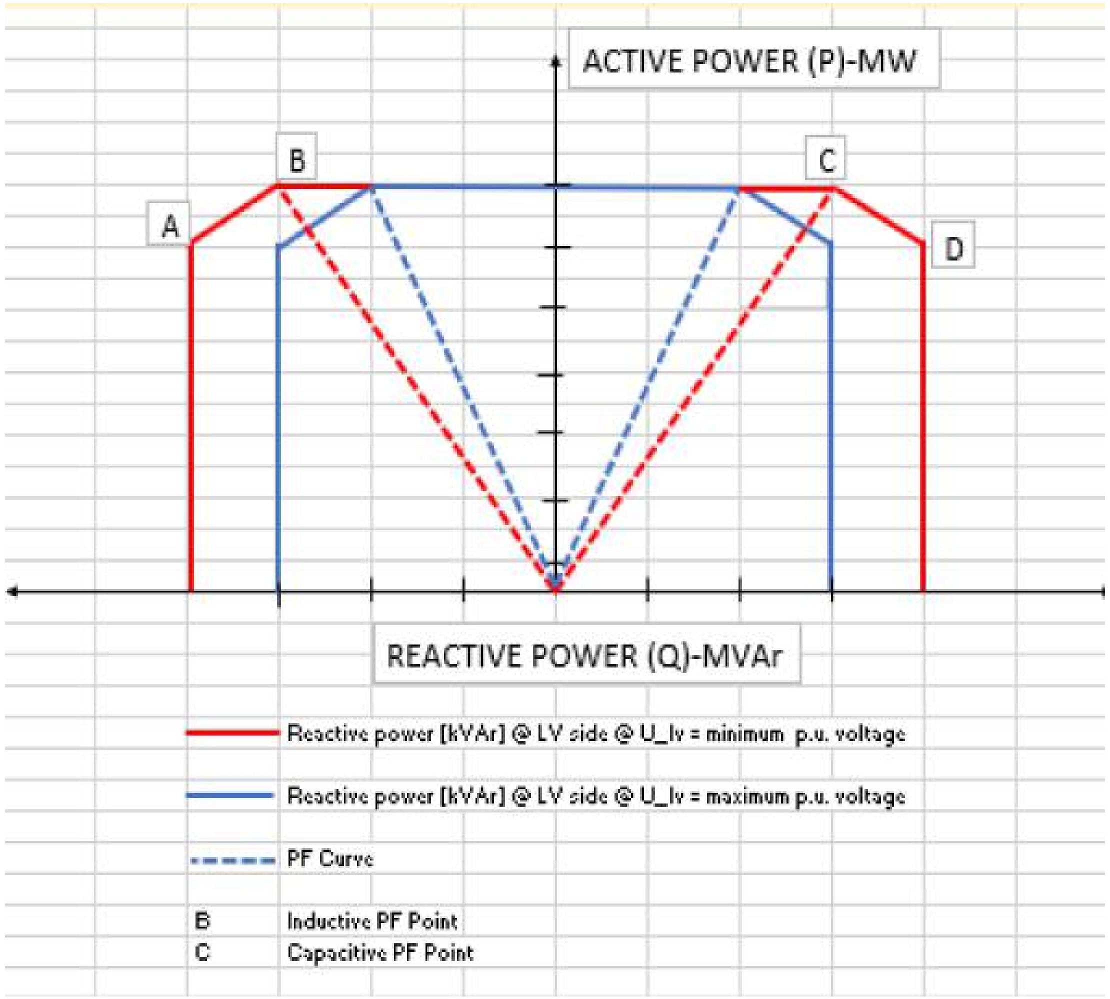
❑EXCITATION SYSTEM

- The Transient Stability of a system can be improved if the excitation system has high speed of response and a high ceiling voltage with faster change in excitation and hence boost of internal machine flux; the electrical voltage output of the machine may be increased which results in improved Transient Response.

STEADY STATE REACTIVE: WHAT MAN! SYNCHRO GEN n MY RE IS SAME!!!



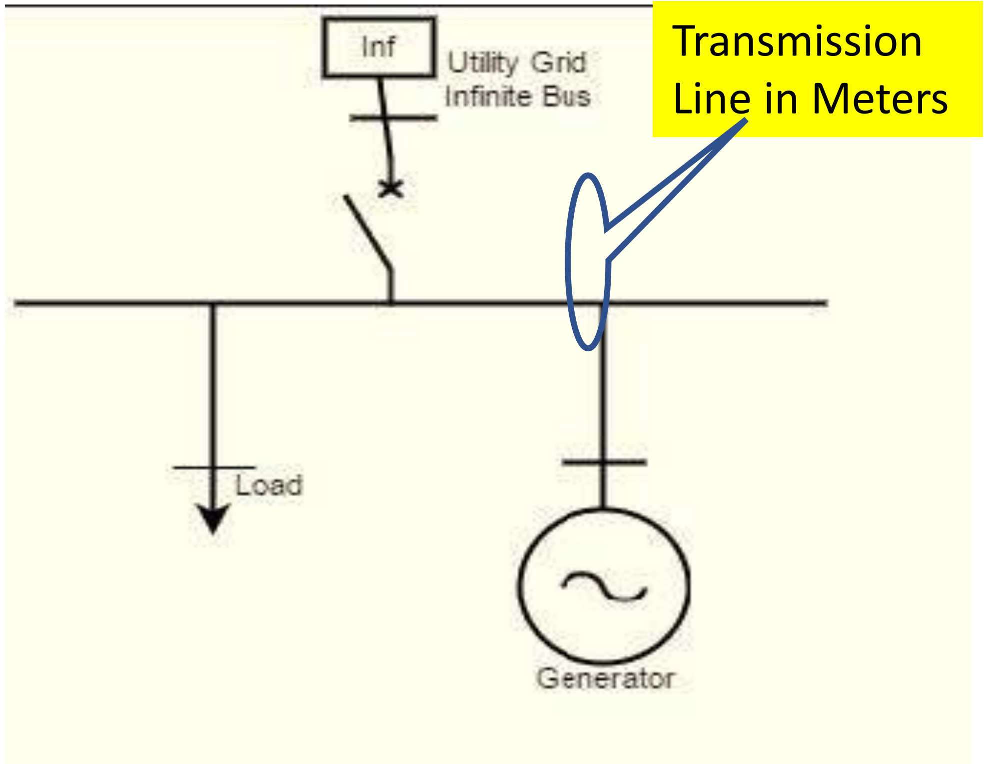
SYNCHRONOUS GENERATOR POWER CAPABILITY CURVE



WTG/INVERTER POWER CAPABILITY CURVE

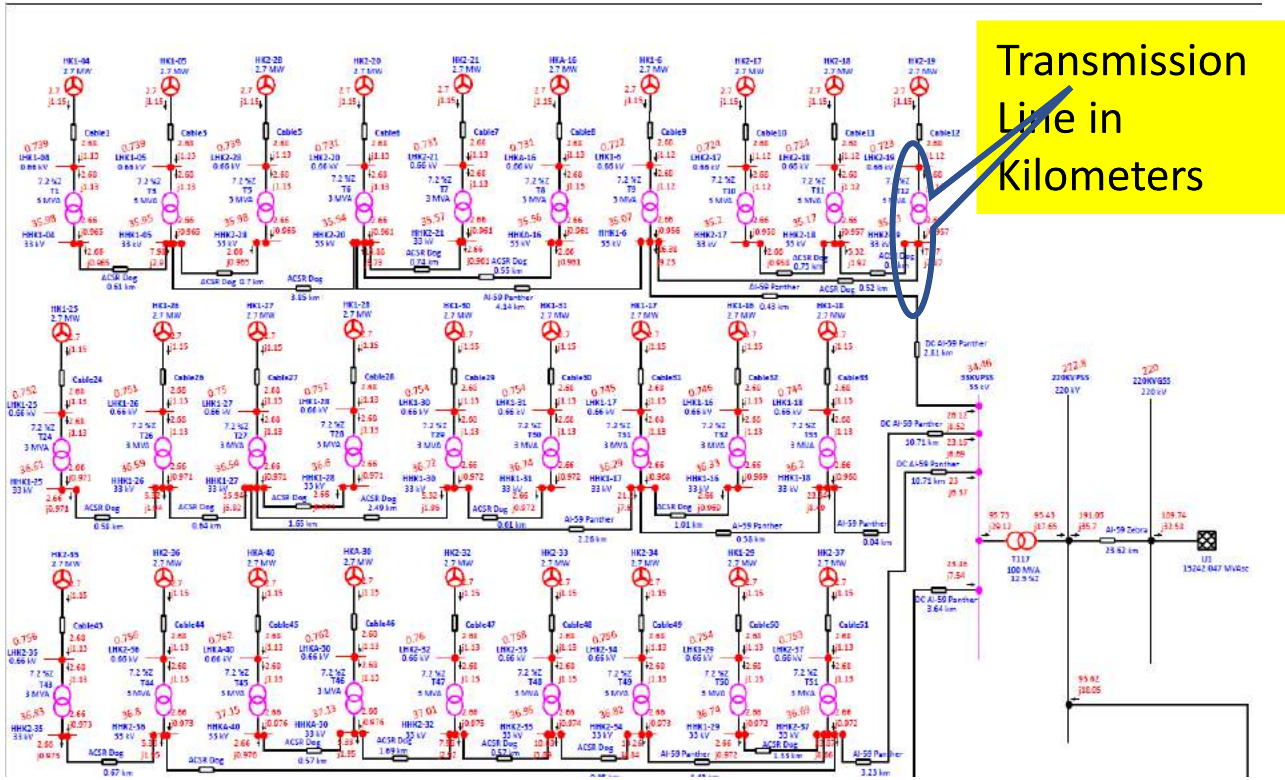
STEADY STATE REACTIVE: BETWEEN THE LINES

THERMAL PLANT



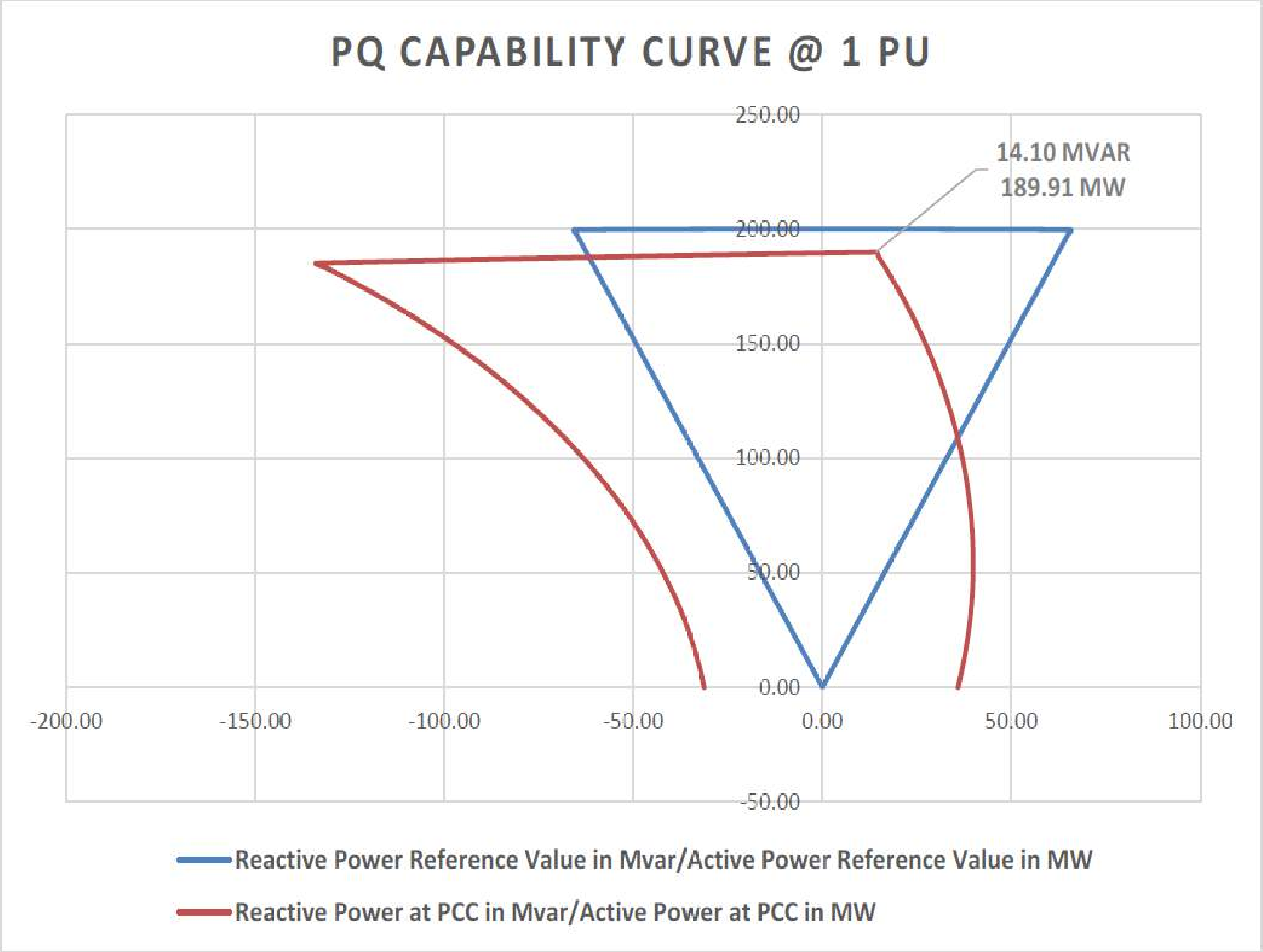
- Alternator distance from Grid Bus range in Meters so Active Power Loss will be less.
- As Distance is less, Reactive Power Requirement of Cables will also be low so Reactive power compensation can be easily done.

WIND PLANT



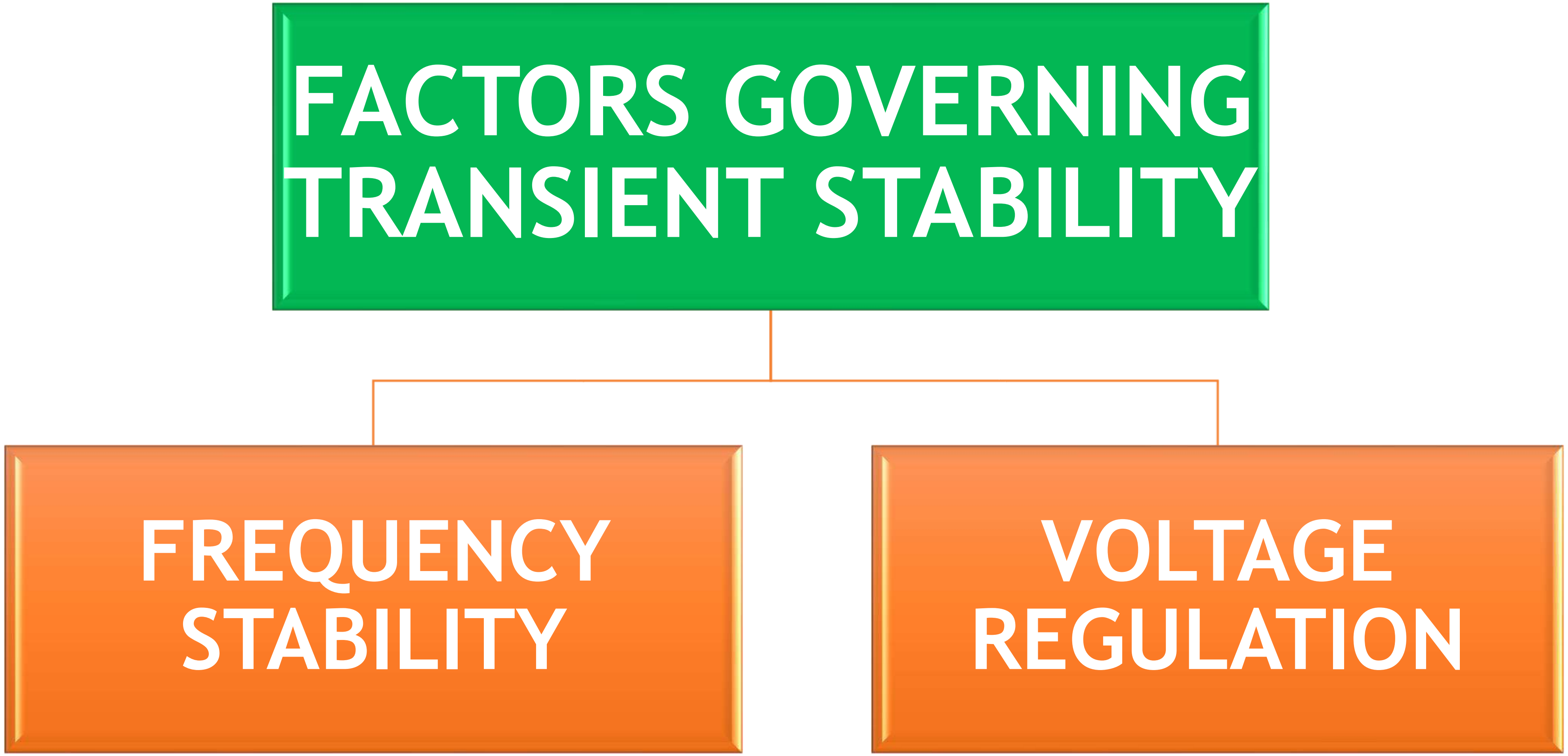
- WTG distance from Grid Bus range in Kilometers so Active Power Loss will be more.
- As Distance is more, Reactive Power Requirement of Cables/Overhead Line will also be more so Reactive power compensation problem prevails.

STEADY STATE REACTIVE: FARM EFFECT….



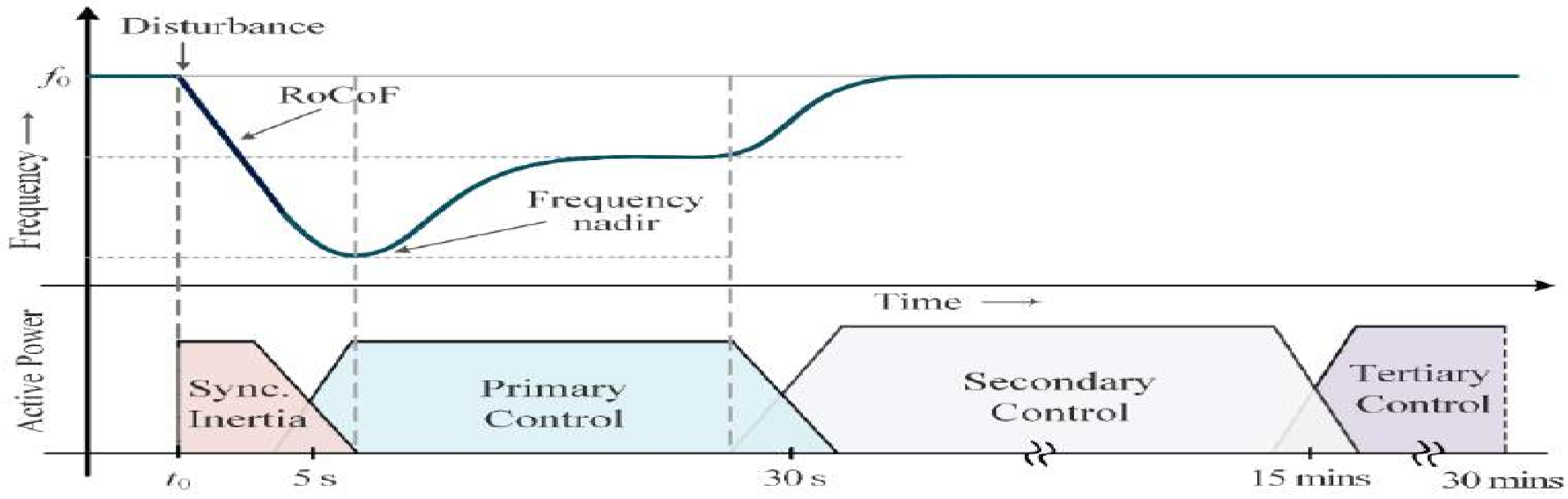
REACTIVE POWER COMPENSATION CAPABILITY CURVE OF WIND/SOLAR PLANT

1. RE PLANTS ACT AS SOURCE OF ACTIVE POWER BUT
2. IMPORTERS OF REACTIVE POWER
3. NO MEASURES IN VOLTAGE SELF REGULATION
4. PRE-FAULT CONDITIONS IN RE-RICH AREA REMAINS HUGELY FRAGILE
5. LEADING TO DYANMIC AND TRANSIENT STABILTY ISSUES
6. STATCON/SVC DEPLOYMENT IN THE GRID IS IMEPRATIVE FOR GRID RESILIENCE


FACTORS GOVERNING TRANSIENT STABILITY
FREQUENCY STABILITY
VOLTAGE REGULATION

MAJOR FACTORS FOR FREQUENCY STABILITY

❑INERTIA



- Generally, frequency response of any power system can be characterised by different time window-based responses, such as, inertial, primary frequency, secondary frequency, and tertiary frequency response, as shown in above figure.
- Inertial response plays a critical role in arresting the frequency fall at the start of the sudden generation-load imbalance before governor response of the synchronous generators starts responding, and hence help in maintaining frequency stability.

CLOSE LOOPED CONVENTIONAL vs UNBRIDDLED RENEWABLES

CHANGE IN GRID CHEMISTRY NEEDED FOR SMOOTH AND RELIABLE ENERGY TRANSITIONING

THERMAL PLANT

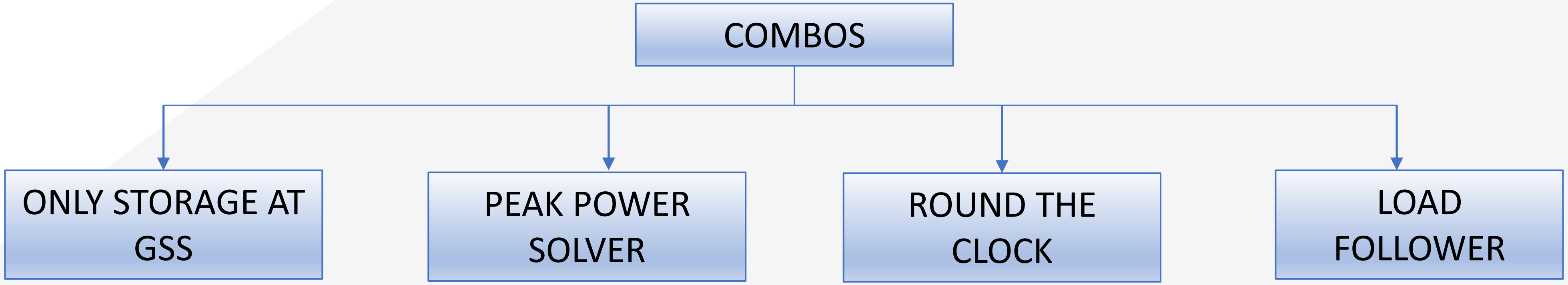
- High Inertia so better Rate of Change of Frequency.
- Controlled Fuel, so fine Close Loop control
- Low Impedance so more short circuit current contribution.
- High Short Circuit Current Contributor so faster fault clearance time.
- Droop Control Mode with robust Governor System
- Highly responsive excitation system

SOLAR & WIND PLANT

- Low Inertia so Frequency Response is poor
- Open Loop as Fuel Uncontrolled.
- Negligible Short Circuit Contribution – fault clearance issue
- Droop Control Mode can be only for Load Throw-off support.
- Communication Latency issues- Distributed Nature
- High system Impedance : Poor Voltage Mirroring- LVRT/HVRT initiation challenges.

STORAGE → FILL IN THE BLANKS → PANACEA → BASE LOAD CONVERTOR

- *DISPATCHABLE FIRM POWER –REPLICATING BASE LOAD STATIONS*
- *ROBUST DYNAMIC & STEADY STATE STABILITY DUE TO BETTER PRE-FAULT CONDITIONING (BM).*
- *HIGH SYNTHETIC INERTIAL LEADING TO FAST FREQUENCY RESPONSCE (FFR)*
- *HIGHLY RESPONSIVE TO GRID CHANGES ! IN Milli-seconds!!*
- *SVC/STATCOM ACTORS THROUGH SMOOTH AND VERSATILE REACTIVE POWER COMPENSATION.*



STORAGE → FILL IN THE BLANKS → PANACEA → BASE LOAD CONVERTOR

CHEMICAL

- Lithium Ion (LFP,LCM..)
- Sodium Ion,
- Calcium Ion,
- Flow(Vanadium,Zirconium ...)
- Metal Air....
- Green Hydrogen

MECHANICAL

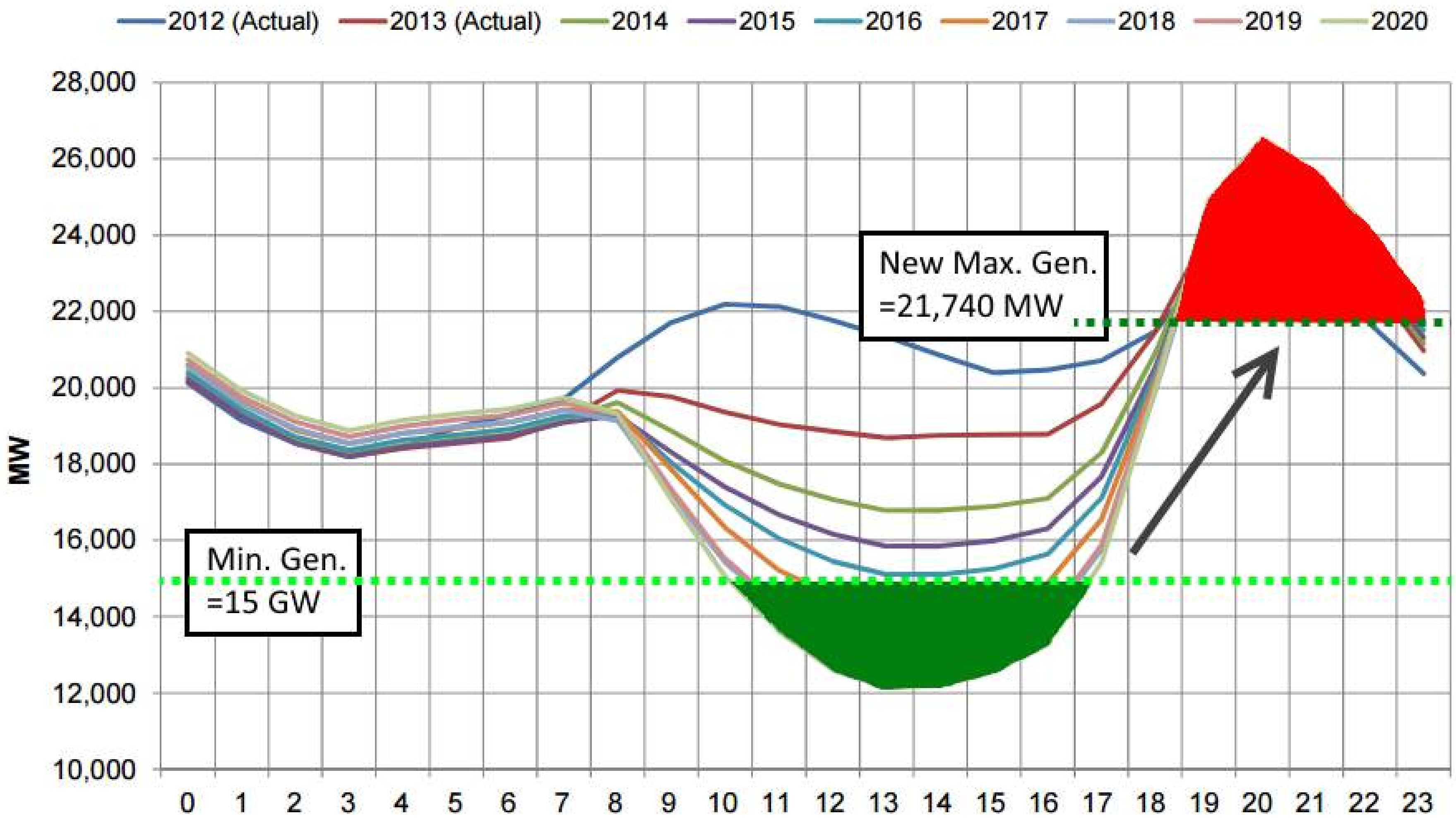
- Pumped Storage (PSP)
- Compressed Air
- Green Hydrogen
- Gravity

CEA HAS ESTIMATED DEPLOYMENT OF 42GW/208GWh OF BESS & 19GW/128GWh OF PSP BY 2030

PAIN POINTS…

- VERY HIGH CAPEX LEADIND TO HIGH TARIFF
- HUGE LAND NEED DUE TO MULTIPLE OVER-SIZING
- CO-LOCATION OF SOLAR AND WIND LAND-----SHADOW ISSUES /RISK IN FUTURE
- ACCELERATION OF RESEARCH,VIABILITY & COMMERCIALISATION OF LONG DURATION ENERGY STORAGE (LDES) ALTERNATIVES
- PARADIGM SHIFT IN THE GRID ELECTRICAL PROTECTION PHILOSPHY ALTHOUGH NEEDED FOR 100% ADOPTION

DUCK RUNS-AWAY…..



Source CAISO.

MAGIC MOLECULE :" JAHAN NA PAHUNCHE ELECTRON WAHAN PAHUNCHE HYDROGEN"

STEP-4:

SCOPE-1 & 2 PATHWAYS TO DECARBONISATION

- Feedstock Replacement– GREY TO GREEN HYDROGEN
- Fuel Replacement- Coal/NG/LPG to Green H_2/Methanol/Ammonia
- CCUS (Blue)
- Mobility → EV (Battery); Hydrogen → Dual Fuel, FCV, HICE
- DRI (Steel)- Green Hydrogen as reducer
- Green Ammonia → Fertiliser, Transportation, Fuel
- Green Methanol- → Chemical, Transportation, Fuel

HYDROGEN MOLECULE CARRIER (Green Ammonia, Green Methanol)

ONE MOLECULE- MULTIPLE USAGE

FEED STOCK	• CHEMICALS, GLASS, REFINERY, FERTILIZER, STEEL, METHANE
NG BLENDING	• HEATING/FURNACE APPLICATION: AUTOMOTIVE, CEMENT, BEVRAGES, GLASS, BUILDING HEATING, STEEL
COAL BLENDING	• HEATING/FURNACE: CEMENT, STEEL(DRI), THERMAL PLANTS
MOBILITY +POWER	• DUAL FUEL/FCEV/HICE/POWER

WELL NOTHING COMES EASY!!

1. Cost of Replacement (LCOH).

LCOH_gen (Electrolyser:Cost/Efficiency)

LCOH_delv (Transportation Infra/Cost/Fuel cell efficiency)

2. R&D- Electrolyser Eff, Different Physics…
3. Demand creation mandate.
4. Water Need (750 Giga Liters PA by 2050…)
5. Hydrogen Transportation– 700Bar/Liquefaction/ Ammonia/Methanol
6. Centre-State Policy consistency, Coherence
7. High cost of De-salination
8. Safety norms for the public domain.
9. Financing

	Green H2	Electrolyser	RE Install	RE Need	Water Need	Ammonia (20% conv)	Investment
	MTPA	GW	GW	BU	GLt	MTPA	Billion USD
2030	5	30	150	392	150	6	156
2040	11	66	330	861	330	13	343
2050	25	150	750	1958	750	30	780

With India GDP 1/7th of US. Similar proportion of IRA (398 Bill USD/7= 55 Bill USD) equivalent can make this success or even exponentially push up)

This is equivalent to consumptive water need for 20GW of TPP or approx. 10% capacity of Bhakra Nangal dam reservoir

ROCKET MOUNTED TO GROUND SCALING → EXPONENTIAL OPPORTUNITY

SOLAR STORY

NOW HYDROGEN STORY

MOTHER EARTH OUT OF VENTILATOR & SMILING.