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India Smart Grid Forum

India SMART UTILITY Week 2024

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MINISTRY OF POWER
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CENTRAL ELECTRICITY AUTHORITY

Session : LONG DURATION ENERGY STORAGE SYSTEMS- GRID IMPACT

Presented By

SUDHIR PATHAK-Head (Engg/QA/Green Hydrogen)--HERO FUTURE ENERGIES

WAY FORWARD→ Energy Transition to Decarbonisation → Carbon Neutralism

STEP-1:

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

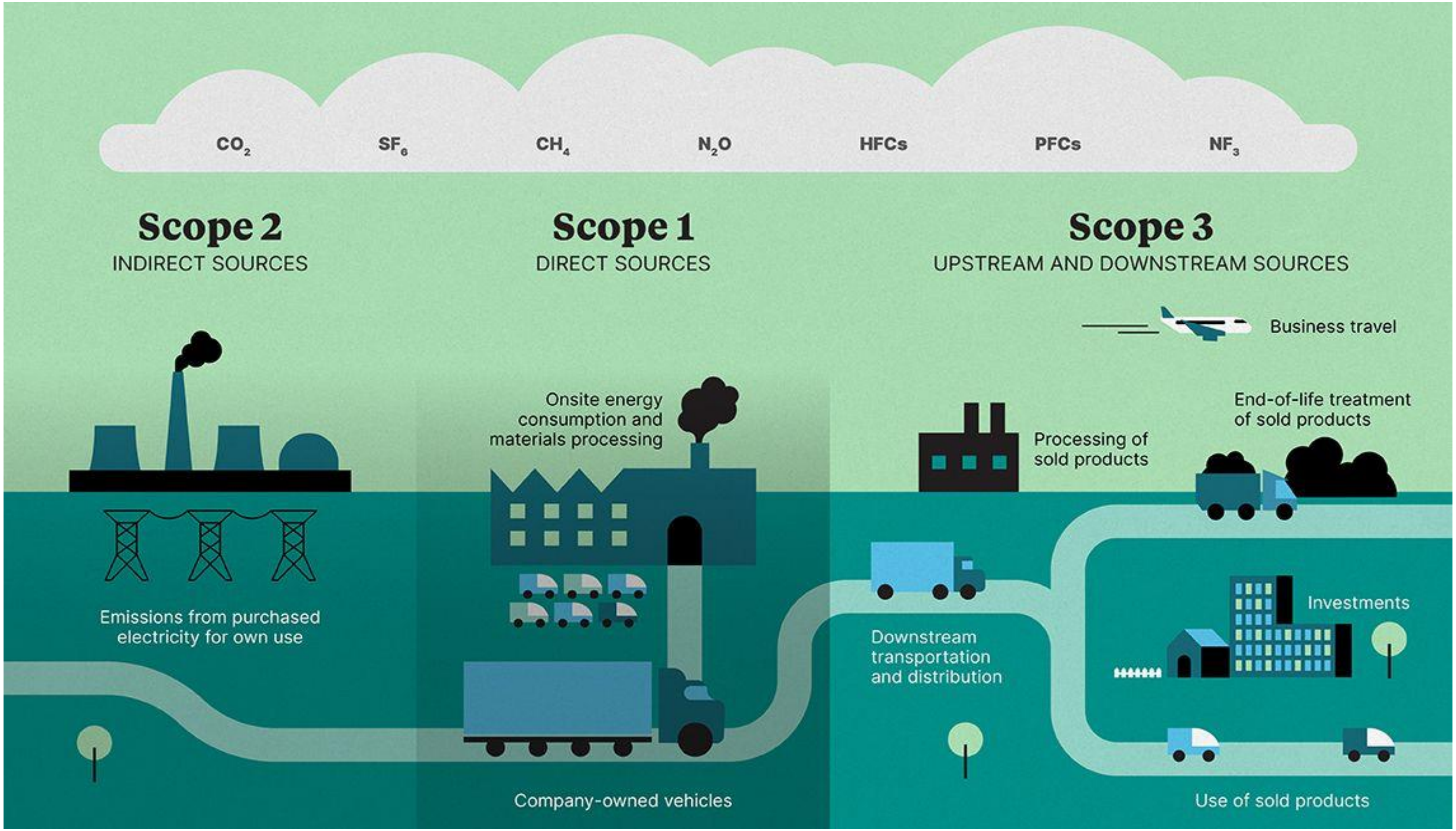
$\left.\begin{array}{l}\text{Measure}\\ \text{Monitor}\\ \text{Mitigate}\end{array}\right\}$ ***CARBON FOOTPRINT***

STEP-2:

Carbon Emissions are typically Classified into three categories.

SCOPE-1 SCOPE-2 SCOPE-3

SCOPE EMMISSION???



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)

Well , More RE for this as well…!!!

DECARBONISATION: OOPS TOLL ON GRID STABILITY !!!

Grid-India is committed to further facilitate this process to realize India's ambitious green energy transition goals while also ensuring reliable operation of the electricity grid. In this context it may be noted that between January 2022 to May 2023, thirty-one (31) events involving generation loss/reduction of 1000 MW to 7800 MW in Rajasthan Renewable Energy (RE) complex were witnessed. These events are broadly classified into four categories of events triggered by:

a) Transmission system faults external to RE plant
b) Transmission system faults within the RE plant
c) Over voltage during line or reactor switching
d) Forced oscillations in reactive power and voltage

DECARBONISATION: OOPS TOLL ON GRID STABILITY !!!

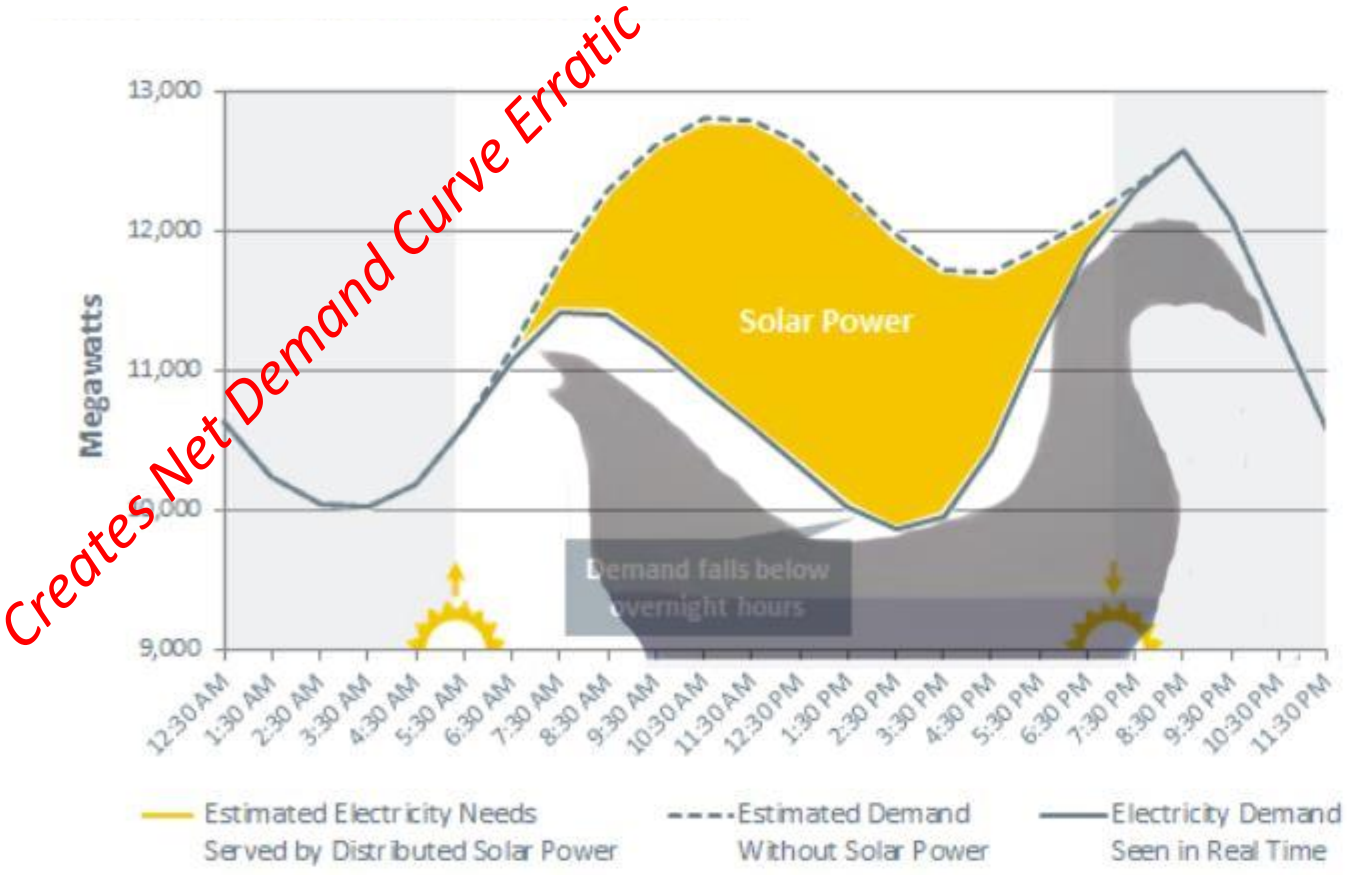
1. STEADY STATE ACTIVE POWER ISSUES

2. STEADY STATE REACTIVE POWER ISSUES

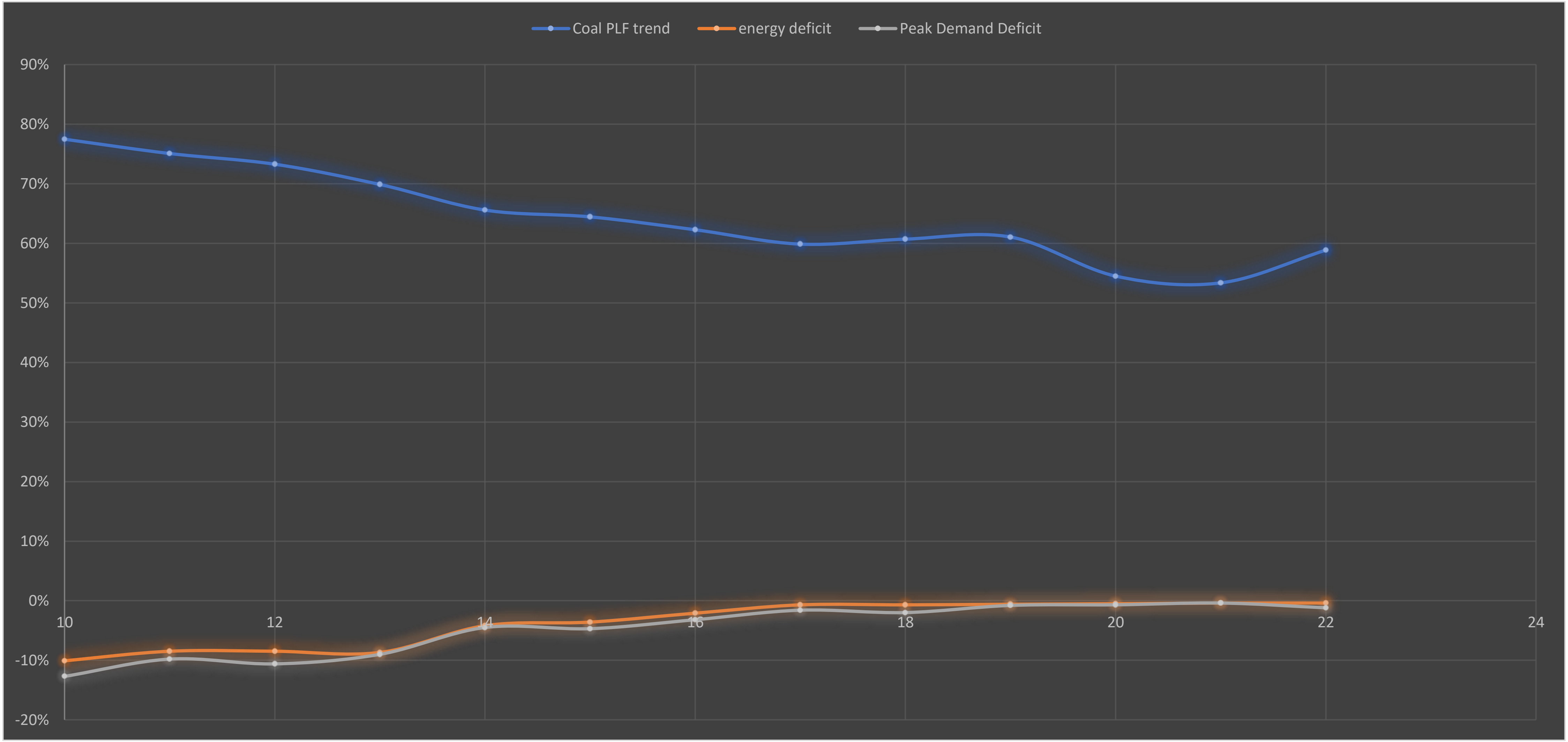
TRANSIENT AND DYNAMIC STABILITY ISSUES

DUCKING THE GRID REALITY…..

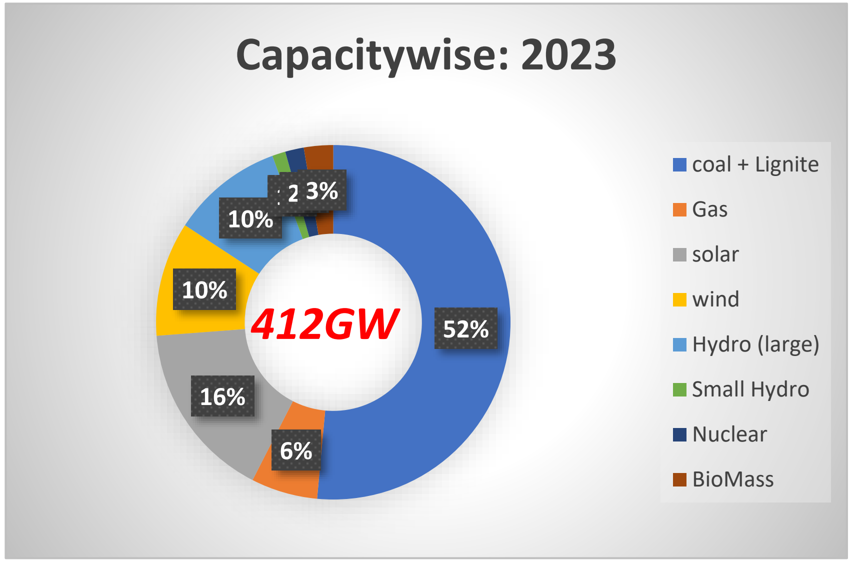
In-famous Duck Curve!

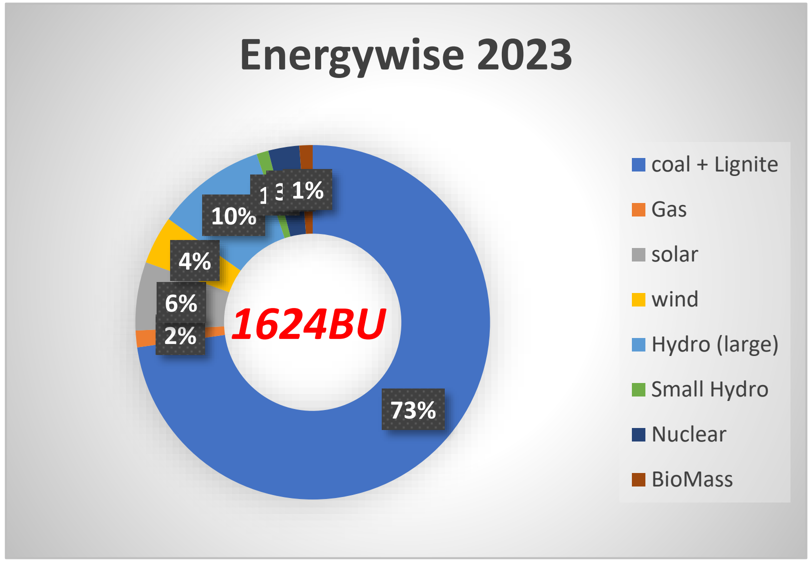


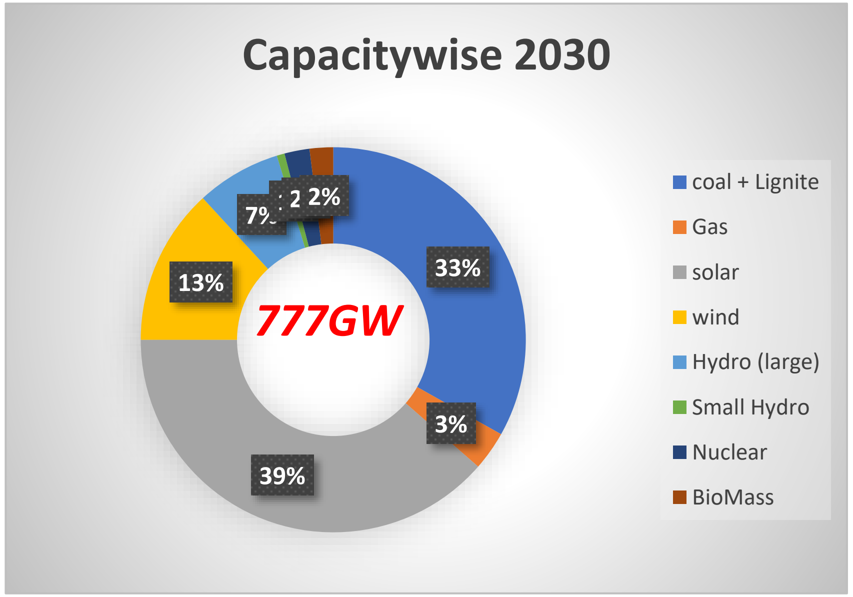
STEADY STATE ACTIVE: RESOURCE IN-EFFICIENCY PRESENTLY

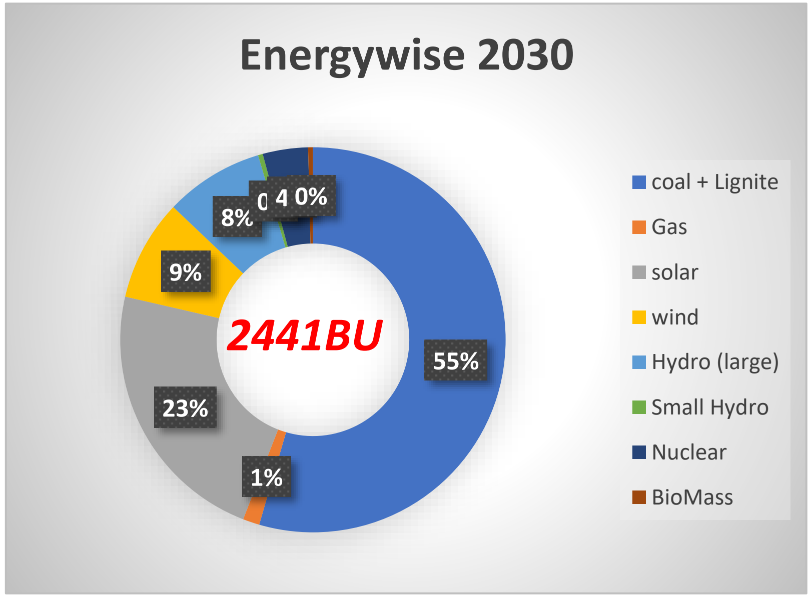


STEADY STATE ACTIVE: RESOURCE IN-EFFICIENCY IF FUTURE IS NOT CORRECTED





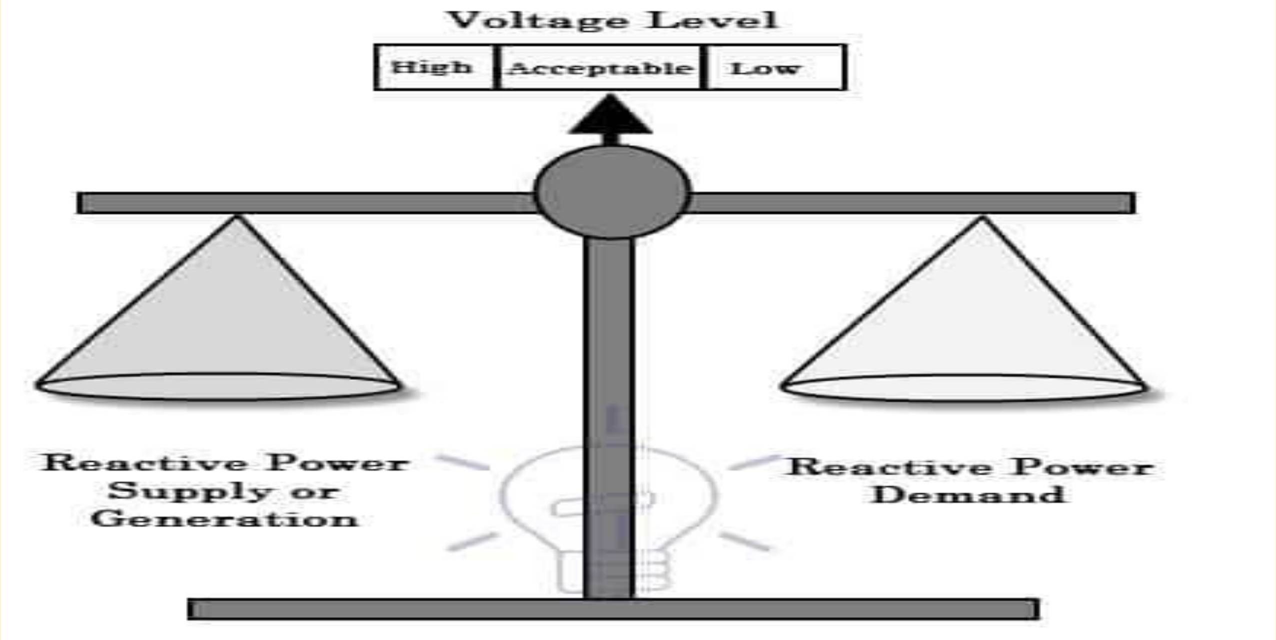




STEADY STATE REACTIVE: VOLTAGE ROLLER COASTER RIDE

❑REACTIVE POWER

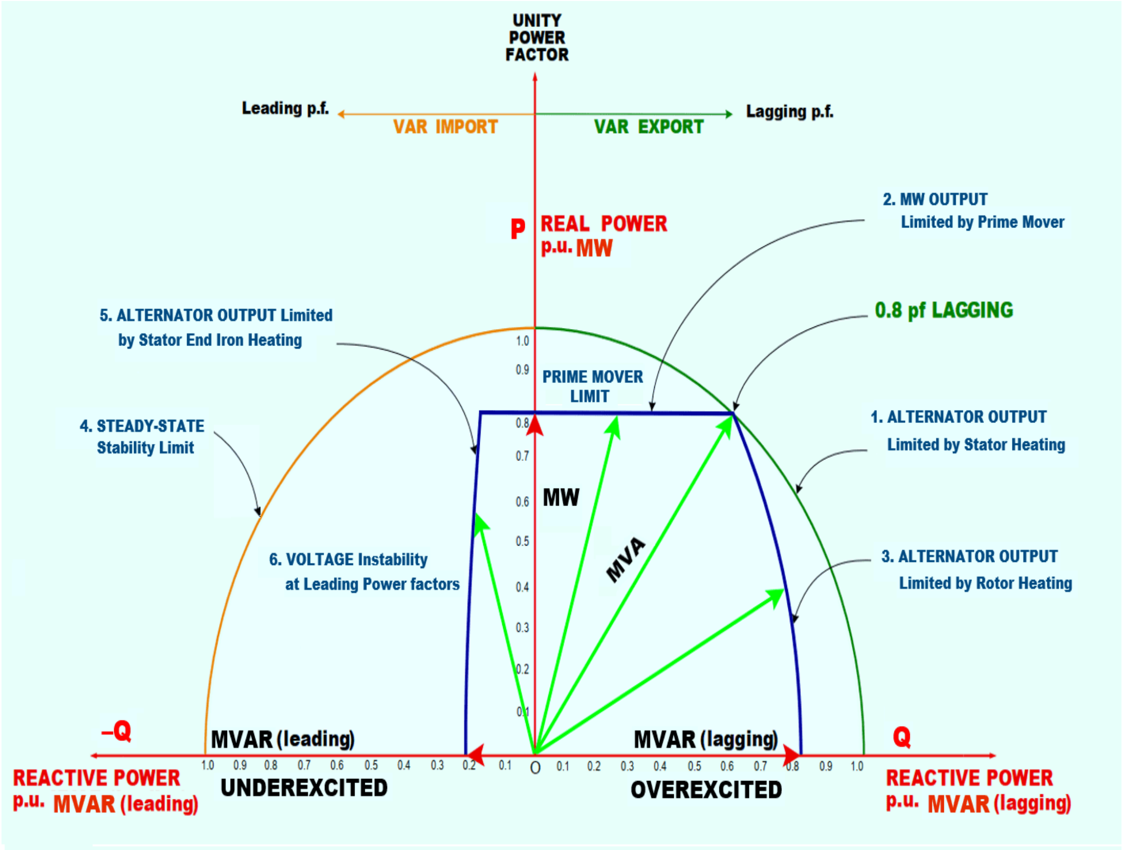
- Supply and absorption of Reactive Power leads to Voltage Stability in the Grid.



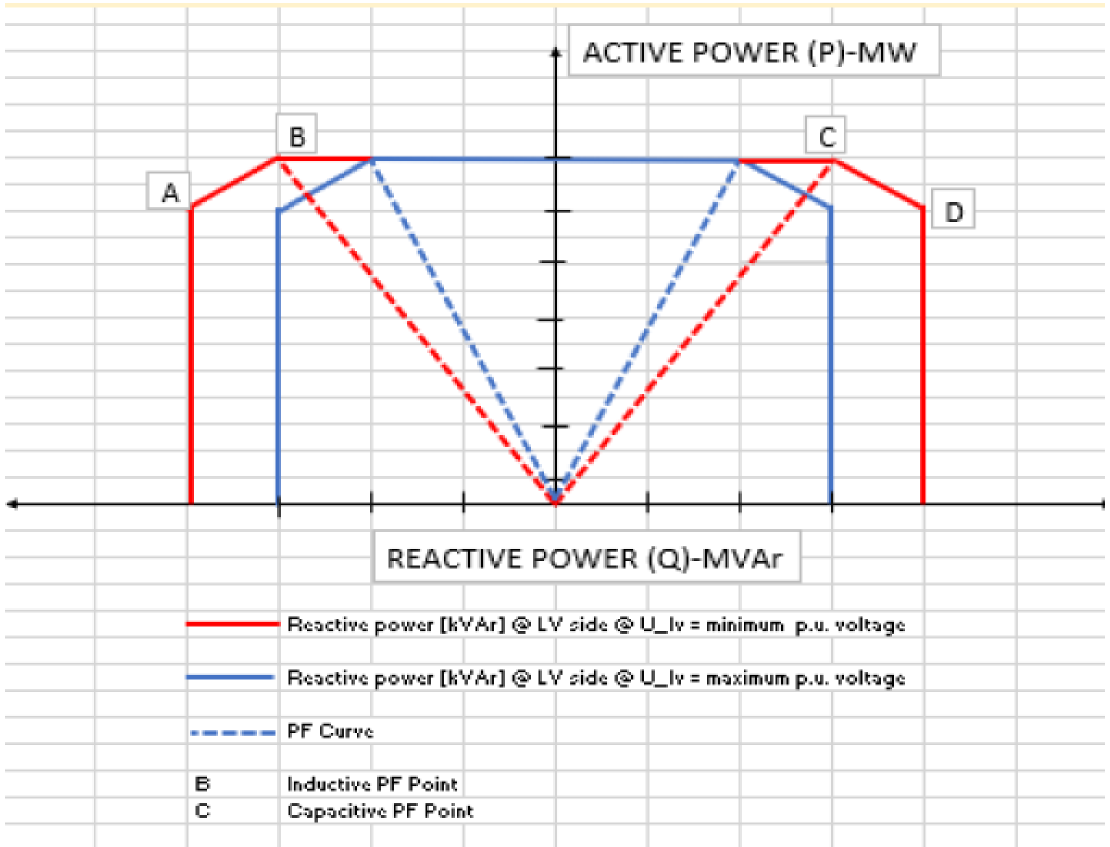
❑EXCITATION SYSTEM

- 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!!!



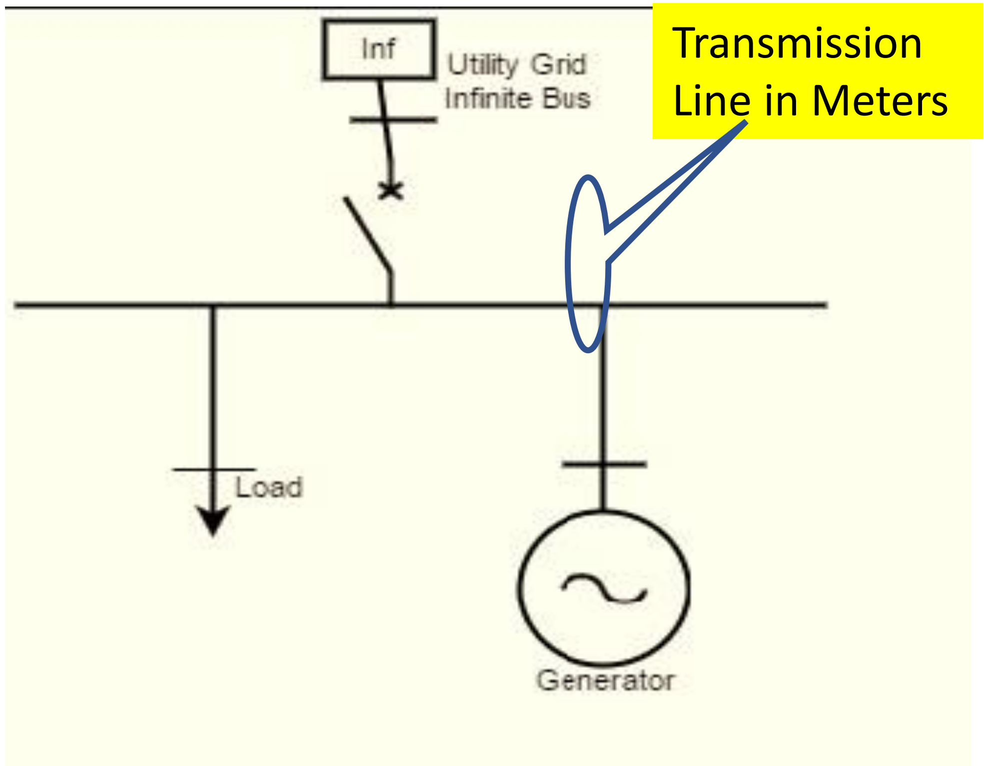
SYNCHRONOUS GENERATOR POWER CAPABILITY CURVE



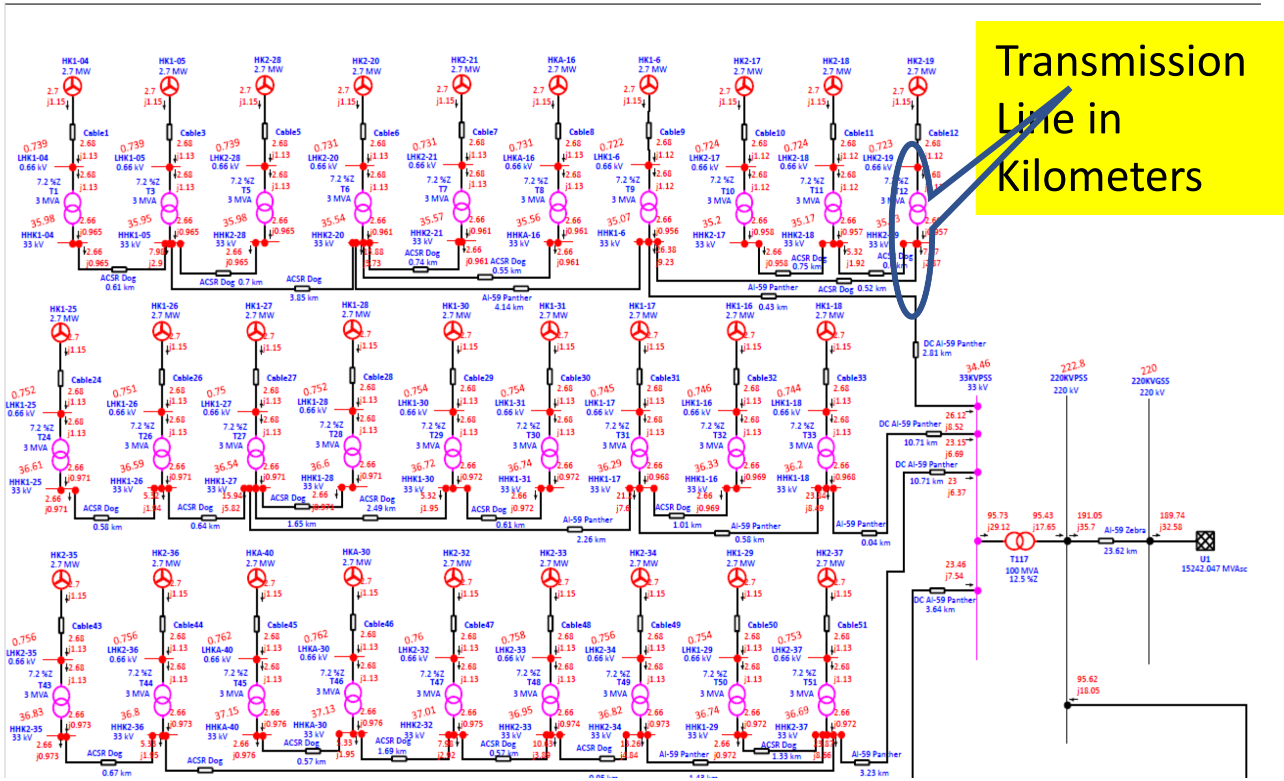
WTG/INVERTER POWER CAPABILITY CURVE

STEADY STATE REACTIVE: BETWEEN THE LINES

- THERMAL PLANT



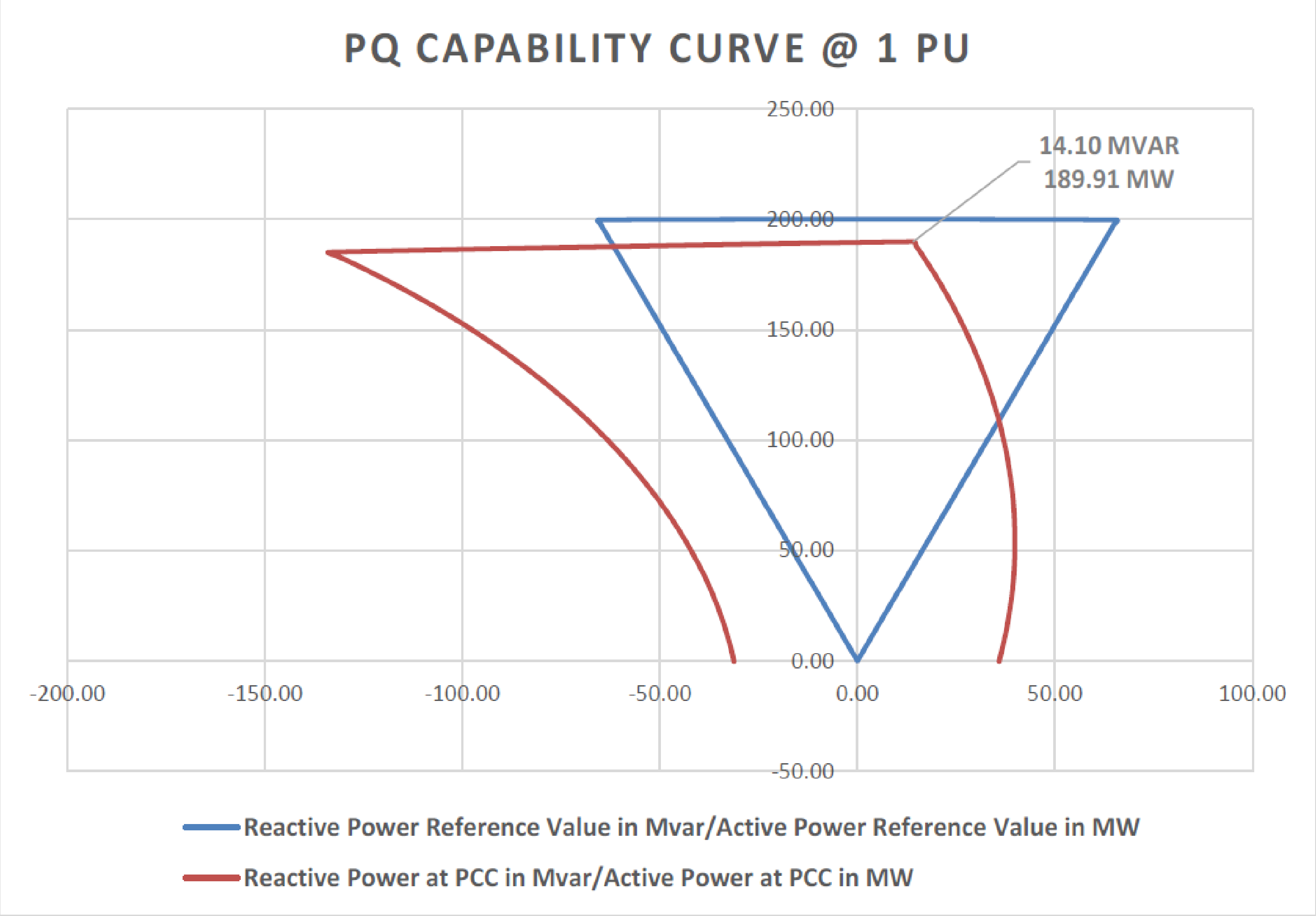
- WIND PLANT



- 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.

- 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/SVG DEPLOYMENT IN THE GRID IS IMEPRATIVE FOR GRID RESILIENCE

DIVING OUT OF TRANSIENT DISTURBANCES

❑ TRANSIENT STABILITY

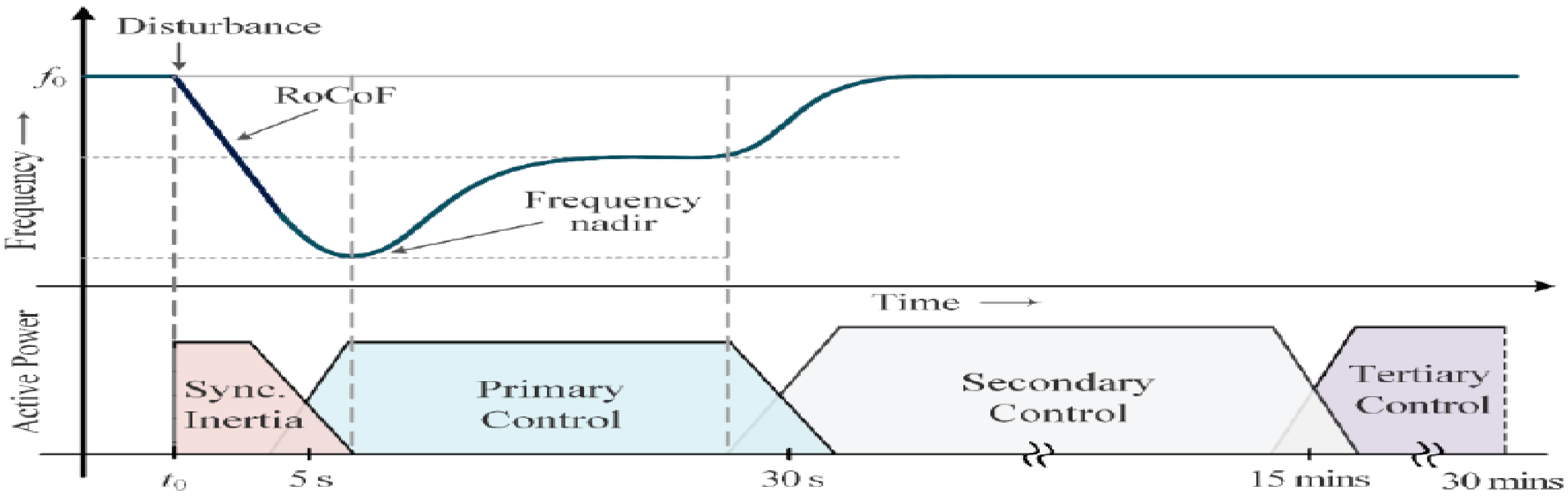
- It refers to the maximum flow of Power possible through a point without losing the stability with sudden and large changes in the network conditions such as brought about by faults, by sudden large increment of Loads, sudden loss of loads.

FACTORS GOVERNING TRANSIENT STABILITY

- FREQUENCY STABILITY
- VOLTAGE REGULATION

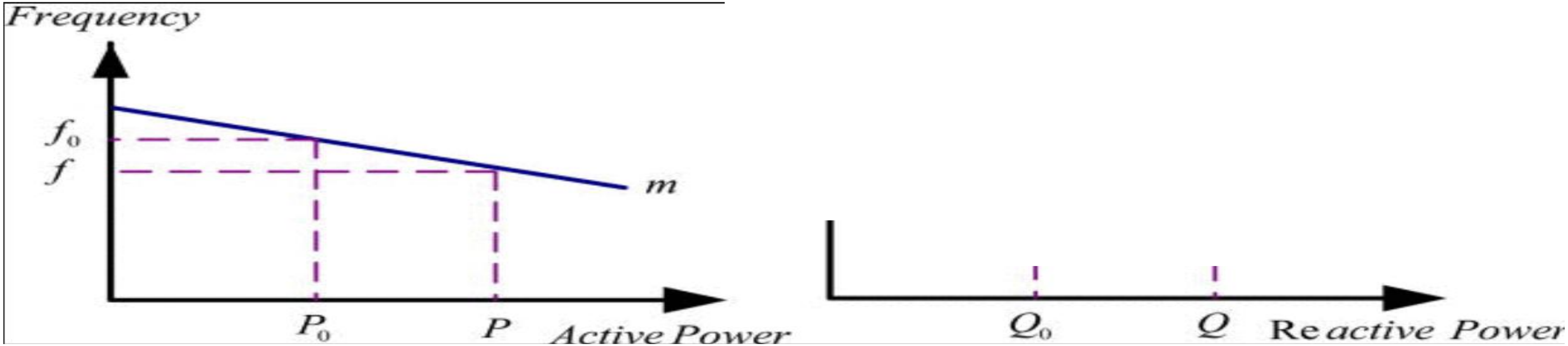
MAJOR FACTORS FOR FREQUENCY STABILITY

❑INERTIA



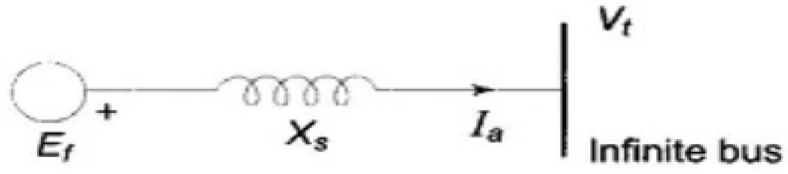
- Generally, frequency response of any power system can be characterised by different time window-based responses, such as, inertial, primary frequency, secondary frequency, and tertiary frequency response, as shown in above figure.
- Inertial response plays a critical role in arresting the frequency 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.

SAVIOUR TO FREQUENCY TRANSIENCE: HIGH RESPONSIVE DROOP CONTROL



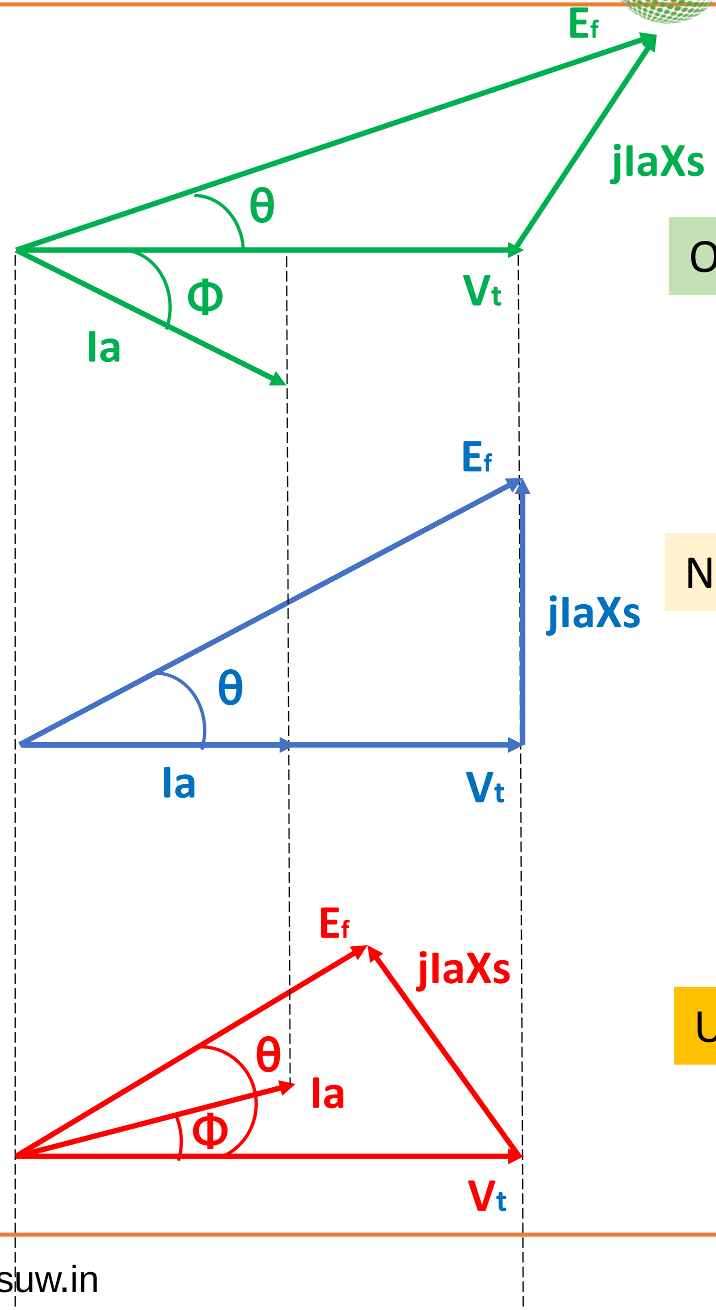
- Droop speed control is a control mode used for AC electrical power generators, whereby the power output of a generator reduces as the line frequency increases. It is commonly used as the speed control mode of the governor of a prime mover driving a synchronous generator connected to an electrical grid.
- It works by controlling the rate of power produced by the prime mover according to the grid frequency. With droop speed control, when the grid is operating at maximum operating frequency, the prime mover's power is reduced to zero, and when the grid is at minimum operating frequency, the power is set to 100%, and intermediate values at other operating frequencies.
- This mode allows synchronous generators to run in parallel, so that loads are shared among generators with the same droop curve in proportion to their power rating.

SAVIOUR TO VOLTAGE TRANSIENCE: HIGH RESPONSIVE EXCITATION CONTROL



Generator Connected to Infinite Bus

E_f : No load EMF
Vt: Terminal Voltage
Ia: Armature Current
Xs: Synchronous Reactance
θ: Power Angle
Φ: Power Factor Angle



OVEREXCITED EXCITATION

NORMAL EXCITATION

UNDER EXCITED EXCITATION

CLOSE LOOPED CONVENTIONAL vs UNBRIDDLED RENEWABLES

- THERMAL PLANT

- SOLAR & WIND PLANT

CHANGE IN GRID CHEMISTRY NEEDED FOR SMOOTH AND RELIABLE ENERGY TRANSITIONING

- 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

- 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

STORAGE:

- ***BATTERY → Lithium Ion,, Calcium Ion, Sodium Ion, NaS, Vanadium Flow, Zirconium Flow….***
- ***Pumped Storage***
- ***LAES/CAES/CO2ES***
- ***Green Hydrogen based***
- ***Concentrated Solar Power (CSP)***

RE+STORAGE COMBO → BASE LOAD POWER PLANT

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

PARADIGM SHIFT IN THE GRID ELECTRICAL PROTECTION PHILOSPHY ALTHOUGH NEEDED FOR 100% ADOPTION

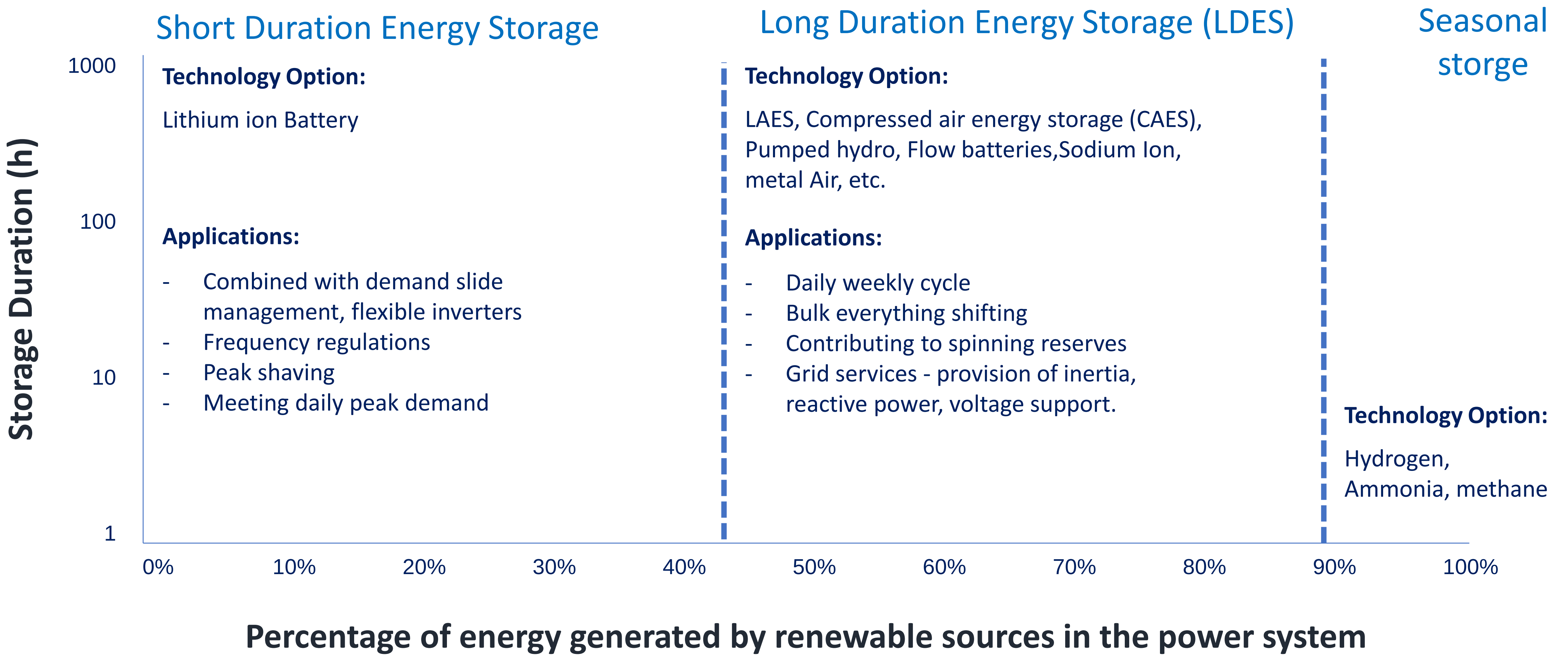
The Essential role of Long Duration Energy Storage (LDES)

Long Duration Energy Storage (LDES) technologies can store energy generated from renewable sources such as wind and solar PV for long duration ranging from 10+ hours to days. weeks, and seasons.

While a range of options are available to provide some flexibility, LDES can meet the most system needs.

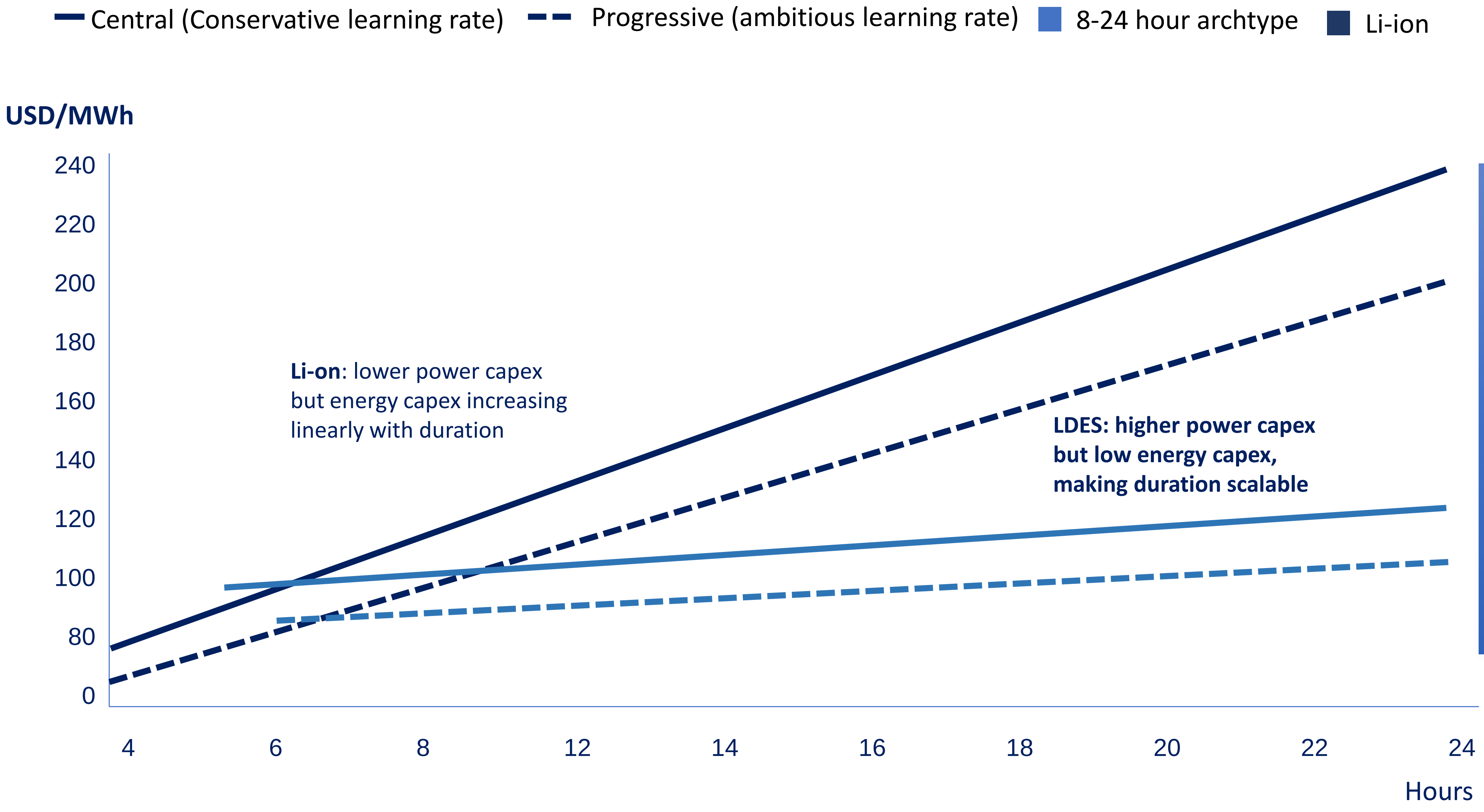
Flexibility Duration	Power System Challenge	Dispatchable Generation	Grid rein-forcement	Curtailment or feed-in management	Li-on Batteries	LDES	Demand-Side response
Intraday	Intermittent daily generation	✓		✓	✓	✓	✓
	Reduced grid stability	✓			✓	✓	
Multiday, multiweek	Multi-day imbalances	✓				✓	
	Grid congestion		✓	✓			
Seasonal duration	Seasonal unbalances	✓	✓			✓	
	Extreme weather events	✓				✓	

Long Duration Energy Storage (LDES) enables a shift towards 24/7 renewable energy



LDES: Cost effective for longer durations

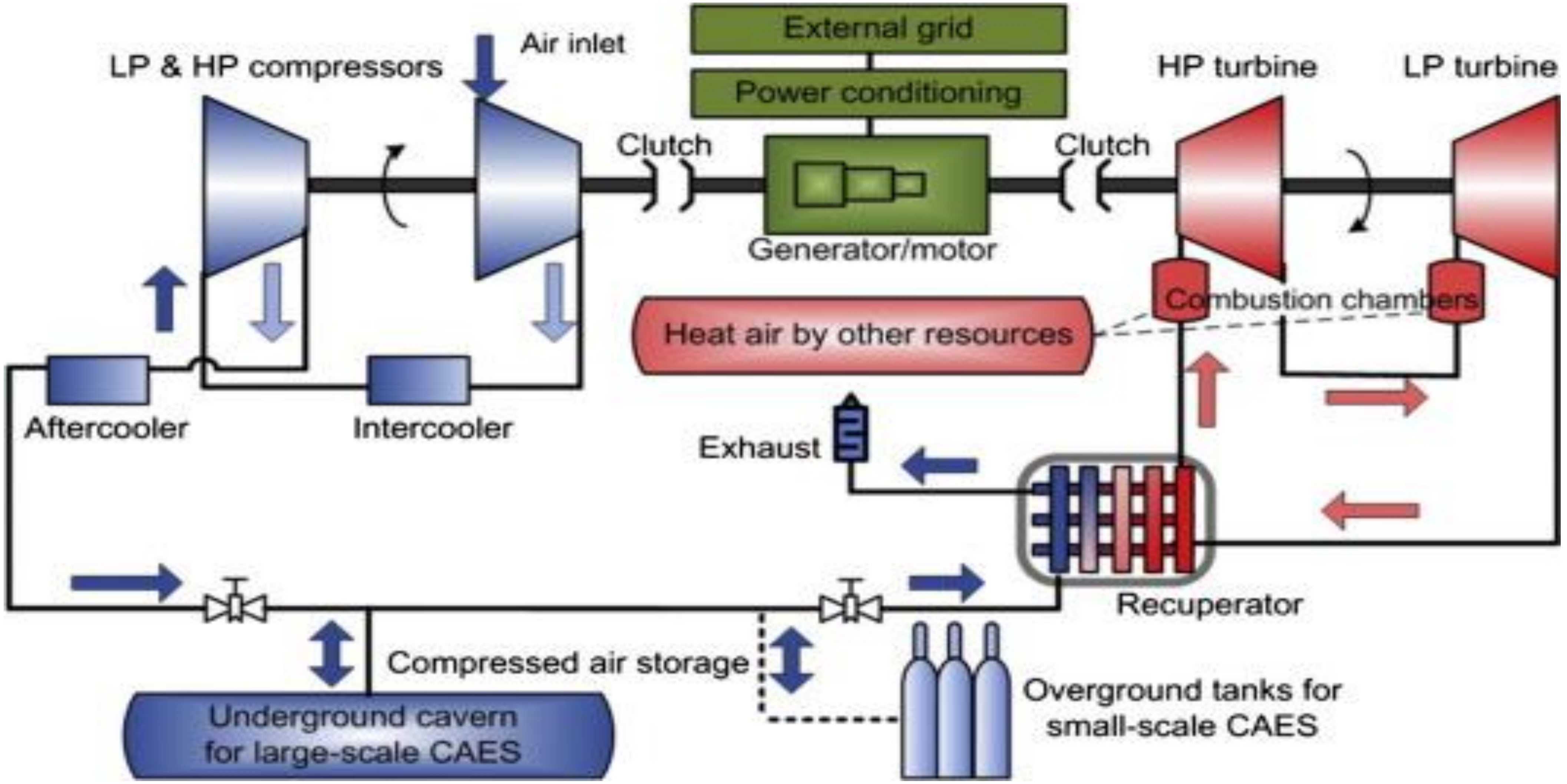
Energy storage LCOS, competitiveness by duration for Li-ion and LDES, 2030



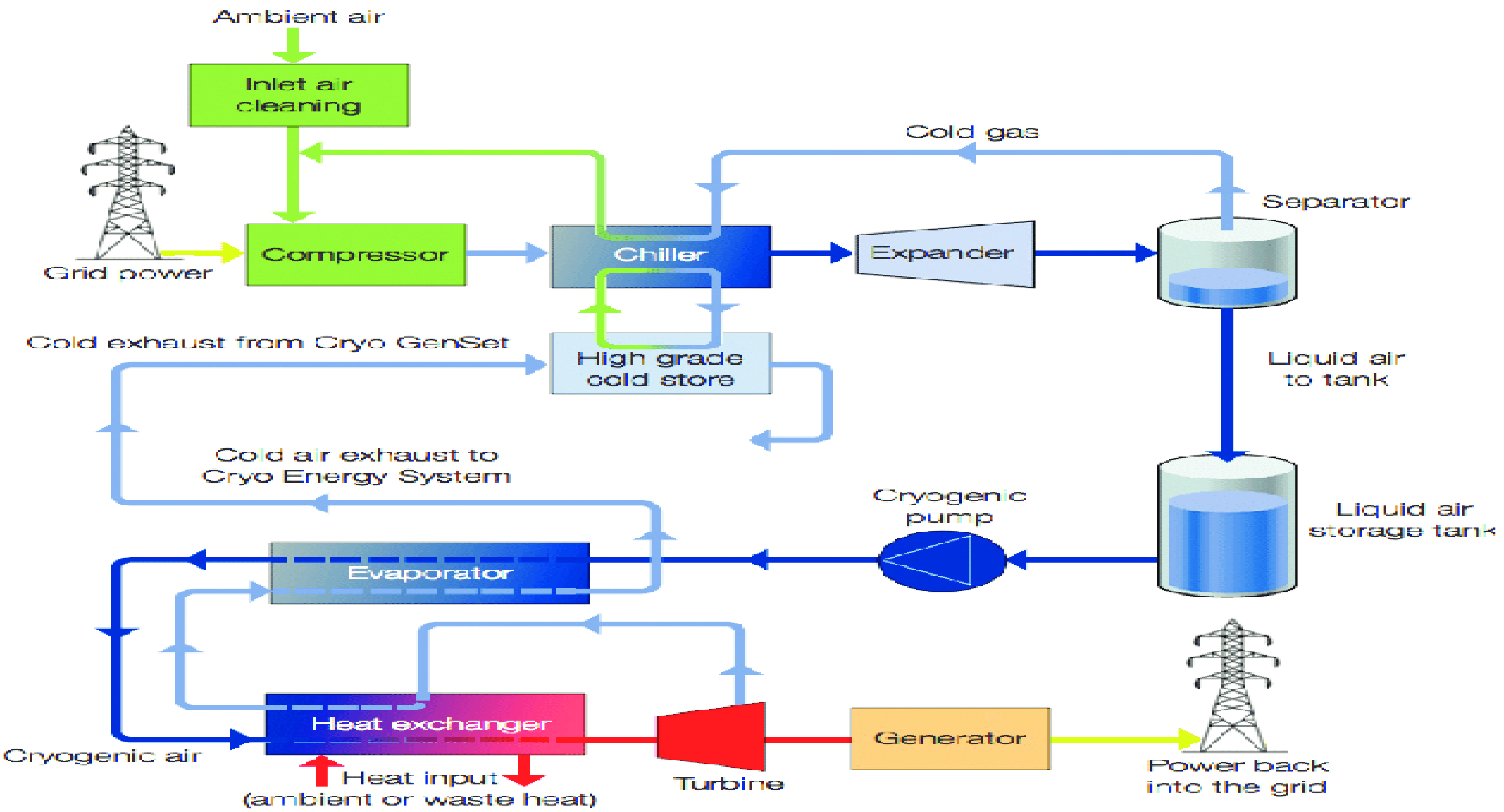
Existing shorter duration technologies such as Lithium-ion batteries are cost-effective
For 0-4 hours.

For longer duration LDES Technologies become most Cost effective.

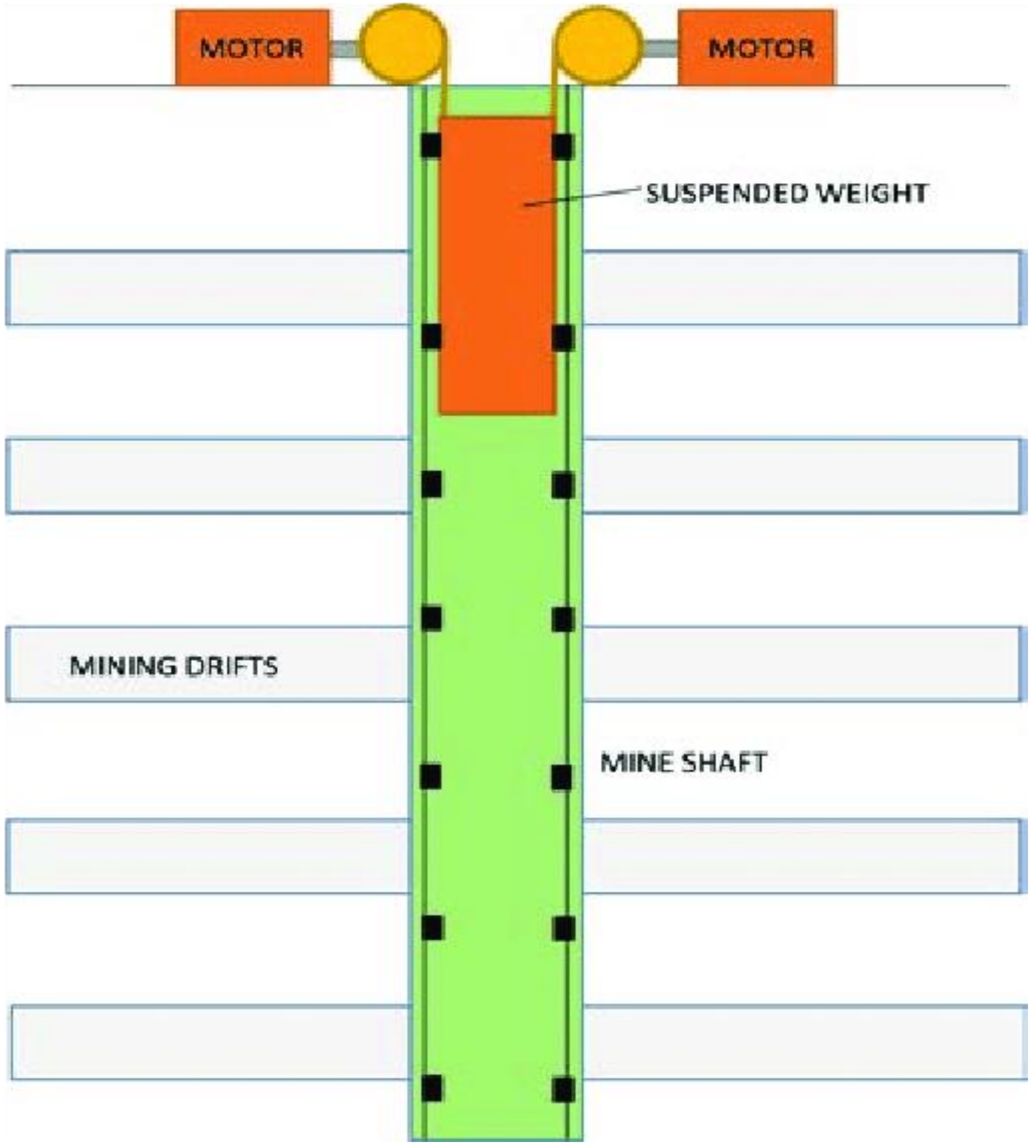
Compressed air energy storage



Liquid air energy storage



Gravity Energy Storage



DUCK RUNS-AWAY…..

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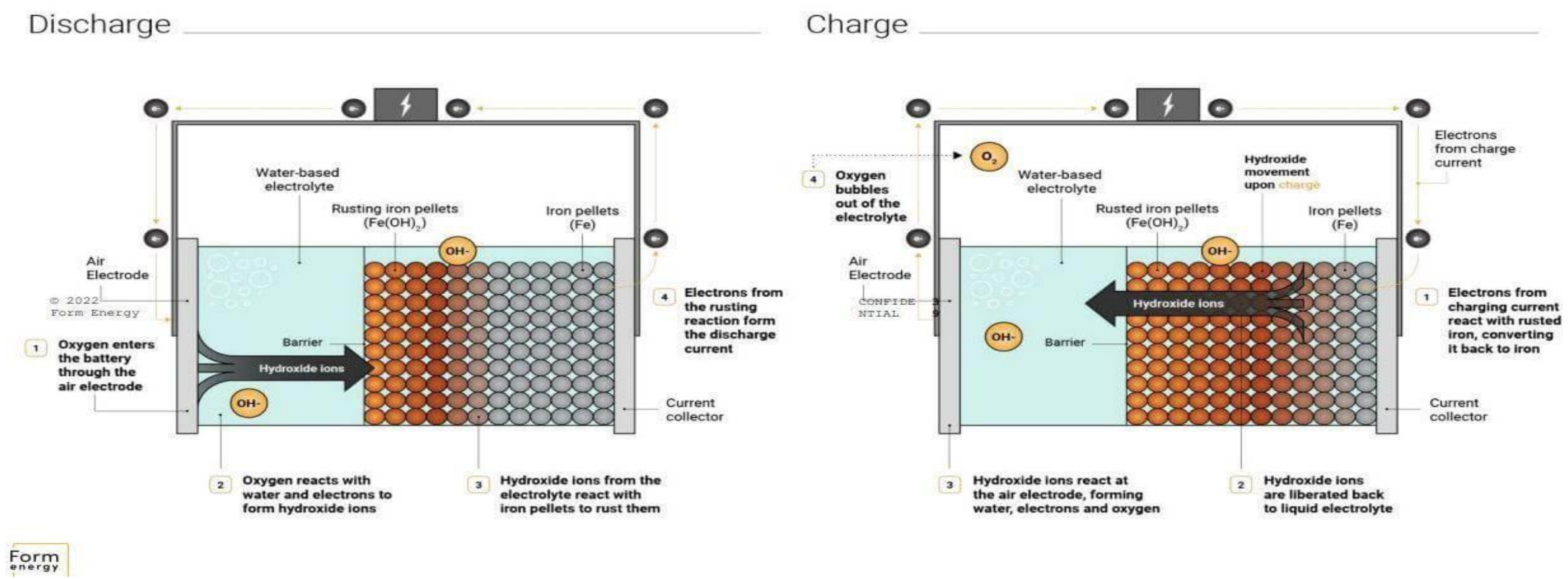
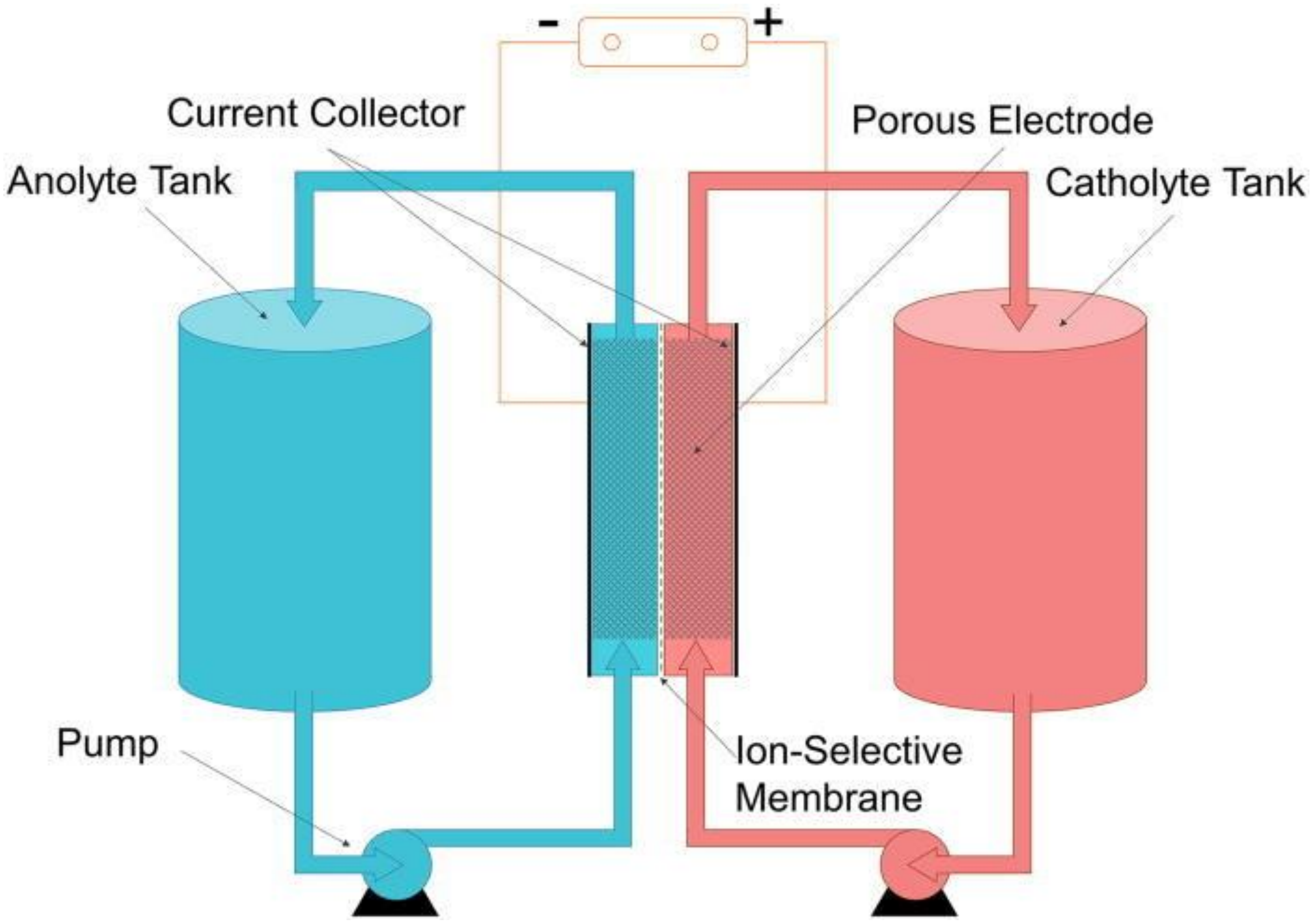
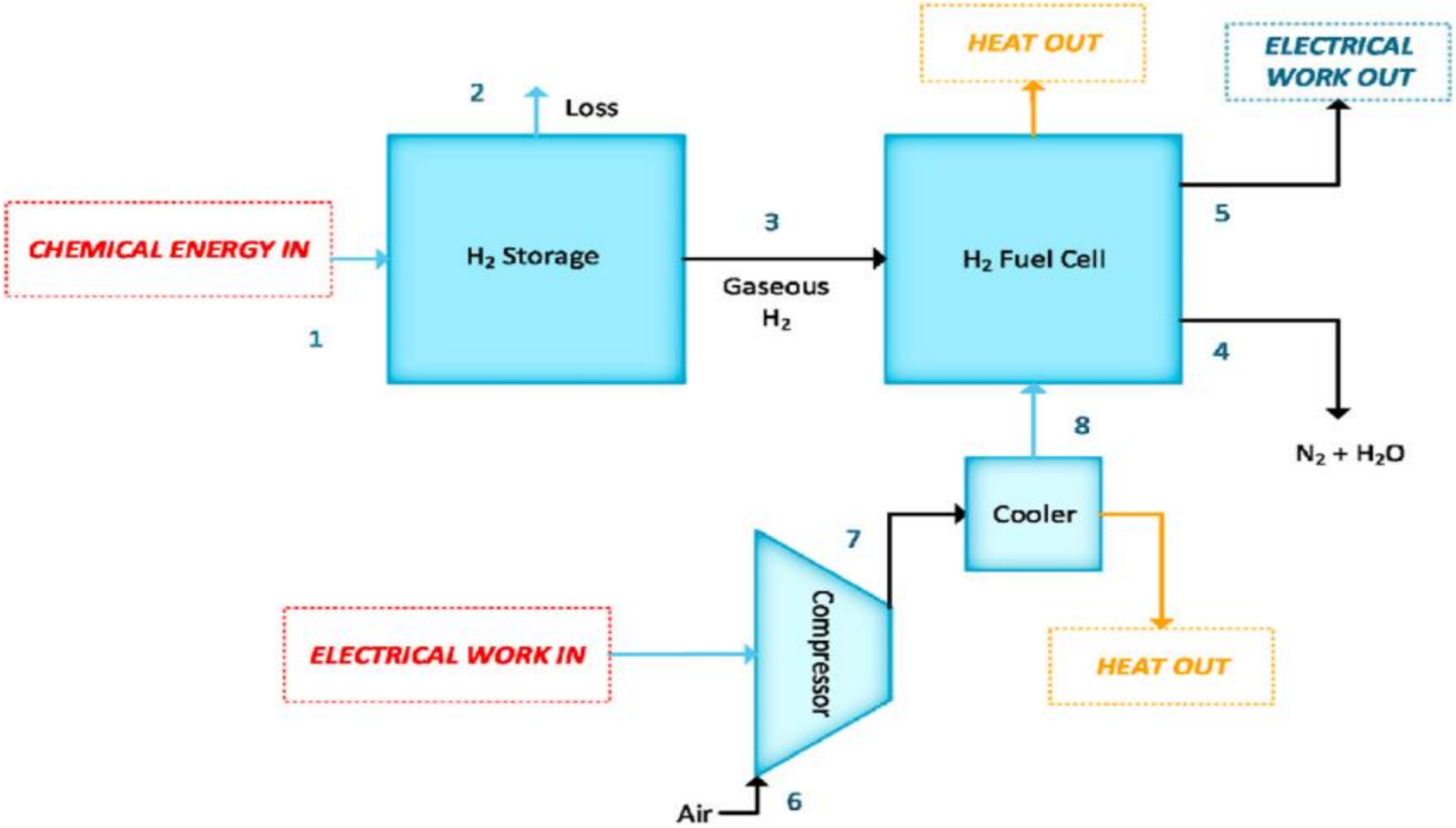
Iron-air principle of operation: "reversible rust"



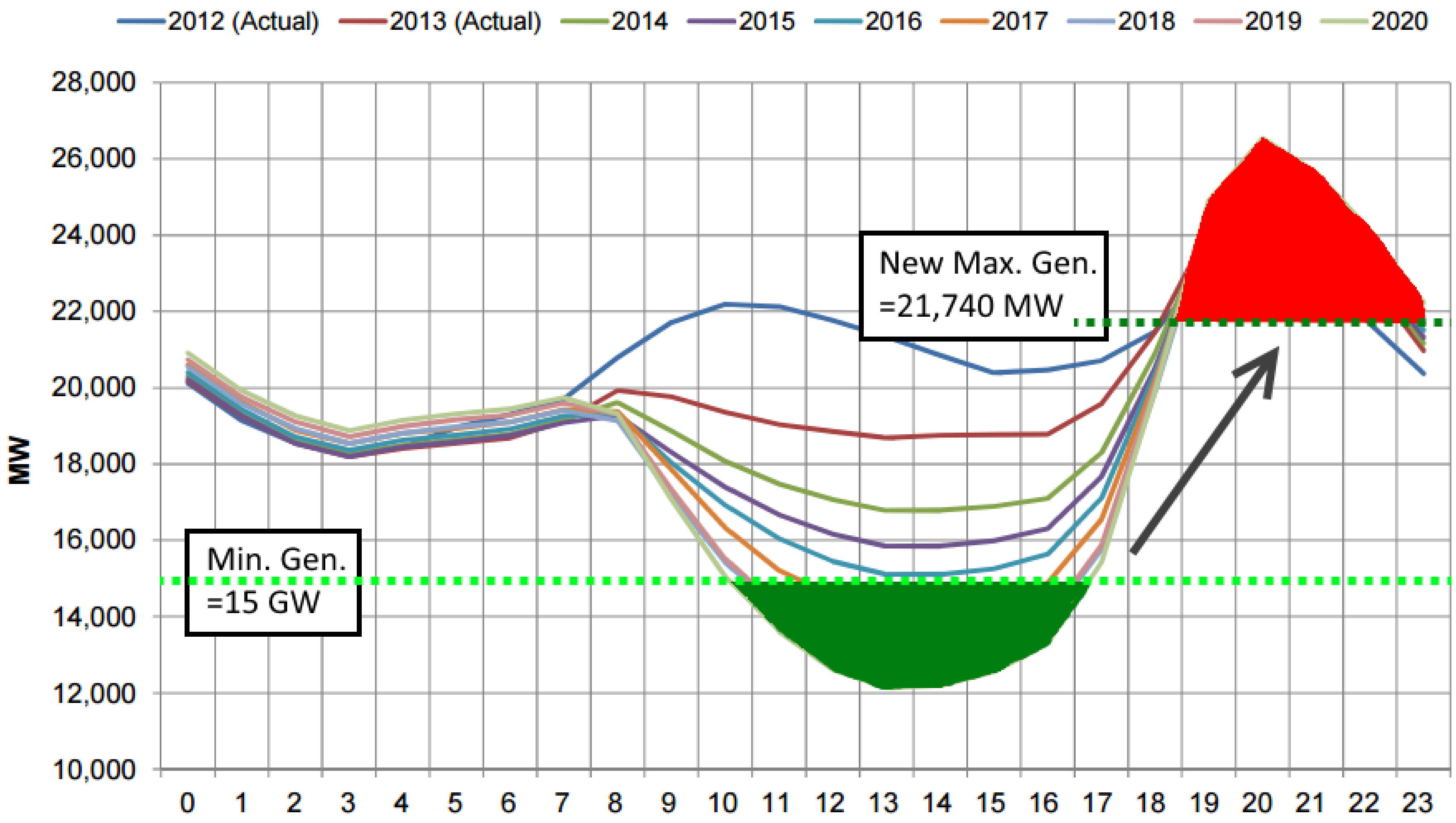
Flow battery…..



Hydrogen Storage.....



DUCK RUNS-AWAY…..



RENEWABLES + STORAGE → THANKS DIRTY FUELS. YOU ARE NO MORE NEEDED.

MOTHER EARTH OUT OF VENTILATOR & SMILING.