

Towards Electrified Green Infrastructure

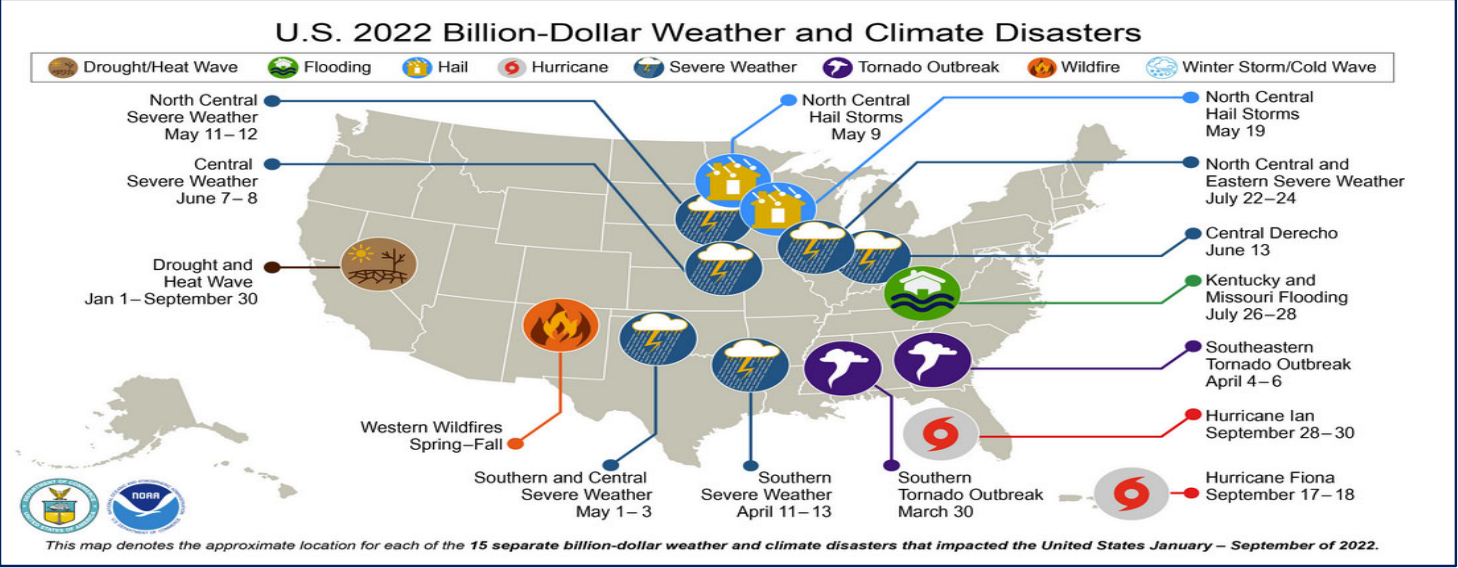
Richard Zhang

2nd Three Corners Power Electronics Extended Collaboration Workshop,
Washington, DC,
April 1-2, 2023

A Gloomy Picture

1952 Great Smog of London

- 4 days
- 4,000 deaths
- 100,000 illness



2021 Feb Texas Winter Storm
... 4 million people lost power



Flooding in Pakistan © AP



2022 Sept Florida Cat. 5 Hurricane Ian
... 2.6 million lost power

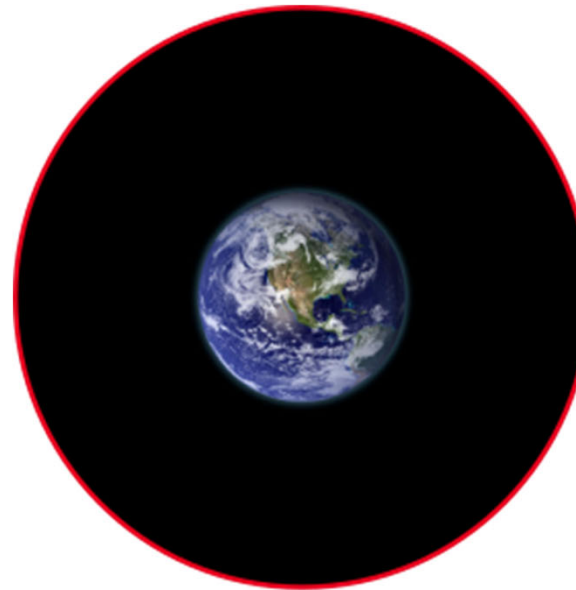
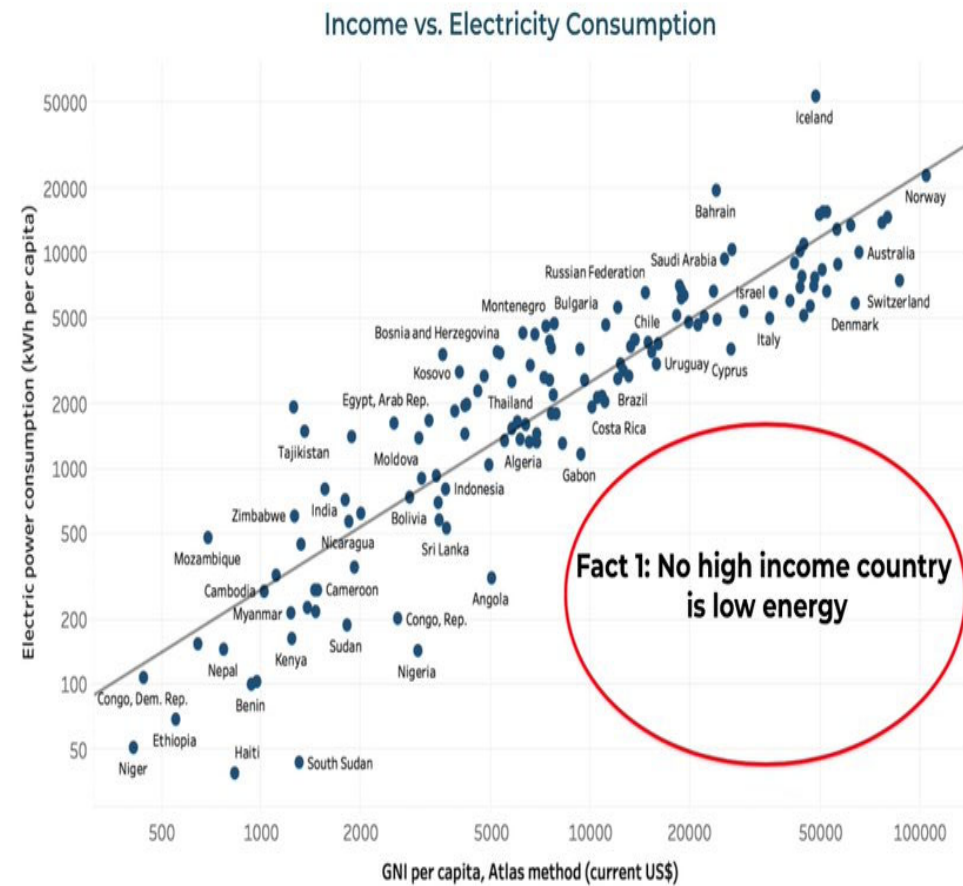
Climate change + Add to myFT

Global warming set to reach 1.5C in the near-term, UN reports

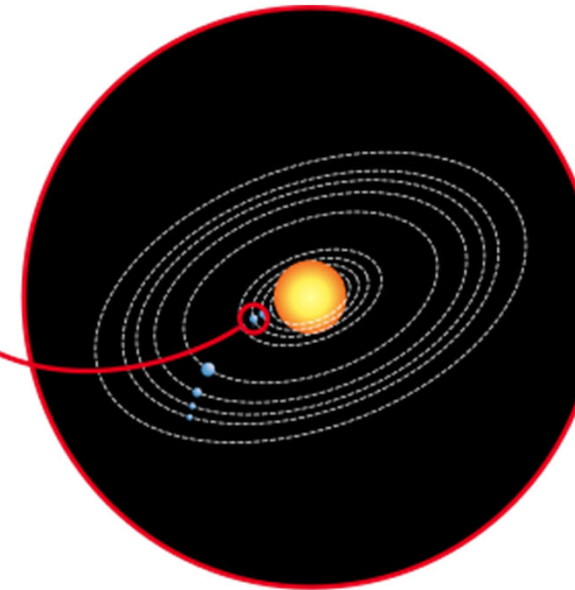
Risks of warming and irreversible changes to the planet greater than thought in previous assessment in 2014

The Energy Conundrum

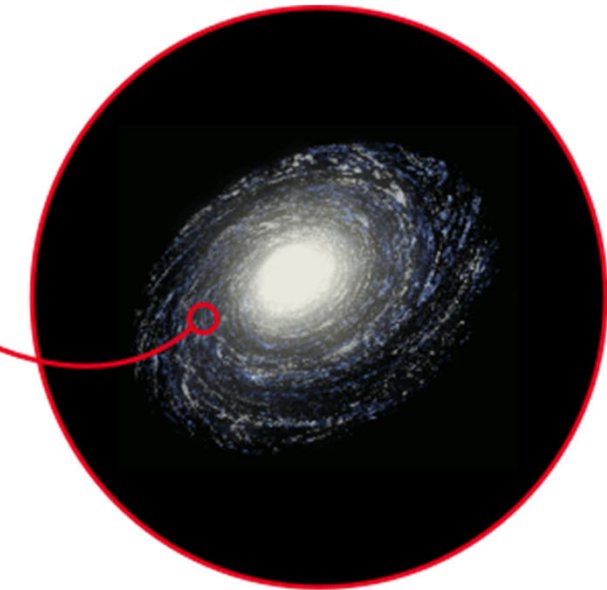
Civilization Levels (Kardashev Scale)



Type I: 10^7 GW



Type II: 10^{17} GW

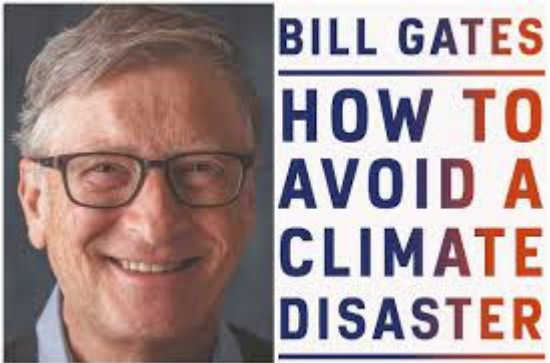


Type III: 10^{27} GW

Energy Abundance

+

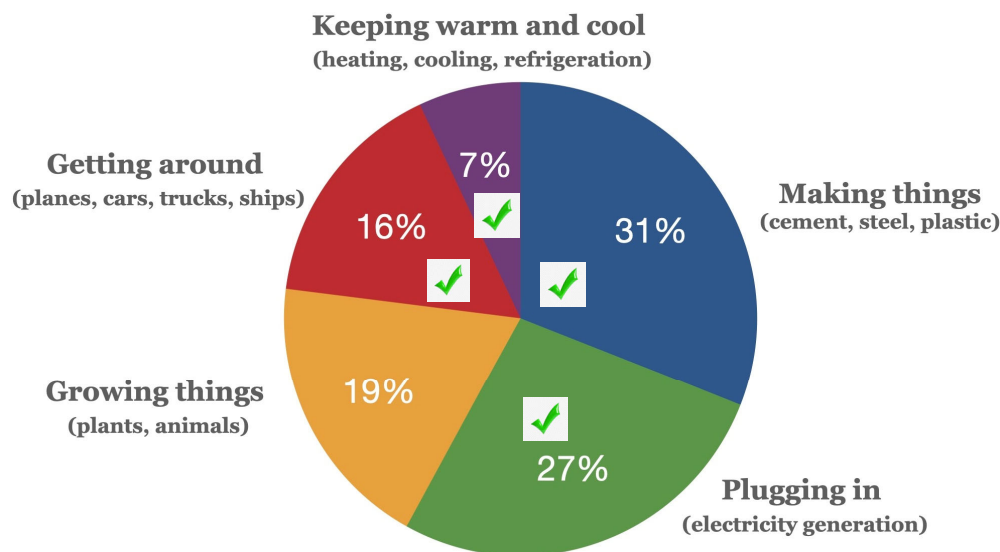
100% Clean & Sustainable Energy



Analysis and Offer by A Wiseman

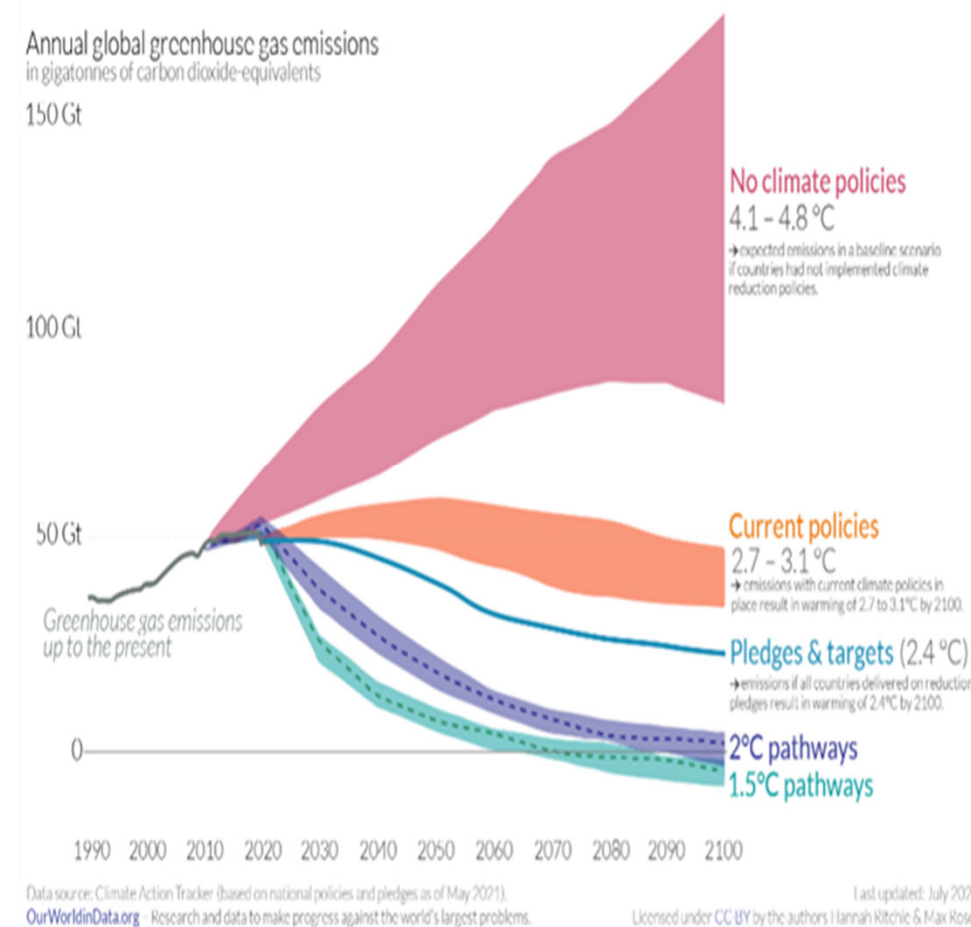
Reality

51 billion tons/yr of CO₂e



- Methane ... 28x worse GHG than CO₂
- NOx ... 265x worse GHG than CO₂

Consequence



Solutions

1. Generate zero-carbon electricity

- Wind
- Solar
- Nuclear

2. Electrify everything

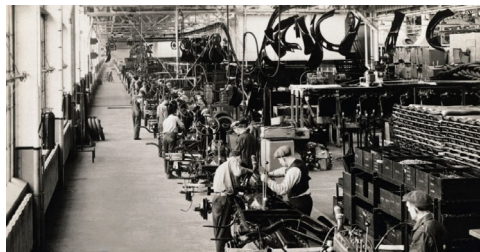
- Power consumption
- Material & food production
- HVAC

3. Grid-scale storage

4. *Green premium*

- Impact from internet, data/AI, crypto currency? Growing fast!
- Power electronics can make impact on 80% of GHG emission

Electricity in Our Life ... Only A Short While Ago



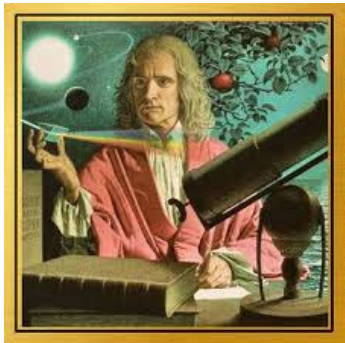
Industrial
Revolution
(58 secs)



Electric Grid
(37 secs)



Internet
(12 secs)



Scientific
Revolution
(2.5 mins)



Agricultural
Revolution
(58 mins)



Homo Sapiens
daily usage of fire

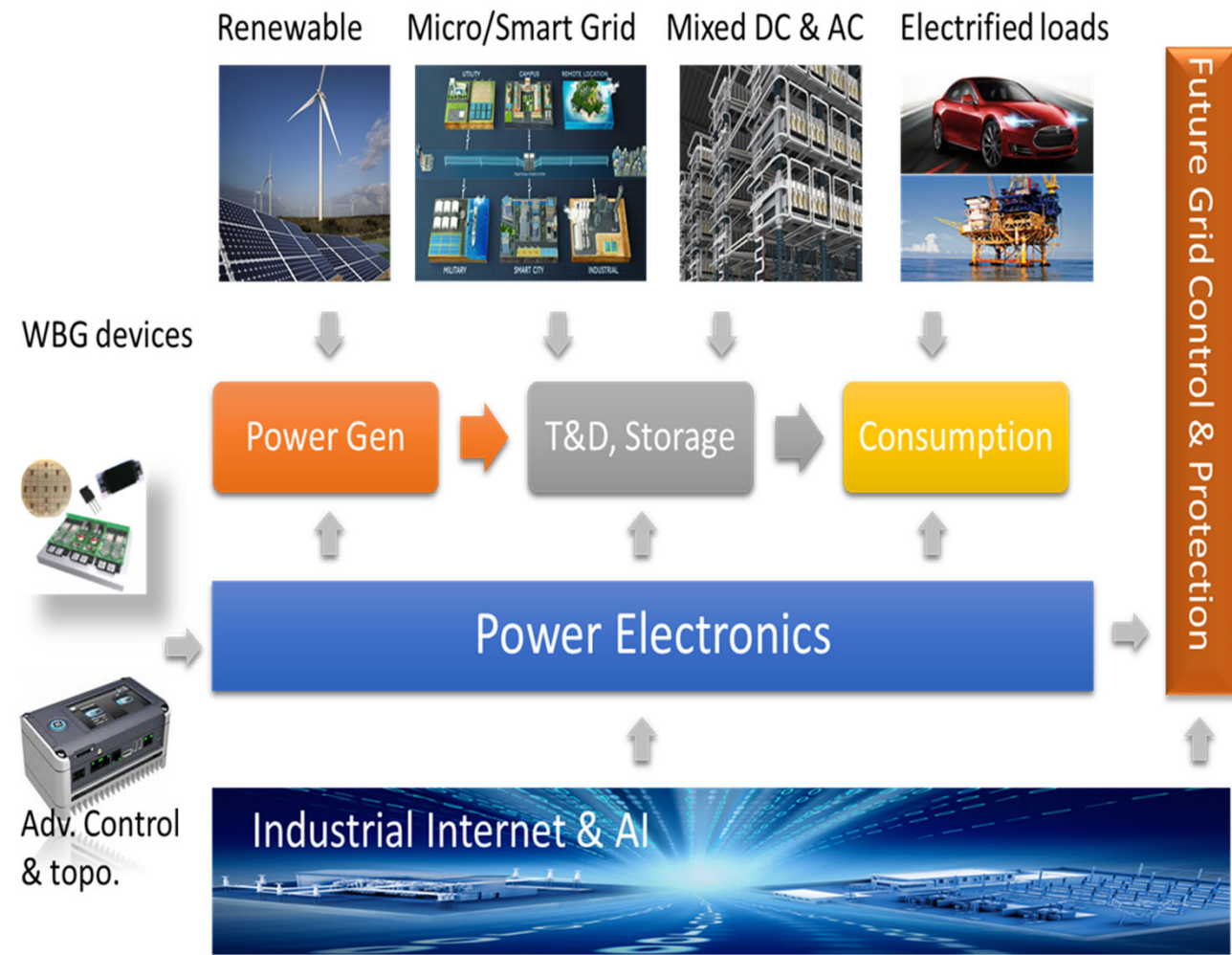


(300,000 yrs ago ... mapping to a 24-hr day)

My Evolving View of Role of Power Electronics

2005 - 2017

Enabling ... Invisible



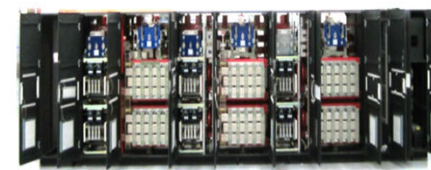
2018 eGrid Conference

Maybe we should be the future power system?

Power Electronics & Power Systems
Parallel Universe



Passives dictate behaviour & protection



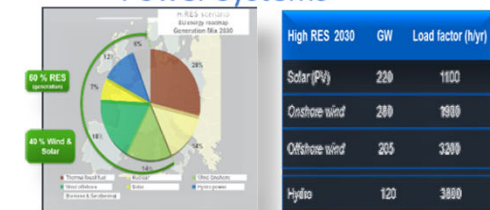
Minimize number of power switches

Power Electronics **in**
Power Systems



LCOE driven ... Efficiency, cost, reliability ... unit & farm level stability

Power Electronics **is**
Power Systems



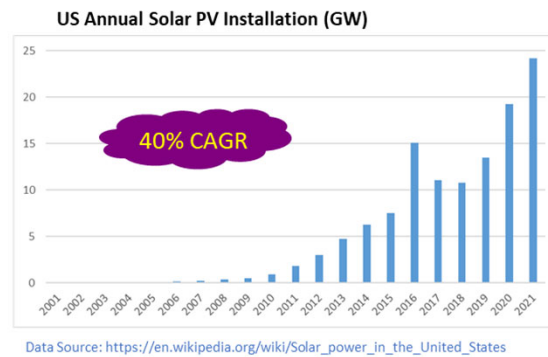
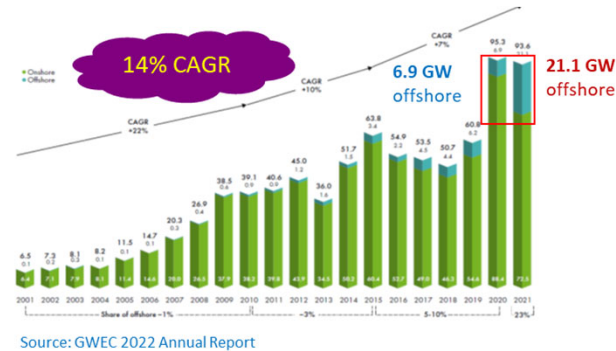
Control dictates behaviour & protection



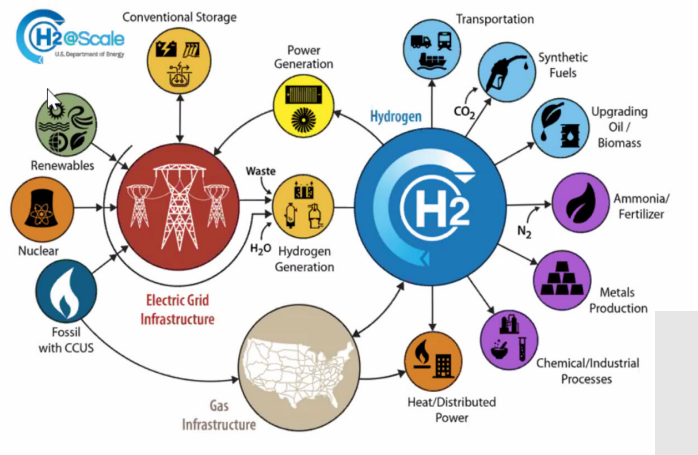
Enhance number of power switches
... power quality, system availability, control degree of freedom

Dynamics That Spawn Strong Pull for New PE Technologies

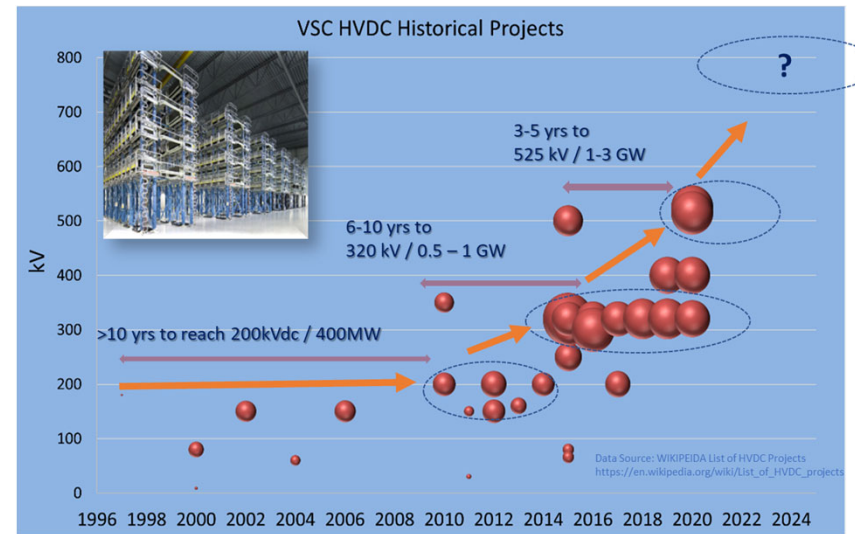
Renewables



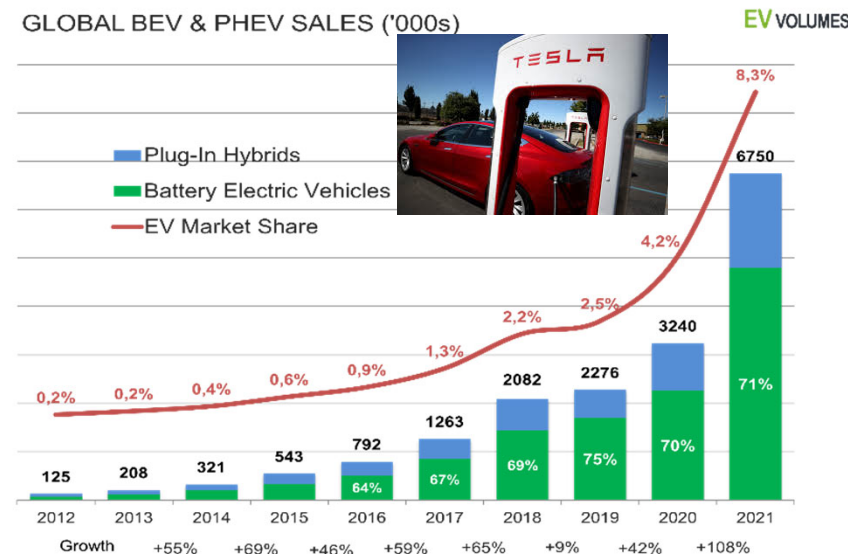
Clean H2 Production



HVDC



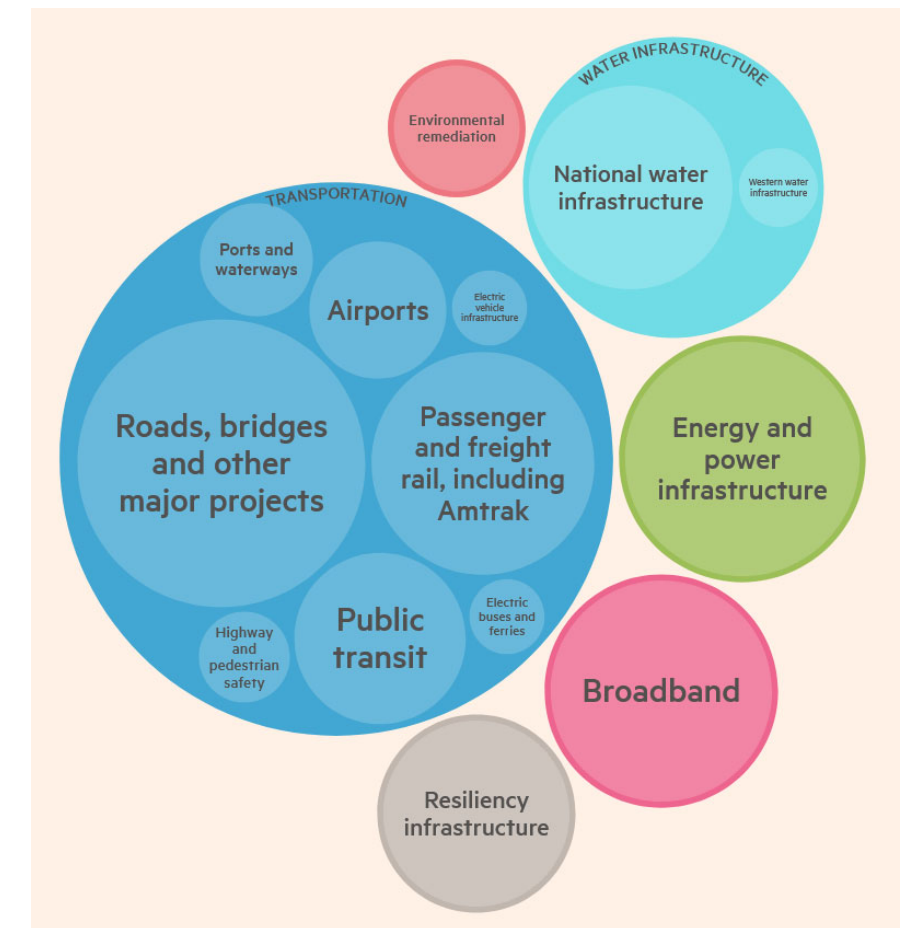
EV Charging Station



COP 26



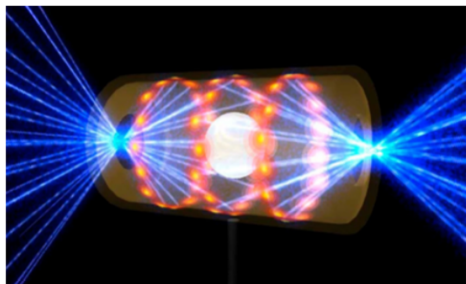
Bipartisan Infrastructure Bill & IRA



Power Electronics to Make Impact for Carbon-Neutral Economy

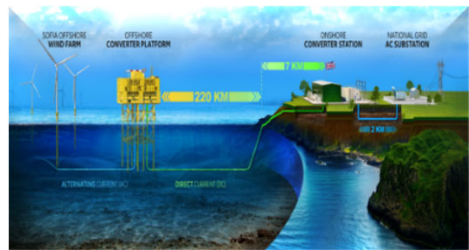
Power Gen

Enable



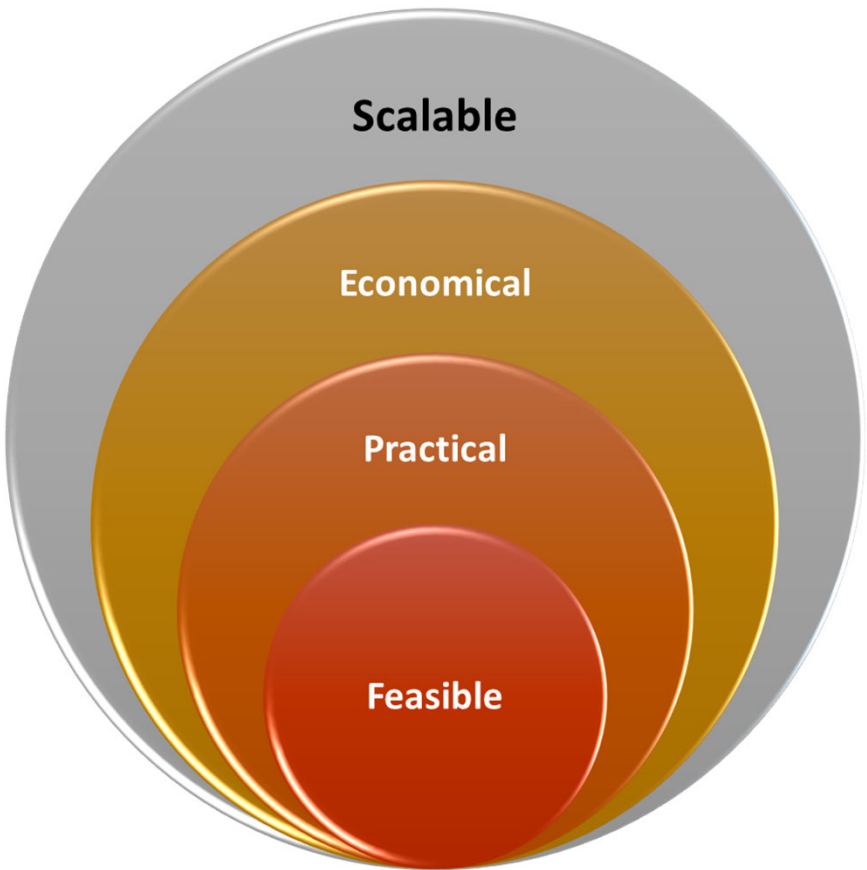
T&D, Storage

Lead & Transform



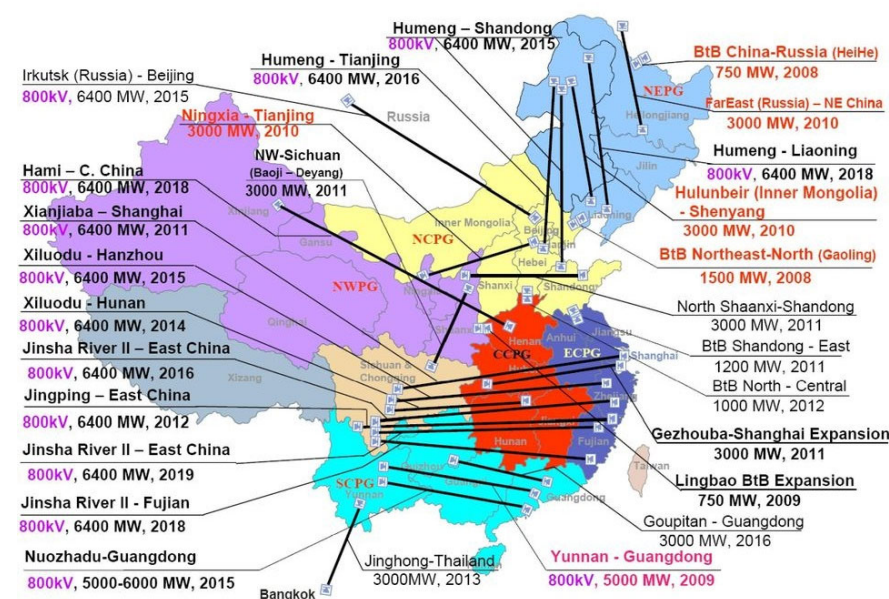
Consumption

Lead & Transform



HVDC Super-Grid Emerging?

China HVDC Links



UK Cross-Boarder HVDC Interconnect



German HVDC Corridors for Offshore Wind Tie-back

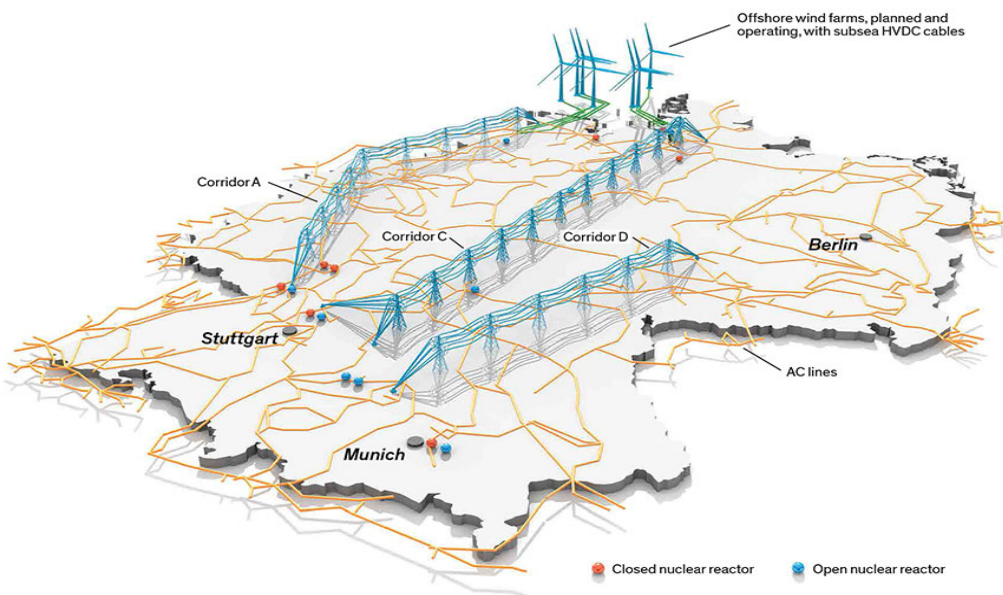
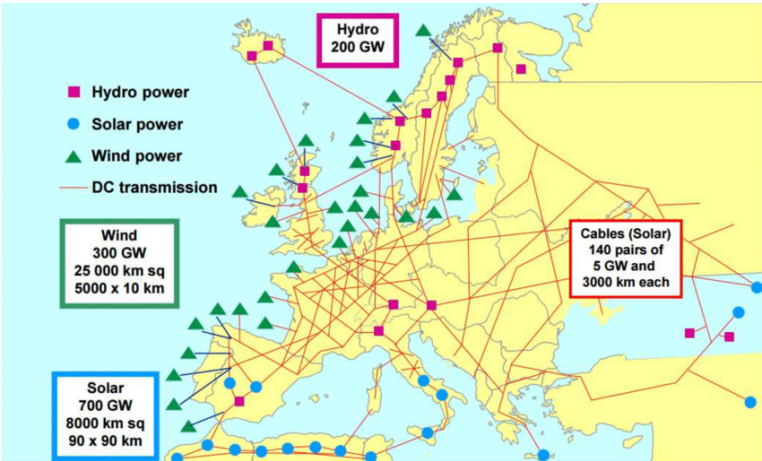


ABB proposed HVDC Grid



Renewable HVDC “Supergrid” by Global Energy Network Institute



Drivers

- Renewable energy interconnect
- Cross-boarder interconnect

Opportunities in the US – Generation and T&D Driven

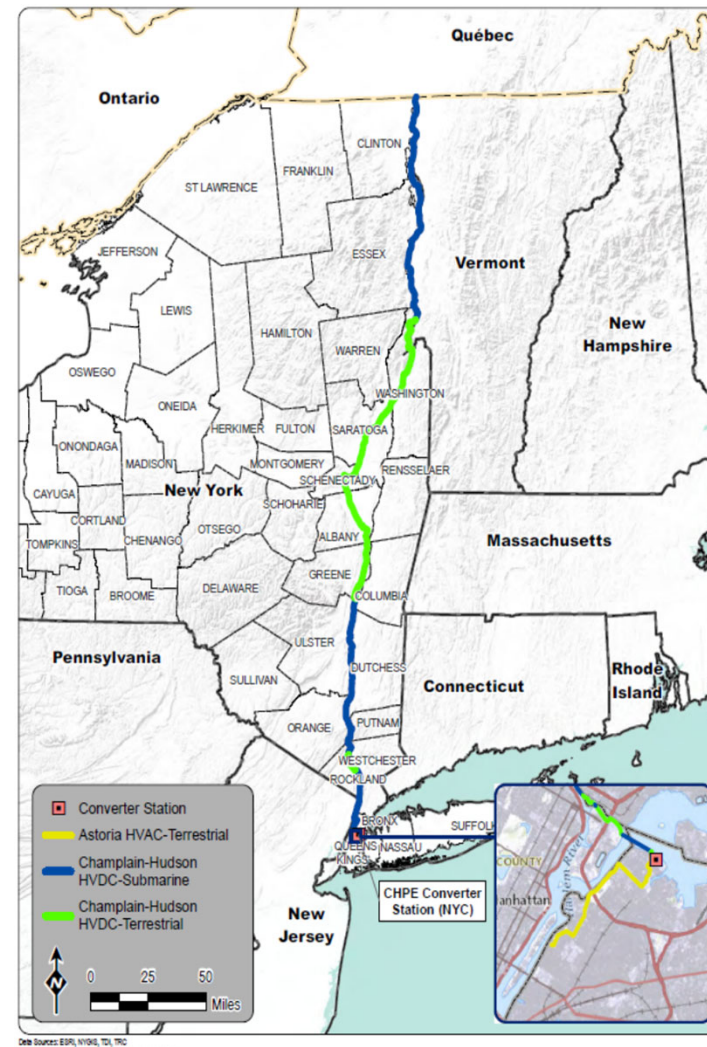
**Trans Bay Cable – world first
MMC VSC-HVDC, 2011
(200 kV/400 MW)**



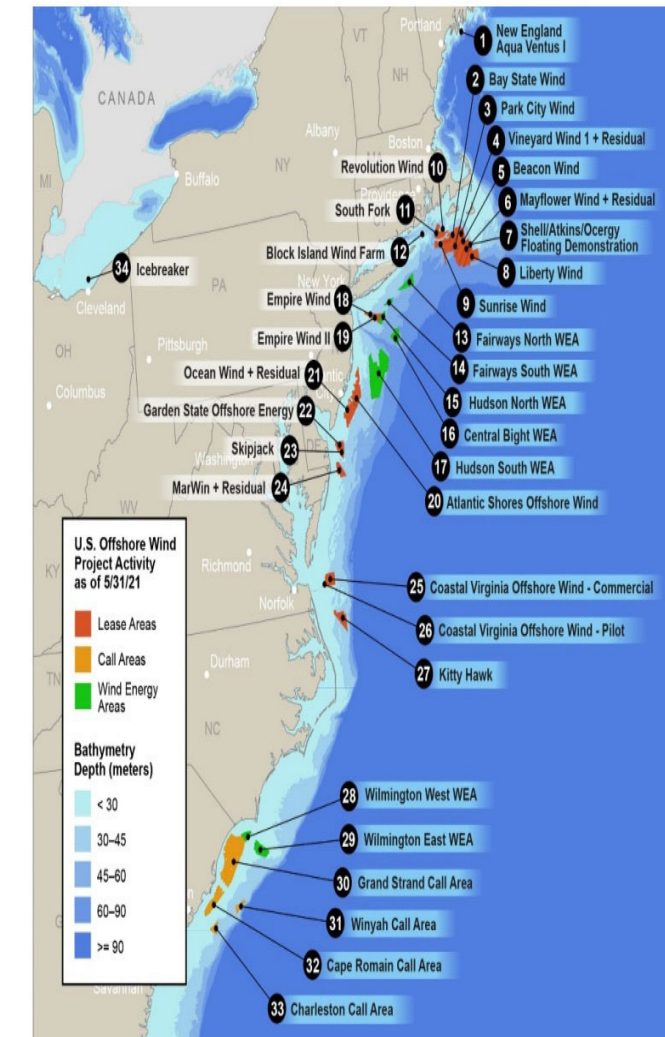
**Sunrise Wind – US first
offshore wind tie-back, 2021
(924 MW, 30 mi from shore)**



**Champlain Hudson Power
Express, 2022
(1.25 GW, 339 mi)**



**US Mid-Atlantic
Offshore Wind
(30 GW)**



A race to zero is on...

The European energy transition is one of the greatest challenges of our time. Its goal: **to make Europe the first climate-neutral continent by 2050**. The Netherlands and Germany have therefore set ambitious targets for offshore expansion: Already by 2030, Germany and the Netherlands want to achieve capacities of 30 and 22.2 gigawatts, respectively.

TenneT's 2GW Program

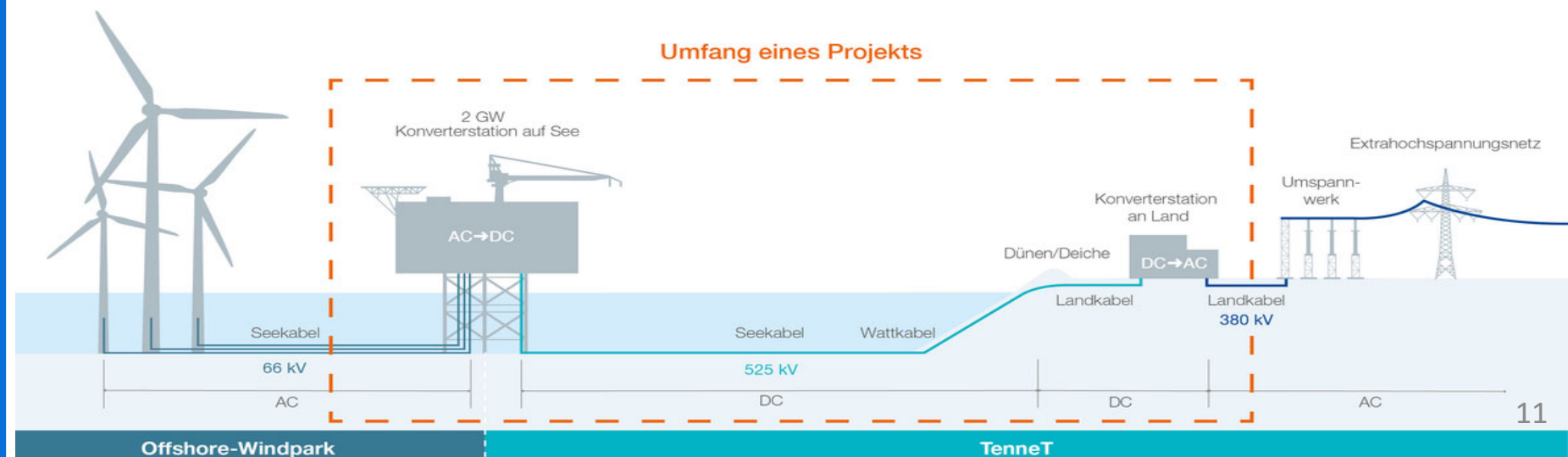
- A new industry standard 525 kV/2GW
- 40 GW planned



PRESS RELEASE

Two GE-led consortiums in agreement with TenneT for award of contracts totaling approx. 10 Bln Euros to build state-of-the-art HVDC systems for TenneT's 2GW program

March 29, 2023

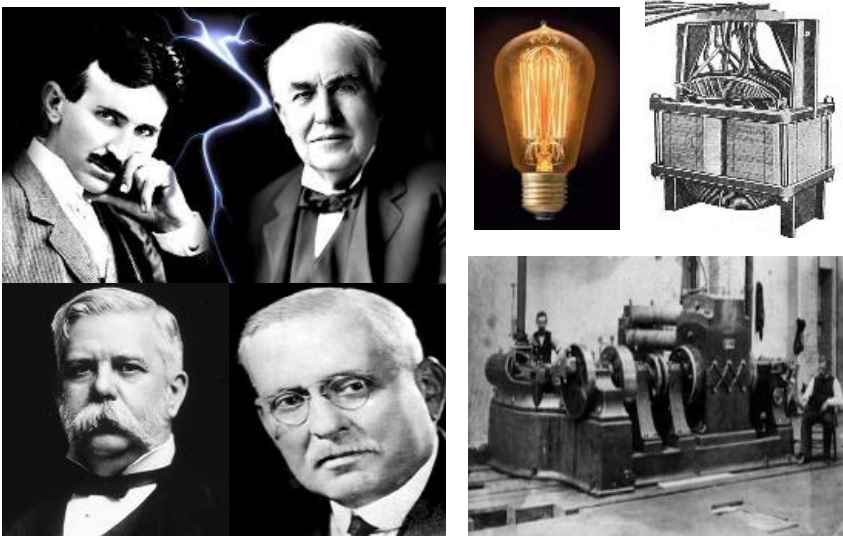


Journey Toward Grid 3.0 with Embedded Intelligence Thru Power Electronics

Scale/Complexity

New chapter of how we generate, transmit, distribute and consume energy

- cost,
- environmental friendliness,
- availability, stability, robustness, security,
- versatility, functionality ...



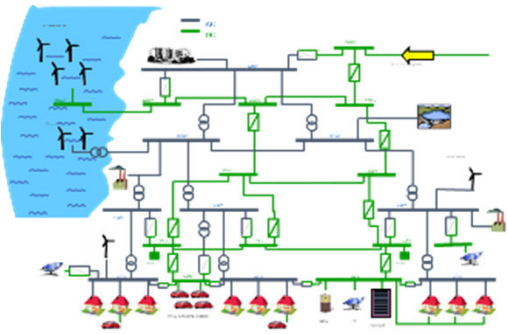
Birth of Grid – Grid 1.0




Go Higher:
Up to 100 MW class MV, 10 GW class HV power electronics systems; Smart Grid, SCADA, IED

- high-speed, high efficiency
- high-fidelity/power quality
- high reliability, resilience, operability

Electrification & Augmented Intelligence – Grid 2.0



Beginning of Future: Grid 3.0



Source: Tesla Source: QuantumScape

Renewables & HVDC:
Transform Power Generation & Transmission

EV & Energy Storage:
Transform Distribution

Embedded Intelligence thru Power Electronics - Grid 3.0

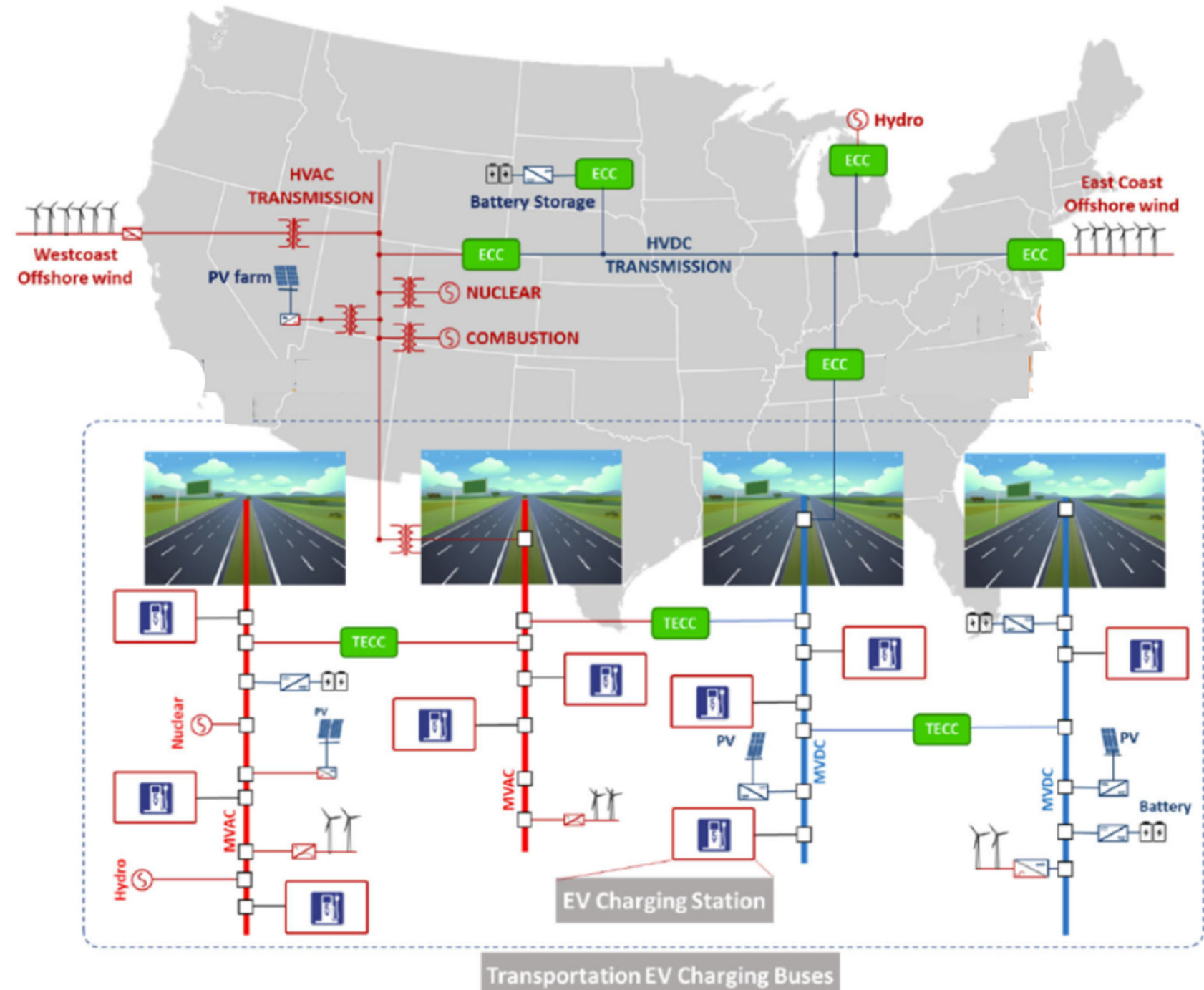
Year

Opportunities in the US – Consumption Driven

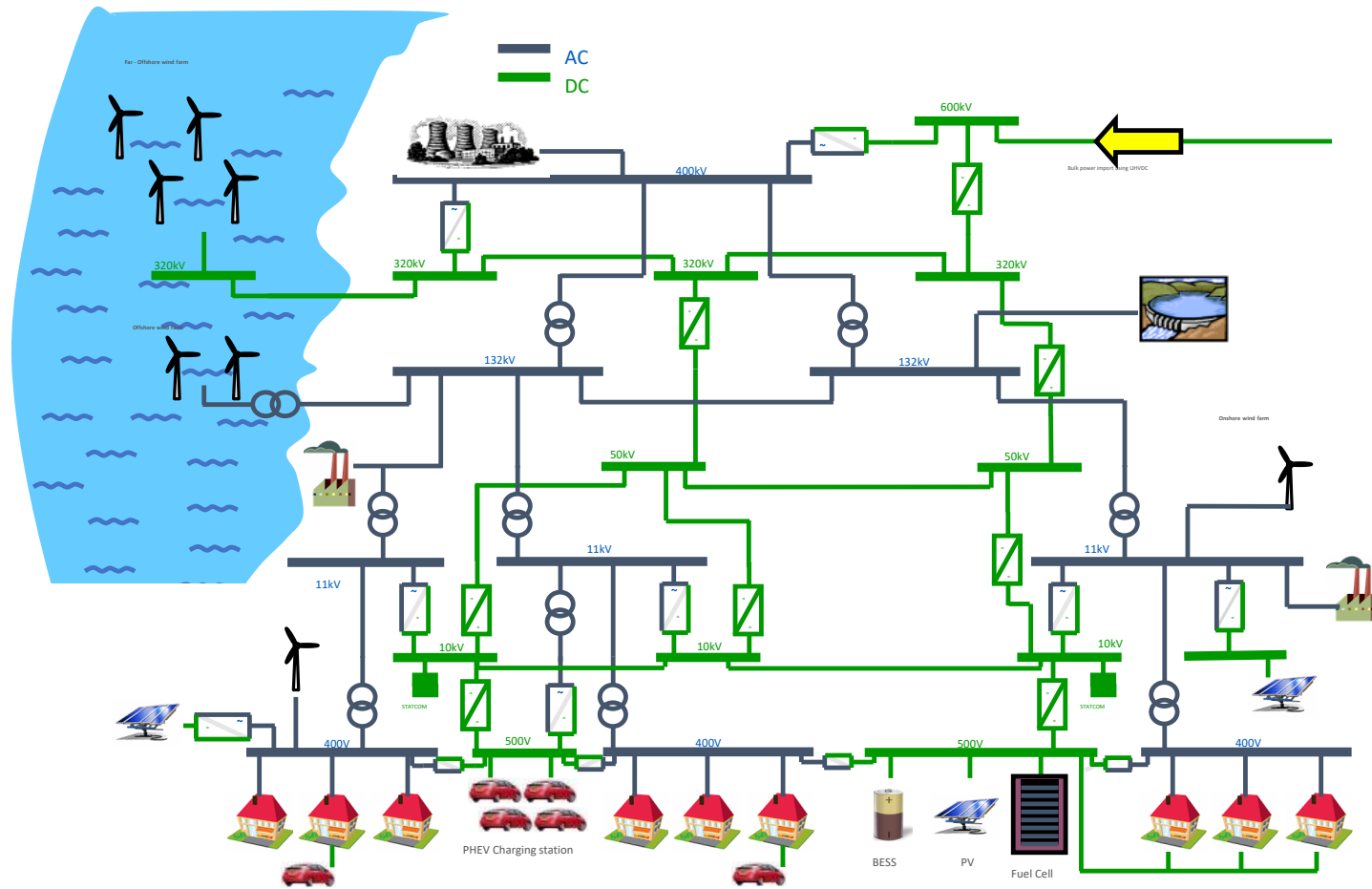
Charles Steinmetz
and his EV in 1917



Tesla Roadster 2008



Electrified Green Infrastructure Power Conversion



Edison & Tesla in the Room

- **Grid 3.0**
 - HVDC/MVDC
 - Renewable integration to the grid
 - Utility-scale energy storage integration
 - DC Circuit Breaker
 - Intelligent Energy Router & microgrids
 - ML/AI applications in high power electronics
 - Cyber security of infrastructure power conversion
- **EV fast-charging power infrastructure**
- **Data Center power solutions**
- **Clean H2 production thru high power electrolysis**
- **WBG device applications in high power electronics**

- Mixed AC & DC
- Power electronics based control
- Fluctuating renewable energy
- ...

Agent Smith: I'd like to share a revelation during my time here. It came to me when I tried to classify your species. **I realized that you're not actually mammals.** Every mammal on this planet instinctively develops a natural equilibrium with the surrounding environment but you humans do not. **You move to an area and you multiply and multiply until every natural resource is consumed. The only way you can survive is to spread to another area.** There is another organism on this planet that follows the same pattern. **Do you know what it is? A virus.** Human beings are a disease, a cancer of this planet. You are a plague, and we are the cure.



If Agent Smith is right...

Earth, 2050

Created with DALL-E

Questions?

Answers Given by ChatGPT

What should power electronics do to achieve a carbon-neutral economy by 2050?

Power electronics play a crucial role in achieving a carbon-neutral economy by 2050. Here are some ways power electronics can contribute:

1.Enable renewable energy: Power electronics can facilitate the integration of renewable energy sources such as wind, solar, and hydro into the grid. Power electronics can convert the variable DC output of renewable energy sources into AC power that can be fed into the grid.

2.Improve energy efficiency: Power electronics can improve energy efficiency in various applications such as lighting, air conditioning, and electric motors. By using power electronics to control the amount of energy that is delivered to these systems, energy waste can be minimized.

3.Enable energy storage: Power electronics can facilitate the integration of energy storage systems such as batteries and supercapacitors. Power electronics can control the charging and discharging of energy storage systems, allowing them to store energy when renewable sources are generating excess energy and supply it to the grid when renewable sources are not generating enough energy.

4.Facilitate electrification of transport: Power electronics can enable the electrification of transport by controlling the power flow between the battery and the motor in electric vehicles. This can help reduce carbon emissions from transportation.

5.Improve grid stability: Power electronics can improve the stability of the grid by controlling the power flow between different parts of the grid. This can help reduce the risk of blackouts and other grid disturbances.

To achieve a carbon-neutral economy by 2050, power electronics must be used to enable the widespread adoption of renewable energy sources, improve energy efficiency in various applications, facilitate energy storage, enable the electrification of transport, and improve the stability of the grid.

Answers Given by ChatGPT

What would be options of global electric system architecture to move to carbon-free world by 2050?

There are various options for global electric system architecture to move towards a carbon-free world by 2050. Here are some potential options:

1.Renewable Energy Grid: A global renewable energy grid could be established, where large-scale renewable energy sources such as wind, solar, and hydroelectric power would be connected to the grid, and power would be distributed around the world. This would require significant investment in infrastructure and interconnectivity.

2.Decentralized Grid: A decentralized grid could be established, where energy is generated locally and distributed within a community. This could include a mix of renewable energy sources and energy storage, such as batteries or hydrogen fuel cells.

3.Nuclear Energy: Nuclear energy could be utilized as a zero-carbon energy source. Advanced nuclear technologies such as small modular reactors (SMRs) or fusion reactors could be developed and deployed to help meet global energy demand.

4.Smart Grid: A smart grid could be implemented, where power distribution and consumption are monitored and optimized using advanced digital technologies. This could help reduce energy waste and enable better integration of renewable energy sources.

5.Electrification of Transportation: The electrification of transportation could be accelerated, with a shift towards electric vehicles powered by renewable energy sources. This would require investment in charging infrastructure and grid upgrades to support increased demand.

6.Energy Storage: Advanced energy storage solutions such as large-scale batteries, hydrogen storage, or compressed air energy storage could be deployed to help balance the variable output of renewable energy sources and provide backup power during periods of high demand.

These are just a few examples of the potential options for global electric system architecture to move towards a carbon-free world by 2050. Ultimately, a combination of these options will likely be required, along with significant investment and policy support, to achieve a carbon-free energy system.