

# What's been happening and where are we going?

*The changing landscape of a swiftly tilting planet*

February 2022

*ESIG Spring Technical Workshop*

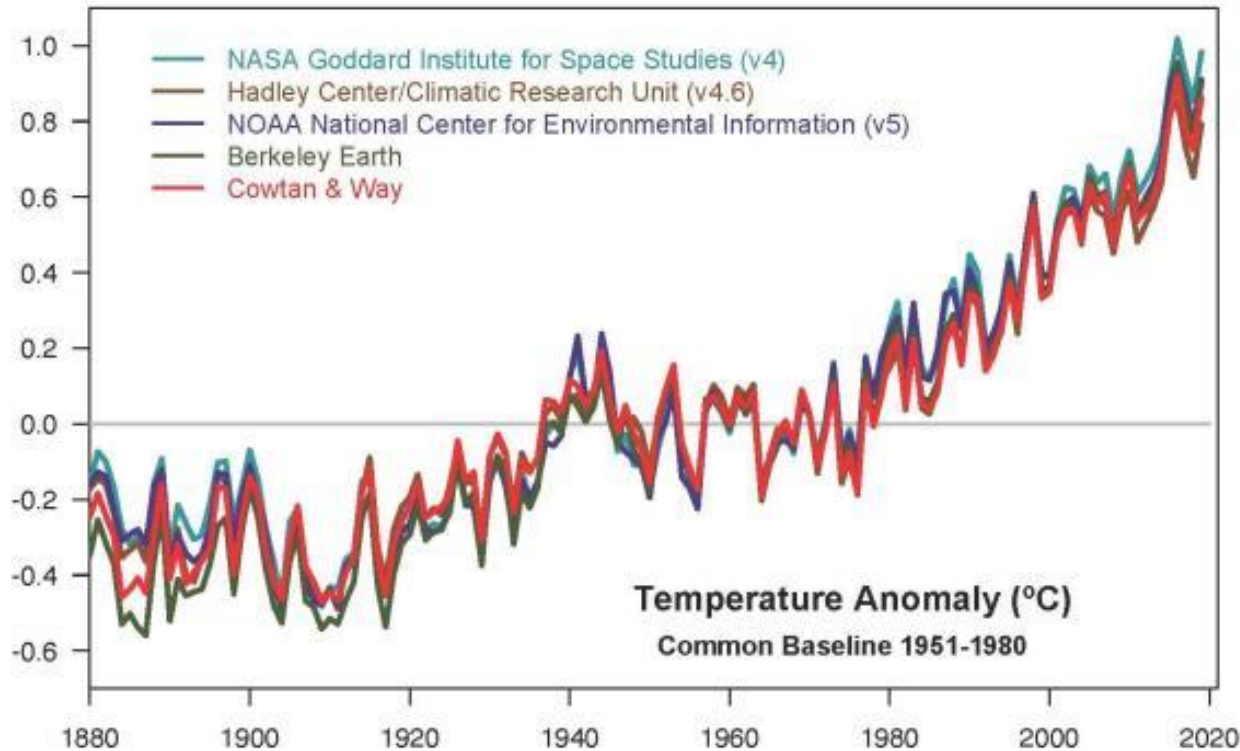
**Danielle Merfeld**

*GE Renewable Energy*

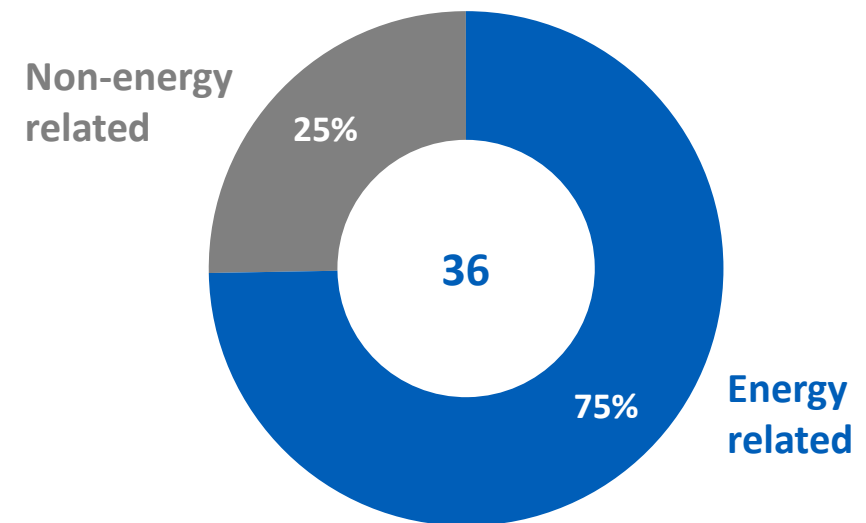




# In a world of rapid change, one unfortunate constant ... extensive use of fossil fuels driving climate change



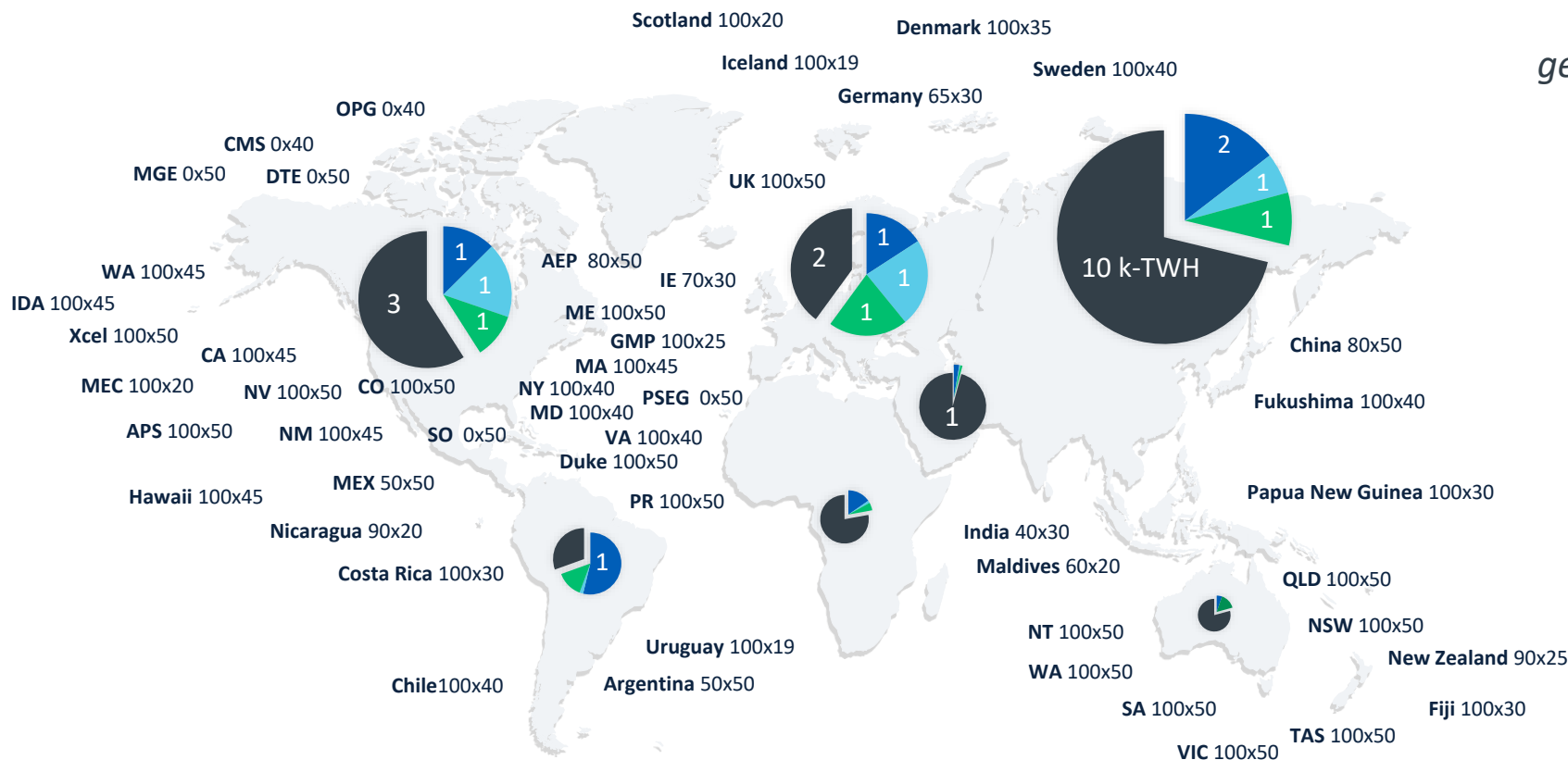
## Total CO<sub>2</sub>eq emissions Gt/year (2021)



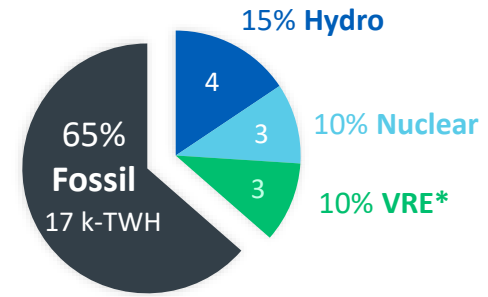
**“Global warming of 1.5°C and 2°C will be exceeded during the 21<sup>st</sup> century unless deep reductions in carbon dioxide (CO<sub>2</sub>) and other greenhouse gas emissions occur in the coming decades.”**

# 100% CO<sub>2</sub>-free power

## Goals emerging globally



Global generation



**CO<sub>2</sub>/REN goals**  
(% goal) x (year)

Decarbonizing fossil-based generation will require record levels of VRE

Ref: BP statistical review of world energy 2019

\*VRE; Variable Renewables ... e.g. Wind + PV

# Unprecedented events impact global perspective

... *creating opportunity for significant change*



## Global Pandemic – Covid 19

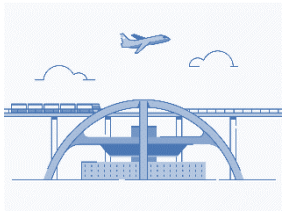
Global shock exposed **fragility of supply chains**, highlighted **social inequities**, and led to a **global economic crisis**, but also demonstrated ...

- New proof points for digital solutions
- Ability to change ingrained social habits
- More efficient information exchange via virtual engagement
- Rapid deployment of new technology

Recovery planning drives gov't support for

- Local content and jobs
- Infrastructure investment

**Energy Transition as vehicle for growth**



## Climate crisis consensus

Youth movement leads to **climate as top voting issue in EU**. Green parties winning, influencing legislation.

**Pressure at COP 26** resulted in announced policies tracking to 1.8 °C, down 0.5 °C

Growing occurrence of **extreme weather events** further challenges grid resiliency

**March '22 IPCC report** offers starkest warning yet ... clear and present danger to humanity, ecosystems at point of no return.



## Russian invasion of Ukraine

Intensified focus on **energy security**

Swift **shift away from Russian gas**, 40% of European gas (NordStream2 cancellation)

Expectations for persistent higher gas price, increased demand for US LNG

Appetite grows for **fast-track green transition** comparable to WWII mobilization



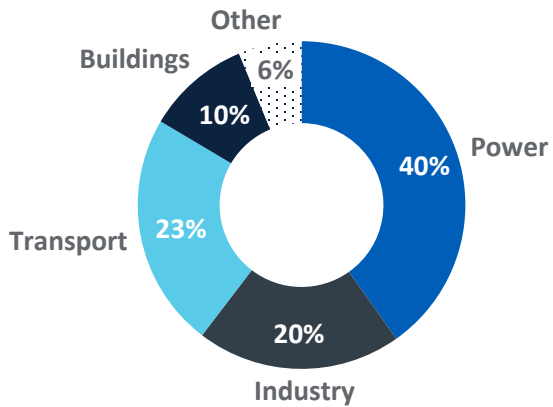
Confidence builds that we can – *and must* – change course through Energy Transition pathway

# Energy transition ... *Get to net zero, retaining reliability and affordability*

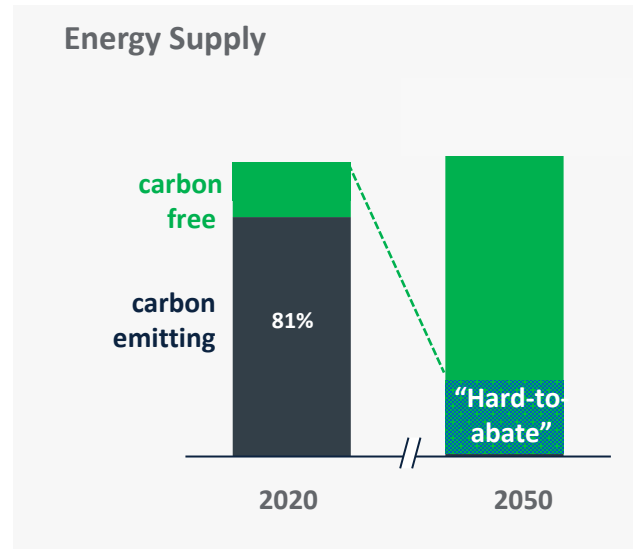


## Decarbonizing energy sector through clean electricity

Energy Emissions by sector, 2020



Energy Supply



Societal, geopolitical and historical choices drive different solutions at regional and country level

## ... drives 3 simultaneous grid transformations

### Physics transformation

synchronous machines → power electronics

### Operational transformation

constant fuel central generation → variable "fuel" DERs, 2-way flow

### Economic transformation

fuel cost value of energy → free "fuel" value of flexibility & capacity   
 5% ..... % variable renewables .....▶ 100%

## ... and a need for grid infrastructure

aging infrastructure classic grid design → new interconnects grid modernization

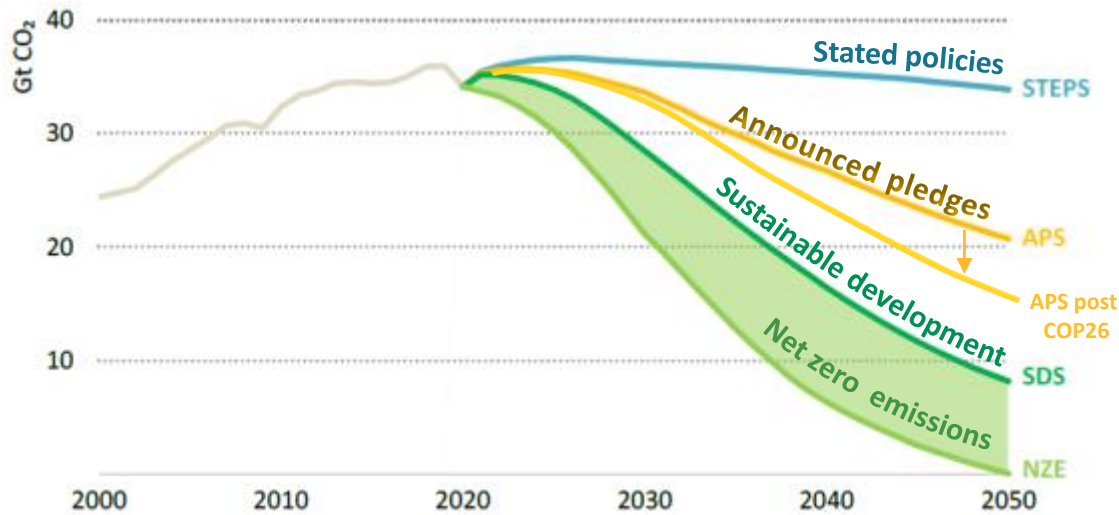
New technology, codes & standards, policies, and market instruments are the enablers

# Energy transition - Scenarios to 2050



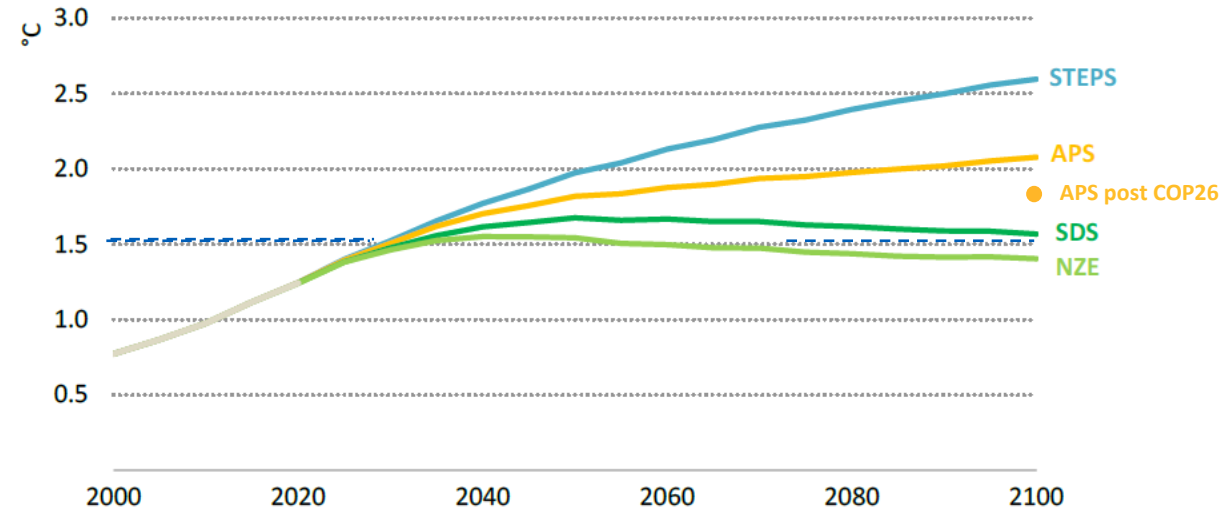
IEA highlighted multiple scenario trajectories ... updated after COP26

### CO<sub>2</sub> emissions in the WEO-2021 scenarios over time



- STEPS shows “implementation gap” between policies & pledges
- SDS goes further/faster to be aligned with the Paris Agreement
- NZE delivers net zero emissions by 2050

### Global median surface temperature rise over time



- Current policies and announced pledges lead to **temperature rise deemed unacceptable** (>2°C by 2100 and rising)
- **Temp increase peaks at 1.7°C in the SDS ... 1.5°C in the NZE around 2050** (both with a 50% probability)

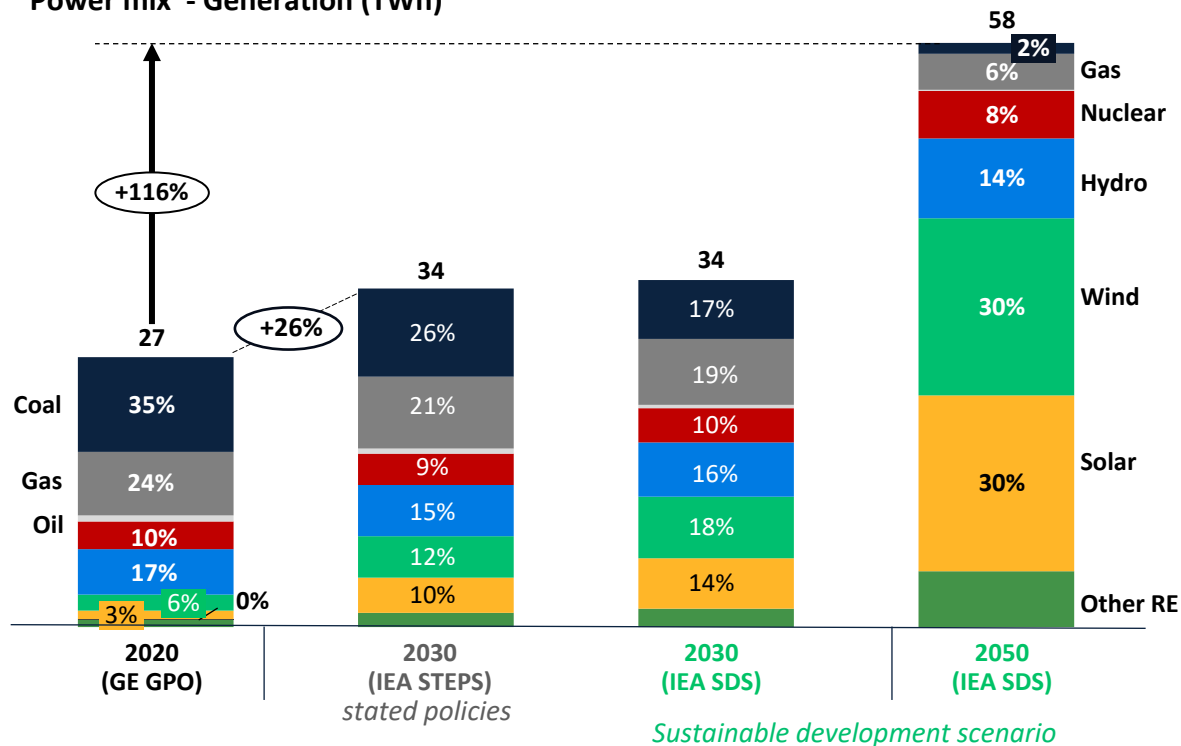
Technology & interoperability required to reach the green zone ... challenge grows with further delay

# Power mix evolution by 2030 ... 2050



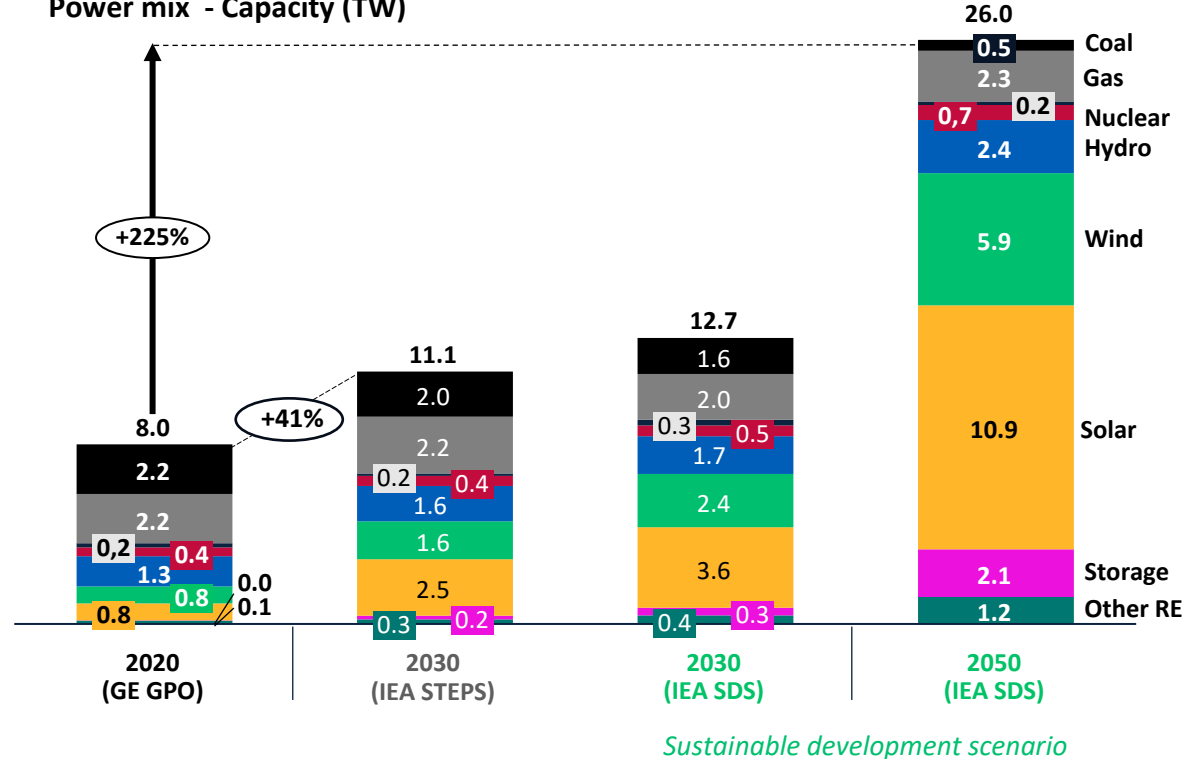
How could the energy transition translate into the power mix?

Power mix - Generation (TWh)



Global power generation to increase by >25% by 2030  
 ... and more than 2x by 2050 to meet 1.5°C Paris goals  
 Solar & Wind soar ... Coal phasing out

Power mix - Capacity (TW)

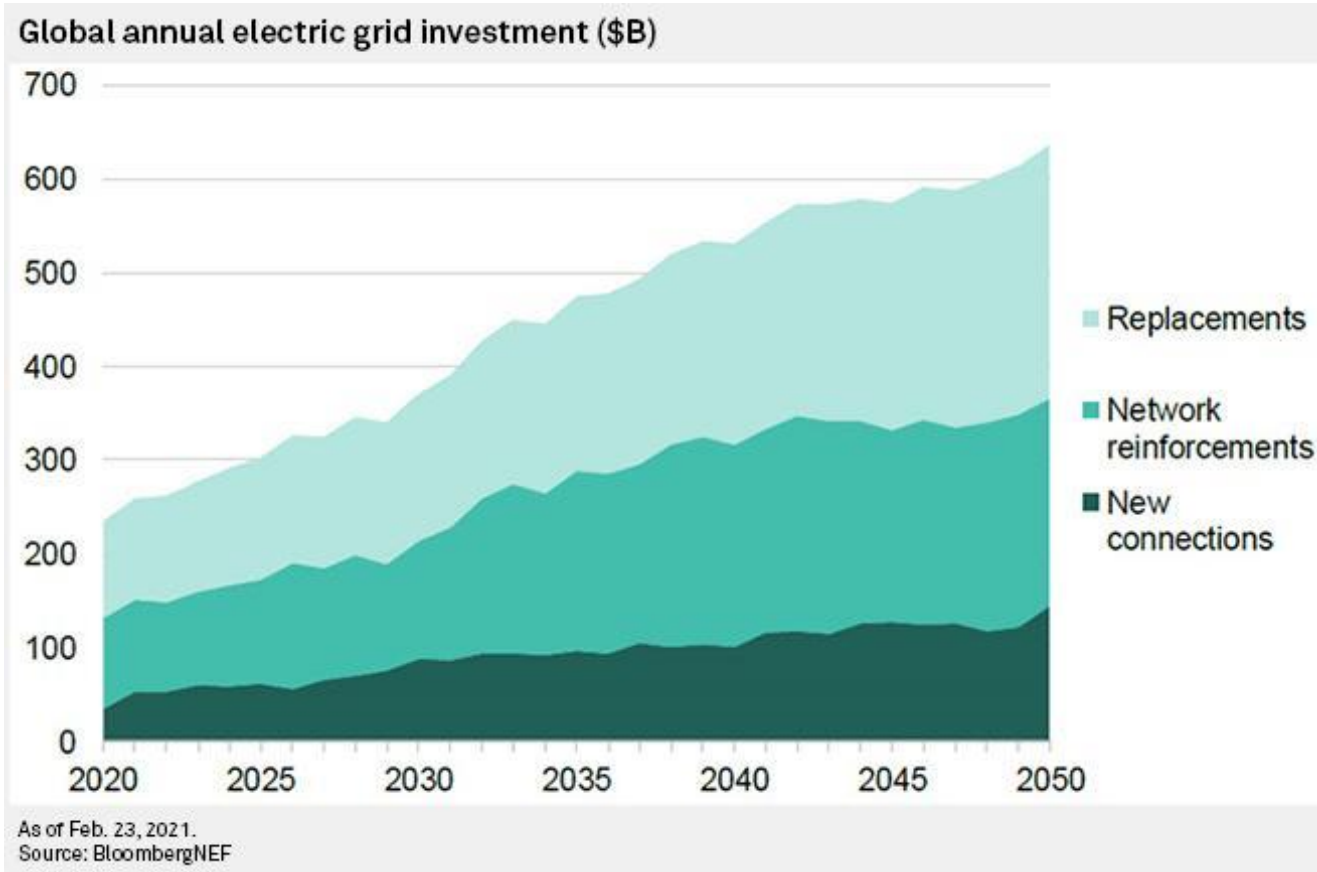


Global power capacity to increase by >40% by 2030  
 ... and more than 3x by 2050 to meet 1.5°C Paris goals  
 Solar & Wind soar ... Gas capacity stable

Scenarios assume solutions for current grid constraints



# Path to net zero boosting grid demand considerably



## Changing paradigm for transmission

- FERC revamping incentive policies for transmission buildout
- FERC Order 2222 allowing aggregated DER in ancillary services markets
- New DoE 'Coordinated Transmission Deployment Program'
- New trends in requirements for IBR tech deployment (GC0137 & IEEE 2800)

## Growing investment share for key trends

- Decentralization (52% → 63%)
- Digitization (19% → 42%) (2020 → 2050)

## Policy

- Key variable to support RE buildout
- Stakeholder models to overcome local opposition
- Facilitate siting and permitting procedures

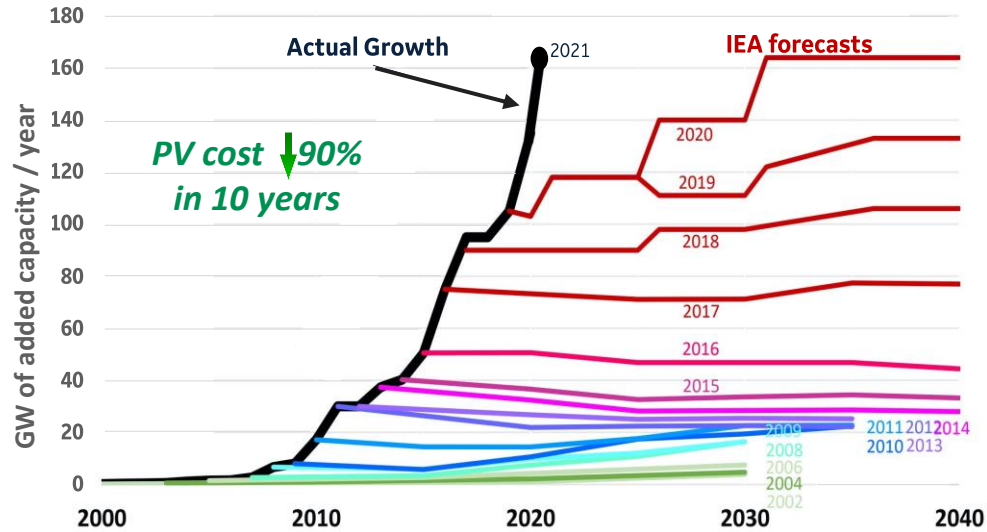
\$14 trillion in global grid investments to decentralize and digitize energy infrastructure



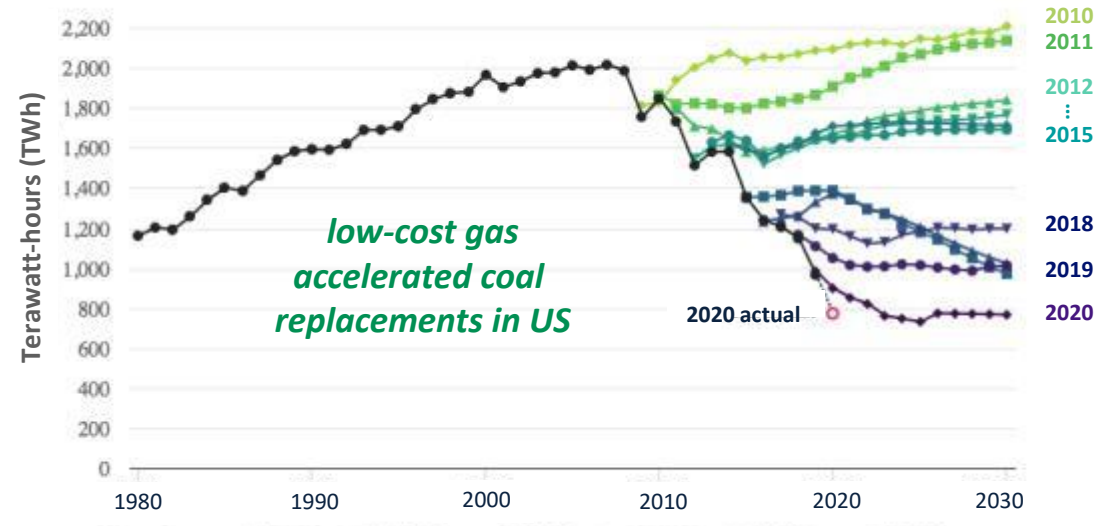
# Is this rate of change even possible? ... history says “yes”

*Exponential change in action warps forecasting capabilities*

### Actual growth of global solar power vs. expert forecasts



### Actual decline in US coal generation vs. expert forecasts



‘Sector Coupling’  
creates drivers for  
accelerating change

### Example: Energy & Transport sector interactions

- Growing electric vehicle fleet provide options for vehicle-to-grid services
- Electrifying U.S. vehicles wipes out the equivalent of the US’s entire current power demand
- 40% of all shipping cargo is fossil fuel
- 25% of tonnage hauled by US rail is coal, *most of which is for electricity generation*

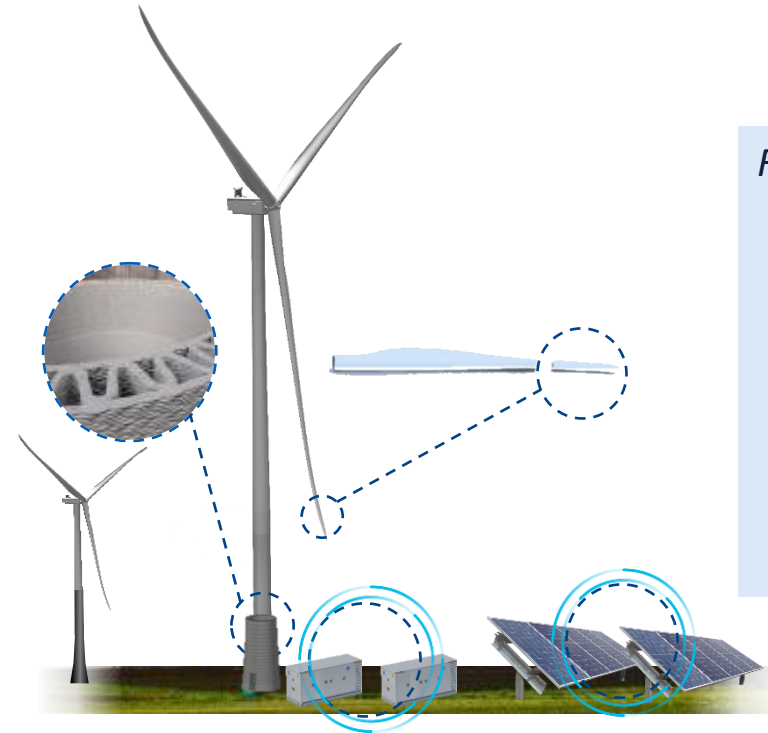
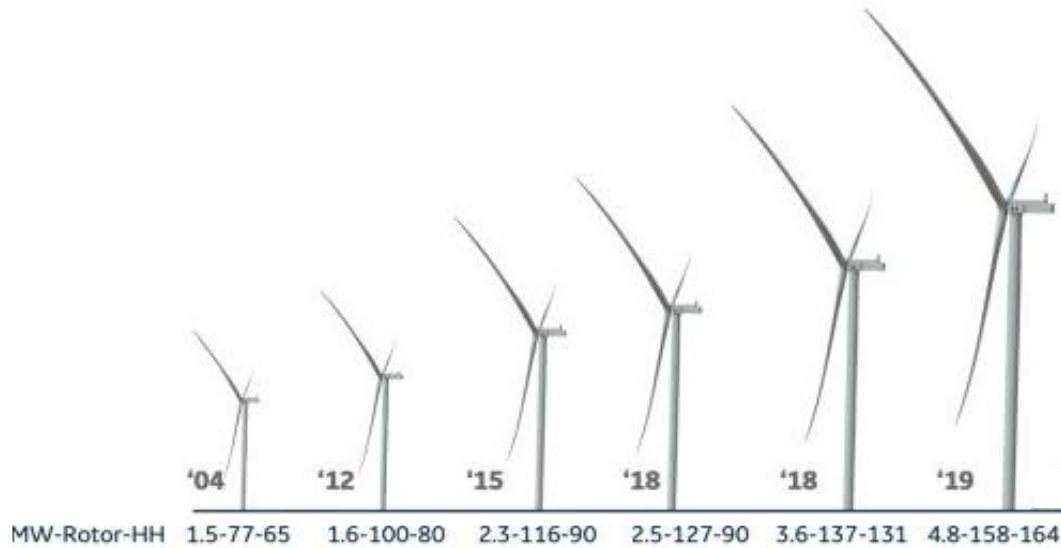
# What's needed to scale renewable energy at necessary pace?



... *advancements in technology, financing, markets, and regulation*

## Example: The challenge for Wind

- Expected to scale rapidly, reaching 390GW by 2030
- Recycling end-of-life turbine blades
- Demand for critical minerals  $\uparrow$  4 $\times$  by 2050



### Focus on:

- *cost*
- *quality at scale*
- *recyclability*
- *forecasting*
- *logistics mgmt.*
- *serviceability*
- *grid integration*

Energy production  $\uparrow$ 4 $\times$  higher ... CapEx 25% lower ... LCOE 70% lower

*turbine size & volume scale*

TODAY

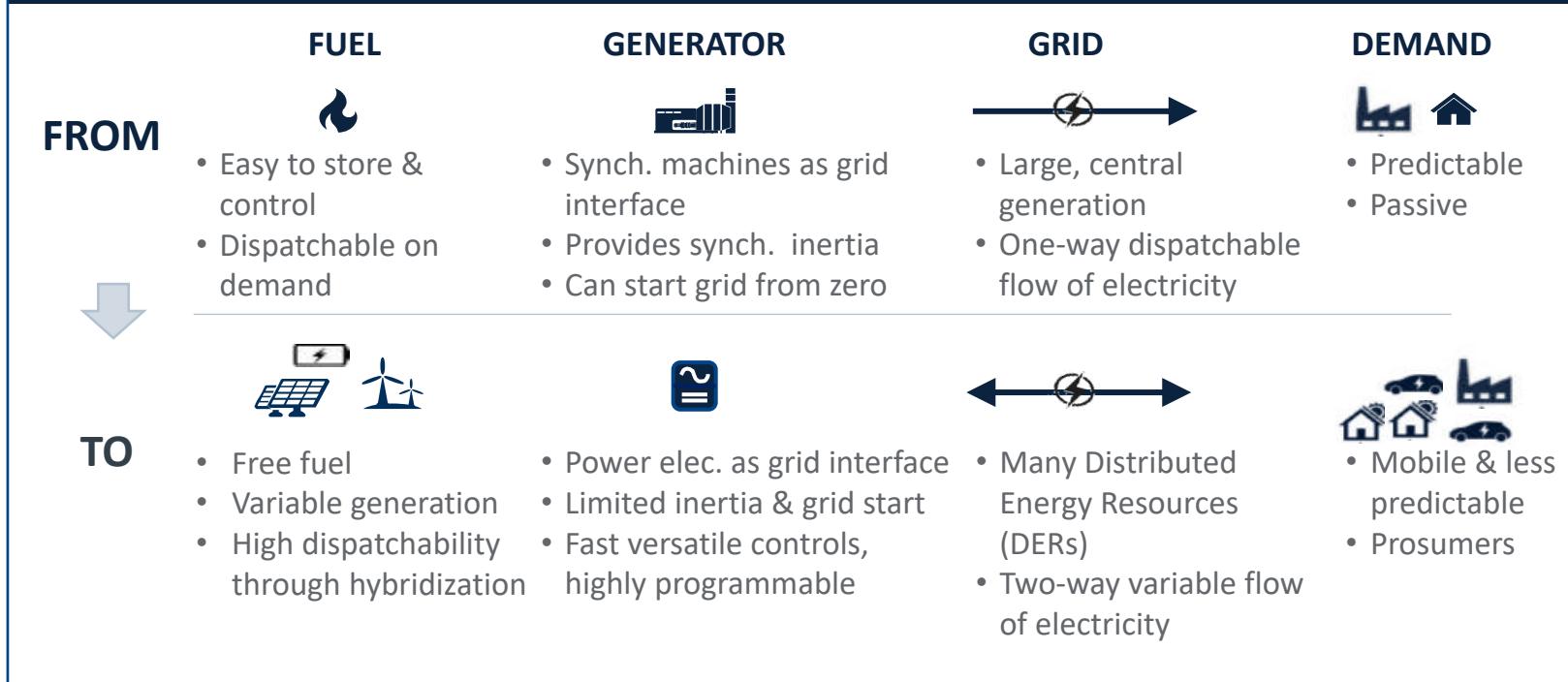
*advanced mfg, modularity, recycling & grid integration*

# Electrical Grid ... the backbone of the Energy Transition

## *System of systems (Generation + T&D + Loads)*



The grid was designed for a different way of producing and consuming power



*... leading to annual T&D grid investment of \$250B, growing at 3.4% CAGR*

## Innovation Focus Areas

### Operation optimization

- Maintain reliability & resiliency
- Grid orchestration & protection
- Flexibility from DERs
- Visibility & Modeling

### Grid stability

- Grid forming & storage integration
- Wide area controls
- Interoperability & cybersecurity

### Performance Optimization

- APM, Digital twins
- Modeling & analytics
- Dynamic rating

Grid re-enforcement, modernization and new technologies are needed

# Problems Worth Solving



## ① The Electric Power Grid ... operation, optimization, stability, and control

- High IBR penetration is a certainty – needs cost-effective enhanced grid capabilities
- Integrated planning & modeling across stability, operations & adequacy disciplines, T&D interface and industry sectors
- Interoperability of controls across multiple resources

## ② Legislation & Regulation ... we need a clear path forward

- Requirements, standards & interconnection processes need reform to unlock full IBR growth potential
- Grid development is highly complex... requires stakeholder collaboration at a new level
- Planning for policy goals requires holistic mindset

## ③ Cybersecurity ... an increasing concern

- More digitalization leads to higher vulnerabilities
- Cloud-based control necessitates cybersecurity
- New type of products are needed with design-for-security from the ground up



Building a world that works