2022 Meteorology and Market Design for Grid Services Workshop

ESIG
ENERGY SYSTEMS INTEGRATION GROUP

Denver, CO

June 7-9, 2022

Workshop Agenda Overview

Tuesday, June 7th

- Session 1: Introduction and Opening Plenary: The Increasing Ubiquity of VRE Forecasting
- Session 2: Solar and Wind Forecasting R&D Advances
- Networking Reception 6:30 pm

Wednesday, June 8th

- Session 3: Integration of Probabilistic Forecasts into the EMS and MMS – Status and Prospects
- Session 4: Dynamic Reserve Applications Panel Discussion
- Session 5: Impacts of Climate Change
- Session 6: Extreme Weather Conditions

Thursday, June 9th

- Session 7: High VRE Futures – How Are Markets Evolving?
- Session 8: Closing Plenary - Taking Stock: Where are We and What Lies Ahead?

Renewable Energy is Very Competitive

- Lazard reports on lowest unsubsidized energy costs at end of 2021 for:

Rooftop residential solar	$147/MWh
Simple Cycle GT	$151/MWh
Nuclear	$131/MWh
Coal	$65/MWh
Community Solar	$59/MWh
Combined Cycle GT	$45/MWh
Utility scale solar	$28/MWh
Wind energy	$26/MWh

- Other reports from industry pubs on recent PPA prices:

Utility scale solar	$15-$22/MWh
Wind energy	$11-$25/MWh

Storage Systems Definitely Making Progress

- Lazard reports at end of 2021 on estimated lowest unsubsidized energy costs for a range of storage systems (10 kw to 100 MW):

Peaker Replacement (4 hr @ 100 MW)
- Lithium Ion $131/MWh

Utility Scale PV + Storage (PV @ 40 MW + storage of 20 MW @ 4 hr)
- Lithium Ion $85/MWh

C&I BTM Standalone (2 hr @ 1 MW)
- Lithium Ion $442/MWh

C&I BTM PV + Storage (PV @ 1 MW + storage of .5 MW @ 4 hr)
- Lithium Ion $235/MWh

Residential BTM PV + Storage (PV @ 20 Kw + storage of 10 Kw @ 4 hr)
- Lithium Ion $416/MWh

- PPA bid at El Paso Electric - **PV plus battery at $21/MWh**

Current Levelized Cost of Hydrogen Production — 100 MW Electrolyzer

Alkaline (100 MW)

Energy Cost ($/MWh)	Electrolyzer Capex ($/kW)				
$/kg	$510	$570	$630	$690	$760
$20	$1.76	$1.77	$1.79	$1.80	$1.81
$30	$2.50	$2.51	$2.53	$2.54	$2.55
$40	$3.24	$3.25	$3.27	$3.28	$3.29
$50	$3.98	$3.99	$4.01	$4.02	$4.03
$60	$4.72	$4.73	$4.74	$4.76	$4.77

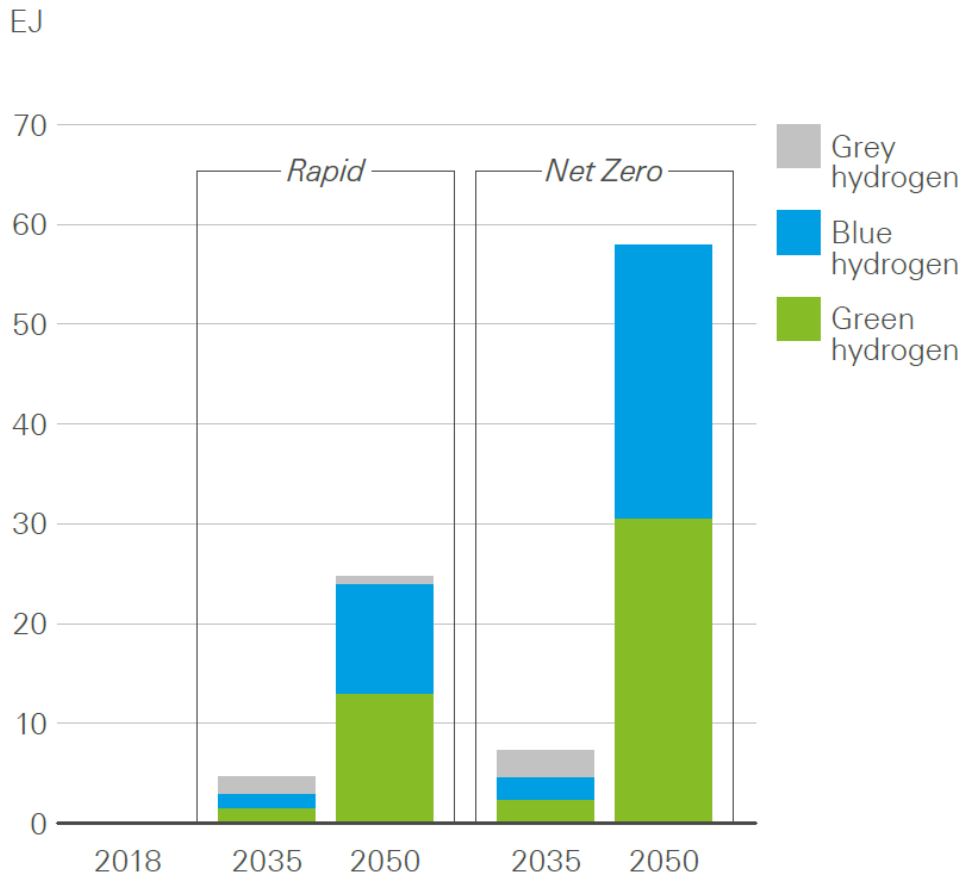
- Sensitivity to Electricity Cost and Electrolyzer Capex

Source: *Fuel Cell and Hydrogen Energy Association, National Renewable Energy Laboratory, Pacific Northwest National Laboratory, and Lazard and Roland Berger estimates.*

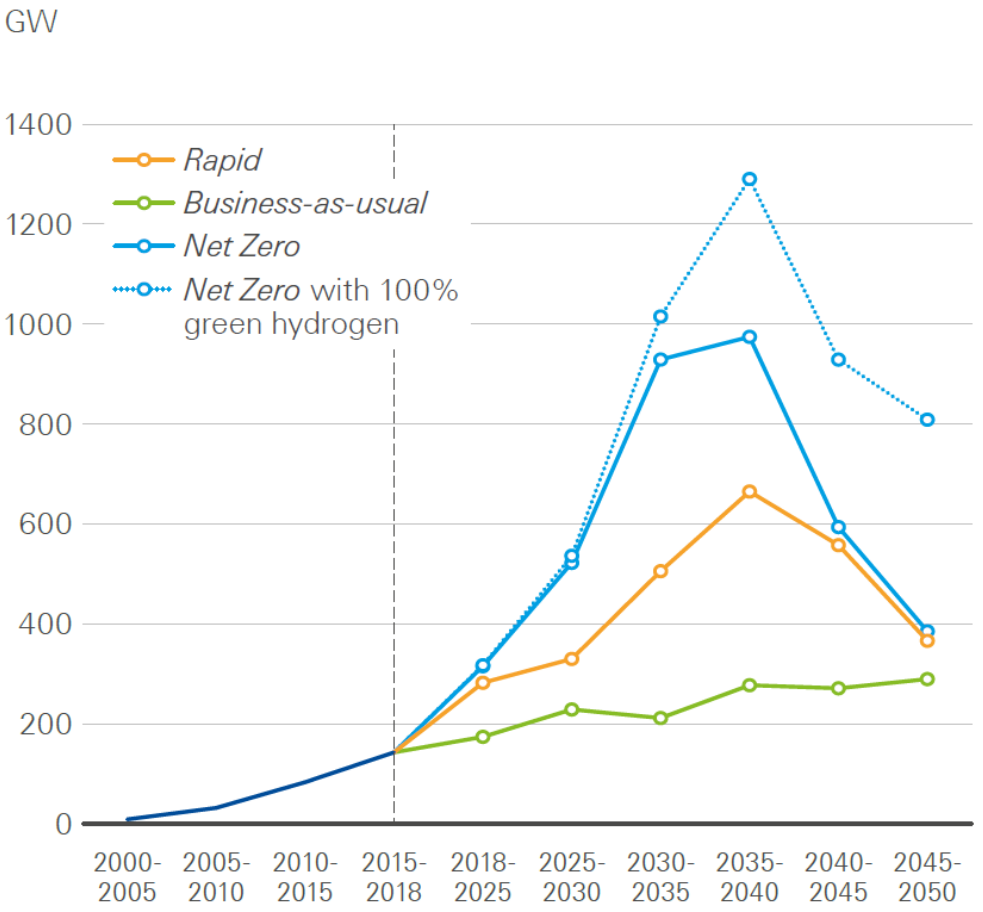
Note: *Sensitivity is based on a 98% electrolyzer utilization rate.*

Most Hydrogen Production by 2050 is a Combination of Green & Blue Hydrogen

Hydrogen production by type

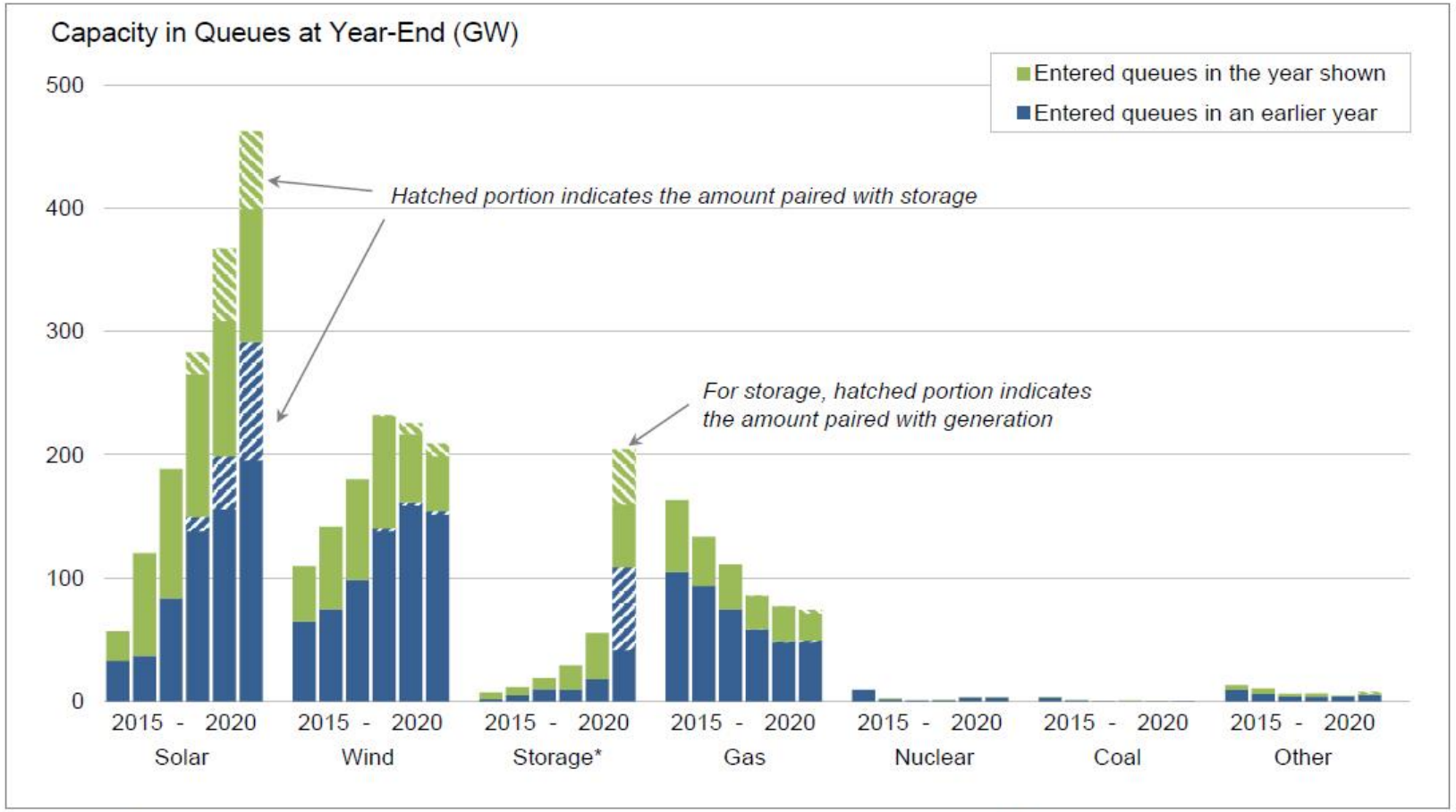


Annual average increase in wind and solar capacity



Source: BP Energy Outlook 2020

Interconnection Queues



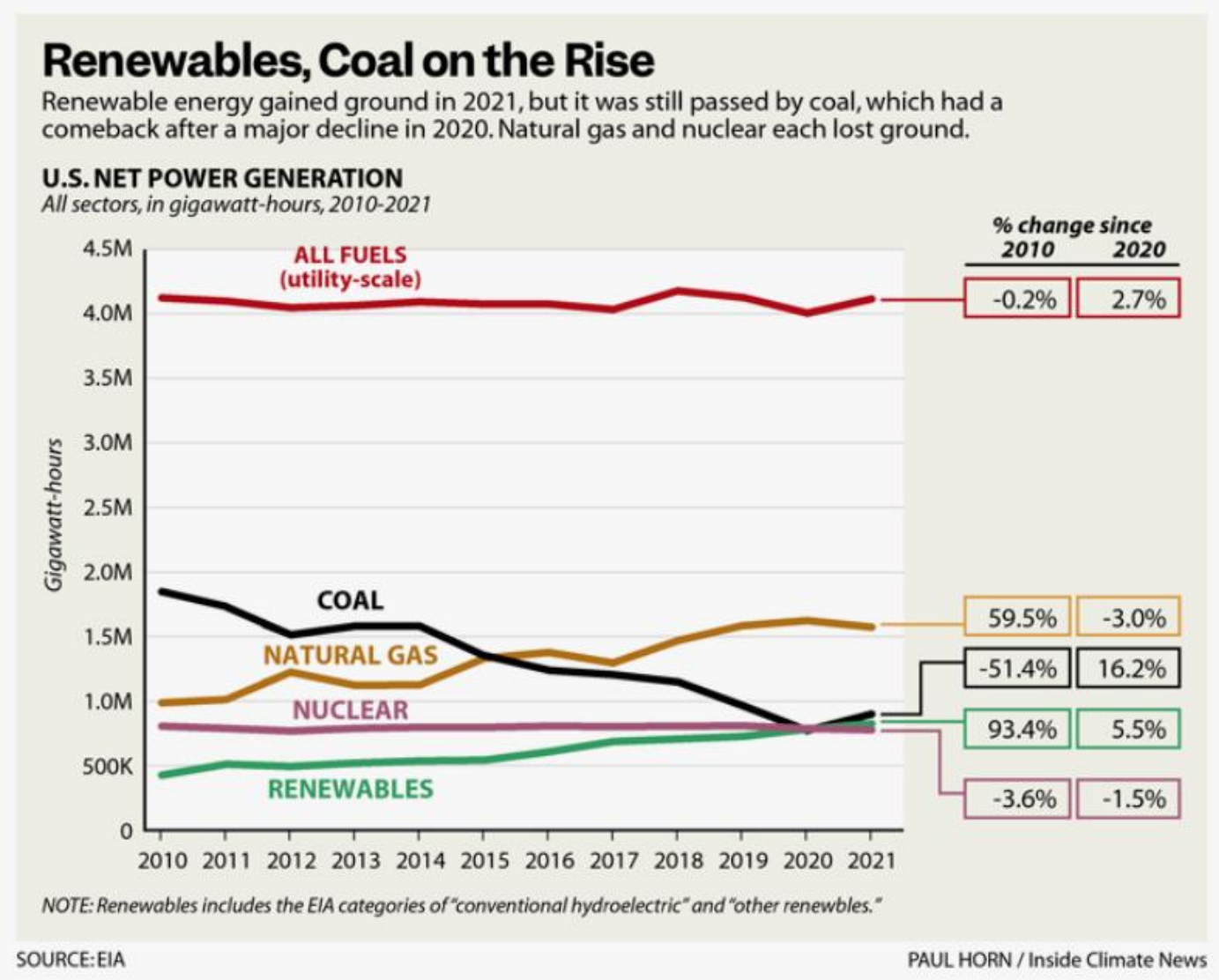
*Hybrid storage capacity is estimated using storage:generator ratios from projects that provide separate capacity data
Storage capacity in hybrids was not estimated for years prior to 2020.
Note: Not all of this capacity will be built

- "**Wind**" includes both onshore and offshore.
- "**Other**" includes
  - Hydropower
  - Geothermal
  - Biomass/biofuel
  - Landfill gas
  - Solar thermal
  - Oil/diesel
- "**Storage**" is primarily (98%) battery, but also includes pumped storage hydro, compressed air, gravity rail, and fuel cell projects.

An Industry Maturing – Globally

- Global wind capacity end of 2020 (REN21): 743 GW
- Global PV capacity end of 2020 (REN21): 760 GW
- Variously Estimated Global VG installations in 2021
  - Wind 90 GW
  - PV 180 GW
- Ballpark estimates for 2022 global VG installations
  - Wind 80 GW
  - PV 195 GW
- Solar growth, new installations slowing in the face of 18% price increases, report says

Still a Ways to Go in the US



Recent Corporate and Geo-Political Trends

- Corporate demand for carbon-free energy is increasing. Bloomberg NEF reported global corporations acquired 25 GW of clean energy in 2020, breaking all records with 31 GW purchased in 2021. Amazon was the largest purchaser at 20%.
- Corporate buyers becoming more sophisticated:
  - Google sets goal to procures carbon-free energy to cover operating power profiles 24/7 worldwide by 2030
  - Daimler signs corporate renewable deal with Norwegian firm Statcraft covering all its German power needs in real time
- RE100 corporate membership expands from 158 at end of 2018 to 340 today
- Countries with renewable energy policies – 161
- “EEI is advocating for policies that support our clean energy transition. We voiced our support for America rejoining the Paris Agreement, as well as getting critical transmission and energy grid infrastructure built more quickly. The transmission system is key to integrating more renewables, more clean energy, and more technologies into the grid affordably and reliably.” Tom Kuhn, President, EEI, Jan 26, 2021.
- US coal giant Peabody announced the launch of a new joint venture, R3 Renewables, which will focus on developing 3.3 GW of solar PV and 1.6 GW of battery storage capacity over the next five years.
- If coal is already facing headwinds, EPA’s power-sector agenda seems poised to make that breeze a lot stiffer.
- **Utilities plan to close more than 70 gigawatts of coal plants by 2028, one-third of all coal capacity in the US**

Some Recent Hydrogen Headlines

- **Global green hydrogen pipeline exceeds 250 GW**
- World's first giga-scale green hydrogen electrolyzer set for Saudi mega-city after Thyssenkrupp deal (12/21). A $500 billion new city on the Red Sea will be powered by up to 40 GW of renewable energy. The $5 billion hydrogen/ammonia plant for export to global markets will be powered by 4 GW of wind, solar and storage and commissioned in 2026. The prototype 20 MW alkaline electrolyzer is under development by Thyssenkrupp.
- World's largest green hydrogen project unveiled in Texas, with plan to produce clean rocket fuel for Elon Musk. The 60 GW Hydrogen City project will be powered by wind and solar, with an on-site salt cavern for H2 storage. First 2 GW phase scheduled to begin operation in 2026.
- The largest single-site green hydrogen project announced had been the Western Green Energy Hub in Western Australia, which would be powered by 50 GW of wind and solar, with first production anticipated by 2030
- Total U.S. investments last year included over 8 GW of announced hydrogen-compatible power turbines
- **The DOE Hydrogen Shot, launched in June 2021, seeks to reduce the cost of green hydrogen by 80%, from $5 to $1 per kilogram ($8/MMBTU), by 2030, which is competitive with fossil fuel sources of hydrogen. Think of it as along the lines of the ambition of the DOE Sunshot program of the last decade.**
- **New EU hydrogen strategy 'marks beginning of the end of the fossil-fuel era'. The European Commission announced plans on Wednesday for at least 40 GW of renewables-powered electrolyzers to be installed by 2030.**

VPPs Take Off

- 2021 - Virtual Power Plants take off, earning revenues as wholesale market capacity or grid services
- Swell startup in CA receives $450 million for projects with 4 utilities in 3 states, for 200 MWh of dispatchable energy in 14,000 PV-battery systems
- Solar and battery provider Tesla has virtual power plants with Vermont utility Green Mountain Power and in Australia
- Shell-owned sonnen has expanded its extensive VPP work in its home market of Germany to California and Utah
- Generac acquires Enbala to enter market
- On the commercial side
  - Enel X is aggregating batteries, EV chargers and commercial and industrial demand response
  - Engie is pulling together solar, storage and demand response
  - Centrica Business Solutions acquired Restore Power to integrate its load flexibility into distributed energy offerings.
- Origin (AU energy provider) announces plan to grow its "in-house" VPP from 200 MW to 2,000 MW over next 4 yrs
- **Over 50 GW of VPP in operation in Europe**

Offshore Wind

- **European offshore wind target – in case you missed it - 60 GW by 2030 and 300 GW by 2050.**
- U.K. contribution – 40 GW offshore wind target contribution to achieving its target of net-zero carbon by 2050. This includes a 5 GW clean hydrogen goal, and a ban on new fossil-fueled cars by 2030. U.K. is officially on a path of deep electrification, with a hydrogen economy in development to eliminate hard-to-reach emissions beyond 2030. The long-term anchor source of energy will be offshore wind
- US goal of 30 GW offshore wind by 2030, state goals of 40 GW by 2040. DOE says meeting the 2030 goal will also "unlock a pathway" to 110 GW by 2050. What's the big concern? Transmission!
- Denmark has approved a plan to build an artificial island for a 10 GW wind hub in the North Sea. A 3 GW first stage is planned for completion around 2033. The 10 GW plant should be more than enough for the whole of Denmark, with spare capacity to sell to other nations, to create green hydrogen and store electricity in large batteries.
- BlueFloat (Spain) and Energy Estate (AU) announce 4.3 GW offshore wind projects in AU; 1.4 GW Hunter Coast floating technology project off NSW; 1.6 GH Wollongong floating technology project off NSW; and 1.3 GW Greater Gippsland project with fixed bottom technology off Victoria.
- Victoria sets "game changing" offshore wind target of 9 GW to replace coal

EVs

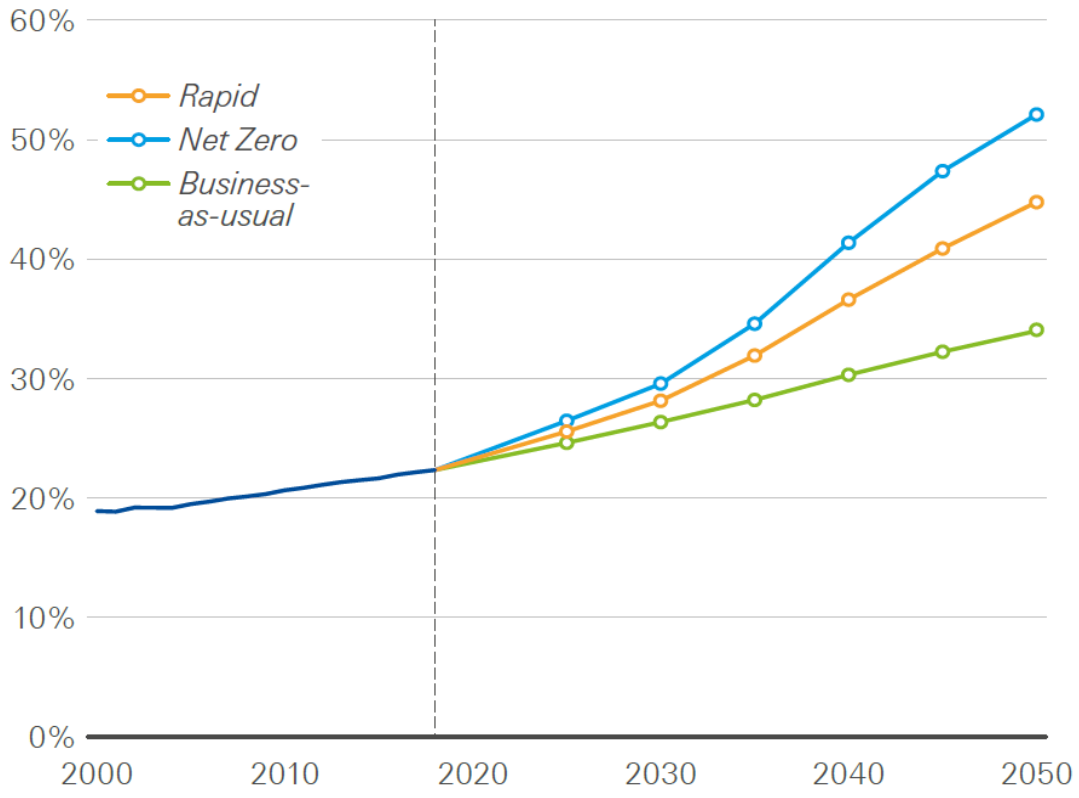
- Bans on ICEs continue to grow
  - UK – 2030
  - Quebec – 2035
  - California – 2035
  - China – 2035
- GM to end the sale of all gasoline and diesel powered passenger cars and light-duty SUVs by 2035
- EVs – the 2021 federal infrastructure package includes $7.5 billion for EV charging stations; “This is the start of a really big turning point” says Dylan McDowell, of the National Caucus of Environmental Legislators
- Northvolt AB (Sweden) is building a new battery plant of 60 GWh capacity in Germany, bringing its annual capacity to over 170 GWh. Northvolt has secured more than $50 billion worth of EV battery contracts since 2016.
- NextEra makes long play on fleet electrification with eIQ Mobility Acquisition – eIQ has the software and NextEra has the balance sheet – reflects a “toe in the water” strategy to get smart in the space”
- **New ONE Gemini battery achieves 752 mile range in Tesla Model S. 200 kwh battery in 100 kwh compartment. Lithium iron phosphate battery without cobalt, at the same price as the current 100 kwh battery by 2026.**
- State of Washington lawmakers passed legislation adopting a target to end the sales of new gasoline-powered cars by 2030, a deadline that is five years ahead of neighboring California, making it the most ambitious goal in the country.

Bulk Storage Tidbits

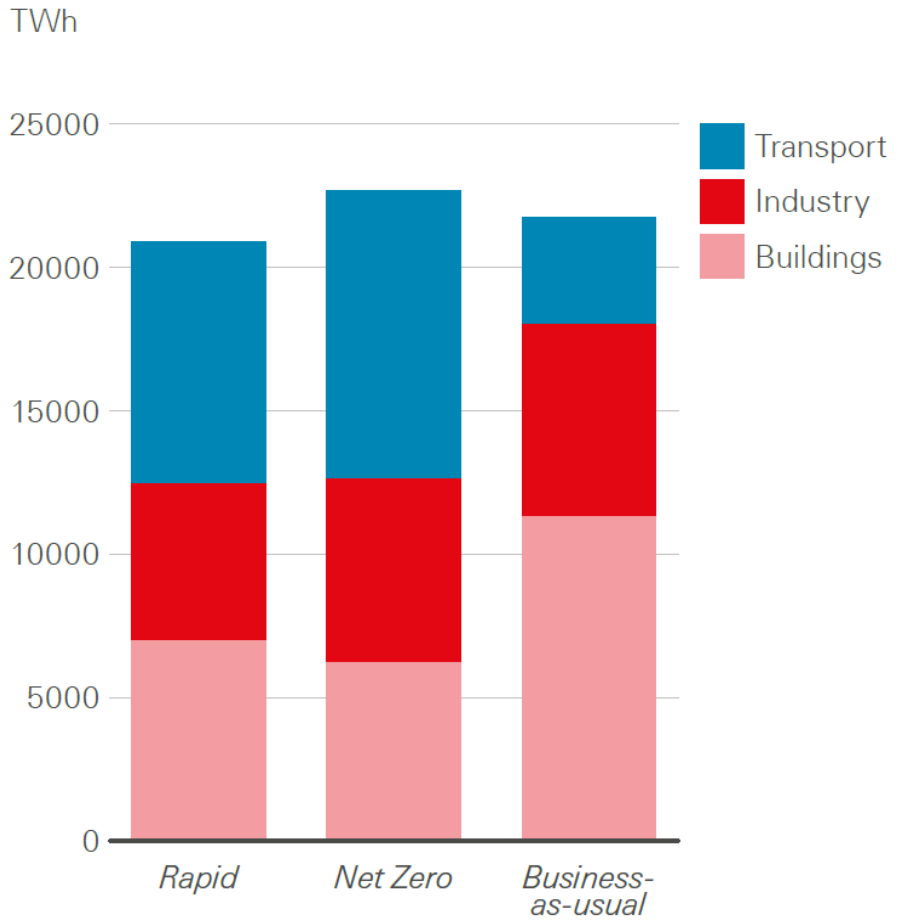
- US added 4.4 GW of battery energy storage in 2021, bringing the cumulative battery storage deployment to 6.6 GW.
  - CAISO and ERCOT each expect to have roughly 5 GW online by the end of 2023 or sooner
  - With pumped hydro sitting at around 22.5 GW, this brings total US storage capacity to 29 GW at the end of 2021
- Capacity market contracts awarded to more than 2 GW of battery storage in UK and Italy
- China is targeting a non-hydro energy storage installed capacity of 30 GW by 2025 (includes all storage processes using electrochemical, compressed air, flywheel and supercapacitor systems), up from 3 GW today
- **State Grid Corporation of China (SGCC) reportedly plans to increase its capacity of battery storage to 100 GW in 2030, and do the same for pumped hydro storage from 26 GW today**
- Quinbrook Infrastructure Partner's solar and storage developer Primergy has chosen the equipment and construction partners for its $1.2 billion Gemini Project with NV Energy, which will have a 1,416 MWh battery energy storage system, one of the largest in the world.
- Other notably large solar-plus-storage projects include:
  - Florida Power & Light's recently completed Manatee project which has a 900 MWh solar-charged BESS
  - **Terra-Gen's Edwards Sanborn phased project in California, planning to reach 760 MW PV and 2,445 MWh of BESS in early 2023. Said to be world's largest PV-battery project planned at the time in August 2021.**

Electricity Demand Grows Robustly as the World Continues to Electrify

Share of electricity in total final consumption

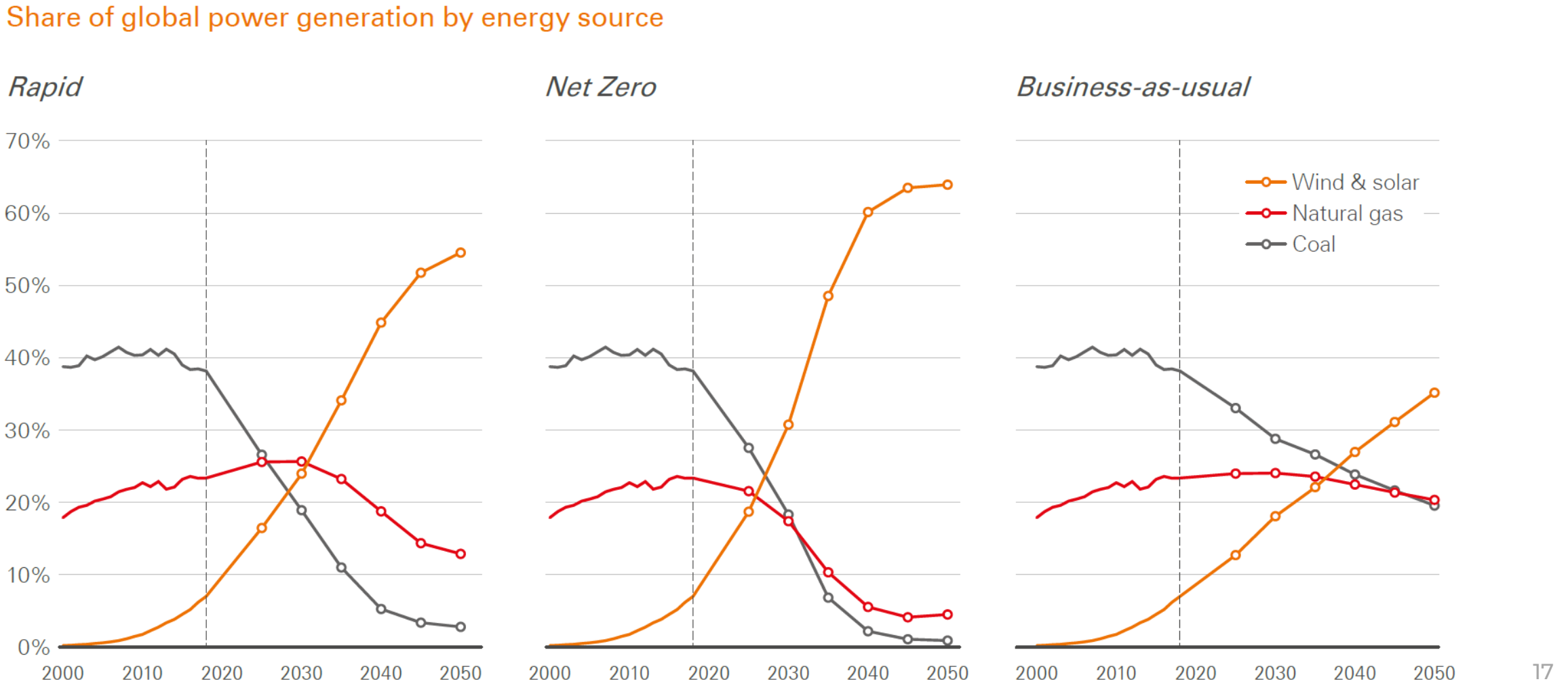


Change in electricity demand by sector, 2018-2050



Source: BP Energy Outlook 2020

Growth in Power Generation is Led by Wind and Solar Power as Coal Loses Share



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Upcoming Meetings – 2022 and 2023

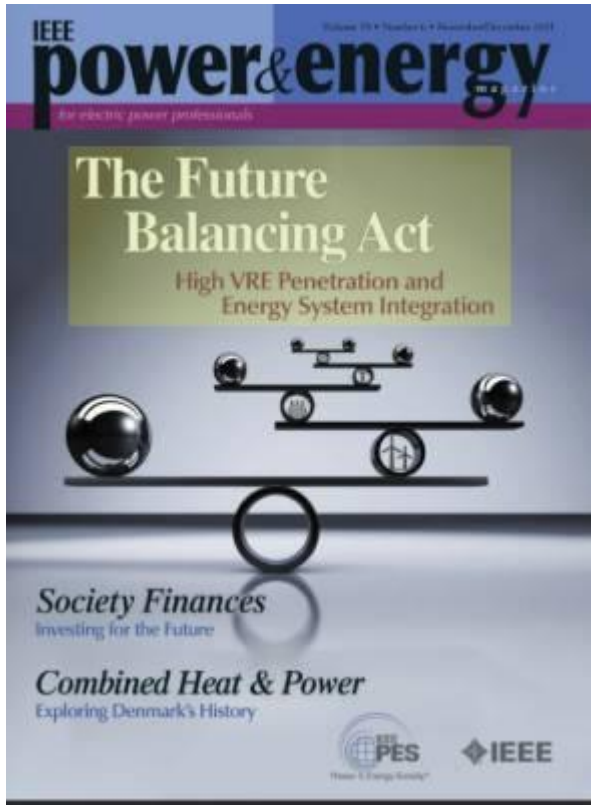
2022 Fall Technical Workshop
October 24-27, 2022
Minneapolis, MN

2023 Spring Technical Workshop and Annual Meeting
March 27–30, 2023
Tucson, AZ

2023 Meteorology and Markets Workshop
June 2023
Denver, CO

Onward and Upward

- New IEEE P&E magazine integration issue is out
- A warm welcome to real and virtual visitors from afar:
  - Australia
  - United Kingdom
  - France
  - Germany
  - Ireland
  - Canada
  - Texas
- Take the time to make some new friends!
- Looking forward to another great meeting!



THANK YOU

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