ESIG
Spring Technical Workshop

ESIG
ENERGY SYSTEMS
INTEGRATION GROUP

Tucson, Arizona

March 21-24, 2022

Meeting Overview - Monday

- **Monday Morning - Pre-Workshop Tutorial**
  - Hydrogen and the Energy Transition
    - *Co-chairs: Aidan Tuohy, EPRI & William D'haeseleer, KU Leuven*
- **Monday Afternoon – Opening Sessions**
  - Introduction – Mark Ahlstrom, President, ESIG Board of Directors
  - Keynote Comments – Danielle Merfeld, Vice President & Chief Technology Officer, GE Renewable Energy
  - Meeting Overview – Charlie Smith, ESIG Executive Director
  - Opening Plenary - System Disturbances and Renewable Energy
    - *Chair: Luke Robinson, Manager Grid Performance & Integration, AEMO*
- **Monday Afternoon – Annual Membership Meeting 5:00 pm**

Meeting Overview - Tuesday

- **Session 1 – Resource Adequacy**
  - Session Keynote: Commissioner Jimmy Glotfelty, PUCT
  - **Session 1A – Evolutions in Resource Adequacy**
    - Chair: Mark O'Malley, Chief Scientist, ESIG
  - **Session 1B – Capacity Accreditation and Market Constructs**
    - Chair: Derek Stenclik, Founding Partner, Telos Energy
- **Session 2 - Progress with Grid Forming Inverters**
  - Session Keynote: Christian Schaefer, GHD, Australia
  - **Session 2A – Grid Forming Inverters – A Quickly Evolving Landscape**
    - Chair: Jason MacDowell, Senior Technical Director, GE
  - **Session 2B - Grid Forming Inverters – Some Practical Considerations**
    - Chair: Nick Miller, HickoryLedge
- **Board Meeting and Dinner** **6:00 pm**

Meeting Overview - Wednesday

- **Session 3 – Flexibility and Complexity: Storage, Hydro, Operations**
  - Session Keynote: Antje Orths, Chief Engineer, Energinet (Denmark)
  - **Session 3A – Looking for Flexibility**
    - Chair: Aidan Tuohy, Program Manager, EPRI
  - **Session 3B – Planning & Operations: A Few New Things to Consider**
    - Chair: Caitlin Murphy, Senior Energy Policy Analyst, NREL
- **Session 4 - Transmission and DER**
  - Session Keynote: Carlos Rodriguez, Senior Vice President, Invenergy
  - **Session 4A – Interconnection Processes: Symptom or Solution?**
    - Chair: Julia Matevosyan, Chief Engineer, ESIG
  - **Session 4B - Buildings as a Source of Grid Flexibility**
    - Chair: Obadiah Bartholomy, Manager, Distributed Energy Resources, SMUD
- **Networking Reception & Awards Ceremony** **6:30 pm**

Meeting Overview - Thursday

- **Thursday Morning**
  - Reliability Working Group – Co-Chairs: Jason MacDowell and Julia Matevosyan
  - System Operation & Market Design Working Group - Co-chairs: Aidan Tuohy and Erik Ela
  - Joint System Operation & Market Design Working Group / Distributed Energy Resources Working Group Session
- **Thursday Afternoon**
  - System Planning Working Group – Chair: Aaron Bloom
  - Distributed Energy Resources Working Group - Chair: Obadiah Bartholomy
  - Joint Meeting of All Working Groups
- **Adjourn** **5:00 pm**

Renewable Energy is Very Competitive

- Lazard reports on lowest unsubsidized energy costs at end of 2018 vs end of 2021 for:

Rooftop residential solar	$160/MWh	< $147
Simple Cycle GT	$152/MWh	< $151
Nuclear	$112/MWh	> $131
Community Solar	$73/MWh	< $59
Coal	$60/MWh	> $65
Combined Cycle GT	$41/MWh	> $45
Utility scale solar	$36/MWh	< $28
Wind energy	$29/MWh	< $26

- 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 2018 vs 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 $204/MWh < $131

Utility Scale PV + Storage (PV @ 40 MW + storage of 20 MW @ 4 hr)
- Lithium Ion $108/MWh < $85

C&l BTM Standalone (2 hr @ 1 MW)
- Lithium Ion $829/MWh < $442

C&I BTM PV + Storage (PV @ 1 MW + storage of .5 MW @ 4 hr)
- Lithium Ion $315/MWh < $235

Residential BTM PV + Storage (PV @ 20 Kw + storage of 10 Kw @ 4 hr)
- Lithium Ion $476/MWh < $416

- 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)	$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

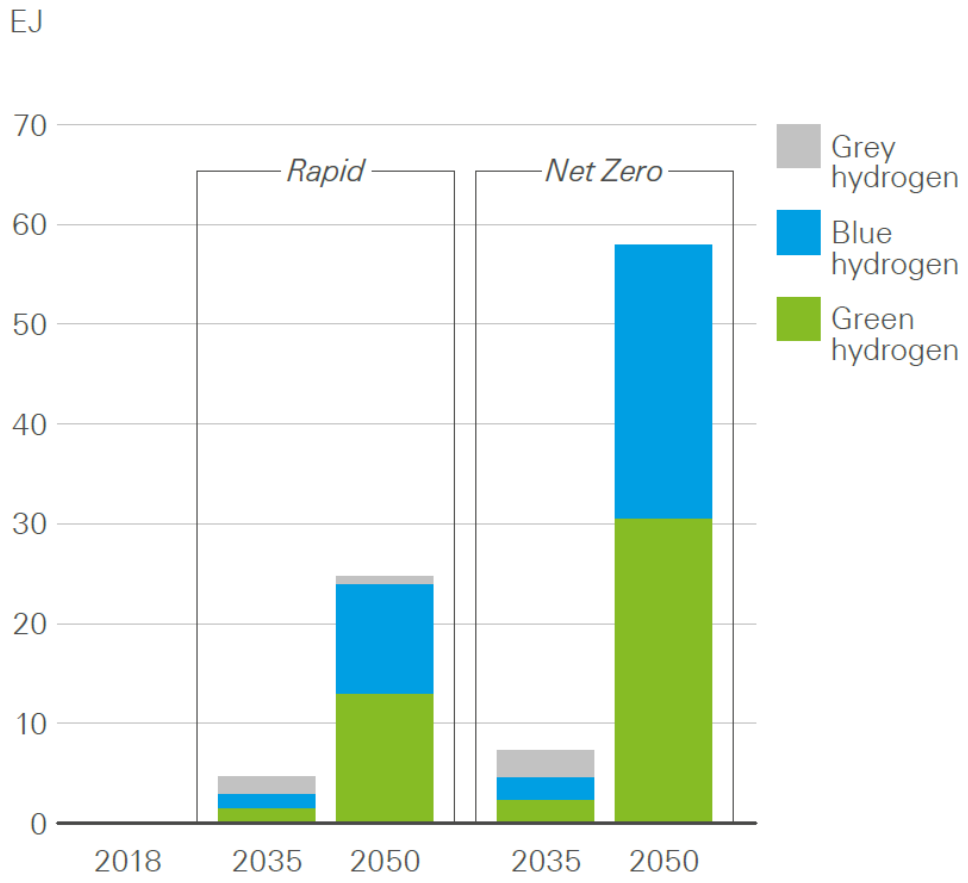
- Sensitivity to Electricity Cost and Electrolyzer Capex

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

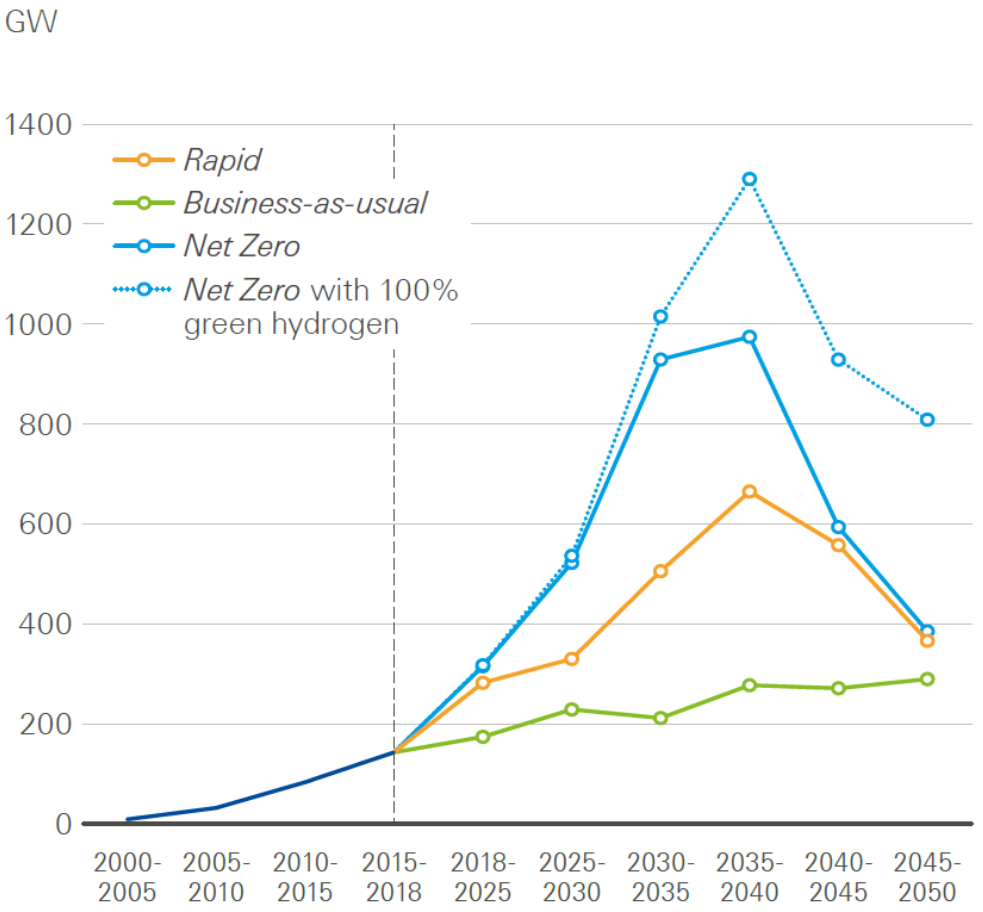
Note: *Sensitivity is based on a 98% electrolyzer utilization rate.*

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

Hydrogen production by type

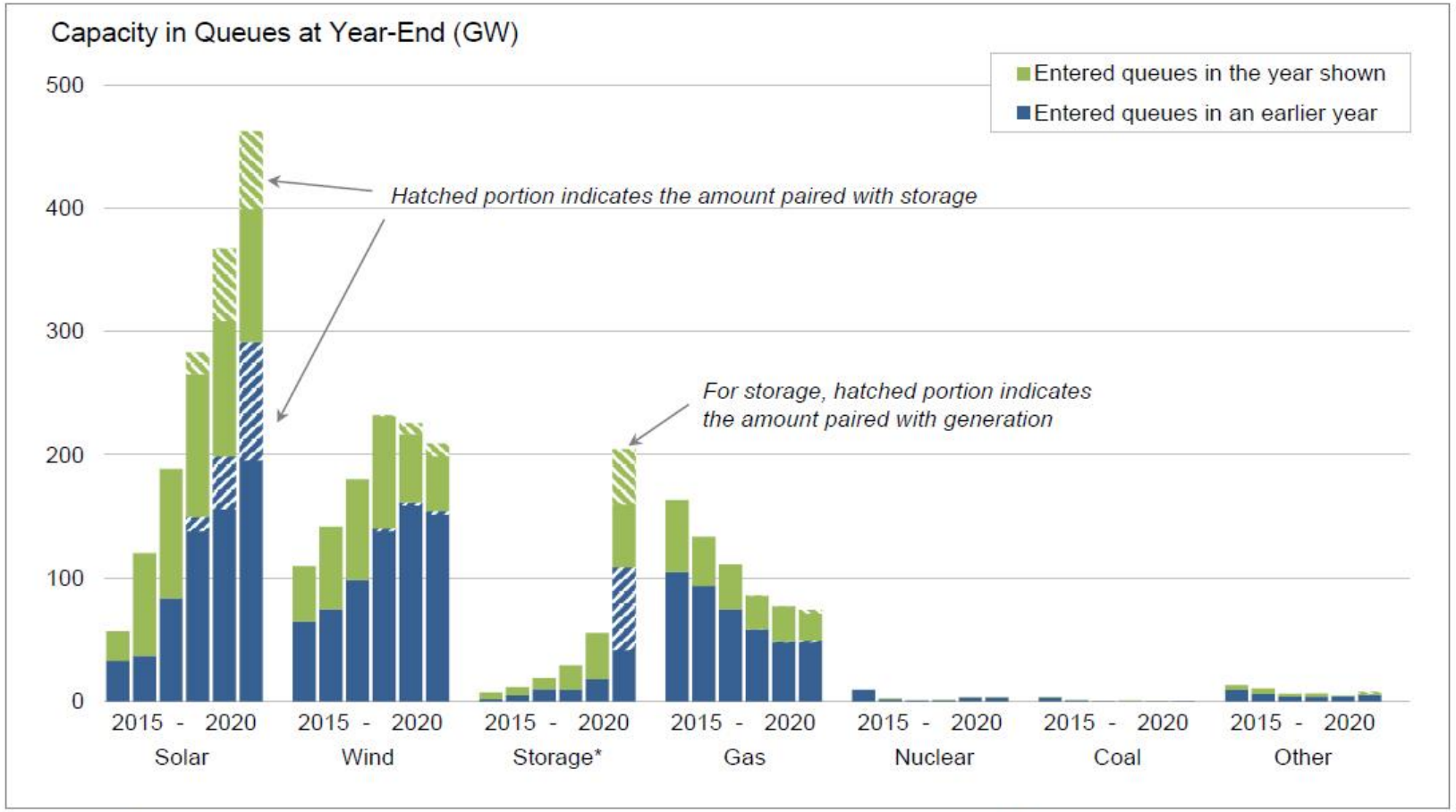


Annual average increase in wind and solar capacity



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

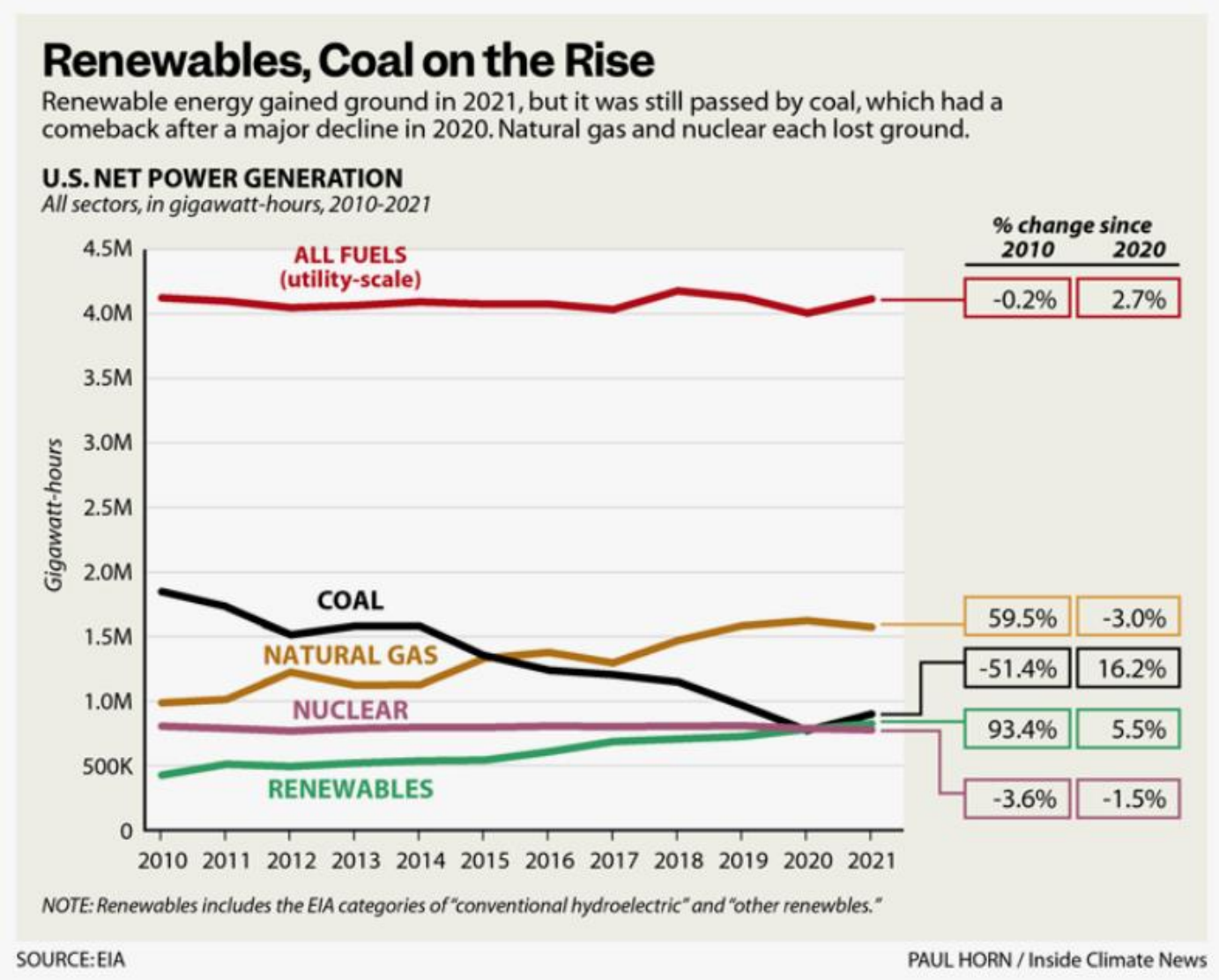
- "**Wind**" includes both onshore and offshore.
- "**Other**" includes
  - Hydropower
  - Geothermal
  - Biomass/biofuel
  - Landfill gas
  - Solar thermal
  - Oil/diesel
- "**Storage**" is primarily (98%) battery, but also includes pumped storage hydro, compressed air, gravity rail, and fuel cell projects.

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 Planning and Operating Headlines

- GB gives renewables the green light to support the grid; modifies grid code through GC 0137 and enables renewables to compete in the market to provide grid services
- South Australia grid just one step away from operating with wind and solar only – achieved 135% instantaneous penetration and 108% share over a 48 hr period in November 2021, with 2 gas units operating, and the excess energy exported to Victoria. Once ProjectConnect transmission line is built by 2025, the plan is to operate without the gas units most of the time. **AEMO to fast-track grid forming inverters to help transition to 100% renewables**
- Denmark, 2020, VRE maximum share of hourly demand, 213%;
- Germany, 2020, VRE maximum share of hourly demand, 74%
- SPP, March 2021, VRE maximum share of hourly demand, 81%
- Iowa, 2020, sets 58% annual VRE penetration record
- SPP, MISO identify 7 cross-seam transmission projects that could unlock up to 53 GW of new generation
- **Blackrock, Morgan Stanley to utilities: tackle climate-related risks or lose market value.** Investors perceive climate change to be happening today. **Analyst research shows utilities that address climate-related physical and transition risks earn higher valuations from investors.** Carbon-heavy utilities can accelerate their earnings growth by shutting down expensive coal plants and investing in cheap renewables.

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.**

More Hydrogen Headlines

- Project called HyDeal Ambition that adds up to 67 GW at multiple sites across Spain, France and Germany.
- A planned 30 GW facility in Kazakhstan, powered by 45 GW of wind and solar has also been unveiled.
- Total Eren, a developer part owned by supermajor TotalEnergies, announces plans for 10 GW onshore wind plant in Chile to power 8 GW of electrolyzer capacity (to produce green hydrogen) and an ammonia plant
- Giant green hydrogen project powered by 6 GW of off-grid PV and wind proposed for South Australia
- Giant off-shore wind plant planned in Ireland to power 3.2 GW onshore green hydrogen facility
- NextEra plans to build a 500 MW wind project to provide power to a fuel cell company to build a nearby hydrogen electrolyzer facility. Nextera's interest extends to potentially investing in the electrolyzer
- The governors of Louisiana, Oklahoma and Arkansas are banding together in hopes of becoming one of four "hydrogen hubs" supported by $8 billion in last year's federal infrastructure bill

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.

Other Battery 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.**

Fallout from the War in Ukraine

- Green groups, some govt's say gas crisis makes transition to renewables even more urgent
- With 40 per cent of its natural gas coming from Russia, the EC stated its intent to draw up a "RepowerEU" package of policies "by the summer" to reduce by two-thirds the volume of Russian gas it imported last year by the end of December (9 March 22)
- Germany and Norway are considering building a hydrogen pipeline linking the two nations to reduce Europe's dependence on Russian energy supplies.
- Fossil fuel industry - crisis demonstrates need for further domestic fossil fuel exploration
- Global conflict over war in Ukraine creating crunch in supply of metals vital to clean technology. Russia also produces nickel, aluminum and palladium, three metals crucial to the EV supply chain. With prices of all three metals reaching astronomical levels, green energy transition will become more expensive.

That was Then (2019) and This is Now (2022)

- **Then –** The big question was, "How much coal is retiring this year or next"
  - **Now –** 40 countries agree to phase out coal in 2030's and 2040's at COP26, but US, China, India missing from the deal. US announced retirements reduce capacity from about 200 GW today to 130 GW in 2028.
- **Then -** Reliability standard (LOLE) of 1 day in 10 years was the gold standard in the good old days
  - **Now –** LOLE inappropriate for the new generation mix. In California heat storm of August 2020, temperature records were shattered across the American West; state agencies failed to adequately plan for that type of heat event; failed to direct electricity providers to buy sufficient power supplies to cover the evening hours when solar panels go offline; created complex energy market mechanisms that masked the inadequacies.

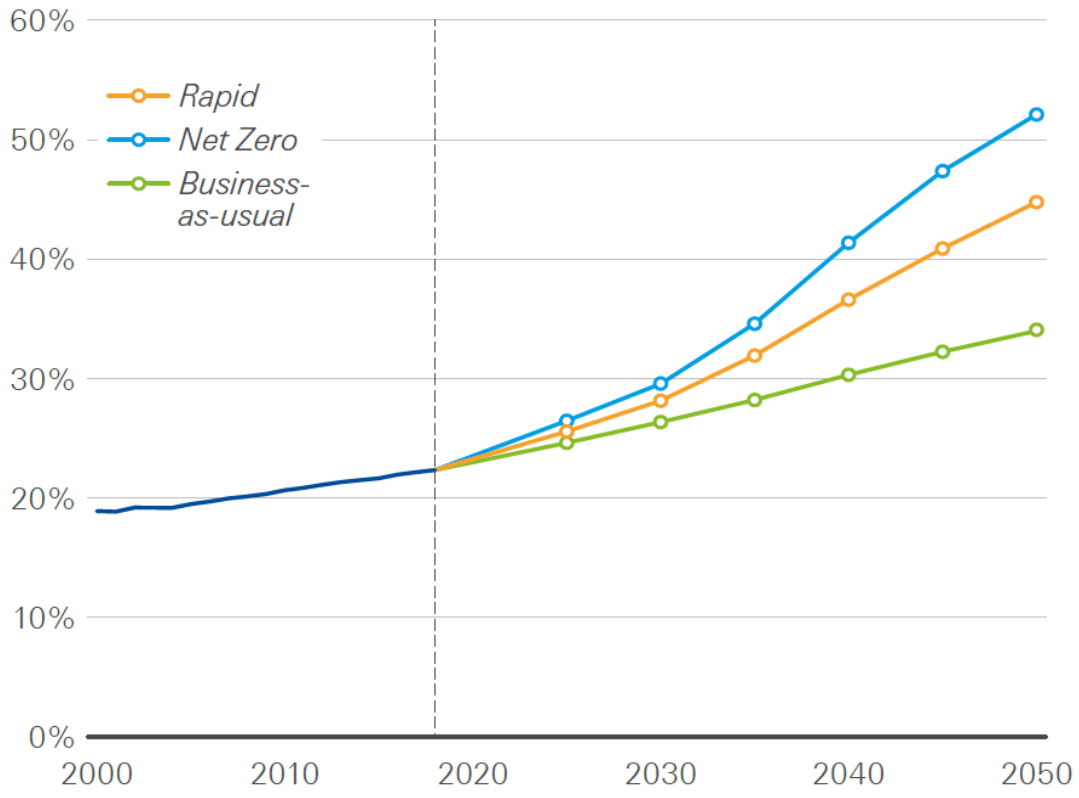
    "The combination of these factors was an extraordinary event. But it is our responsibility and intent to plan for such events, which are becoming increasingly common in a world rapidly being impacted by climate change," wrote Independent System Operator President Elliot Mainzer, Public Utilities Commission President Marybel Batjer and Energy Commission Chair David Hochschild.
- **Then -** Idaho Power claims one of lowest priced solar deals at $22/MWh
  - **Now –** El Paso Electric – record low prices in New Mexico project approvals – 100 MW of PV at $15/MWh
- **Then –** 11 states with 100% clean energy goals
  - **Now –** 20 states with 100% clean energy goals

That was Then (2019) and This is Now (2022)–cont.

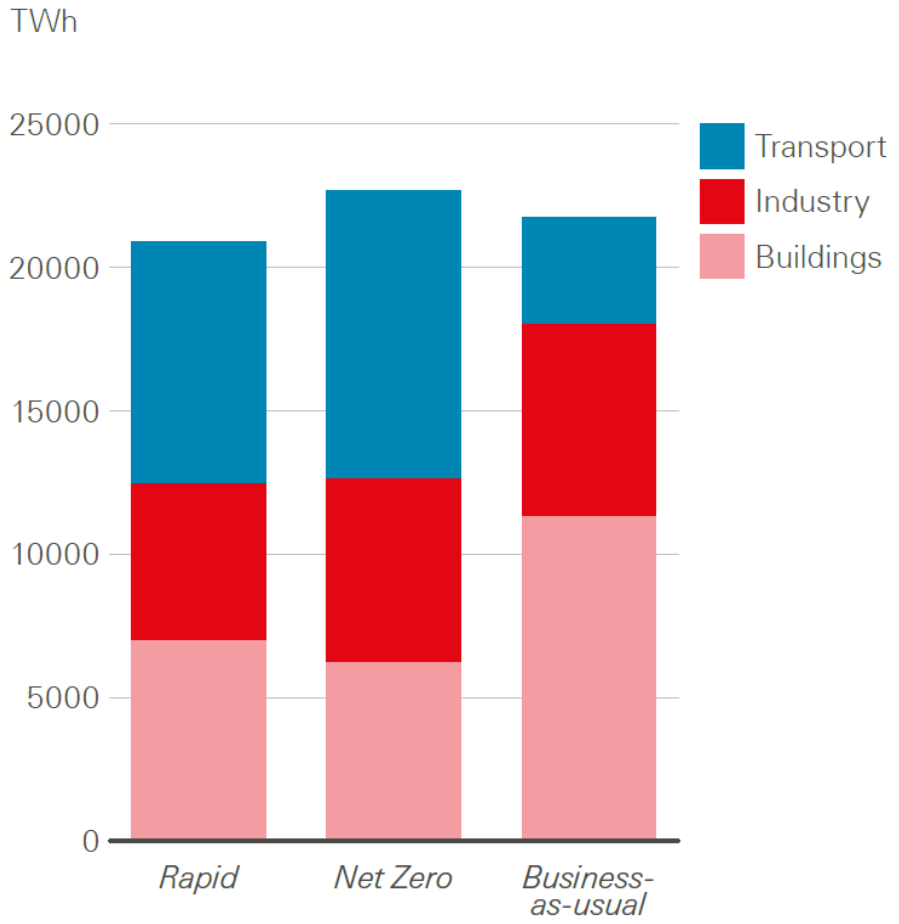
- **Then -** Sunrun clears ISO-NE capacity auction with 20 MW VPP with aggregation of residential PV and storage, first ever (2019)
  - **Now -** U.S. residential solar leader Sunrun has taken a lead with projects in California, Massachusetts, NY and Hawaii
- **Then -** January 25, 2019 - NextEra Energy earnings release conference call of CEO Jim Robo predicting that solar and wind plus storage will be cheaper than coal, oil or nuclear early in the next decade. Will be very disruptive:
    - Unsubsidized new wind: 2.0-2.5 cents per kilowatt-hour
    - Unsubsidized new solar: 2.5-3.0 cents per kilowatt-hour
    - Storage will add .5-1 cents per kilowatt-hour to cost of solar
  - **Now –** from the 2021 Lazard report:
    - Unsubsidized new wind: 2.6 cents per kilowatt-hour
    - Unsubsidized new solar: 2.8 cents per kilowatt-hour
    - Storage adding .6 cents per kilowatt-hour to cost of solar

Electricity Demand Grows Robustly as the World Continues to Electrify

Share of electricity in total final consumption



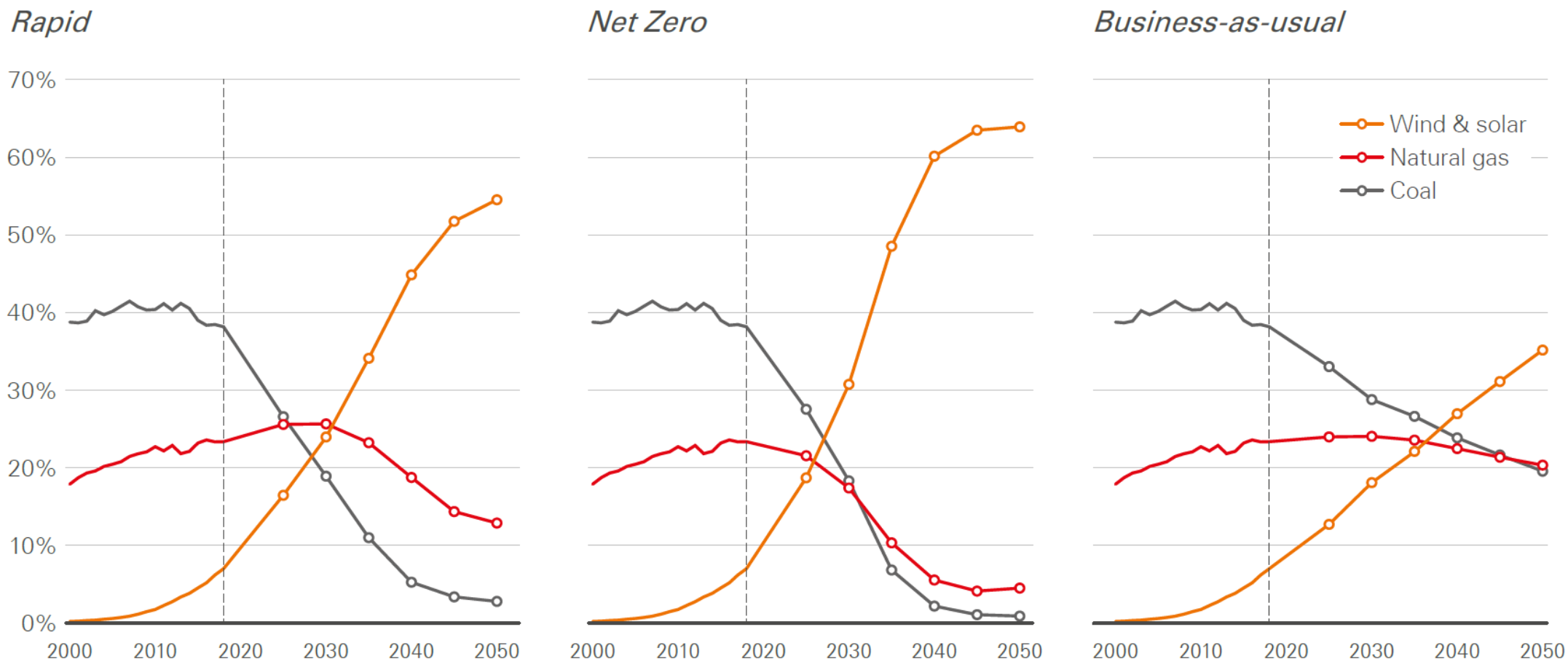
Change in electricity demand by sector, 2018-2050



Source: BP Energy Outlook 2020

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

Share of global power generation by energy source



Source: BP Energy Outlook 2020

Upcoming Meetings - 2022

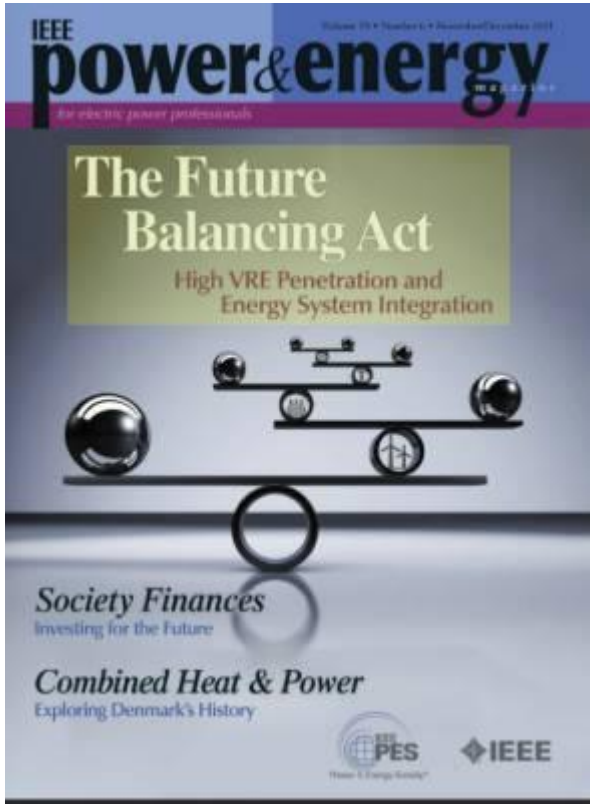
2022 Meteorology & Market Design for Grid Services Workshop
June 7-9, 2022
Denver, CO

2022 Special Topic Workshop on IBR and GFM
June 7-9, 2022
Denver, CO

2022 Fall Technical Workshop
October 2022
Location TBD

Onward and Upward

- New IEEE P&E magazine integration issue is out
- A warm welcome to real and virtual visitors from afar:
  - Australia
  - Japan
  - China
  - South Korea
  - Germany
  - Denmark
  - Belgium
  - Canada
  - Texas
- Take the time to make some new friends!
- Looking forward to another great meeting!



THANK YOU

Charlie Smith
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