ESIG Fall Technical Workshop

ESIG
ENERGY SYSTEMS
INTEGRATION GROUP

Minneapolis, MN

October 24-27, 2022

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For additional guidelines, please click here.

Workshop Agenda Overview

Monday, October 24

- Introduction & Keynote Comments
- Opening Plenary: A Panel Discussion: High VRE Futures – 100% Clean Electricity
- Board Meeting and Dinner 6:00 pm

Tuesday, October 25

- Session 1: Congestion Management Practices, Challenges and Potential Mitigation Solutions
- Session 2: IEEE 2800 and IBR Modelling
- Session 3: Planning and Deployment Implications with Storage and IBRs
- Session 4: Aligning Retail Pricing with Grid Needs
- Networking Reception 6:30 pm

Workshop Agenda Overview

Wednesday, October 26

- Session 5: Future Market Design for Resource Adequacy
- Session 6: IBR Stability and Control
- Session 7: Topics in Power Systems Operations
- Session 8: Closing Plenary: Inter-regional Transmission Planning - Why Is it Important and How Do We Make it Happen?
- Advisory Council Dinner 6:00 pm

Thursday, October 27

- Advisory Council meeting
- Working Group and Task Force meetings

Renewable Energy is Very Competitive

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

Simple Cycle GT	$151/MWh
Rooftop residential solar	$147/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:

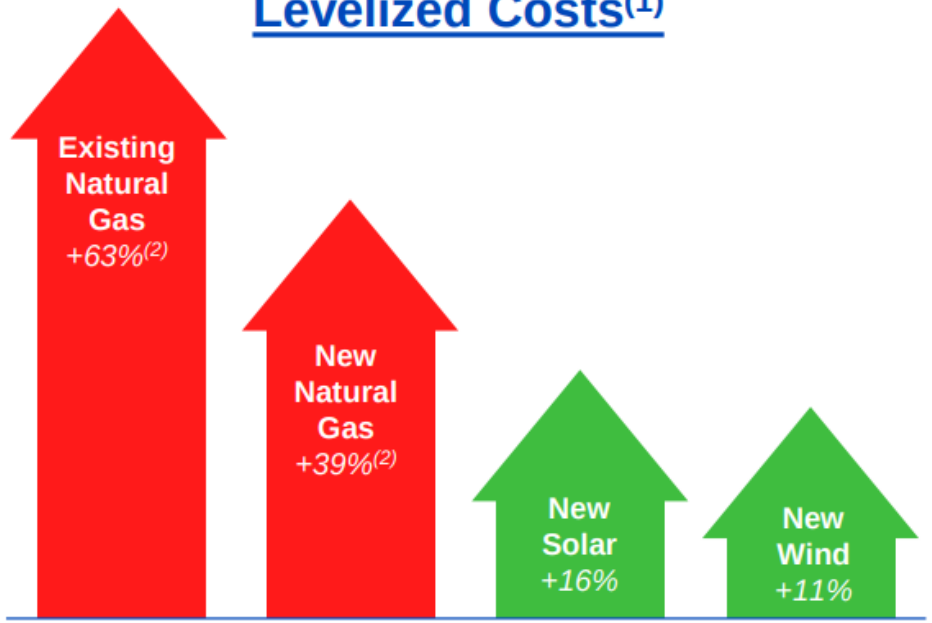
Utility scale solar	$15-$22/MWh
Wind energy	$11-$25/MWh

View of Difference in Energy Cost from New Renewables and New Natural Gas CCGT

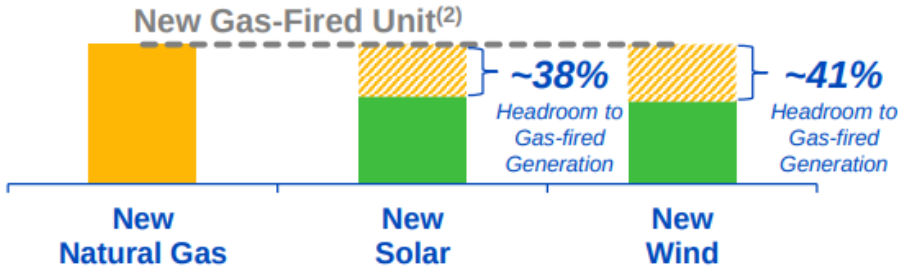
On a relative basis, renewables are now even cheaper than new gas fired generation after accounting for the impacts of the circumvention investigation and inflation

Prevailing Inflation Impacts on Levelized Costs(1)

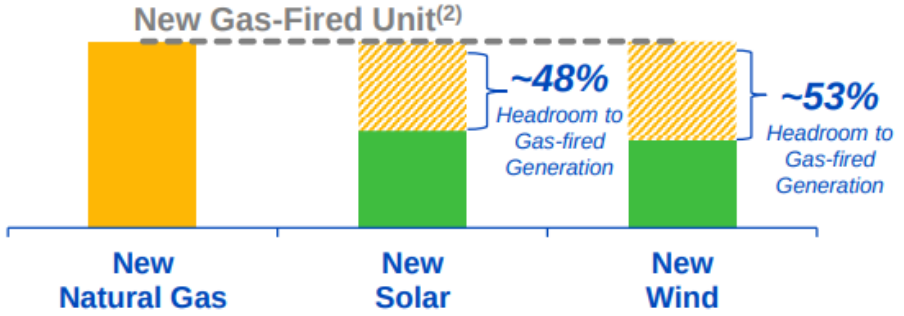
Impacts of Inflation on Levelized Costs(1)



$/MWh Comparison in 2021(3)



$/MWh Comparison in 2022(3)



Source: from NextEra June 14 analyst presentation *Retrieved from NextEra Energy on June 14, 2022*

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**

Inflation Reduction Act (IRA) of 2022 per Investment Bank Credit Suisse 9/22 Research Note

- IRA "will have a **profound effect across industries** in the next decade and beyond"
- IRA's most important provisions, such as its incentives for electric vehicles and zero-carbon electricity, are "uncapped" tax credits. That means that as long as you meet their terms, the government will award them. **There's no budget or limit written into the law that restricts how much the government can spend.**
- U.S. is "poised to become the world's leading energy provider". IRA could further enhance its advantage in all forms of energy production, giving it a "competitive advantage in low-cost clean electricity and hydrogen production, infrastructure, geologic storage, and human capital". **By 2029, U.S. solar and wind could be the cheapest in the world at less than $5 per megawatt-hour, the bank projects;** it will also become competitive in hydrogen, carbon capture and storage, and wind turbines. **(This reflects a PTC of $26/MWH plus a 10% bonus for $28.60/MWH.)**
- For big corporations, the **IRA "definitively changes the narrative from risk mitigation to opportunity capture."** They should be scared of missing out on the economic growth that the energy transition (and the IRA) will bring about.
- Clean energy is now the safe, smart, government-backed bet for conservative investors. **It's really a shocking reversal of the past 40 years.** It is such a change that it hasn't yet been metabolized by the world of people involved in the issue.

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

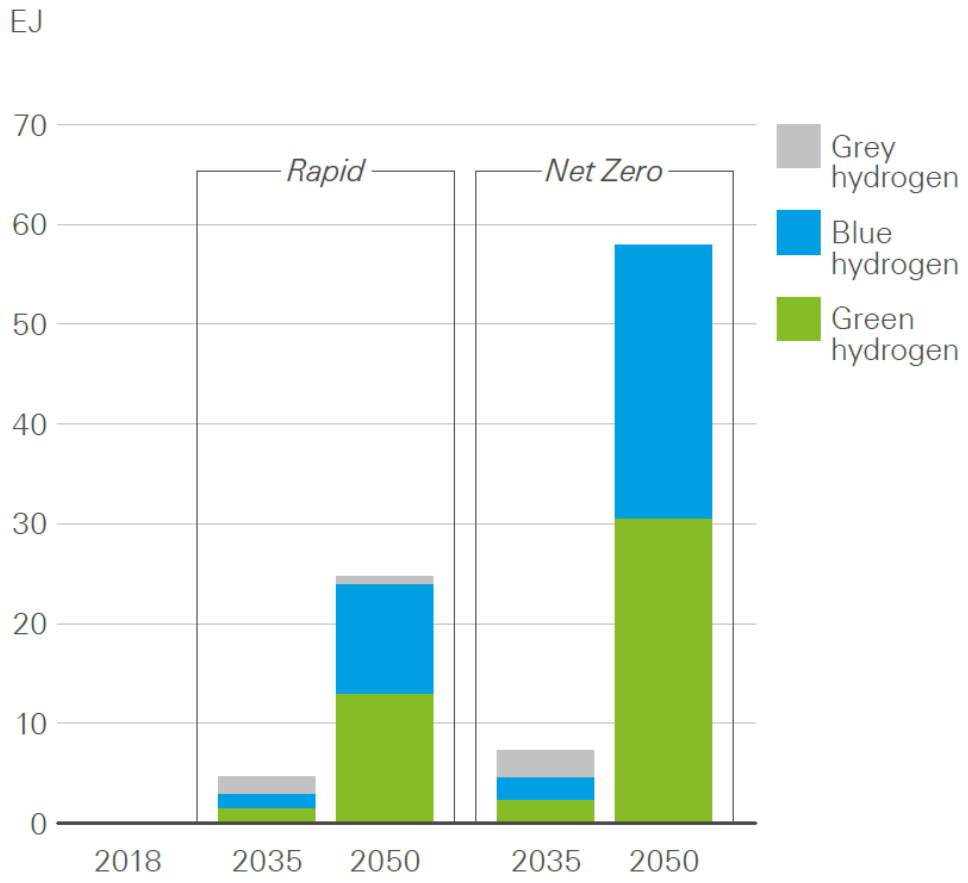
- Sensitivity to Electricity Cost and Electrolyzer Capex

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

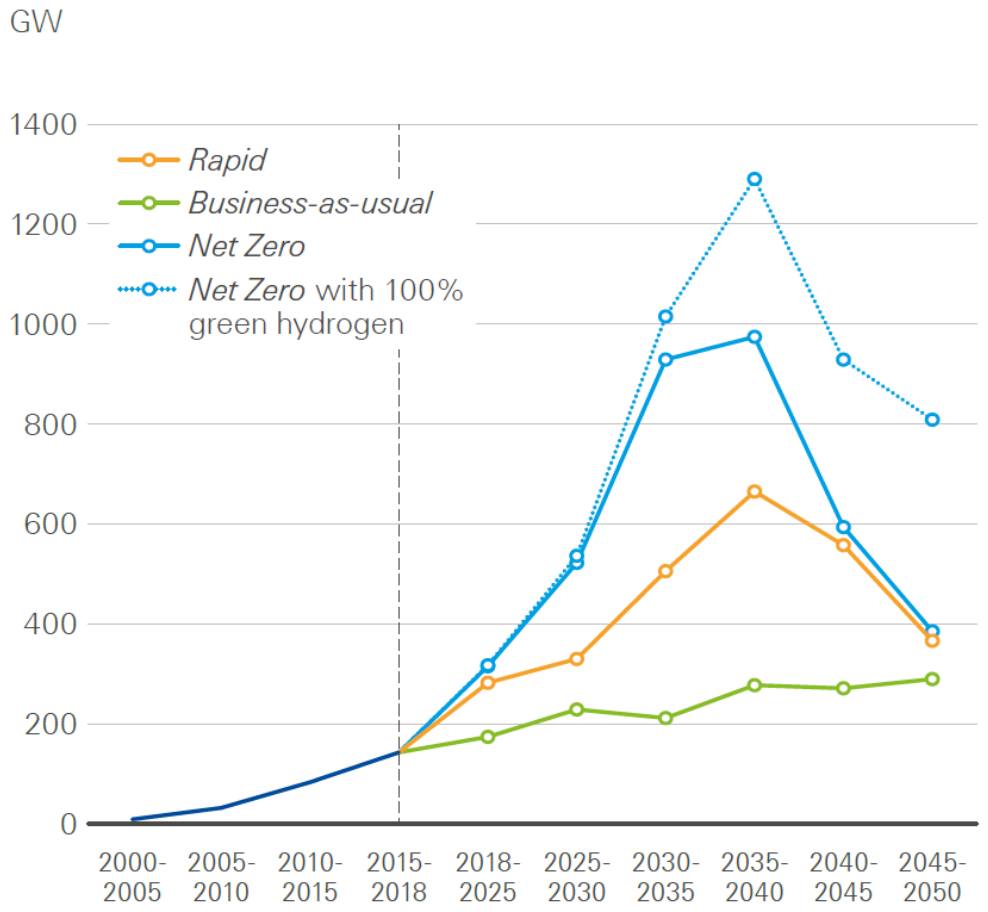
Note: *Sensitivity is based on a 98% electrolyzer utilization rate.*

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

Generating Capacity and Queues – Then and Now

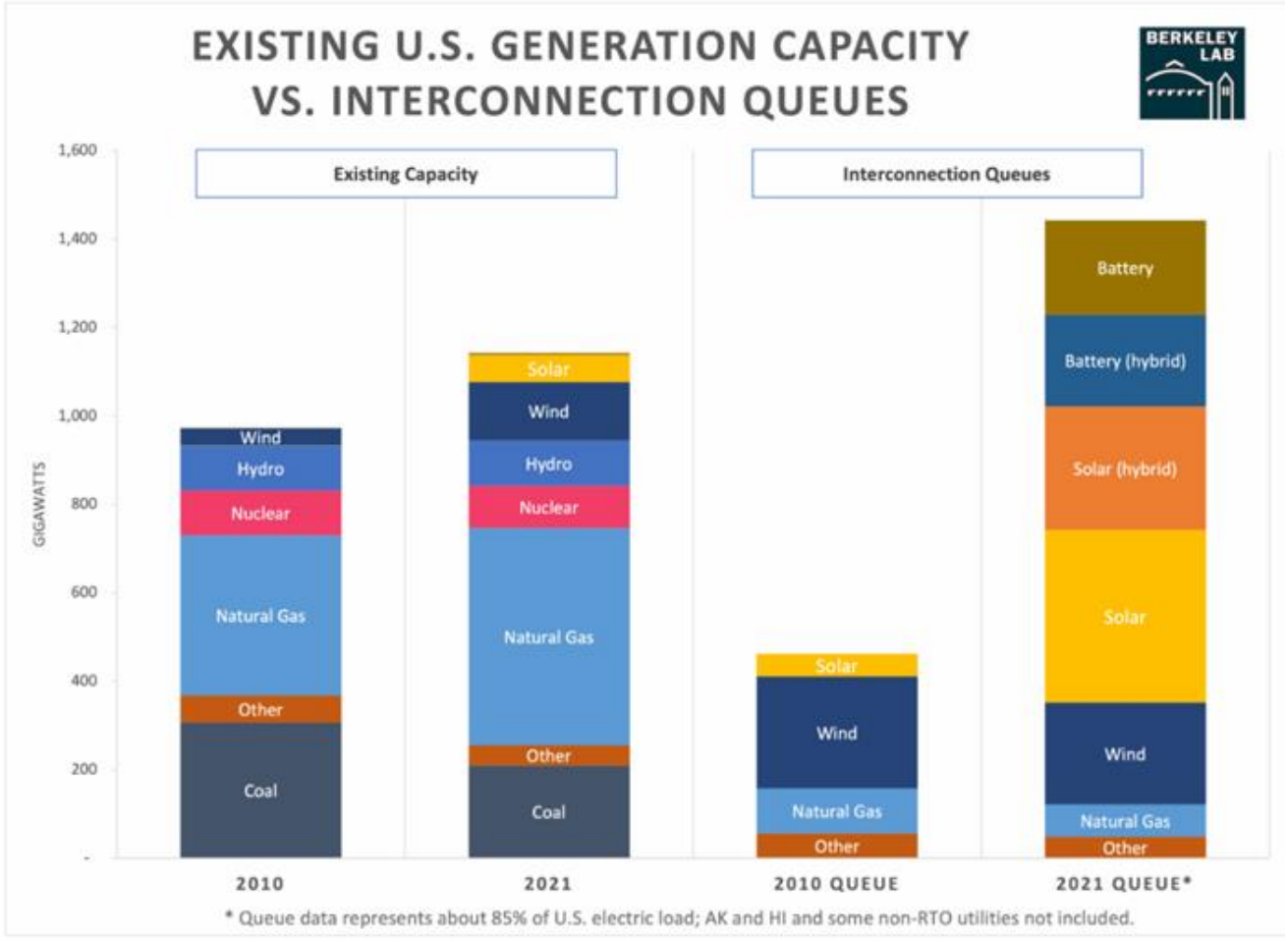


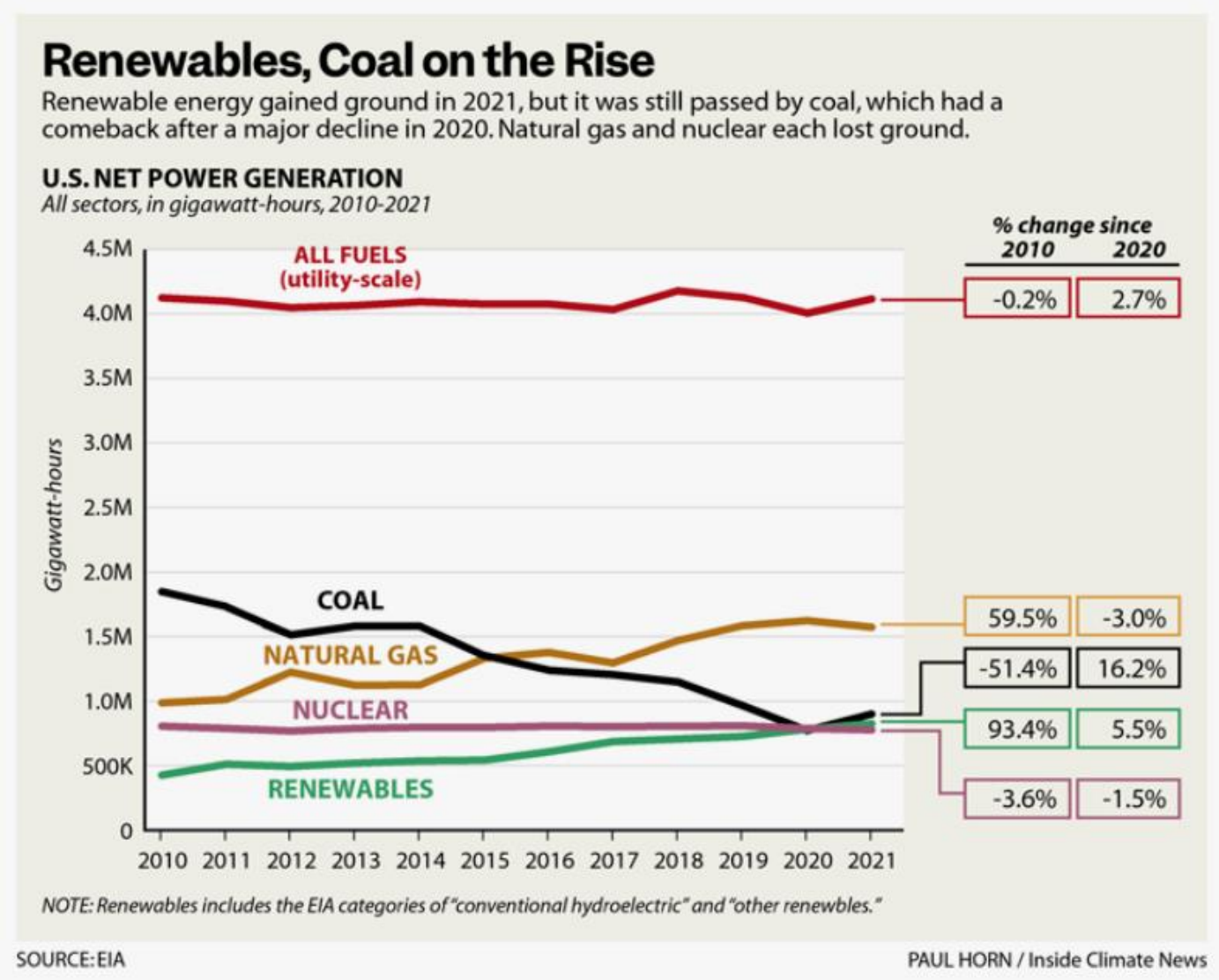
Figure 1: Existing U.S. capacity (2010 and 2021) compared to interconnection queue capacity (2010 and 2021).

Source: Lawrence Berkeley National Laboratory

An Industry Maturing – Globally

- Global wind capacity end of 2021 (GWEC): 837 GW
- Global PV capacity end of 2021 (various): 950 GW
- Variously Estimated Global VG installations in 2022
  - Wind 100 GW
  - PV 150 GW

Still a Ways to Go in the US



Recent Industry Trends

- **“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.
- New Rhode Island law requires 100% clean electricity by 2033, most ambitious in US
- PGE and NextEra open first wind/solar/battery (300MW/50MW/30MW) hybrid plant in the US
- NextEra plans to cut all carbon emissions by 2045, partly via FPL adding 90 GW solar, 50 GW batteries, without increasing customer bills due to lower cost of renewables. Plan includes converting 16 GW of GT to run on green hydrogen. Sees $4T investment opportunity in decarbonizing the US economy by 2050.
- **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). 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. Prototype 20 MW alkaline electrolyzer under development by Thyssenkrupp.
- Siemens Energy and Air Liquide form JV for large scale electrolyzers, 3 GW annual production by 2025
- 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 in 2021 included over 8 GW of announced hydrogen-compatible power turbines
- NYPA, GE successfully pilot hydrogen/natural gas blend firing at 45 MW LM6000 GT at Brentwood plant
- **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'. European Commission announces plans 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
- **Sunrun provides 20 MW capacity from 5,000 customers in ISO-NE capacity market in summer of ’22, a first in US**
- 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
- 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

- **In case you missed it - REPowerEU Action Plan would grow wind energy from 190 GW today to 480 GW in 2030.**
- 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!**
- CA adopts 25 GW planning goal for offshore wind by 2045, bringing US targets to 77 GW
- **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.

EVs

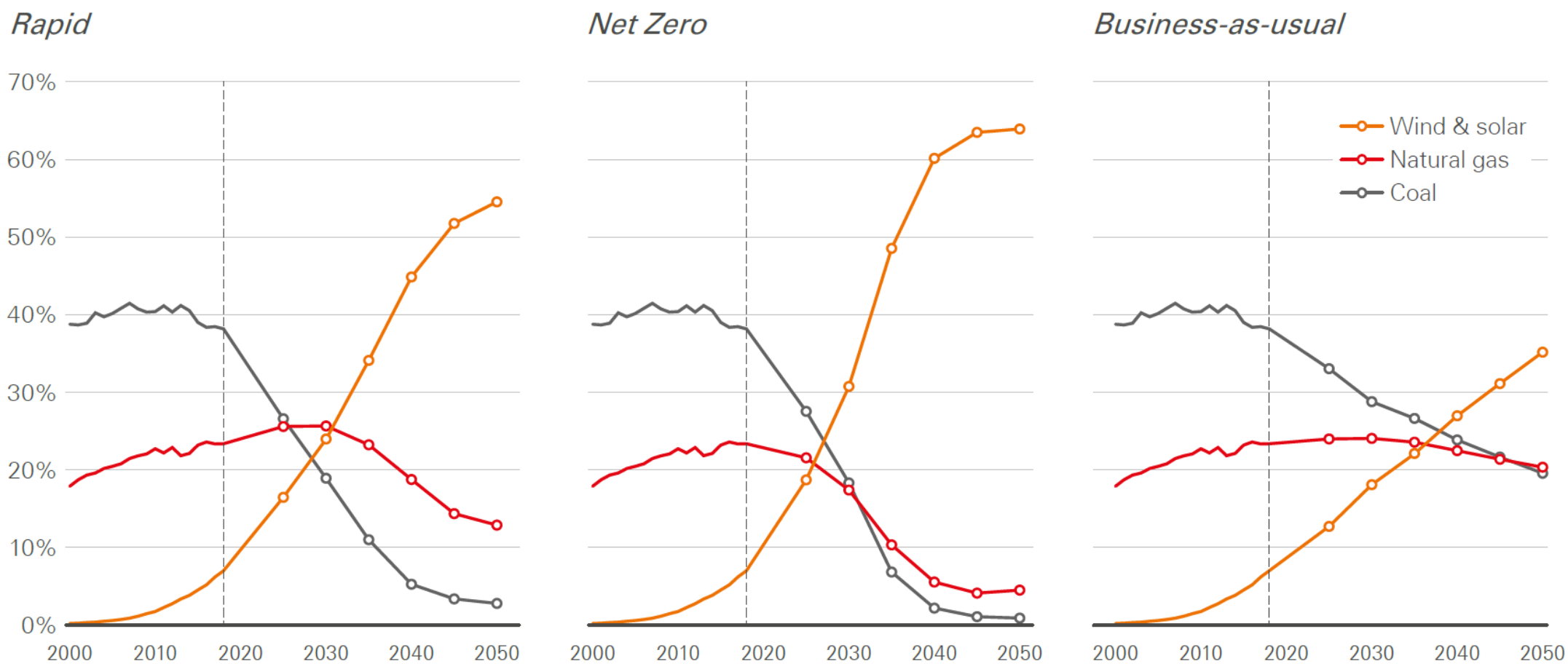
- **Bans on ICEs continue to grow:**
  - UK – 2030
  - Quebec – 2035
  - California – 2035
  - Washington - 2035
  - China – 2035
- **GM to end the sale of all gasoline and diesel powered passenger cars and light-duty SUVs by 2035**
- EVs – the 2021 federal infrastructure package includes $7.5 billion 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.
- **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.**

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**
- 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**
- **Queensland Government has announced the commencement of a detailed design and cost analysis for a potential 5-gigawatt, 24 hr pumped hydro energy storage (PHES) facility, which would be world's largest**
- 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.**

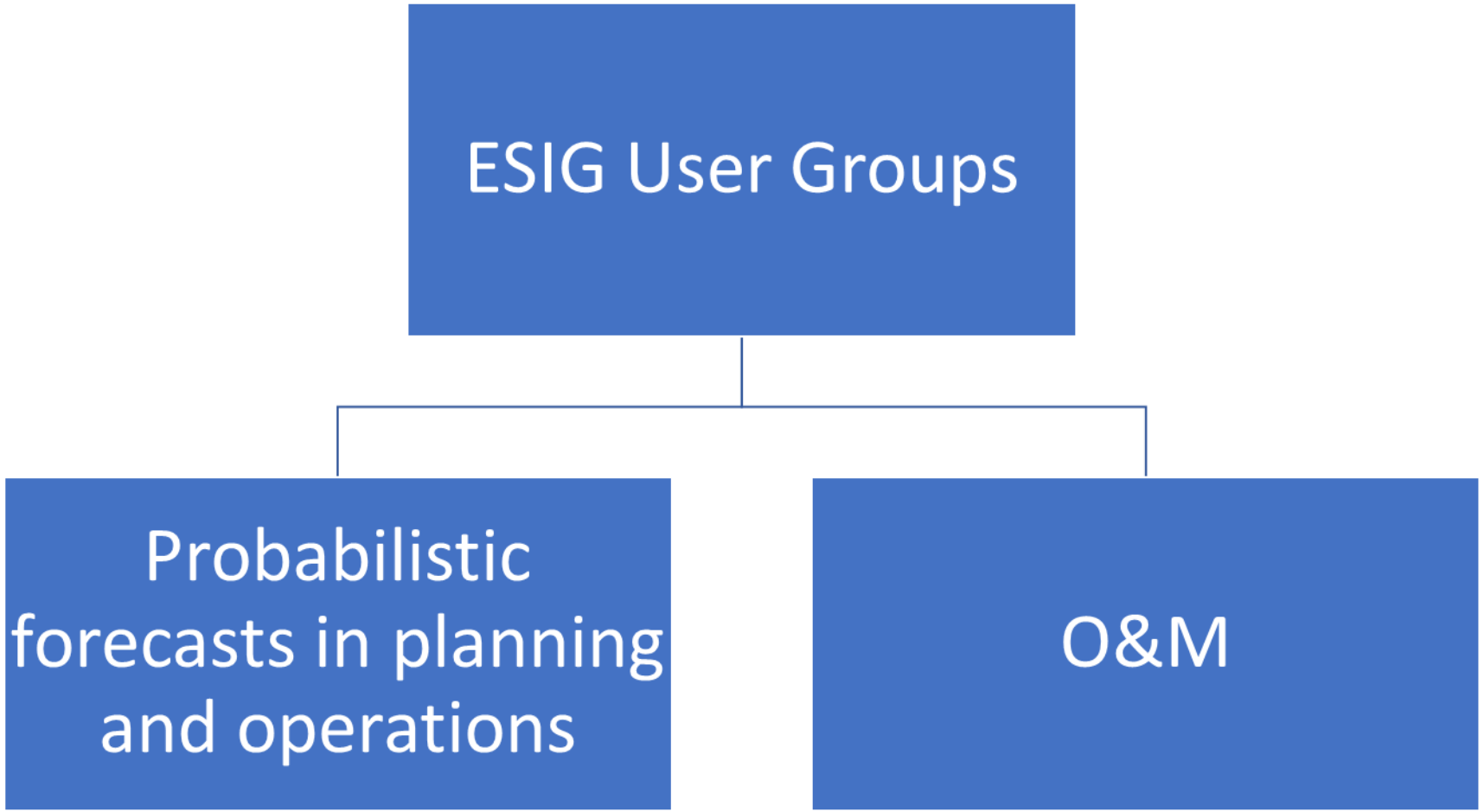
Growth in Power Generation is Led by Wind and Solar Power as Coal Loses Share

Share of global power generation by energy source

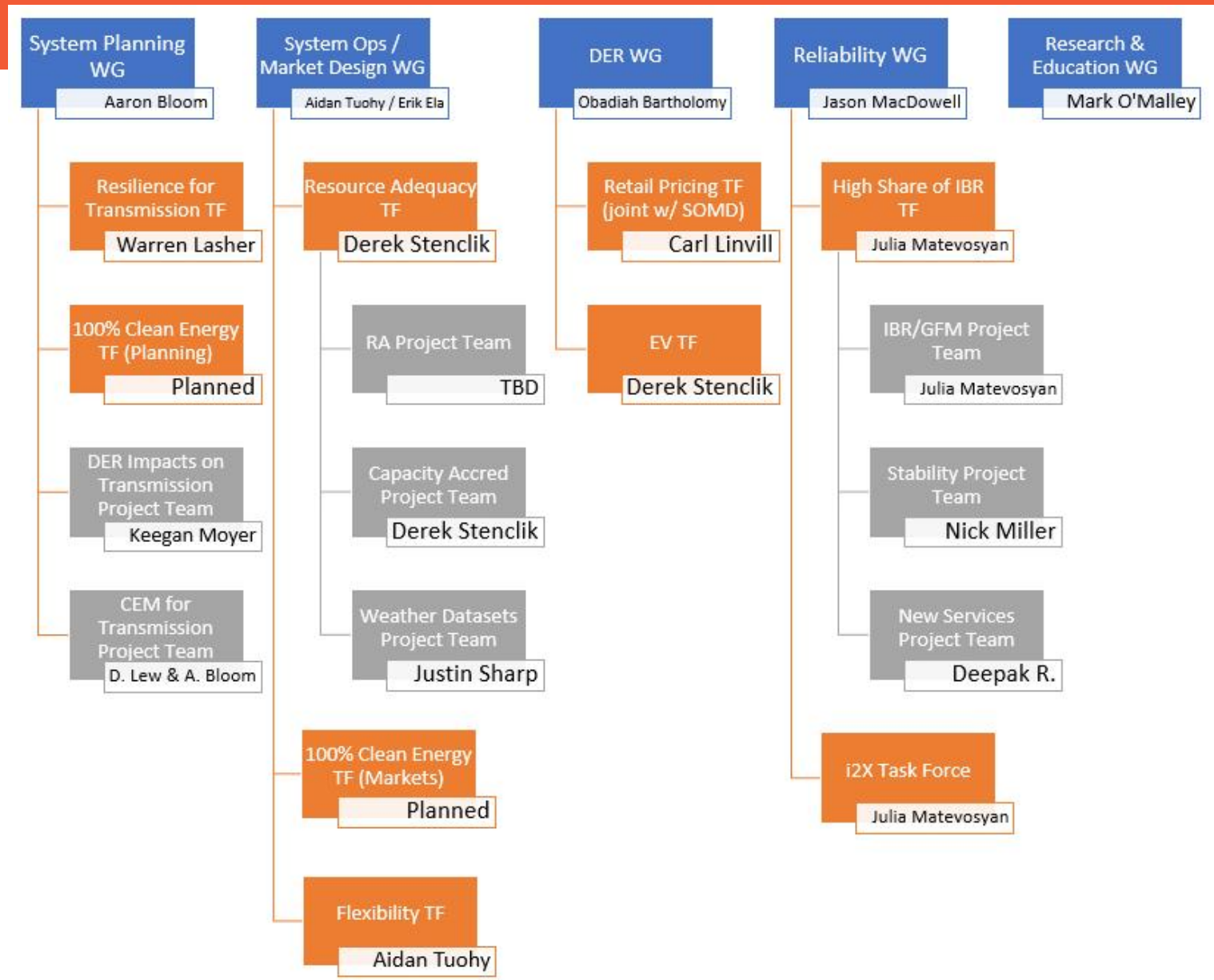


Source: BP Energy Outlook 2020

ESIG User Group Expansion



ESIG Working Group/Task Force Structure



Upcoming Meetings – 2022 and 2023

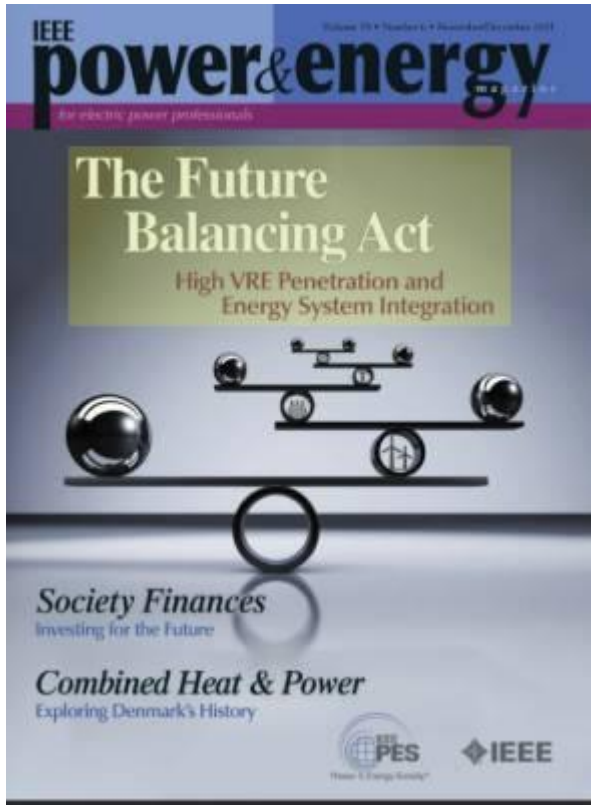
2023 Spring Technical Workshop and Annual Meeting
March 27 – 30, 2023
Tucson, AZ

2023 Meteorology and Markets Workshop
June 13 – 15, 2023
Denver, CO

2023 Fall Technical Workshop
October 23-26, 2023
San Diego, CA

Onward and Upward

- Latest IEEE P&E magazine integration issue published November 2021
- A warm welcome to real and virtual visitors from afar:
  - Australia
  - Korea
  - Belgium
  - Germany
  - Denmark
  - Ireland
  - Canada
  - Texas
- Take the time to make some new friends!
- Looking forward to another great meeting!



THANK YOU

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