Outlook for Renewable Energy and the Global Power System Transformation (GPST)

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CIGRE NGN Webinar
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ESIG Background

- ESIG started as the Utility Wind Interest Group (UWIG) in 1989, a group of six utilities interested in learning more about wind energy

- Wind integration understanding rapidly improved, and was helped by consolidation of balancing areas and growth of larger market operators (ISO/RTOs) in early 2000’s

- Solar energy emerged at scale and with similar integration issues, and UWIG became the Utility Variable Generation Integration Group (UVIG) in 2011

- With renewables, storage and decarbonization as mainstream pathways to the future, UVIG merged in the International Institute for Energy Systems Integration (iiESI) and became the Energy Systems Integration Group (ESIG) in March 2018
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
  - Community Solar $59/MWh
  - Coal $65/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
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

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<th>Electrolyzer Capex ($/kW)</th>
<th>$/kg</th>
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- 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

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
Evolution of Queue Capacity by Generation Type

Figure 2: Total capacity in interconnection queues over time. *Hybrid storage capacity was estimated for some projects using known generator:storage ratios, and was not estimated for years prior to 2020.

Source: Lawrence Berkeley National Laboratory
Regional Queue Distribution

Figure 3: Regional distribution of proposed solar, wind, storage, and gas capacity.

Source: Lawrence Berkeley National Laboratory
Completion Rate and Duration

Figure 4: Completion rate and typical duration to reach commercial operations for projects in the queues.

Source: Lawrence Berkeley National Laboratory
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 and trade barriers, report says
The Data Is Pretty Convincing

Share in Additions to Global Power Capacity

83% renewables in net additions

Source: REN 21

Non-renewable share
Renewable share
Still a Ways to Go in the US

Renewables, Coal on the Rise

Renewable energy gained ground in 2021, but it was still passed by coal, which had a comeback after a major decline in 2020. Natural gas and nuclear each lost ground.

U.S. NET POWER GENERATION
All sectors, in gigawatt-hours, 2010-2021

- ALL FUELS (utility-scale): -0.2% (2010), 2.7% (2020)
- COAL: 59.5% (2010), -3.0% (2020)
- NATURAL GAS: -51.4% (2010), 16.2% (2020)
- NUCLEAR: 93.4% (2010), 5.5% (2020)
- RENEWABLES: -3.6% (2010), -1.5% (2020)

NOTE: Renewables includes the EIA categories of "conventional hydroelectric" and "other renewables."

SOURCE: EIA

PAUL HORN / Inside Climate News
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%.

- “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.

- Utilities plan to close more than 70 gigawatts of coal plants by 2028, one-third of all coal capacity in US

  - April 7, 2022 - Georgia Power Co. outlined planned mix of generating sources for next 20 years
    - Nine coal-burning units and three oil-burning units will be closed by 2028, remaining 2 units shut by 2035
    - “It’s no longer economical to operate the company’s coal units,” said Jeffrey Grubb, director of resource planning. “We don’t see a lot of positives in the future for the coal fleet.”
    - Will replace electricity from coal plants by purchasing 2,356 megawatts of natural gas and adding 2,300 megawatts of power from renewable sources by 2029, increasing to 6,000 megawatts by 2035.
    - “Customers want renewables and no-carbon solutions,” Grubb said.
Some Recent Planning and Operating Headlines

- Great Britain 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 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.
  - With ProjectConnect transmission line by 2025, the plan is to operate without the gas units most hours
  - AEMO to fast-track grid forming inverters to help transition to 100% renewables
- Denmark, 2020, VRE maximum share of hourly demand, 213%;
- 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. Analyst research shows that utilities who 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 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 previously was 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 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.

- **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

- 2019 - Sunrun clears ISO-NE capacity auction with 20 MW VPP aggregating residential PV and storage, first ever
- 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.
Bans on sales of new ICEs continue to grow
- UK – 2030
- Washington State - 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.

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
- Same price as the current 100 kwh battery by 2026
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

• 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
- Fossil fuel industry - crisis demonstrates need for further domestic fossil fuel exploration
- 9 March 22 - 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
- 18 May 22 - EU released legislative package REpowerEU; supports transition from Russian gas by 2027. Increases 2030 solar power capacity target to 600 GW, 40% increase over current target
- Germany and Norway are considering building a hydrogen pipeline linking the two nations to reduce Europe’s dependence on Russian energy supplies.
- 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** - 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

- **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
Electricity Demand Grows Robustly as the World Continues to Electrify

Source: BP Energy Outlook 2020
Growth in Power Generation is Led by Wind and Solar Power as Coal Loses Share

Source: BP Energy Outlook 2020
**Global Power System Transformation (G-PST) Consortium**

**What?**
A global Consortium focused on support to power system operators with advanced, low-emission solutions

**Who?**
- Founding System Operators

**Why?**
Because the **technical and engineering knowledge** is not being created or transferred to power system operators at the **speed and scale** required to support the global energy transition

**G-PST Core Team**
- Technical Institutes

**Developing Country System Operators**
- Indonesia, Ukraine, Vietnam, India, South Africa, Tanzania, Morocco, Peru, Colombia, WAPP and others
Why system operators are key to transition

System operators are responsible for implementing power system transformation

Policymakers and other stakeholders listen to system operators, which can help raise confidence and ambition

System operators must transform procedures and grids to integrate high levels of clean energy and can attract private investment

System operators best learn from and become inspired by their peers, including those at the forefront of integrating RE

System operators have an emerging role in cross-sector electrification and end-use efficiency efforts
Global Power System Transformation Consortium advances action in 5 key areas

1. System Operator Research & Peer Learning
   - CORE TEAM – All Core Team members contribute to all activity pillars
   - REGIONAL LEADS – Coordinate regional peer learning networks and country-level TA delivery efforts for Africa, Asia, and Latin America and the Caribbean
   - INTERIM SECRETARIAT – Work program coordination, partnerships and support, outreach, etc.
   - Perform cutting edge applied research to create novel system operator solutions and globally disseminate and infuse new insights through peer learning

2. System Operator Technical Assistance
   - CORE TEAM – All Core Team members contribute to all activity pillars
   - REGIONAL LEADS – Coordinate regional peer learning networks and country-level TA delivery efforts for Africa, Asia, and Latin America and the Caribbean
   - INTERIM SECRETARIAT – Work program coordination, partnerships and support, outreach, etc.
   - Provide implementation support to scale established best practice engineering and operational solutions

3. Foundational Workforce Development
   - CORE TEAM – All Core Team members contribute to all activity pillars
   - REGIONAL LEADS – Coordinate regional peer learning networks and country-level TA delivery efforts for Africa, Asia, and Latin America and the Caribbean
   - INTERIM SECRETARIAT – Work program coordination, partnerships and support, outreach, etc.
   - Build the inclusive and diverse workforce of tomorrow through enhanced university curriculum and technical upskilling for utility and system operator staff

4. Localized Technology Adoption Support
   - CORE TEAM – All Core Team members contribute to all activity pillars
   - REGIONAL LEADS – Coordinate regional peer learning networks and country-level TA delivery efforts for Africa, Asia, and Latin America and the Caribbean
   - INTERIM SECRETARIAT – Work program coordination, partnerships and support, outreach, etc.
   - Adapt modern power system technologies to individual country contexts through testing programs and standards development activities

5. Open Data and Tools
   - CORE TEAM – All Core Team members contribute to all activity pillars
   - REGIONAL LEADS – Coordinate regional peer learning networks and country-level TA delivery efforts for Africa, Asia, and Latin America and the Caribbean
   - INTERIM SECRETARIAT – Work program coordination, partnerships and support, outreach, etc.
   - Support rigorous planning, operational analysis and enhanced real-time system monitoring through open data and tools
Pillar 1: System Operator Research and Peer Learning

Consensus Priority Research Program Areas

- Inverter Design
  - Designing inverter capabilities for power systems
- Analytical Tools and Methods
  - Generating new simulation methods for power system operation
- Control Room of the Future
  - Enhancing real-time awareness and control over future power systems
- Black Start
  - Ensuring resiliency through novel inverter-based system restart methods
- Power System Planning
  - Creating new approaches for reliable planning of future power systems

Quick Wins

- Understand and apply known cutting-edge solutions from System Operator peers
- Translate existing state-of-the-art research results into application
- Commence coordinated research and piloting activities

Transformative Solutions

- Breakthrough technologies
- Innovative engineering solutions
- Paradigm shifts

All areas highly interrelated

Effective Coordination to Achieve Holistic Solutions

9+ month consultation process with leading System Operators and global Research Institutes

2021
Pillar 1: System Operator 
Research & Peer Learning

**Research Agenda Group:** 6 CTOs (or equivalent) from 6 Founding System Operators + Senior Research Institute Staff

**Immediate Focus:** Identifying critical research opportunities to address the priorities laid out in the Inaugural Research Agenda via focused research teams

**Research Support:** FSOs and researchers have commenced deeper discussions seeking support from national research programs and are exploring opportunities to leverage existing or planned research projects well-aligned with FSO priorities

**Structured Peer Learning:** ESIG series of knowledge exchanges and webinars amongst Founding System Operators and other system operators on cutting edge operational innovations and applied R&D solutions ongoing

**Research Advisory Committee:** Launched as a mechanism of collecting broader stakeholder input for research activities and for exploring critical topics outside of the Research Agenda
Pillar 2: System Operator
Technical Assistance Approach

Dynamic and targeted technical assistance program – coordinated with existing initiatives

Emerging and Developing Economy System Operator

Ongoing technical assistance – imbedded advisors and expert analytic and technical support

G-PST Fellowship

Fellowship at FSO for 1-3 months (2 staff per System Operator)

Application of Learning

Return to system operator institution and receive ongoing technical assistance (remote and in-person) to apply advanced engineering and operational solutions
Pillar 2: System Operator Technical Support

- Control room roadmap technical collaboration
- Contingency analysis and inertia monitoring technical collaboration
- Technical peer learning as follow-on to NREL USAID project
- Peer learning and technical collaboration on forecasting, system recovery and resilience
- Capacity building, women's professional development and data and tool development
- Knowledge sharing on cyber security, control room upgrades (planned) and training on open-source tools
- Collaboration on open inertia monitoring tool and TSO-DSO for DER peer learning with FSOs
- Peer-to-peer knowledge sessions (10) with FSOs and support for control center upgrade
THANK YOU

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