Resource Generation Adequacy

January 25, 2023

Black & Veatch

PRESENTATION OUTLINE

- Introduction to Black & Veatch
- Grid and Reliability Needs
- Coal Unit Retirement
- Fuel Availability and Delivery Issues (Natural Gas)
- Supply Chain Issues for Renewable Transition
- Emerging Technologies
- Technology Outlook: Renewable Reliability and Resilience

Introduction to Black & Veatch

Making the Invisible, Invaluable

Casey Hicks, Sr. Client Account Manager

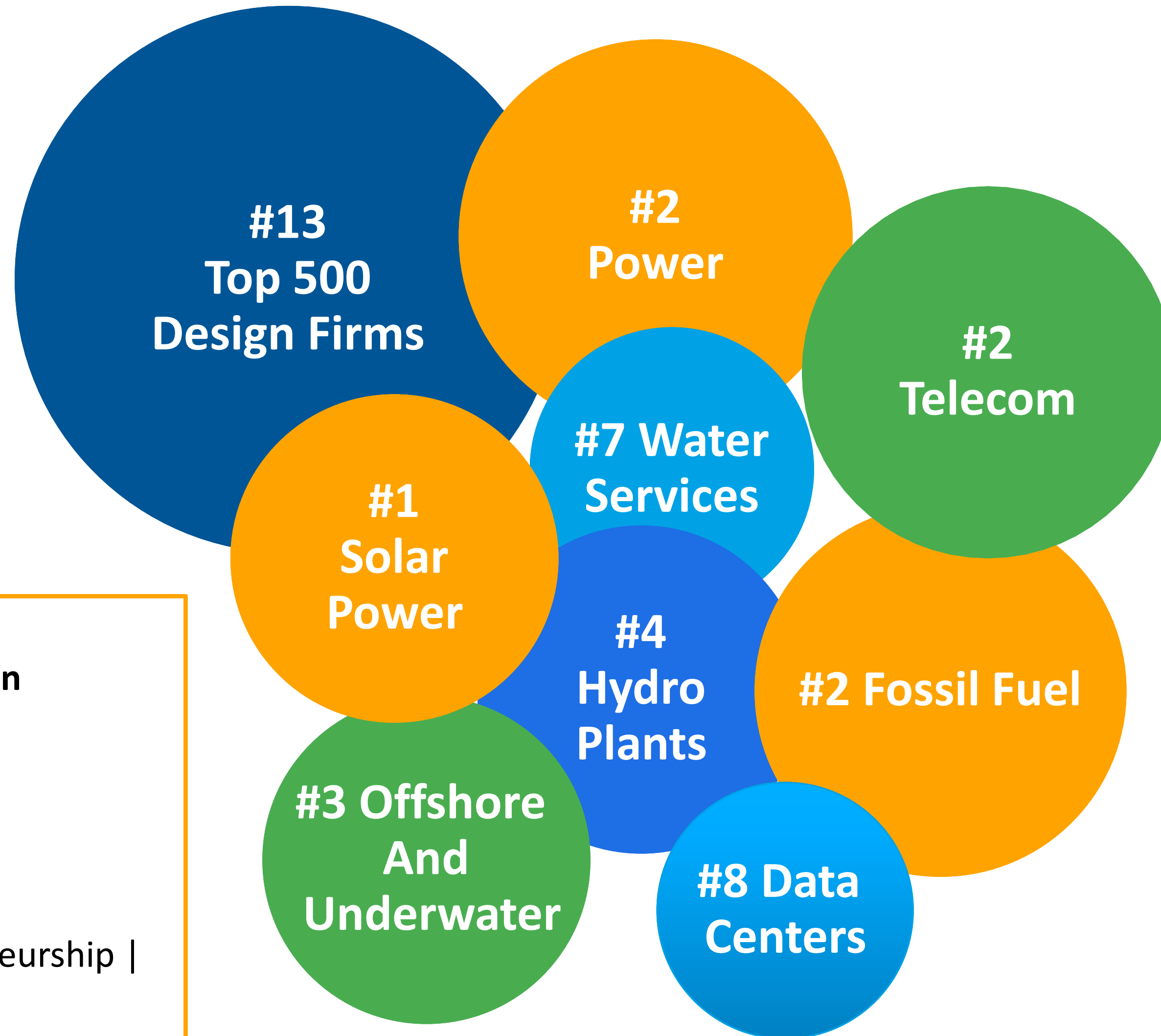
Today’s Black & Veatch

- **9,200+ professionals in 120+ offices**
- **HQ in USA; 50+ years across Asia**
- **100% Employee Owned**
- **Projects in 100+ countries on six continents**
- **$4+ billion revenue in 2022**
- **10.5M Site Hours in 2021**

Mission: *Why we exist*
Building a world of difference **through innovation in sustainable infrastructure**

Vision: *What future we aspire to achieve*
We work relentlessly to solve humanity’s critical infrastructure challenges

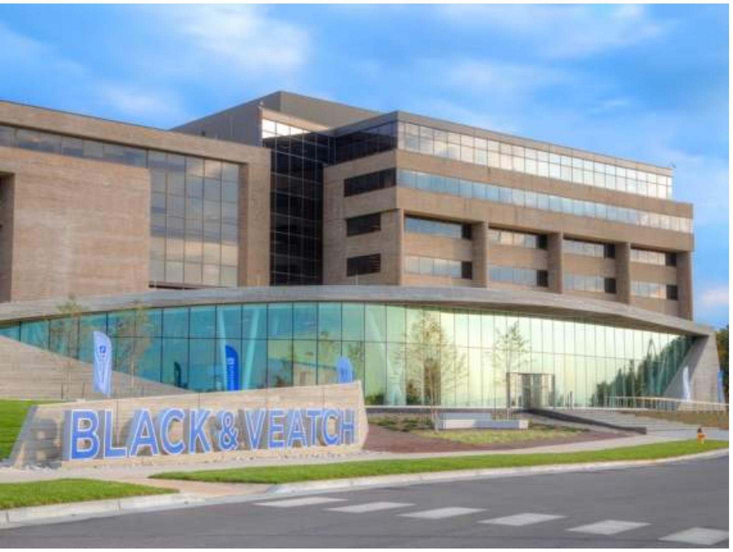
Values: *What we believe and how we behave*
Safety | Accountability | Collaboration | Entrepreneurship | Integrity | Ownership | Respect



Current Engineering News-Record rankings.

No Place Like Home (Kansas)

- Established in 1915 "Get work. Do work. Get paid."
- The business core in 1915 was in KCMO
- In 2009 we made Kansas our Global Headquarters
- **Sustainable human infrastructure** – engineering, procurement, consulting and construction



Building a World of Difference through Innovation in Sustainable Infrastructure

- Decarbonization
- Sustainable Water Management
- Materials & Waste
- Environmental Footprint
- Resilient & Adaptive Infrastructure
- Systems Connectivity
- Community & Social Resilience

Grid and Reliability Needs

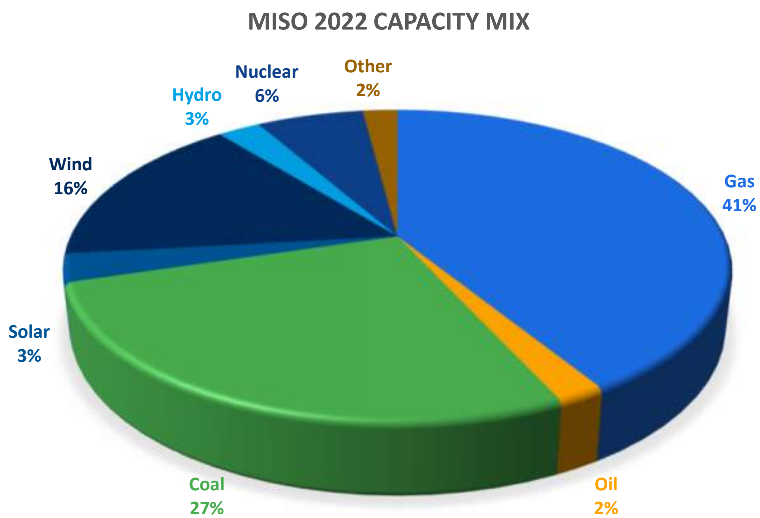
Current Generation Mix

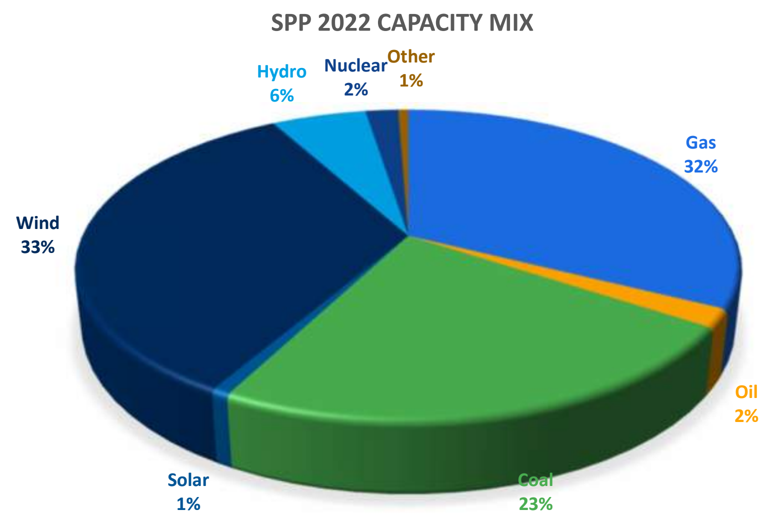
Hua Fang, North America Energy Markets Strategy and Planning Practice Lead

MISO & SPP CURRENT GENERATION MIX

- MISO and SPP capacity mixes are dominated by gas and coal. These resources reflect 68% of the capacity mix in MISO and 55% in SPP.

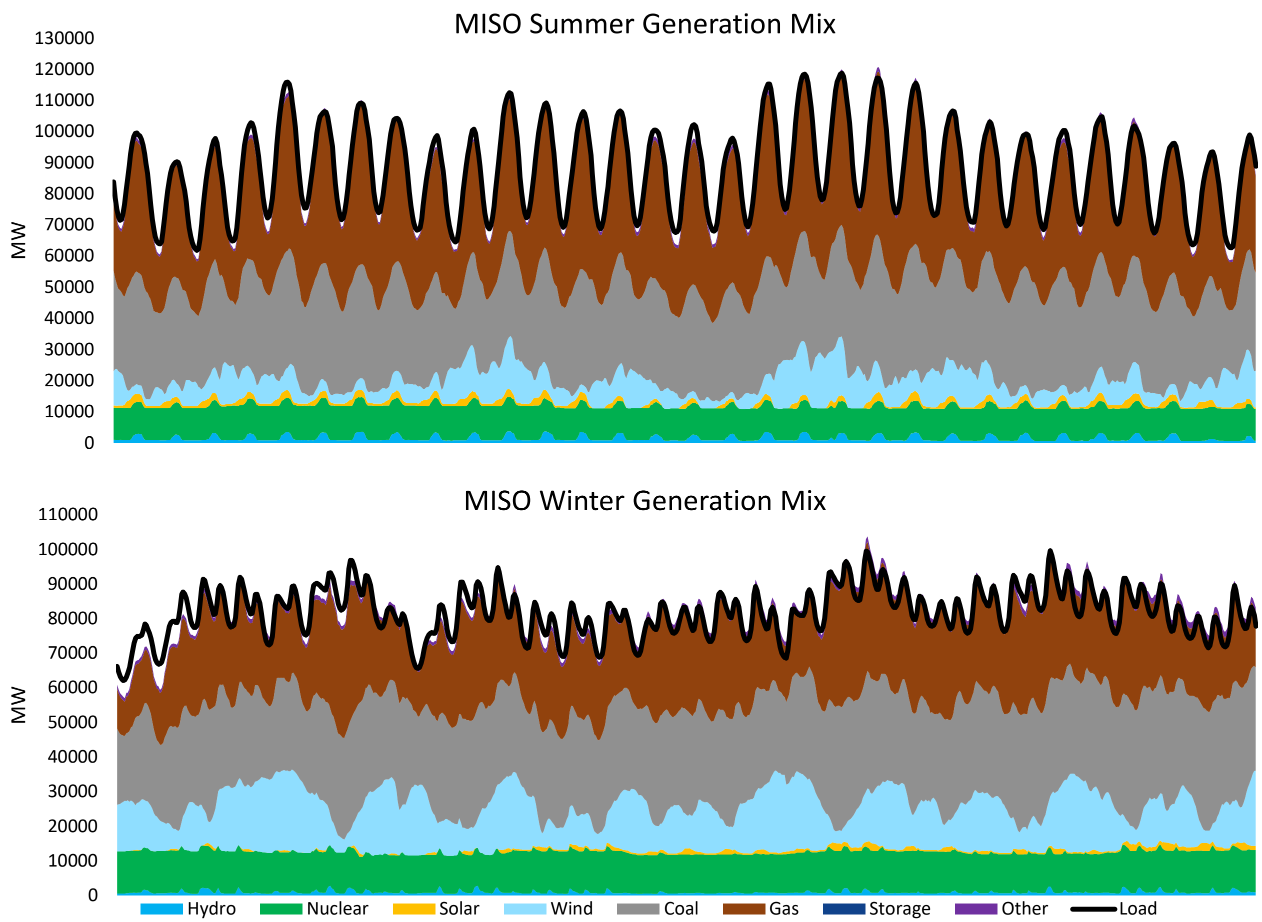
- Wind is the major source of clean energy generation in both the ISOs due to higher production potential for wind resources in the Midwest states. SPP has a larger share of clean energy resources compared to MISO.





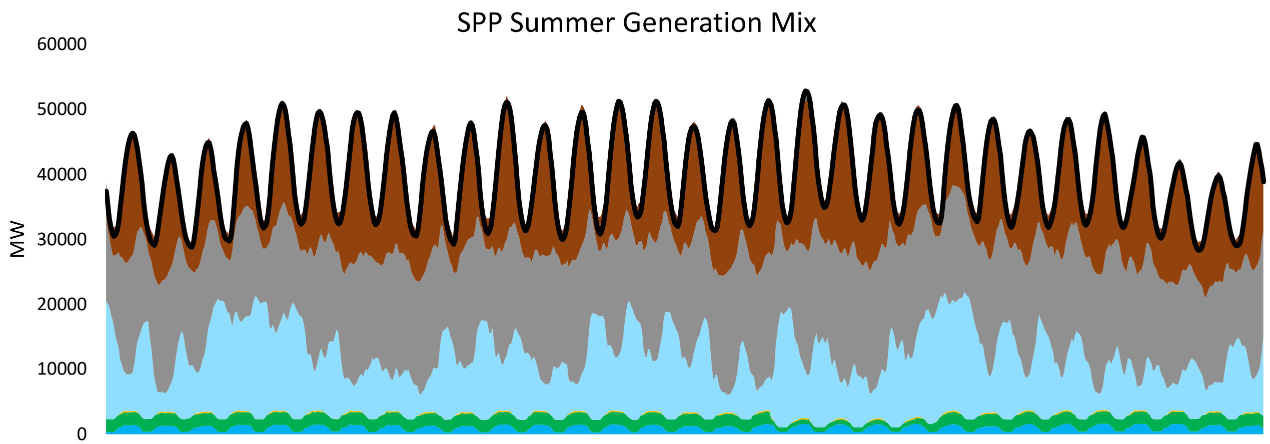
MISO SEASONAL GENERATION

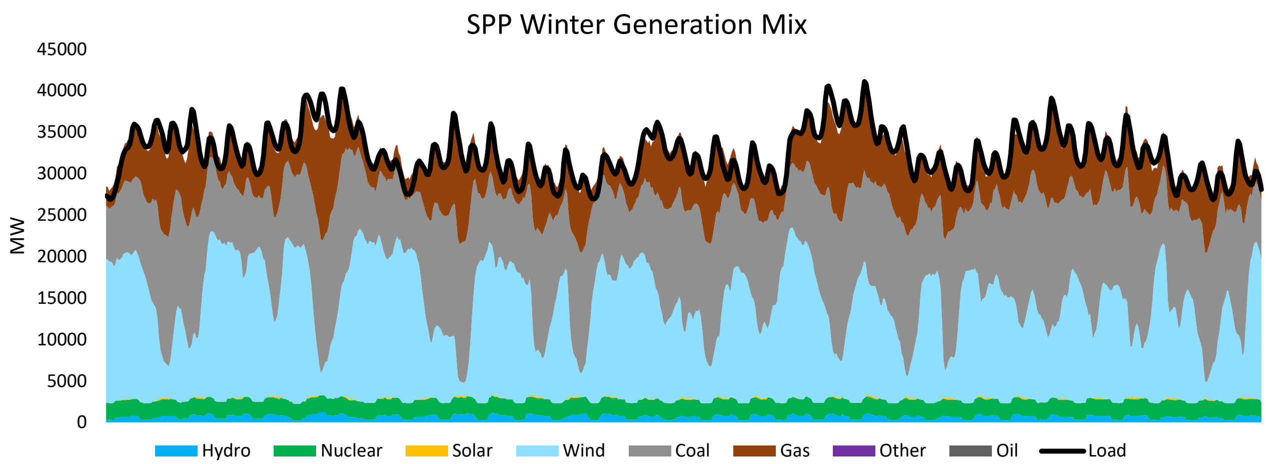
- MISO currently has heavy reliance on both coal and gas to meet its generation requirements especially in summer months.
- A majority of the current ramping needs in the summer months resulting from load volatility is met through gas-fired generation.
- Wind generation plays a critical role in MISO during winter months when wind capacity factors are higher with wind roughly providing 17% of the total generation.



SPP SEASONAL GENERATION

- With wind reflecting more than 30% of the capacity mix, SPP has heavy reliance on wind generation with wind providing a large portion of the generation needs in both seasons (more in winter than in summer)
- SPP also has heavy reliance on coal for baseload generation during both summer and winter months.
- Gas-based generation provides most of the ramping needs in SPP with gas ramping up and down with changes in load and wind generation.





THERMAL GENERATION RELIABILITY

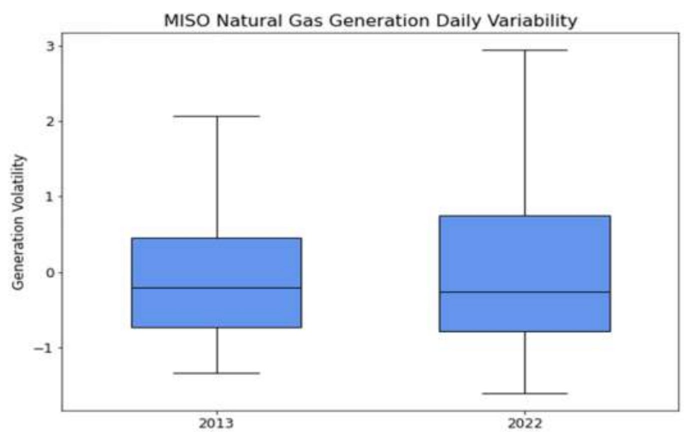
- Thermal generation typically has high reliability, however, increase of renewable generation in the system changes the operational profile of thermal resources that could adversely impact their reliability and economics over time.

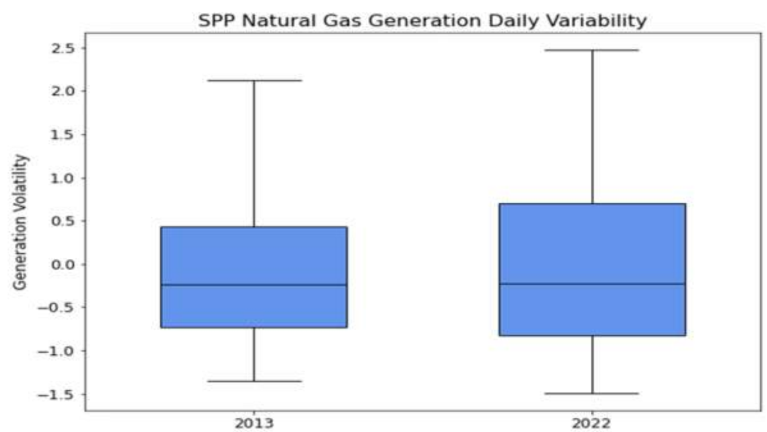
- As a result of intermittent nature of renewable generation, increase in share of such resources results in increase in system ramp requirements, energy balancing requirements, price, and generation volatility.

- This results in conventional thermal resources to increasingly cycle more often and ramp up and down as renewable generation changes. Higher amount of cycling or generation variability can result in more frequent maintenance or higher maintenance cost for conventional thermal generators which could adversely impact the underlying economics for such generators.

- Declining energy prices due to renewable penetration may create less of an incentive for baseload conventional thermal generation to invest in maintenance.

- Increase in need for more frequent maintenance but lack of incentives do so could result in higher outages for conventional generation and impact their over reliability.





Reliability Issues with Continued Transition to Variable Generation

Kevin Ludwig, Grid Solutions Portfolio Leader

Changing Grid – Leads to New Topologies

- Retiring of Synchronous Generators due to Generation Mix adjustments leading to increasing needs in
  - Dynamic Reactive Power
  - Short Circuit Current
  - Grid Inertia
- Variable Generation commonly correlated with Inverter Based Generation which operate differently than Synchronous Generators
- Variable Generation with some established technologies can bridge the gap.
- Trends are leading to additional demand for FACTS, Synchronous Condensers and Battery Energy Storage Systems (BESS)

Dania Beach - BESS

Inertia – Real World Examples

- Inertia Examples and Resolutions
  - UK August 9, 2019 electrical disruption (loss of over 1 million consumers due to a loss of 1,000MW of generation)
  - Frequency drop due to loss of system inertia with change in generation portfolio
  - UK establishes an Inertia Market and solicits tenders from the market awarding contracts for Inertia
  - Initial awards routed towards offers which considered Synchronous Condensers (some at retired power plants)

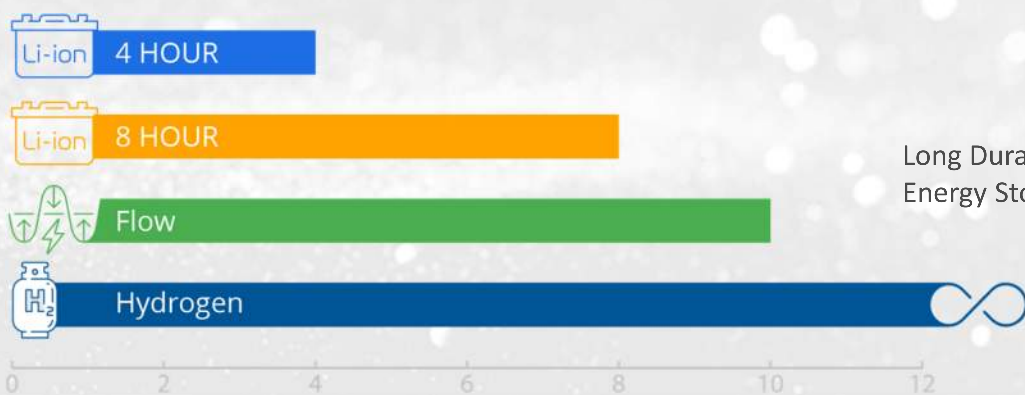
Inertia solutions available and deployable with proactive planning

Voltage and Reactive Power Support

- Inverter Based Generation may require supplemental reactive power
  - Capacitor Banks
  - FACTS devices – STATCOMs
- Supplemental Reactive Power is proven technology with significant market demand

Regulation and Contingency Reserve

- Long duration energy storage (LDES) developments along with traditional options
- Carbon-free baseload developments plus reliance on traditional fuels
- Contingency review margins and potential increase as a result of climatic variability
- Overbuild of variable resources paired with storage to offer fuel assurance
- Interregional bulk power transmission



Long Duration and Long-Term Energy Storage, LDES

Coal Unit Retirement

Sufficient Replacement of Coal Units with Natural Gas

Hua Fang, North America Energy Markets Strategy and Planning Practice Lead

MISO COAL CAPACITY

- As of 2022, there is 51 GW of coal capacity in MISO that operates at an average capacity factor of 49%.
- A significant portion of the coal capacity (~ 28 GW)in MISO has been announced or planned to retire and more coal capacity could retire over time with increase in penetration of renewables that would put downward pressure on energy prices especially during off-peak hours.
- Coal generation reflects a significant portion of MISO's capacity mix and typically has high reliability contribution.
- Approximately 31 GW of new combined cycle capacity would be required to replace existing coal generation for maintaining similar system reliability.
- Assuming a heat rate of 6400 Btu/kWh for new combined cycles, this would translate to a natural gas demand of roughly 548 MMBtu/day.

Tenaska Westmoreland Generating Station – Combined Cycle

SPP COAL CAPACITY

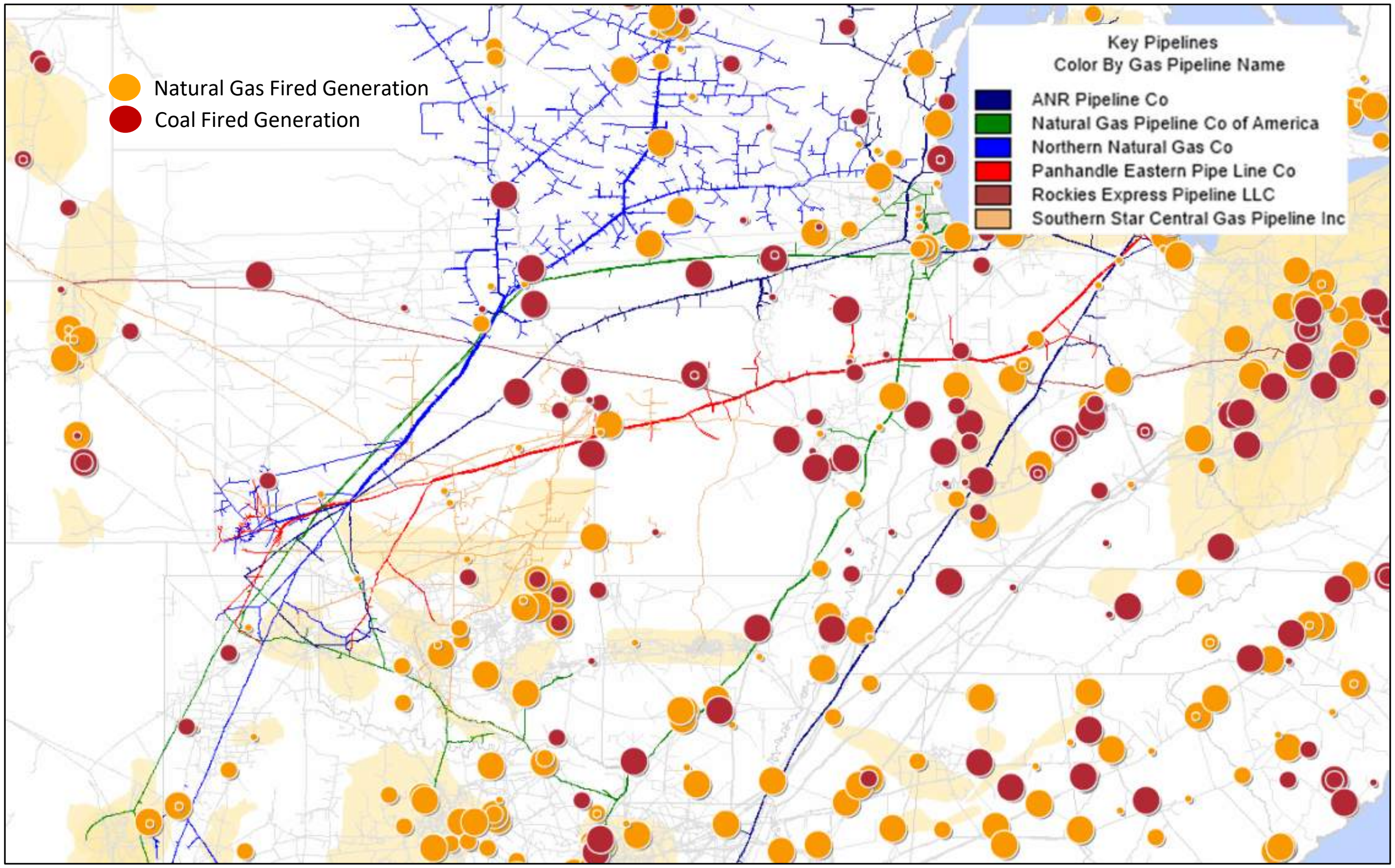
- As of 2022, there is 24 GW of coal capacity in SPP that operates at an average capacity factor of 46%. Similar to MISO, coal generation reflects a significant portion of SPP's capacity.
- However, in contrast to MISO, currently there is not much coal capacity that has been announced or planned to retire in SPP.
- As of 2022, announced coal plant retirements have been roughly around 4 GW in SPP. But with expected increase in penetration of renewables, more coal capacity could retire.
- Approximately 14 GW of new combined cycle capacity would be required to replace all existing coal generation in SPP for maintaining similar system reliability.
- Assuming a heat rate of 6400 Btu/kWh for new combined cycles, this would translate to a natural gas demand of roughly 242 MMBtu/day.

Fuel Availability and Delivery Issues (Natural Gas)

Concerns for Fuel Deliverability and Availability

Hua Fang, North America Energy Markets Strategy and Planning Practice Lead

Natural Gas Infrastructure and SPP Thermal Generation



- Most prolific production basins are in Marcellus/Utica Shale and the Permian basin transported via interconnected interstate pipeline network
- Natural gas utilities hold firm transportation capacity on interstate pipelines with priority rights under tight conditions
- Critical gas generation facilities need to have firm fuel supply

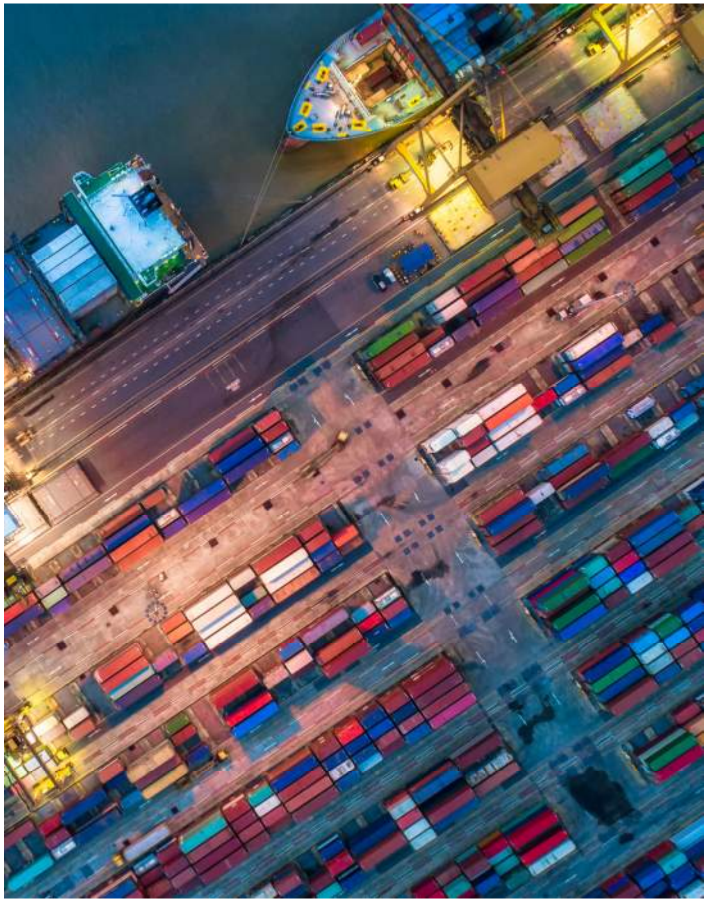
Supply Chain Issues for Renewable Transition

Supply Chain Issues and Implications

Aaron Kinkelaar, Supply Chain Lead - Renewables

Supply Chain Market Updates

- Some relief in supply chain disruptions expected in first half of 2023. Global inventory levels of raw materials and commodities are low, a slight increase in demand could cause large price increases and extended lead times.
- Transportation prices have decreased with lower consumer demand, however prices remain above pre-pandemic levels, and like commodities could increase quickly with any increase in demand.
- Labor market shortages and strikes; US-China trade relationship; continued COVID-19 issues; and resource shortages across critical technologies (such as semiconductors).
- Transformers, switchgear, and other electrical equipment packages used in other industries are still reporting significant lead times, some quoting more that 2 years out.



The passage of the Creating Helpful Incentives to Produce Semiconductors for America (CHIPS) and the Inflation Reduction Act in 2022 should provide supply chain relief, but starting new production lines takes time.

Solar Market Update

- **Anti-Dumping Countervailing Duties (AD/CVD)** Investigation started March 2022, preliminary findings released Dec 2022, final determination expected May 2023. Investigation based on claim by Auxin Solar that Chinese owned module production is using production lines in Malaysia, Cambodia, Vietnam, and Thailand to circumvent duties otherwise applied to Chinese produced modules. Possibility of significant retroactive tariffs caused pause in module shipments to US. The Executive Order issued June 2022 provided a 2-year bridge on no new tariffs, but didn't seem to increase confidence in importation.
- **Uyghur Forced Labor Prevention Act (UFLPA)** Largest tier 1 module suppliers detained starting in July 2022 while US Customs determined what was required for new traceability requirements. Some release of detainment began to take place December 2022, some continues. Mostly it is the manufacturer that bears the cost of detainment, which is significant. Because of this, many manufacturers are not shipping to the US until this is resolved.
- **Inflation Reduction Act (IRA)** Suppliers incentivized to move production to the US. Project level 10% tax incentive to buy 40% domestic content. It is widely believed that reaching domestic content will require the modules to be considered "domestic". IRS/Treasury determination on what is considered "domestic" has been delayed but expected early 2023.

Many module suppliers interested in expanding production in the US, but could be 2 or more years before the volume enters the US market. Existing US production is reporting they are sold out for next 3-5 years.

Emerging Technologies

Emerging Technologies – Small Modular Reactors

Mark Gake, Nuclear Technology Manager

New Nuclear is Getting a ~~Second~~ Third Look

- Renaissance Part 3
  - LLWR renaissance didn't happen in early 2000's
  - Interest in LWR SMRs in 2012-2014 quickly faded due to gas market
  - Growing interest in the potential of advanced SMRs but still challenges
- Government providing funding to encourage technology
  - Technology awards
  - ARDP Demonstration Projects
  - Infrastructure Bill provided $25 Billion to industry projects (out of $1.2T)

Utilities are increasingly looking to nuclear as an option to meet 2050 carbon-free goals, but industry must deliver on this third opportunity

Nuclear Generation Trends in U.S.

- Subsequent License Renewal (SLR) for existing plants
- Vogtle likely last new LLWR in U.S.
- U.S. utilities are updating their IRPs and looking at potential of SMRs to fill carbon free energy gaps beyond 2030
- Several U.S. utilities doing SMR siting and technology studies
- Starting to see non-nuclear utility/industrial interest in SMR technology
- Need to replace coal-fired generation to provide “baseload” capacity
- Uncertainty of timing regarding hydrogen build-out
- SMR developers and Big Tech securing sites and providing capital

The Nuclear SMR Technology

GEN III+

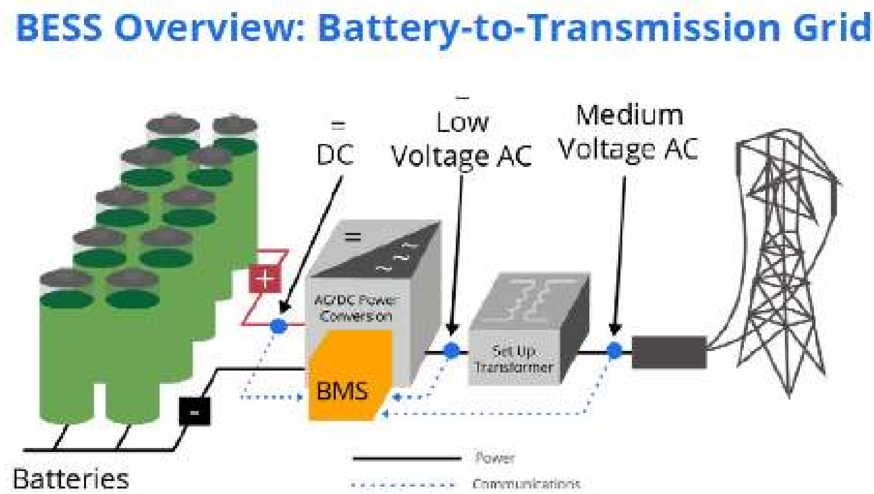
- LWR technology well understood
- BWR and PWR options
- Gen III+ provides passive safety with inherent safety features
- Conventional fuel
- Ready today
- NuScale VOYGR, GEH BWRX-300, Holtec SMR-160

GEN IV

- Gen IV technology not new
- LMFBR, HTGR, MSR/FHR designs
- Higher temperatures for better efficiency and process heat
- TRISO fuel provides additional safety (accident tolerant fuel)
- Terrapower, Kairos, PRISM, Moltex, Oklo, X-energy, Terrestrial Energy

Both Gen III+ and Gen IV can address decarbonization goals and both are likely to support the timing needs if funding continues and cost targets are met


2050 Will Look Different with Nuclear
Third Way



Emerged and Emerging Technologies – Energy Storage

Frank Jakob, Energy Storage Solution Director

Energy Storage Solutions (ESS)

- **Past: Pumped Hydroelectric Storage (PHS)**
  - **Primary *use case*: load level coal, nuclear, gas power plants night-to-day**
    - **Over 90% of storage on the grid today is still PHS**
- **Present: Lithium-ion Batteries (LIB)**
  - **Primary *use case*: short (<1 hour) and medium (2 to 4, up to 8 hours)**
    - **Short: frequency regulation, primary & secondary frequency reserves**
    - **Medium: smoothing, time shifting variable renewable generation**
- Future: Long Duration Energy Storage (LDES)
  - Primary *use case*: longer durations than LIB, days to weeks
  - Paired with generation, transmission, distribution, and facilities

As variable renewable generation increases, ESS steps in to provide
1) reliability, 2) resiliency, 3) adequacy, and 4) operational flexibility

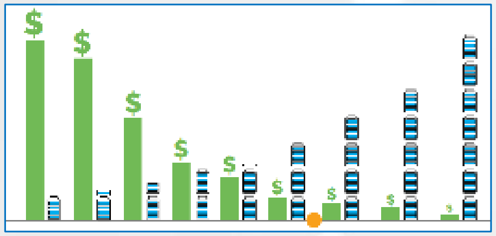
Storage is
not new
to the region.

2010 KCP&L "SmartGrid" Project:
Battery component
1 MW, 1 hour of storage (1MWh)

- 2010 1 hour of storage, >$1000/kW
- 2015 1 hour of storage, >$500/kW
- 2020 1 hour of storage, >$250/kW
- **Today: ~ $200 /kW for 1 hour**
- *2028: <$100/kW for 1 hour*
- *2032: <$75/kW for 1 hour*
- Simple LCC: Cost/kW (1h/365d/20y)
  - < $0.01/kWh electricity produced

Ref:
https://smartgrid.gov/project/kansas_city_power_and_light_green_impact_zone_smartgrid_demonstration

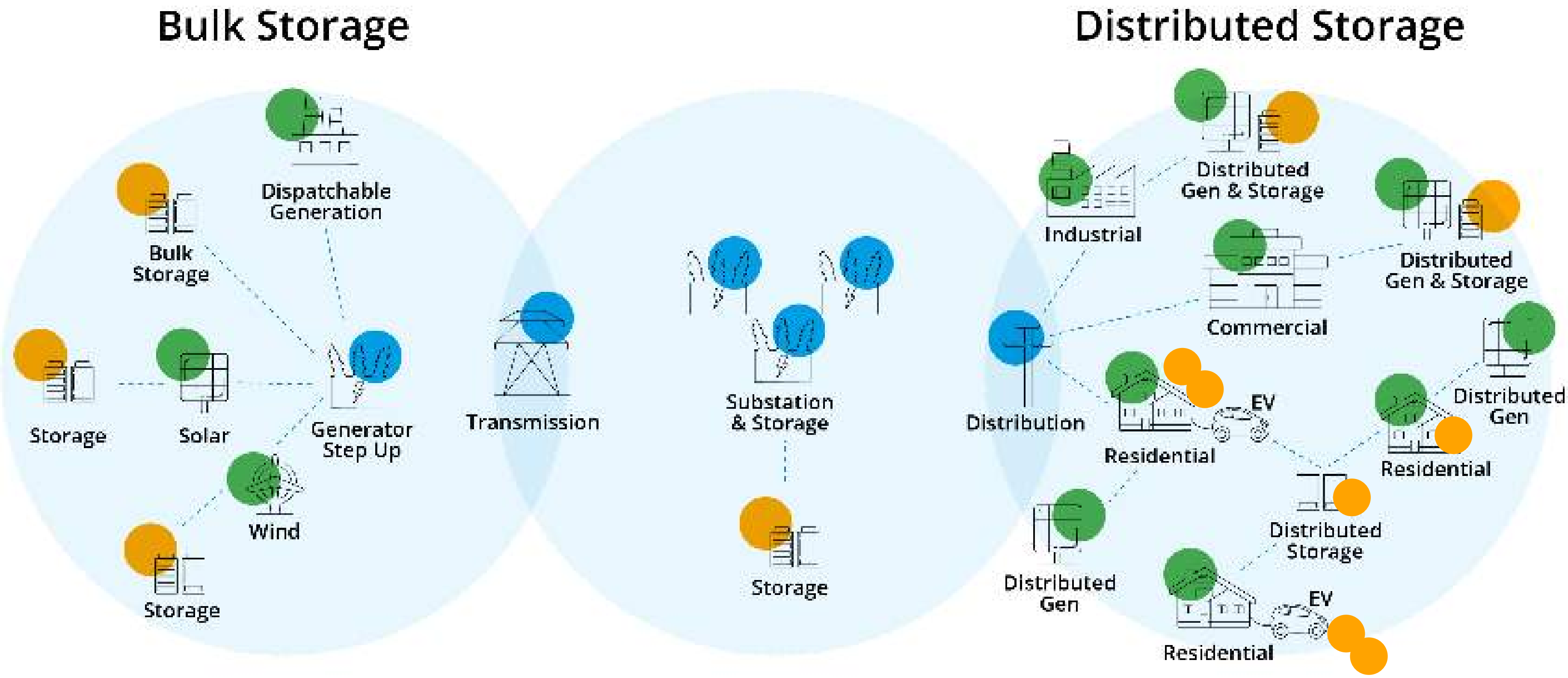
What's All the Buzz About Energy Storage?



- Energy storage is as inexpensive as ever
  - The storage ... $/kWh ... 20% of the cost in 2012
  - Projected to be less than half of what it is today by 2032
  - *But it is not cheap, so sizing and optimization are still important*
- Lithium-ion battery cells used for mobile devices and electric vehicles
  - Same shaped cells used there are used for stationary storage
  - Economies of scale for those cells *drives cost down for stationary storage*
- With the IRA there are incentives: tax credits, and now direct pay
- Issues are being addressed
  - Safety, lifetime, decommissioning, repurposing, recycling, ...

Storage is a solution to many problems ... more so every day as price declines.

Power Grid: Storage Alone and Hybrid Generation with Storage

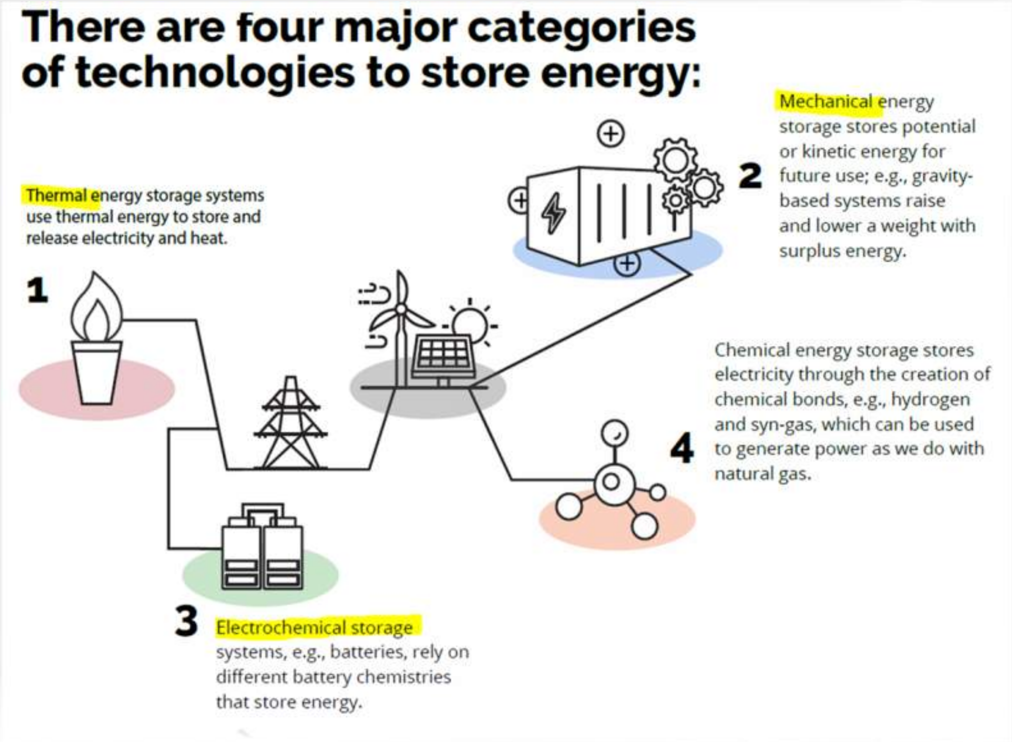


Energy storage, equipment that enables flexibility and increases benefits

Long Duration Energy Storage (LDES)

Tomorrow's solutions are evolving & emerging

- *Abundant, low-cost* materials: iron, salt, air, water, ...
- *Proven*, *conventional* equipment in new systems
- Cost targets *10 to 100 times less* than batteries



8-12 hours, 2-4 days, ... Weeks ... Months
Demonstrations and Deployments today, commercialization by 2025

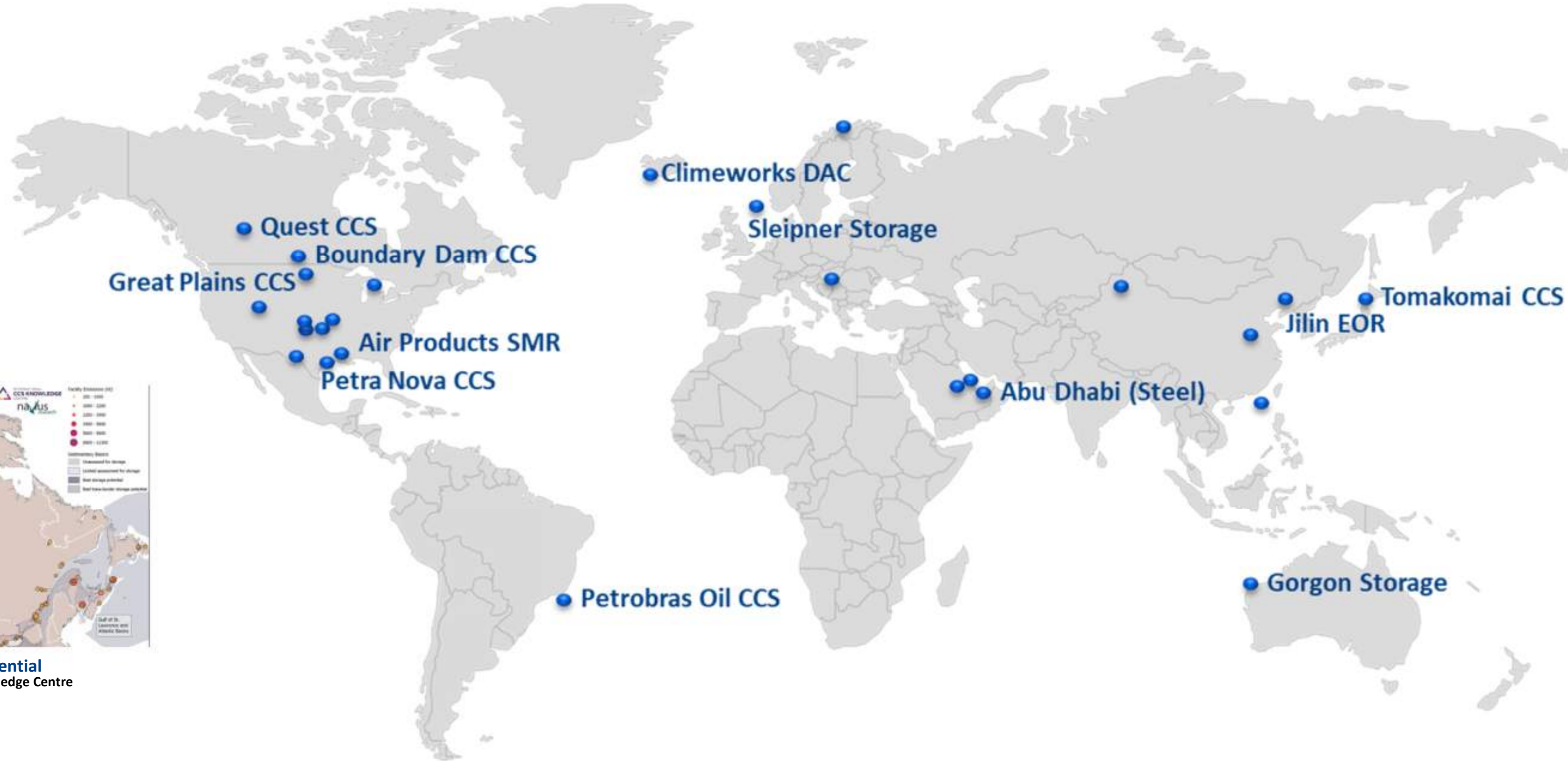
ESS are here to stay:

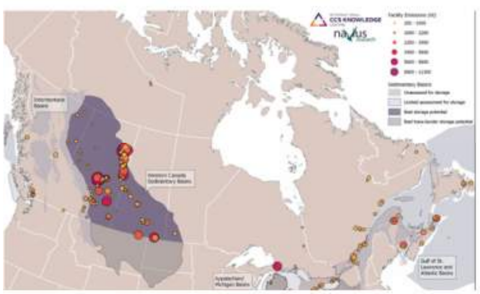
- Reliability
- Resiliency
- Adequacy
- Flexibility

Emerging Technologies - CCS

Algert Prifti, Carbon Capture Portfolio Solution Manager

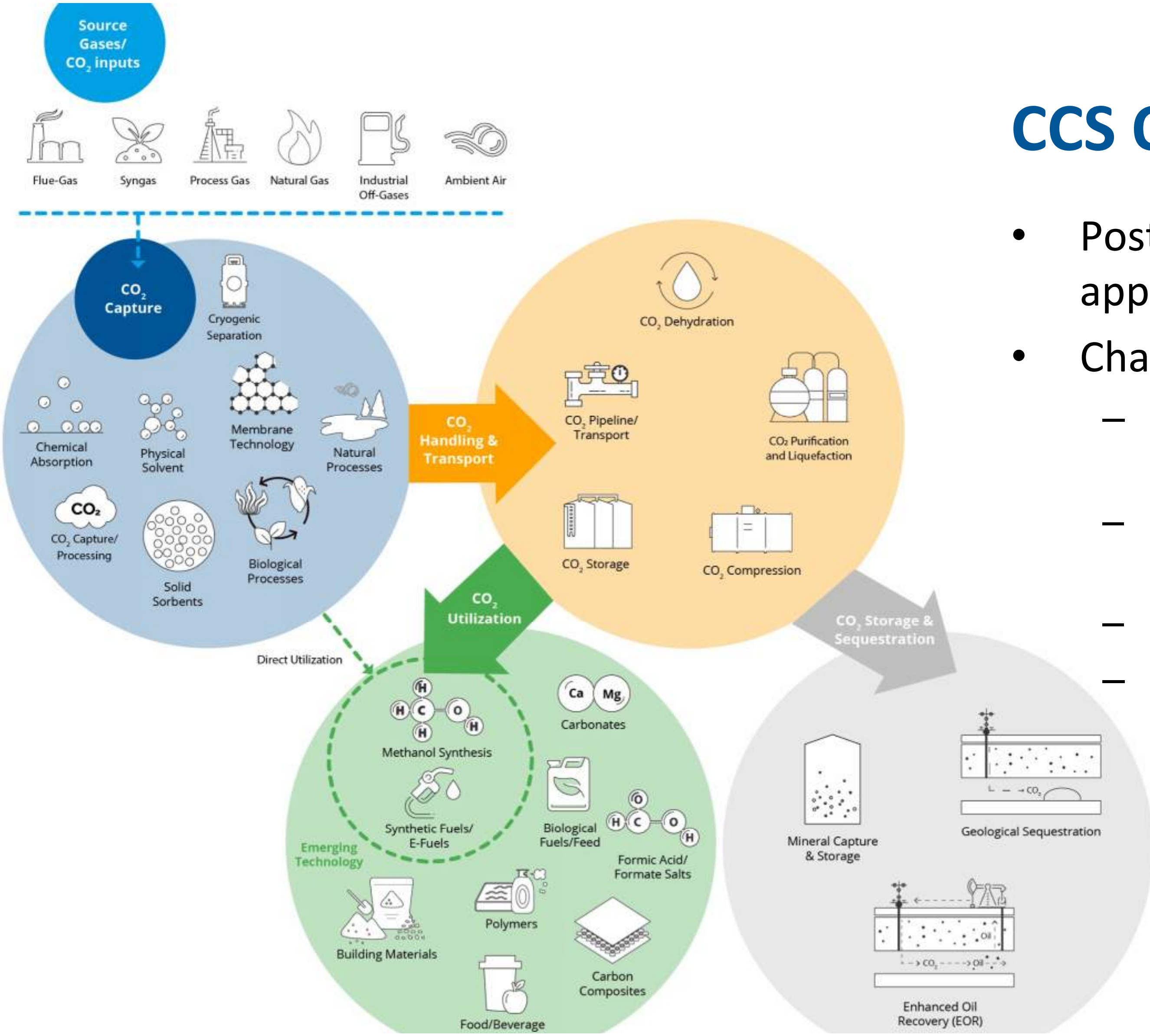
CARBON CAPTURE AND SEQUESTRATION (CCS)





Canada CO_2 Storage Potential
Source: The International CCS Knowledge Centre

>40 years operations with 600 million tonnes sequestered



CCS OVERVIEW

- Post-Combustion technologies differ by application
- Characteristics and benefits
  - Higher CO_2 concentration = cheaper capture
  - Cleaner exhaust stream = improved reliability
  - 90 - 95% capture efficiencies
  - Proven amine solvent technology considered state of the art for power generation

CO2 separation technology implemented in gas processing plants for decades…

CCUS VALUE CHAIN

Emission Source

- Industrial Processes (>15% by vol)
- Power Plants (~ 10 % by vol) (≤ 5% by vol)
- Ambient Air (≤1% by vol)

Capture Technology

- Pre and Post-Combustion CCS
- Direct Air Capture

Process & Conditioning

- Scrubbing
- Dehydration
- Pressurization
- Liquifying

Transport

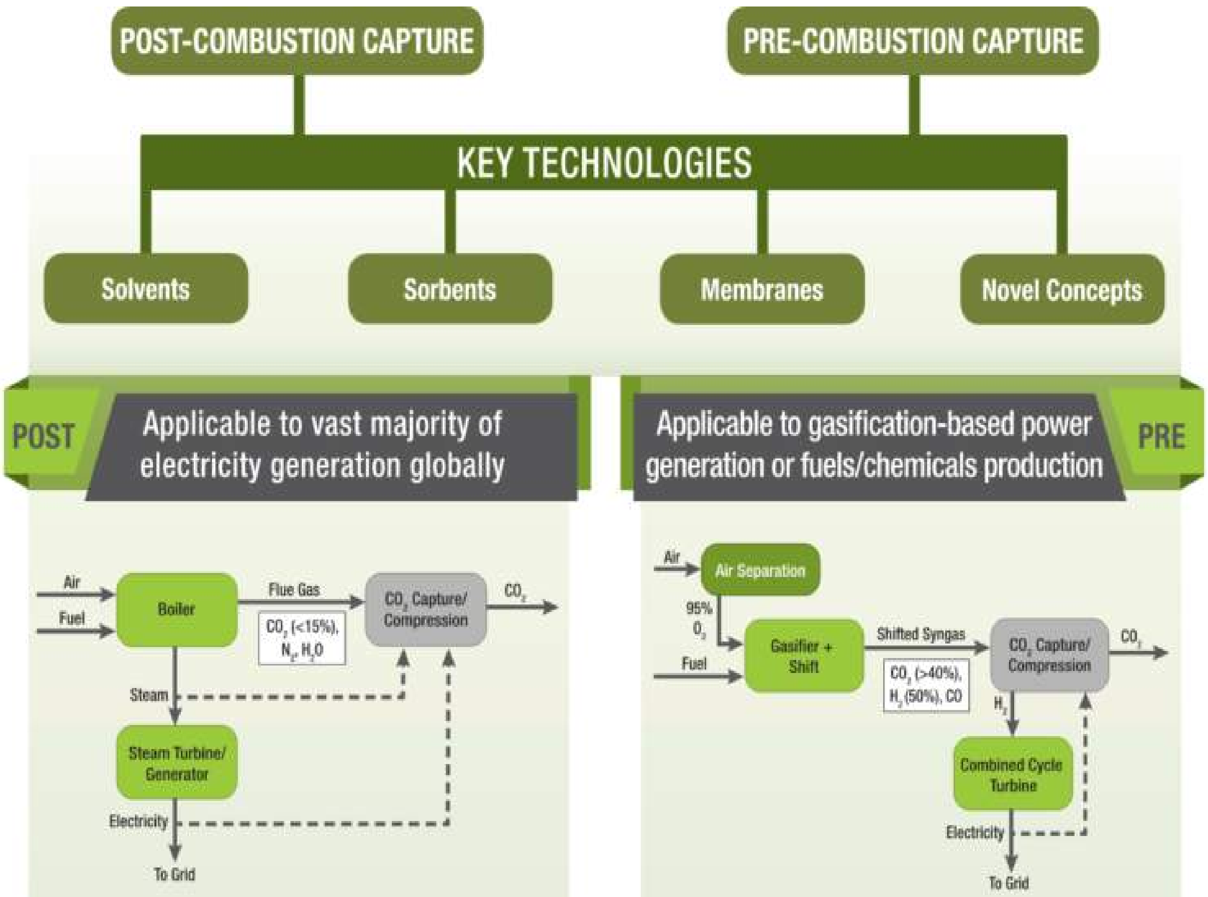
- Pipeline Conveyance
- Trucking
- Rail
- Ship

Utilization & Storage

- Enhanced Oil Recovery (EOR)
- Mineralization
- Building Materials
- CO_2 Catalytic Conversions
- Underground Storage

Successful CCUS projects require starting with the end in mind!

POINT-SOURCE CARBON CAPTURE AND SEQUESTRATION (CCS)



Source: US Department of Energy-Fuel Emissions/ NETL Carbon Capture R&D Program

- CCS technologies available for decades, not substantially implemented at scale
- Chemical solvent absorption (amine absorption) most proven for post-combustion capture
- Sorbent adsorption technology used in both post and pre-combustion CCS applications
- Membrane include metallic, polymeric or ceramic materials for CO_2 separation
- Most CCS technologies require considerable quantity of utilities (steam, power & water) to operate

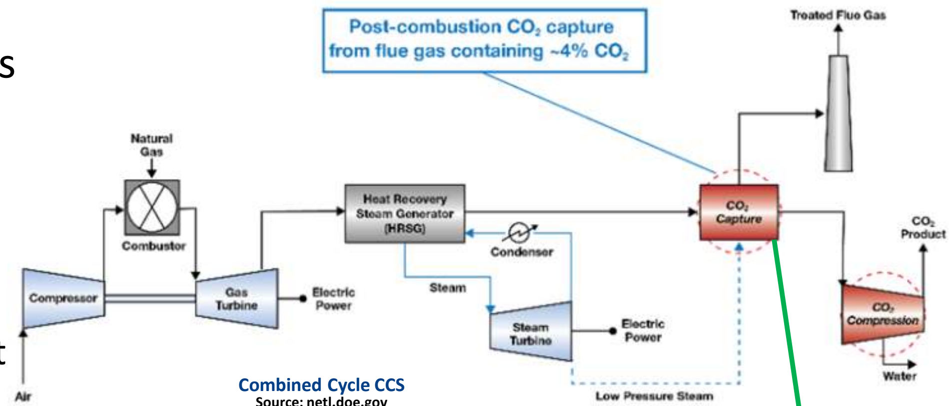
CONSIDERATIONS FOR POST-COMBUSTION CARBON CAPTURE INTEGRATION

- High **energy consumption** during CO2 removal process and compression
- **Corrosion** due to presence of chemicals requires resistant metallurgy selection
- **Degradation of solvent/sorbent** in the presence of O2, SO2, NOX and other impurities
- If integrated, steam and power extraction impact host site **plant performance, output and efficiencies**
- Increased **CAPEX** and **OPEX** costs to existing operations
- Accommodating increased plant **footprint** can be challenging for existing sites
- **Scale up** from pilot to commercial CO2 Capture capacity.
- Flexibility for **Next-Gen** solvents

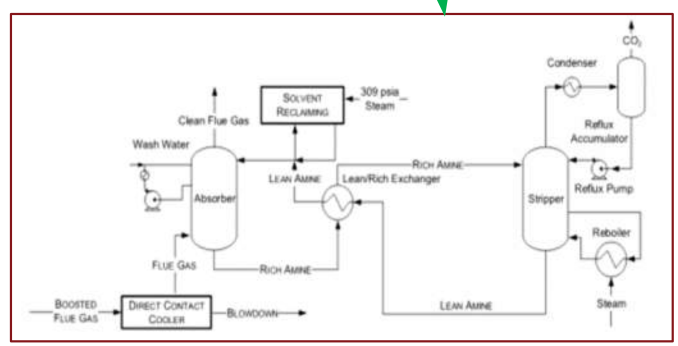
All these challenges can be addressed and project de-risked through proper planning and design efforts from the various project stakeholders!

CCUS DEVELOPMENT AND OPPORTUNITIES

- Demonstration of improved capture technologies
  - Lower concentrations
  - Higher volumes
  - Lower parasitic consumption
  - Flexibilities for upgrades
  - Better performing next-generation solvent/sorbent
- Economies of scale for cost reduction
- Market alignment from OEMs
- Sequestration beyond enhanced oil recovery
- Lessons Learned



Combined Cycle CCS
Source: netl.doe.gov



Amine-Based Shell Cansolv Technology PFD
Source: netl.doe.gov

No combined or simple cycles operating with CCS…***yet***

CCUS TRENDS AND SIGNPOSTS

DCP O'Connor Gas Plant CCS, Kersey Colorado

Point Source Capture Costs

- Past & current ~ \$50 to \$150 USD/tCO2
- Long-term ~ \$18 to \$45 USD/tCO2

Global and US Outlook

- Global oil & gas industry under pressure and looking for CCUS-as-a-business opportunities
- CCUS imperative for heavy industries (i.e cement and steel)
- CCUS on Power industry/operations located near sequestration sites to move on with increased 45Q tax incentives

Signposts

- Alberta, Texas, Wyoming, Louisiana
- Industrial users
- Bi-partisan support of 45Q legislation

Regulations, incentives, and penalties will govern carbon capture adoption

Emerging Technologies - Hydrogen

Bryan Mandelbaum, Director of Hydrogen Solutions

Pure Hydrogen Combustion Turbines Availability

- Most major combustion turbine suppliers state their equipment supports 100% hydrogen as fuel today.
- Limiting factor is not mechanical but sustained hydrogen supply
- Economic factors around storage and transport are usually challenging
  - Large quantities need to be stored nearby to keep turbine operations online; or
  - Constant flow through a dedicated H2 pipeline

Pure Hydrogen Combustion Turbines are currently fuel supply limited, economically.

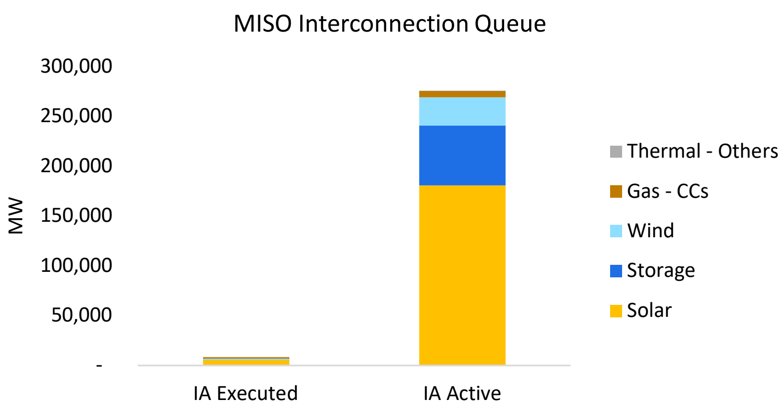
Technology Outlook

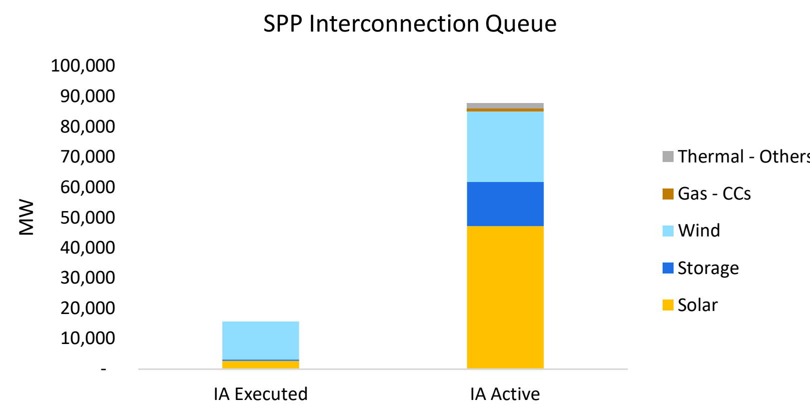
Renewable Reliability and Resilience

Hua Fang, North America Energy Markets Strategy and Planning Practice Lead

FUTURE SUPPLY MIX

- There is a significant amount of solar in the interconnection queue for both MISO and SPP. Having more solar over the next few years would be beneficial for both MISO and SPP as solar typically complements wind generation which constitutes a large share of existing capacity mix in MISO and SPP.
- However, as coal generation capacity retires and share of intermittent generation increases in MISO and SPP, the generation variability (seasonal, daily and intraday) is going to increase which would result in potential for higher generation forecast error and needs to maintain system reliability
  - Wind and solar have lower effective load carrying capability (ELCC). In SPP, wind ELCC ranges from 16% to 29% and solar ELCC ranges from 31% to 77%. In MISO, wind ELCC ranges from 9% to 17% and solar ELCC ranges from 5% to 50%.
  - Wind and solar ELCC is dynamic and decreases over time with increase in penetration of such resources.
- A diversified portfolio of "dispatchable" generation resources are needed in addition to wind and solar resources:
  - Battery storage
  - Seasonal or long duration storage
  - Efficient and low carbon gas generation (gas with CCS, hydrogen blend, ammonia or hydrogen generators)





ACHIEVABLE TARGETS AND RELIABILITY NEEDS

- The electric system decarbonization can’t be achieved overnight and needed to be carefully managed with a balanced mix of generation resources.

- Short-term
  - Manage the retirement of coal capacity and increased penetration of wind and solar resources
  - Lithium-ion battery (2-8 hours)
  - Efficient gas generation as replacement

- Mid- to Long-term:
  - Continue to build up short duration battery
  - Not rely on any one specific type of resources
  - Introduce and deploy low carbon “dispatchable” generation resources
    - Seasonal and long duration energy storage systems
    - Hydrogen/ammonia generators
    - Other emerging technology?

- Based on BV’s off-the-shelf assessment and work for other utility clients, 70% to 80% of RPS target or renewable generation share is achievable. The remaining amount of clean energy needs should come from other clean energy resources such as a mix of nuclear, hydro and hydrogen with short and long-duration storage providing intra-day and seasonal balancing and ramping needs as required.

Discussion.

Contact Us

Casey Hicks, Sr. Client Account Manager

HicksCJ@bv.com