Electric Energy Storage
IRP and Regulatory Topics

North Carolina Utilities Commission and Staff

November 25, 2019

SCHULTE ASSOCIATES LLC

Overview

- About Schulte Associates LLC
- About Storage
- Our Topic Today
- Grid-Level Storage
- Distributed Storage
- Storage for 100% Clean Energy.
- Frequently-Asked Questions (FAQ)

About Schulte Associates LLC (SA)

- Executive management consultants.
- Offices in Raleigh.
- 40 years with public and private utilities.
  - Integrated Resource Plans (IRP).
  - Project development.
  - Renewables and energy storage.
  - Regulatory and cost recovery topics.

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SA's Storage Activities

- Current: Contract arrangements for storage project.
  - 160 MW, 26 hours, 4,480 MWh.
- Current: 2019 IRP for Burbank Water & Power.
  - Replacing share in coal unit with renewables and storage.
  - 54 MW, 48 hours, 2,600 MWh.
- Current: U.S Market Assessment for storage.
  - International technology company.
- Utah CAES* Strategic Studies (2014-2017).
  - Options for replacement of IPP coal plant (to be retired in 2025)
  - 1200 MW, 48 hours, 57,600 MWh.

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*Compressed air energy storage (CAES).

SA's Storage Activities (cont'd)

- Co-author: "Market and Tariff Challenges to Grid-Scale Electric Storage Enabling Renewables in RTO/ISO Markets" (2015).
- Gregory County pumped hydro feasibility study (2013).
  - 1200 MW, 26 hours, 31,000 MWh.
- Iowa Stored Energy Park Due-Diligence (2010-2012).
  - 270 MW, 12 hours, 3,240 MWh.
  - Primary author, "*Lessons from Iowa*" DOE/Sandia Labs report (www.lessonsfromiowa.org)

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Perspective:

Battery Storage Installed in the U.S. in 2018:

777 MWh

Utah CAES:

Phase I: 4,480 MWh

Eventual: 57,600 MWh

3/5/2019 US Energy Storage Broke Records in 2018, but the Best Is Yet to Come | Greentech Media

ENERGY STORAGE (/ARTICLES/CATEGORY/STORAGE)

US Energy Storage Broke Records in 2018, but the Best Is Yet to Come

The groundbreaking installations came from business as usual, rather than in response to extreme events.

JULIAN SPECTOR

MARCH 05, 2019

Energy storage is moving out of pilot-scale projects and into grid planning conversations around the country.

Photo Credit: NextEra

The U.S. energy storage industry delivered record deployments in 2018, driven by a strong fourth quarter for utility-scale projects.

But the new achievement for the young industry pales compared to what's to come: an expected doubling in 2019, followed by a tripling in 2020. Such growth will propel energy storage out of pilot-scale projects and into grid planning conversations around the country.

Battery installations for 2018 totalled 311 megawatts and 777 megawatt-hours, according to the new Energy Storage Monitor (https://www.woodmac.com/research/products/power-and-renewables/us-energy-storage-monitor/) released by energy research firm Wood Mackenzie, with data from Q4 and 2018 as a whole.

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About Energy Storage

The process of capturing and holding energy until a later time when we need it, and can release it in a controlled manner.

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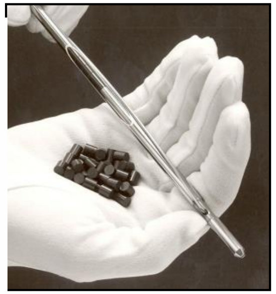
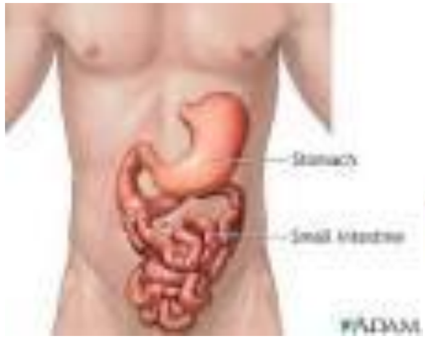
Energy Storage is All Around Us





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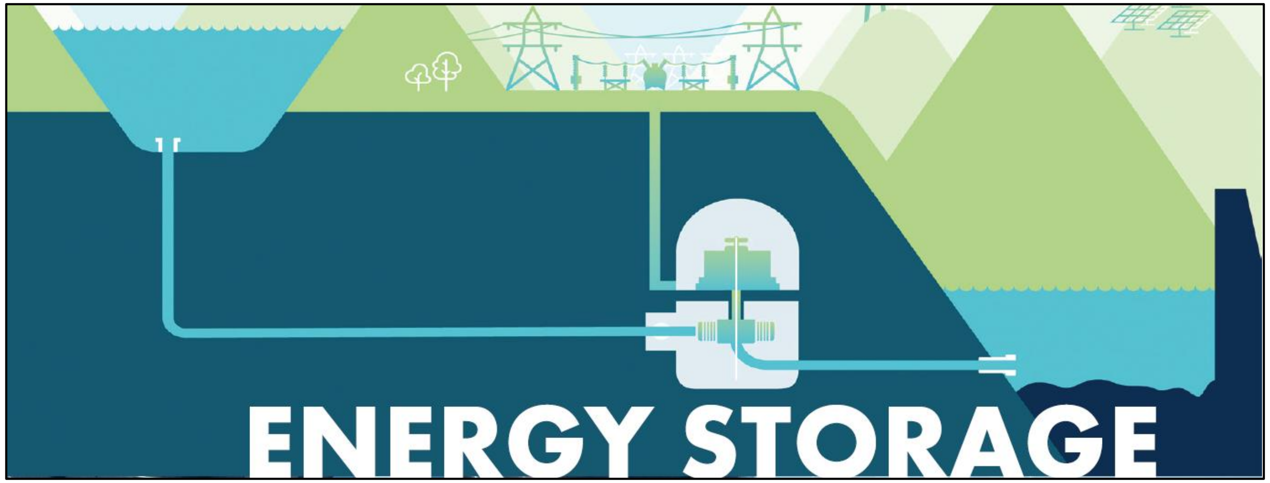
Important Concept



Storage is the act of creating "<u>time diversity</u>".

That is, separating the moment of electricity production from its use.

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Our Topic Today

- Storage that involves storing electric energy and regenerating it as electricity.
  - Does ***not*** include thermal energy storage.

Electric water heaters

Commercial refrigeration

Swimming pool heaters

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Not Our Topic Today

- Storage by customers behind-the-meter (BTM).
- Storage at retail accessing wholesale markets.

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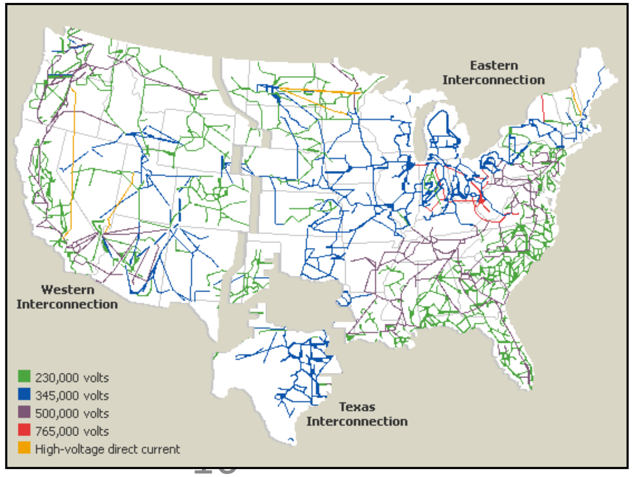
Ways to Store Energy for the Grid

- Thermal energy
  - Example: Water heaters or concentrated solar power (CSP)
- Chemical energy
  - Examples: Batteries or hydrogen
- Electrostatic energy
  - Example: Supercapacitors
- Spin a heavy wheel on a shaft
  - Example: Flywheels
- Gravity: Move a massive object or fluid to a height.
  - Example: Pumped hydro storage
- Compressed gas

Kinetic Energy (movement) or Photovoltaics → Potential Energy (storage) → Kinetic Energy (movement)

Bulk Storage on the Electric Grid

- Typically located on the transmission system.
  - Multiple Megawatts of capacity.
  - Ability to store and generate for multiple hours.
- Dispatch authority varies
  - In organized markets, dispatched by the RTO or ISO.
  - Local utility or Balancing Authority dispatches in other areas.
- Aggregated, distributed storage interested in accessing the transmission grid.



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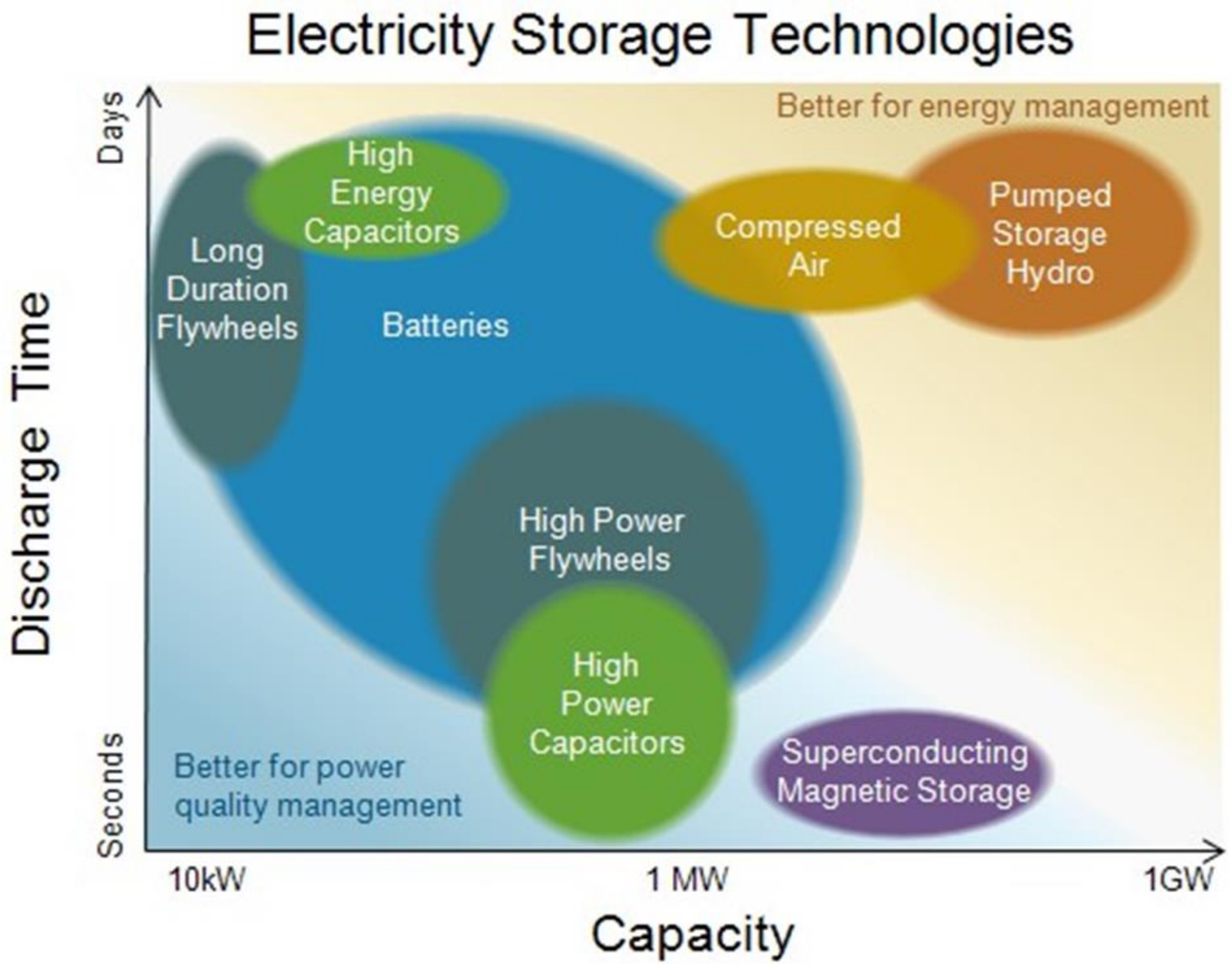

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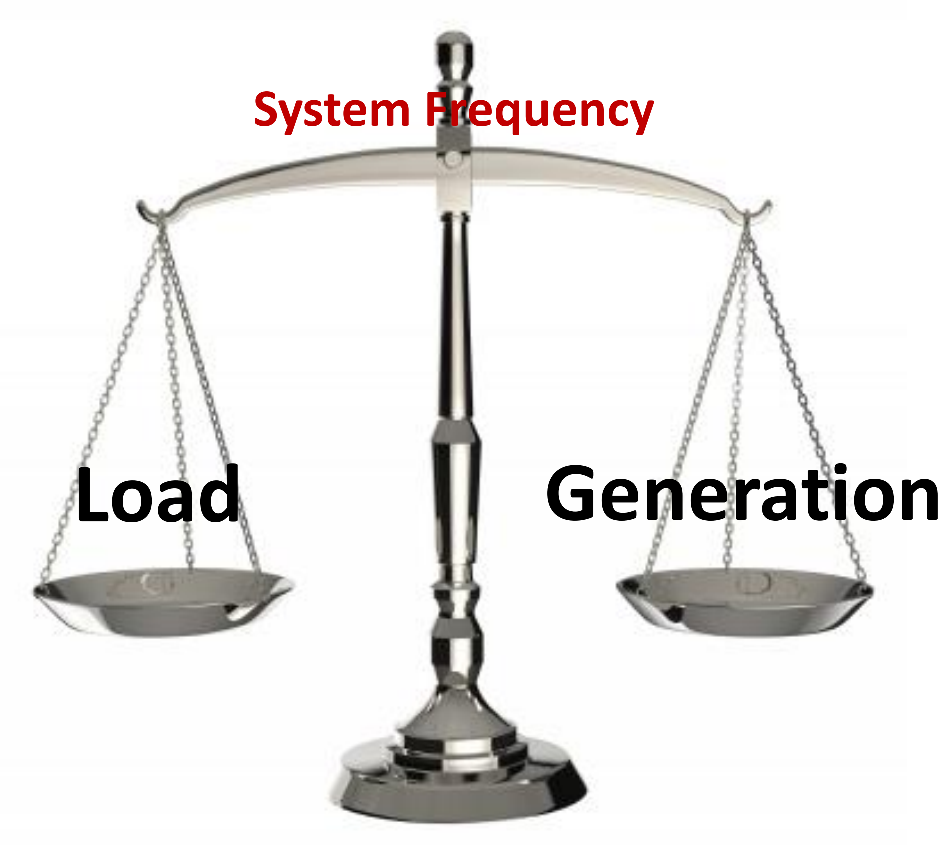
Source: eia.gov

Grid Stability Considerations



"<u>Ancillary Services</u>":

- Frequency regulation.
- Ramping (Up, Down).
- Operating reserves.
  - Spinning.
  - Non-spinning.
- Black start.

Key Factors: Flexibility, Ramp Rate, and Inertia

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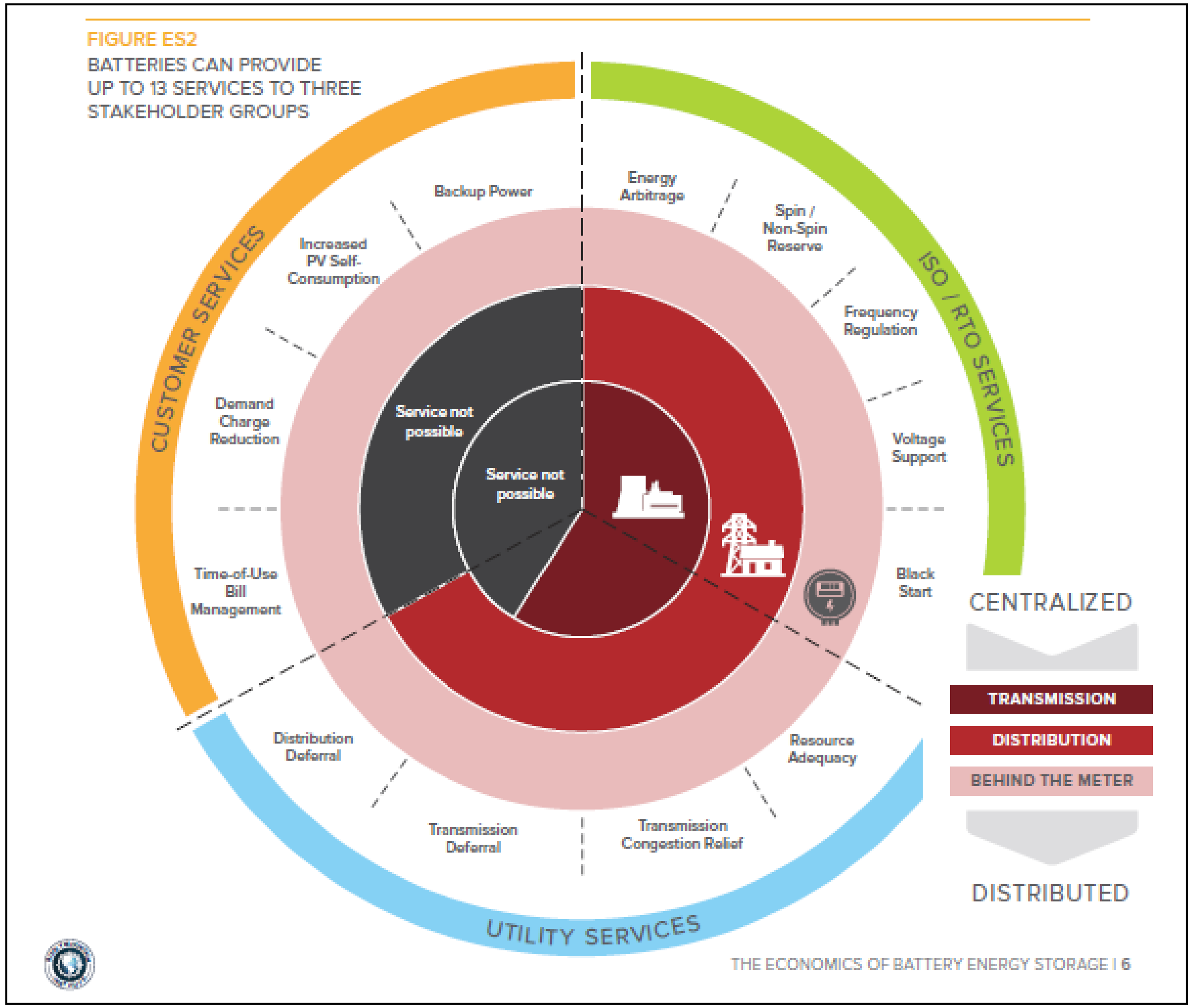
Bulk Storage Can Also Provide Multiple Services*



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*Source: Rocky Mountain Institute.

Storage Technologies: Pros and Cons

	Pumped Hydro	CAES	Batteries
Pros	*Long duration storage *Economies of scale *Low cost per kWh stored *Fair ramping Up/Down *No GHG emissions *Long project lifetime (40-50 years) *Reliable capacity for RA *Little/no capacity degradation over time.	*Long duration storage *Modest enviornmental site impact *Can be located in urban environment *Economies of scale *Low cost per kWh stored *Fast ramping Up/Down *Swift transition storage to generation *Long project lifetime (30 years) *Reliable capacity for RA *Little/no capacity degradation over time.	*Little enviornmental site impact *Can be located in urban environment *Modular, flexible sizing *Very fast ramping Up/Down *Instant transition storage to generation. *No GHG emissions. *No moving parts.
Cons	*Sites geology limited *Large environmental site impact *Cannot be located in urban environment *Slow transiton storage to generation *Many moving parts	*Sites geology limited *Some GHG emissions[1] *Many moving parts	*Higher cost per kWh stored *Short duration storage *Relatively short project lifetime (15 - 20 years) *Short storage duration not as reliable for RA. *Cell replacements necessary over time.

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1. Subject to future transition to hydrogen.

Storage Capital Costs: Indicative Examples
(for Commercial Operation Date (COD) in 2025)

Technology	Project Example	Project Capacity (MW)	$/kW	Storage Duration	$/kWh Stored	Nominal Lifetime
Pumped Hydro	Gregory County	1,200	**$3,000**	26 hours	**$115**	40 - 50 years
CAES	Utah CAES (Large)	840 - 1,200	**$1,660**	48 hours	**$35**	30 years
	Utah CAES (Small)	150	**$2,050**	28 hours	**$73**	30 years
Batteries (Li-Ion)	Burbank 2019 IRP, 4 - hour	Variable	**$580**	4 hours	**$145**	15 - 20 years*
	Burbank 2019 IRP, 1 - hour	Variable	**$381**	1 hour	**$381**	15 - 20 years*
	Burbank 2019 IRP, 1/2 - hour	Variable	**$231**	1/2 hour	**$426**	15 - 20 years*

When discussing storage, always ask about the duration and lifetime.

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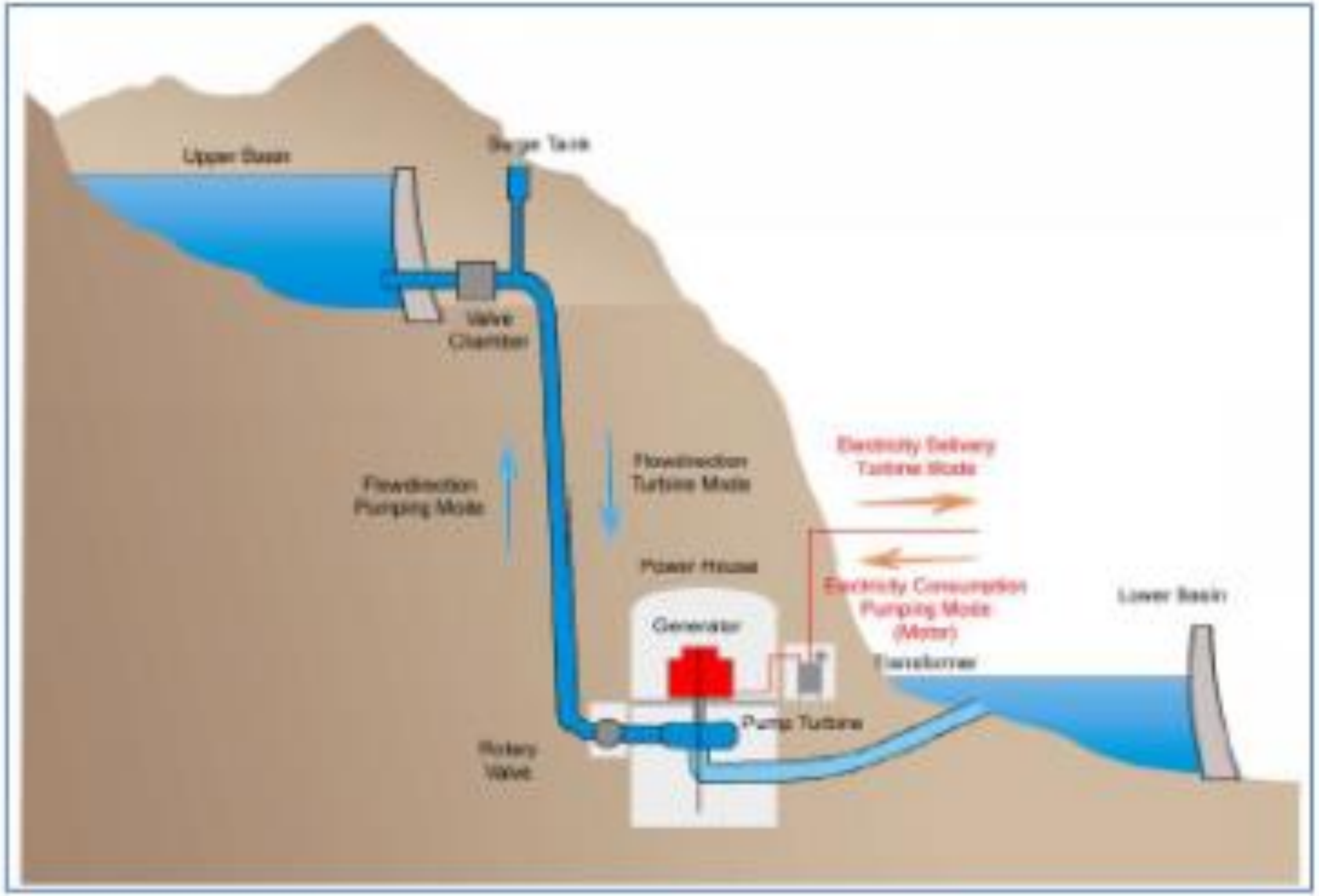
*Subject to periodic cell replacements during the lifetime.

Grid Storage and Distributed Storage are Complimentary

- Grid Storage for management of supply
  - Reliability
    - Manage intermittency of grid-level renewable resources.
  - Enable more renewables within transmission limits.
  - Combined with renewables, replace legacy carbon-emitting resources.
- Distributed Storage for management of load
  - Reliability
    - Backup for grid outages.
    - Manage intermittency of customer-owned renewable resources.
  - Reduce customer electric bills.

They can and should be used together.

Technologies: What is Pumped Hydro Storage?



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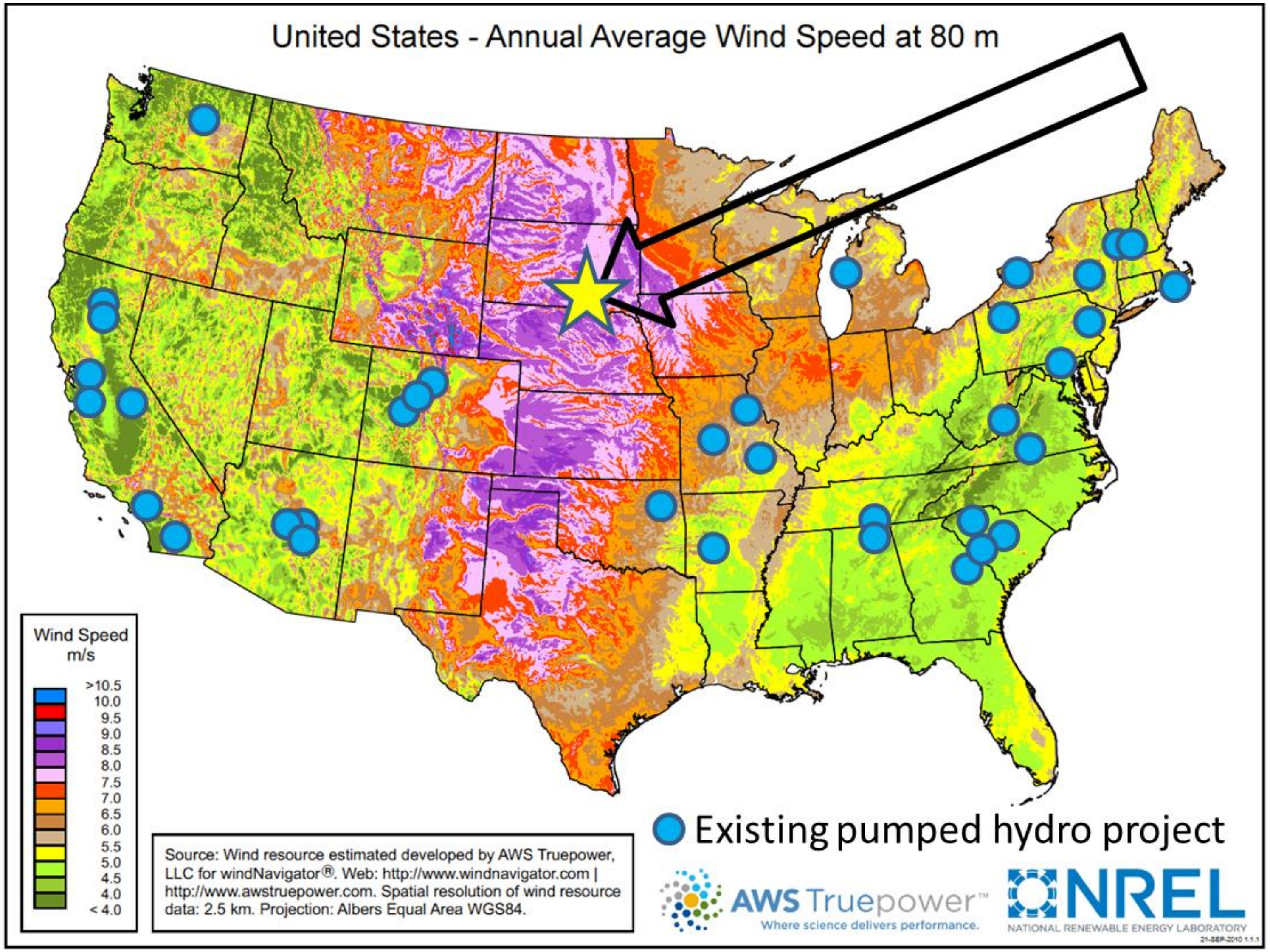
Case Study: Gregory County

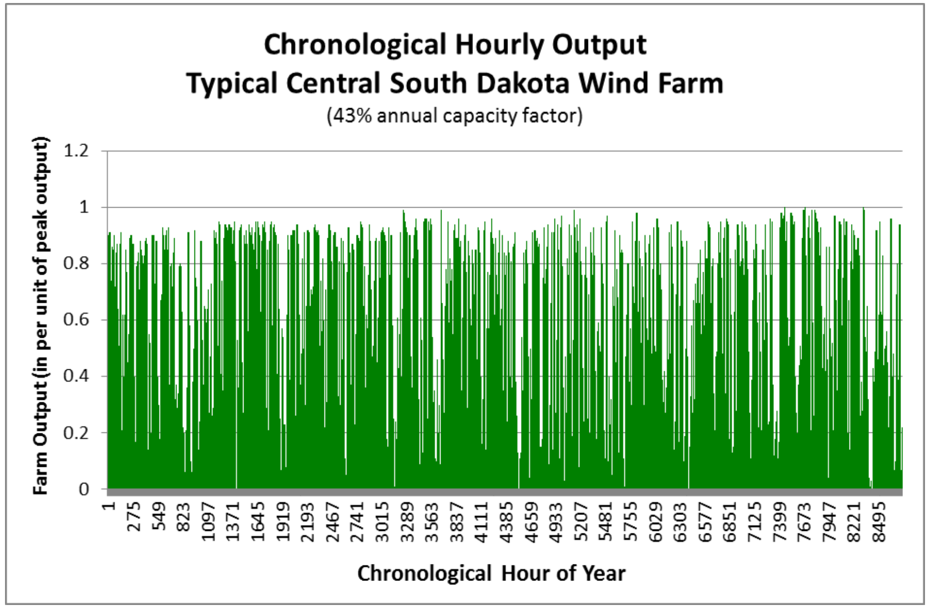


A Pumped Hydro/Wind Combo

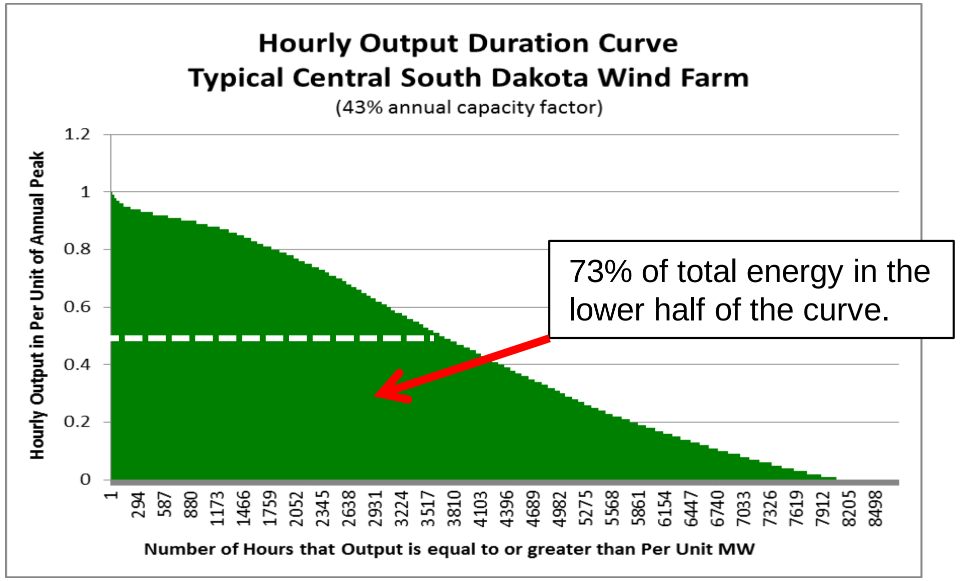
Artist's Conception

“Central South Dakota” Wind Farm

2012 Actual Hourly Data



Arrange hourly values in order of magnitude



43% annual capacity factor

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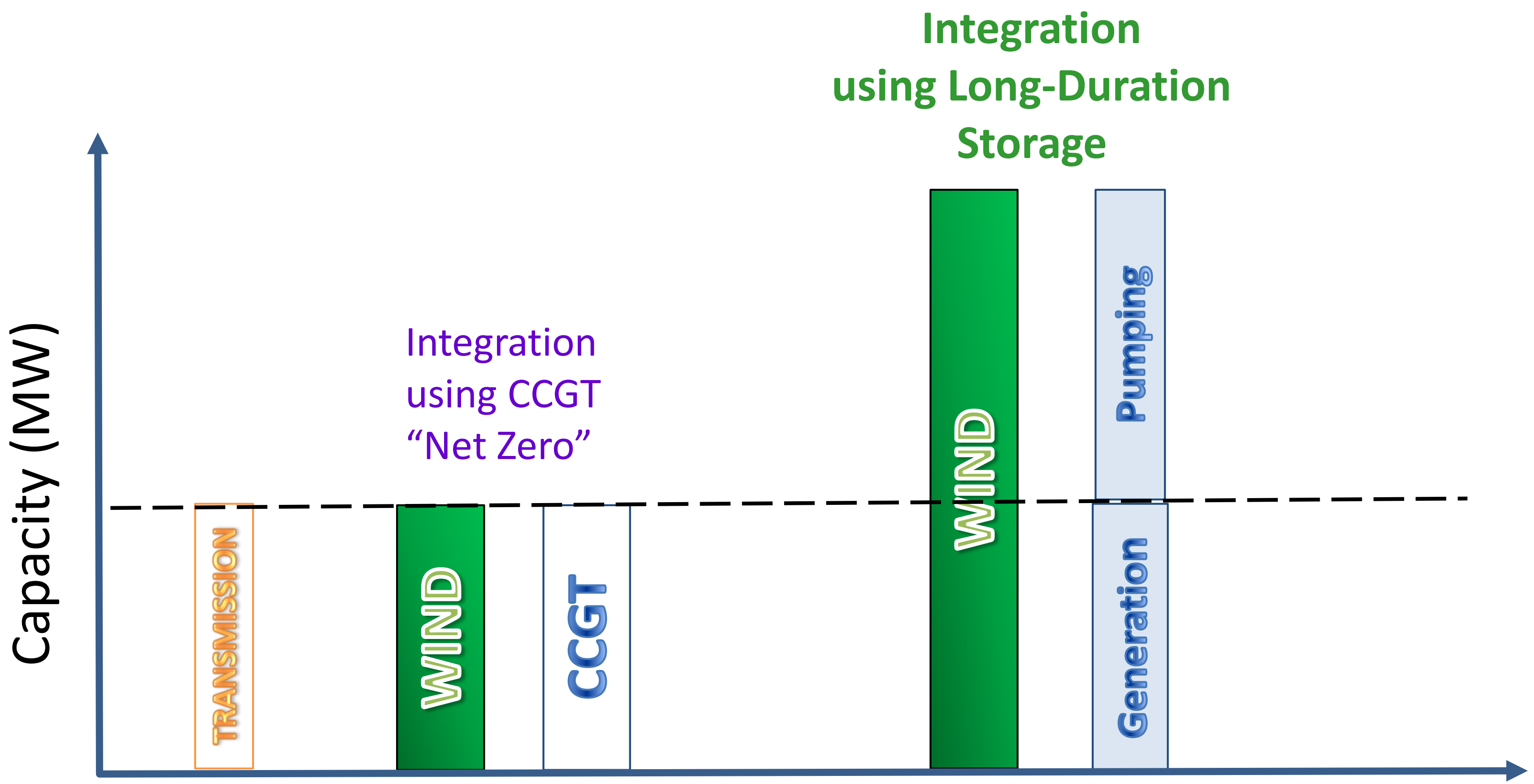
Long-Duration Storage Can Integrate More Renewables than CCGT, for the Same Transmission



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Gregory County: Case Study Results

- A Gregory County/wind energy combination
  - 1,200 MW of pumped storage, 26 hours of storage.
  - 2,400 MW of high capacity-factor wind.
  - 1,200 MW of outlet transmission capacity
  - Reliable, dispatchable, near-baseload capacity and energy source.
  - Costs less than conventional natural gas-fired CCGT alternative.

A near-baseload, 100% renewable energy option.

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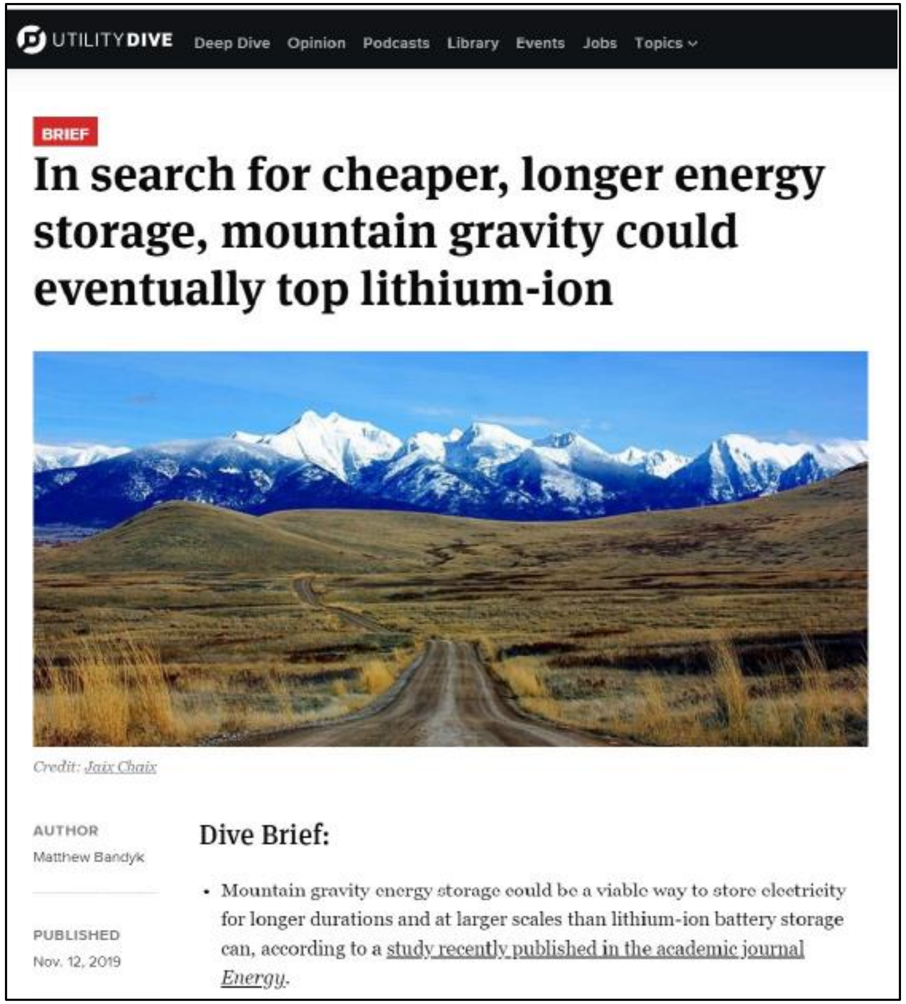
Technologies: Long Duration Storage in the News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BRIEF

In search for cheaper, longer energy storage, mountain gravity could eventually top lithium-ion

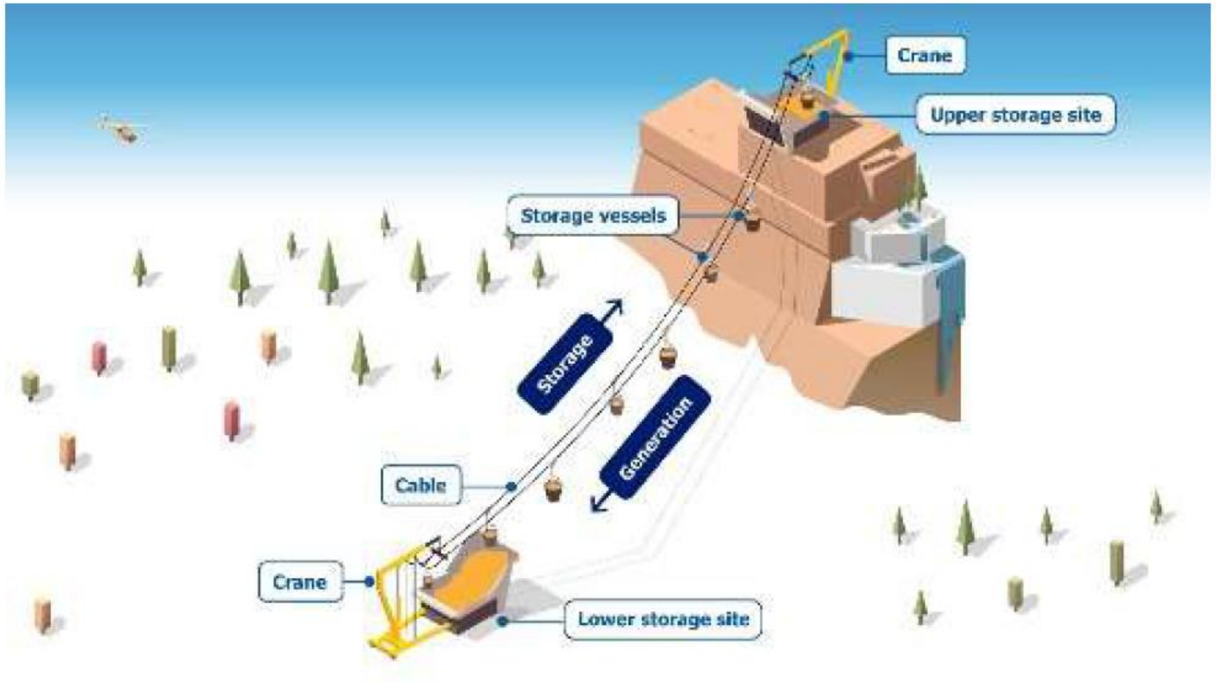
Credit: Jaix Chaix

AUTHOR
Matthew Bandyk

PUBLISHED
Nov. 12, 2019

Dive Brief:

- Mountain gravity energy storage could be a viable way to store electricity for longer durations and at larger scales than lithium-ion battery storage can, according to a study recently published in the academic journal *Energy*.

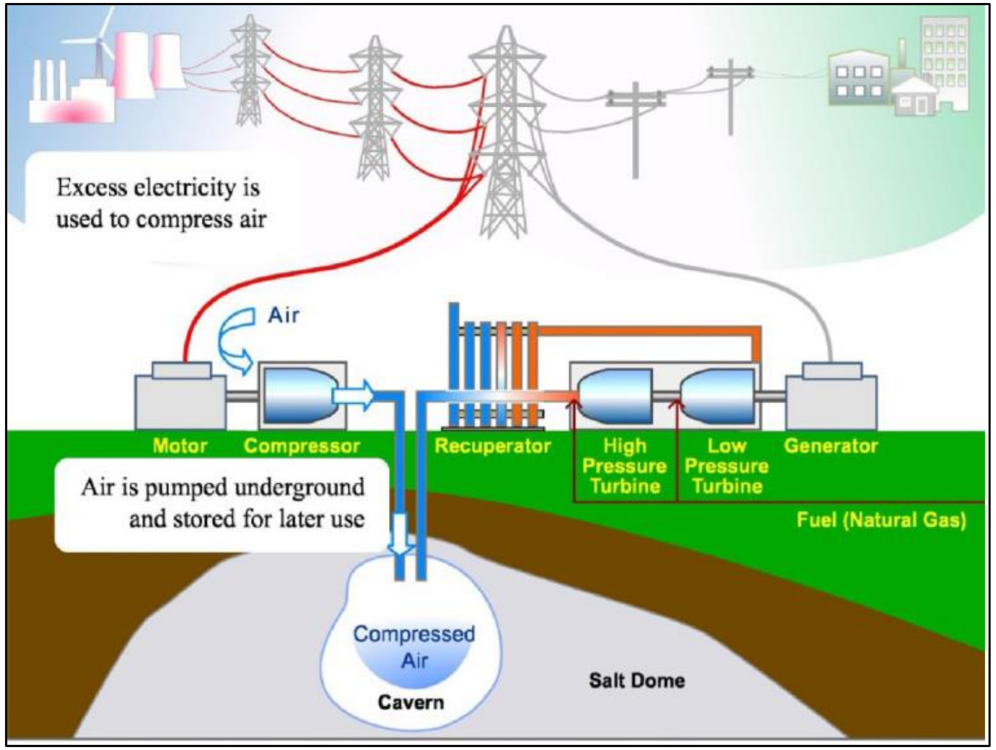


Reference

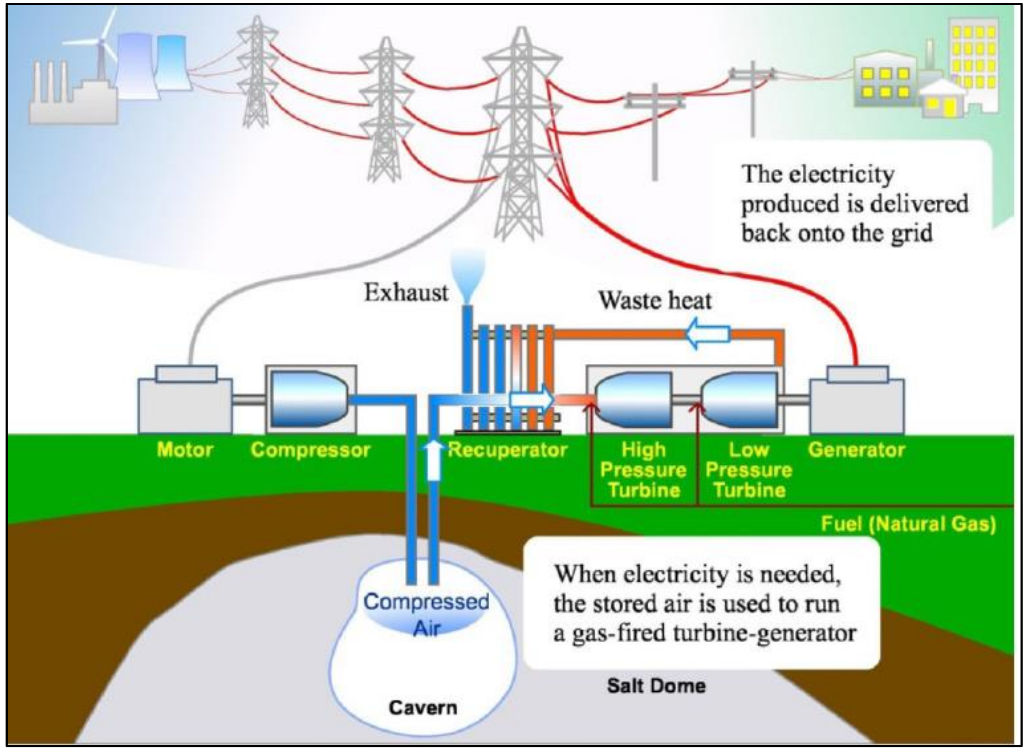
Hunt J, Zakeri B, Falchetta G, Nascimento A, Wada Y, & Riahi K (2019). Mountain Gravity Energy Storage: A new solution for closing the gap between existing short- and long-term storage technologies. *Energy* DOI: https://doi.org/10.1016/j.energy.2019.116419 [pure.iiasa.ac.at/id/eprint/16155/]

Technologies: What is Compressed Air Energy Storage (CAES)?

Storage Cycle



Generation Cycle



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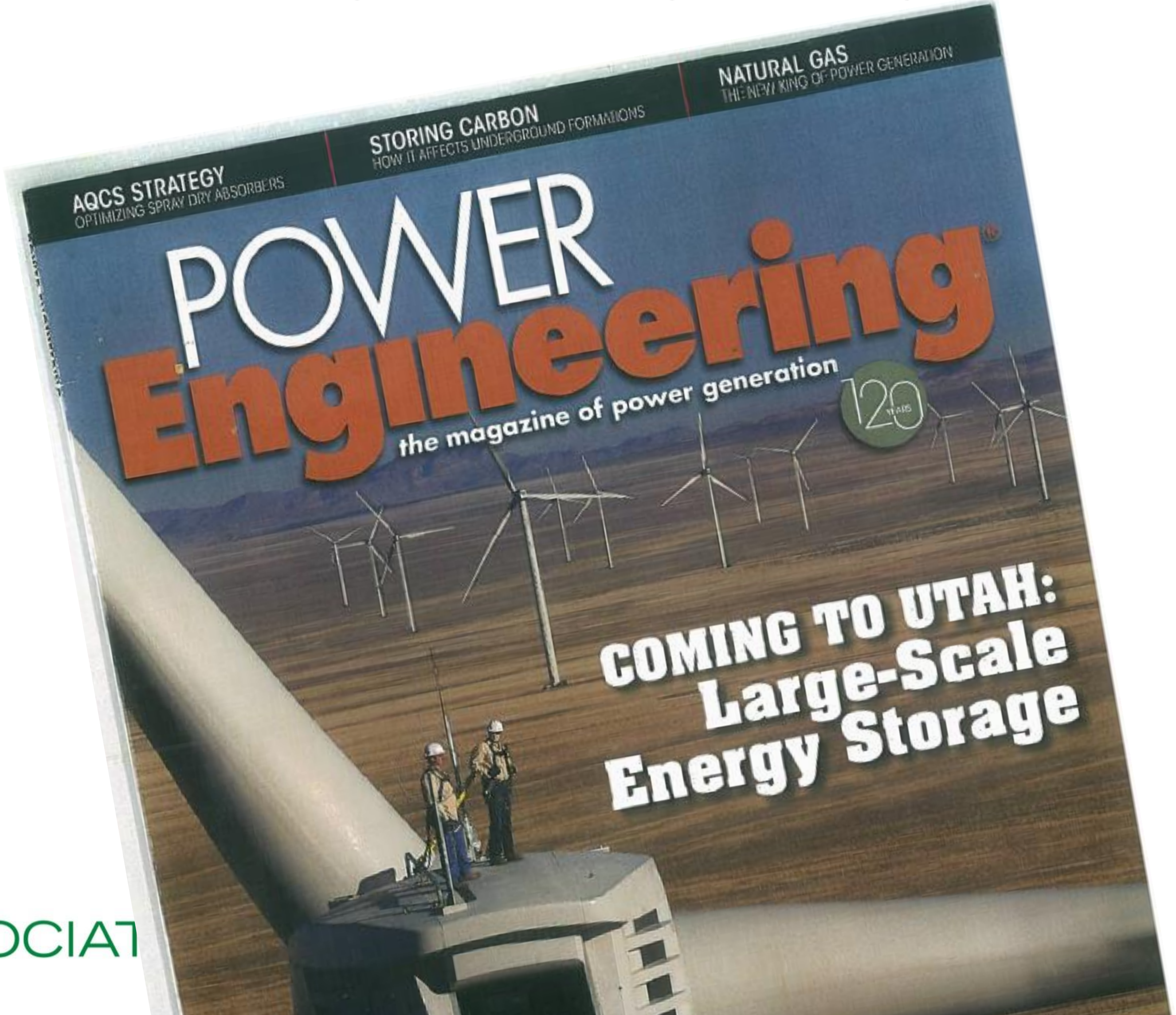
Case Study: Utah CAES
"Power Engineering" Magazine



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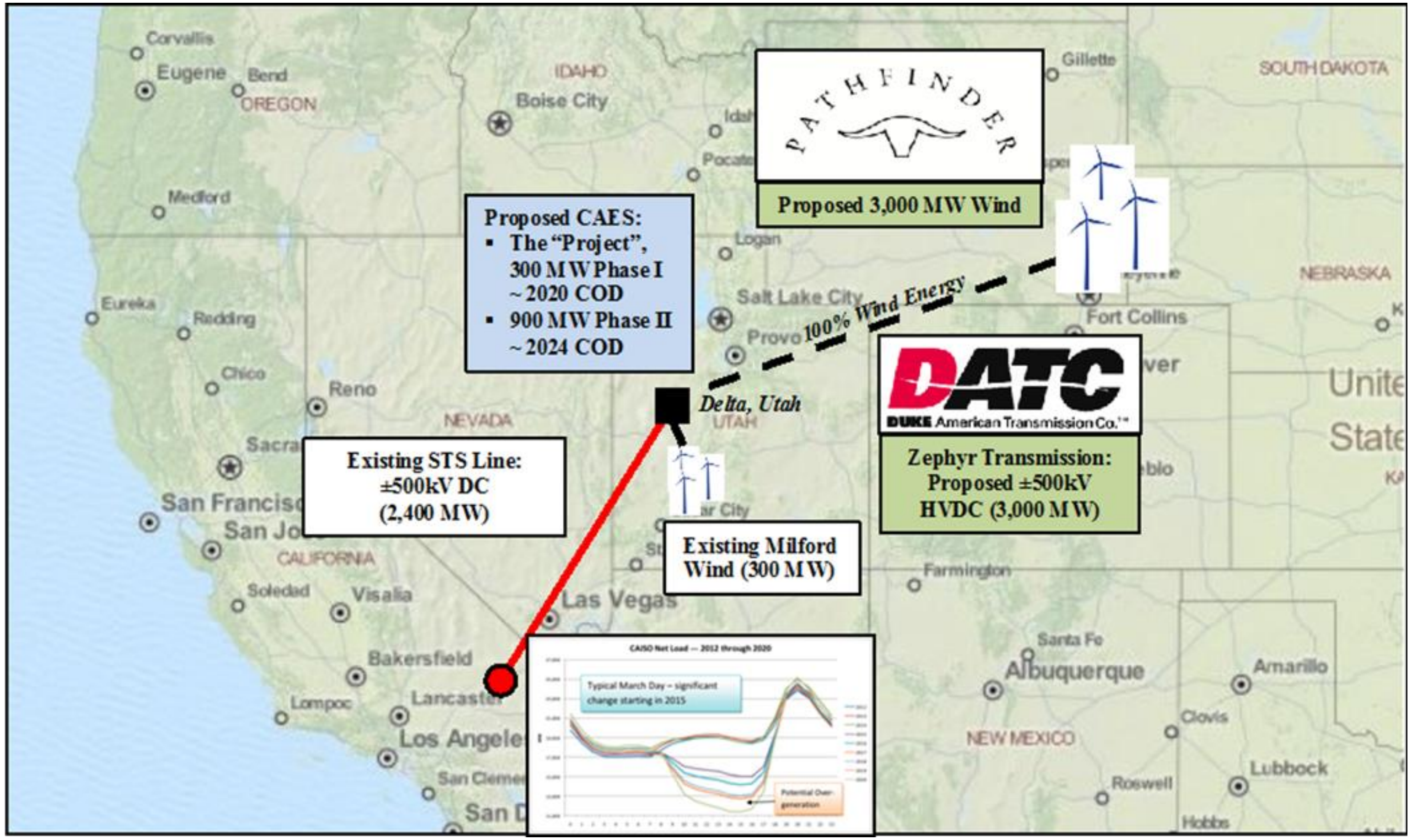
Utah CAES Project Layout



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Utah CAES Study Components

- WECC-level study using ABB GridView model.
  - CAES + Wyoming Wind and HVDC replacing IPP coal.
  - Production cost modeling by ABB Consulting, Raleigh.
  - Fixed cost analysis by Schulte Associates LLC, Raleigh.

- WECC-level study by Energy Exemplar using Plexos.
  - Initial CAES installation while IPP coal still in service.
    - Prior to Wyoming wind being available.

Pathfinding studies for IPP coal preplacement.

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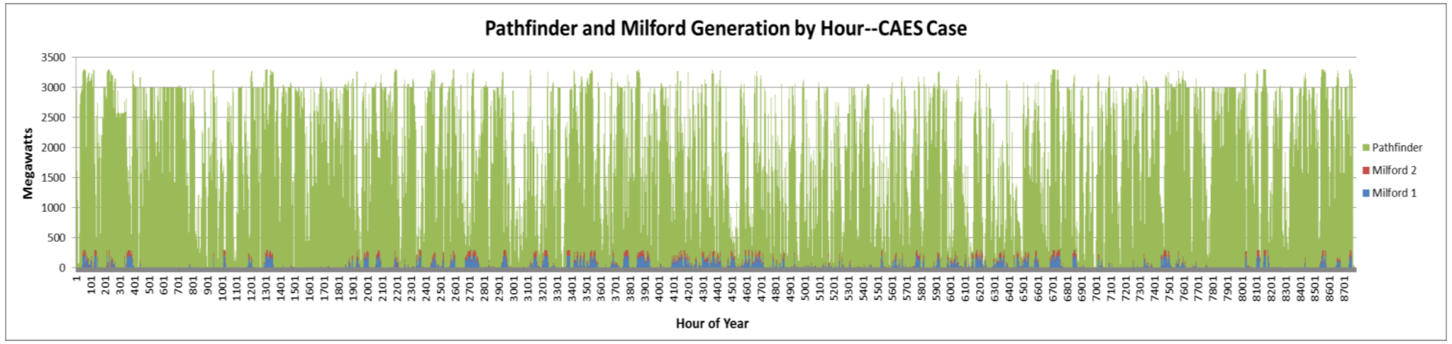
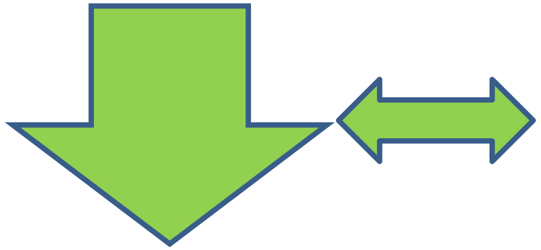
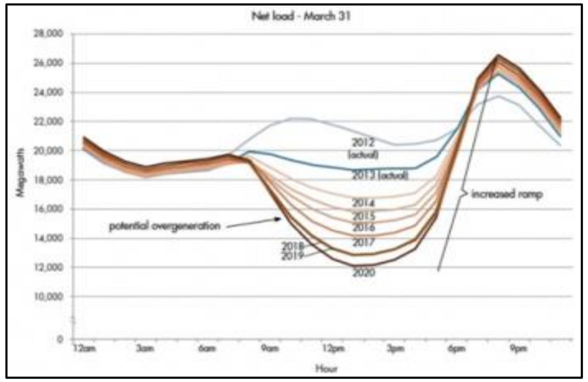


3300 MW of intermittent wind energy



1200 MW of CAES at Delta, Utah

2400 MW of existing 500 kVDC transmission to Southern California



The California "Duck Curve"

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Utah CAES Study Results

- A CAES/Wyoming wind combination would:
  - Reliably deliver more annual energy than legacy 1800 MW baseload Intermountain Power Project (IPP) coal plant.
  - Dramatically reduce GHG emissions.
  - Cost less than:
    - A natural gas-fired combined cycle addition.
    - The existing IPP coal plant.

Transition from coal to renewables and storage.

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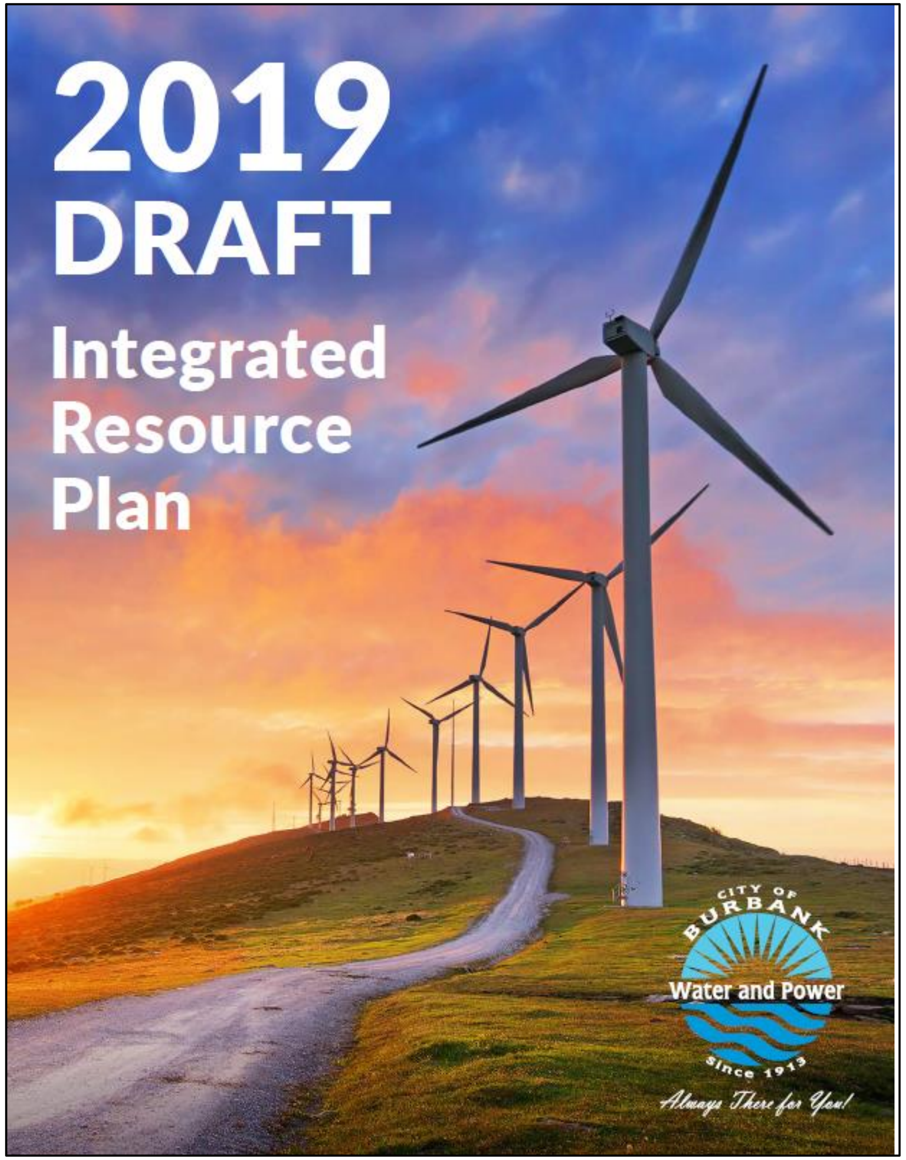

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Case Study

Burbank Water & Power (BWP)

2019 IRP

Case Study: Burbank 2019 IRP

- Municipal utility in Southern California.
  - 320 MW peak demand.
  - Located in LADWP Balancing Area.
- As one of 16 largest municipal utilities in CA, developed and submitted IRP to California Energy Commission (CEC) for first time.
- Highlights:
  - Proposes replacing share in coal unit (to be retired in 2025) with combinations of renewables and energy storage.

Transition from coal to energy efficiency, renewables and storage.

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Numerous Supply Scenarios Analyzed

Partial list of Scenarios Considered

Portfolio #	CC	WY Wind	Utah Solar	CAES	Batteries (MW of 4 hr)	ICEs	Wind/Solar Addition	Ancillary Batteries (MW of 1 hr)	Transmission on STS
1	35	0	0	0	113	0	221	74	126
2	35	102	0	0	113	0	69	81	126
3	35	188	0	80	0	0	44	120	126
4		102	0	0	50	54	69	74	54
5		46	44	54	0	0	113	73	54
6		46	44	0	113	0	113	73	54
7		46	44	0	50	54	113	73	54
8	35	0	0	100	0	0	221	74	126
9		102	0	0	113	0	69	74	54
10		102	0	54	0	0	69	74	54
11	35	46	44	54	113	0	113	73	126
12	35	46	44	0	0	0	113	73	126

Table 6.5: Resource Portfolios Evaluated under SB350 (Megawatts)

The Lowest Cost, "Preferred" Scenarios

	Preffered A: Wind, Solar, and CAES	Preffered B: Wind, Solar, and Batteries	Preffered C: Wind, Solar, ICEs, and Batteries
Wyoming Wind	46 MW	46 MW	46 MW
Utah Solar	44 MW	44 MW	44 MW
CAES (48 Hour Duration)	54 MW		
ICEs			54 MW
Batteries (4 Hour Duration)		113 MW	50 MW

Table 2.8: Resources in SB100 Preferred Portfolios A, B and C.

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Results: 68% RPS by End of Planning Period

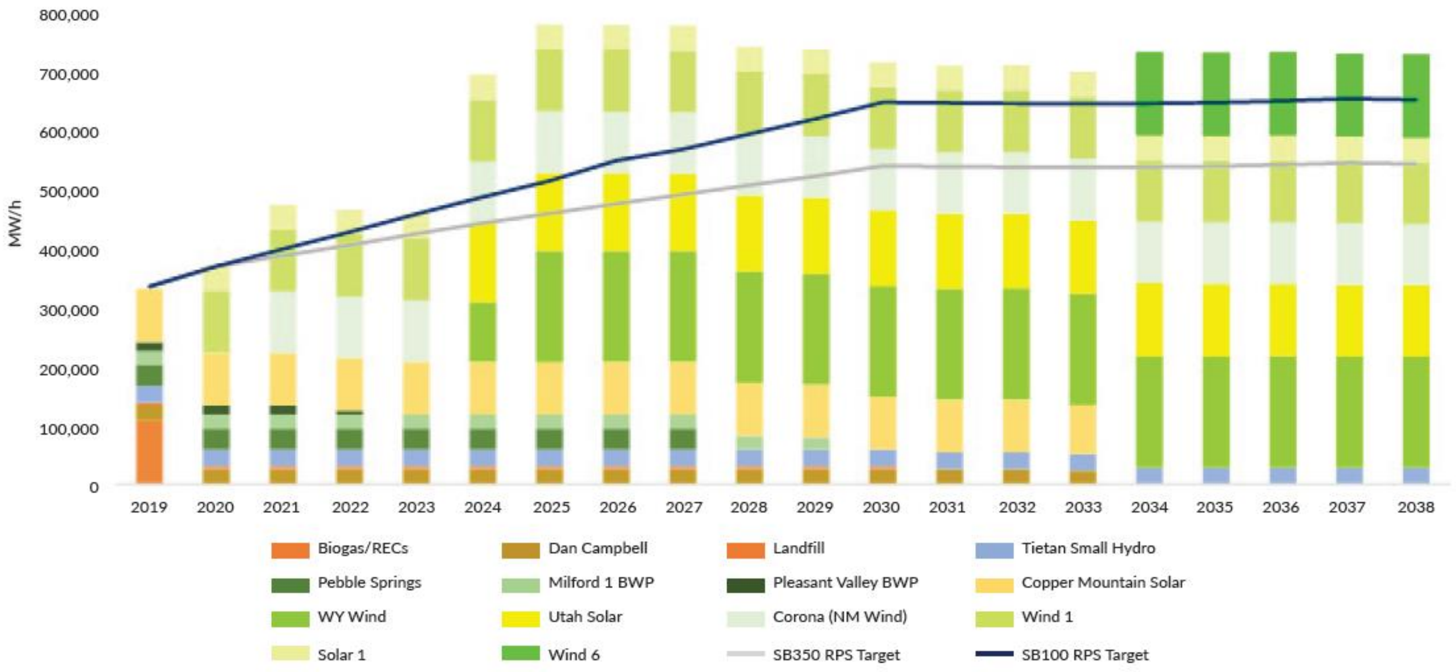

Figure 2.4: Example: Renewable Capacity to Meet 60% RPS by 2030, All Preferred Portfolios.

RPS of 67% to 70% can be done with rate increases at or less than general rate of inflation.

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Results: 87% GHG Emissions Reduction

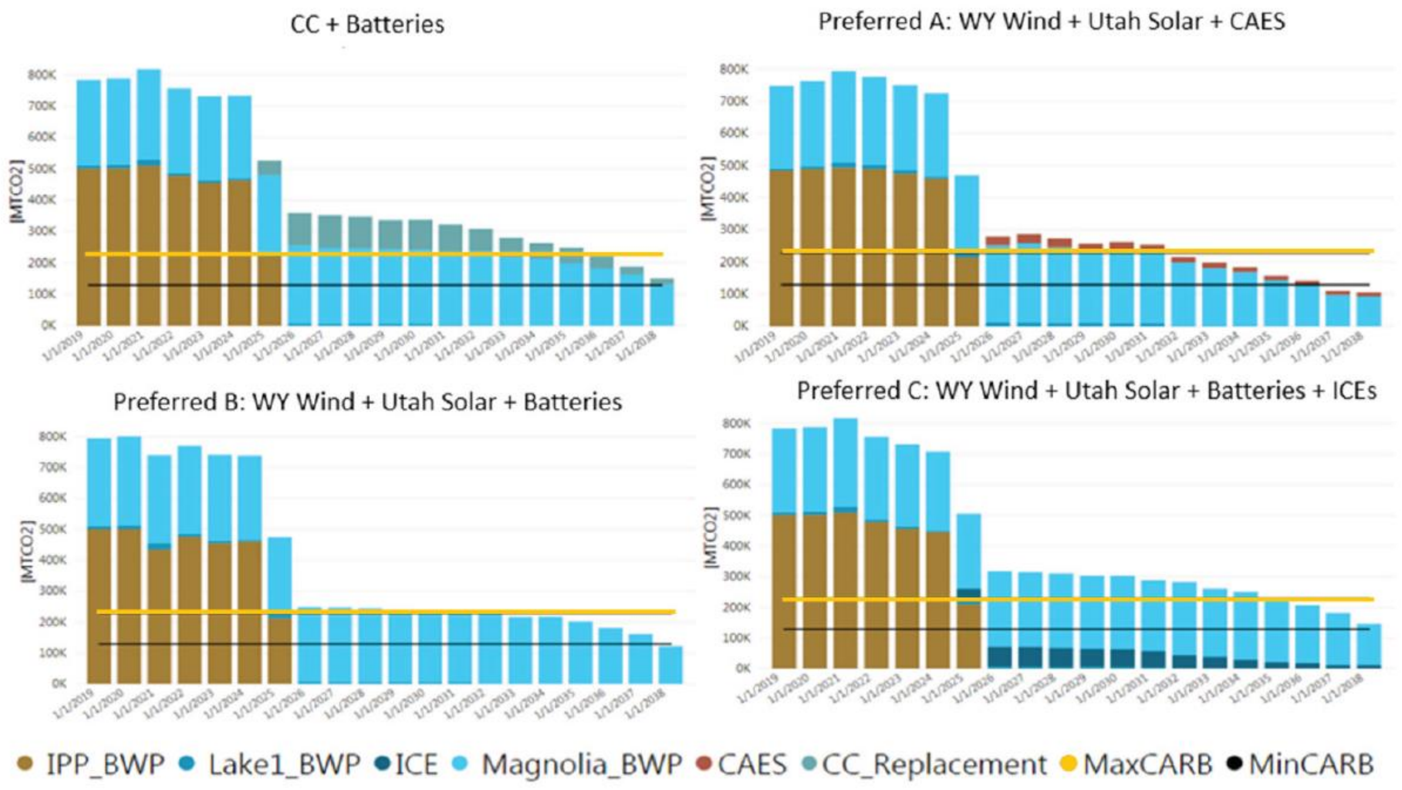

Figure 2.8: BWP GHG Emissions Reductions with Increasing Renewables in SB100 for CC Renewal project at IPP and the 3 IRP Preferred Portfolios.

Results:
Storage and Renewables Lowest Cost Options

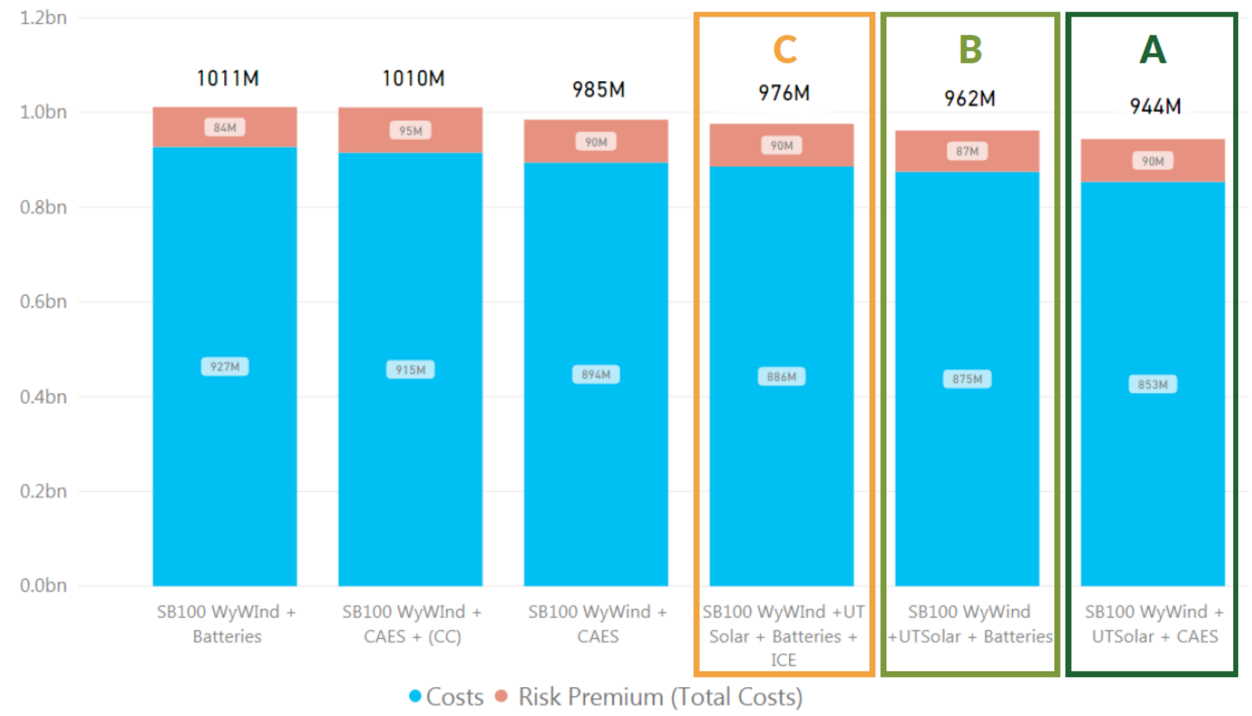

Figure 2.5: Total Cost Ranking of the Lowest-Cost Portfolios for SB100. (Present Value 2019$)

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BWP IRP: Solar Intermittency

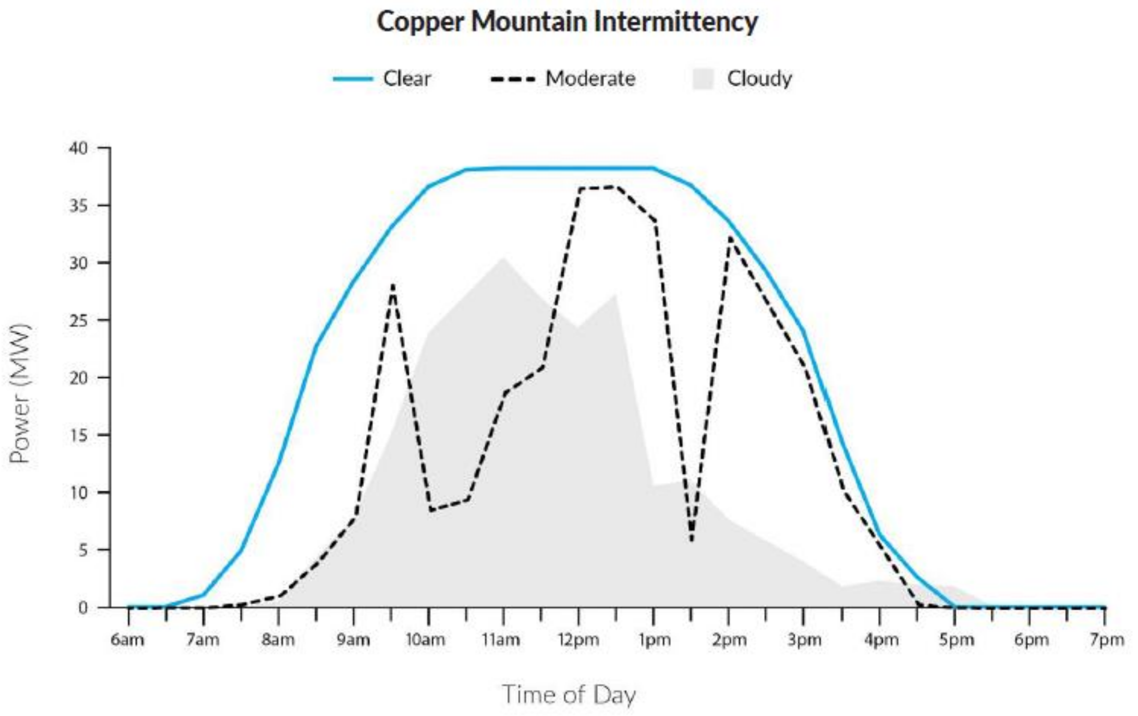

Figure 3.6: Copper Mountain Solar 3 Intermittency
Source: BWP

- ***Weather conditions (clouds) affect solar output during the day.***
- ***Wind also varies with weather.***
- ***Supply resources need to compensate for these effects.***

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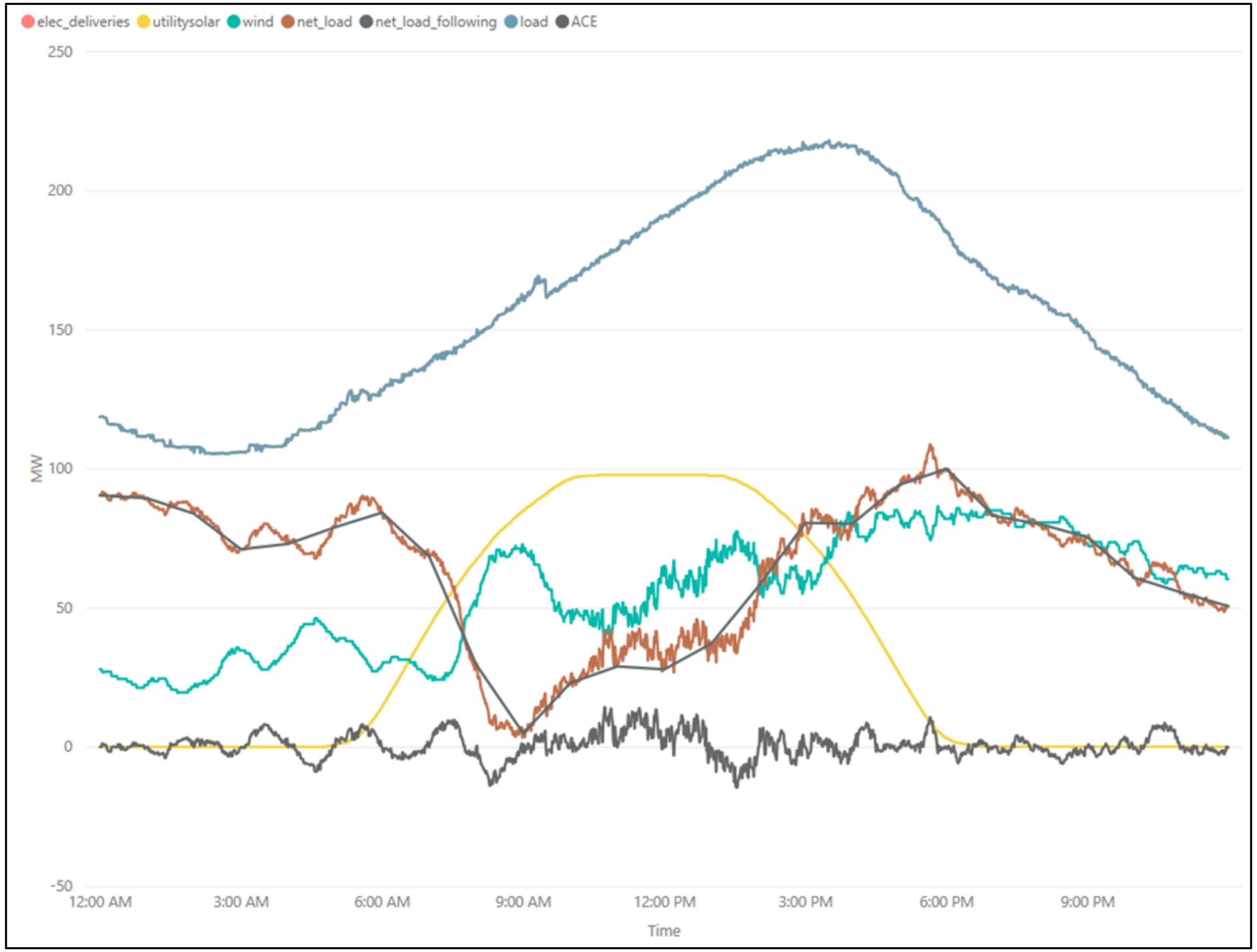
Results: Needs for Regulation and Ramping



- ***Solar and wind outputs are volatile over time.***
- ***High ramping requirements as the sun rises and sets each day.***
- ***Supply resources must start and ramp quickly.***
- ***Good applications for batteries.***

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BWP IRP: Storage for Ramping

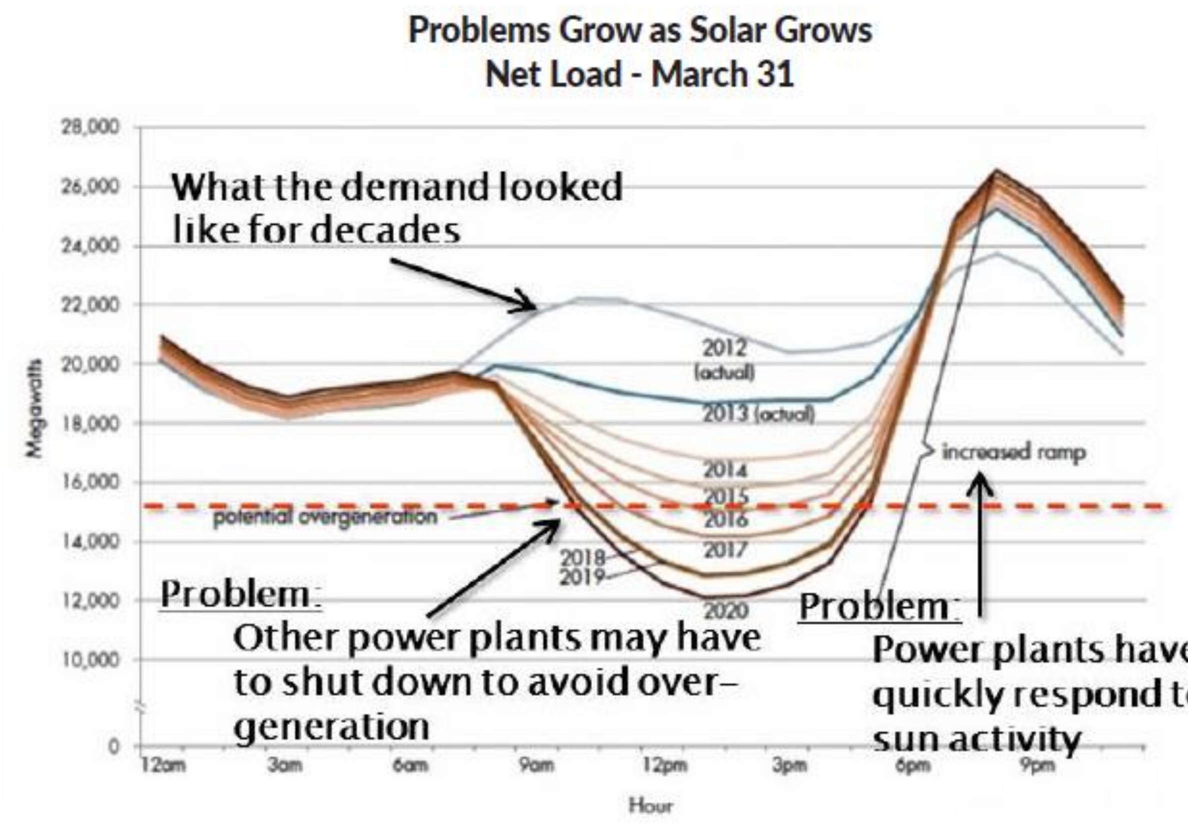

Figure 3.7: Problems Grow as Solar Grows
Source: CAISO

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Results: Batteries in the Supply Scenarios

Portfolio #	CC	WY Wind	Utah Solar	CAES	Batteries (MW of 4 hr)	ICEs	Wind/Solar Addition	Ancillary Batteries (MW of 1 hr)	Transmission on STS
1	0	102	0	0	113	0	160	79	54
2	0	102	0	54	0	0	160	79	54
3	0	46	44	0	50	54	204	97	54
4	0	102	0	54	0	0	160	79	126*
5	0	46	44	54	0	0	204	97	54
6	0	46	44	0	113	0	204	97	54

Table 2.7: Resource Portfolios Evaluated for an SB100 future.

Significant quantities of ½- and 1-hour batteries for ancillary services (ramping and frequency regulation) needed in all scenarios.

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Distributed Storage Overview

- Front of the Meter
    - Substation end
    - Feeder (or Customer) end

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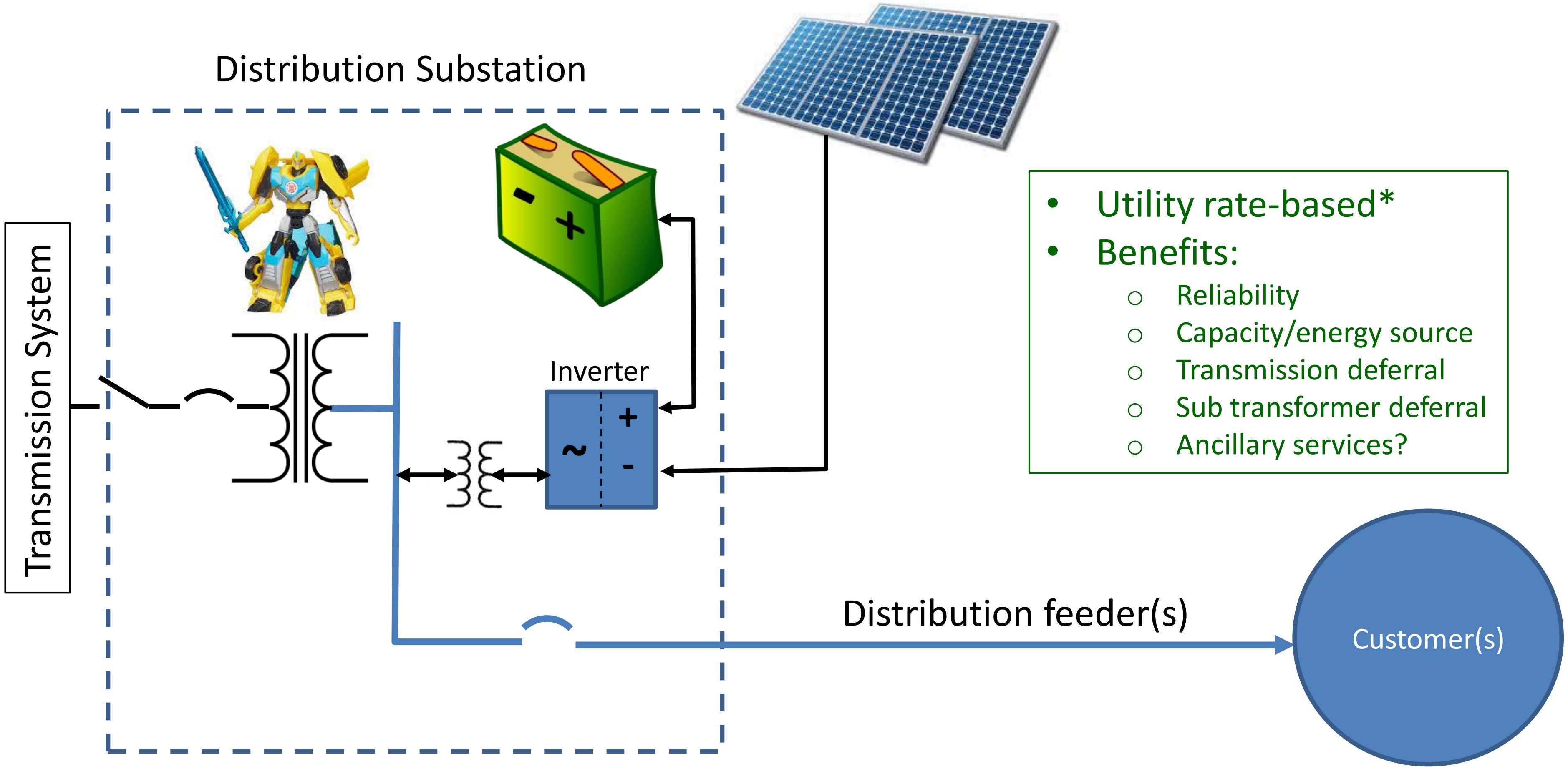
Front of the Meter: Substation End



- Utility rate-based*
- Benefits:
  - Reliability
  - Capacity/energy source
  - Transmission deferral
  - Sub transformer deferral
  - Ancillary services?

*Could be third-party supplier.

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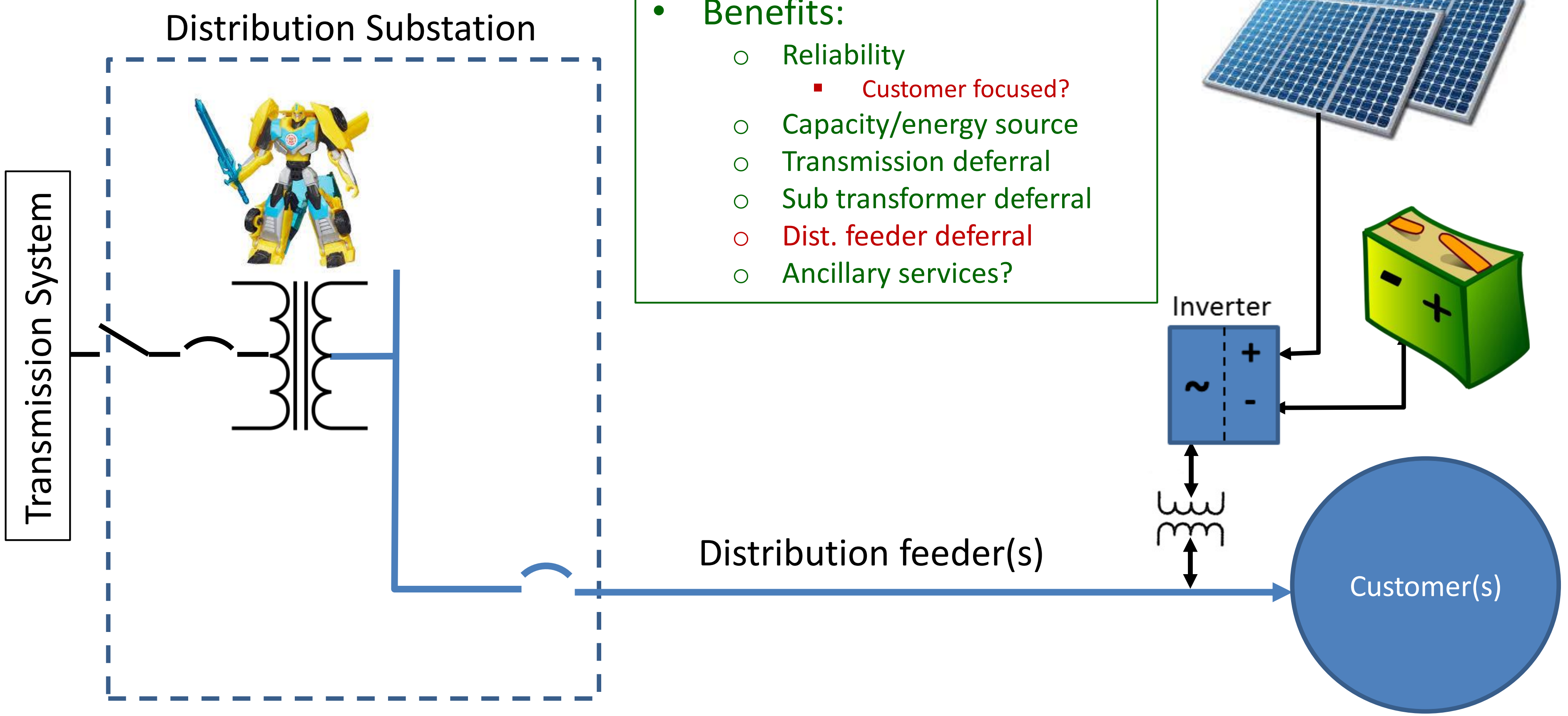
Front of the Meter: Feeder End

- Utility rate-based*
  - or customer contribution
- Benefits:
  - Reliability
    - Customer focused?
  - Capacity/energy source
  - Transmission deferral
  - Sub transformer deferral
  - Dist. feeder deferral
  - Ancillary services?



*Could be third-party supplier.

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Front of the Meter: Conclusions

- Typically a utility asset that is ratebased.
  - Part of the utility's distribution or integrated resource plan.
    - But may have a third-party supplier via a Power Purchase Agreement or other agreement negotiated with utility.
- Could be located at substation end, or feeder end.
- Could be a community-based solar + storage project.
- Potential benefits
  - Reliability
    - Could be customer-specific if located near customer.
  - Capacity and energy source
  - Transmission deferral
  - Substation transformer deferral
  - Distribution feeder deferral (if located at feeder end)
  - Ancillary services?

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- Frequently-Asked Questions (FAQ)

100% Clean Energy Goals

<u>To be clear</u>:

- ***The goal is not 100% renewable or clean energy.***
- ***It is reductions in greenhouse gas (GHG) emissions.***

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100% Goals: States*

STATE	TYPE OF 100% TARGET	YEAR	STATUS	SOURCE
California	Clean energy	2045	Law	SB100
Washington DC	Renewable energy	2032	Law	B22-0904
Hawaii	Renewable energy	2045	Law	HB623
New Jersey	Clean energy	2050	Order	EO 28
New York	Clean energy	2040	Law	S6599
Washington	Clean energy	2045	Passed	SB 5116
New Mexico	Clean energy	2045	Law	SB 489
Puerto Rico	Renewable energy	2050	Law	PS 1121
Maine	Renewable energy	2050	Law	LD 1494
Wisconsin	Clean energy	2050	Goal	Governor Evers
Minnesota	Renewable energy	2050	Goal	Governor Walz
Nevada	Clean energy	2050	Law	SB 358

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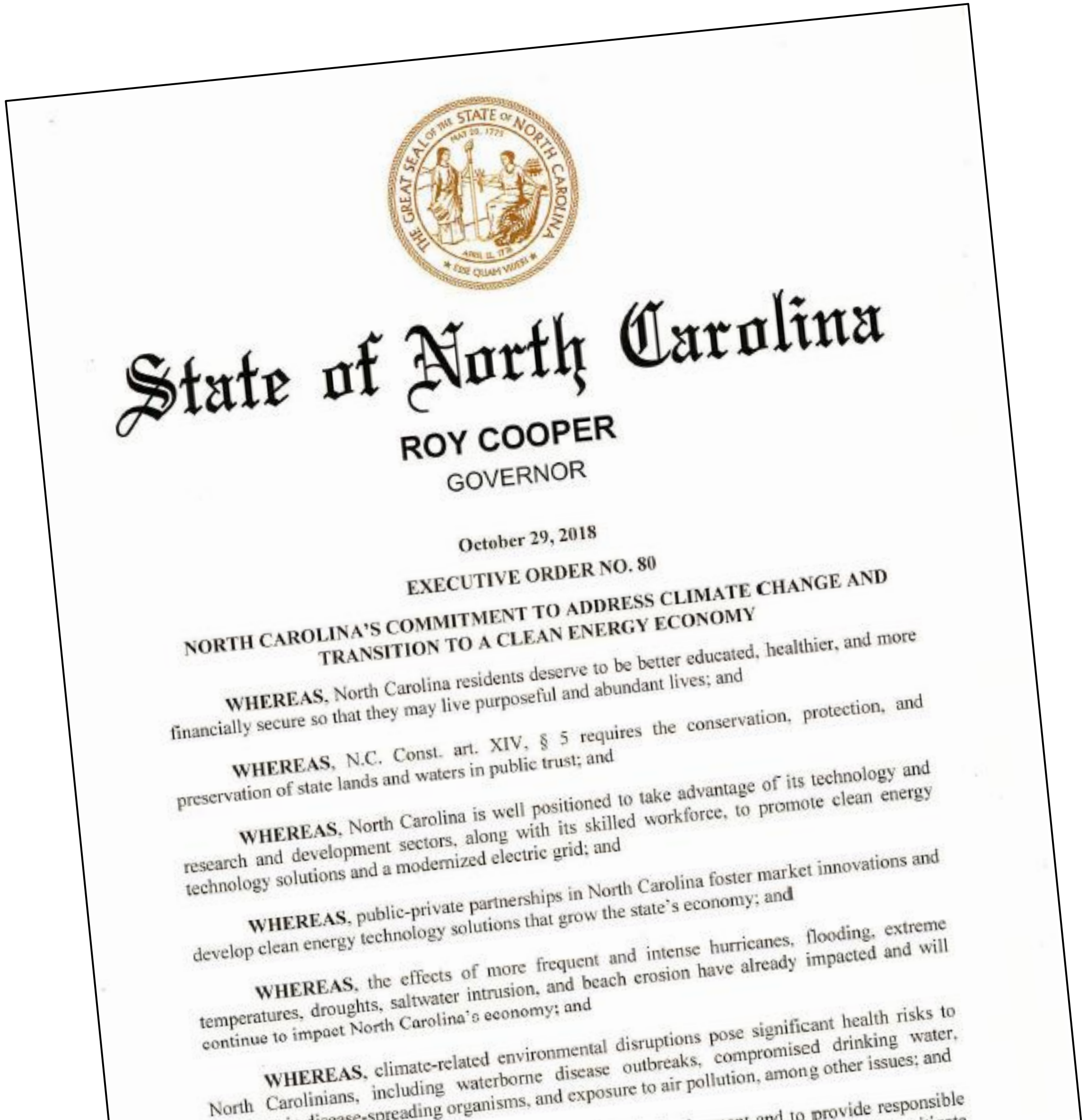
*Source: https://news.energysage.com

Clean Energy Goals: North Carolina

Executive Order, 10/29/2018

- Goals by 2025:
  - Reduce GHG emissions 40%.
  - 80,000 more zero-emission vehicles.
  - Reduce energy consumption in state buildings by 40%.
- Establishes NC Climate Change Interagency Council.
- Multiple other actions.



State of North Carolina

ROY COOPER
GOVERNOR

October 29, 2018

EXECUTIVE ORDER NO. 80

NORTH CAROLINA'S COMMITMENT TO ADDRESS CLIMATE CHANGE AND TRANSITION TO A CLEAN ENERGY ECONOMY

WHEREAS, North Carolina residents deserve to be better educated, healthier, and more financially secure so that they may live purposeful and abundant lives; and

WHEREAS, N.C. Const. art. XIV, § 5 requires the conservation, protection, and preservation of state lands and waters in public trust; and

WHEREAS, North Carolina is well positioned to take advantage of its technology and research and development sectors, along with its skilled workforce, to promote clean energy technology solutions and a modernized electric grid; and

WHEREAS, public-private partnerships in North Carolina foster market innovations and develop clean energy technology solutions that grow the state's economy; and

WHEREAS, the effects of more frequent and intense hurricanes, flooding, extreme temperatures, droughts, saltwater intrusion, and beach erosion have already impacted and will continue to impact North Carolina's economy; and

WHEREAS, climate-related environmental disruptions pose significant health risks to North Carolinians, including waterborne disease outbreaks, compromised drinking water, ... disease-spreading organisms, and exposure to air pollution, among other issues; and

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100% Goals: 141 Cities (continued)

100% Commitments in Cities, Counties, & States

Powered by 100% Renewable Energy: These communities have fully transitioned to 100% clean, renewable energy sources to power the community's electricity needs.

Committed to 100% Renewable Energy: These communities have made community-wide commitments to transition to 100% clean, renewable energy no later than 2050.

Source: Sierra Club https://www.sierraclub.org/ready-for-100/commitments

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100% Goals: Corporations

- Google and Apple now 100% “powered” by renewable energy.
- More than 130 corporations have committed to 100% clean energy via the RE100 initiative.
  - Examples: Anheuser-Busch InBev, General Motors, IKEA, NIKE, 3M, Adobe, Accenture and Wal-Mart.

Source: Forbes, Energy Innovation: https://www.forbes.com/sites/energyinnovation/2018/04/12/google-and-apple-lead-the-corporate-charge-toward-100-renewable-energy/#4910d0721b23

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A Word about "100% Renewable"

- Most entities claiming to be "100% renewable" are doing it *on the average*.
  - That is, they are simply procuring a quantity of renewable energy equal to their annual energy use.
- But renewable energy is non-dispatchable and intermittent.
  - The timing of its output *does not match the timing* of customers' use of electricity.

They are either unaware of
or ignoring this timing challenge,
or assuming someone else will reconcile it.

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100% Goals: Utilities (Examples)

Utility	Year
Avista	2045
Green Mountain Power	2025
Idaho Power	2045
Public Service Company of New Mexico	2040
Xcel Energy	2050

Utilities understand what doing 100% clean energy really requires.

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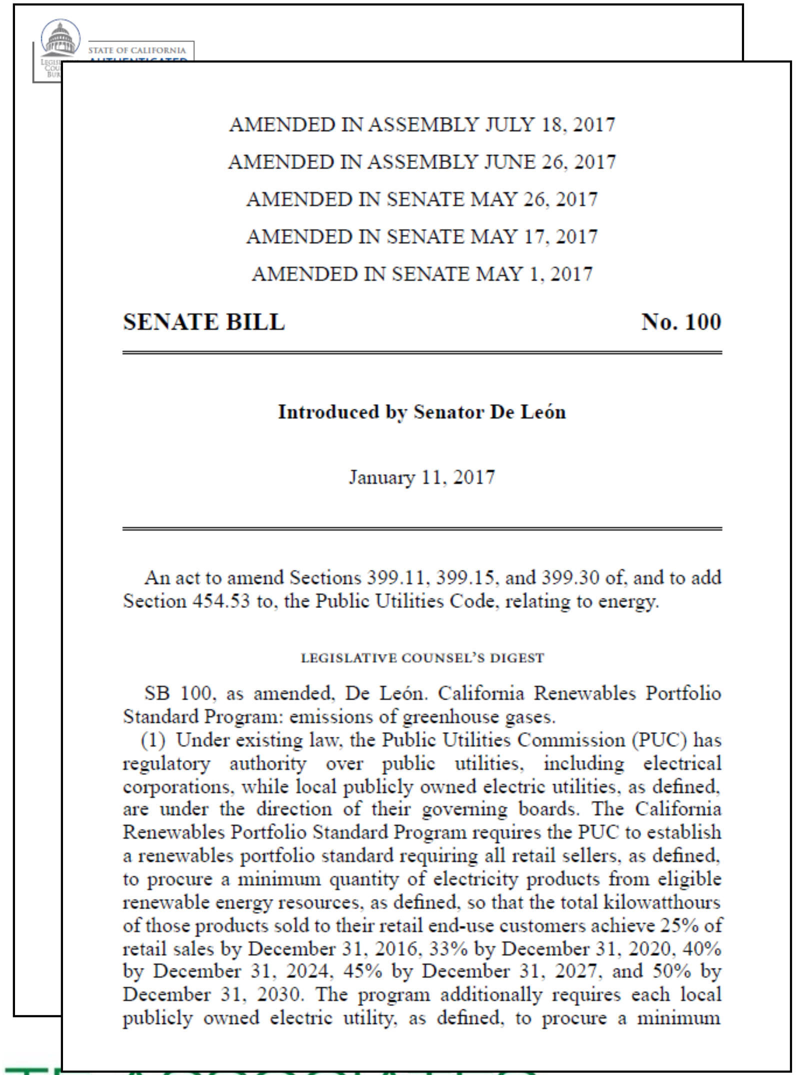
Renewables in California



STATE OF CALIFORNIA

AMENDED IN ASSEMBLY JULY 18, 2017
AMENDED IN ASSEMBLY JUNE 26, 2017
AMENDED IN SENATE MAY 26, 2017
AMENDED IN SENATE MAY 17, 2017
AMENDED IN SENATE MAY 1, 2017

SENATE BILL **No. 100**

Introduced by Senator De León

January 11, 2017

An act to amend Sections 399.11, 399.15, and 399.30 of, and to add Section 454.53 to, the Public Utilities Code, relating to energy.

LEGISLATIVE COUNSEL'S DIGEST

SB 100, as amended, De León. California Renewables Portfolio Standard Program: emissions of greenhouse gases.

(1) Under existing law, the Public Utilities Commission (PUC) has regulatory authority over public utilities, including electrical corporations, while local publicly owned electric utilities, as defined, are under the direction of their governing boards. The California Renewables Portfolio Standard Program requires the PUC to establish a renewables portfolio standard requiring all retail sellers, as defined, to procure a minimum quantity of electricity products from eligible renewable energy resources, as defined, so that the total kilowatthours of those products sold to their retail end-use customers achieve 25% of retail sales by December 31, 2016, 33% by December 31, 2020, 40% by December 31, 2024, 45% by December 31, 2027, and 50% by December 31, 2030. The program additionally requires each local publicly owned electric utility, as defined, to procure a minimum

- Previously a 50% RPS* by 2030 (SB350).
- SB100 (enacted Sept 10, 2018):
  - 50% RPS by 2026.
  - 60% RPS by 2031.
  - 100% zero-carbon electricity by 2045.

*Renewable Portfolio Standard. The percent of an electric utility's retail energy sales that must be served by renewable energy.

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Renewables in So. California

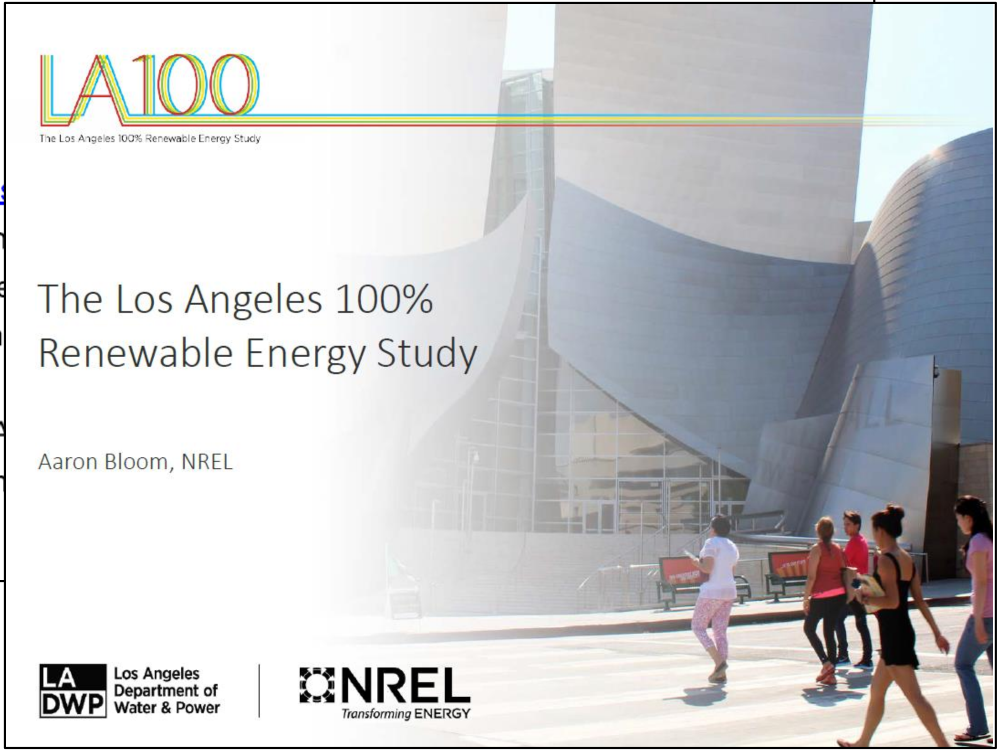
Utility Dive

Los Angeles to study 100% clean energy goals

By Robert Walton | September 20, 2016

Dive Brief:

Los Angeles last week joined a growing list of metro areas
angeles-takes-major-step-toward-100-clean-energy) lookin
100% on renewable power while reversing a years-long tre
For the third consecutive year, Los Angeles has been ran
Council member pointed out.
Sierra Club notes that Los Angeles would be the largest A
likes of Salt Lake City, San Diego and Boulder, along with
examine the goal.



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"100% Clean Energy: The California Conundrum"

The Electricity Journal 32 (2019) 31–36

Contents lists available at ScienceDirect

The Electricity Journal

journal homepage: www.elsevier.com/locate/tej

ELSEVIER

100% Clean Energy: The California Conundrum

ARTICLE INFO

Keywords:
Power from the Prairie
Clean energy
Diversity
Energy storage
HVDC transmission
Over-generation
Renewable energy
Renewable portfolio standard
Virtual storage

ABSTRACT

The state of California has embarked on an ambitious effort to achieve very high levels of clean energy in the interest of minimizing greenhouse gas (GHG) emissions. California Senate Bill 100 (SB100), enacted in September 2018, increased the statewide required Renewable Portfolio Standard (RPS)[1] for electric utilities from 50% to 60% by 2030. It further established an aspirational goal of 100% clean energy in all sectors by 2045. Achieving 60% to 70% or more in the electric sector is projected to be achievable at reasonable cost, if current planning assumptions prove true.

However, getting all the way to the ideal 100% is a different matter, based on current technology projections, system configurations and costs. The challenges are two-fold. First, what to do with the renewables over-generation that will inevitably occur when necessarily large levels of installed and non-dispatchable renewable capacity produces in hours when there is no need for it?

Second, without backup from fossil resources, reliability of the electric grid is a risk. Batteries have a bright future in helping integrate the intermittency of renewable resources on an hourly operating basis going forward. But at currently-projected storage durations and costs, the projected cost of using batteries to ensure installed resource adequacy and grid reliability in a 100% renewable, zero-fossil world is prohibitive without further technological advances and associated cost reductions.

This article describes the unique challenges for California and potential solutions for them as the quest for 100% clean energy in California and other states continues.

Securing enough clean energy to achieve 100% isn't the problem.
It is reliably managing it once you have it.
That is, be careful what you ask for.

1. The 100% clean energy target

presents about 38% of total GHG emissions in California, the electric utility industry represents an additional 19% from operation of their fossil-fired generating plants.[2]

California lawmakers have made significant efforts to address GHG emissions over the past few years. The most recent development, Senate

to 60% by the Year 2030. It also includes an aspirational goal of 100% clean energy in all sectors by the Year 2045—including but not limited to the electric utility sector.

In an electric utility context, the term "clean energy" can include several energy resources or approaches that involve zero GHG emissions. It includes energy efficiency, renewable energy (e.g., wind, solar,

electric use can be conserved away via energy efficiency efforts. The concept of carbon capture and storage is an interesting concept but remains technologically and environmentally challenging and prohibitively expensive. Finally, California is in the process of shutting down all of its legacy nuclear electric generation plants with no plans for similar replacements.[4]

Available at: www.schulteassociates.com/publications

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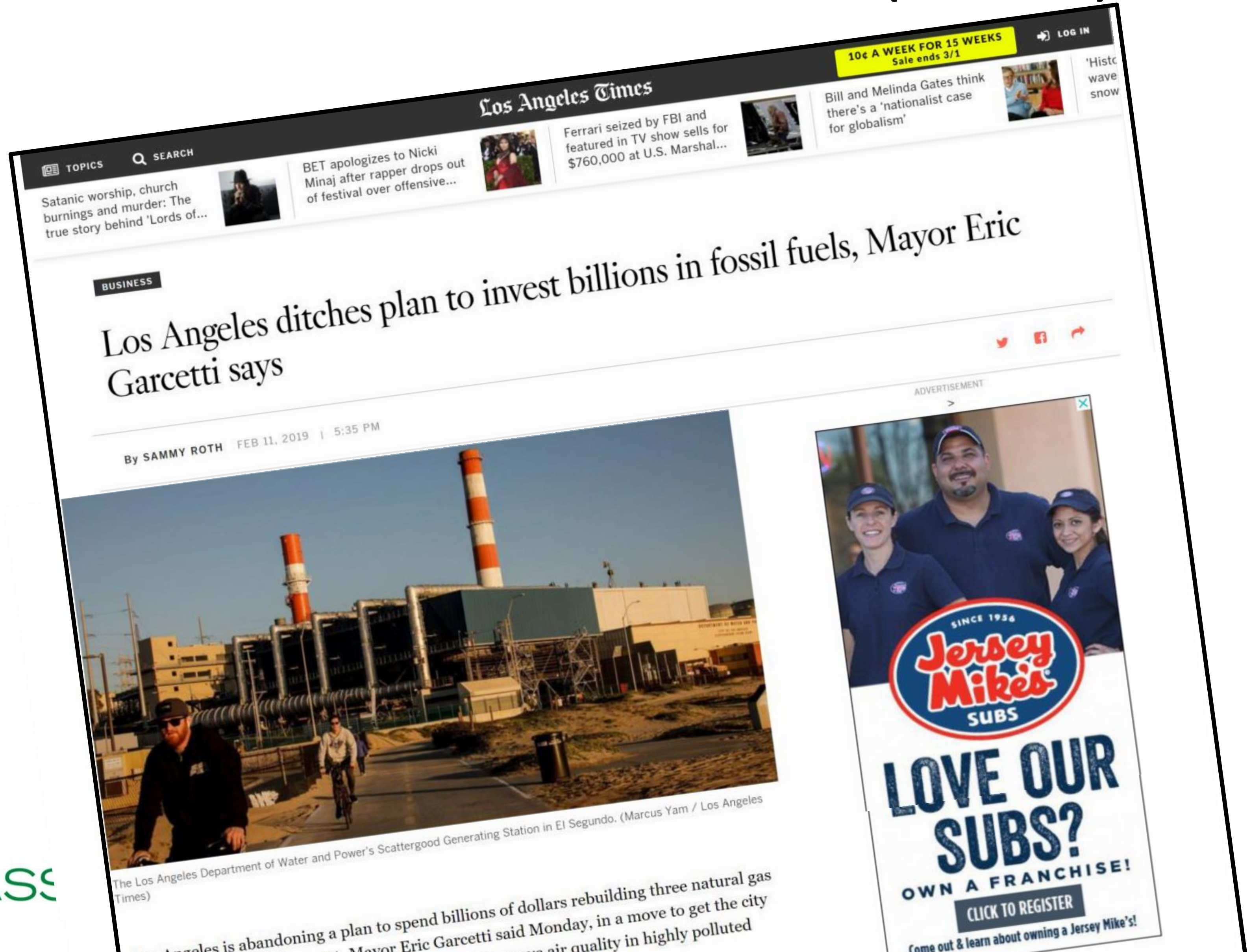
Renewables in So. Cal. (cont'd)



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Bill and Melinda Gates think there's a 'nationalist case for globalism'

'Histc wave snow

BUSINESS

Los Angeles ditches plan to invest billions in fossil fuels, Mayor Eric Garcetti says

By SAMMY ROTH FEB 11, 2019 | 5:35 PM

The Los Angeles Department of Water and Power's Scattergood Generating Station in El Segundo. (Marcus Yam / Los Angeles Times)

...geles is abandoning a plan to spend billions of dollars rebuilding three natural gas ... Mayor Eric Garcetti said Monday, in a move to get the city ... air quality in highly polluted

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Renewables in So. Cal. (cont'd)

UTILITY DIVE

BRIEF

California muni shelves gas plant to consider renewable options

By Gavin Bade • April 9, 2018

Dive Brief:

- The governing board of Glendale Water and Powe[r] California municipal utility, last week halted plans [t] MW natural gas plant to explore renewable energy storage options instead.
- The Glendale Water and Power Commission voted Monday to table discussions on an environmental i[...] the $500 million Grayson Power Plant [...] request for [...]

POWER Engineering

Glendale Rejects $500 Million Gas Plant Renovation

04/17/2018

By Editors of Power Engineering

The city council of Glendale, California has rejected a sweeping $500 million renovation of an 80-year-old natural gas plant being pushed by Glendale Water and Power Commission.

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UTILITY DIVE Deep Dive Opinion Library Events Jobs Topics

DEEP DIVE

California strives to nix its natural gas habit without letting the lights go out

The state relies on natural gas for reliability, but won't reach its 100% zero emissions goal without looking to alternatives.

AUTHOR
Herman K. Trabish

PUBLISHED

When California's lawmakers mandated 60% renewables by 2030 and targeted zero emissions by 2045 in Senate Bill 100, passed in September, they took on never-before-answered questions about reliability.

... of those questions is how to keep the lights on without natural gas at

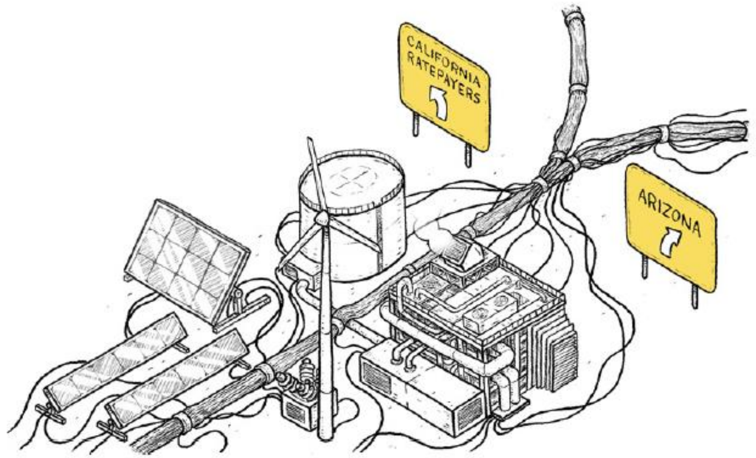
California: Balancing Renewables and Reliability

SCHULT

Solar Oversupply Growing in California

Los Angeles Times

(HTTP://WWW.LATIMES.COM/)



California invested heavily in solar power. Now there's so much that other states are sometimes paid to take it

By IVAN PENN

JUNE 22, 2017

On 14 days during March, Arizona utilities got a gift from California: free solar power.

Well, actually better than free. California produced so much solar power on those days that it paid Arizona to take excess electricity its residents weren't using to avoid overloading its own power lines.

Source: http://www.latimes.com/projects/la-fi-electricity-solar/

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Why California Needs Something Different

- California electric customers' annual load factor (i.e., average load) is about 50% to 55%.
- Annual capacity factor of California solar and wind is about 20% to 25%.
- A 60% RPS based on energy means:

California needs installed MW of renewable capacity exceeding its annual peak demand.

All other days of the year, they will over-generate during daytime hours when the sun is shining.

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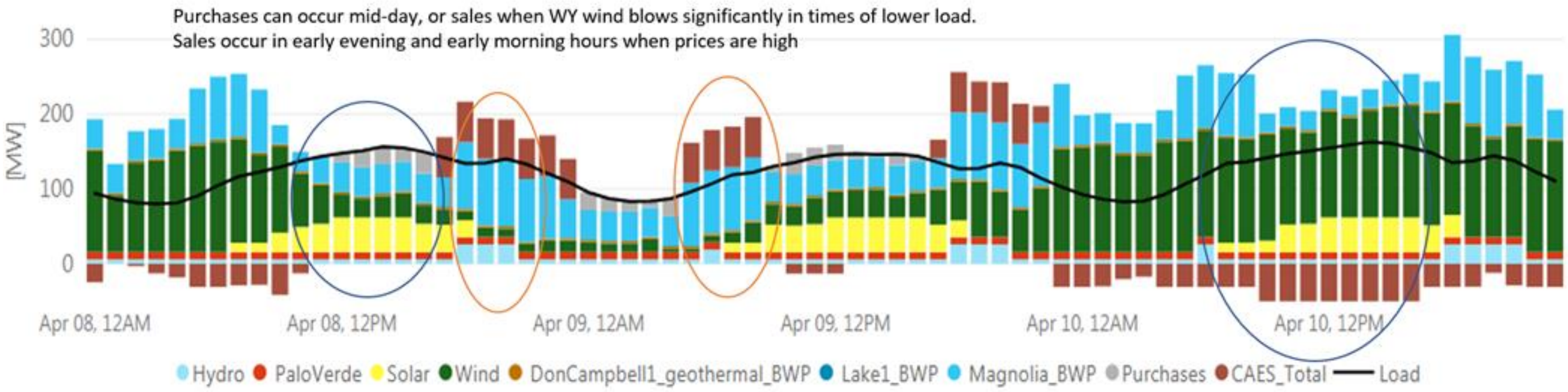
Renewables Over-Generation at **60% RPS**

Modeling results for two days in April 2030 for a Southern California utility.



It is likely that the other California utilities' models look the same.

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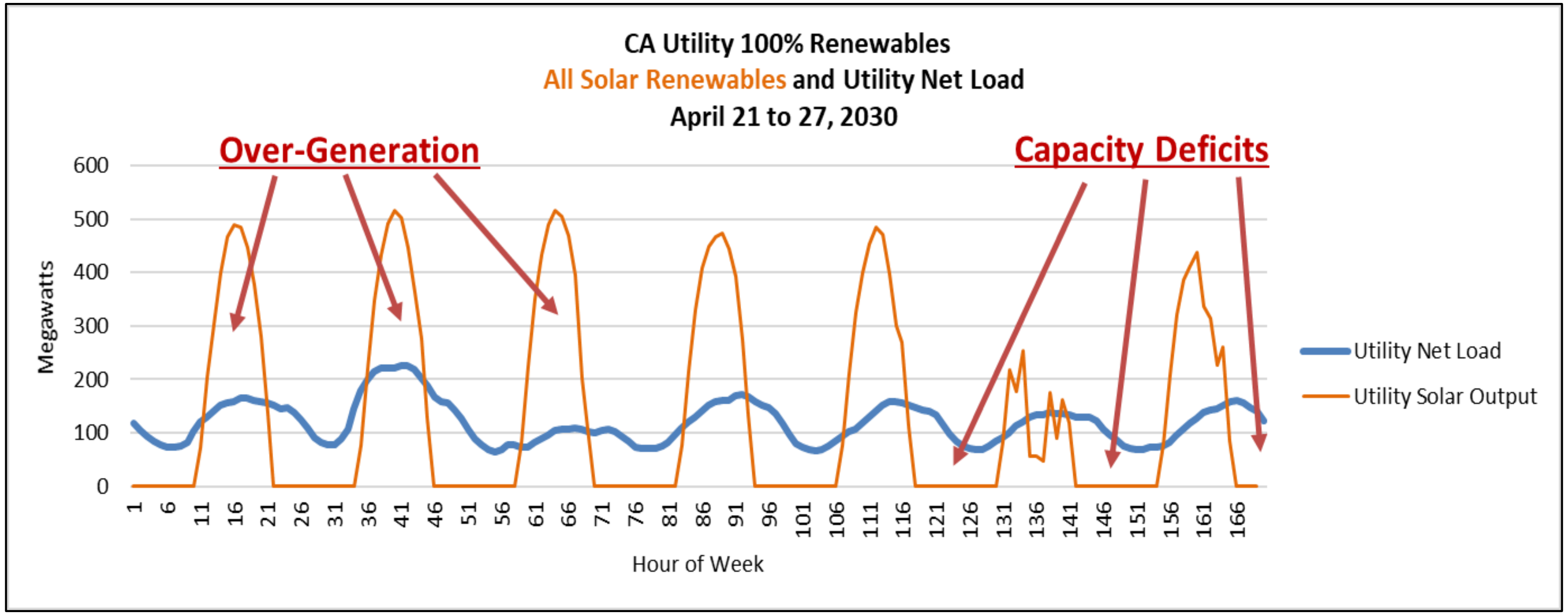
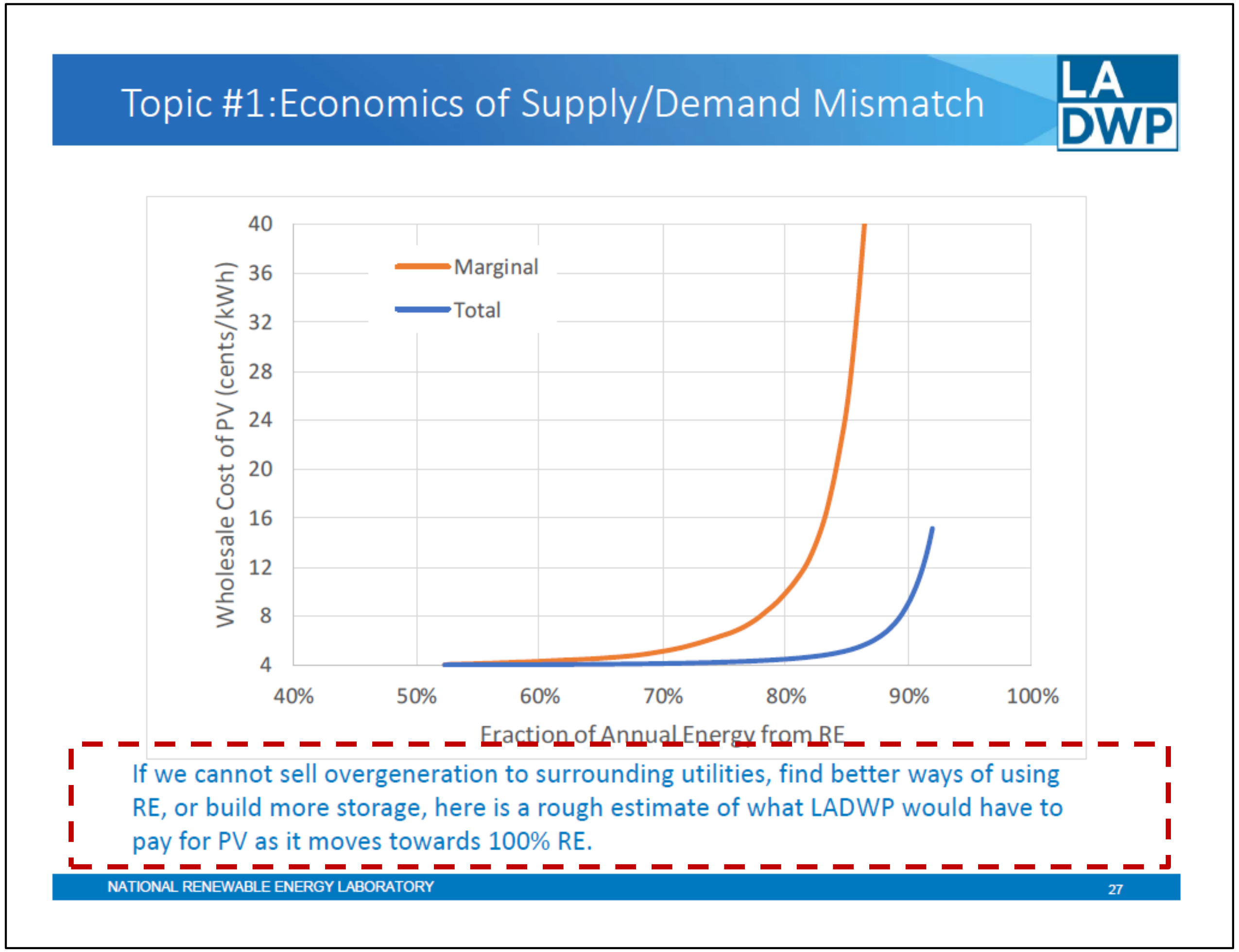
Renewables to Load Mismatch at **100% RPS**

Example of a week in April 2030 for a California utility with 100% solar.



The Challenge Approaching 100% (cont'd)



NREL presentation, LA100 Advisory Group meeting June 7, 2018.

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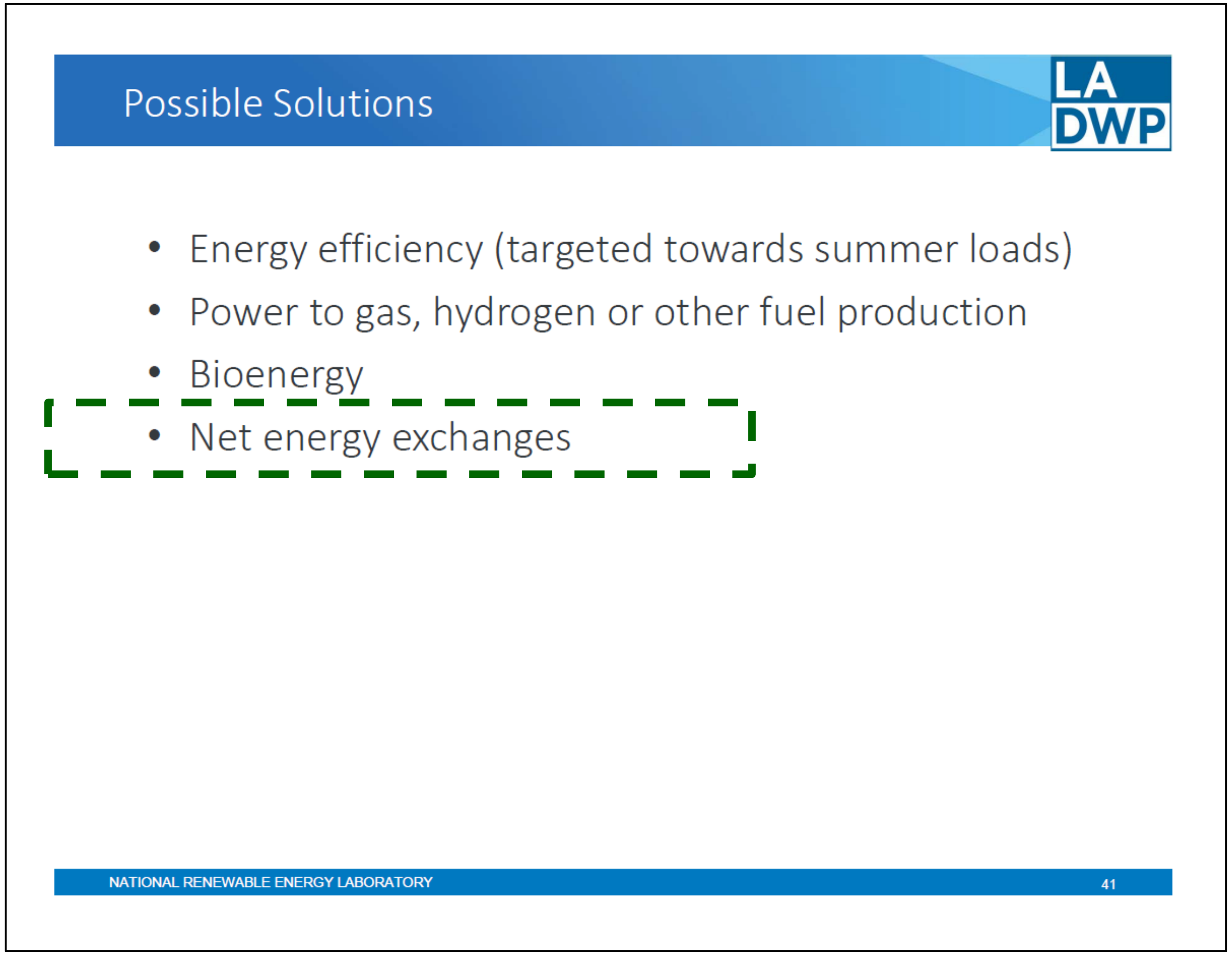
Possible Solutions

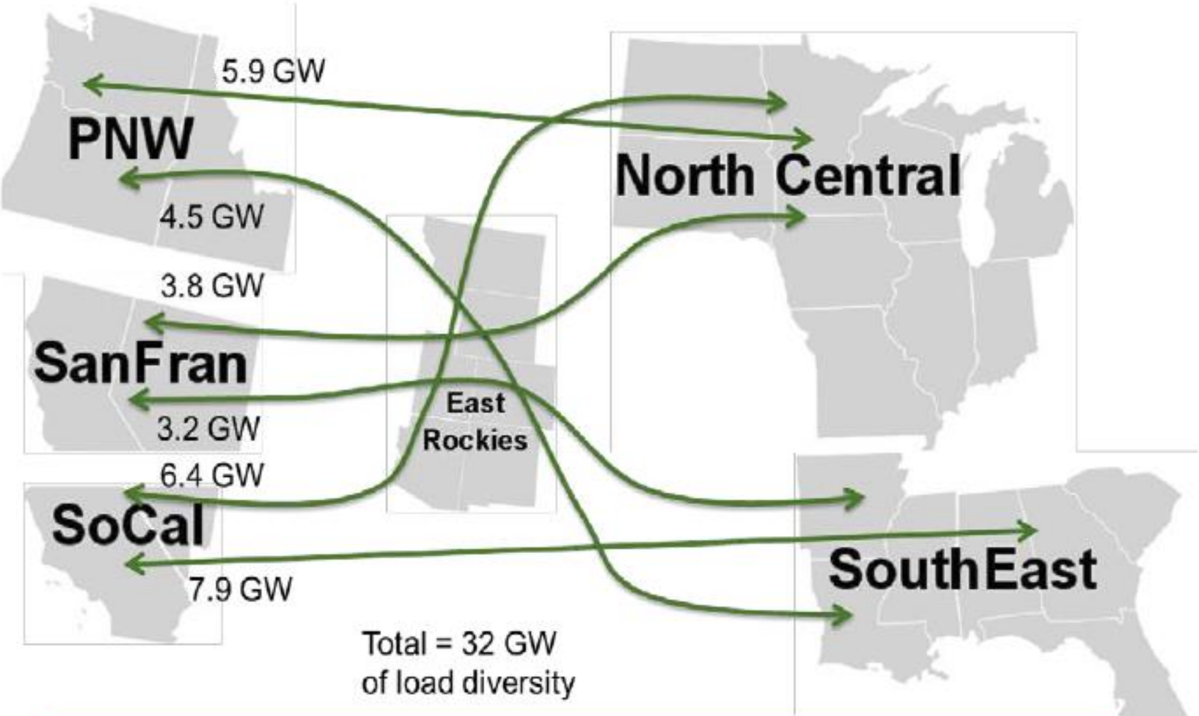


SCHULTE ASSOCIATES LLC NREL presentation, LA100 Advisory Group meeting June 7, 2018.

Desired transfers (MISO's study)

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

- Why these numbers?
  - WECC → EI: 14.4GW.
  - EI → WECC: 14.4GW



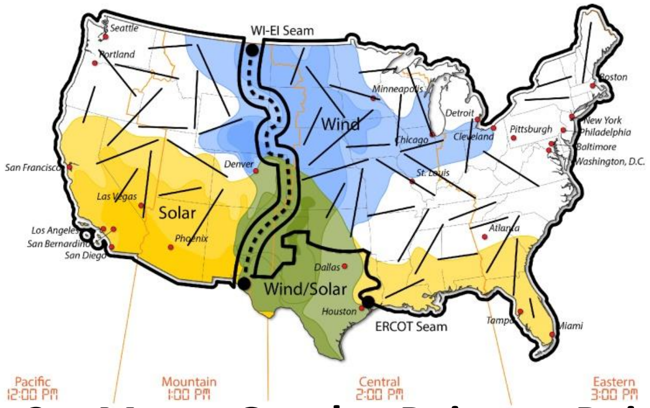
- Largest value driver: load diversity
- Benefit-to-cost ratio about 1.14:1
- Solar and wind delivery off-peak could increase ratio to 1.25:1

[Source: MISO's 2014 TEP report]

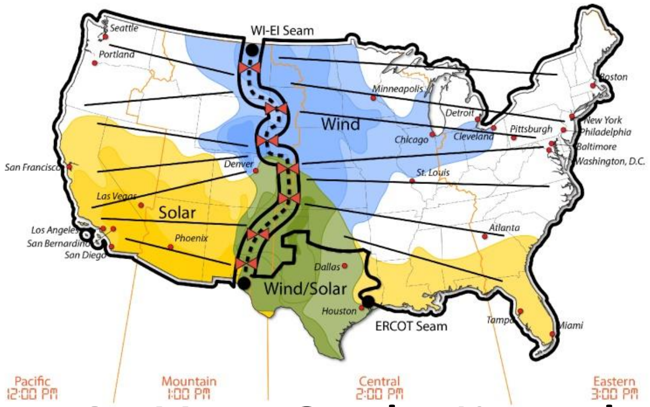
Load diversity capacity 32GW (capacity exchange)
15 GW of transmission (captures 30GW of diversity)
[Source: MISO's 2014 TEP report]

NREL “Seams Study” Scenarios

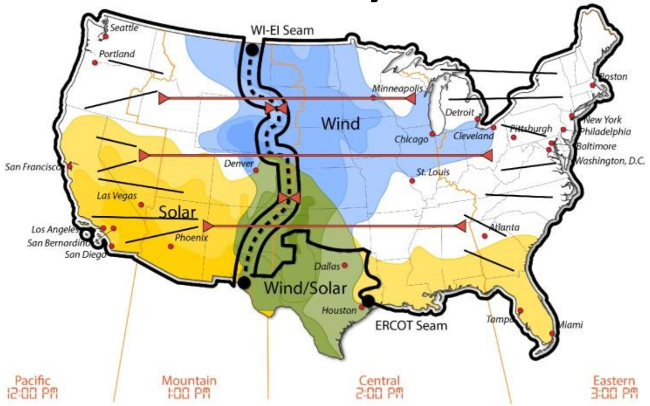
1. Baseline



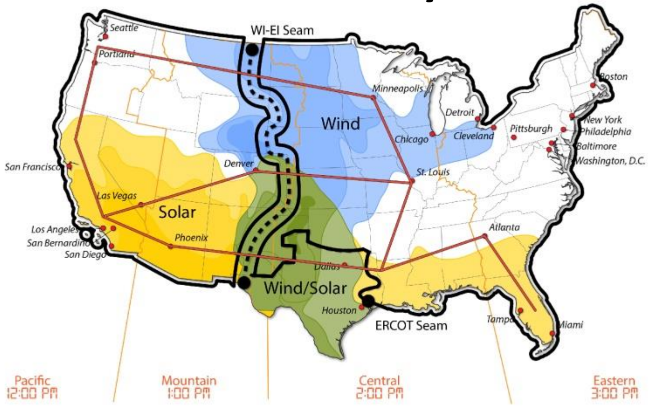
2. Modernize Existing



3. Macro Overlay Point-to-Point



4. Macro Overlay Network



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*Graphic source: NREL

NREL Seams Study Conclusions

- Conceptually, a large-scale *national* high voltage direct current (HVDC) transmission overlay with renewables would be cost-effective.

- By the end of the planning period:
  - Thousands of MW of additional renewables will have been installed.
  - Most of the remaining legacy coal power plants will have been retired.

The Seams Study results represent the coming transition to clean energy, enabled by HVDC transmission.

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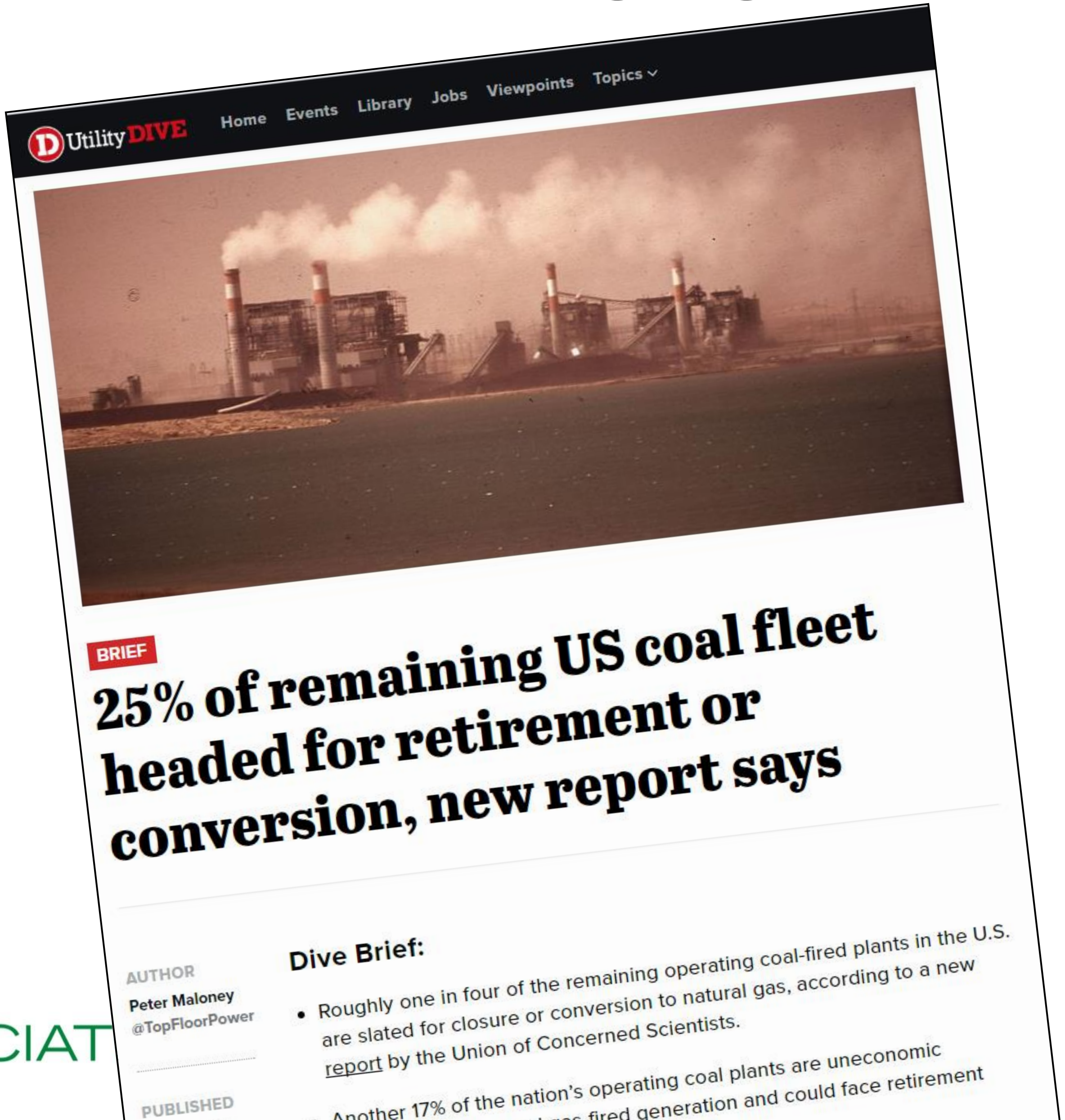
Coal Plants Aging Out



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BRIEF

25% of remaining US coal fleet headed for retirement or conversion, new report says

AUTHOR
Peter Maloney
@TopFloorPower

PUBLISHED

Dive Brief:

- Roughly one in four of the remaining operating coal-fired plants in the U.S. are slated for closure or conversion to natural gas, according to a new report by the Union of Concerned Scientists.
- Another 17% of the nation's operating coal plants are uneconomic ... fired generation and could face retirement

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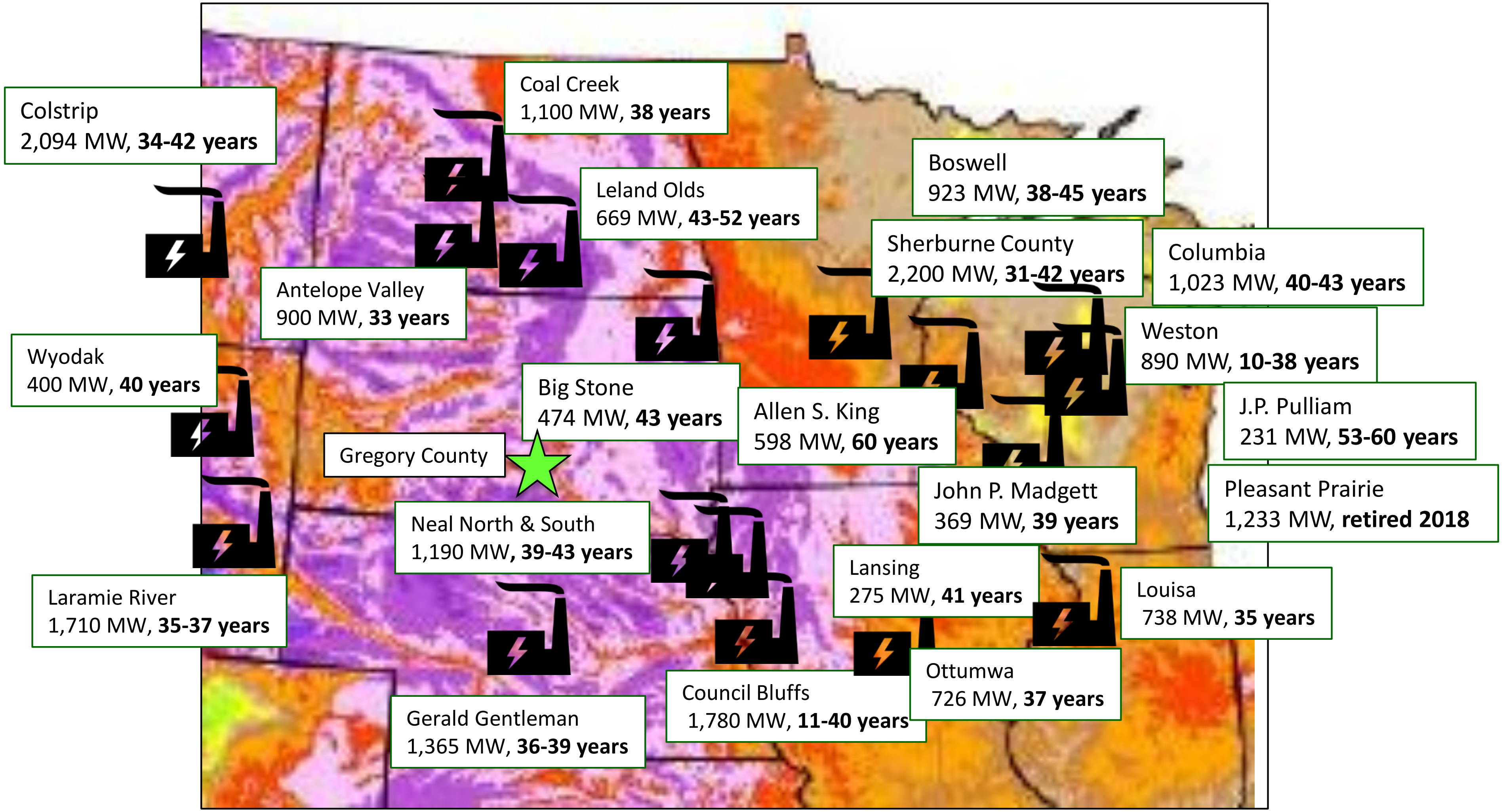
Upper Midwest Coal Plants: Ages in 2018



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As Seen in January 2018
"Power Engineering" Magazine

RENEWABLES

Authors:
Bob Schulte is a Principal in Schulte Associates LLC, an executive management consulting firm with offices in Raleigh, North Carolina. Fredric Fletcher is Chairman of Power from the Prairie LLC.

Enabling LARGE-SCALE RENEWABLES in the WESTERN U.S.

BY ROBERT H. SCHULTE AND FREDRIC C. FLETCHER

The Northern Prairie region of the United States (i.e., Wyoming, Nebraska, the Dakotas, etc.) has an abundance of wind and wide-open spaces that could be used to develop large, wind-powered electricity generation resources. The opportunity is daily, bi-directional renewable energy swaps between California, the Northern Prairie, Chicago and points East.

Power from the Prairie is a proposed 4,000 Megawatt HVDC transmission project in the wind-rich energy resource of the Upper Midwest.

16 WWW.POWER-ENG.COM WWW.POWER-ENG.COM 17

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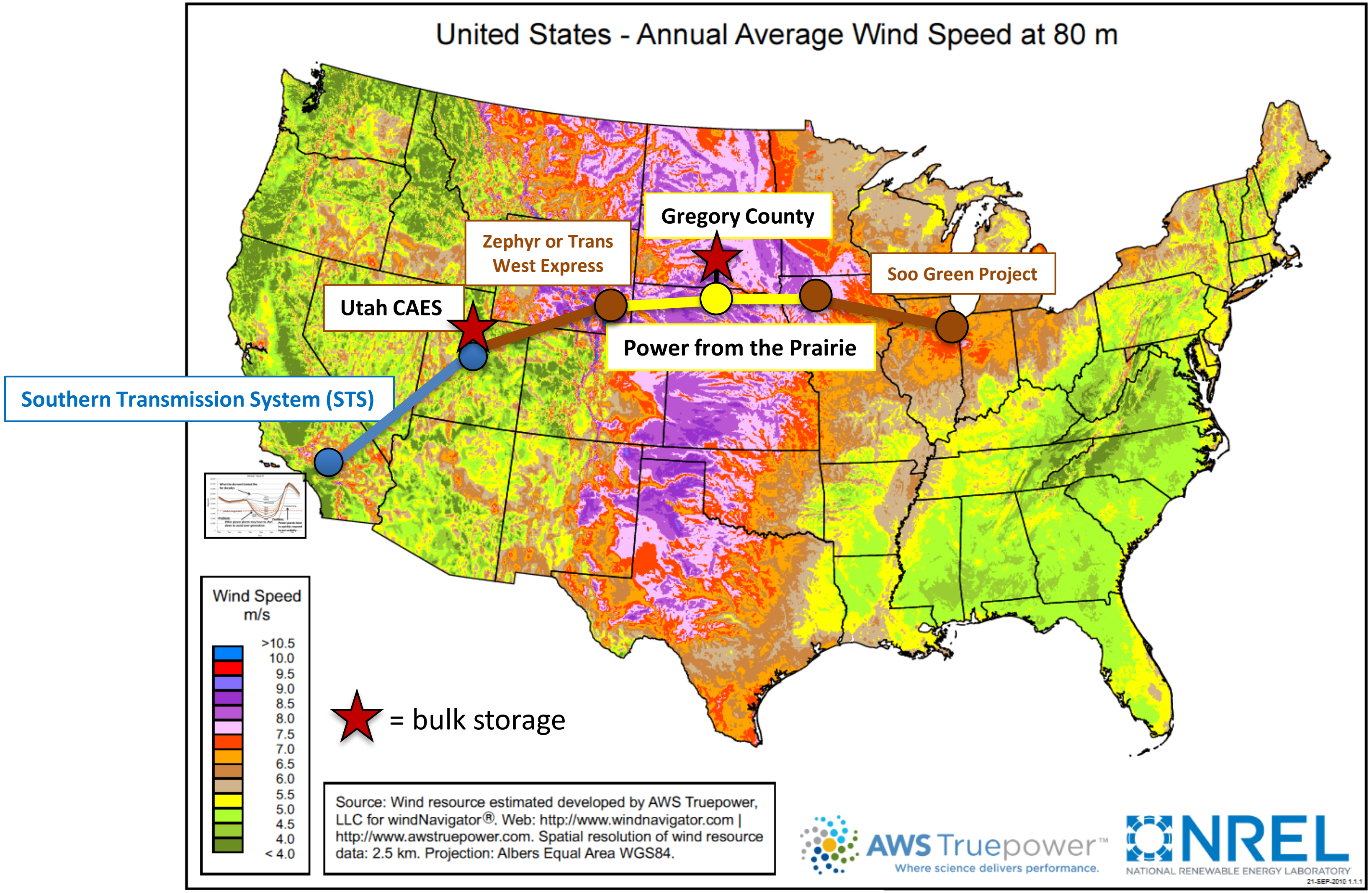
http://www.power-eng.com/articles/print/volume-122/issue-1/features/enabling-large-scale-renewables-in-the-western-u-s.html?eid=326858386&bid=1974335

Power from the Prairie Concept



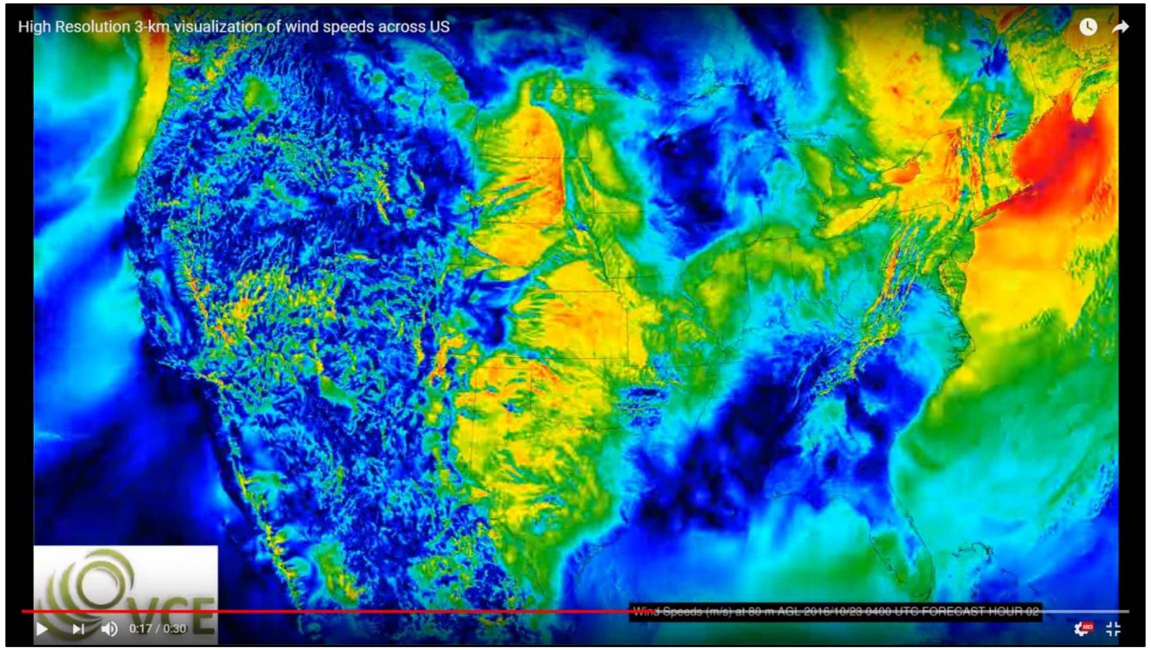
HVDC transmission lines

Existing | Proposed | Power from the Prairie | AC/DC terminal

SCHU

Diversity Effects (Example)

- Hourly wind speed patterns across the U.S.
  - https://www.youtube.com/watch?v=_epX8zog9Ug



Source: Dr. Christopher Clack, Vibrant Clean Energy

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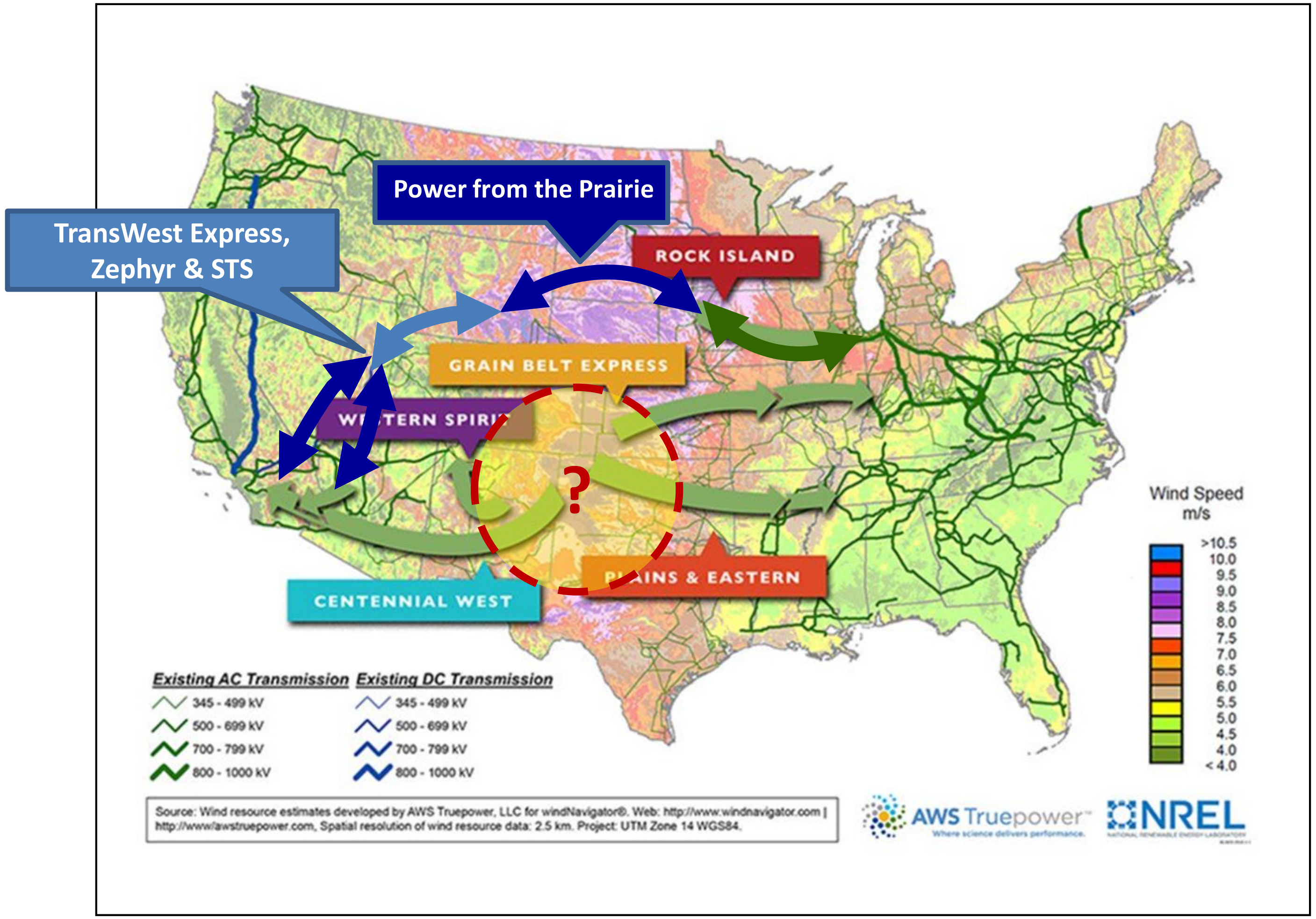
Part of a ^Bi-Directional National HVDC Overlay



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Why Is Time Diversity Between California Solar and Midwest Wind Output Important?

- Enables daily swaps of renewable energy between California (solar) and the Midwest (wind).
    - Better reliability.
    - Better utilization of transmission investment.
    - Less curtailment of renewable energy.

Transmission can enable "virtual" energy storage.

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Overview

- About Schulte Associates LLC
- About Storage
- Our Topic Today
- Grid-Level Storage
- Distributed Storage
- Storage for 100% Clean Energy.
- Frequently-Asked Questions (FAQ)

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Q: In Regulatory matters, should storage be classified as generation, transmission, distribution or load?

Answer:

- It can be any or all of these, depending on the application.
    - Need to avoid forcing storage into only one box.

An SNL analogy:

https://www.nbc.com/saturday-night-live/video/shimmer-floor-wax/n8625

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Q: Does storage reduce greenhouse gas emissions?

Answer:

- Storage typically tends to *increase* GHG emissions.*

Unless:

- It enables more clean energy than would otherwise occur without the storage.

* It could be storing coal energy and offsetting lower-GHG gas generation when it generates. And it has storage efficiency losses.

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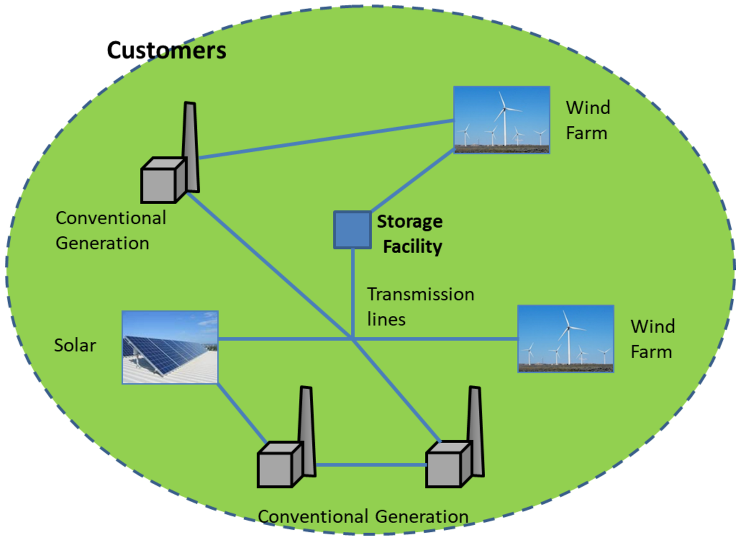
Q: How can we know if the storage is storing renewable energy, or fossil energy?

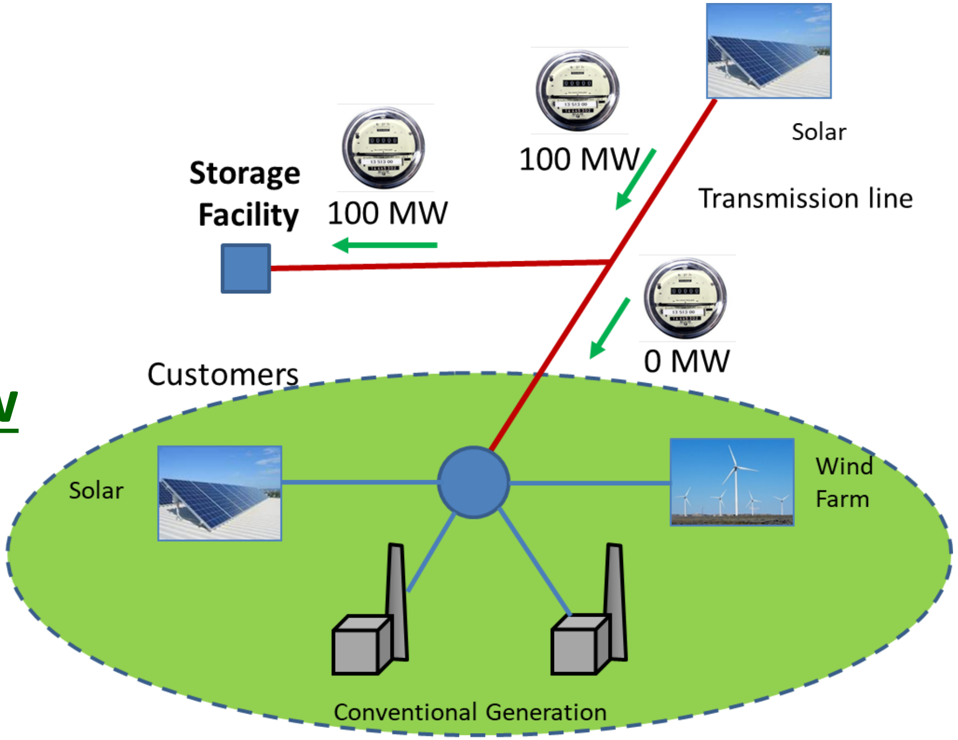
Answer:

1. Where is the storage located on the grid?
2. Read the meters.

Don't Know



Do Know



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Q: Should storage be eligible for investment tax credit (ITC) treatment like renewables?

<u>Answer (SA opinion)</u>:

- Yes, if it can be demonstrated the storage enables more renewables than would otherwise happen without the storage.

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Q: Should renewable energy sent to storage qualify for Renewable Energy Credits (RECs)?

<u>Answer (SA Opinion)</u>:

- Yes. That portion of storage output that comes from renewables should be eligible for RECs.
  - If the energy input to the storage is not already eligible for REC treatment (i.e., no double-counting).

Q: Which is better for utility customers: distributed storage or grid-level storage?

Answer (SA opinion):

- They are not mutually-exclusive options.
- Both will be needed.
- Considerations:
  - Does the storage option result in lower costs and better service; for both participating and non-participating customers?

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Q: What are the most likely applications for grid-level storage today?

- On the transmission system:
  - As a supplemental peaking power resource.
  - To integrate additional renewables (when used as tx resource).
  - To provide ancillary services (ramping, frequency reg, etc.)

Most valuable: when used as a transmission asset and combined with renewables as an IRP alternative to other traditional fossil energy sources.

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Q: What are the most likely applications for grid-level storage today? (continued)

- On the distribution system:
  - To defer or displace investments in distribution substation or feeder equipment.
  - To address particularly high reliability requirements of certain customers.

Q: Are 4 – hour batteries a one-for-one replacement for natural gas-fired peakers to ensure system reliability?

Answer:

- No.
  - 4-hour batteries can contribute to reliability, but they are not as reliable as traditional peaking units.

Do not confuse usefulness for daily "Duck Curve" operations as a substitute for installed capacity Resource Adequacy (RA).

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FAQ: 4 – hour batteries for reliability? (cont'd)

From the Burbank 2019 IRP analysis:*

Scenario Option	Needed Installed Capacity Reserve Margin
CAES Storage + Renewables	**8% - 11%**
4-hour Battery Storage + Renewables	**22% - 27%**
Internal Combustion Engines + Renewables	**12% - 16%**

Options Scenarios with primarily 4-hour batteries needed twice the installed reserve capacity margin as peakers or CAES to achieve similar Loss of Load Probability (LOLP) system reliability.

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*BWP 2019 IRP at page 159.

Q: How do 4 – hour batteries compare to reciprocating internal combustion engines (ICE) for reliability service?

Answer:

- You need about twice as many MW of the batteries for similar system reliability.
- But comparable in overall life cycle costs.

Four-hour duration means the batteries are less reliable per MW than ICE, natural gas peakers or CAES.

Requires twice the installed reserve margin for system reliability.

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ICEs: From the Burbank 2019 IRP

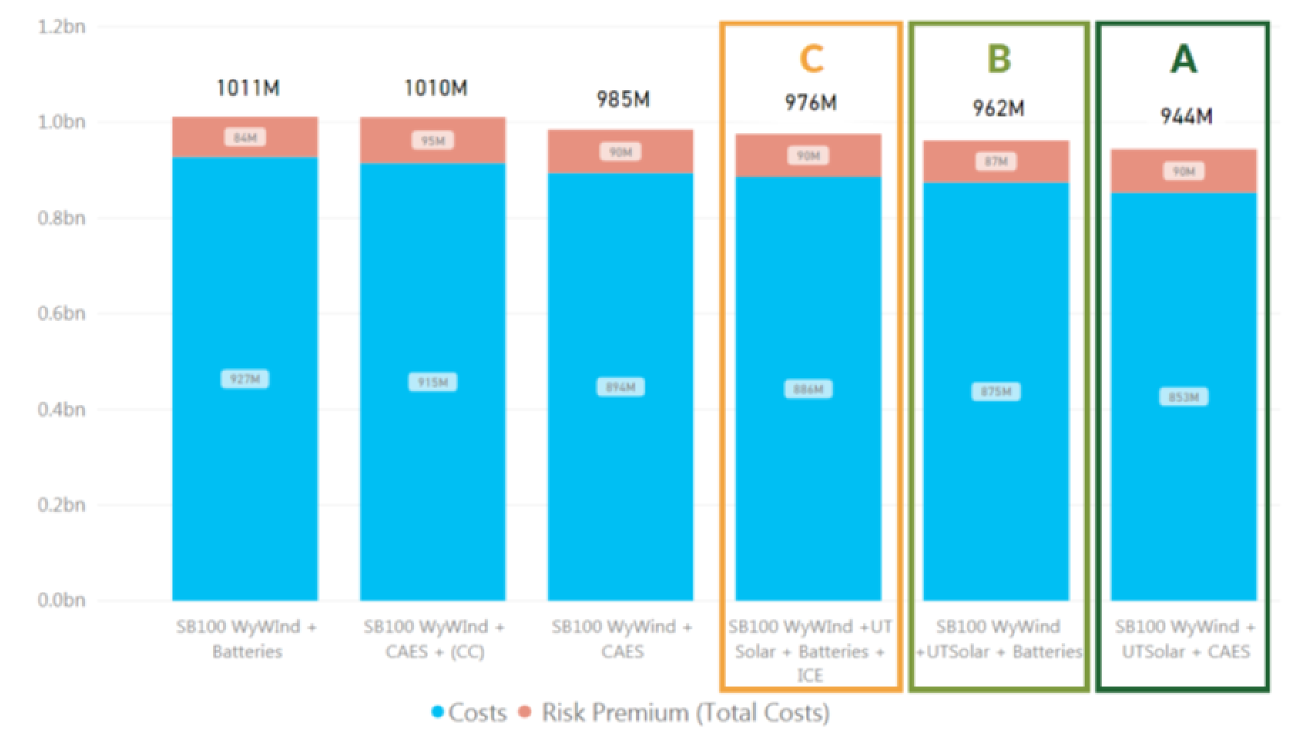

Figure 2.5: Total Cost Ranking of the Lowest-Cost Portfolios for SB100. (Present Value 2019$)

Lifetime costs of best three preferred scenarios were similar. (ICEs in Scenario C)

All cost less than traditional natural gas-fired CCGT option.

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Q: Is “value stacking” to monetize storage benefits real?

Answer:

- It is real in non-RTO markets.
  - Utilities in vertically-integrated, non-RTO markets typically achieve value stacking in the normal course of IRP business.
- It is real in RTO markets.
  - But more difficult to achieve there.
  - Comprehensive tariffs not yet available to reward all value attributes of storage.
    - Example: Value of avoided renewables curtailment.

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Q: Is it easier for a storage owner to monetize their storage investment in an RTO/ISO market, or in a vertically-integrated market?

Answer:

- If the storage owner is a utility, it is easier in a *vertically-integrated market*.
- If the storage owner is a merchant, it is easier in an *RTO/ISO market*.
    - o But it is still not easy in an RTO/ISO market.

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Read All About It

December 4, 2015

Market and Tariff Challenges to Electric Grid-Level Bulk Energy Storage Enabling Renewable Energy in RTO/ISO Markets

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Abstract

Proposed new installations of electric grid-level (i.e., transmission level) bulk energy storage to enable additional renewable energy in the United States currently face unique market and tariff barriers to success. The primary issue relates to grid-level storage and the renewables it enables create benefits that occur away from the storage facility itself. This creates a challenge to the prospective storage facility owner in regard to monetizing the benefits of the proposed storage facility, thereby justifying the investment in it. In areas with traditional, vertically integrated utilities and no organized wholesale markets, cost recovery is not a problem because a utility that owns the storage can self-dispatch the storage to benefit other specific facilities that it also owns.

However, in today's open access Regional Transmission Organization (RTO) and Independent System Operator (ISO) markets, resources are dispatched by the system operator in a manner to

pay for it. This paper describes the issues and suggests potential solutions for them, such as new tariff structures. Target audiences for this information include grid-level storage project developers, utilities, RTOs, ISOs, regulators, legislators, and others interested in enabling large

Available for download at:
www.schulteassociates.com/publications

- ***Current FERC Dockets working on interconnection and cost recovery for storage.***
- ***But currently focused on interconnection rules and equal treatment of storage vs. traditional resources; not value monetization.***

Ancillary Services Markets for Batteries?

New information suggests ancillary services markets are finite in size.

They could saturate quickly as additional batteries are installed.

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New battery storage on shaky ground in ancillary service markets

Credit: Ernesto Sanchez

AUTHOR
Derek Sackler

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The following is a contributed article by Derek Sackler, an energy markets expert at PA Consulting.

Key to the conventional wisdom around investment in new battery energy storage systems (BESS) has been the lucrative earning opportunity in ancillary service markets- markets used to compensate flexible generating

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QUESTIONS?

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