The Rapidly Evolving Energy Landscape:
What's Occurring, Why, and How to Think About It

Peter Kelly-Detwiler, NorthBridge Energy Partners

NPA Annual Conference, August 30, 2022

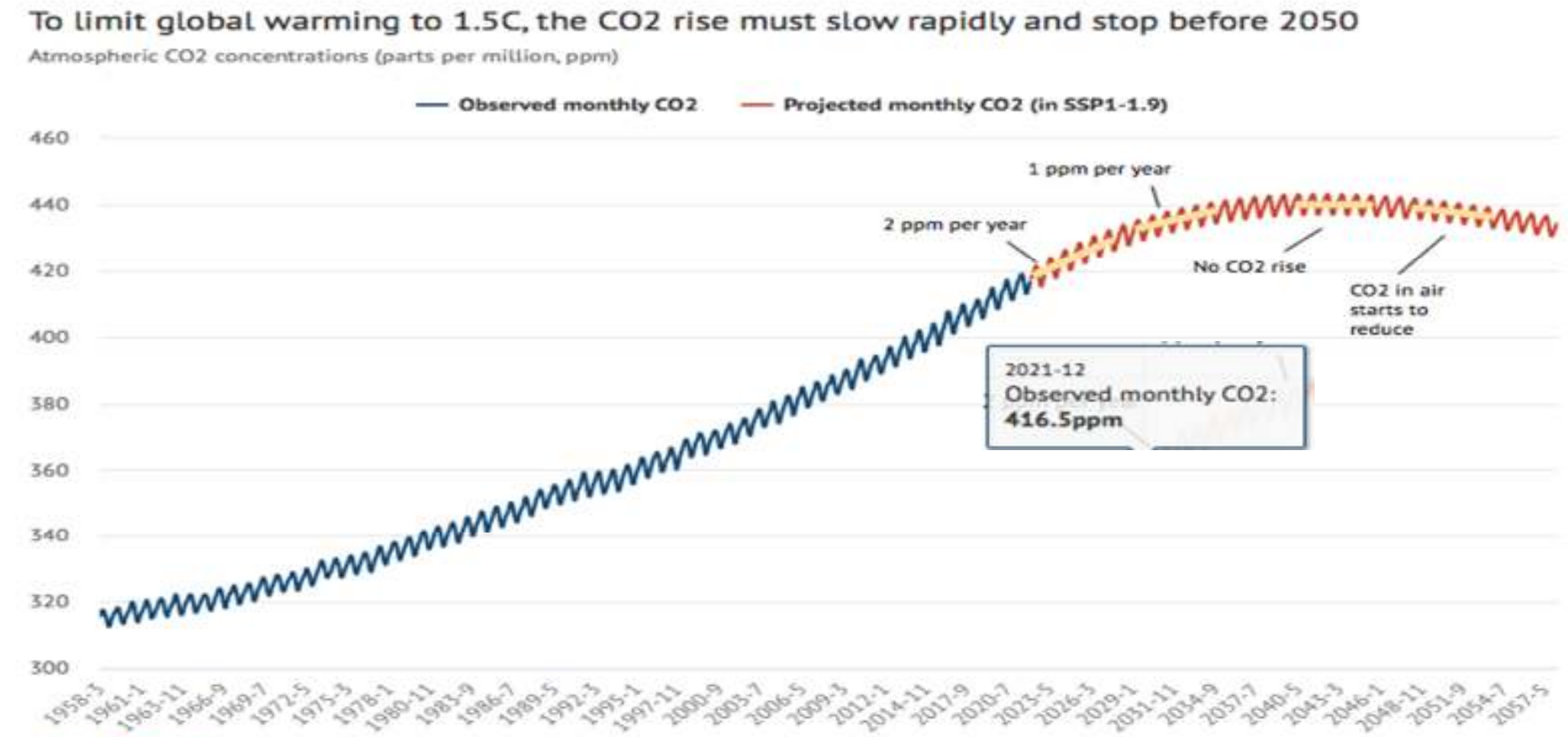
The Future is Coming to You in 3D:

Decarbonization

Digitalization

Decentralization

Carbon: The Fundamental (and Existential) Challenge

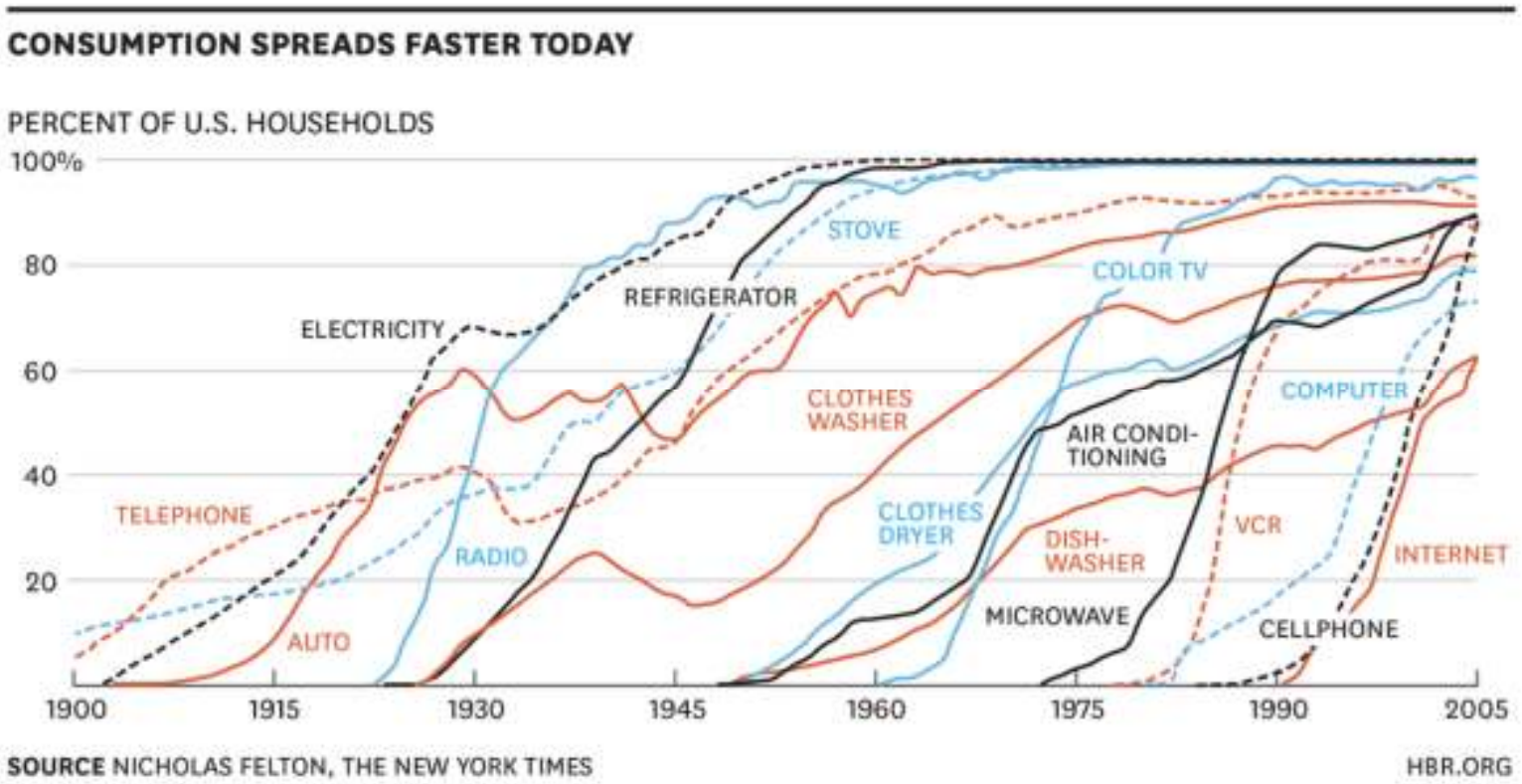


https://www.carbonbrief.org/guest-post-how-the-keeling-curve-will-need-to-bend-to-limit-global-warming-to-1-5c/

A Word About The Pace of Change…

The Cori supercomputer has roughly 750,000 more disk capacity than the average desktop computer. Photo | Lawrence Berkeley National Laboratory

… and Tech Adoption Curves

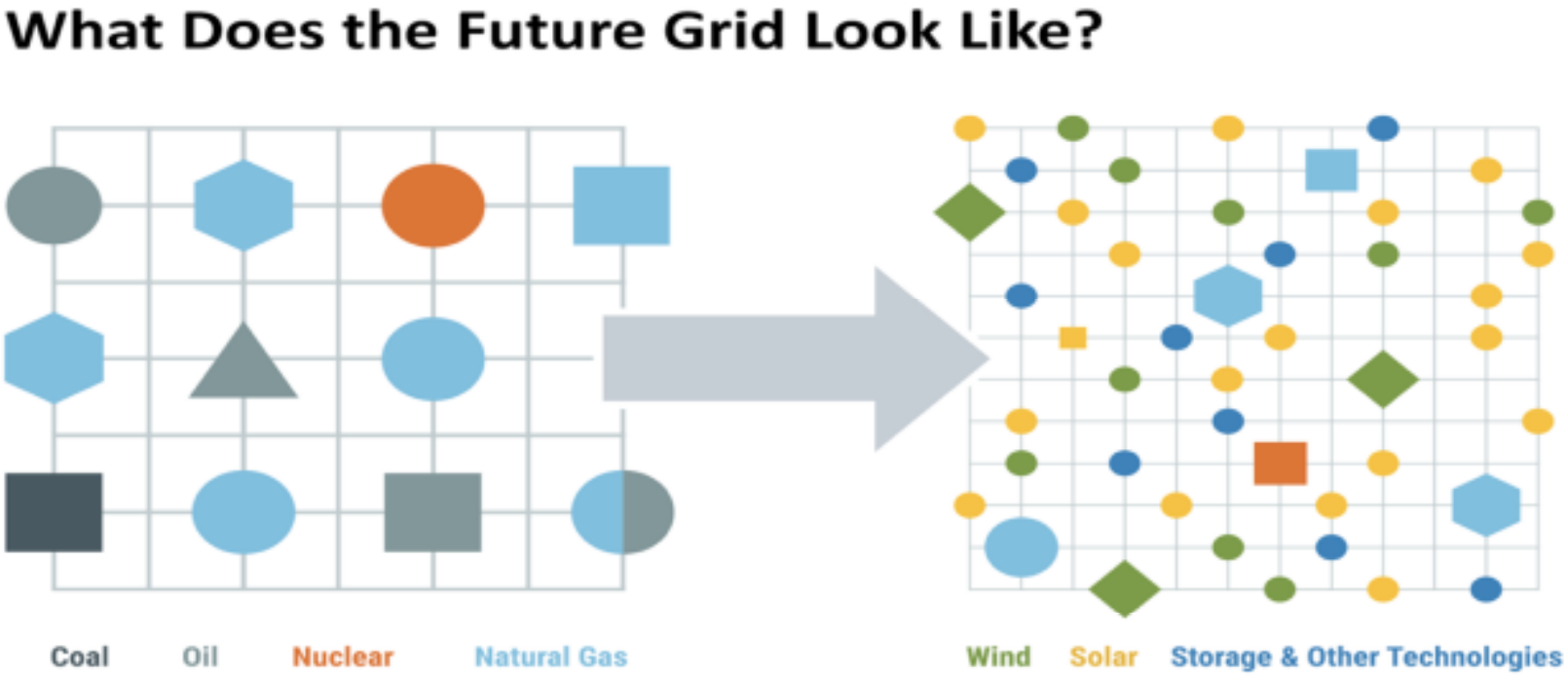


https://hbr.org/2013/11/the-pace-of-technology-adoption-is-speeding-up

$369 Bn of New Federal Incentives Will Accelerate the Dynamic

https://www.bbc.com/news/uk-england-gloucestershire-60765050

Centralized vs Decentralized: Which Future Dynamic Predominates?



https://www.iso-ne.com/static-assets/documents/2022/07/2021_economic_study_future_grid_reliability_study_phase_1_report.pdf

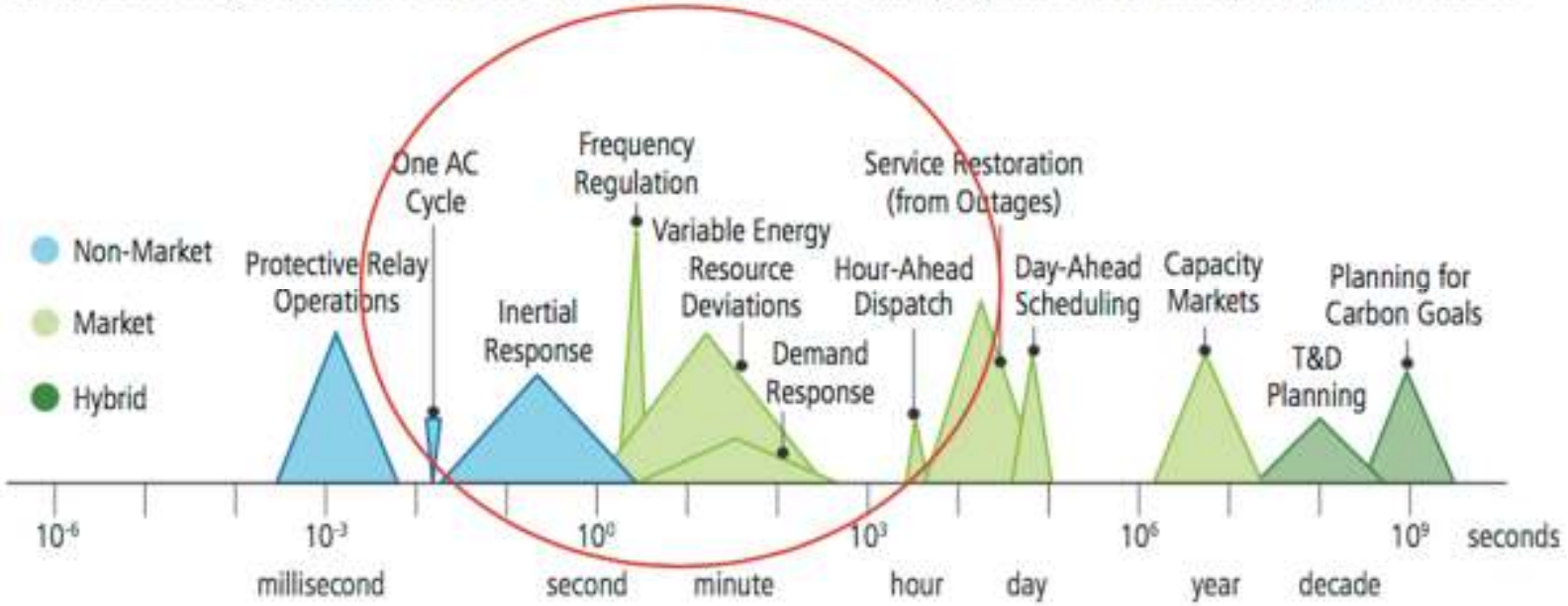
Bulk Power Markets: Trends & Challenges

You Are Here, Which Means You Are in a Competitive Market

From Decades to Milliseconds: It All Has to Work

Figure 4-3. System Reliability Depends on Managing Multiple Event Speeds[18]

Markets are used for grid operations in the order of seconds to minutes, such as frequency regulation and demand response (DR). Some essential

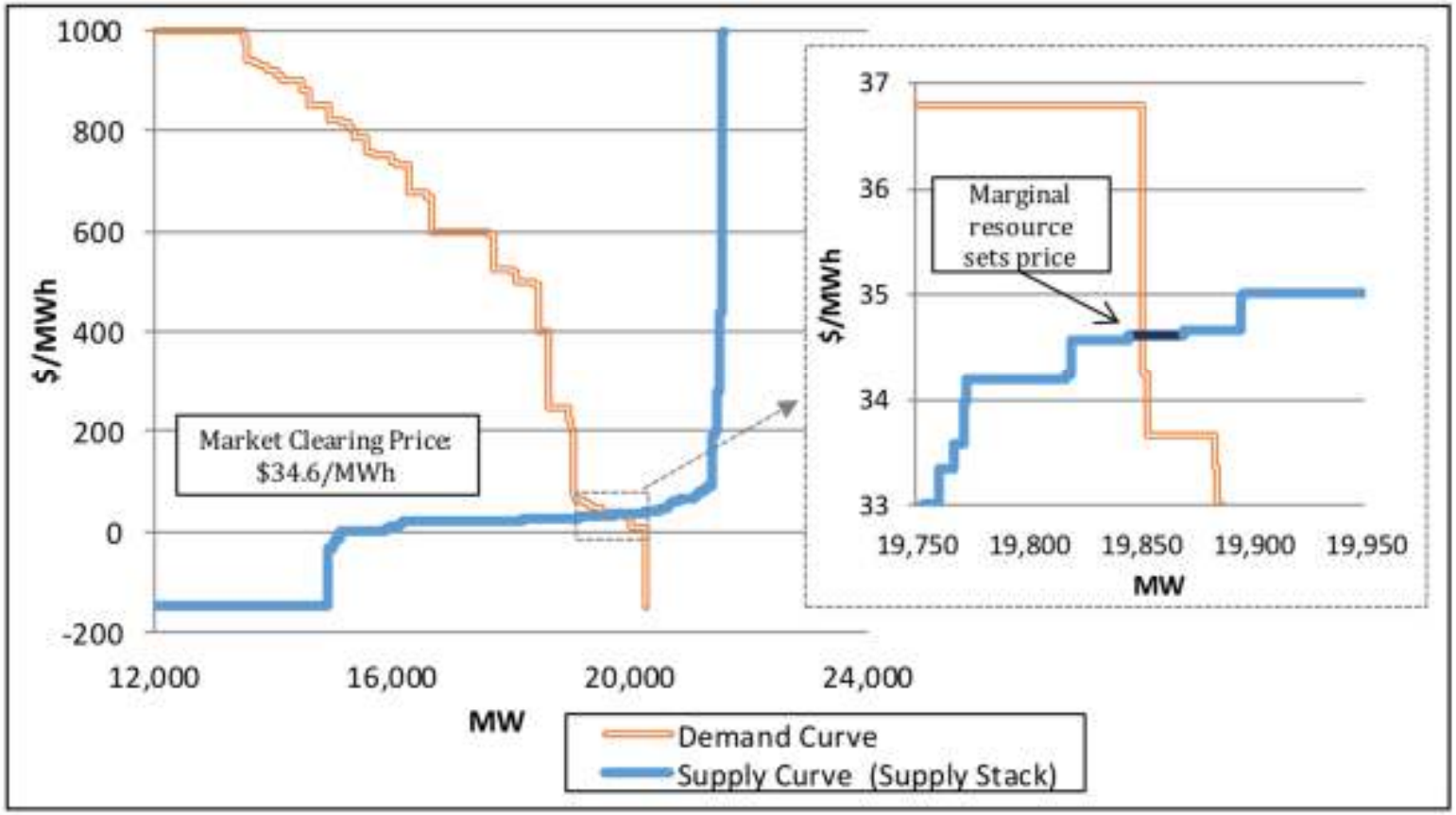


reliability capabilities, such as inertial response, occur faster than typical market signals. Acronyms: transmission and distribution (T&D), alternating current (AC).

https://www.energy.gov/sites/prod/files/2017/02/f34/Quadrennial%20Energy%20Review--Second%20Installment%20%28Full%20Report%29.pdf

WholeSale Competitive Markets: S&D

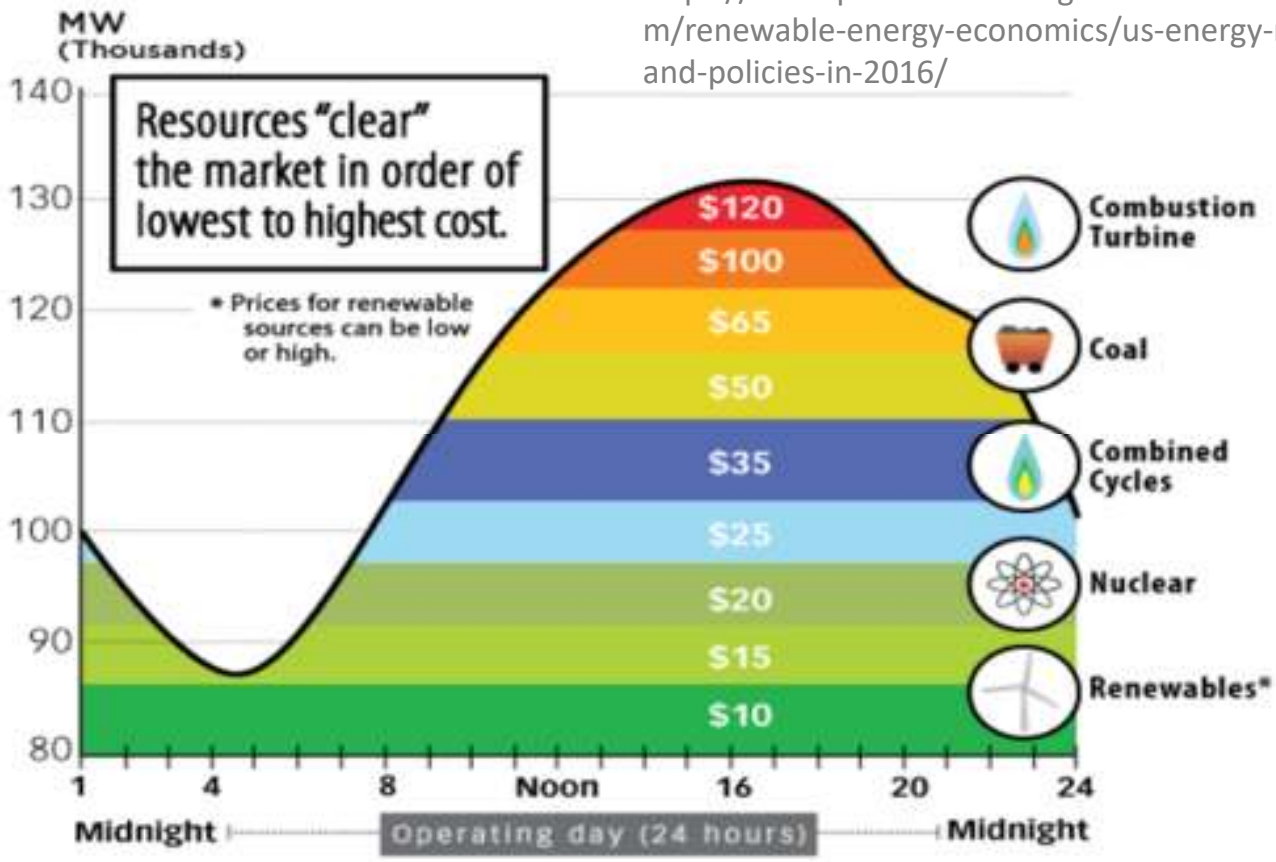
Figure 3-34: Day-Ahead Supply and Demand Curves – July 25, 2018, HE 13



https://www.iso-ne.com/static-assets/documents/2019/05/2018-annual-markets-report.pdf

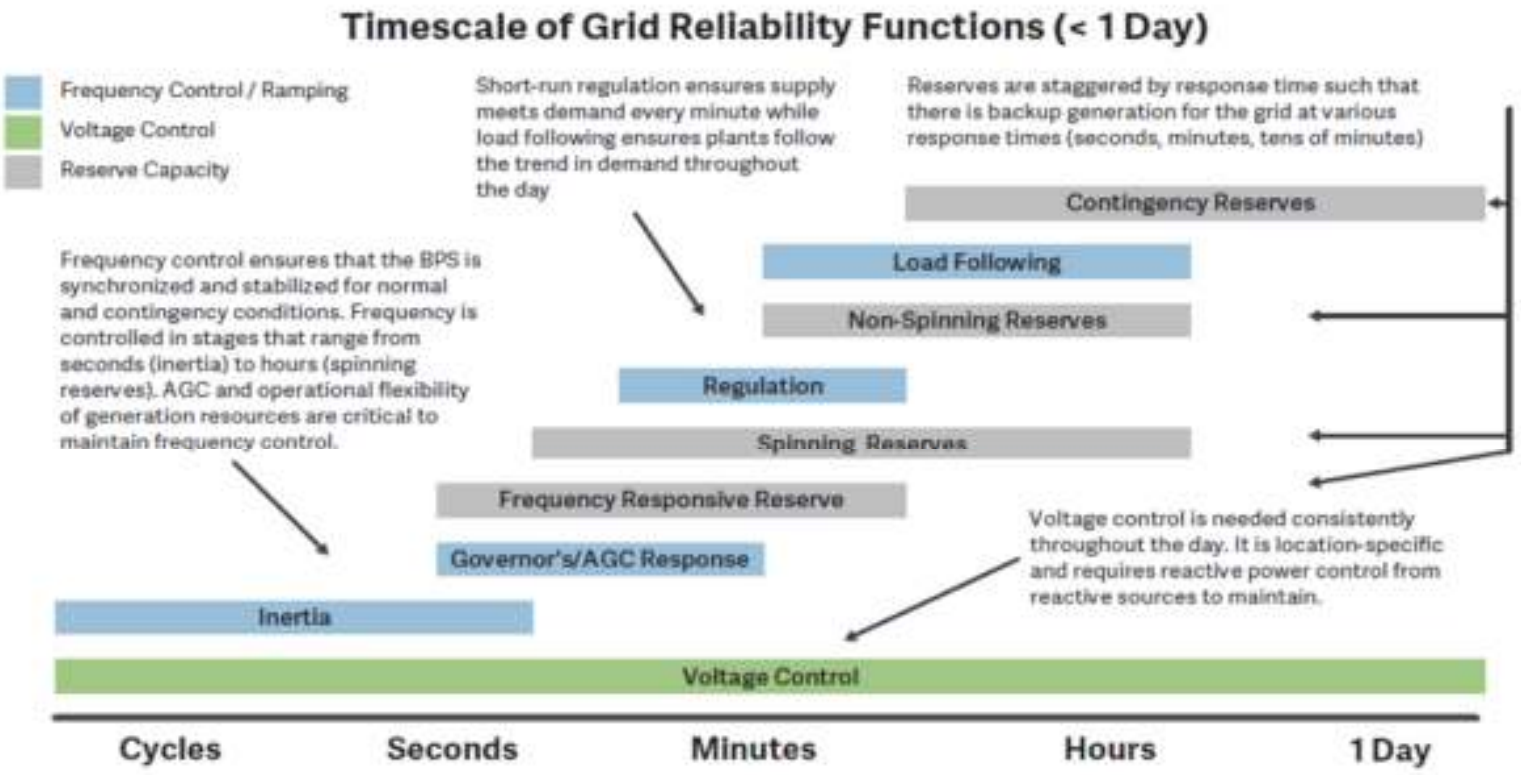
The Shifting Dispatch Order

https://theimportanceofbeingearnestaboutenergy.com/renewable-energy-economics/us-energy-markets-and-policies-in-2016/



Learn.pjm.com/three-priorities/keeping-the-lights-on/how-pjm-schedules-generation.aspx

Non-Energy Services

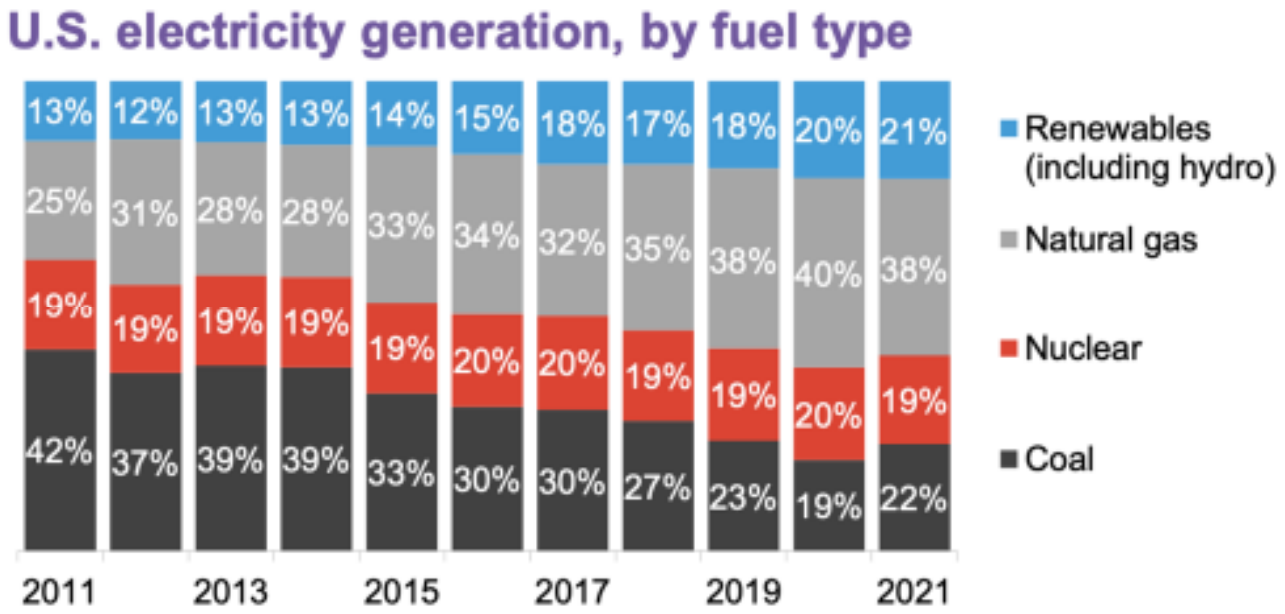


Notes and Sources:

[1] Adapted from Kirby, Brendan, "Potential New Ancillary Services: Developments of Interest to Generators," August 2014.
[2] NERC, "Special Report: Ancillary Service and Balancing Authority Area Solutions to Integrate Variable Generation," March 2011.
[3] Kirby, Brendan, "Ancillary Services: Technical and Commercial Insights," July 2007.

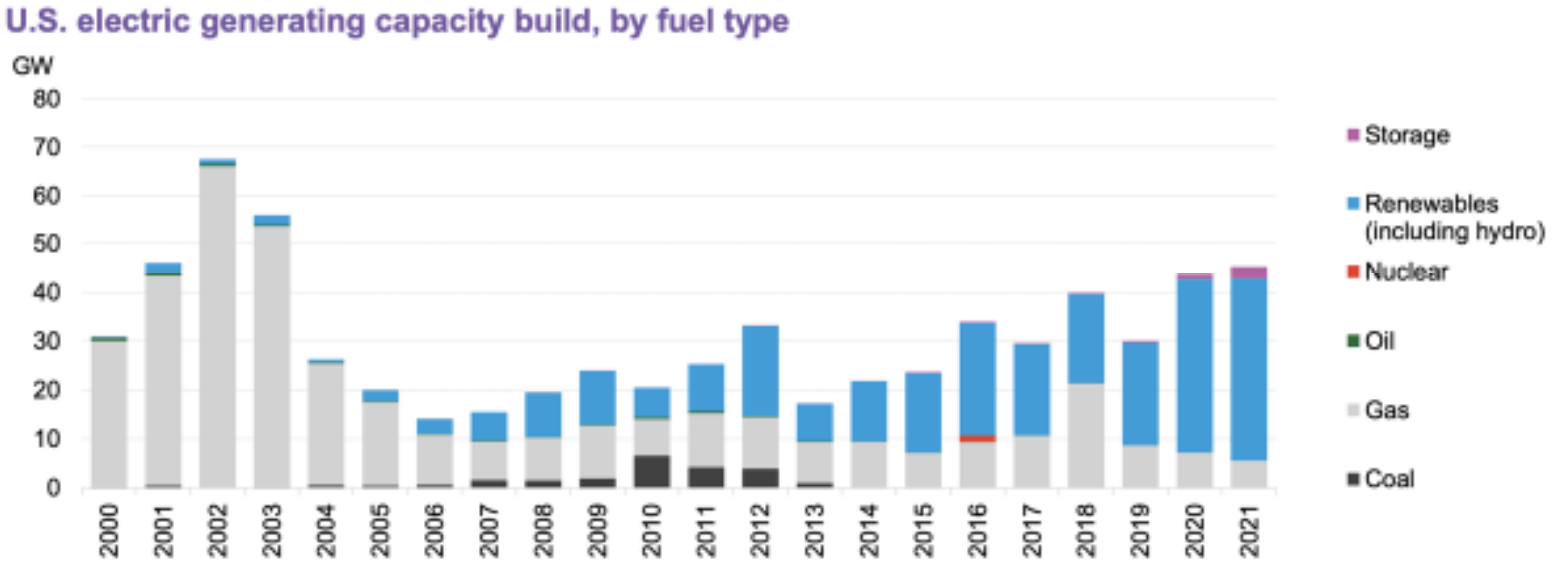
http://nescoe.com/wp-content/uploads/2017/11/AnxSvcPrimer_Sep2017.pdf

The Supply Mix is Rapidly Evolving = Volatility



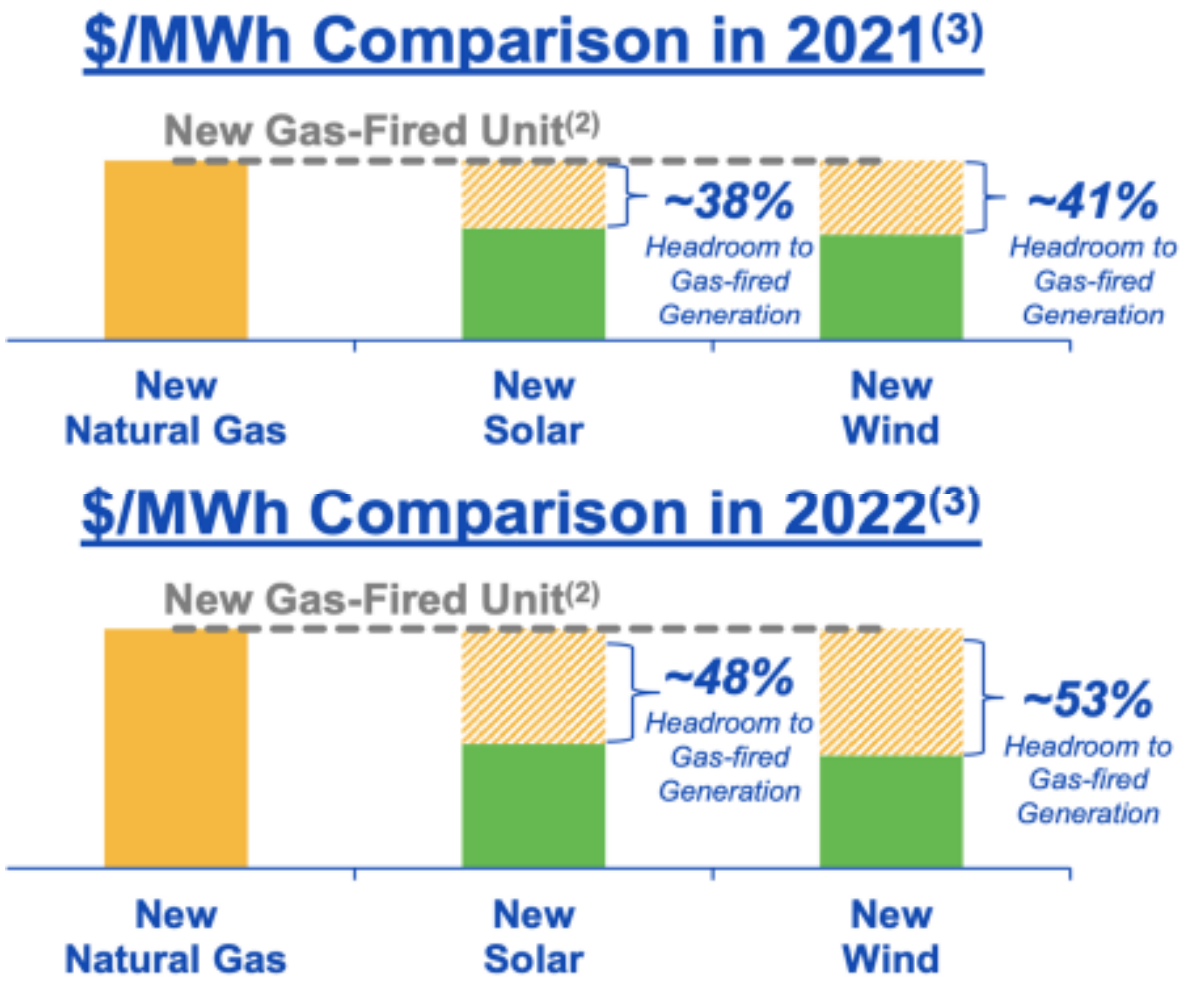
https://www.bcse.org/factbook/#

The New Generation Mix is Renewables-Based



https://www.bcse.org/factbook/# 2022

Recent Inflationary Trends Favor Renewables



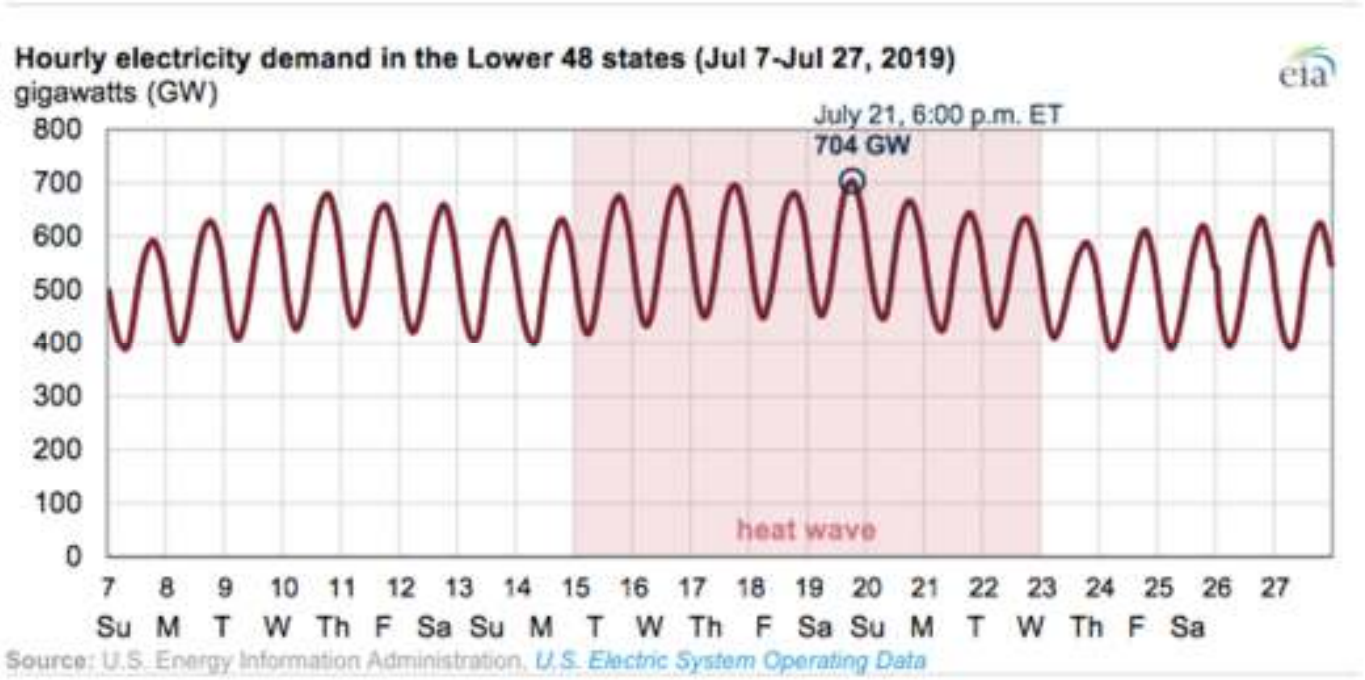
https://www.investor.nexteraenergy.com/~/media/Files/N/NEE-IR/news-and-events/events-and-presentations/2022/06-14-2022/June%202022%20Investor%20Presentation_Website_vF.pdf

Let's Talk Solar

U.S. energy overview: Renewable energy capacity build by technology

https://www.bcse.org/factbook/# 2022

New Volatilities: Marginal Demand & Supply Driven by Weather

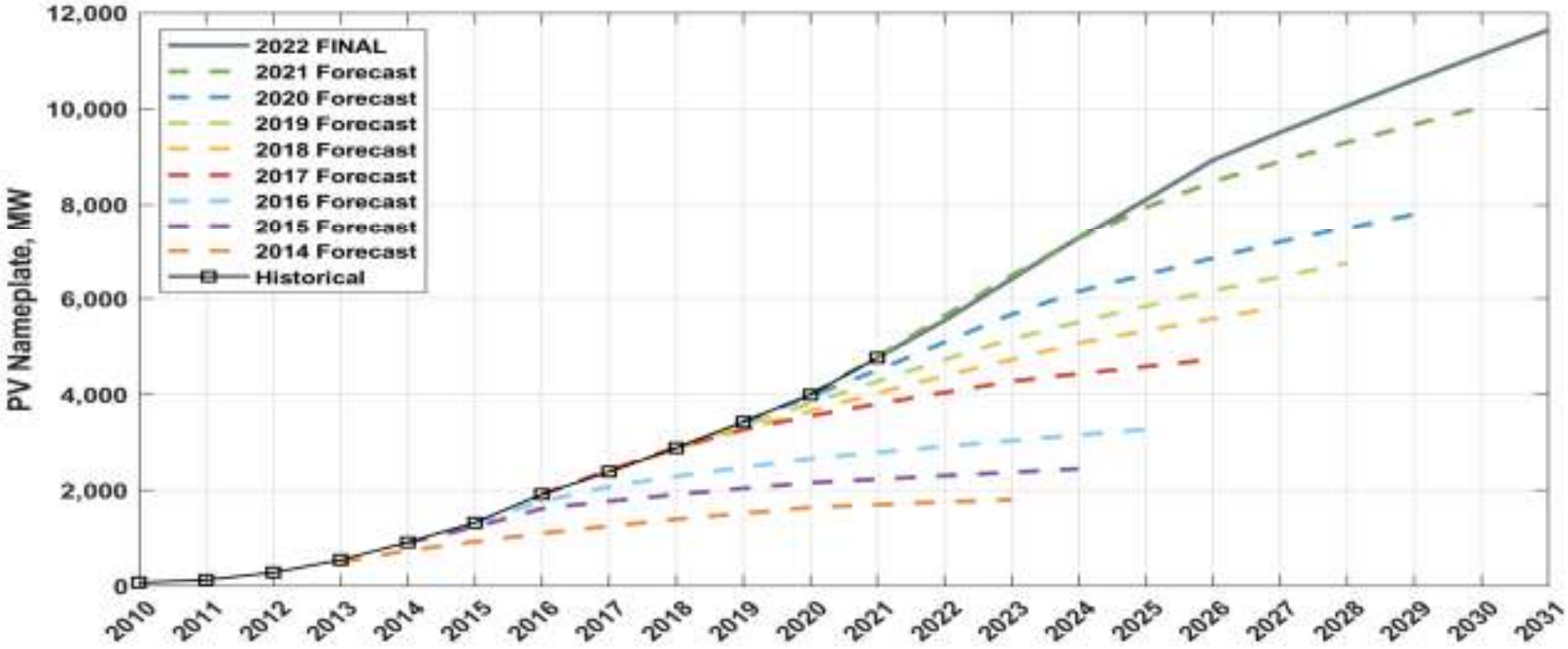


https://www.eia.gov/todayinenergy/detail.php?id=40253&src=email

We Keep Underestimating the Adoption Dynamic

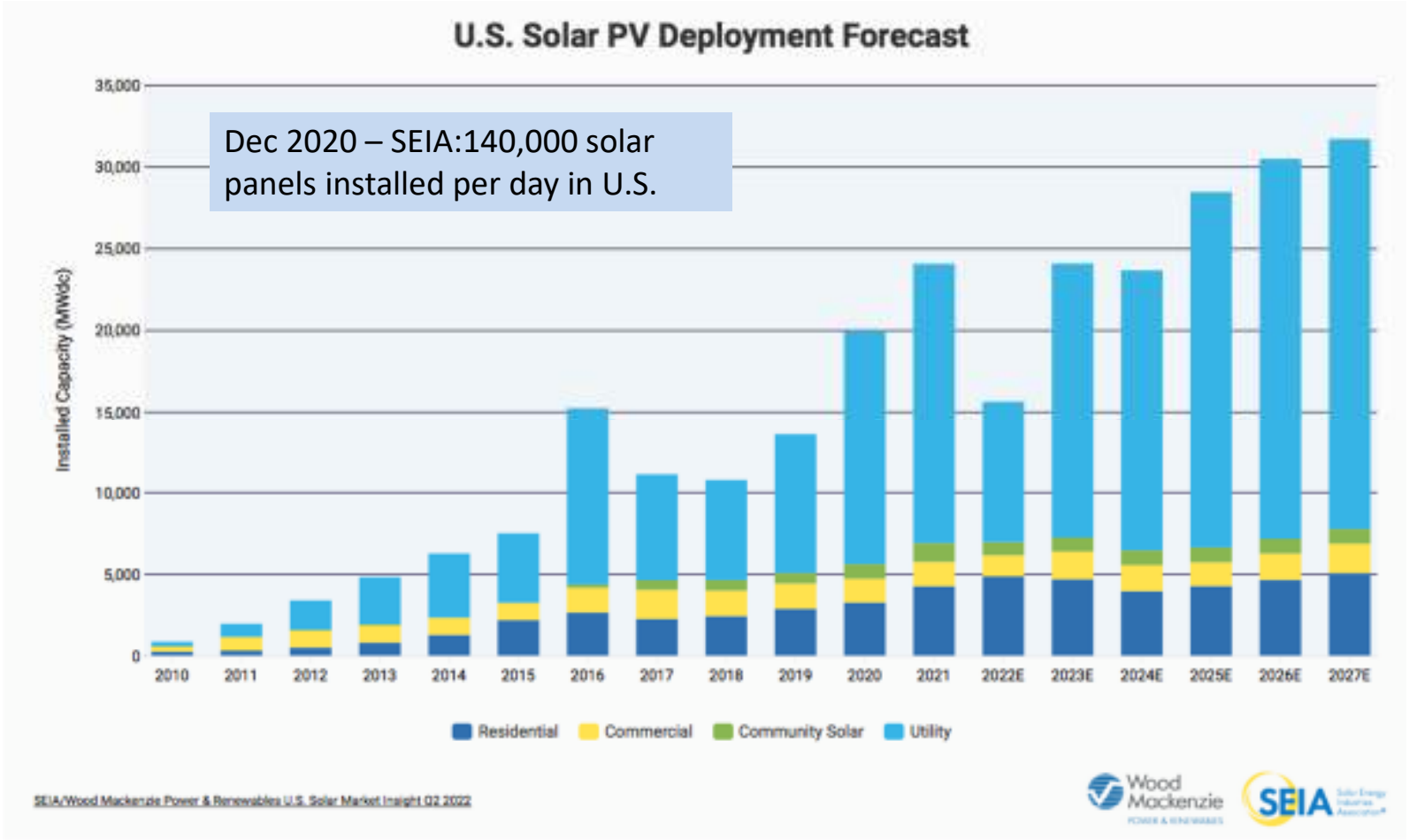
Total PV Nameplate Capacity Growth

Reported Historical vs. Forecast (FCM+EOR+BTM), MW_{ac}



https://www.iso-ne.com/static-assets/documents/2022/04/final_2022_pv_forecast.pdf

And Will Continue to Do So

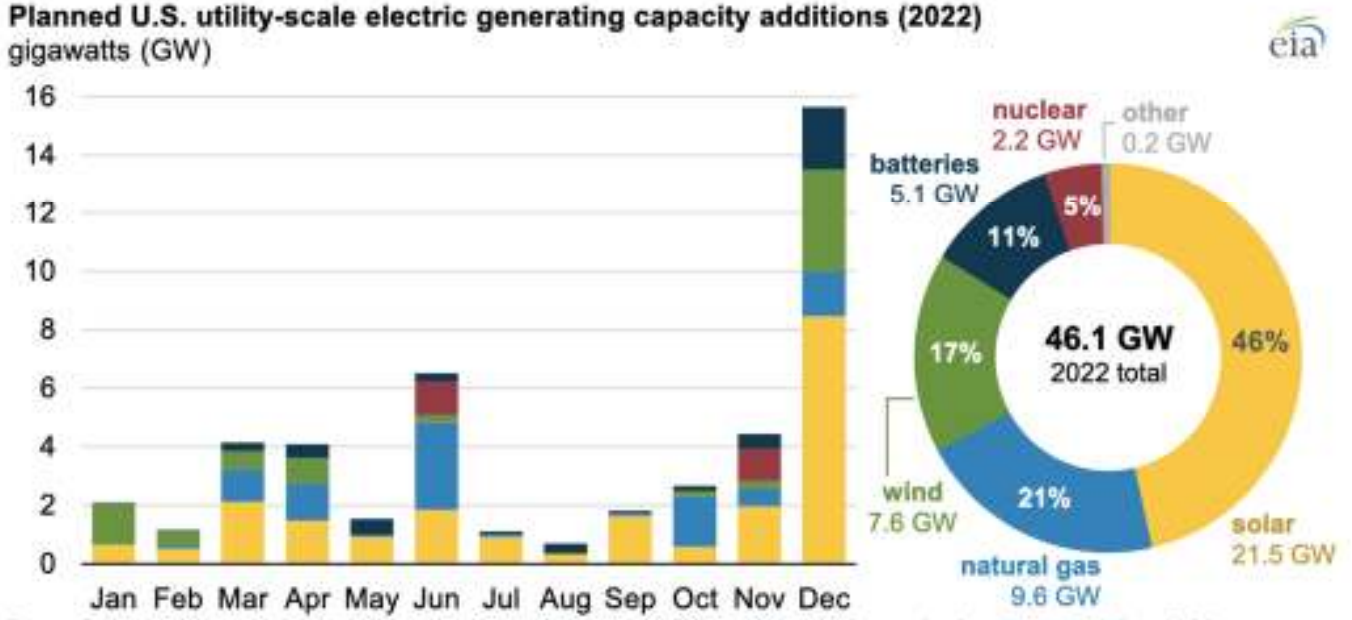


https://www.seia.org/solar-industry-research-data

It's Currently the Biggest Game in Town

JANUARY 10, 2022

Solar power will account for nearly half of new U.S. electric generating capacity in 2022



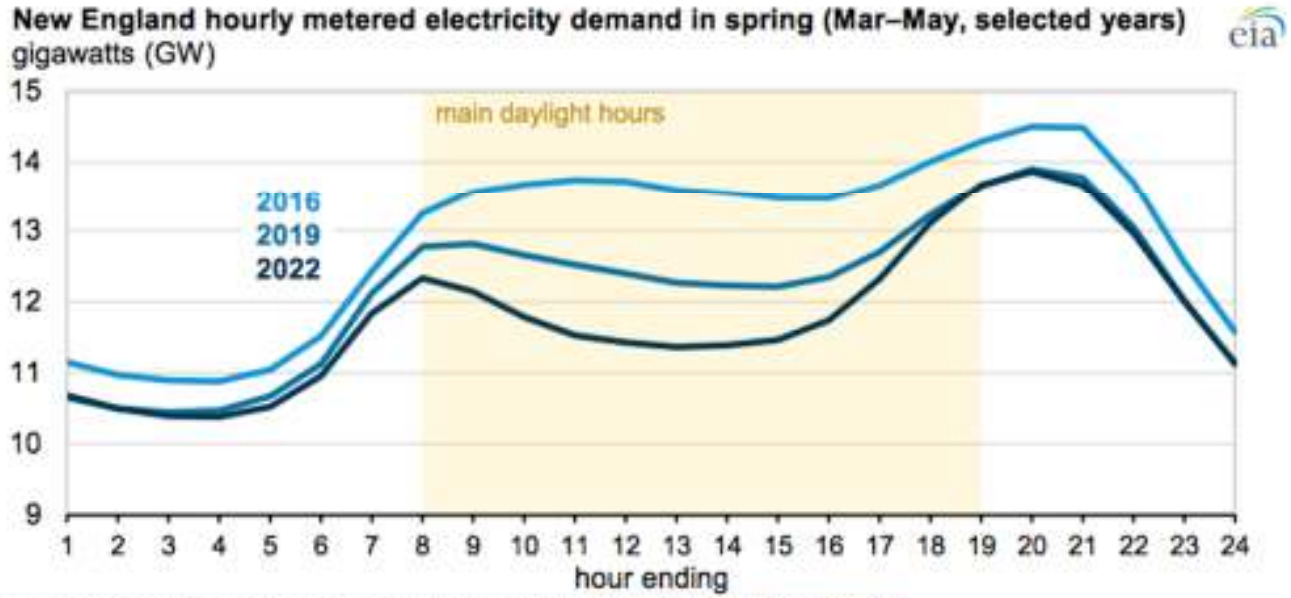
Source: U.S. Energy Information Administration, *Preliminary Monthly Electric Generator Inventory*, October 2021

https://www.eia.gov/todayinenergy/detail.php?id=50818

And It's Changing the Planning Paradigm…

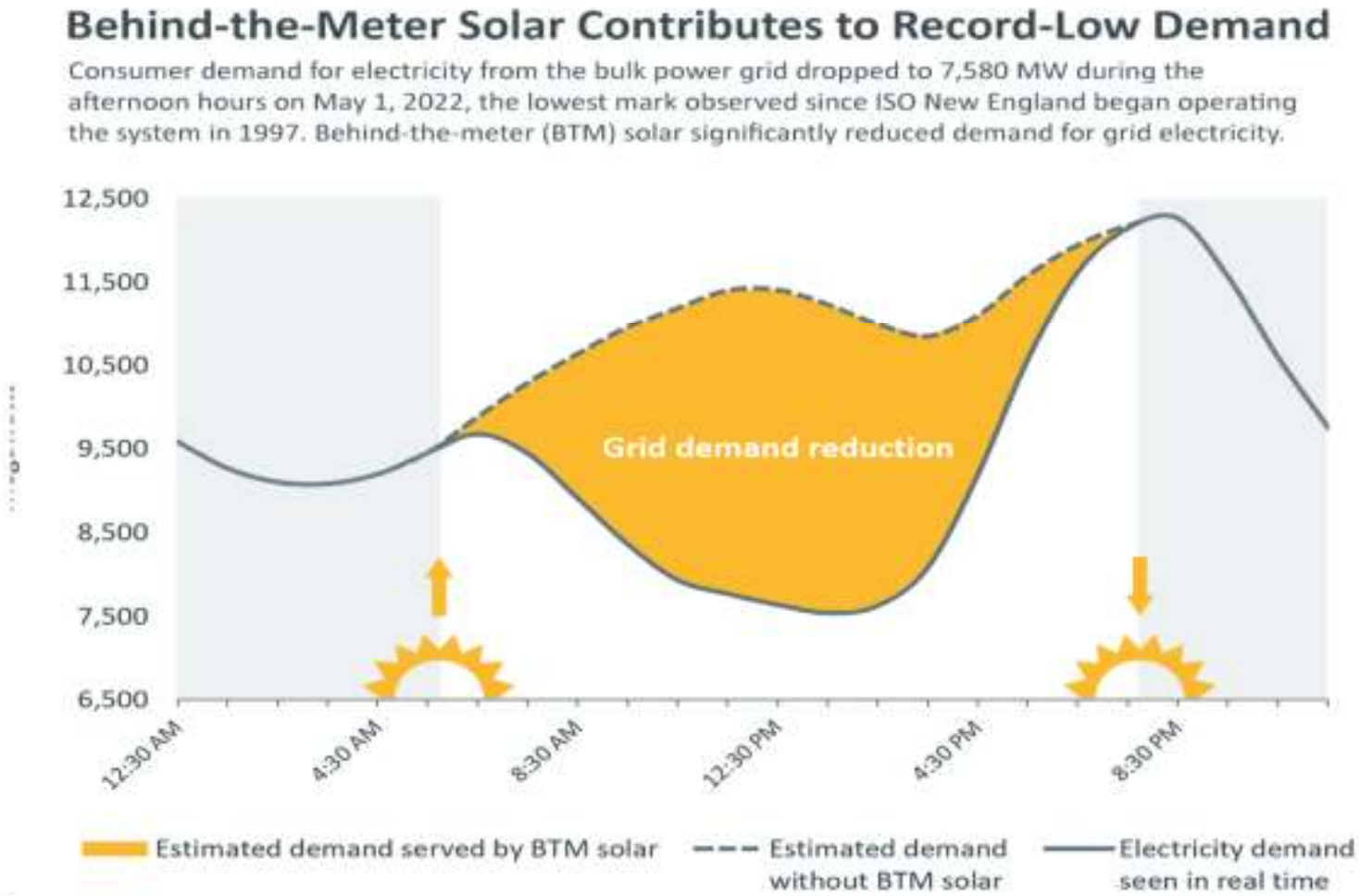
JULY 29, 2022

Small-scale solar is changing hourly utility electricity demand in New England



https://www.eia.gov/todayinenergy/detail.php?id=53239&src=email

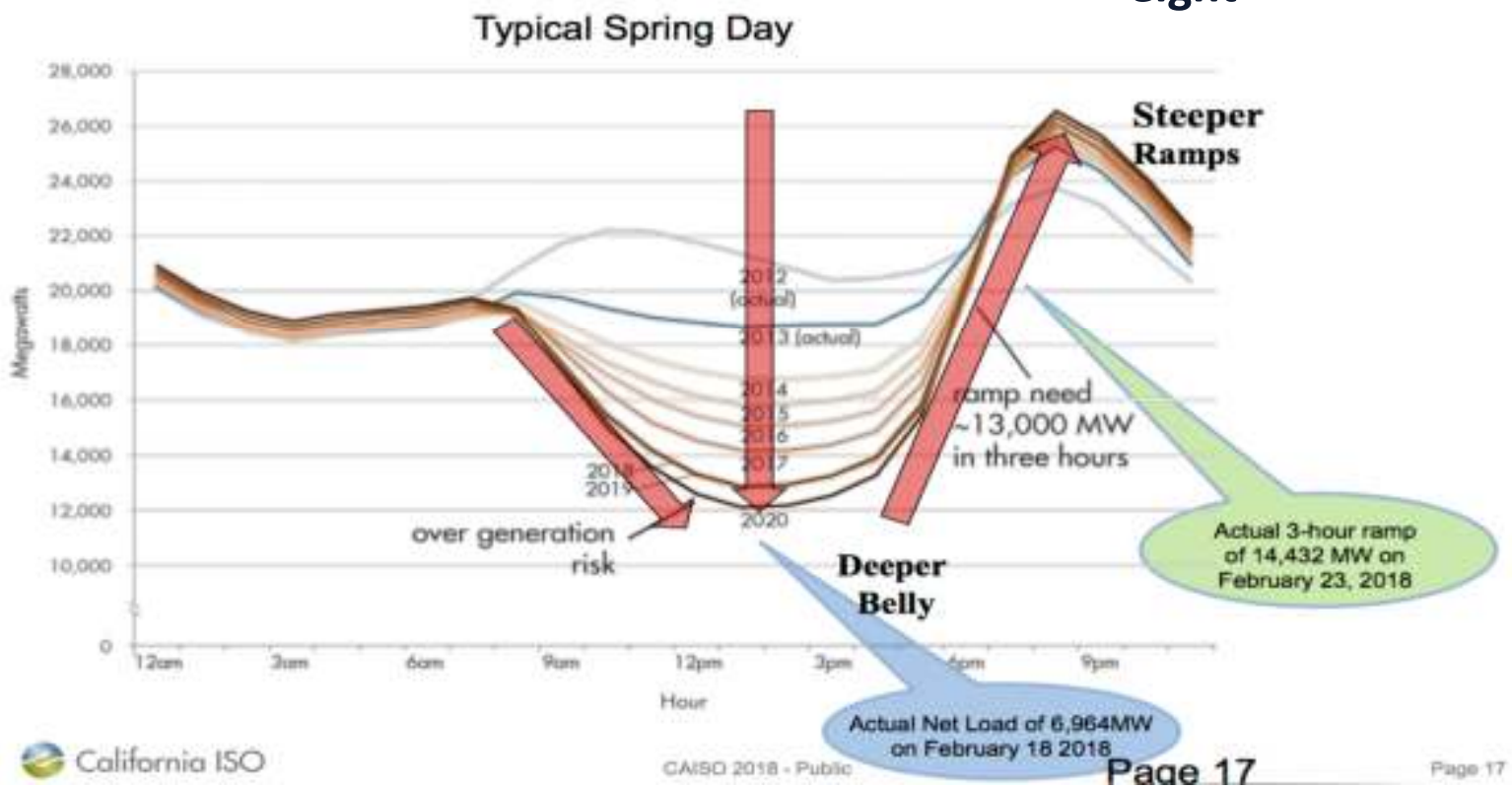
As Well As How We Operate the Grid



https://www.iso-ne.com/static-assets/documents/2022/07/2021_economic_study_future_grid_reliability_study_ph

A Big Challenge: Integrating Renewables

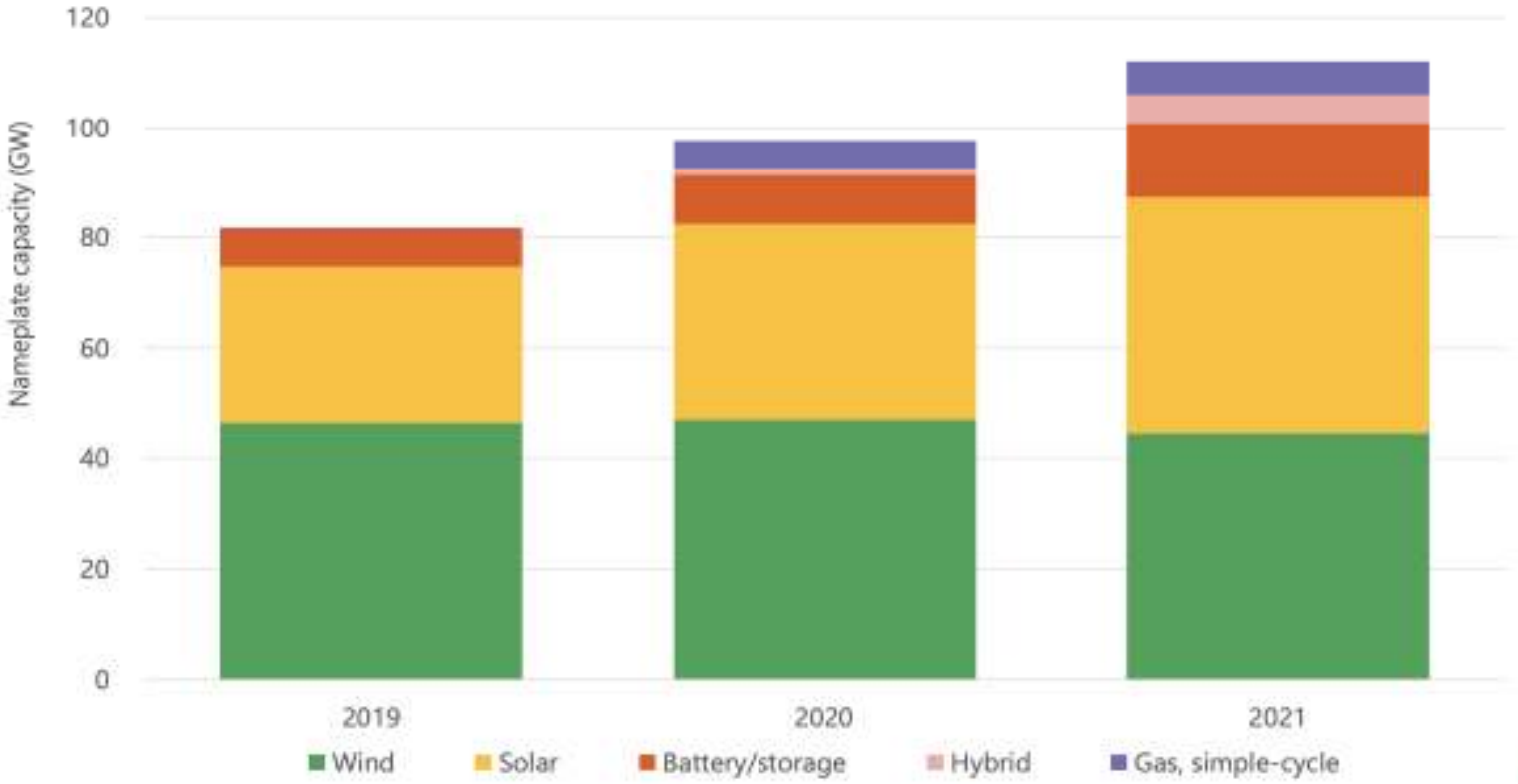
Actual net-load and 3-hour ramps are about ~~four~~ eight years ahead of ISO's original estimate



http://www.storagealliance.org/sites/default/files/2018%20MDF_Presentations.pdf#page=18

Lest You Think That's Only California or New England…

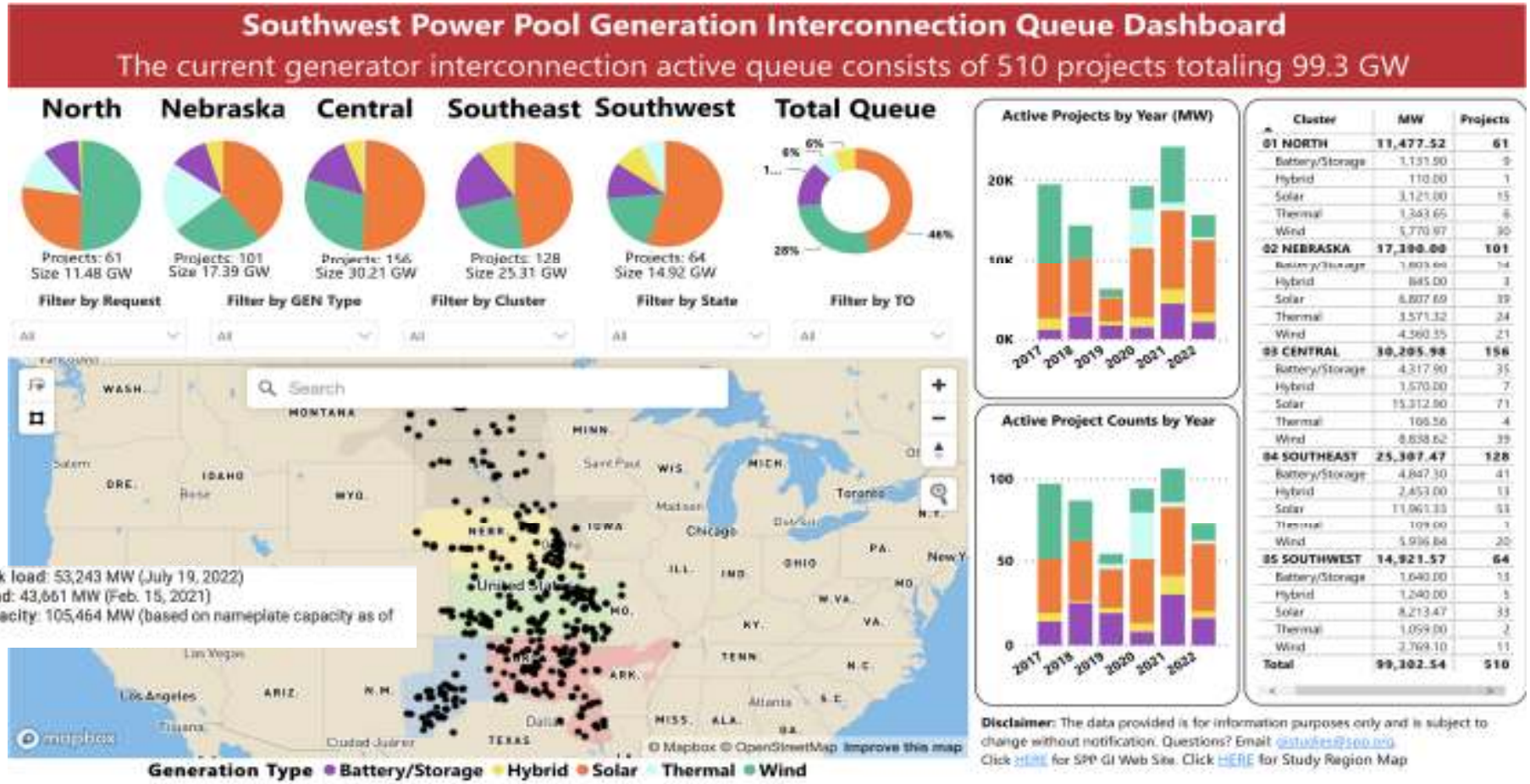
SLIGHTLY LESS WIND IN GENERATION INTERCONNECTION QUEUE, BUT OTHER TYPES UP



SPP MMU

https://www.spp.org/documents/67169/2021%20annual%20state%20of%20the%20market%20presentation.pdf

That Solar Party is Coming to You

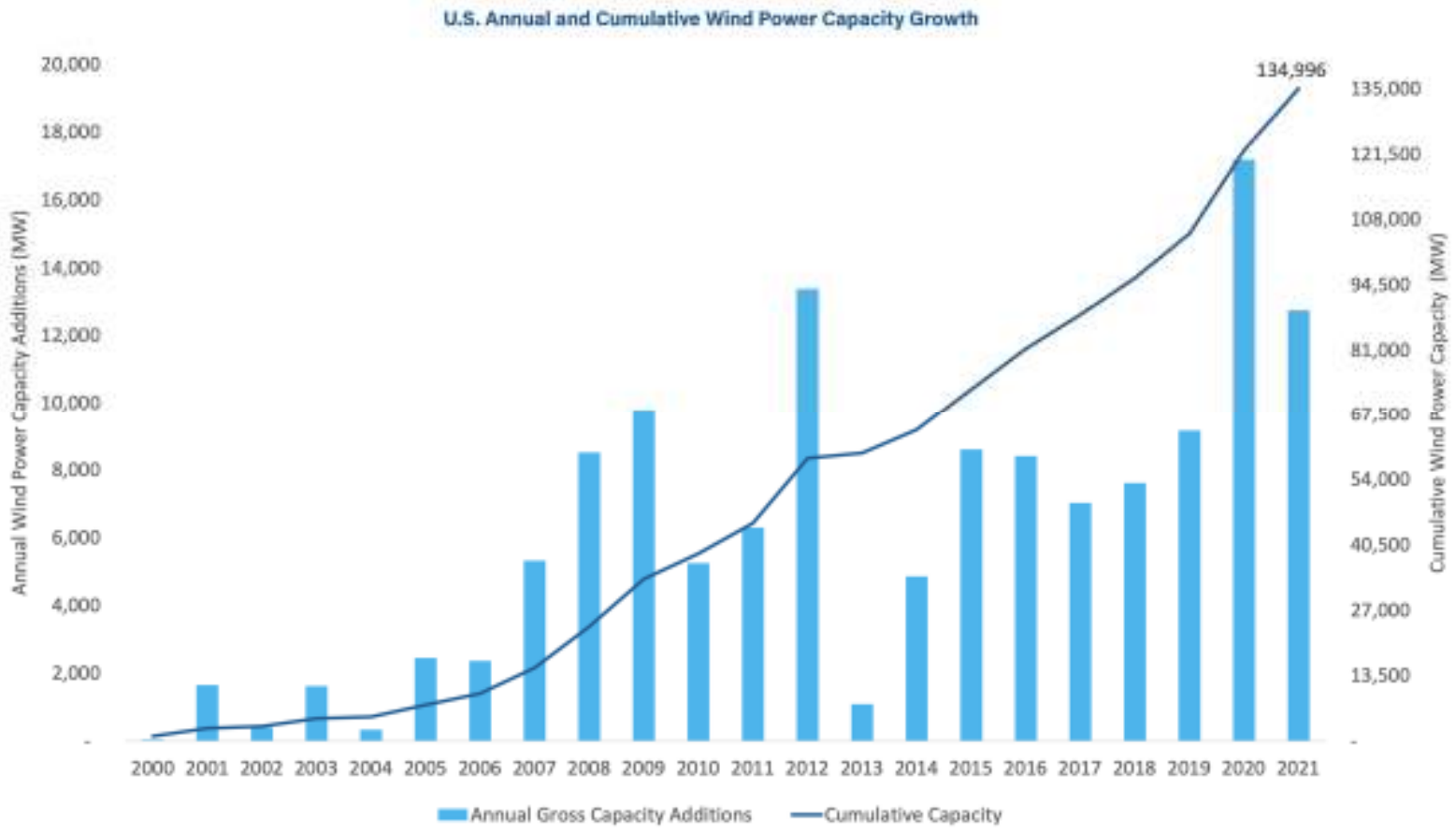


Cluster	MW	Projects
01 NORTH	11,477.52	61
Battery/Storage	1,131.90	9
Hybrid	110.00	1
Solar	3,121.00	15
Thermal	1,343.65	6
Wind	5,770.97	30
02 NEBRASKA	17,390.00	101
Hybrid	845.00	3
Solar	6,807.69	39
Thermal	3,571.32	24
Wind	4,560.35	21
03 CENTRAL	30,205.98	156
Battery/Storage	4,317.90	35
Hybrid	1,570.00	7
Solar	15,312.90	71
Thermal	166.56	4
Wind	8,838.62	39
04 SOUTHEAST	25,307.47	128
Battery/Storage	4,847.30	41
Hybrid	2,453.00	13
Solar	11,961.33	53
Thermal	109.00	1
Wind	5,936.84	20
05 SOUTHWEST	14,921.57	64
Battery/Storage	1,640.00	13
Hybrid	1,240.00	5
Solar	8,213.47	33
Thermal	1,059.00	2
Wind	2,769.10	11
Total	99,302.54	510

- Coincident peak load: 53,243 MW (July 19, 2022)
- Winter peak load: 43,661 MW (Feb. 15, 2021)
- Generating capacity: 105,464 MW (based on nameplate capacity as of Jan. 27, 2022)

https://app.powerbi.com/view?r=eyJrIjoiNDFiMTkzMGItOTZlZS00NzZmLTg1ODMtMzEzMmQ3MThmYWYxIiwidCI6IjA2NjVkY2EyLTExNDEtNDYyNS1hMmI1LTY3NTY0NjNlMWVlMSIsImMiOjF9

What About Wind?



https://cleanpower.org/wp-content/uploads/2022/03/CPQ_4Q21_PUBLIC.pdf

Wind: An Ugly Output Curve

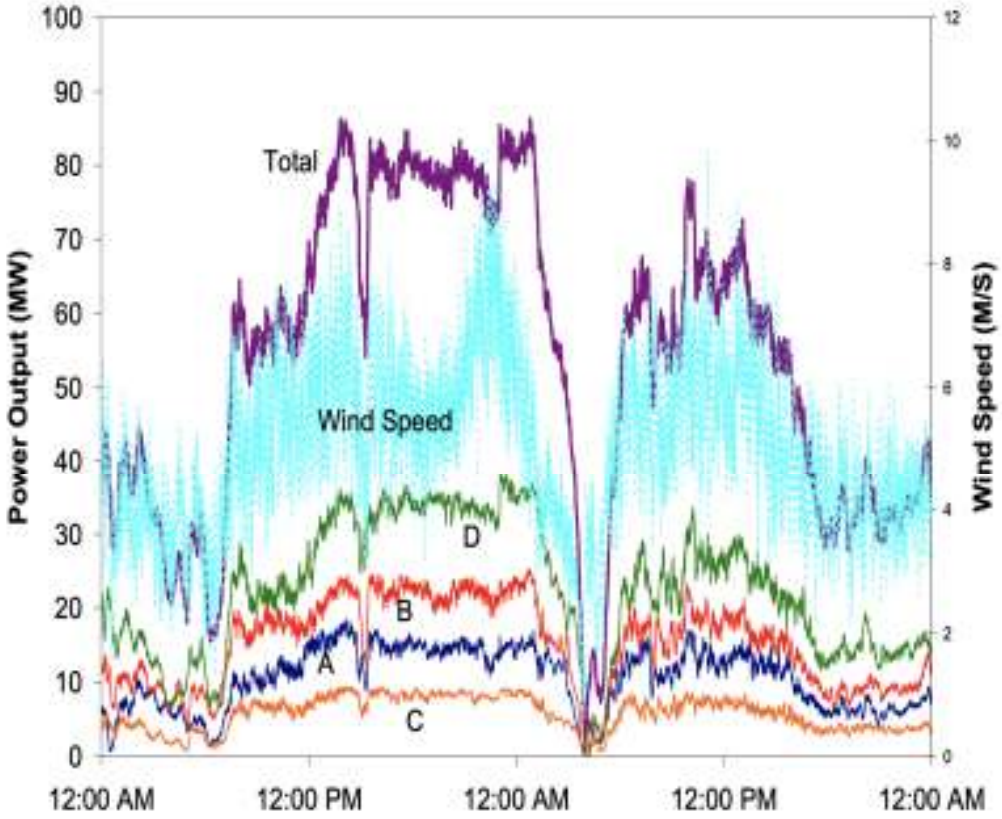
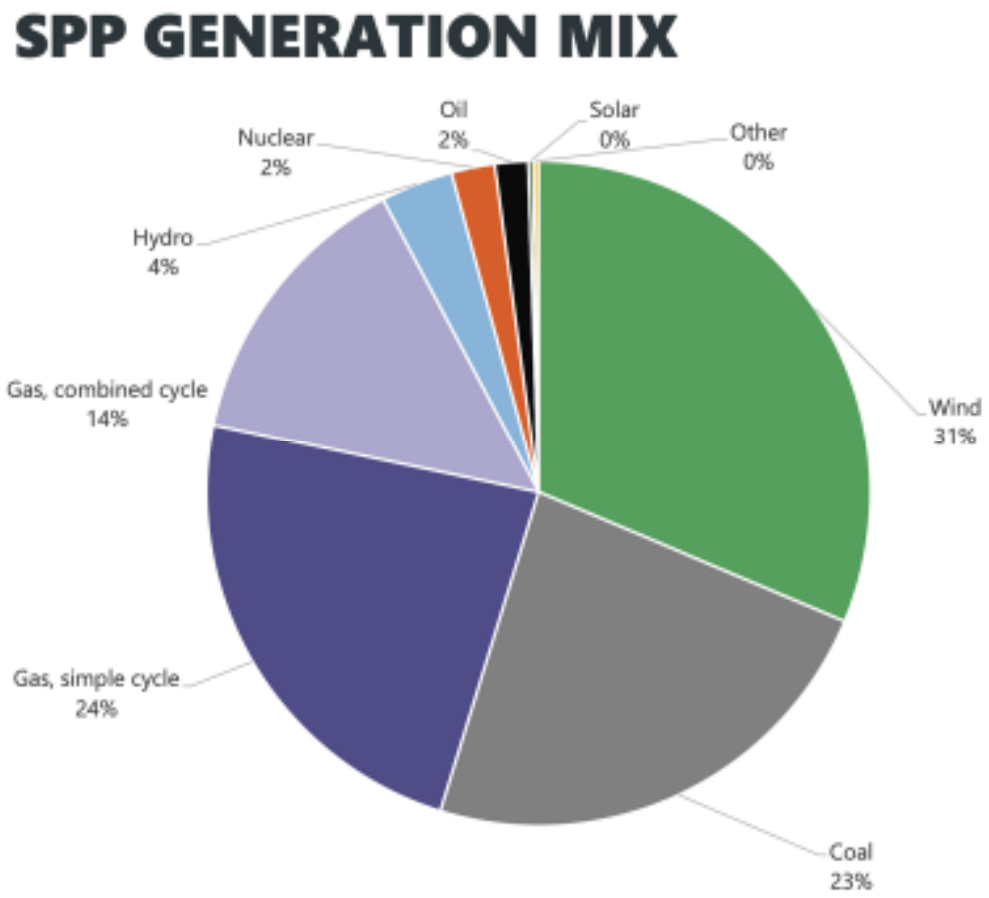


Fig. 8. Two days of output and wind speed from a four-section midwestern wind plant.

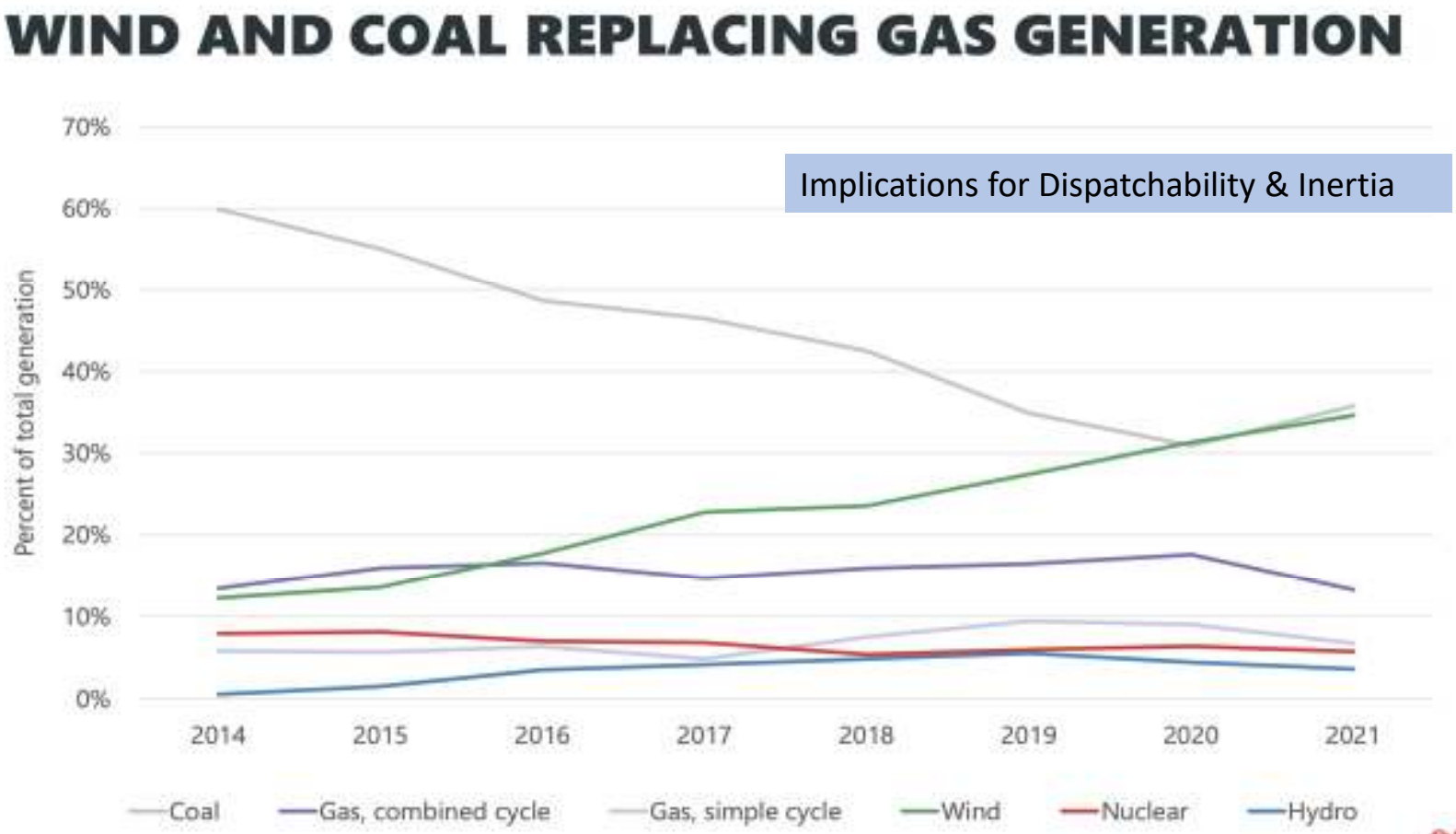
https://info.ornl.gov/sites/publications/Files/Pub57475.pdf

Today's Gen Mix



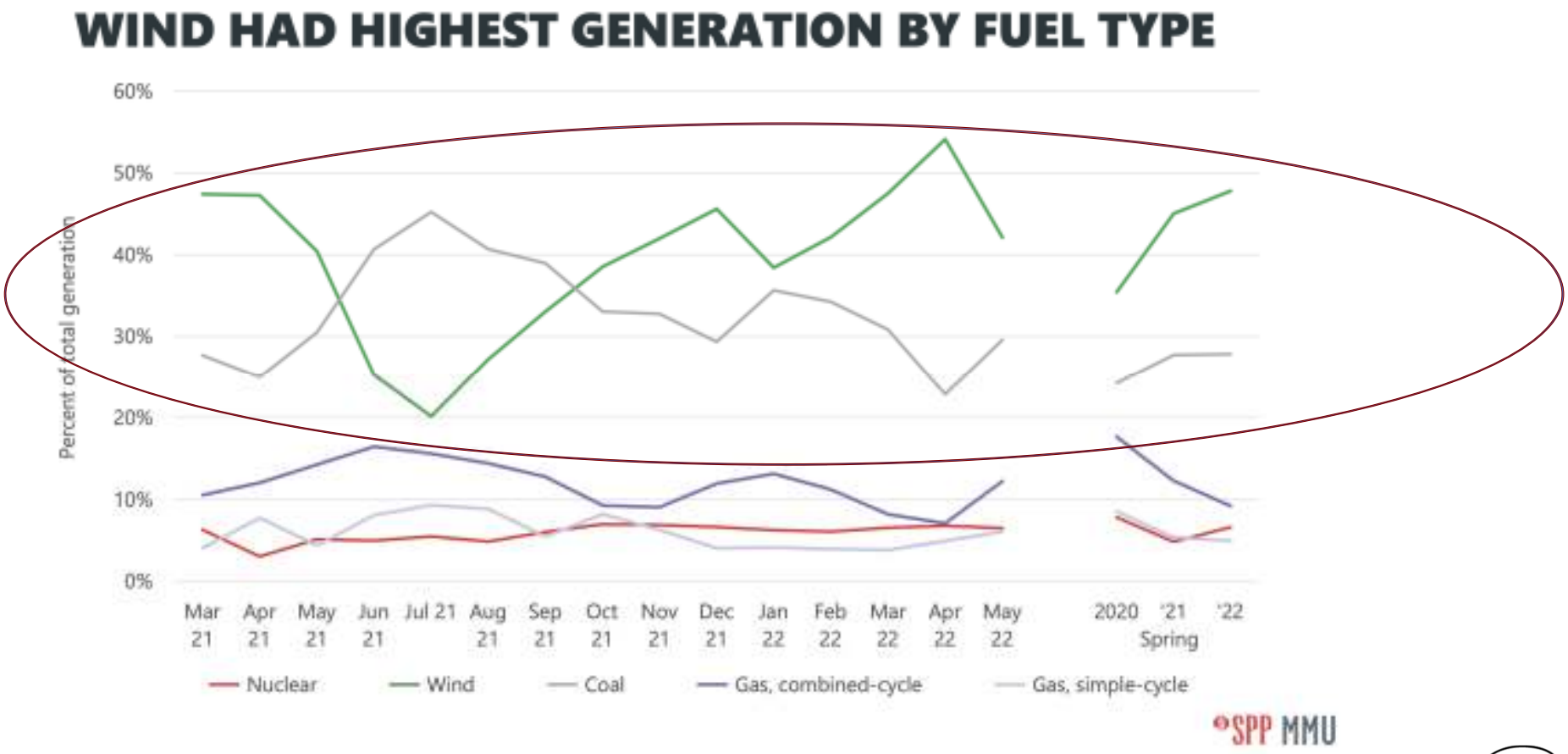
https://www.spp.org/documents/67169/2021%20annual%20state%20of%20the%20market%20presentation.pdf

Historically, Wind Has Eaten Coal's Lunch (Gas Contribution is Smaller)



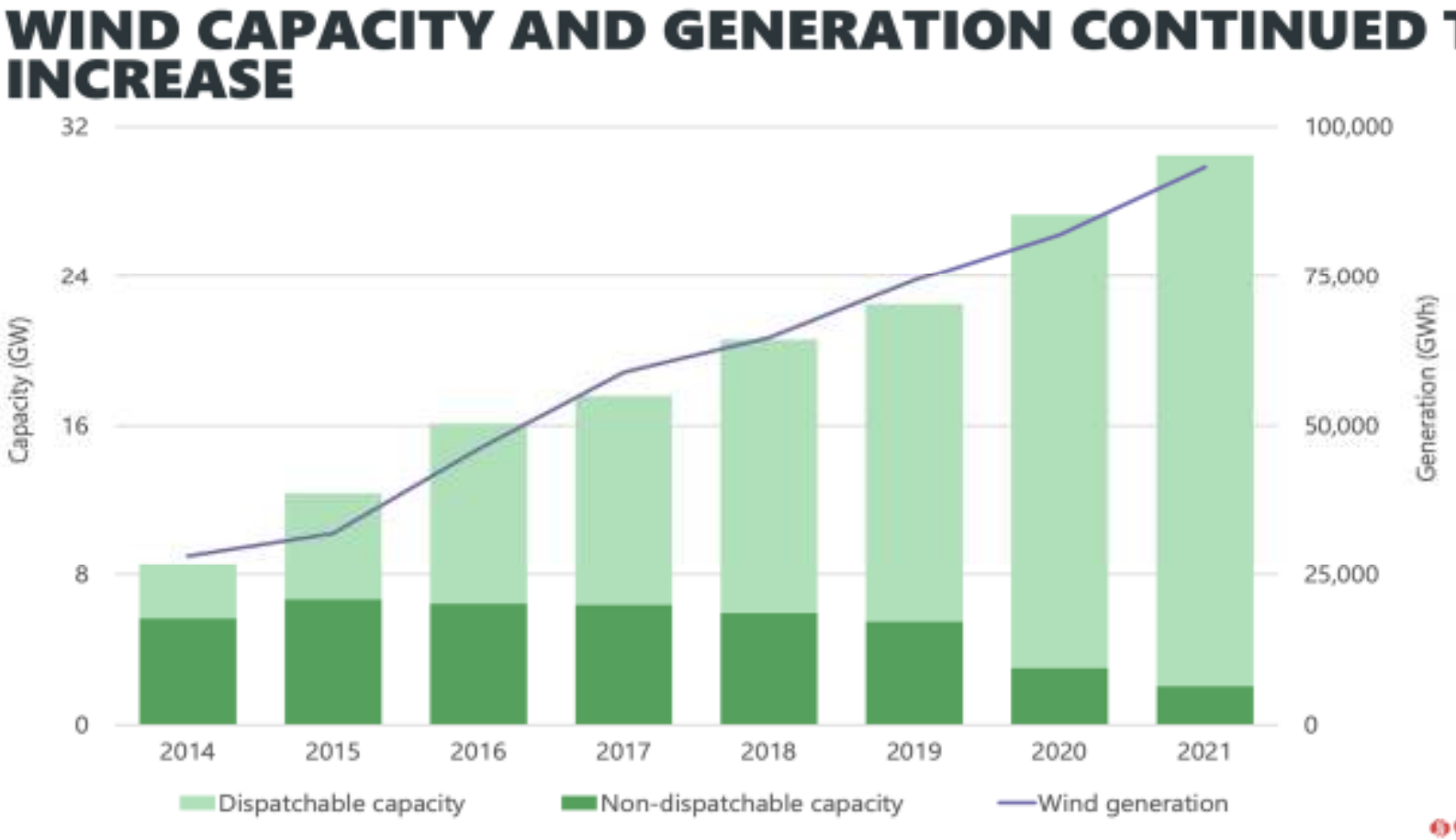
https://www.spp.org/documents/67169/2021%20annual%20state%20of%20the%20market%20presentation.pdf

Note the Inverse Relationships of Wind and Coal



https://www.spp.org/documents/67642/spring%202022%20quarterly%20presentation%20stakeholder.pdf

Wind Eating Coal's Lunch



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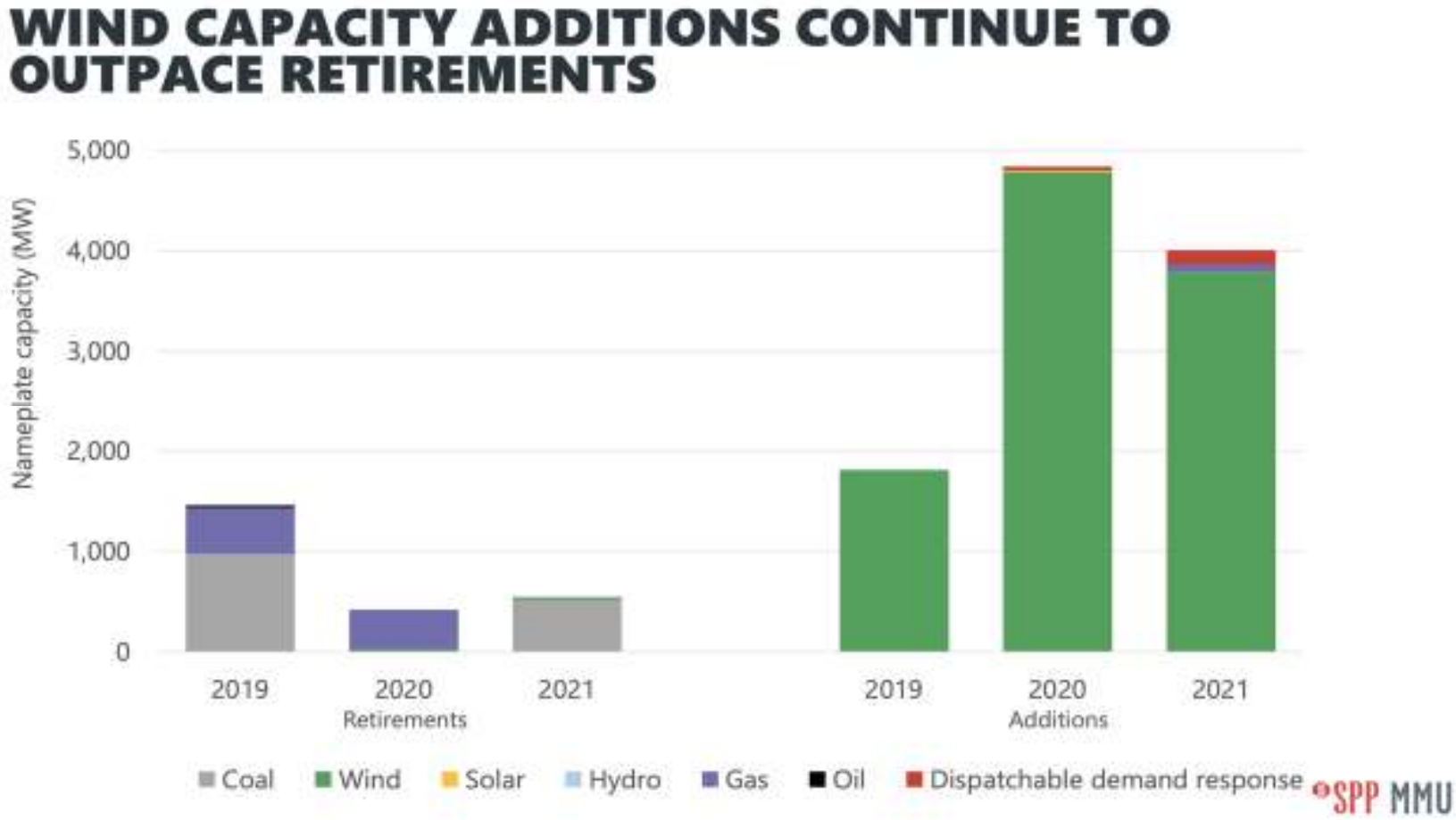
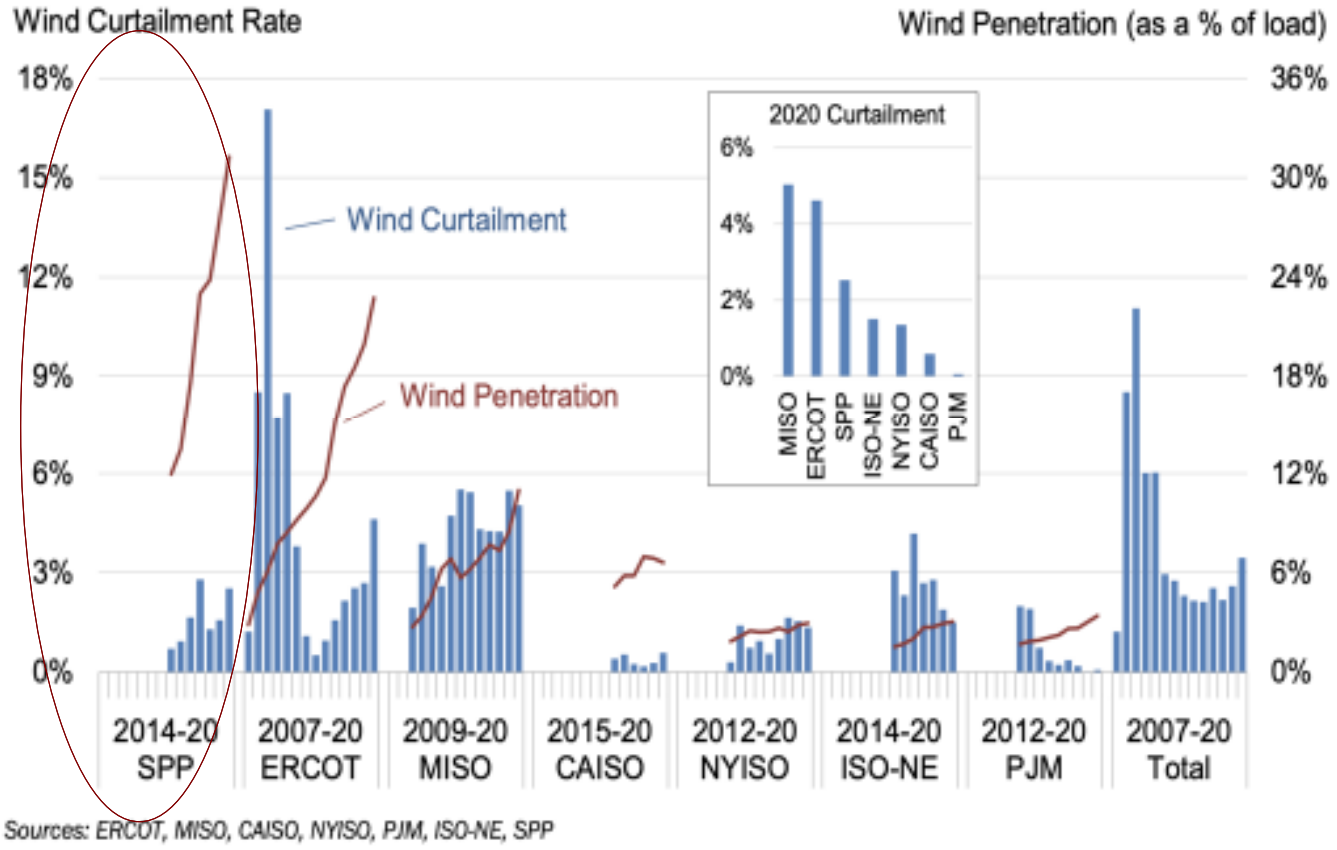
https://www.spp.org/documents/67169/2021%20annual%20state%20of%20the%20market%20presentation.pdf

Hydrocarbon Capacity ≠ Renewables Capacity



https://www.spp.org/documents/67169/2021%20annual%20state%20of%20the%20market%20presentation.pdf

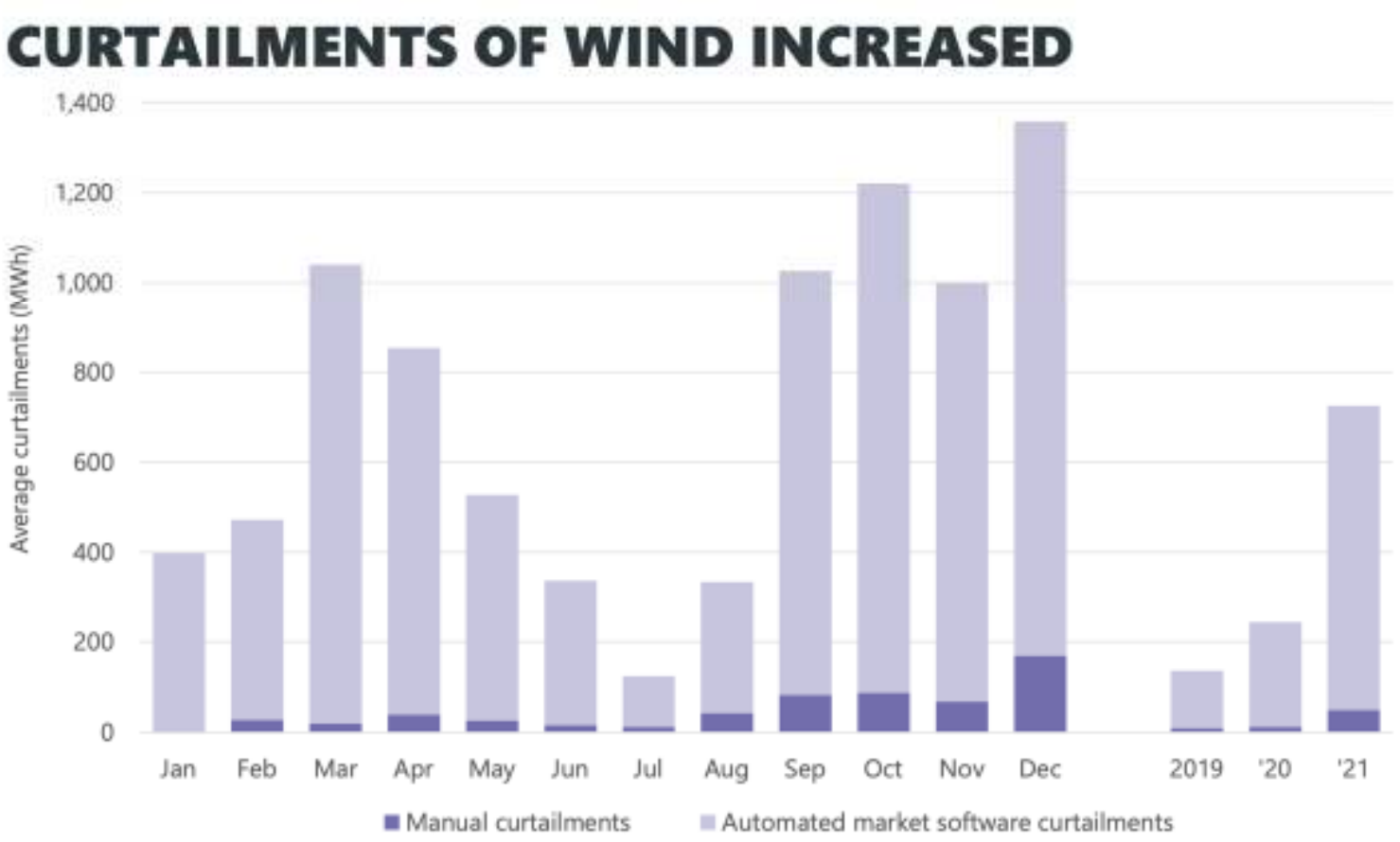
As Wind Percentages Increase, So Does Curtailment



Sources: ERCOT, MISO, CAISO, NYISO, PJM, ISO-NE, SPP

https://www.energy.gov/sites/default/files/2021-08/Land-Based%20Wind%20Market%20Report%202021%20Edition_Full%20Report_FINAL.pdf

2021 An Increase Over Prior Years (note monthly variability)



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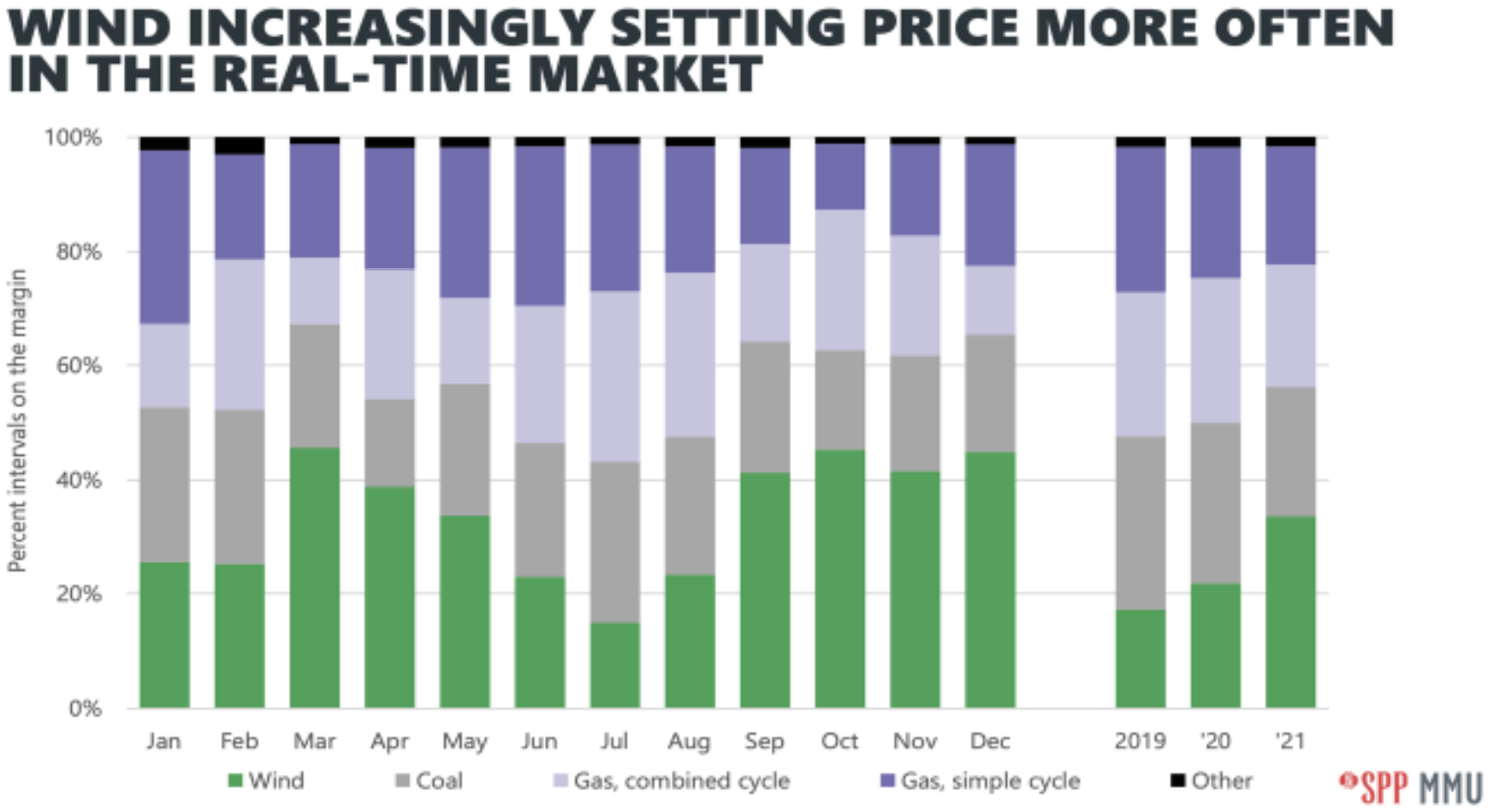
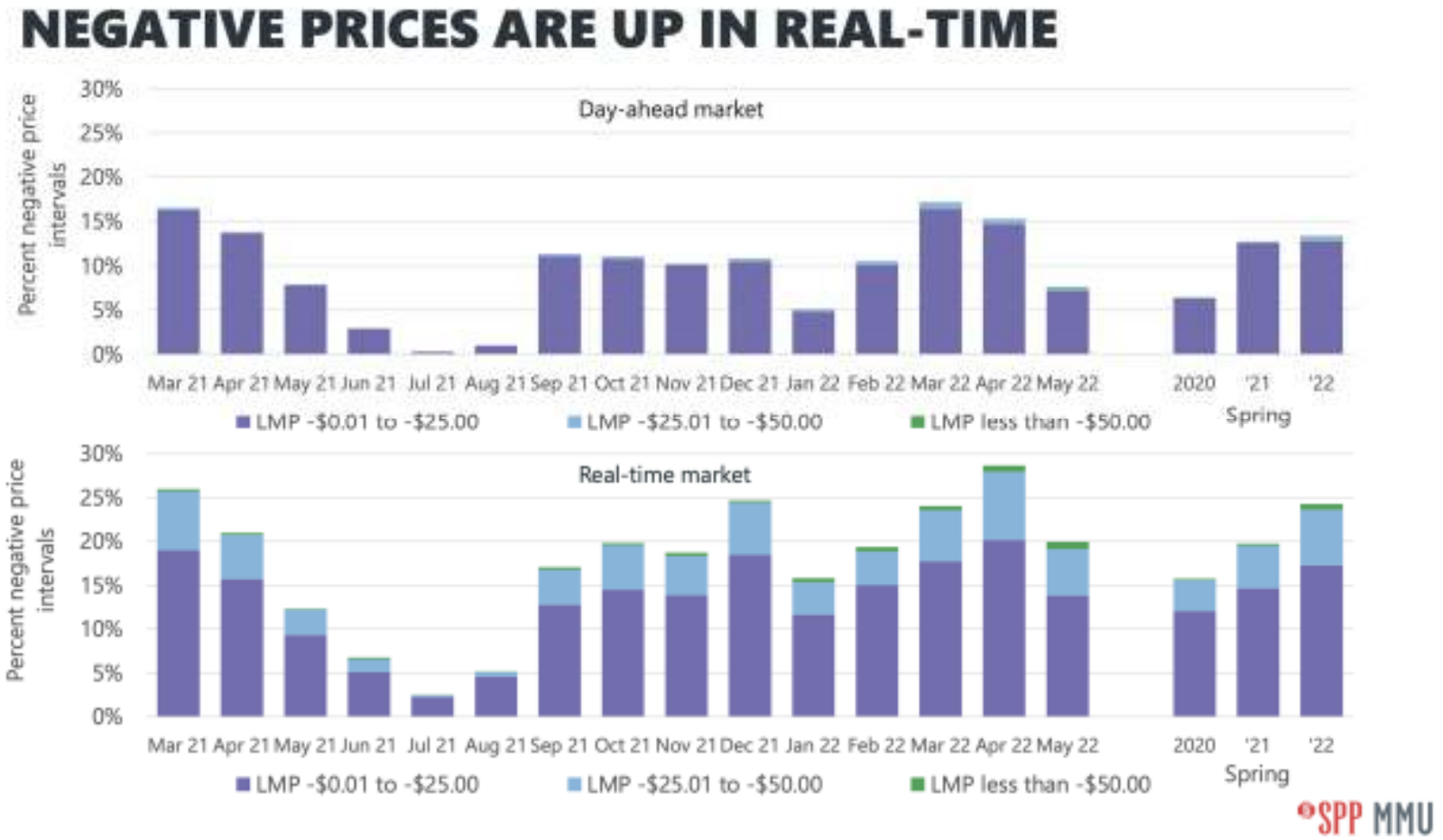
This Pricing Dynamic Has Significant Implications



https://www.spp.org/documents/67169/2021%20annual%20state%20of%20the%20market%20presentation.pdf

With Increasing Periods of Negative (and Soft) Pricing: Negative Co-Variance



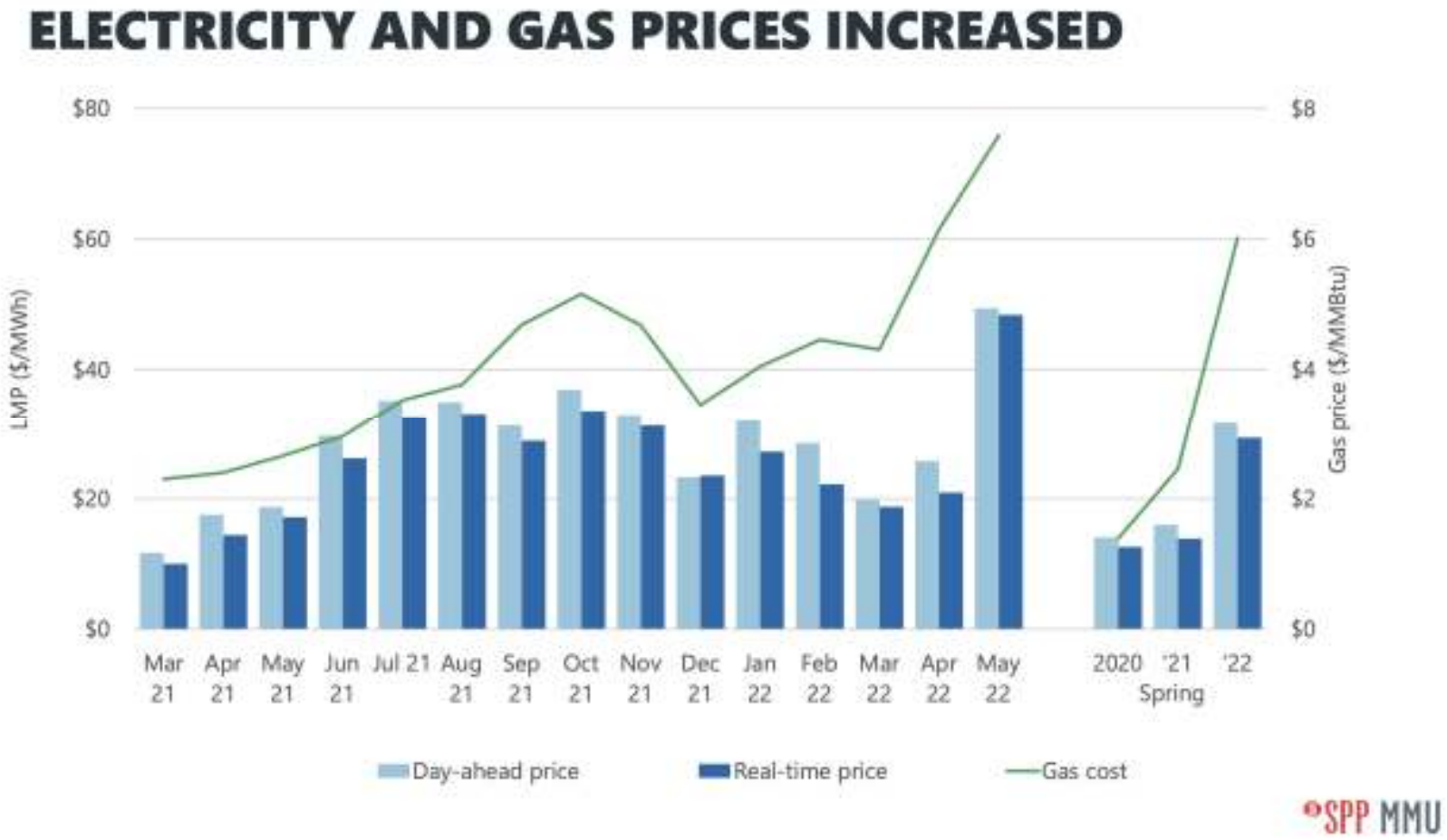
https://www.spp.org/documents/67642/spring%202022%20quarterly%20presentation%20stakeholder.pdf

Despite Some Negative Prices, Power Prices Generally Follow Gas

SPP MMU

https://www.spp.org/documents/67169/2021%20annual%20state%20of%20the%20market%20presentation.pdf

Bad News: With the Ukraine Conflict & LNG, Markets Are Up

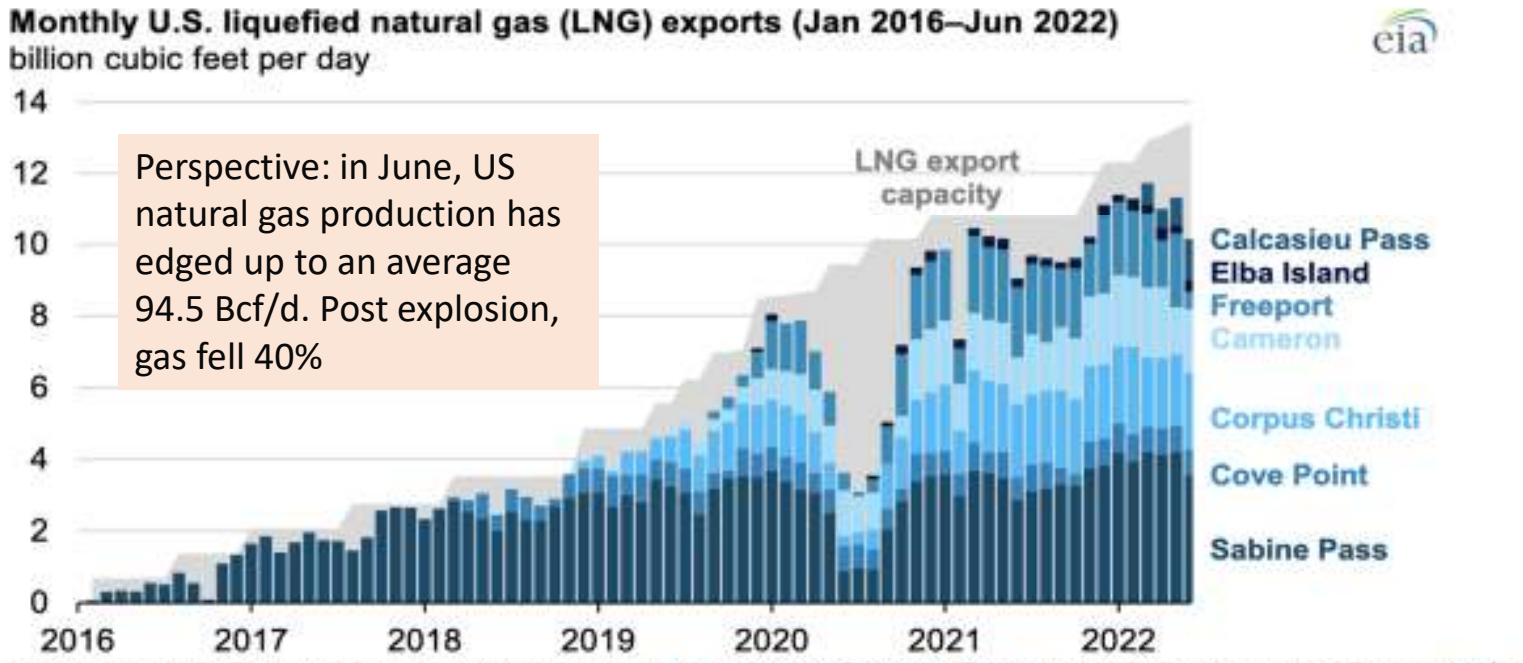


https://www.spp.org/documents/67642/spring%202022%20quarterly%20presentation%20stakeholder.pdf

Macro - LNG Exports: A New "Liquid Market" and Floor for Gas?

JULY 25, 2022

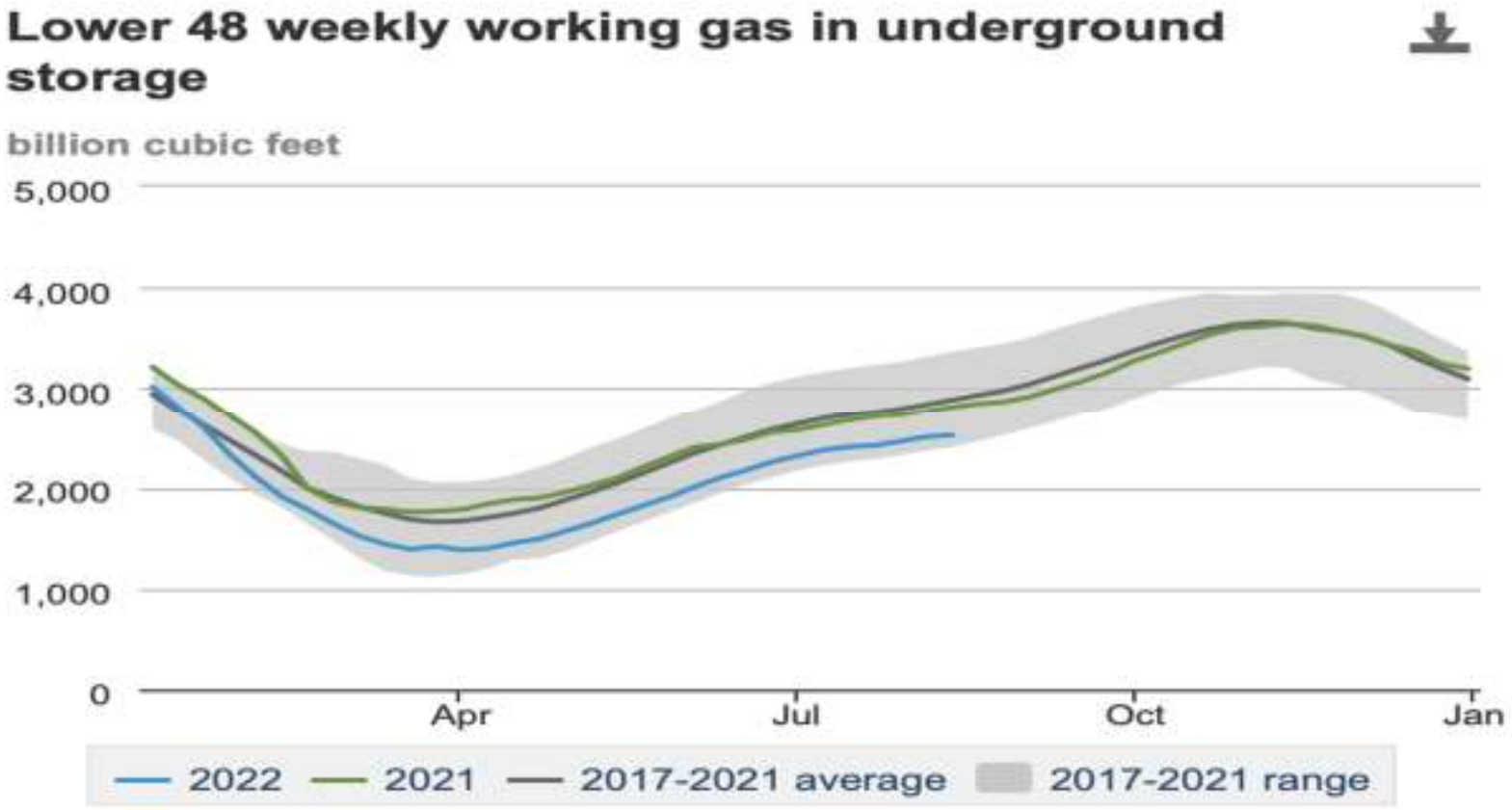
The United States became the world's largest LNG exporter in the first half of 2022



https://www.eia.gov/todayinenergy/detail.php?id=53159

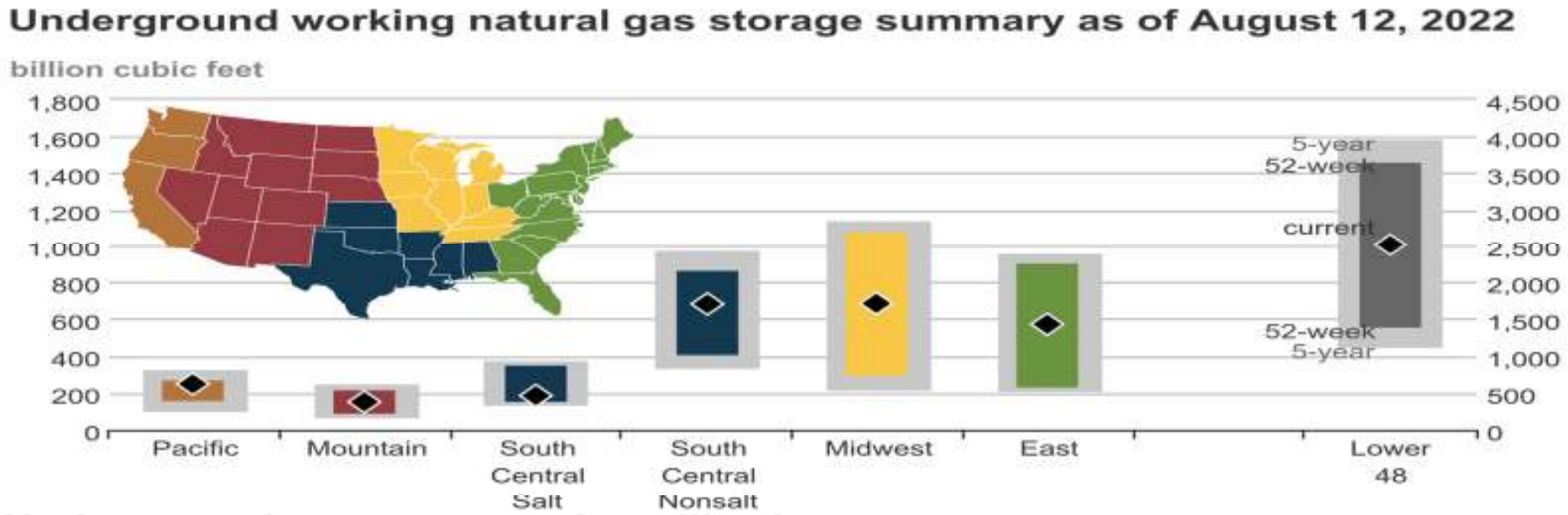
Things This Winter Looking Tighter Than Normal Thus Far

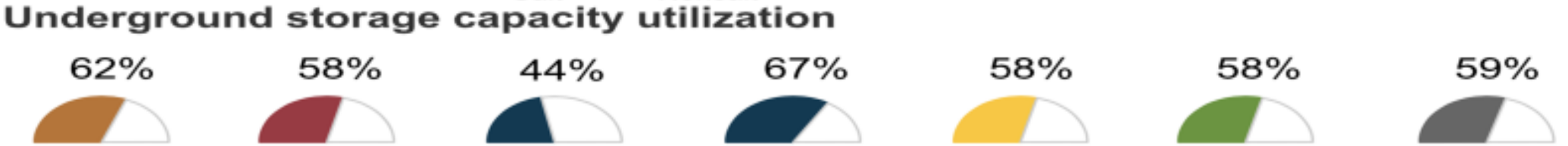
Injections Well Below Average



https://www.eia.gov/naturalgas/storage/dashboard/

Shortfall Especially Pronounced in Eastern U.S.





We Begin to See Questions About RESOURCE ADEQUACY

Table 3.3: Maximum and Minimum Daily Range of Variation in Wind and Solar PV Generation

Assessment Area	Extrema in Daily Range of Solar PV and Wind Output	Change in MW in One Day	Month Occurring (2021)
MISO	Minimum	1,070	January
	Maximum	18,300	December
SPP	Minimum*	865	February
	Maximum	15,079	August
	* SPP's minimum was determined from all months except August. Due to a data issue, the minimum for August cannot be accurately determined from the data set.		
ERCOT	Minimum	1,810	February
	Maximum	19,514	October
CAISO	Minimum	4,636	December
	Maximum	13,608	April

With VERs and just-in-time natural-gas-fired generation comprising an increasingly greater percentage of the generation fleet, the Winter 2021 planning reserve assessments for these areas illustrate how incomplete a picture capacity reserve margin by itself provides.

https://www.nerc.com/pa/RAPA/PA/Performance%20Analysis%20DL/NERC_SOR_2022.pdf

Esp. W/Revenues Not Sufficient to Attract Investment in New Capacity

MARKET REVENUE INSUFFICIENT* TO SUPPORT NEW GENERATION

Technology	Average marginal cost ($/MWh)	Net revenue from SPP market ($/MW yr.)	Annual revenue requirement ($/MW yr.)	Able to recover new entry cost	Annual fixed O&M cost ($/MW yr.)	Able to recover avoidable cost
Scrubbed coal	$25.77	$403,045	$631,590	NO	$54,570	YES
Combined-cycle (single-shaft)	$17.98	$341,261	$150,043	YES/NO	$14,170	YES/NO
Combustion turbine (industrial frame)	$28.28	$260,927	$96,073	YES/NO	$7,040	YES/NO
Wind	-$30.00	$311,137	$258,283	YES	$26,470	YES
Solar	$0.00	$164,261	$234,758	NO	$32,330	YES

SPP MMU

https://www.spp.org/documents/67169/2021%20annual%20state%20of%20the%20market%20presentation.pdf

The Planning Synergy For Solar: 1+1 = 2+

Figure 2. Schematic of "Diversity Impacts" between Solar and Energy Storage[6]

https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/energy-division/documents/integrated-resource-plan-and-long-term-procurement-plan-irp-ltpp/20210831_irp_e3_astrape_incremental_elcc_study.pdf

Batteries Jump into the Fray

State	Project Name	Project Sponsor	Offtaker	Actual or Expected COD (PV/Wind/Battery)	Capacity (MW-AC) PV	Wind	Battery	Battery Storage Hours	Battery Storage MWh	Battery:PV Capacity Ratio	Levelized PPA Price (2018 $/MWh)
AL	Redstone Arsenal	SunPower	Redstone Arsenal	Dec-17	10	0	1	2.0	2	10%	?
AR	Searcy	NextEra	Entergy (owner)	Dec-21	100	0	30	?	?	30%	#N/A
AZ	Pinal Central	NextEra	SRP	Apr-18	20	0	10	4.0	40	50%	68.9
AZ	Wilmot	NextEra	TEP	Dec-19	100	0	30	4.0	120	30%	40.7
AZ	Redhawk(?)	First Solar	APS	Jun-21	65	0	50	2.7	135	77%	?
CA	Desert Harvest II	EDF-RE	SCPPA	Dec-20	70	0	35	4.0	140	50%	LMP plus $15.25
CA	RE Slate 2	ReCurrent	MBCP and SVCE	Jun-21	150	0	45	4.0	180	30%	≤31.8
CA	BigBeau	EDF-RE	MBCP and SVCE	Dec-21	128	0	40	4.0	160	31%	≤30.9
CA	?	NextEra	Kaiser Permanente	Dec-20/Dec-21/Dec-21	131	50	110	?	?	84%	?
CA	Sonrisa	EDPR	SJCE & EBCE	Dec-22	200	0	40	4.0	160	20%	?
CA	Raceway	sPower	EBCE	Dec-22	125	0	80	2.0	160	64%	?
CA	Eland	Bminute Solar	LADWP/Glendale	Dec-23	400	0	300	4.0	1200	75%	28.5
FL	Babcock	NextEra	FPL (owner)	Dec-16/NA/Mar-18	74.5	0	10	4.0	40	13%	#N/A
FL	Citrus	NextEra	FPL (owner)	Dec-16/NA/Mar-18	74.5	0	4	4.0	16	5%	#N/A
FL	Manatee	NextEra/FPL	FPL (owner)	Dec-16/NA/Dec-21	74.5	0	409	2.2	900	549%	#N/A
HI	Kapaia	Tesla	KIUC	Apr-17	13	0	13	4.0	52	100%	119.8
HI	Lawai	AES	KIUC	Oct-18	20	0	20	5.0	100	100%	89.4
HI	Kekaha	AES	KIUC	Sep-19	14	0	14	5.0	70	100%	85.5
HI	West Loch	HECO	HECO (owner)	Oct-19	20	0	20	4.0	80	100%	#N/A
HI	Waikoloa Solar	AES	Hawaiin Electric	Jul-21	30	0	30	4.0	120	100%	59.8
HI	Kuihelani Solar	AES	Hawaiin Electric	Jul-21	60	0	60	4.0	240	100%	58.5
HI	West Oahu	AES	Hawaiin Electric	Sep-21	12.5	0	12.5	4.0	50	100%	79.5
HI	Hoohana Solar 1	174 Power Global	Hawaiin Electric	Dec-21	52	0	52	4.0	208	100%	76.3
HI	Mililani I Solar	Clearway	Hawaiin Electric	Dec-21	39	0	39	4.0	156	100%	68.0
HI	Waiawa Solar	Clearway	Hawaiin Electric	Dec-21	36	0	36	4.0	144	100%	74.0
HI	Hale Kuawehi	Innergex	Hawaiin Electric	Jun-22	30	0	30	4.0	120	100%	65.8
HI	Paeahu	Innergex	Hawaiin Electric	Jun-22	15	0	15	4.0	60	100%	87.9
MN	Ramsey/Athens	Engie/NextEra	Connexus	Dec-18	10	0	15	2.0	30	150%	?
NV	Battle Mountain	Cypress Creek	NV Energy	Jun-21	101	0	25	4.0	100	25%	22.3
NV	Dodge Flat	NextEra	NV Energy	Dec-21	200	0	50	4.0	200	25%	23.1
NV	Fish Springs Ranch	NextEra	NV Energy	Dec-21	100	0	25	4.0	100	25%	25.9
NV	Townsite	Capital Dynamics	Munis/Co-op	Dec-21	180	0	90	4.0	360	50%	?
NV	Arrow Canyon	EDF-RE	NV Energy	Dec-22	200	0	75	5.0	375	38%	21.8
NV	Southern Bighorn	Bminute Solar	NV Energy	Sep-23	300	0	135	4.0	540	45%	21.9
NV	Gemini	Quinbrook/Arevia	NV Energy	Dec-23	690	0	380	3.8	1460	55%	25.1
OK	Skeleton Creek	NextEra	WFEC	Dec-23/Dec-19/Dec-23	250	250	200	4.0	800	80%	?
OR	Wheatridge	NextEra	PGE	Dec-21/Dec-20/Dec-21	50	300	30	4.0	120	60%	?
TX	Castle Gap	Luminant	Luminant (owner)	Jun-18/NA/Dec-18	180	0	10	4.2	42	6%	#N/A

https://emp.lbl.gov/sites/default/files/lbnl_utility-scale_solar_2019_edition_slides_final.pdf

Why Storage is So Critical to Solar, and Not Wind

Table ES1. Recommended ELCC Values for 2022[2]

Region	BTM PV	Fixed PV	Tracking PV	Tracking PV Hybrid	Wind	Wind Hybrid
PGE	4.3%	5.4%	6.9%	99.6%	21.8%	54.0%
SCE/SDGE	3.6%	4.6%	5.4%	99.9%	18.0%	47.0%
AZ APS		4.6%	5.4%	99.0%	38.8%	78.3%
NM EPE		4.6%	5.4%	99.0%	38.8%	78.3%
BPA					32.7%	57.2%
CAISO	4.0%	5.0%	6.2%	99.8%	19.9%	50.5%
Average	4.0%	4.8%	5.8%	99.4%	30.0%	62.0%

W/solar, I can charge my battery most days. Wind? Meh…

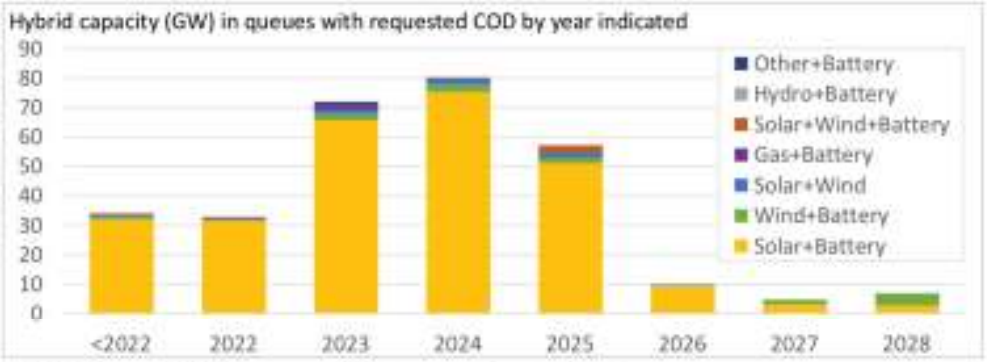
Table ES2. Recommended ELCC Values for 2026

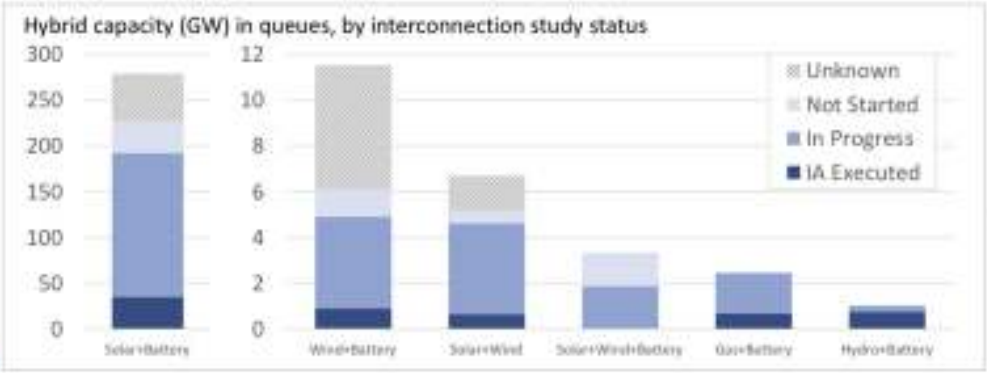
Region	BTM PV	Fixed PV	Tracking PV	Tracking PV Hybrid	Wind	Wind Hybrid
PGE	1.3%	2.1%	3.4%	98.8%	17.9%	43.5%
SCE/SDGE	0.6%	1.2%	1.9%	96.4%	17.8%	35.3%
AZ APS		~0.0%	1.9%	96.0%	30.8%	79.2%
NM EPE		~0.0%	1.9%	96.0%	30.8%	79.2%
BPA					32.8%	52.8%
CAISO	1.0%	1.7%	2.7%	97.6%	17.9%	39.4%
Average	1.0%	0.8%	2.3%	96.8%	26.0%	58.0%

https://library.sce.com/content/dam/sce-doclib/public/regulatory/filings/pending/electric/ELECTRIC_4243-E.pdf

So We'll Need Batteries to Shift Output

The majority (71%) of hybrid (generator) capacity in the queues has requested to come online by the end of 2024; 12% has an executed interconnection agreement (IA)





- Nearly all hybrid capacity in the queues is requesting to come online before 2026
- Solar+Battery dominates requested hybrid capacity additions through 2027
- Over 35 GW of Solar+ Battery has an executed IA, compared to <1 GW of each of the other hybrid types
- Proportions of interconnection status are fairly similar across types

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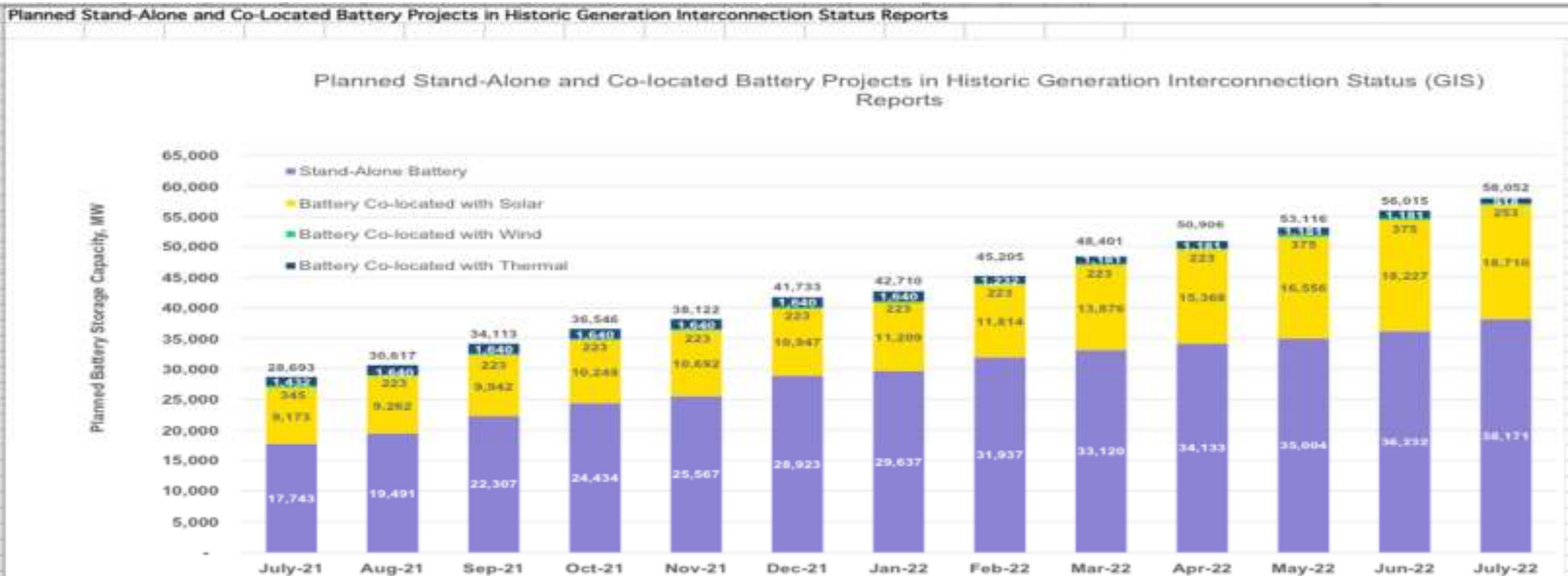
https://emp.lbl.gov/sites/default/files/hybrid_plant_tracking_2022.pdf

Texas a Precursor? Solar & Storage Flood the Zone

Planned Stand-Alone and Co-Located Battery Projects in Historic Generation Interconnection Status Reports



	July-21	Aug-21	Sep-21	Oct-21	Nov-21	Dec-21	Jan-22	Feb-22	Mar-22	Apr-22	May-22	Jun-22	July-22
Stand-Alone Battery	62%	64%	65%	67%	67%	69%	69%	71%	68%	67%	66%	65%	66%
Battery Co-located with Solar	32%	30%	29%	28%	28%	26%	26%	26%	29%	30%	31%	33%	32%
Battery Co-located with Wind	1%	1%	1%	1%	1%	1%	1%	0%	0%	0%	1%	1%	0%
Battery Co-located with Thermal	5%	5%	5%	4%	4%	4%	4%	3%	2%	2%	2%	2%	2%

http://mis.ercot.com/misapp/GetReports.do?reportTypeId=15933&reportTitle=GIS+Report&showHTMLView&micKey

Hybrids Have Grown Rapidly

https://cleanpower.org/wp-content/uploads/2022/02/CPQ_4Q21_PUBLIC.pdf

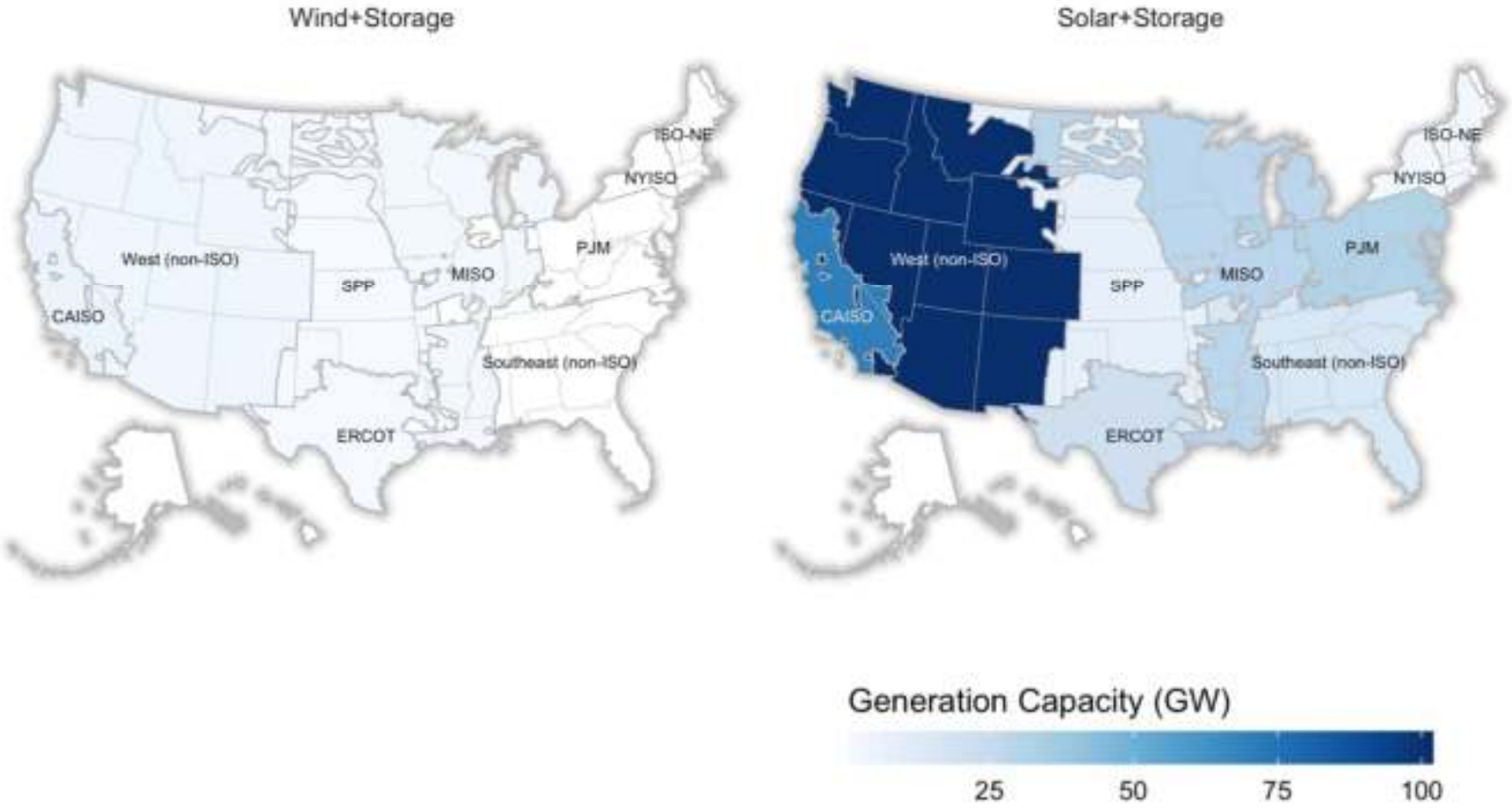
In Some Regions, (Not SPP) Solar Practically Demands Storage

Region	% of Proposed Capacity Hybridizing in Each Region			
	Solar	Wind	Nat. Gas	Battery
CAISO	95%	42%	15%	51%
ERCOT	27%	4%	27%	33%
SPP	18%	1%	0%	24%
MISO	27%	8%	0%	n/a
PJM	21%	1%	0%	n/a
NYISO	6%	3%	0%	3%
ISO-NE	24%	0%	0%	n/a
West (non-ISO)	75%	15%	0%	n/a
Southeast (non-ISO)	28%	0%	0%	n/a
TOTAL	42%	8%	3%	n/a

Note: Hybrid percentages for SPP are likely undercounted, since the SPP queue data contains a number of unknown / unclassified hybrid plants

https://emp.lbl.gov/sites/default/files/hybrid_plant_tracking_2022.pdf

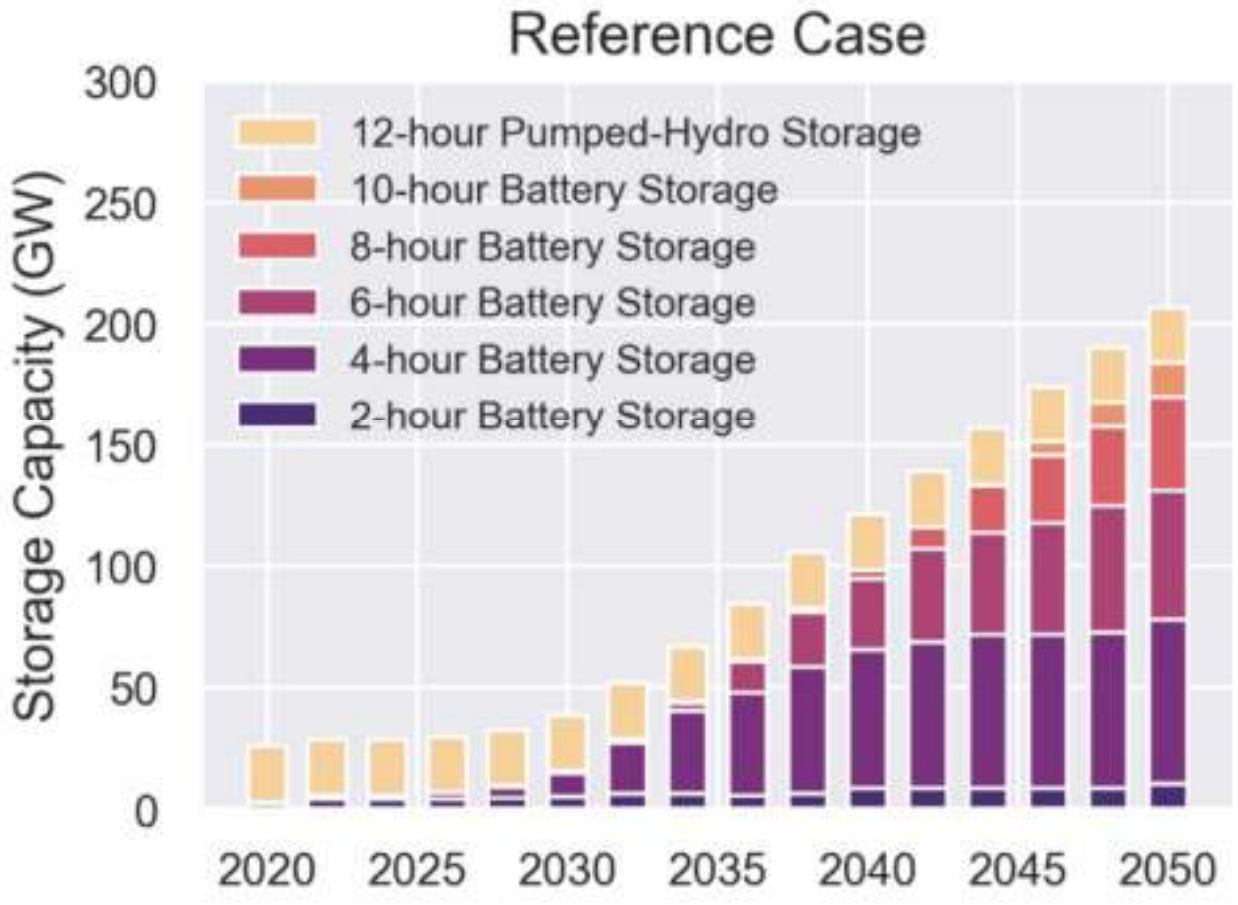
SPP is Not the Hot Spot for Hybrids (Yet)



But Skeleton Creek is an Interesting Hybrid

https://www.energy-storage.news/turbines-operational-at-skeleton-creek-wind-solar-storage-hybrid-project-in-oklahoma/

Four Hours OK, But the Future Will Need Longer-Duration Assets



https://www.nrel.gov/docs/fy22osti/81779.pdf

New Technologies Coming to the Fore?

Form Energy claims aqueous air battery provides 150 hours of storage

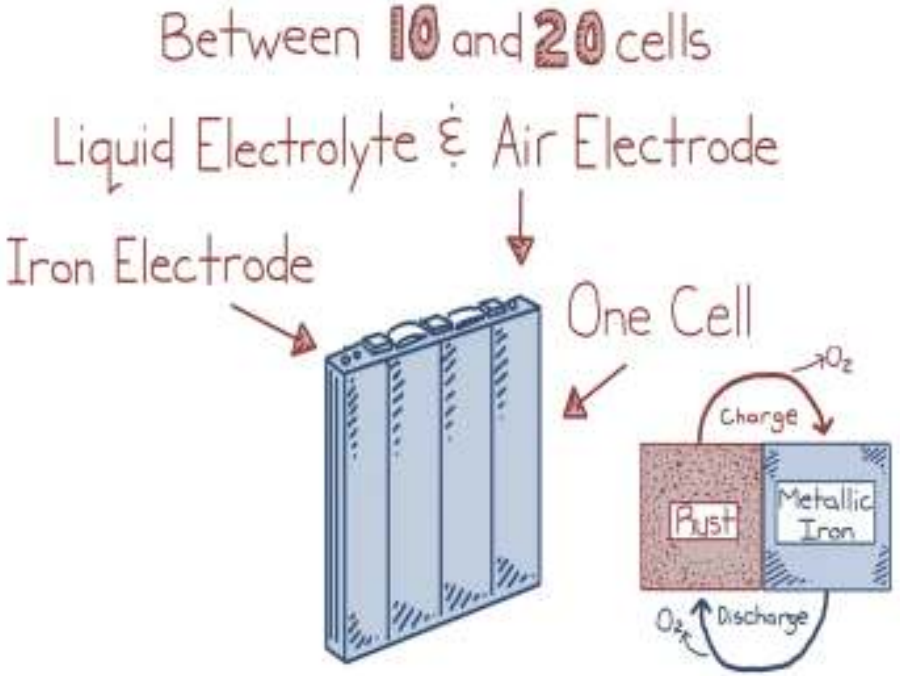
The holy grail of energy storage has always been low-cost and long-duration. Form Energy intends on deploying a 1 MW/150 MWh system with a Minnesota utility before 2023, an unprecedented energy storage duration if successful.

Stable

No need for lithium, nickel, or cobalt

10% cost per kWh vs li-ion

100+ hours



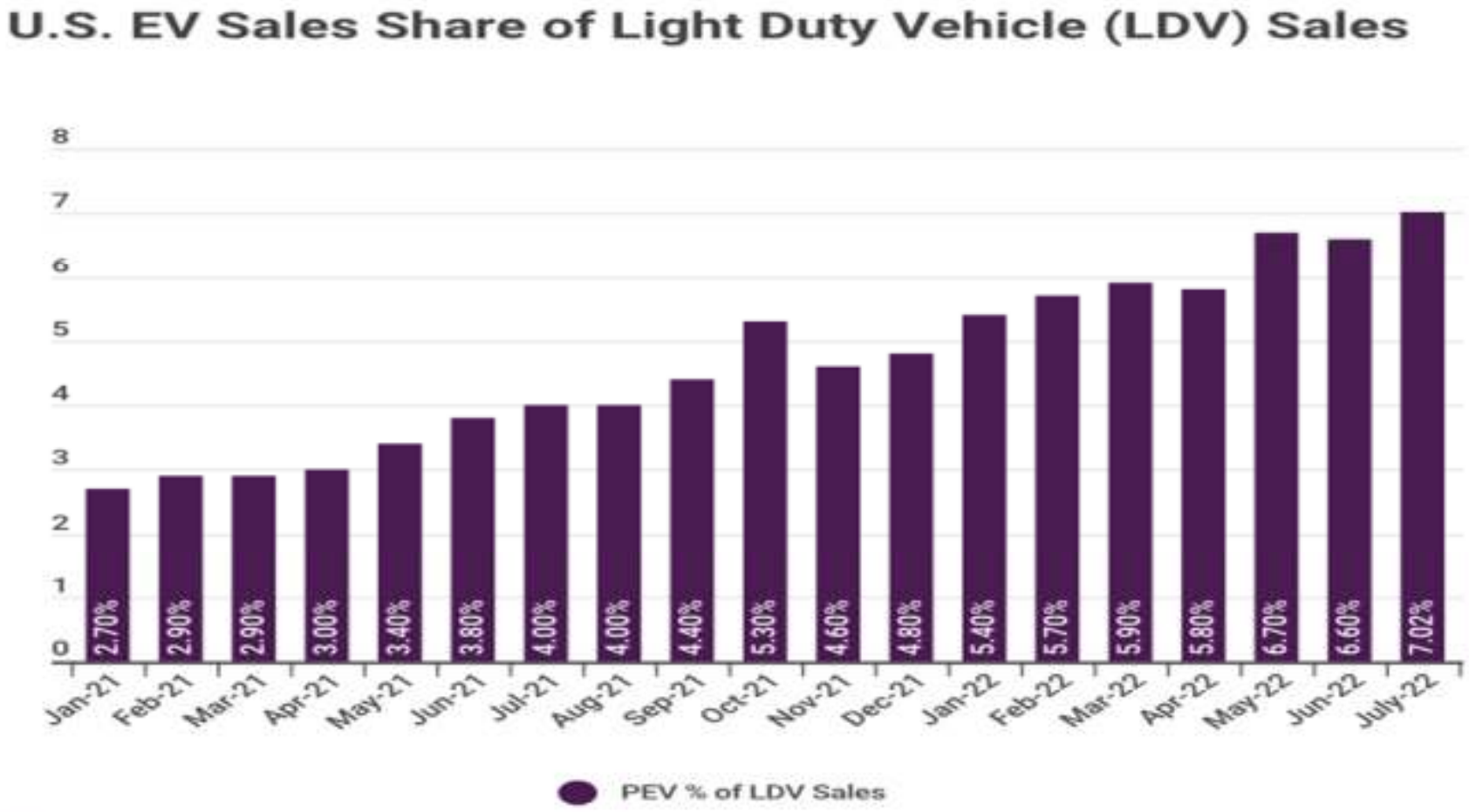
https://formenergy.com/technology/battery-technology/

54

What About The Grid Edge?

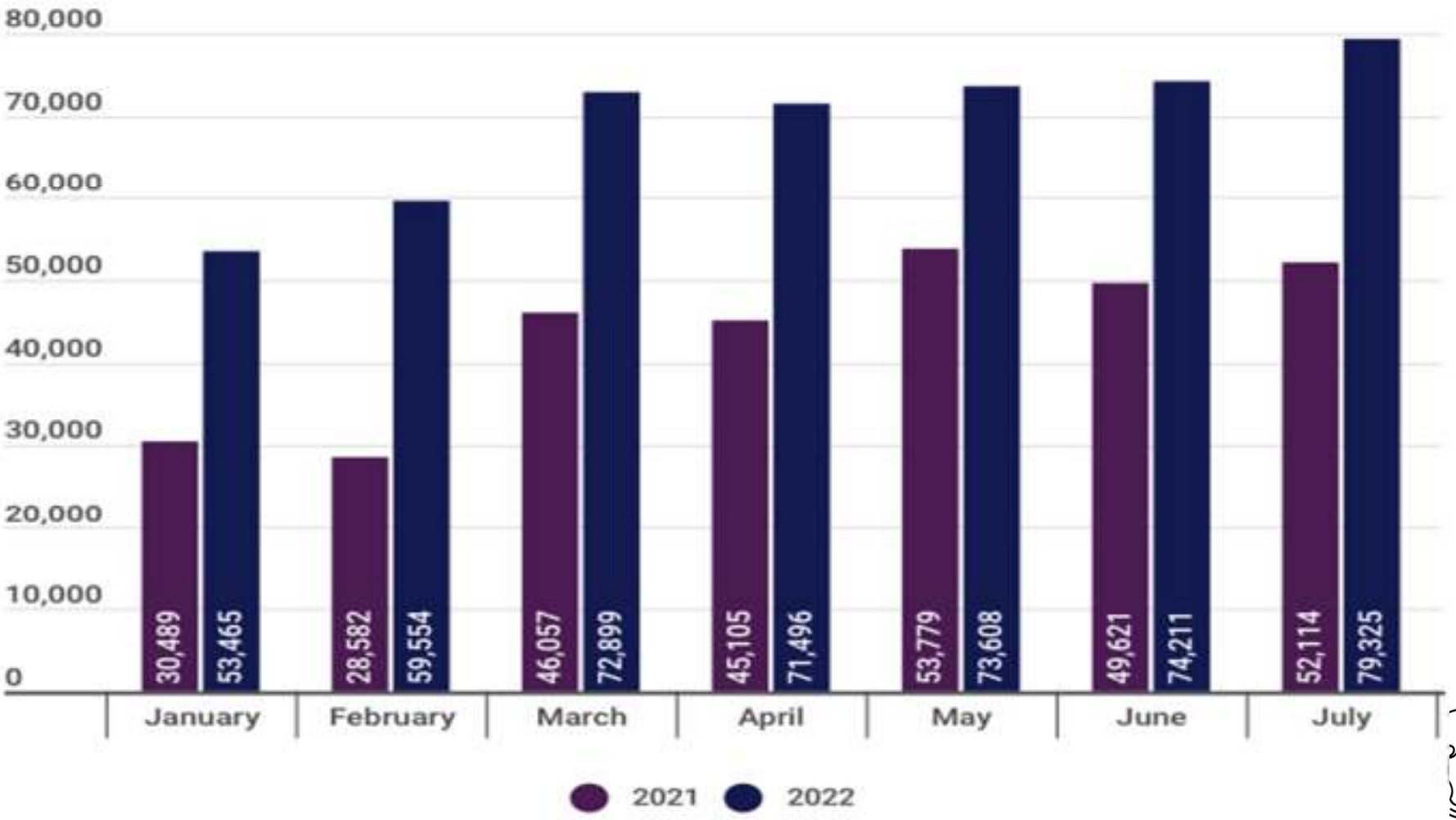
55

EV Sales Starting to Take Off

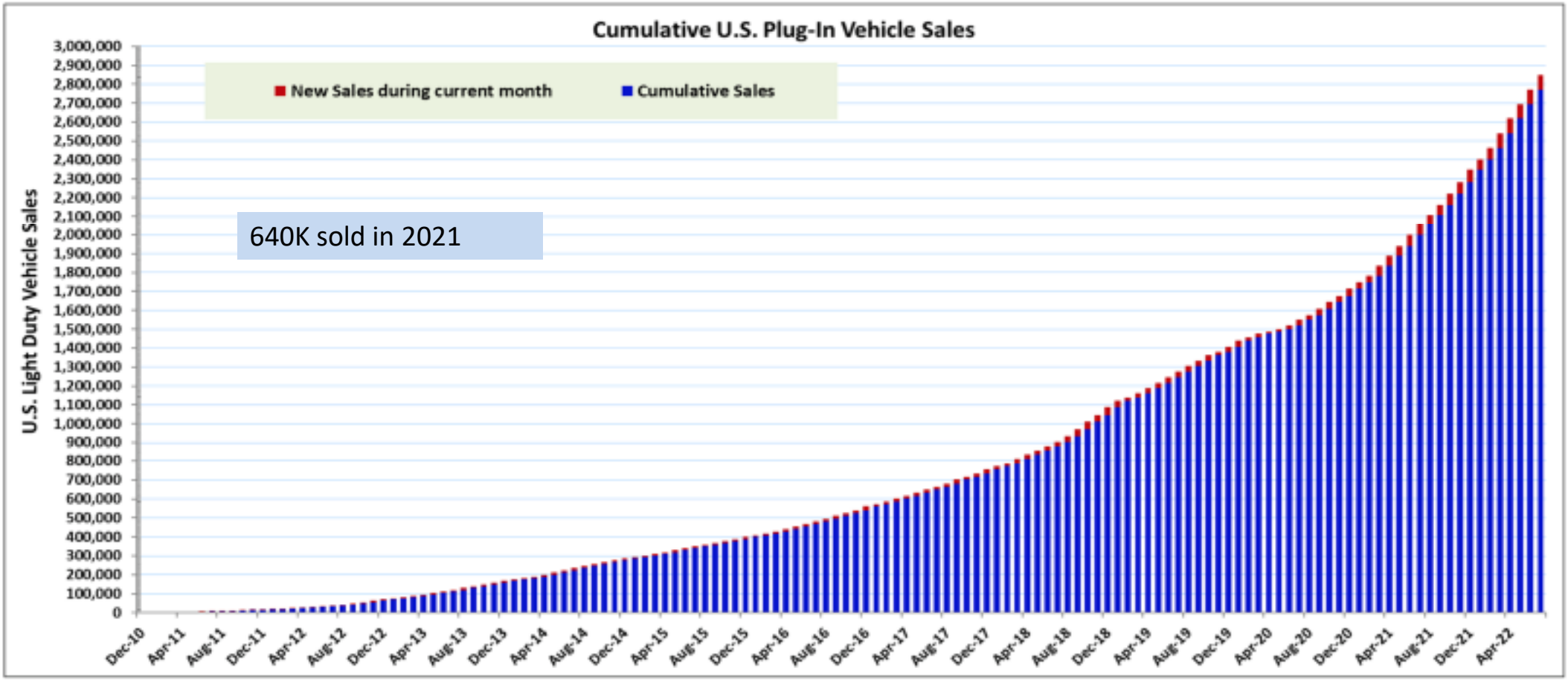


https://zpryme.com/utility-response/u-s-electric-vehicle-sales-2/

U.S. EV Sales by Month, 2021 vs 2022



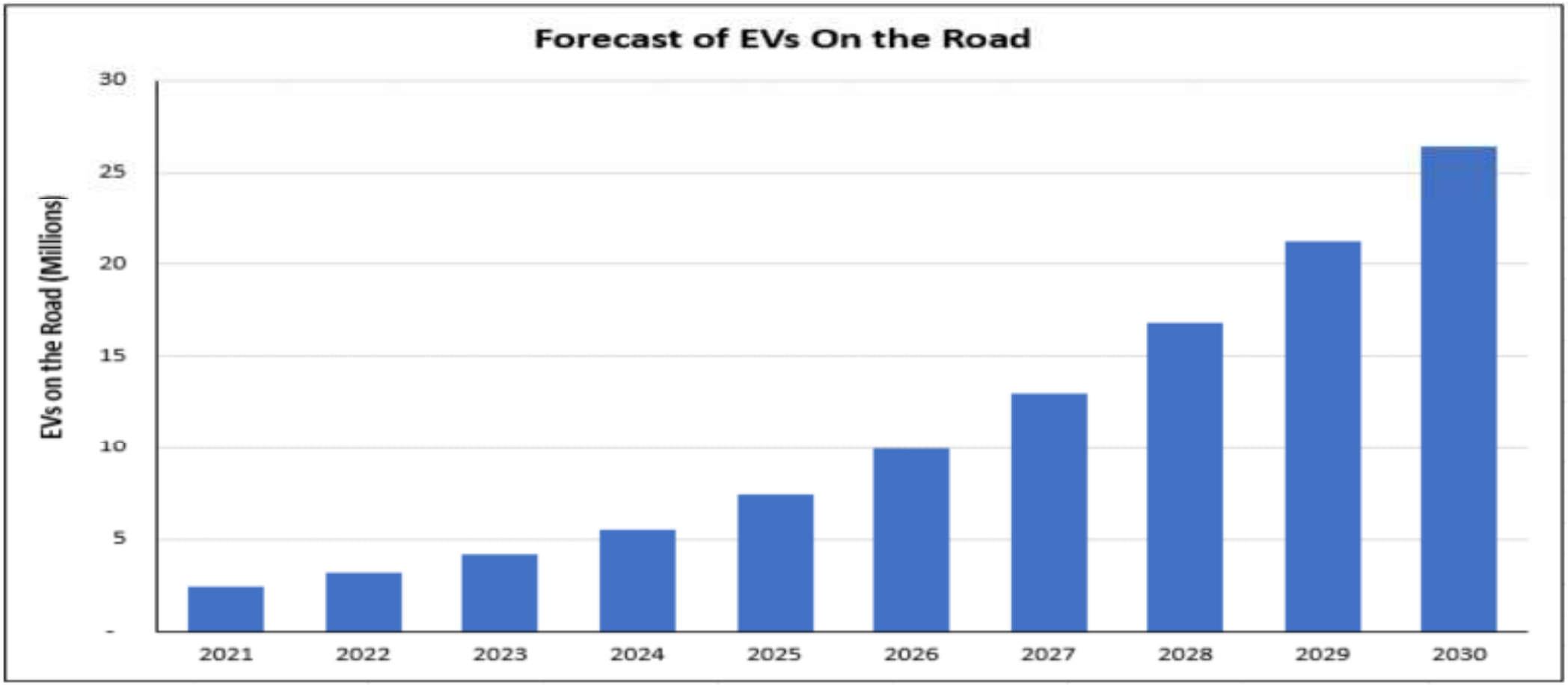
EV Sales on the Rise



https://www.anl.gov/esia/light-duty-electric-drive-vehicles-monthly-sales-updates

EEI's View (Pre IRA and Pre-CARB)

Figure 1. EEI Forecast of EV Stock: 26.4 Million EVs on U.S. Roads in 2030



https://www.eei.org/-/media/Project/EEI/Documents/Issues-and-Policy/Electric-Transportation/EV-Forecast--Infrastructure-Report.pdf

U.S. Auto Industry Ramping Up

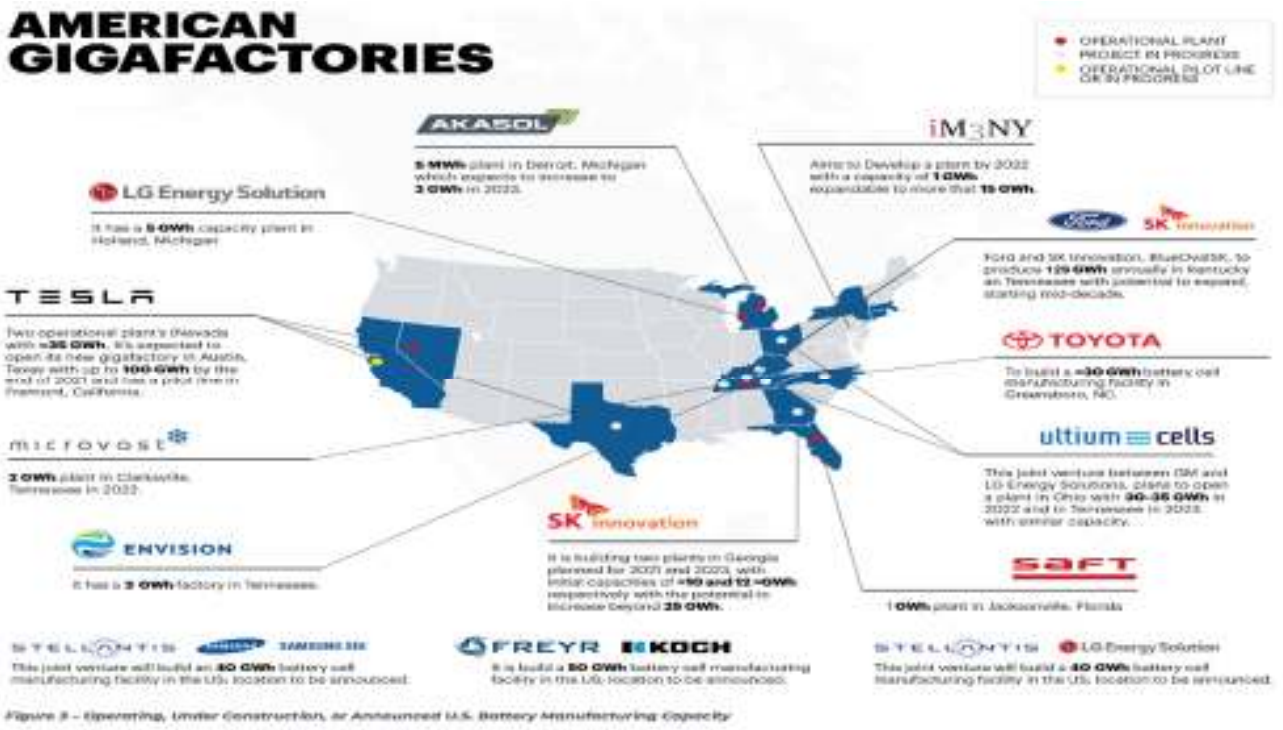
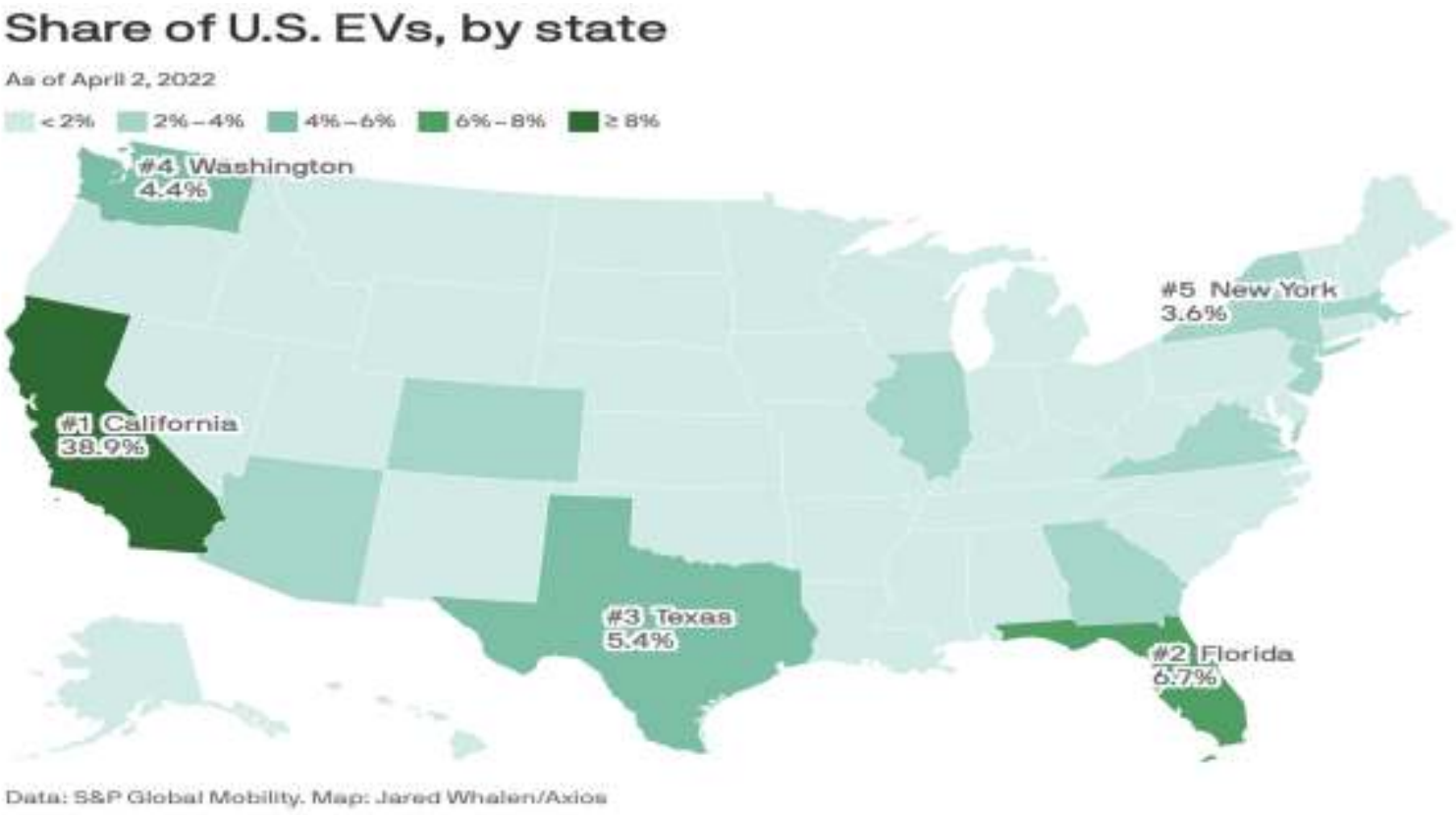


Figure 3 – Operating, Under Construction, or Announced U.S. Battery Manufacturing Capacity

Strong Estimated Financial Results With Potential For Extended Operational Life

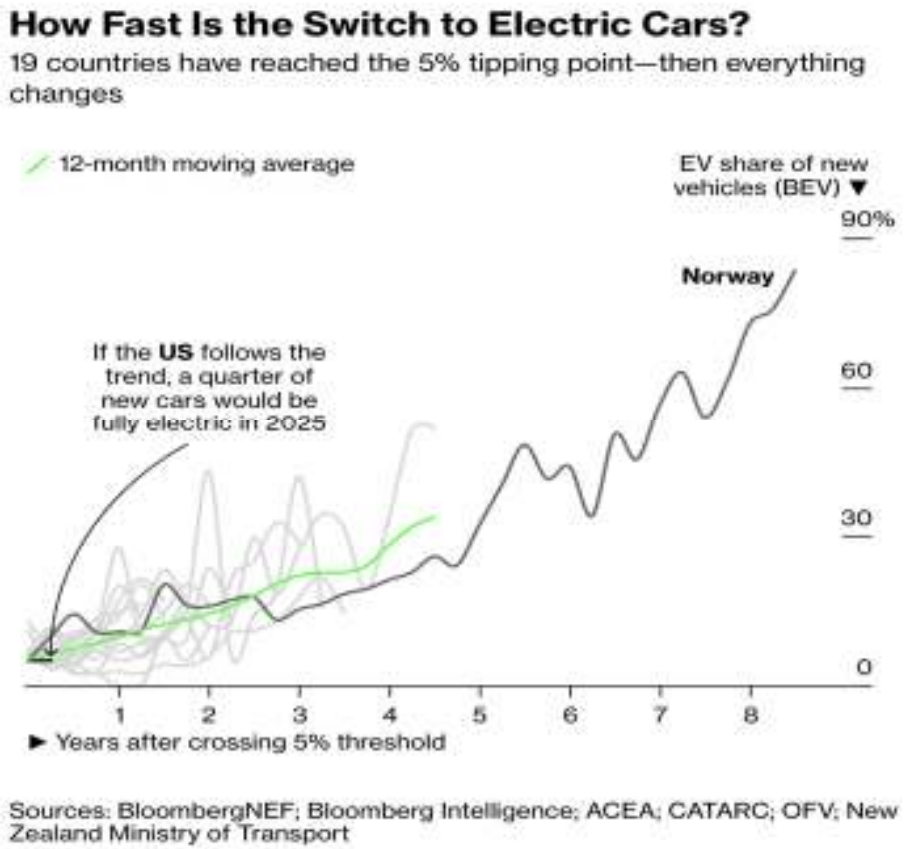
https://piedmontlithium.com/piedmont-completes-bankable-feasiblity-study-of-the-carolina-lithium-project-with-positive-

Where They're Being Sold



https://www.axios.com/2022/08/01/states-ev-electric-cars?utm_medium=email

Does 5% Herald a Switch



https://www.bloomberg.com/news/articles/2022-07-09/us-electric-car-sales-reach-key-milestone?sref=xfyiavTX

Fleets: Companies Are Beginning to Make the Commitments

https://ngtnews.com/sysco-set-to-purchase-close-to-800-freightliner-ecascadias-from-daimler

USPS Just Upped Its First Order to 25K: Commits to 40% of New Purchases

https://electrek.co/2022/03/25/usps-doubles-order-electric-vehicles-but-buying-inefficient-gas-trucks/

Municipalities Committing as Well: Transit Buses

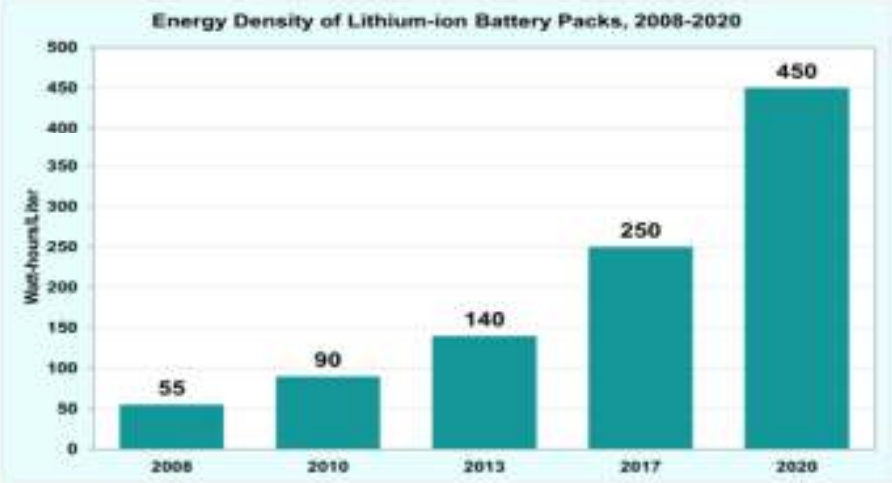
https://www.electrive.com/2022/06/23/wireless-chargers-help-to-halve-operating-costs-for-link-transit/

When Has Garbage Hauling Ever Looked This Good?

Batteries Become More Powerful/Energy Dense

Volumetric Energy Density of Lithium-ion Batteries Increased by More than Eight Times Between 2008 and 2020

Volumetric energy density refers to the amount of energy that can be contained within a given volume. Increasing the volumetric energy density of batteries allows electric vehicles (EVs) to travel further without increasing the size of the battery pack. Conversely, it can allow an EV to travel the same distance with a smaller battery pack, thus saving space, weight, and manufacturing costs. Given the enormous benefit of increasing the energy density of batteries for EVs, there has been heavy investment in battery development by the Department of Energy and private industry that has yielded impressive gains. In 2008, lithium-ion batteries had a volumetric energy density of 55 watt-hours per liter; by 2020, that had increased to 450 watt-hours per liter.



Source: Nitin Muralidharan, Ethan C. Self, Marm Dixit, Zhija Du, Rachid Essehli, Ruhul Amin, Jagjit Nanda, Ilias Belharouak, Advanced Energy Materials, *Next-Generation Cobalt-Free Cathodes – A Prospective Solution to the Battery Industry's Cobalt Problem*, January 2022.

https://www.energy.gov/eere/vehicles/articles/fotw-1234-april-18-2022-volumetric-energy-density-lithium-ion-batteries

The Trajectory Is Clear

Nissan LEAF Passenger EV	**2010** **24 kWh**
	2016 **30 kWh**
	2018 **40 kWh**
	2019 **62 kWh**
Rivian R1T Electric Pickup Truck	**2020 onward** **105 – 180 kWh**

Projected increase in battery size from 2010 to 2020 onward

Enel X 2022 Smart-EV-Load-Management-eBook.pdf

Range Has Increased Significantly in Recent Years

https://www.energy.gov/eere/vehicles/articles/fotw-1220-january-10-2022-model-year-2021-electric-vehicle-longest-range

Wireless Charging Allows for Faster/Shorter “Sips” and Longer Operating Hours

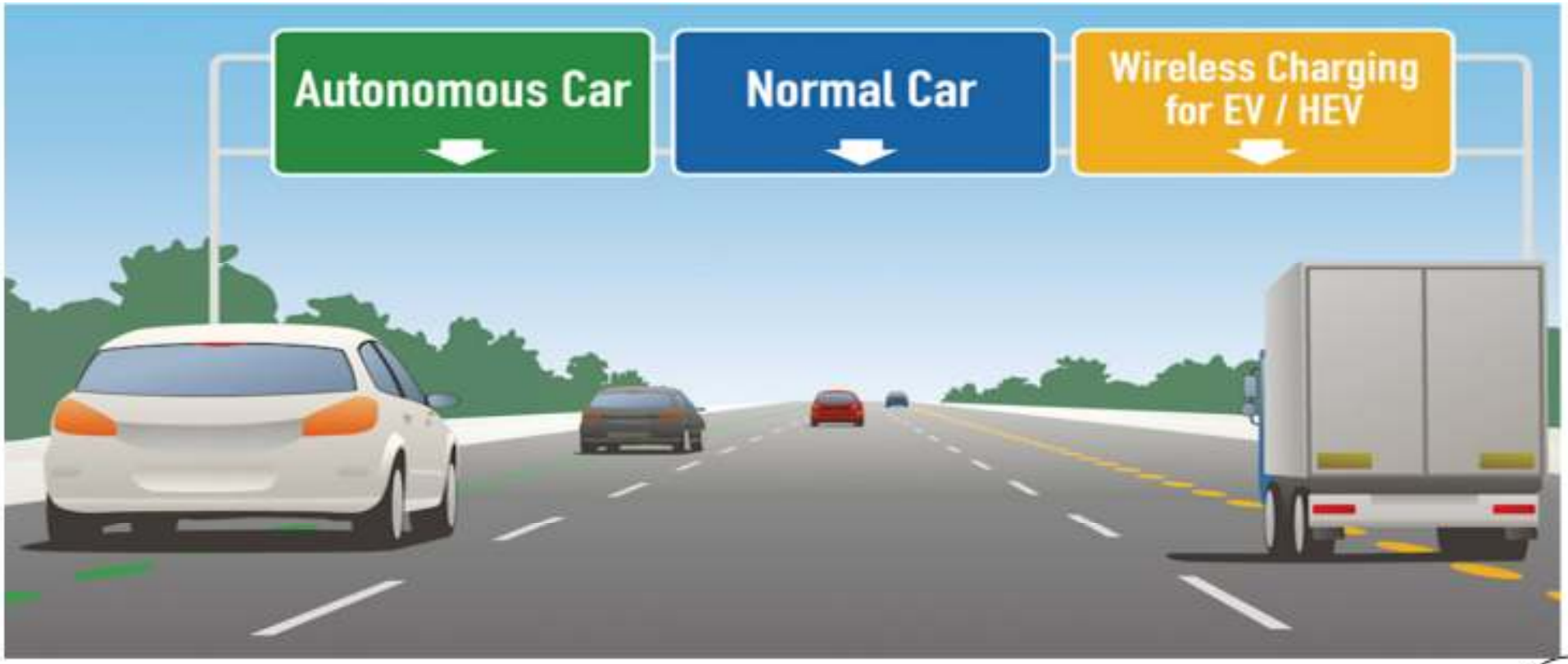
MARKETS > AUTOMOTIVE

Wireless Charging for EV Taxis Launches in Gothenburg

April 8, 2022

https://www.electronicdesign.com/markets/automotive/article/21237878/electronic-design-wireless-charging-for-ev-taxis-launches-in-gothenburg

A Future Scenario From Australia

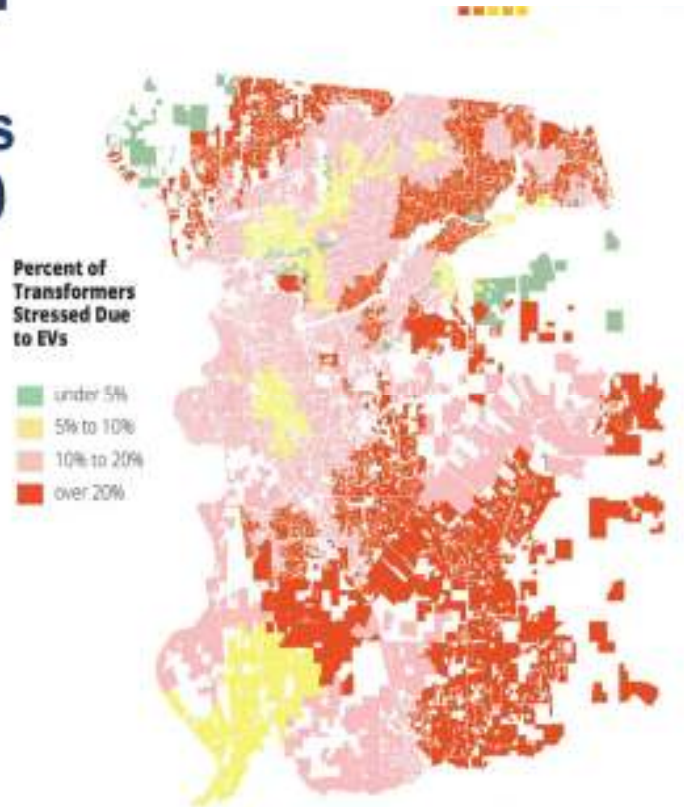


https://www.drive.com.au/news/wireless-electric-car-charging/

The Impact on Some Utilities Will be Significant

EV Impact on SMUD Transformers through 2030

- Under current assumptions, distribution impacts could cost *$50M to $100M+* to address
- Potential mitigation solutions include EV managed charging

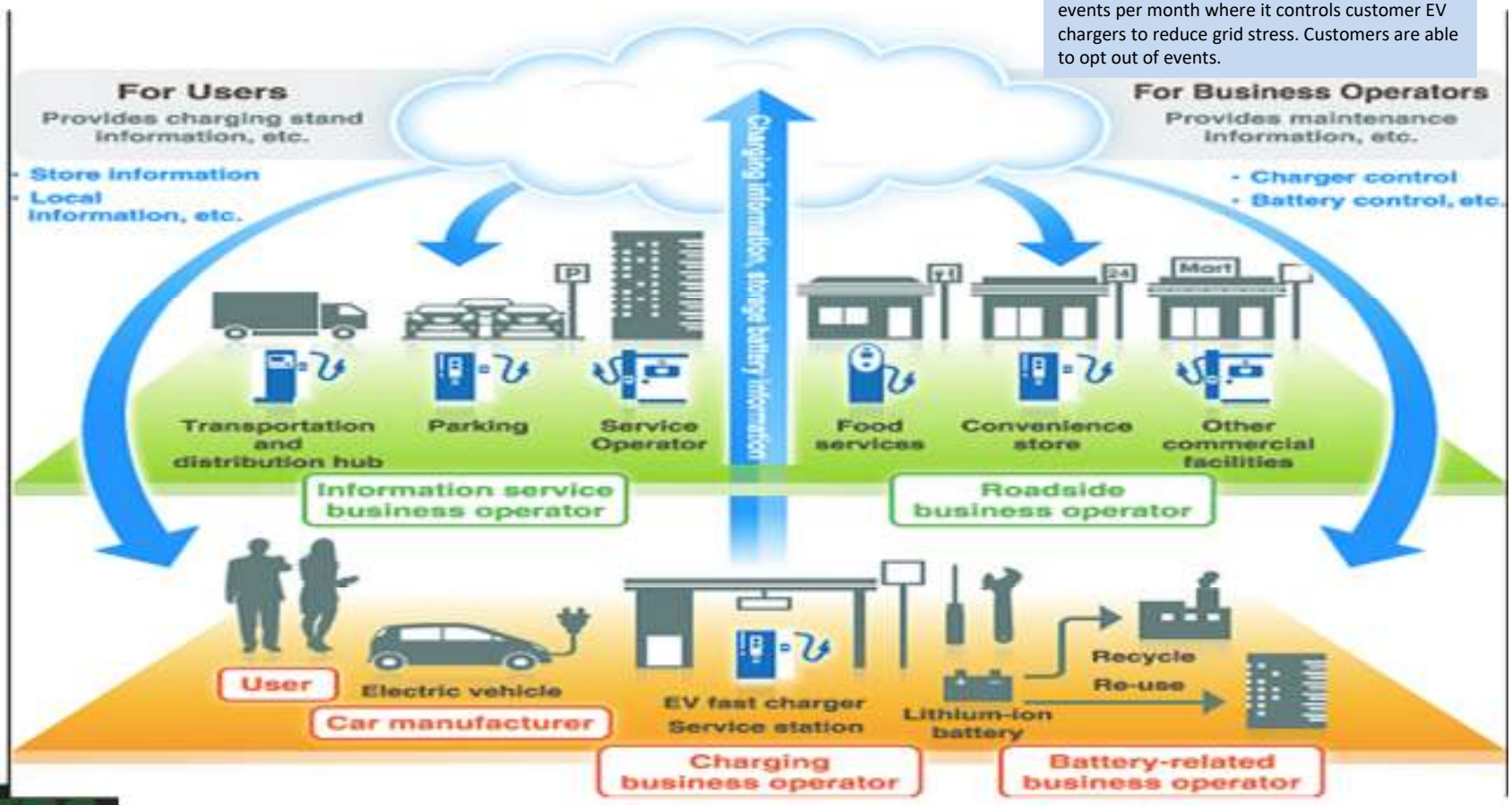


Source: Smart Electric Power Alliance, Black & Veatch, and SMUD, 2017
www.sepapower.org

https://www.peakload.org/assets/36thConf/A1.SEPA&NVENERGY-%20Managed%20Electric%20Vehicle%20Charging.pdf

Smart Charging: Early Stage - Mostly Uni-Directional

In the first year of its Connecticut program, Avangrid could call up to 15 demand response events per month where it controls customer EV chargers to reduce grid stress. Customers are able to opt out of events.



But Bi-Directional Will Arrive Quickly

155 kWh batteries – can be aggregated and deployed for back-up power or to sell grid services

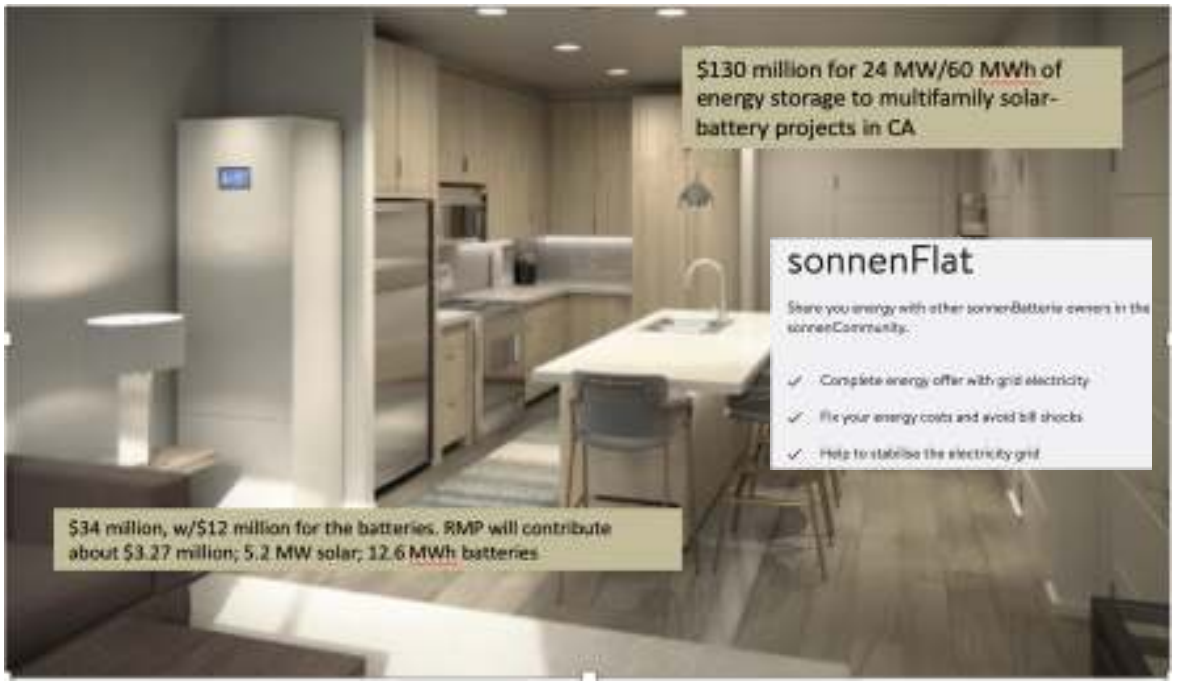
2 buses; 7 MWh

Montgomery County, MD – 326, w/ 1st 25 for 2021/22; Con Edison 5; CPower/Amply/Logan Bus for NYC DOE

One Nissan Leaf Earned $4,200 Summer 2021 in V2X

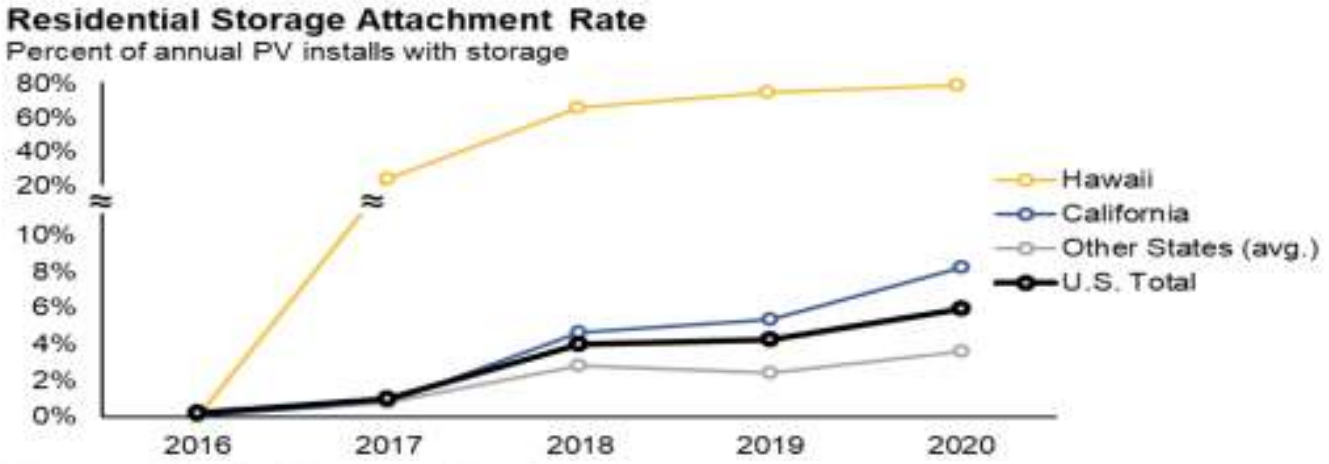
https://chargedevs.com/newswire/nissan-leaf-earns-4200-in-fermata-energy-v2x-pilot/

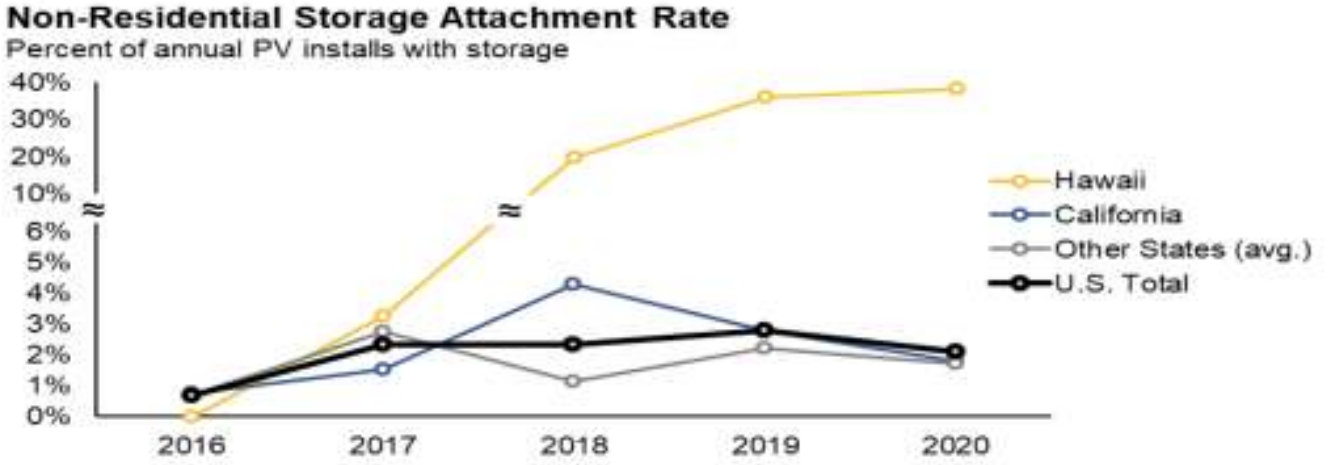
New Models Emerge at the Grid Edge



https://sonnen.com.au/sonnenflat/

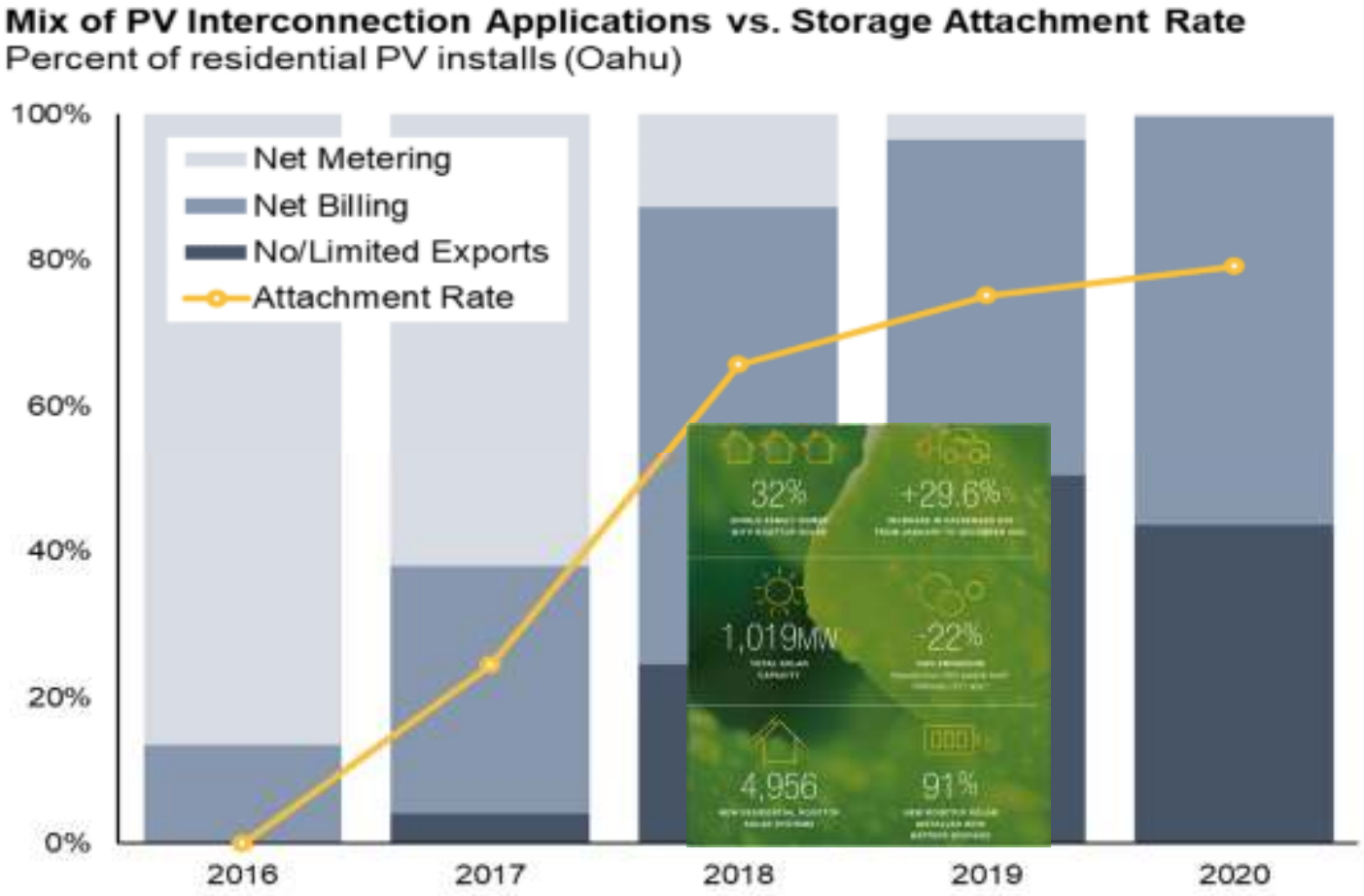
On-Site (Residential & Commercial Hybrids)





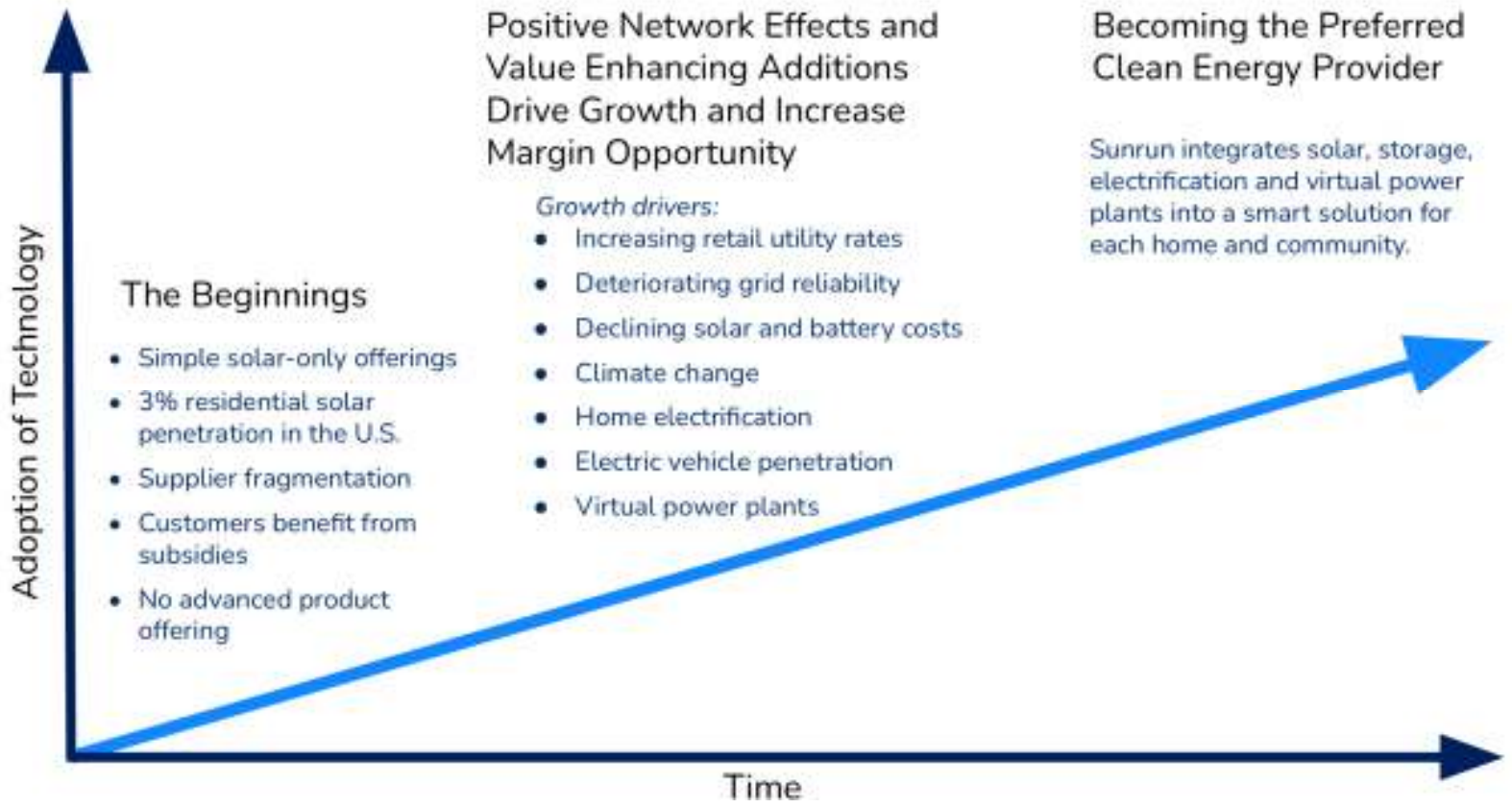
https://eta-publications.lbl.gov/sites/default/files/btm_solarstorage_trends_final.pdf

Hawaii: The Postcard from Tomorrow?



https://eta-publications.lbl.gov/sites/default/files/btm_solarstorage_trends_final.pdf

SunRun's View of the Migration Path



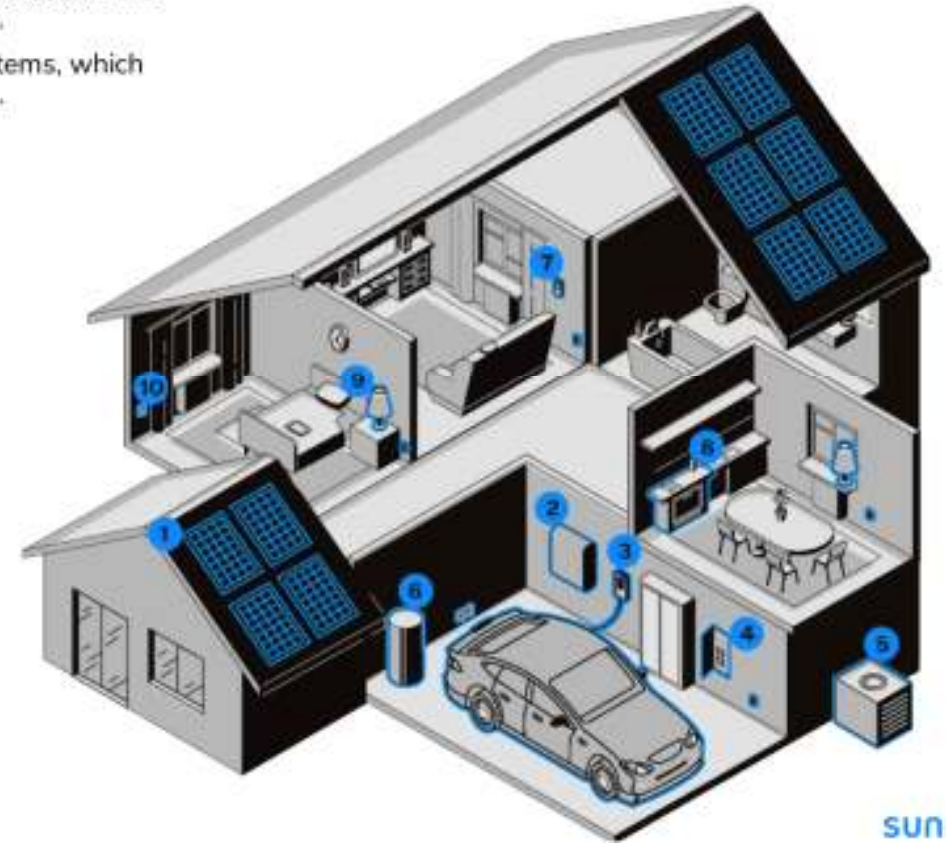
https://d1io3yog0oux5.cloudfront.net/_e650fb85155475e8405e68705dcb1b4b/sunrun/db/276/2243/pdf/Sunrun+Investor+Presentation+-+August+2022.pdf

What An Integrated Home Looks Like

Sunrun's High Performance Home Vision

- Full home electrification enables decarbonization and increases the need for a service provider.
- More fuel switching results in larger systems, which have high incremental returns to Sunrun.

1. Rooftop Solar Power
2. Batteries
3. Electric Vehicle Charger
4. Smart Circuits
5. Heat pump heating & cooling
6. Heat pump water heater
7. Smart thermostat
8. Induction cooktop
9. Smart bulbs
10. Smart plugs

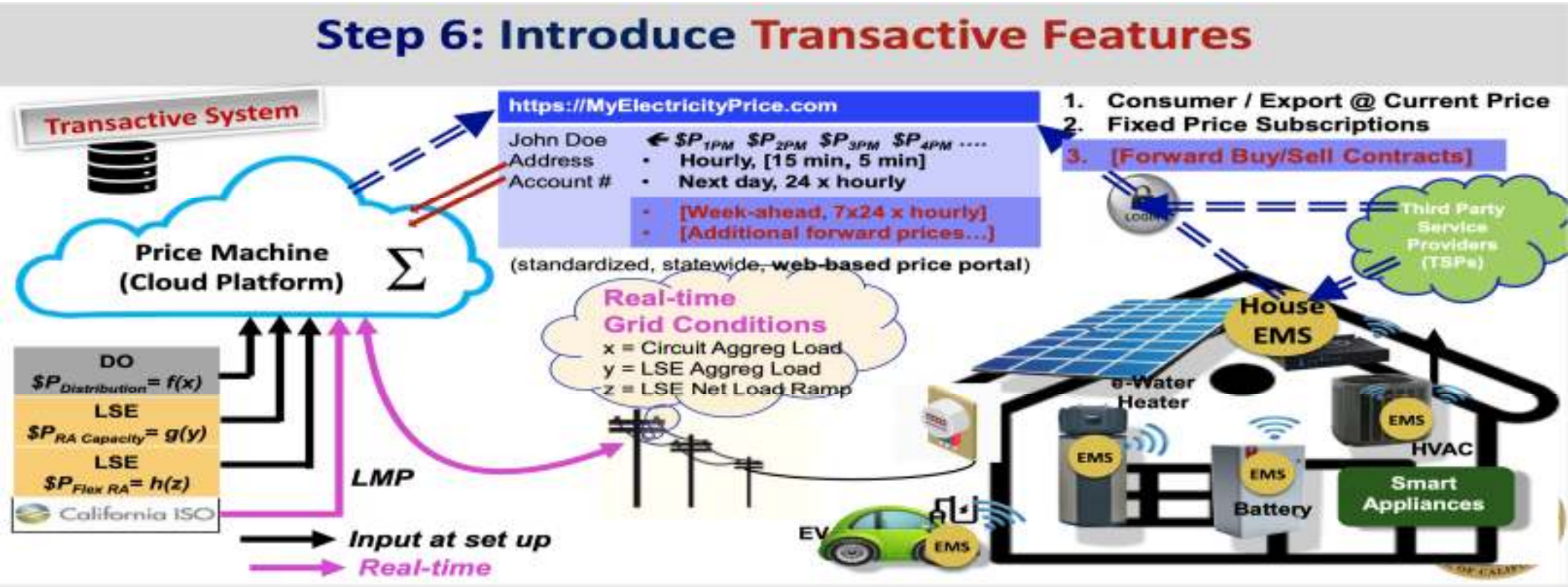


https://d1io3yog0oux5.cloudfront.net/_e650fb85155475e8405e68705dcb1b4b/sunrun/db/276/2243/pdf/Sunrun+Investor+Presentation+-+August+2022.pdf

Coming to You in 2023

https://d1io3yog0oux5.cloudfront.net/_e650fb85155475e8405e68705dcb1b4b/sunrun/db/276/2243/pdf/Sunrun+Investor+Presentation+-+August+2022.pdf

What Might This Eventually Mean for the Customer?



A Possible Future ‘Plug and Play’ Approach

Figure 13 Smart Grid Contracts

The Coordination Challenge w/Competitive Markets

Lack of Visibility, Situational Awareness and Control

GRIDWORKS

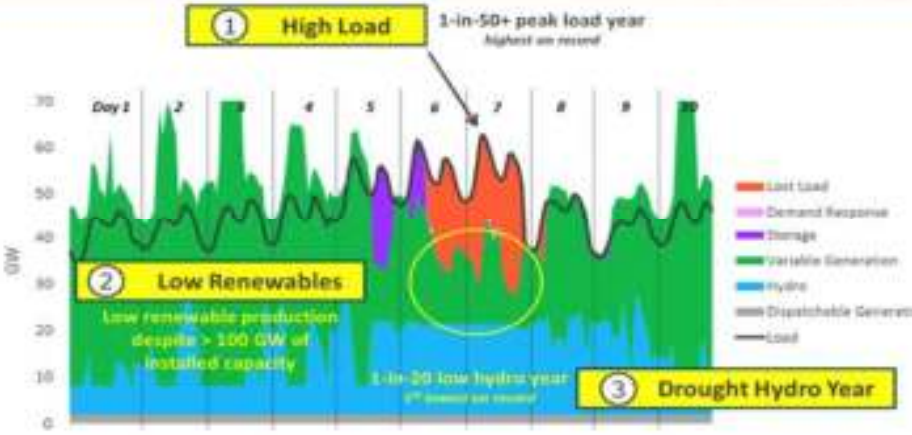
- DO and the ISO do not have visibility and situational awareness about location, status and output of DERs
- DER Operator does not have visibility into distribution system to ensure exported energy is feasible and deliverable
- DO need better visibility into own distribution systems
  - Predict DER behavior
  - Real time DER response
  - Forecast DERs' impacts on grid

https://pubs.naruc.org/pub/67F0F5A8-F49D-9E86-FD4D-EDDE825B007E

The Resource Adequacy Challenge – The Reliability Planning Dynamic Shifts

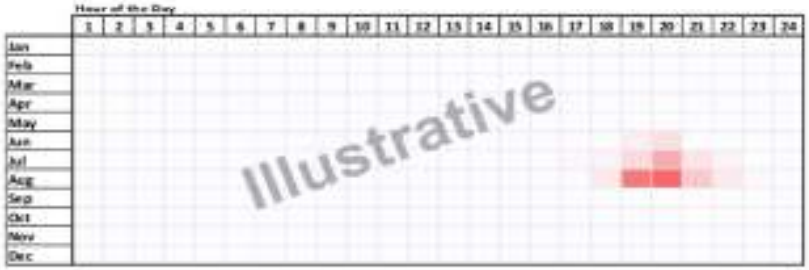
The nature of the resource adequacy challenge is changing

- **Resource adequacy is a measure of the ability of the bulk grid (generation) to meet a reliability standard across a wide range of system conditions**
  - NY uses a 0.1 day / year standard
- **As renewable penetration grows, planning problems shift from traditional need to meet peak demand hours (e.g., summer) to new questions of meeting net demand (e.g., over multi-day low renewable events)**
  - The timing of these needs will change
    - From summer gross peak to winter net peak
    - To account for unexpected high load and low renewable output during planned outages in the shoulder months
- **This new planning problem highlights the need to assess reliability in a time-sequential way over full spectrum of system conditions**



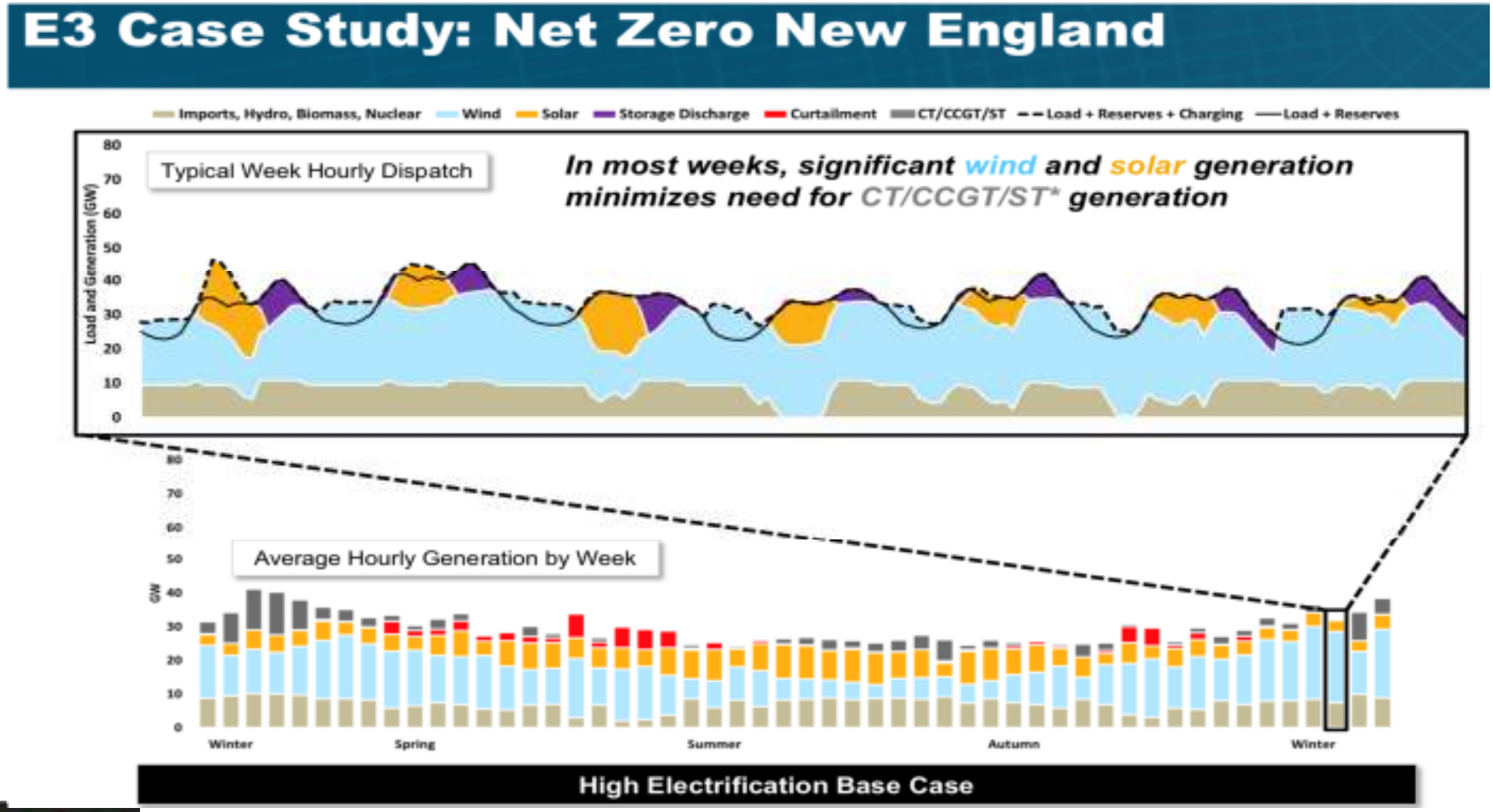
Loss of Load Probability Table

Identifies the probability of each hour to be deficient



https://www.nyiso.com/documents/20142/24172725/NYISO%20ELCC_210820_August%2030%20Presentation.pdf

Most of the Time, You're OK (and Dispatchable Resources Struggle)



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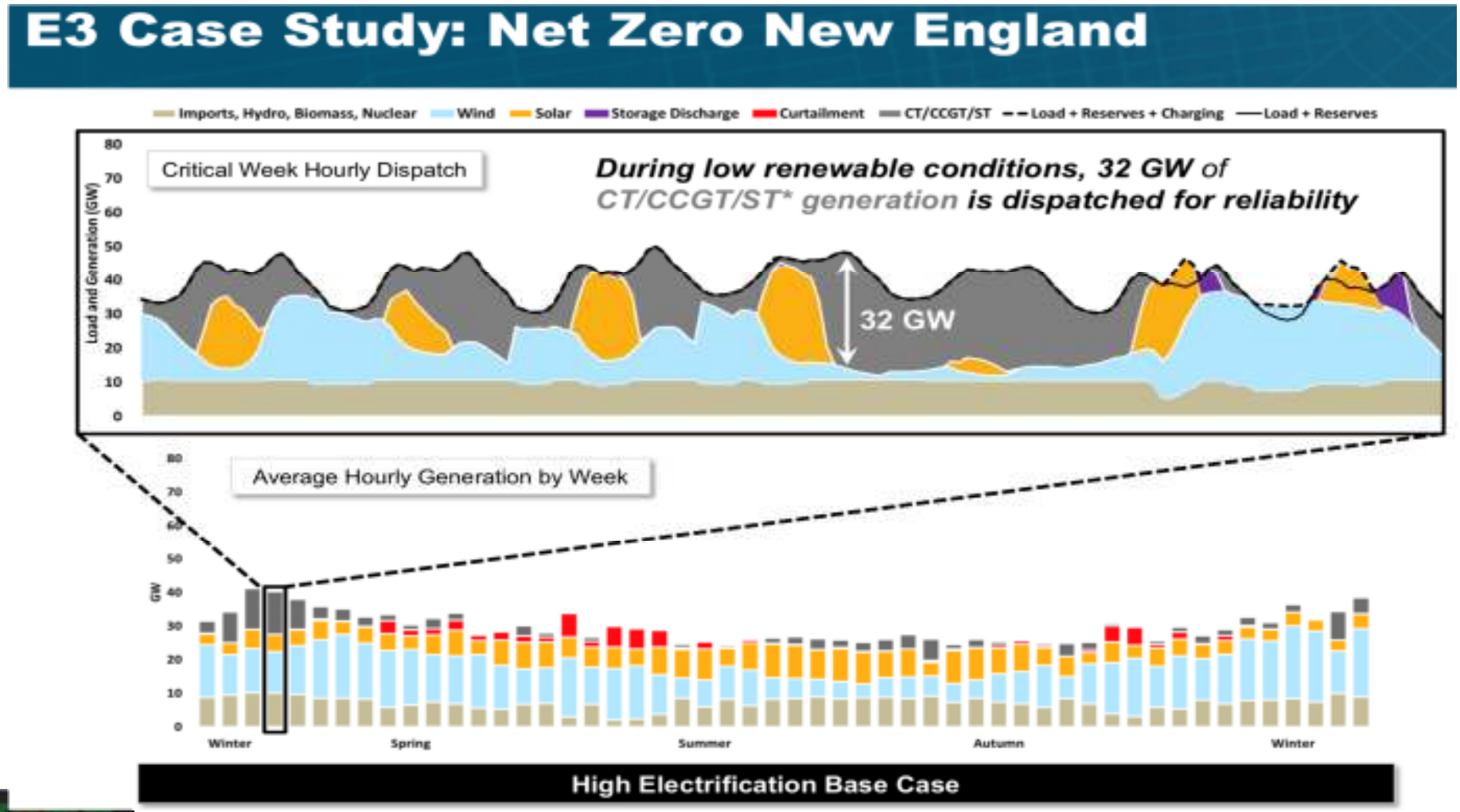
But Then There are Those Days…The Resources MUST Show Up



https://www.nyiso.com/documents/20142/24172725/NYISO%20ELCC_210820_August%2030%20Presentation.pdf

We Can’t Not Make Decisions, But We Can Strive to Preserve As Much Optionality as Possible