

**BEFORE THE NEW MEXICO PUBLIC REGULATION COMMISSION**

**IN THE MATTER OF PUBLIC SERVICE )  
COMPANY OF NEW MEXICO'S )  
CONSOLIDATED APPLICATION FOR )  
APPROVALS FOR THE ABANDONMENT, )  
FINANCING, AND RESOURCE REPLACEMENT )  
FOR SAN JUAN GENERATING STATION )  
PURSUANT TO THE ENERGY TRANSITION ACT )**

**Case No. 19-00195-UT**

**REBUTTAL TESTIMONY**

**OF**

**WILLIAM KEMP**

**January 13, 2020**

**NMPRC CASE NO. 19-00195-UT  
INDEX TO THE REBUTTAL TESTIMONY OF  
WILLIAM KEMP**

**WITNESS FOR  
PUBLIC SERVICE COMPANY OF NEW MEXICO**

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PNM Exhibit WK-1 (Rebuttal)	Sandia National Laboratory Briefing on Energy Storage Systems
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PNM Exhibit WK-2 (Rebuttal)	Sandia National Laboratory Workshop on Energy Storage Policy
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AFFIDAVIT

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**I. INTRODUCTION**

1

2 **Q. PLEASE STATE YOUR NAME AND POSITION.**

3 **A.** My name is William J. Kemp. Since the beginning of this proceeding, I and the  
4 rest of the Enovation Partners, LLC leadership team have moved to Roland Berger  
5 LP (“Roland Berger”). Roland Berger is one of the top five largest global strategy  
6 consulting firms. I am now a Director there. Roland Berger is continuing the  
7 expert witness services provided by Enovation Partners, LLC to PNM Resources  
8 (“PNM”).

9

10 **Q. HAVE YOU PREVIOUSLY FILED TESTIMONY IN THIS PROCEEDING?**

11 **A.** Yes. I filed direct testimony in this proceeding on July 1, 2019.

12

13 **Q. WHAT IS THE PURPOSE OF YOUR REBUTTAL TESTIMONY IN THIS**  
14 **PROCEEDING?**

15 **A.** The purpose of my rebuttal testimony is to respond to various substantive issues  
16 raised by intervenors and staff in their testimonies filed on December 13, 2019. I  
17 have limited this rebuttal testimony to the major substantive issues most deserving  
18 of response. My decision not to rebut particular portions of intervenor or staff  
19 testimony should not be interpreted as an admission of fact or opinion.

20

21 For economy of presentation, my rebuttal testimony is organized around issues  
22 rather than particular intervenor or staff testimonies. Many of them raise similar

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1 issues. I will of course refer to specific pieces of intervenor or staff testimony  
2 when summarizing their positions.

3  
4 My rebuttal testimony generally is based on my industry perspective on how  
5 battery and other energy storage technologies initially should be integrated into an  
6 electricity system such as that of PNM, while giving due consideration to the  
7 desired longer-term energy supply/demand mix.

8  
9 More specifically, I will address the following issues in rebuttal:

- 10 1. Is PNM's proposal to limit the project size and total volume of storage  
11 resources in the first phase of its storage procurement prudent, cost-  
12 effective and aligned with New Mexico's 2045 goals for 100% carbon-free  
13 electricity?
- 14 2. Does a measured and balanced storage procurement strategy provide  
15 substantial benefits to PNM customers?
- 16 3. Are there compelling reasons to favor utility ownership of a substantial  
17 portion of storage resources?
- 18 4. Is a "No New Gas" strategy appropriate for PNM at this time?

19  
20 In addressing these issues, my rebuttal testimony will respond to the testimonies  
21 filed by the following intervenors:

- 22 • Sierra Club: Michael Goggin  
23 • Concerned Citizens for Affordable Energy (CCAEE): Mihir Desu

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- 1                   • Southwest Generation Operating Company (SWG): William Babcock  
2                   • New Energy Economy (NEE): Dahr Jamail

3

4 **Q.     COULD YOU PLEASE SUMMARIZE YOUR CONCLUSIONS?**

5 **A.**     My conclusions are as follows:

6           1. *Is PNM's proposal to limit the project size and total volume of battery storage*  
7           *resources in the initial phase of its storage procurement prudent, cost-effective*  
8           *and aligned with New Mexico's 2045 goals for 100% carbon-free electricity?*

9           Yes. The proposed initial battery storage levels defined by PNM are  
10          reasonable and prudent for a utility of its size and level of storage experience.  
11          The resulting storage portfolio and project sizes, in relation to the size of  
12          PNM's system, are on the upper end of what other U.S. utilities are pursuing.  
13          PNM expects to add substantially more storage to its system in future resource  
14          procurements.

15          2. *Does a measured and balanced approach to storage procurement strategy*  
16          *provide substantial benefits to PNM customers?*

17          Yes. Procuring storage resources as needed will enable PNM to take  
18          advantage of expected future improvements in storage costs, performance and  
19          safety, and to better match its choice of storage technologies with its emerging  
20          future needs as its resource portfolio evolves. It is prudent to "keep some  
21          powder dry" for future procurements.

22          3. *Are there compelling reasons to favor utility ownership of a substantial portion*  
23          *of storage resources?*

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1 Yes. PNM ownership of a substantial portion of the storage resources on its  
2 system will enable it to learn more quickly how to optimize storage operations  
3 and siting, as well as capture the full value of the multiple uses of storage, with  
4 the attendant benefits for customers.

5 4. *Is a "No New Gas" strategy appropriate for PNM at this time?*

6 No. A flexible multi-unit plant like Piñon will be an inexpensive reliability  
7 insurance policy to smooth the transition of PNM's grid to net zero carbon. Its  
8 carbon footprint through 2040 will be small, and it could continue to play a  
9 reliability-enhancing role even in a zero-carbon grid after 2040 through  
10 burning biogas or hydrogen.

11  
12 **II. PROPOSED INITIAL STORAGE PORTFOLIO AND PROJECT SIZE**

13 **Q. DO YOU AGREE WITH SIERRA CLUB WITNESS GOGGIN'S CLAIM**  
14 **THAT PNM'S PROPOSED LEVELS OF STORAGE IN THE INITIAL**  
15 **INTEGRATION OF BATTERIES INTO ITS SYSTEM ARE ARBITRARY**  
16 **AND BASED SOLELY ON ANECDOTAL INFORMATION? (GOGGIN,**  
17 **PAGES 3 AND 55)**

18 **A.** No. The initial levels of storage procurement are not arbitrary. As explained in my  
19 direct testimony, the recommended project sizes are in line with the largest energy  
20 storage system currently installed on U.S. electric grids today.

21

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1 Nor are my recommendations based solely on anecdotal information. My firm has  
2 very substantial experience in advising utility clients on storage technologies,  
3 strategies and procurement. We are also management consultants, so we consider  
4 both quantitative and qualitative information in advising our clients on the best  
5 path forward, which typically is a more complex decision than solely following the  
6 results of a resource planning modeling analysis. In this case, we considered such  
7 factors as the underlying technology drivers, the experience of other utilities, and  
8 the experience and capabilities of PNM. PNM is a relatively small investor-owned  
9 utility operating in a state with no experience in large, let alone very large, energy  
10 storage projects.

11  
12 **Q. DO YOU AGREE WITH THE ASSERTIONS OF SIERRA CLUB WITNESS**  
13 **GOGGIN (PAGES 49-62), CCAE WITNESS DESU (PAGES 31-46), AND**  
14 **SWG WITNESS BABCOCK (PAGES 51-55) THAT PNM'S PROPOSAL**  
15 **WOULD LIMIT THE SIZE AND AMOUNT OF BATTERIES OVER THE**  
16 **LONG TERM AND IMPOSE LARGE COSTS ON CUSTOMERS**  
17 **WITHOUT BENEFIT?**

18 **A.** No. Like a number of intervenor witnesses, Messrs. Goggin, Desu and Babcock  
19 are setting up a straw man that does not reflect PNM's actual position. As stated  
20 clearly in my direct testimony and in several interrogatory responses<sup>1</sup>, the 40 MW  
21 limit on individual storage project size and 130 MW limit on storage portfolio size

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<sup>1</sup> E.g., PNM responses to NEE Interrogatory 2-9, Sierra Club Interrogatories 1-8 and 1-9

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1 apply only to the initial storage procurement associated with San Jan replacement  
2 resources, i.e. for replacement resources beginning operations by 2023. PNM is  
3 not proposing to make these limits permanent.

4  
5 As discussed in the rebuttal testimonies of PNM witnesses Fallgren, Phillips and  
6 Dorris, PNM expects that substantially more storage capacity (not necessarily all  
7 batteries or all lithium ion) will be added in the medium and long term to meet  
8 resource needs for load growth or replacement of other existing generation  
9 resources to meet ETA goals. The decisions on storage project size, cumulative  
10 portfolio size, technology and location will be made, as they should be, in the  
11 context of those future resource procurement processes.

12  
13 **Q. DO YOU SEE LARGE GAPS BETWEEN THE POSITIONS OF PNM,**  
14 **SIERRA CLUB, CCAE AND SWG ON THE TIMING AND SCOPE OF**  
15 **STORAGE PROCUREMENTS, GIVEN PNM'S CLARIFICATION OF ITS**  
16 **POSITION ON THE LONG-TERM ROLE OF STORAGE?**

17 **A.** Not over the longer term. Those parties are looking at similar sets of facts  
18 regarding PNM's resource options to meet the ETA's requirements, although some  
19 of their more granular assumptions might differ. Since utilities carry the heavier  
20 burden of meeting regulatory requirements regarding system reliability, by nature  
21 they are prone to take a more measured approach. They want to make sure the  
22 lights stay on. It is prudent to apply sensible parameters for size and amounts of

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1 storage when adding utility-scale batteries at multiple locations to PNM's system  
2 for the first time.

3

4 **Q. DO YOU AGREE WITH THE ASSERTION OF CCAE WITNESS**  
5 **SOMMMER (PAGES 2-3) THAT PNM PLACED UNREASONABLE**  
6 **LIMITS ON BATTERY STORAGE IN DEVELOPING ITS**  
7 **REPLACEMENT PORTFOLIO?**

8 **A.** No. For the reasons discussed above, there are good reasons to limit the size of its  
9 initial storage procurement.

10

11 **Q. DO YOU AGREE WITH THE CONCLUSIONS DRAWN BY CCAE**  
12 **WITNESSES DESU (PAGES 14-21) AND SIERRA CLUB WITNESS**  
13 **GOGGIN (PAGES 58-63) FROM THEIR REVIEWS OF ANNOUNCED**  
14 **BATTERY STORAGE PROGRAMS AT OTHER U.S. UTILITIES?**

15 **A.** No. In his critique of PNM's approach, Desu inappropriately relies on examples  
16 from other states regarding limits on battery portfolio size. Many of the examples  
17 he includes from states such as California, New York and Massachusetts are the  
18 result of concerted public policy mandates alongside foundational energy storage  
19 studies. New York, for example, has a mandate to deploy up to 3.0 GW of energy  
20 storage by 2030 with a near-term goal of 1.5 GW by 2025. Massachusetts has a  
21 different goal – 200 MWh by 2020 – while California has a statewide mandate to  
22 install 1.825 GW by 2024.

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1 New York, with its Energy Storage Roadmap<sup>2</sup>, and Massachusetts, with its State of  
2 Charge<sup>3</sup> Report, also conducted intensive analyses with stakeholder input to  
3 evaluate the optimal amount, location and timing of energy storage resources in  
4 their respective states.

5  
6 A mandate has not yet been deemed appropriate for New Mexico. The energy  
7 storage industry lobbied aggressively for New Mexico to set an energy storage  
8 mandate or target in 2017, but the Commission declined to do so, saying "The  
9 record only demonstrates one public utility in the State of New Mexico has one  
10 energy storage facility. For that reason, at this time there is not an adequate record  
11 on which to base benchmarks or targets even though targets or benchmarks may in  
12 the future be determined to be in the public interest..."<sup>4</sup> This precedent aligns with  
13 PNM's more measured approach as demonstrated by the proposed portfolio in this  
14 docket. Further, it points to a more systematic approach for all of the state's  
15 utilities, rather than an immediate "all in" requirement for a single utility.

16  
17 The above comments also apply to Goggin's examples of utility "plans" in New  
18 York and Arizona. (pages 58 to 59). PNM operates in New Mexico, a state with no  
19 significant experience with utility-scale storage. In fact, it could be interpreted that  
20 the state, when it did not set a mandate in 2017, was looking to each utility to

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<sup>2</sup> <https://www.nysedra.ny.gov/All-Programs/Programs/Energy-Storage>

<sup>3</sup> <https://www.mass.gov/files/2017-07/state-of-charge-report.pdf>

<sup>4</sup> Final Order Amending Integrated Resource Planning Rules 17.7.3 NMAC to Include Energy Storage Resources. Docket 17-00022-UT, at 25.

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1 proceed deliberately in the early stages of its storage procurement. This more  
2 measured approach also comports with the Energy Transition Act's requirement to  
3 demonstrate consistent progress over time towards the 2045 100% zero carbon  
4 mandate.

5  
6 **Q. CAN YOU CITE EXAMPLES OF WHAT OTHER UTILITIES ARE**  
7 **PLANNING FOR BATTERY STORAGE IN TERMS OF PERCENTAGE**  
8 **OF SYSTEM PEAK DEMAND, AND COMPARE THOSE EXAMPLES TO**  
9 **WHERE PNM'S PROPOSAL FALLS?**

10 **A.** Yes. As shown in PNM Table WK-1 of my direct testimony, Pacific Gas and  
11 Electric has the largest current penetration of battery storage in operation or under  
12 active development, with total battery storage (operating or development) equal to  
13 2.6% of peak demand, compared to the 5 percent of peak demand in PNM's  
14 proposal for initial battery deployment. Several other states and individual utilities  
15 have announced future storage targets, which are summarized below. As shown  
16 below in PNM Table WK-1 (Rebuttal), PNM's proposal for 5% as an appropriate  
17 initial storage portfolio size, as a percentage of its system peak demand, is within  
18 the range of state-level penetration targets, even among states with much more  
19 experience in storage<sup>5</sup>. At the utility level, utilities with targeted storage  
20 penetration levels above 5 percent of peak demand generally have more direct

---

<sup>5</sup> As noted in the rebuttal testimony of PNM Witness Fallgren, PNM's proposed initial portfolio size is actually over 6 percent when calculated on an apples-to-apples basis with other utilities, i.e., as a percentage of utility retail peak demand rather than balancing area peak demand.

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1 experience with storage or are guided by significant state level analysis of the  
2 impact of battery additions to their grid.

3

4

5

**PNM Table WK-1 (Rebuttal)  
State and Utility Storage Penetration Targets**

**State Targets**

State	Target (MW)	IOU 2018 Peak Load (MW)	Target (% of IOU Peak)	Target Date
NY	3,000	34,673	8.7%	2030
NY	1,500	34,673	4.3%	2025
NJ	2,000	12,428	16.1%	2030
NJ	600	12,428	4.8%	2021
CA	1,825	45,202	4.0%	2020
MA	50 (200MWh)	4,693	1.1%	2020

**Utility Targets**

Utility	Target (MW)	IOU 2018 Peak Load (MW)	Target (% of IOU Peak)	Target Date
PNM	130	1,956	6.6%	2023
APS	850	7,253	11.7%	2025
NV Energy	590	7,831	7.5%	2023
Pacificorp	1,407	10,551	13.3%	2036-2038
Xcel (CO)	275	6,649	4.1%	2025
Consumers Energy	450	7,513	6.0%	2040

6

7 **Q. BASED ON THE TARGETS SET BY THE STATES CITED IN PNM**  
8 **TABLE WK-1 (REBUTTAL) DO YOU HAVE ANY OBSERVATIONS?**

9 **A.** Yes. We notice that with both NY and NJ, there are near-term and longer-term  
10 goals. The near-term goals for both states are less than 5% of the aggregate IOU  
11 peak retail load, less than the initial target of PNM which on an apple-to-apples

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1 basis<sup>6</sup> is 6.6% of peak retail load. California, widely seen as a leader in the  
2 transition to zero carbon at the state level has only set a relatively modest target of  
3 4% of the IOU retail peak load, significantly less than the PNM target of 6.6% of  
4 retail peak load. Finally, Massachusetts, even with its groundbreaking State of  
5 Charge report has set a very modest target of 1.1% of IOU retail peak load relative  
6 to the initial target set by PNM.

7  
8 **Q. PLEASE COMMENT ON OTHER RELEVANT CONSIDERATIONS**  
9 **AROUND THE COMPARABILITY OF PNM'S INITIAL BATTERY**  
10 **STORAGE PENETRATION GOAL WITH STORAGE PENETRATION**  
11 **GOALS OF OTHER UTILITIES.**

12 **A.** Both Pacificorp and Consumers Power have set very long-term energy storage  
13 goals in the context of their IRP processes. In both IRPs, storage is not installed in  
14 significant amounts until the end of the 2020s and well into the 2030s. By  
15 comparison, PNM is installing a significant amount of storage in the next 2-3  
16 years. The remaining utilities (Xcel, APS and NV Energy) all have goals prior to  
17 2025. PNM falls in the middle of the range of these goals with its 6.6% initial  
18 target.

19  
20 **Q. IN A SIMILAR VEIN, DO YOU AGREE WITH THE CONCLUSIONS**  
21 **DRAWN BY SERRA CLUB WITNESS GOGGIN (PAGES 52-58) AND**

---

<sup>6</sup> I.e. percentage of system retail peak demand rather than and percentage of larger balancing area peak demand

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1           **CCAЕ WITNESS DESU (PAGES 14-21) FROM THEIR REVIEWS OF THE**  
2           **LARGEST INDIVIDUAL BATTERY STORAGE PROJECTS**  
3           **ANNOUNCED BY OTHER U.S. UTILITIES?**

4    **A.**    No. Goggin brings forward eleven examples of large planned and not yet built  
5           battery energy storage projects (“BESS”). Seven of those eleven projects are in  
6           New York or California, states where utilities have significant previous experience  
7           in storage (California utilities) or where there is a strong and specific policy  
8           mandate for storage (New York). Two other examples cited are Western Farmers  
9           Coop in Oklahoma and Salt River Project in Arizona, which have different  
10          governance and financial structures than an investor-owned utility and may not be  
11          a good comparison.

12  
13          One of the remaining two projects is an FPL project in Florida. FPL is one of the  
14          largest utilities in the U.S. and its unregulated arm (NextEra Resources) has  
15          substantial storage experience with at least 140 MW of storage systems in  
16          operation.<sup>7</sup> The last example is an APS/AEP project in Arizona, which I address  
17          below.

18  
19          The relevance of the planned energy storage projects mentioned by Desu can be  
20          rebutted in a similar manner. Of his 11 examples, nine of them are based in states  
21          with storage mandates or goals (California, Massachusetts, New York) or states

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<sup>7</sup> <http://www.nexteraenergy.com/company/work/battery-storage.html>

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1 that have completed an energy storage study (Nevada<sup>8</sup>). As described above,  
2 Massachusetts and New York have also completed state-level energy storage  
3 studies. Desu repeats Goggin's examples of FPL and the Western Farmers Coop,  
4 which I explain more fully above in response to Goggin. Of the six energy storage  
5 projects now in operation with capacity greater than 40 MW, just one is located in  
6 the United States, and that one is based in California, whose policy support of and  
7 experience with energy storage is documented above.

8  
9 **Q. WHEN VIEWED AS A PERCENTAGE OF SYSTEM PEAK DEMAND,**  
10 **HOW DO THE APS AND FPL PROJECTS COMPARE WITH THE 40 MW**  
11 **MAXIMUM STORAGE PROJECT SIZE DEFINED BY PNM?**

12 **A.** For investor-owned utility storage projects outside of states with significant battery  
13 storage experience, i.e., Florida or Arizona, the MW maximum project size defined  
14 by PNM, in proportion to its system peak demand, represents a larger percentage  
15 than the projects referenced by Goggin or Desu. PNM Table WK-2 (Rebuttal)  
16 shows a comparison of the size of the cited individual storage projects as a  
17 percentage of peak demand on the host utility system.

18  

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<sup>8</sup> <https://www.brattle.com/news-and-knowledge/publications/the-economic-potential-for-energy-storage-in-nevada>

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1

**PNM Table WK-2 (Rebuttal)**

<b>Utility</b>	<b>Facility Size (MW)</b>	<b>Peak Demand (2018)<sup>9</sup></b>	<b>Facility Size (% of Peak)</b>
PNM	40	1,956	2.0%
FPL	409	25,173	1.6%
APS	100	7,253	1.4%

2

3 Viewed in this context, the examples cited by Goggin and Desu actually help to  
4 make my point. No storage projects larger than 40 MW or representing more than  
5 2.0% of peak demand in their lists are being procured by a smaller IOU in a U.S.  
6 state with no significant utility-scale storage experience. PNM's proposed initial  
7 levels of storage procurement, viewed either from the portfolio or project  
8 perspective, are substantial for an IOU in its circumstances.

9

10 **Q. DO YOU AGREE WITH SWG WITNESS BABCOCK'S CLAIM THAT**  
11 **PNM'S LEVEL OF INITIAL BATTERY STORAGE PROCUREMENT IS**  
12 **NOT CONSISTENT WITH THE OPTIMAL BATTERY CAPACITY**  
13 **INDICATED BY PNM'S UNCONSTRAINED MODELING?**

14 **A.** No. As discussed by PNM Witness Wintermantel in his rebuttal testimony, PNM's  
15 unconstrained modeling of the optimal battery storage portfolio size indicated an  
16 optimal portfolio only modestly larger than the proposed initial battery storage  
17 level of 130 MW. PNM proposed size and location limits on battery storage to be

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<sup>9</sup> Source: Actual retail peak demands as reported to U.S. EIA

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1           procured as part of this particular replacement portfolio are consistent with the  
2           Brattle Study.

3

4   **Q.   DO YOU AGREE THAT DEFERRING PROCUREMENT OF**  
5   **ADDITIONAL BATTERY STORAGE CAPACITY UNTIL THE NEXT SET**  
6   **OF REPLACEMENT DECISIONS RESULTS IN AN UNREASONABLE**  
7   **TRADE OFF BY ADDING CURRENT NATURAL GAS RESOURCE**  
8   **COSTS, AS CLAIMED BY CCAE WITNESS DESU?**

9   **A.**   My testimony does not address specific resource planning trade-offs between  
10       storage resources and natural gas resources. It focuses on the prudent path forward  
11       for adding whatever storage capacity may be needed, given PNM's proposed  
12       resource portfolio. Those more specific resource planning issues are addressed  
13       primarily by PNM witnesses Fallgren and Phillips. However, I agree that adding  
14       modest amounts of gas-fired generation capacity would increase the operational  
15       flexibility and efficiency of PNM's overall system for meeting its own loads and  
16       participating in future energy markets. It is my understanding that this incremental  
17       gas-fired capacity is expected to operate at a quite low capacity factor, so their  
18       aggregate carbon emissions should not be large. It is also my understanding that  
19       the economics of these natural gas units assumed they would be fully depreciated  
20       by 2040, the time set for PNM to achieve its early goal of a carbon free portfolio.

21

22   **Q.   DO YOU AGREE THAT THERE IS AN OVERLOOKED RISK OF A**  
23   **SIMULTANEOUS LOSS OF NATURAL GAS UNITS THAT CAN BE**

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1       **SOLVED BY ADDING LARGER BATTERY STORAGE SYSTEMS TO**  
2       **PNM'S SYSTEM, AS ASSERTED BY SIERRA CLUB WITNESS GOGGIN**  
3       **(PAGES 41-48)?**

4    **A.**    No, unless cost is no consideration. With existing commercially available storage  
5       technologies, it would be technologically feasible but economically cost-  
6       prohibitive to add enough battery storage to meet PNM's loads through periods of  
7       extended loss of gas supply from pipelines or storage. Such incidents of loss of  
8       gas supply are expected to be quite rare. This is also true of extended periods of  
9       low renewable energy production, which are expected to be less rare. See the  
10      rebuttal testimony of PNM witness Dorris for more details on accounting for  
11      variability in renewable generation. The electricity industry is searching for good  
12      technologies to meet economically this need for long duration storage (days rather  
13      than hours), but there are currently no obvious winners.

14  
15       **III.    BENEFITS OF INCREMENTAL STORAGE PROCUREMENT**

16    **Q.    WHAT ARE SOME OF THE BENEFITS OF A MORE INCREMENTAL,**  
17       **BALANCED APPROACH TO PROCURING STORAGE CAPACITY?**

18    **A.**    This type of approach will enable PNM to:  
19       

- Take advantage of improvements in cost and performance for the whole range

  
20       of energy storage technologies (not just the currently dominant lithium ion  
21       batteries),

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- 1           • Match its highest value use cases for storage (e.g., time shifting of delivery,  
2           reserve, ancillary services, long duration storage) with its updated resource  
3           needs,
- 4           • Incorporate improved safety designs into its storage resources, as the industry  
5           develops and implements stronger standards specifically for utility-scale  
6           battery storage, and
- 7           • Save customers money by not buying too far in advance of need and  
8           technology improvements.

9

10          It makes eminent public policy sense to "keep some (investment) powder dry"  
11          when future needs - and means to meet those needs - are uncertain.

12

13   **Q.    WHAT IMPROVEMENTS IN ENERGY STORAGE TECHNOLOGIES**  
14   **ARE ON THE HORIZON?**

15   **A.**    In addition to the currently dominant lithium ion technologies, a variety of other  
16          energy storage technologies are on the horizon. These include lithium metal,  
17          lithium sulfur, zinc, high temperature, flow batteries and high-power technologies.  
18          While not yet fully commercialized, each technology has different attributes that  
19          may be relevant for stationary storage applications. These attributes include the  
20          number of charge/discharge cycles over the life of the system, the calendar life of  
21          the equipment, energy density, power density, cost and finally relative safety. Grid  
22          planners, operators and developers will need to weigh such factors in deciding the  
23          most appropriate storage technology for a given application.

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1

2 Emerging lithium metal and zinc technologies include solid state battery  
3 technologies that are safer, more durable and longer lasting than existing  
4 technologies on the market today. Other battery technologies not based on lithium  
5 or similar chemistries are set to provide grid planners with options for longer  
6 duration storage over the next decade.<sup>10</sup>

7

8 PNM Figure WK-1 (Rebuttal) shows the "sweet spots," in terms of discharge  
9 duration and size, for some of the major types of storage technologies. Other  
10 technologies are also progressing through various stages of the technology  
11 maturation life cycle. The briefing presented on October 31, 2019, by Howard  
12 Passell of Sandia National Laboratory to New Mexico Public Regulation  
13 Commission ("NMPRC") commissioners and staff provides more details on many  
14 of these technologies. See PNM Exhibit WK-1 (Rebuttal). Dr. Passell's material  
15 reinforces my point about utilities having other storage options to choose from in  
16 the future.

17

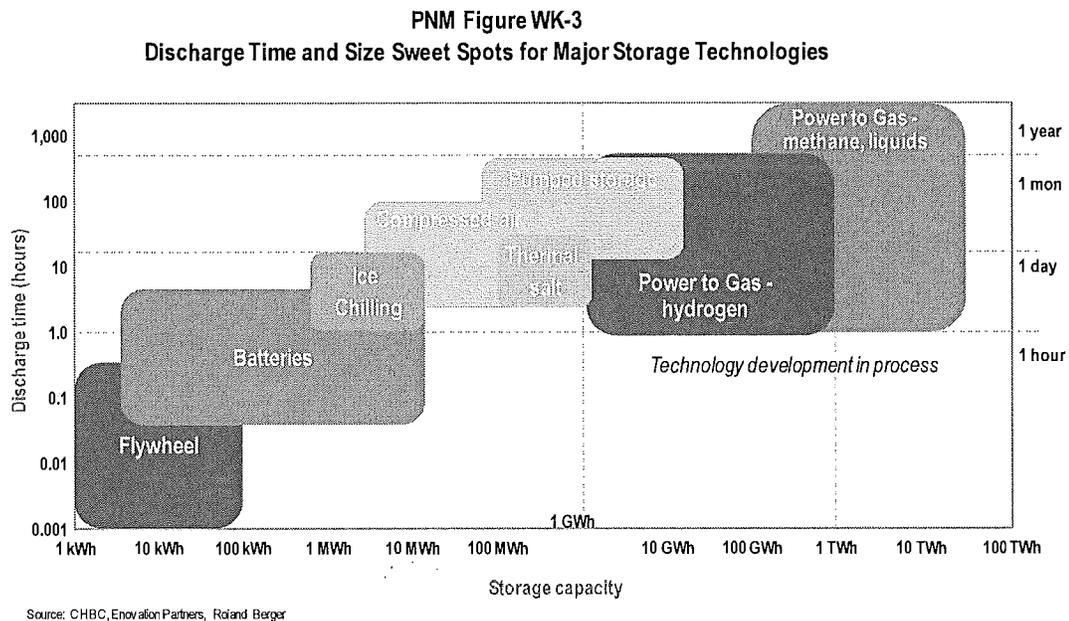
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<sup>10</sup> <https://rmi.org/insight/breakthrough-batteries/>

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1

**PNM Figure WK-3 (Rebuttal)**



2

3 **Q. WHAT DOES THIS MEAN FOR PNM?**

4 **A.** There is no single storage technology that will solve all of PNM's operational  
5 needs at once. While Lithium ion is the dominant technology for stationary energy  
6 storage systems installed today, other technologies such as flow batteries, thermal  
7 and compressed air energy storage could be just as appropriate for grid use  
8 depending on the system need and use case, as discussed further by PNM Witness  
9 Fallgren. As such, it is appropriate for PNM to be initially cautious as the storage  
10 market continues to develop technologies appropriate for grid requirements.

11

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1 **Q. HOW WOULD YOU EXPECT PNM'S NEEDS FOR STORAGE TO**  
2 **EVOLVE OVER TIME, AS ITS LOADS CHANGE AND IT REPLACES**  
3 **OTHER EXISTING GENERATION PLANTS?**

4 **A.** As discussed by in the rebuttal testimonies of PNM witnesses Fallgren and  
5 Phillips, PNM will almost certainly need to add more storage capacity as it shifts  
6 its generation mix more strongly toward renewables in future resource replacement  
7 decisions. Its relative needs for short-duration, medium-duration and long-  
8 duration storage within the arbitrage (time-shifting) use case for storage will also  
9 likely shift as a result. The relevant characteristics of projects suitable to meet  
10 other use cases for storage will similarly be affected by the evolution of the  
11 resource portfolio. See also the rebuttal testimony of PNM witness Dorris.

12  
13 The point here is that PNM is likely in the future to have different needs for  
14 storage, and therefore will look at other types of storage technologies in deciding  
15 how to meet those needs. Procuring more storage capacity than needed in this  
16 initial set of replacement resources may result in suboptimal mix of storage  
17 technologies over time.

18  
19 **Q. PLEASE RESPOND TO CCAE WITNESS DESU'S CRITICISM THAT**  
20 **PNM OVERSTATED BATTERY TECHNOLOGY RISKS?**

21 **A.** I disagree that PNM has overstated risks. A significant technology risk for PNM is  
22 deploying battery energy storage technologies that could quickly become obsolete  
23 over the course of their useful lives. This risk is especially acute in an industry that

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1 is as fast-moving as the stationary storage industry, where there is significant  
2 investment being made in a multitude of alternative battery technologies that seek  
3 to solve the known limitations of available technologies on the market today.<sup>11</sup>  
4 These limitations include power density, safety, and battery durability, among  
5 others.

6  
7 **Q. COULD YOU PLEASE PROVIDE AN EXAMPLE OF HOW SAFETY**  
8 **CONSIDERATIONS HAVE DRIVEN REGULATORS AND UTILITIES TO**  
9 **LOOK AT ALTERNATIVE BATTERY TECHNOLOGIES?**

10 **A.** Yes. That example is next door, in Arizona. Regulators in Arizona expressed  
11 concern at the current type of lithium-ion batteries being used at Arizona Public  
12 Services' McMicken and Elden facilities in Surprise and Flagstaff, Arizona,  
13 respectively. In a letter to stakeholders, Arizona Corporation Commissioner Sandra  
14 D. Kennedy asked that APS and stakeholders consider several emerging  
15 technologies for grid use.<sup>12</sup> These included liquid metal, nickel-iron, zinc air, and  
16 other emerging technologies.

17  
18 **Q. DO YOU AGREE WITH DESU'S IMPLICATION THAT EXISTING**  
19 **STANDARDS ADEQUATELY ADDRESS ALL UTILITY-SCALE BESS**  
20 **RISKS?**

---

<sup>11</sup> Automakers such as Ford, BMW and Hyundai invest in solid state battery manufacturer Solid Power.  
://electrek.co/2019/04/11/ford-solid-power-state-battery/

<sup>12</sup> Arizona Corporation Commission Docket E-01345A-19-0076, letter of Sandra D. Kennedy. August 2,  
2019.

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1    **A.**    No. While I agree that the industry has made significant efforts to develop and  
2           implement codes and standards for BESS design, installation and operation, I  
3           caution that the enforcement of these standards, such as NFPA 855<sup>13</sup> and  
4           UL9540A<sup>14</sup>, can vary depending on the local government requirements in effect  
5           where BESS projects are installed. Moreover, the existing standards that Desu lists  
6           do not address the more complex and variable requirements of utility-scale  
7           installations, particularly as it applies to Battery Management Systems.

8

9    **Q.    DO YOU EXPECT CHANGES TO BATTERY ENERGY STORAGE**  
10       **SYSTEM CODES AND STANDARDS IN THE NEAR TO MEDIUM**  
11       **TERM?**

12   **A.**    Yes. I would expect changes to current codes and standards in the near to medium  
13           term. While it is difficult to guess exactly which ones will come first, I expect  
14           several updates to fire protection codes and standards following the investigation  
15           into the April 2019 fire at Arizona Public Service Company's McMicken Storage  
16           facility, as well as the nearly two dozen battery fires in South Korea.<sup>15</sup> One  
17           outcome could be a new standard that addresses whether fire-suppression systems  
18           used for BESS technology should be chemical or water-based. The National Fire  
19           Protection Association, which issued NFPA 855 to set fire protection standards for

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<sup>13</sup> <https://www.nfpa.org/codes-and-standards/all-codes-and-standards/list-of-codes-and-standards/detail?code=855>

<sup>14</sup> <https://www.ul.com/offerings/ul-9540a-test-method>

<sup>15</sup> IHI Energy Storage Webinar. October 29, 2019.  
<https://www.greentechmedia.com/webinars/webinar/understanding-energy-storage-safety-insights-from-expert-researchers>

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1 BESS in September 2019, has so far allowed developers to select either  
2 approach.<sup>16</sup> PNM is an active participant in the development of these new safety  
3 standards for large-scale battery storage.

4  
5 **Q. HOW DOES PNM PLAN TO MITIGATE SAFETY RISKS RELATED TO**  
6 **BATTERY ENERGY STORAGE SYSTEMS?**

7 **A.** PNM's risk mitigation plan revolves around three potential causes of failures for  
8 energy storage systems, based on its discussions with other utilities and reviews of  
9 BESS failures in South Korea. This includes plans to mitigate risks from 1)  
10 material defects; 2) installation defects; and 3) control system interface defects.  
11 Control system integration is an important area for improving battery storage  
12 safety, which the industry is also moving to address.

13  
14 A measured and balanced approach to storage procurement would improve the  
15 long-term safety profile of PNM's portfolio through leveraging lessons learned by  
16 the industry, as embodied by future standards.

17  
18 **Q. HOW WOULD A MEASURED APPROACH TO STORAGE**  
19 **PROCUREMENT SAVE MONEY FOR PNM'S CUSTOMERS?**

20 **A.** As discussed above, a measured approach provides several advantages related to  
21 accumulation of industry and PNM operational knowledge on storage. This will

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<sup>16</sup> Energy Companies Continue to Wrestle with Fire Safety. S&P Global Market Intelligence. December 5, 2019.

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1 better inform future expectations for battery storage operational performance and  
2 the subsequent storage system specifications for procurement.

3  
4 A measured response also protects PNM from several potential undesirable  
5 outcomes on the cost of its long-term storage portfolio.

6 • First, PNM can avoid over-reliance on current Li-ion technology, whose  
7 chemistry was not originally designed for utility scale applications, but rather  
8 was adapted from mobile applications. Technologies currently in development  
9 and arising in the medium term are considered likely to make current Li-ion  
10 products obsolete in the reasonable planning horizon for any utility. By taking  
11 a measured approach, PNM would keep open the option to take future  
12 advantage of superior technology in both cost and performance terms.

13 • Second, new technology breakthroughs notwithstanding, Li-Ion battery  
14 technology is declining rapidly in cost. The most recent update of Lazard's  
15 Levelized Cost of Storage study estimates cost declines of over 8% per year  
16 through the mid-2020s. PNM will be able to take advantage of these cost  
17 declines by phasing in battery integration instead of going "all in" immediately.

18 • Third, by taking a measured approach, PNM will be able to take reasonable  
19 advantage projects in the current PPAs of the ITC-driven pricing of co-located  
20 solar plus storage, while limiting the portion of its storage portfolio that is  
21 located adjacent to utility scale solar plants well outside the load center. Such  
22 sub-optimal locations would not allow PNM to harvest the full value provided

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1 by storage for localized critical grid services and T&D system cost deferral  
2 opportunities.

- 3 • Fourth, procuring additional storage closer to the time of need for future  
4 resource expansions or replacements will push back the related expenditures  
5 and reduce the NPV of costs to customers, reflecting the time value of money.

6  
7 These considerations make it clear that PNM's recommended measured and  
8 balanced approach to procuring energy storage for its system is more financially  
9 prudent for its customers and will save them money in the long term. This seems  
10 particularly relevant for a utility such as PNM, which must make additional  
11 changes to its existing resource portfolio over the next several years to achieve the  
12 zero carbon goals set by the state.

13  
14 **Q. WOULD IT BE PRUDENT FOR PNM TO RUSH TO ACQUIRE STORAGE**  
15 **CAPACITY TO TAKE ADVANTAGE OF THE AVAILABLE FEDERAL**  
16 **INCOME TAX CREDIT, BEFORE IT EXPIRES, AS SUGGESTED BY**  
17 **CCAE WITNESS DESU?**

18 **A.** No. As discussed earlier, the ITC is driving sub-optimal location of storage. In  
19 the absence of the ITC, the obvious location for a flexible resource like battery  
20 storage is near the load center where locational benefits can be added to the bulk  
21 power benefits. PNM's proposed portfolio approach takes advantage of this  
22 temporary tax-driven disruption of the market, but also recognizes that there are  
23 benefits in optimally placing storage assets within and around the load center.

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1

2 **Q. DO YOU AGREE WITH THE ASSERTION OF CCAE WITNESS DESU**  
3 **(PAGE 42) THAT GAS-FIRED PEAKING UNITS HAVE A GREATER**  
4 **RISK OF PREMATURE OBSOLESCENCE THAN THE CURRENT**  
5 **GENERATION OF LITHIUM ION BATTERY STORAGE**  
6 **TECHNOLOGIES?**

7 **A.** No. From my firm's annual forward looks into the state of electricity storage  
8 across a wide range of technologies, it is clear that battery technologies are  
9 changing much faster than gas combustion turbine technologies. Given the very  
10 substantial investments into storage technology RD&D being made by the  
11 transportation industry, energy industry, and the major manufacturers serving those  
12 industries, I have no doubt that significantly improved storage technologies will  
13 come to market over the next few years, e.g., solid state batteries. A measured and  
14 balanced storage procurement strategy will enable PNM to take advantage of these  
15 future improvements. PNM Witness Dorris expands on this point in his rebuttal  
16 testimony.

17

18 Further, PNM's plan already incorporates into its analysis the costs and benefits of  
19 alternative resource portfolios, and the outcome is to include the Piñon gas-firing  
20 peaking plants, with a depreciable life that by 2040 gives them additional  
21 opportunities for technology advances in renewable fuels or other plant  
22 technology. Batteries may not have an equal opportunity for their original plant

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1 investments to be “repurposed” due to technological advances in alternative fuels  
2 and emissions control equipment.

3

4 **Q. WHAT LESSON CAN BE DRAWN FROM UTILITY EXPERIENCE IN**  
5 **EARLIER ROUNDS OF RENEWABLE ENERGY PROCUREMENT,**  
6 **REGARDING THE OPTIONS FOR THE TIMING OF STORAGE**  
7 **PROCUREMENT?**

8 **A.** The experience of the large California electric utilities in procuring large amounts  
9 of renewable energy, through waves of Power Purchase Agreements ("PPAs") with  
10 developers of renewable energy projects, provides a number of cautionary notes.  
11 The utilities had mandates to meet specified percentages of renewables in their  
12 energy mix. Those mandated percentages ratcheted up every three years.

13

14 Meanwhile, the costs of utility-scale solar and wind PPAs, as represented by their  
15 levelized prices, was dropping steadily over period from the early 2000s to 2017.  
16 Prices in the oldest PPAs were sometimes 8-10 times higher than prices in the  
17 newest PPAs.

18

19 Two of the three large California electric utilities used an "in advance"  
20 procurement practice within the three-year procurement cycles, to meet the next  
21 ratchet up in renewable percentage requirements. They started signing new PPAs  
22 at the beginning of each cycle and continued until they had met or even exceeded  
23 the next target. The other large utility purposefully backloaded its PPA executions

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1 into the last year of the three-year cycle, with the expectation that they could get  
2 better prices due to the declining trend in solar and wind costs. The result was that  
3 the utility that followed a more measured and balanced procurement practice ended  
4 up with a cumulative PPA portfolio that had significantly lower cost for both solar  
5 and wind.

6  
7 The cautionary lesson from California is that buying in advance of overall need  
8 (through PPAs or utility project contracting) in an environment of falling prices for  
9 the resource being procured leads – naturally enough – to higher average portfolio  
10 costs. Without counterbalancing advantages from buying in advance, it is more  
11 prudent to take a measured, balanced, commercially sensible procurement  
12 approach – which will save customers money while achieving the same  
13 environmental goals.

14  
15 **Q. WHAT ARE THE IMPLICATIONS OF THE STORAGE WORKSHOPS**  
16 **RECENTLY PRESENTED TO PNM BY SANDIA NATIONAL**  
17 **LABORATORY, REGARDING THE DEVELOPMENT OF POLICIES**  
18 **AND PLANS FOR A MUCH-EXPANDED PORTFOLIO OF STORAGE**  
19 **RESOURCES?**

20 **A.** As shown by even a cursory review of PNM Exhibits WK-1 and WK-2 (Rebuttal),  
21 a large number of technology and policy issues around storage must be addressed  
22 by the NMPRC, PNM and interested stakeholders. Storage is a different animal,  
23 with characteristics of both generation and transmission/distribution resources. Its

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1 uses on utility systems will be varied and complex. Many states have embarked on  
2 extensive stakeholder processes to develop policies around storage. New Mexico  
3 would be well served by similarly thoughtful consideration of how best to leverage  
4 storage technologies for the long-term benefit of the state.

5  
6 **IV. BENEFITS FROM UTILITY OWNERSHIP OF STORAGE**

7 **Q. HOW WILL UTILITY OWNERSHIP OF BATTERY STORAGE**  
8 **FACILITIES HELP ACCELERATE PNM'S LEARNINGS AROUND**  
9 **OPTIMIZING STORAGE OPERATION?**

10 **A.** A key aspect of integrating battery storage systems into the PNM system is  
11 operational control, which helps maximize the value of a battery system by better  
12 utilizing the full range of battery storage capabilities. Our contacts in the storage  
13 and utility industries consistently expect that significant technology advances will  
14 be achieved in multi-use battery control technologies in the future. Utility  
15 ownership of a substantial portion of the battery storage facilities on its system will  
16 be critical for PNM to understand and gain experience in these areas to better  
17 inform future PPA or EPC contracts.

18  
19 Several intervenor witnesses have asserted that PPA contracts can give PNM  
20 "operational control" of the BESS, but they fail to mention that the control given is  
21 provided within prescribed operational envelopes so as to ensure the maintenance  
22 expense does not exceed the amounts baked into the PPA price. Ownership and

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1 control by PNM will remove these constraints and allow PNM to test boundaries in  
2 terms the storage operations patterns that maximize benefit to the grid, while  
3 assessing the impact on the battery systems. Gaining this critical knowledge for  
4 PNM will help inform future system specifications and operational performance  
5 expectations.

6  
7 **Q. HOW WILL UTILITY OWNERSHIP OF BATTERY STORAGE**  
8 **FACILITIES HELP TO ACHIEVE GREATER LOCATIONAL VALUE**  
9 **FROM STORAGE?**

10 **A.** PNM ownership will allow optimal siting of batteries, to achieve the maximum  
11 benefits to the grid. Such benefits extend beyond simple load shifting, renewable  
12 smoothing, and frequency response. They include more location-specific benefits  
13 such as voltage control, reactive power response, T&D infrastructure deferral and  
14 outage mitigation. Beyond location-specific benefits, ownership will provide  
15 PNM with more flexibility and allow it to plan for the optimal mix of wires and  
16 non-wires alternatives across its distribution system, with storage as an important  
17 tool.

18  
19 **Q. HOW DID EXPERTS FROM SANDIA NATIONAL LABORATORY**  
20 **ASSESS THE PROS AND CONS OF UTILITY OWNERSHIP OF ENERGY**  
21 **STORAGE?**

22 **A.** Will McNamara of Sandia National Laboratory provided a useful overview of  
23 policy issues around energy storage in the workshop he led on December 3, 2019,

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1 for NMPRC commissioners and staff, plus other interested parties. He laid out the  
2 approaches of various states on various policy issues related to energy storage.

3  
4 On the issue of utility ownership, he listed the following pros and cons. See page  
5 21 of PNM Exhibit WK-2 (Rebuttal).

**The Issue:** Given that storage is typically classified as energy storage, should utilities be allowed to own storage assets in deregulated markets?

**PROS**

- Opportunity for long-range, system-wide planning
- Opportunity to optimize the distribution system
- Enhanced flexibility to use cost-effective resources
- Enhanced economies of scale (i.e., prices drop with larger projects)

**CONS**

- Market power concerns
- Utilities would have an advantage over 3<sup>rd</sup> parties, creating an unlevel playing field
- Uncertainties about utility cost recovery and equitable rate treatment among customers

6 The "pros" seen by Mr. McNamara line up well with the discussion earlier in this  
7 section, and in my view are even stronger in a vertically integrated market like  
8 New Mexico. In a vertically integrated market, the utility is in a much better  
9 position than other players to realize the full value of battery storage's multiple  
10 uses. And that value will be passed on to customers in cost-based ratemaking.

11  
12 Of the three "cons" listed by Mr. McNamara, the first (market power concerns)  
13 does not apply in a vertically integrated market. The second (unlevel playing

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1 field) is manageable through open procurement processes that consider both self-  
2 build and independent supplier options. The third (ratemaking issues) is a normal  
3 set of prudence and cost allocation issues that the NMPRC must deal with in any  
4 utility investment.

5  
6 **V. NATURAL GAS MORATORIUM**

7 **Q. NEE WITNESS JAMAIL ARGUES THAT NO NATURAL GAS-FIRED**  
8 **RESOURCES SHOULD BE APPROVED. SHOULD THE COMMISSION**  
9 **ADOPT THIS APPROACH TO REPLACING THE SAN JUAN COAL**  
10 **PLANT?**

11 **A.** No. I agree strongly with his pleas to address global warming. However, the  
12 simplest decarbonization pathway is not necessarily the best decarbonization  
13 pathway for PNM's customers. If we can agree that achieving the climate change  
14 limitation goals of New Mexico is essential, then we should strive to achieve those  
15 goals in the way most beneficial for PNM's customers. Cost and reliability should  
16 be major considerations in choosing from the envelope of feasible pathways that  
17 meet the goals. While relying sooner on renewable generation plus storage may be  
18 technically feasible (with very large and at present expensive amounts of storage  
19 capacity), it would not be the most reliable or even the most cost-effective  
20 combination of resources to meet the ETA mandates.

21

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1 A flexible multi-unit plant like Piñon will be an inexpensive reliability insurance  
2 policy to smooth the transition of PNM's grid to net zero carbon. And it could  
3 continue to play a reliability-enhancing role even in a zero-carbon grid after 2040,  
4 through burning biogas or hydrogen from electrolysis driven by surplus renewable  
5 energy. See the rebuttal testimony of PNM Witness Dorris.

6  
7 As the recent President of Southern California Edison noted at an industry  
8 conference in 2018, if no thermal generation is allowed on the system, the last 10  
9 percent of the journey toward grid decarbonization could be as expensive as the  
10 first 90 percent.

11  
12 Finally, it should be kept in perspective that the carbon emissions from the Piñon  
13 peaking generators operating at very low capacity factors will be miniscule  
14 compared with the emissions from the San Juan plant running 60-80 percent of the  
15 time.

**VI. CONCLUSIONS**

16  
17  
18 **Q. PLEASE SUMMARIZE YOUR CONCLUSIONS ON THE MAJOR ISSUES**  
19 **THAT YOU ADDRESS IN YOUR REBUTTAL.**

20 **A.** My conclusions are as follows:

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1           1. *Is PNM's proposal to limit the project size and total volume of battery storage*  
2           *resources in the initial phase of its storage procurement prudent, cost-effective*  
3           *and aligned with New Mexico's 2045 goals for 100% carbon-free electricity?*

4           Yes. The proposed initial battery storage levels defined by PNM are  
5           reasonable and prudent for a utility of its size and level of storage experience.

6           The resulting storage portfolio and project sizes, in relation to the size of  
7           PNM's system, are on the upper end of what other U.S. utilities are pursuing.

8           PNM expects to add substantially more storage to its system in future resource  
9           procurements.

10          2. *Does a measured and balanced approach to storage procurement strategy*  
11          *provide substantial benefits to PNM customers?*

12          Yes. Procuring storage resources as needed will enable PNM to take  
13          advantage of expected future improvements in storage costs, performance and  
14          safety, and to better match its choice of storage technologies with its emerging  
15          future needs as its resource portfolio evolves. It is prudent to "keep some  
16          powder dry" for future procurements.

17          3. *Are there compelling reasons to favor utility ownership of a substantial portion*  
18          *of storage resources?*

19          Yes. PNM ownership of a substantial portion of the storage resources on its  
20          system will enable it to learn more quickly how to optimize storage operations  
21          and siting, as well as capture the full value of the multiple uses of storage, with  
22          the attendant benefits for customers.

23          4. *Is a "No New Gas" strategy appropriate for PNM at this time?*

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1           No. A flexible multi-unit plant like Piñon will be an inexpensive reliability  
2           insurance policy to smooth the transition of PNM's grid to net zero carbon. Its  
3           carbon footprint through 2040 will be small, and it could continue to play a  
4           reliability-enhancing role even in a zero-carbon grid after 2040 through  
5           burning biogas or hydrogen.

6  
7   **Q.   HAVE YOUR RECOMMENDATIONS CHANGED IN LIGHT OF THE**  
8   **INTERVENOR TESTIMONIES TO WHICH YOU RESPOND?**

9   **A.**   No. As I conclude in my direct testimony, battery storage is clearly an important  
10       component of the utility industry's future. The Commission should oversee the  
11       incorporation of this technology into PNM's portfolio through measured additions  
12       to ensure that risks associated with this technology are reasonable, and the  
13       economics of the market in bringing down prices over time are optimized. PNM's  
14       proposed battery storage penetration rate in the range of 2% - 5% of balancing area  
15       peak load is a prudent first addition for its system. PNM will have significant  
16       opportunities going forward to add much more battery storage with improved  
17       technology and reduced pricing, providing higher benefits to PNM's customers.  
18       The criticisms of intervenors regarding PNM's approach to adding batteries in this  
19       case are unfounded.

20  
21   **Q.   DOES THIS CONCLUDE YOUR TESTIMONY?**

22   **A.**   Yes, it does.

*GCG#526581*

Sandia National Laboratory Briefing on Energy Storage Systems

# PNM Exhibit WK-1 (Rebuttal)

Is contained in the following 54 pages.



# Energy Storage Systems



**Howard Passell, Ph.D.**  
**Sandia National Laboratories**  
**NM PRC Presentation, 31 October 2019**



*Sandia National Laboratories is a multitechnology laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525. SAND2019-13351 C*



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in the  
national  
interest*



# The NMPRC/SNL Outreach Project

Sandia is funded by the Energy Storage Programs Office in the DOE Office of Electricity to provide outreach to regulatory commissions around the U.S.



In collaboration with PNNL and other institutions . . .

**Hawaii PUC**, Dec. 7, 2018, Honolulu: ES Introductory Workshop  
**California Energy Commission (CEC)**, June 14, 2019, Sacramento: Energy Storage Academy

**Southeastern PUCs – Alabama, Arkansas, Florida, Georgia, Kentucky, Maryland, New Jersey, North Carolina, Virginia**, July 17-18, Birmingham: Second Southeast Energy Storage Symposium and PUC Workshop (with Southern Research)  
**Nevada, New Jersey, Texas, and Iowa PUC** workshops are being planned



# Workshop Formats

All other workshops have been 1- or 2-day events, carefully planned with Commission staff

New Mexico PRC Introductory Workshops:

Today – Energy Storage Systems, and Energy Storage Economics and Valuation

Dec. 4 – Energy Storage Policy

Help us identify topics for a series of future workshops

**Big thanks to Commissioners Hall and Fischmann, Milo Chavez, Brian Harris, Isaac Leshin-Sullivan – and to you all**

Howard Passell, [hdpasse@sandia.gov](mailto:hdpasse@sandia.gov), 505 550 5752





# The “energy transition” is happening now

If you were in a shipwreck and a piano top came floating by, you might climb up on top of it and use it as a life preserver. But if you were in the business of designing life preservers, you probably would not make one in the shape of a piano top.

*Buckminster Fuller, Operating Manual for Spaceship Earth, 1969*

- Climate crisis
- Declining costs for renewables
- Public Health
- Geopolitics
- Ecosystem Health



# Energy dynamics are fundamentally different

- Demand is flat or declining -- little demand for new generation
- “Decarbonization” and “electrification” are on the rise
- Coal is no longer king
- PV + storage is supplanting old and new gas peakers
- 100-years of one-way electricity flow is a thing of the past
- 10% EV penetration will shift demand to nighttime\*
- Wholesale and retail markets are shifting

The job of regulatory commissions is way more complicated than it has ever been.

\* <https://www.utilitydive.com/news/with-10-penetration-evs-could-shift-all-residential-peak-load-to-night-a/565207/>

# Energy storage (ES) is fundamentally different



Energy storage . . .

- Is both a load and a generation source
- Provides alternative to “locational marginal price”
- Facilitates demand management
- Unleashes the power of renewables
- Provides flexibility, resilience, and reliability
- Provides various services and value streams



# Energy Storage Terminology



- **Watt (W)** – 1 Joule/second (~4 Joules = 1 calorie, the energy required to raise 1 gm of water 1° C)
- **kW, MW, TW** – a measure of maximum generation capacity -- **POWER**
- **kWh, MWh, TWh** – a measure of capacity \* time – **ENERGY**
  - A 40 MW, 4 hr battery = 160 MWh
  - A 40 MW, 40 MWh battery = 40MW for an hour, 20 MW for 2 hours, etc. (nominal)
- **Cycles** – the number of times a storage device can be charged and discharged
- **Depth of discharge** – the depth to which discharge occurs relative to capacity
- **Energy density** -- ratio of energy from a battery to battery mass
- **Round trip efficiency** -- refers to energy losses that occur (or don't) in each cycle of the device (for batteries ~approx. 70-80% is good . . .)
- **Real power** – power that does work
- **Reactive power (VARs** – volt-ampere reactive power) – power that maintains voltage in transmission systems; power absorbed (and generated) by generators and capacitors in the grid; <https://business.directenergy.com/blog/2016/may/reactive-power>
- **Levelized cost of energy** – total energy produced over the lifetime of the project divided by the total cost over the lifetime



# Grid scale ES market is growing fast, and expected to grow faster

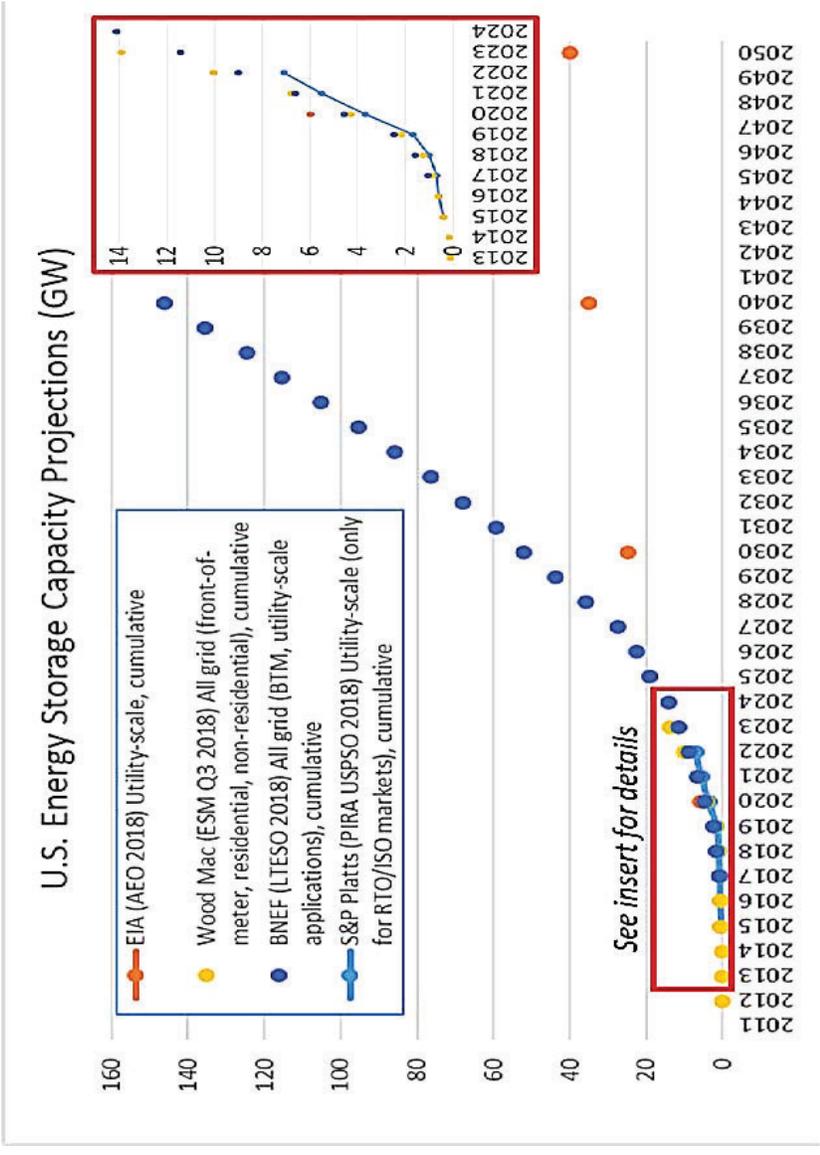


## 2018

- 310 MW / 777 MWh new storage deployments in US

## Market Penetration

- Grid-scale battery storage still < 0.1% of U.S. generation capacity
- EV's < 1% of vehicles sold in US

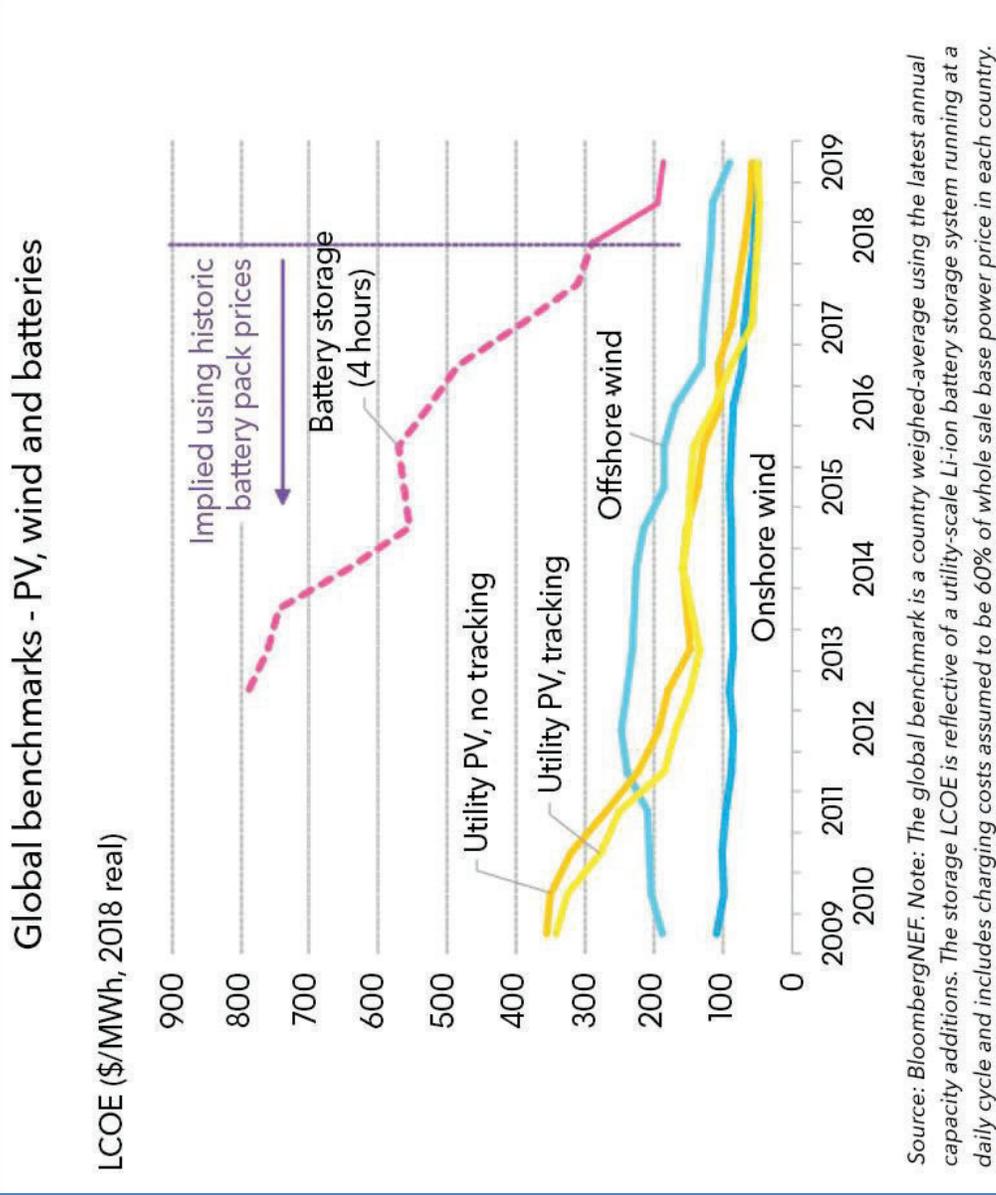


Wood Mackenzie P&R / ESA | U.S. energy storage monitor 2018 Y1R and Q132

“2019 Q3 residential installations by Tesla represent a 99% growth over Q3 in 2018 . . .”

PV Magazine, 10/24/19

# Declining costs...



“Batteries co-located with solar or wind projects are starting to compete, in many markets and without subsidy, with coal- and gas-fired generation for the provision of ‘dispatchable power’ that can be delivered whenever the grid needs it (as opposed to only when the wind is blowing, or the sun is shining).”

Bloomberg New Energy Frontiers

<https://about.bnef.com/blog/battery-powers-latest-plunge-costs-threatens-coal-gas/>

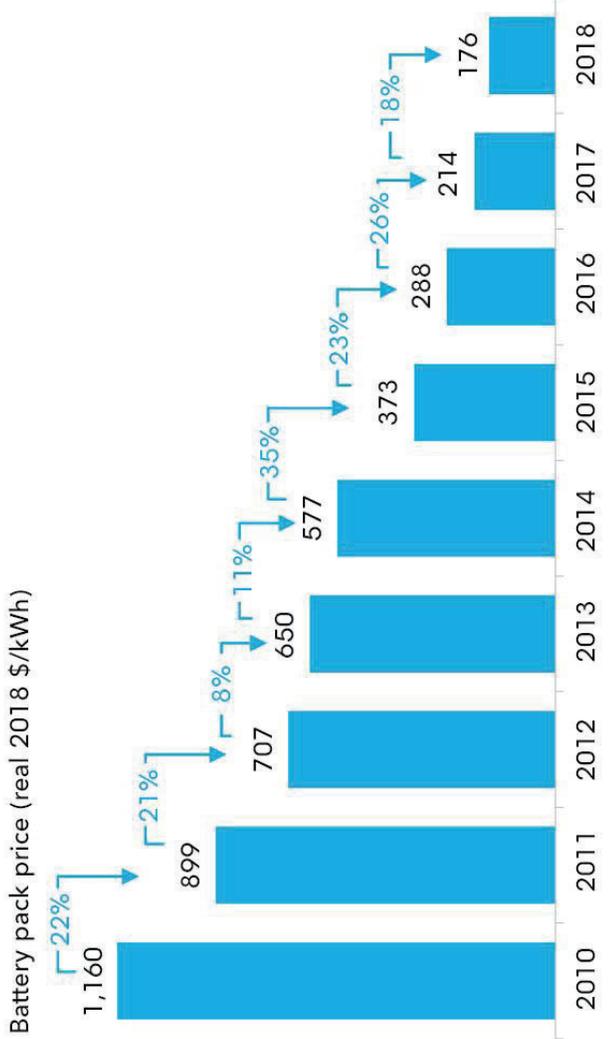
Residential PV, -55%  
 Utility Scale PV, -71%  
 Wind, -75%  
 EV Batteries, -79%

<http://energyfreedomco.org/f4-costs.php>

# Battery costs are dropping fast



Lithium-ion battery price survey results: volume-weighted average



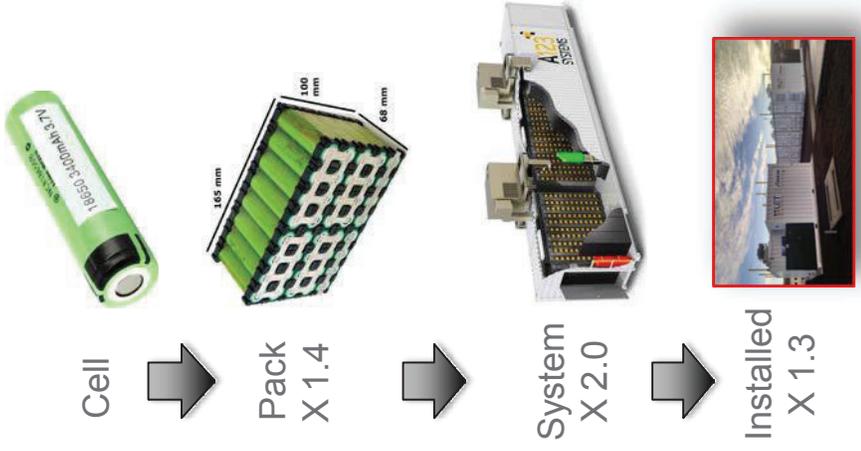
Source: BloombergNEF

<https://about.bnef.com/blog/behind-scenes-take-lithium-ion-battery-prices/>

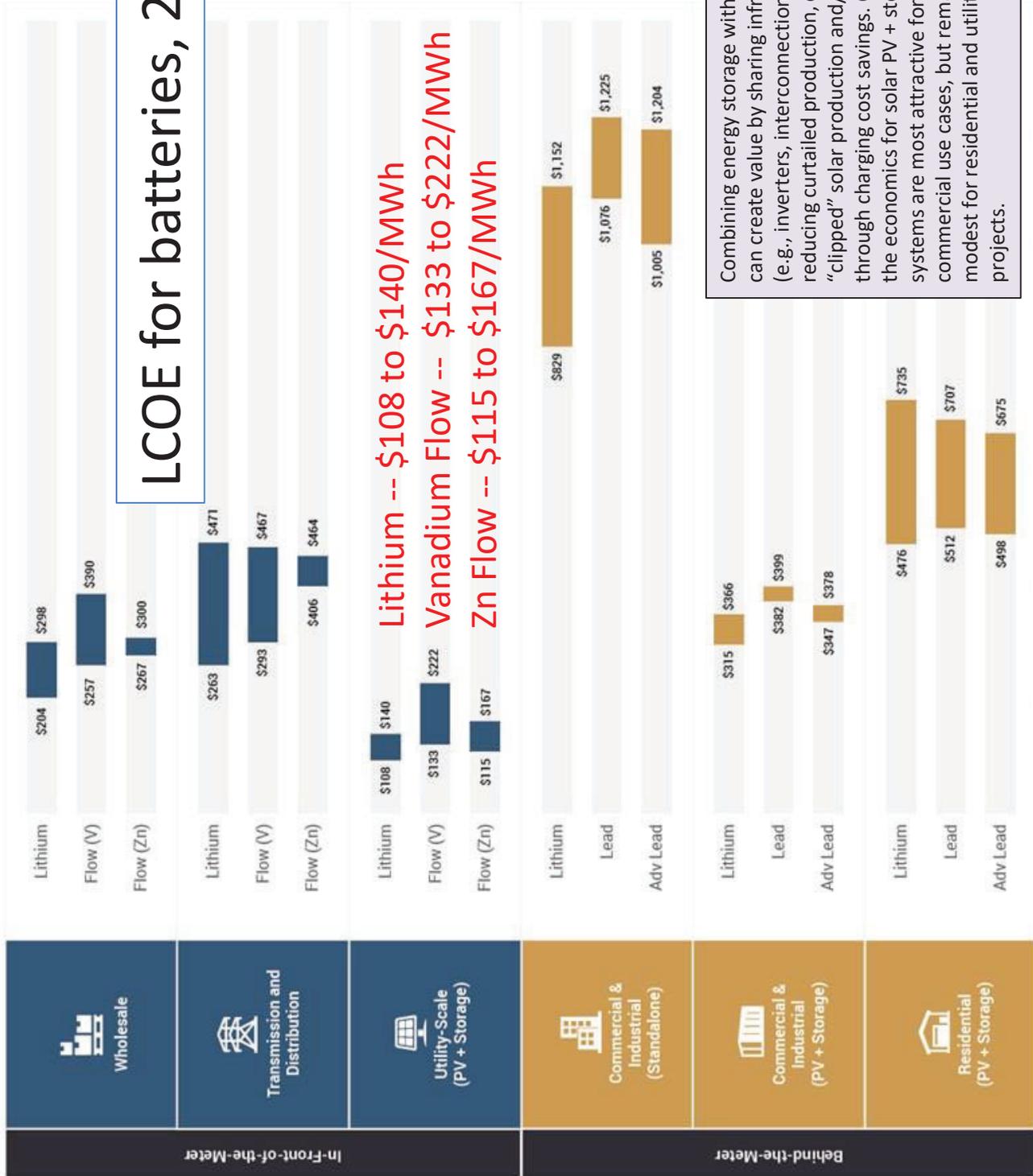
13 kWh Tesla Powerwall now sells for about \$481/kWh

**\$200/kWh cell** → **\$~1000/kWh system**

**Big savings now are not in the cells, but in the systems . . .**



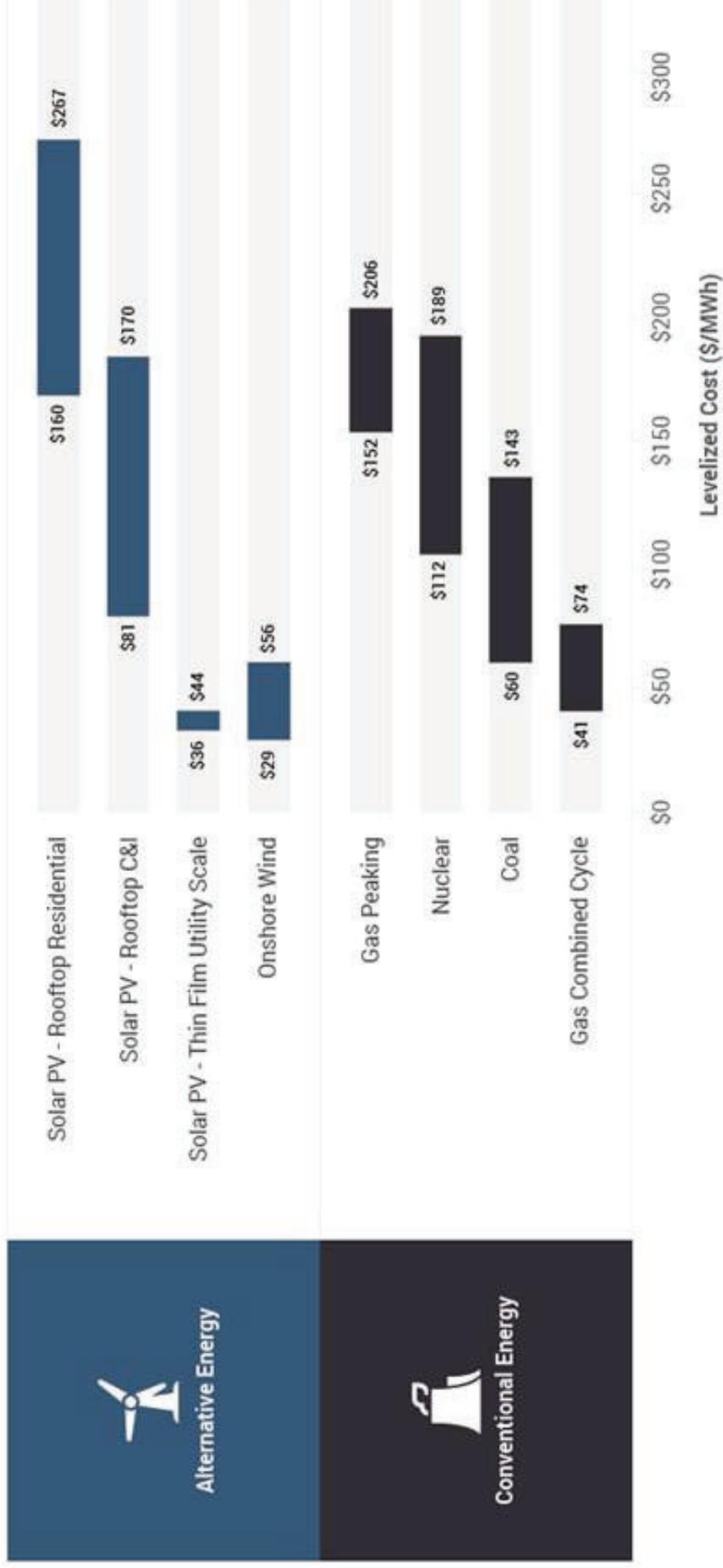
# LCOE for batteries, 2018



Lithium -- \$108 to \$140/MWh  
Vanadium Flow -- \$133 to \$222/MWh  
Zn Flow -- \$115 to \$167/MWh

Combining energy storage with solar PV can create value by sharing infrastructure (e.g., inverters, interconnection), reducing curtailed production, capturing "clipped" solar production and/or through charging cost savings. Currently, the economics for solar PV + storage systems are most attractive for commercial use cases, but remain modest for residential and utility-scale projects.

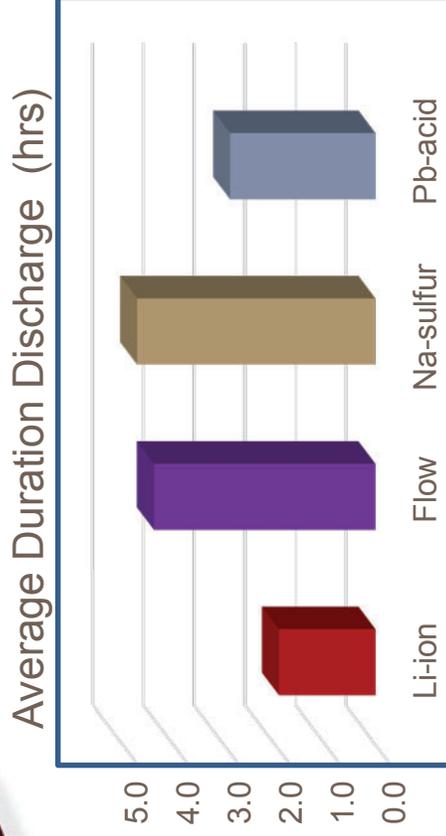
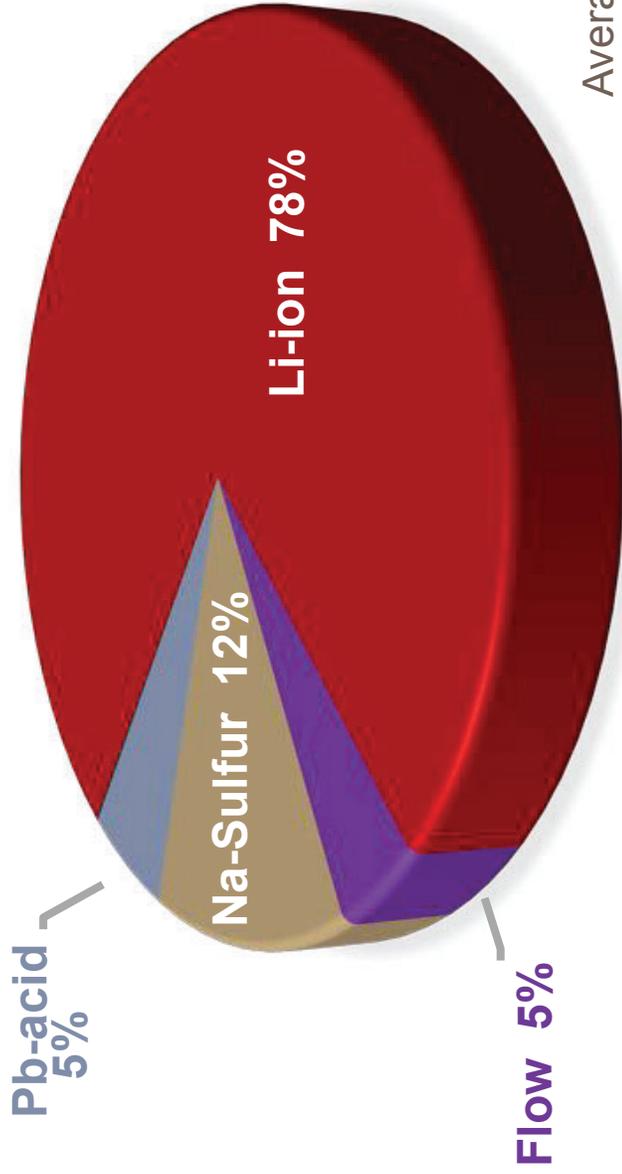
# LCOE for alternative and conventional energy



Remember, PV + Storage . . .

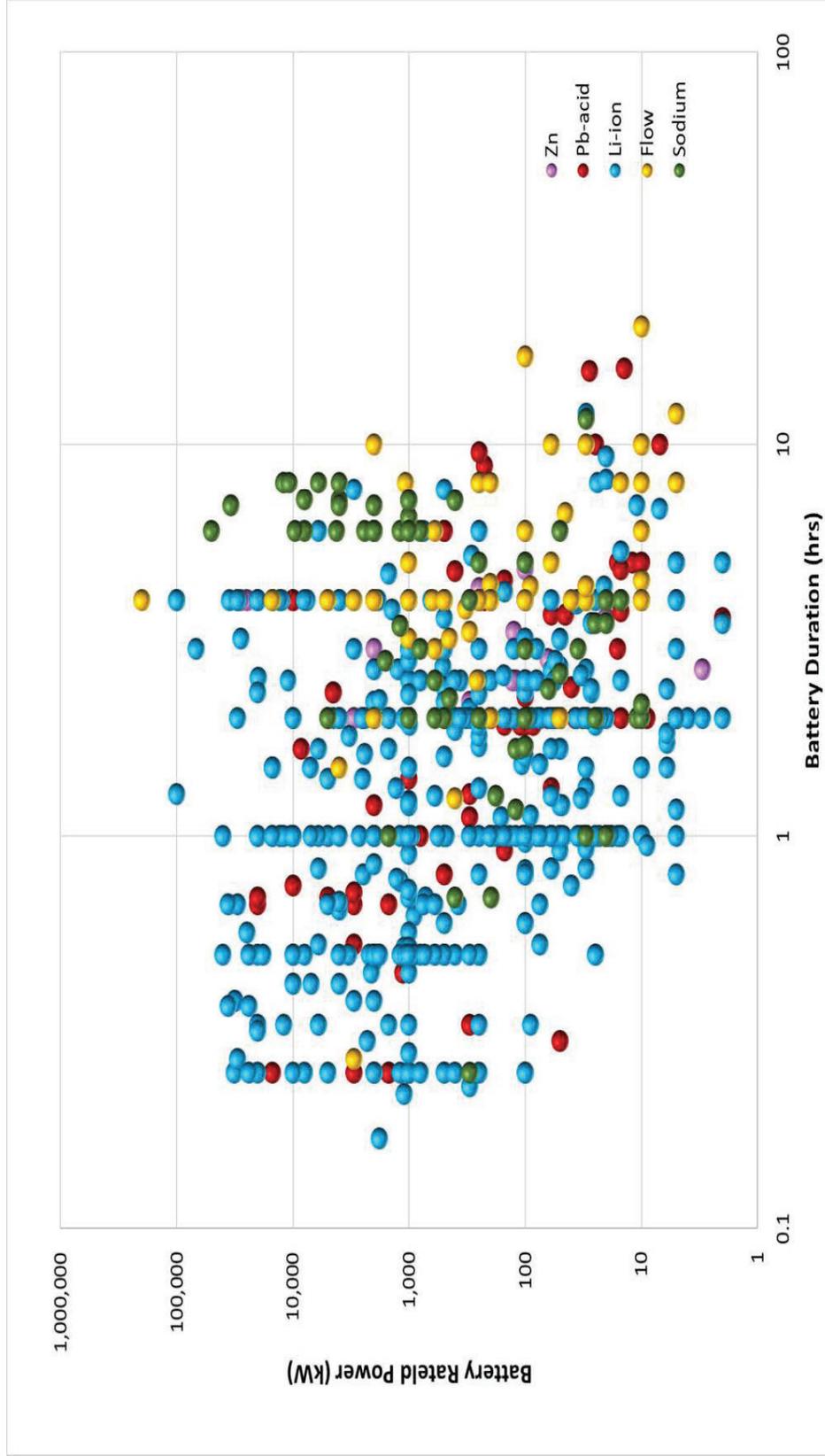
- Lithium -- \$108 to \$140/MWh
- Vanadium Flow -- \$133 to \$222/MWh
- Zn Flow -- \$115 to \$167/MWh

# Battery energy storage deployments



*\*Operational as of Nov. 2017 – being updated for 2018*

# Mapping of Grid Scale Battery Energy Storage System (BESS) Deployments



Source: US DoE Energy Storage Database, March 2019, <https://www.energystorageexchange.org/>  
Based on Shell International Exploration & Production (US) Inc.; analysis presented by Shell | 11 March 2019, ARPA-e DAYS

# US grid battery storage > 1 GW



# As costs go down, size and duration go up

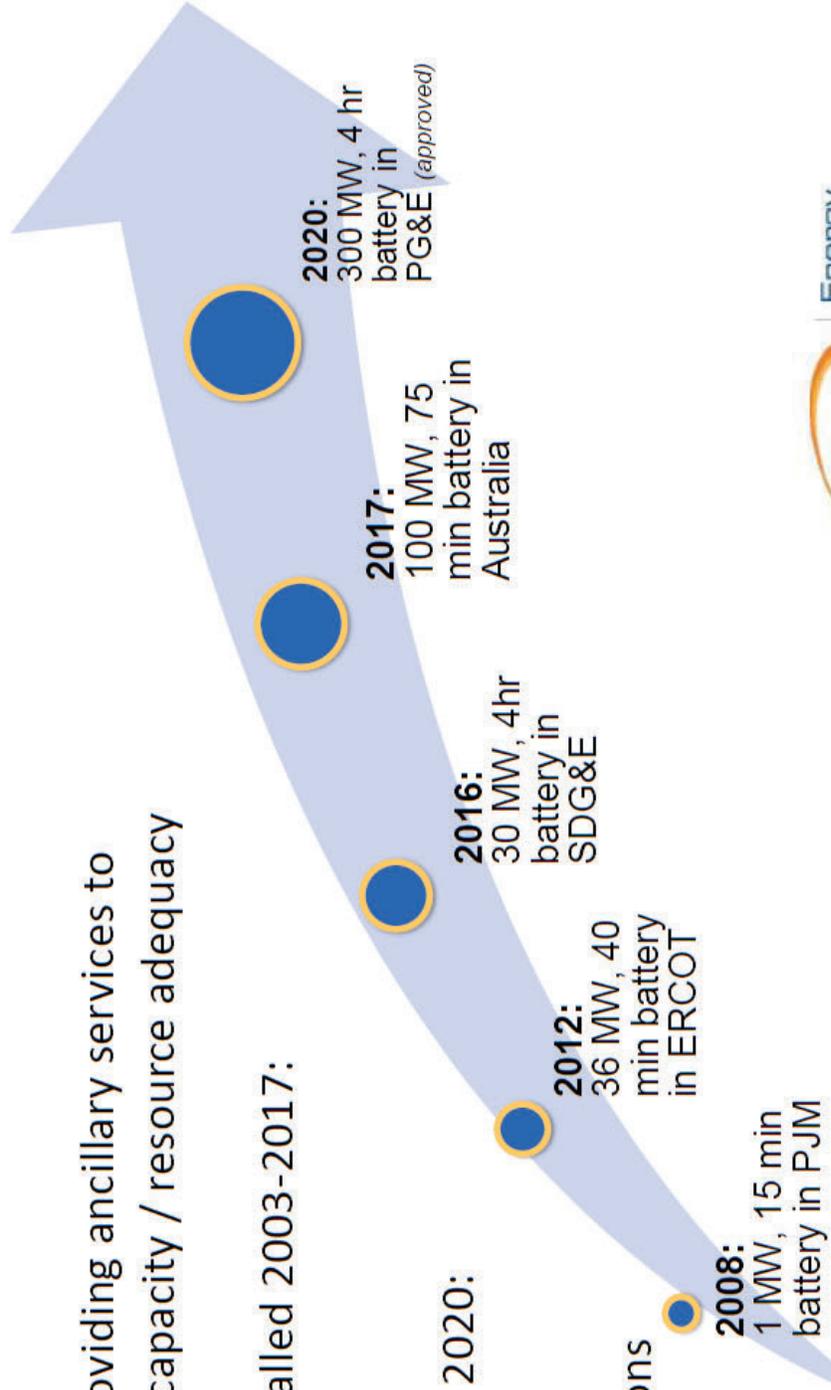


Shift from primarily providing ancillary services to increasingly providing capacity / resource adequacy

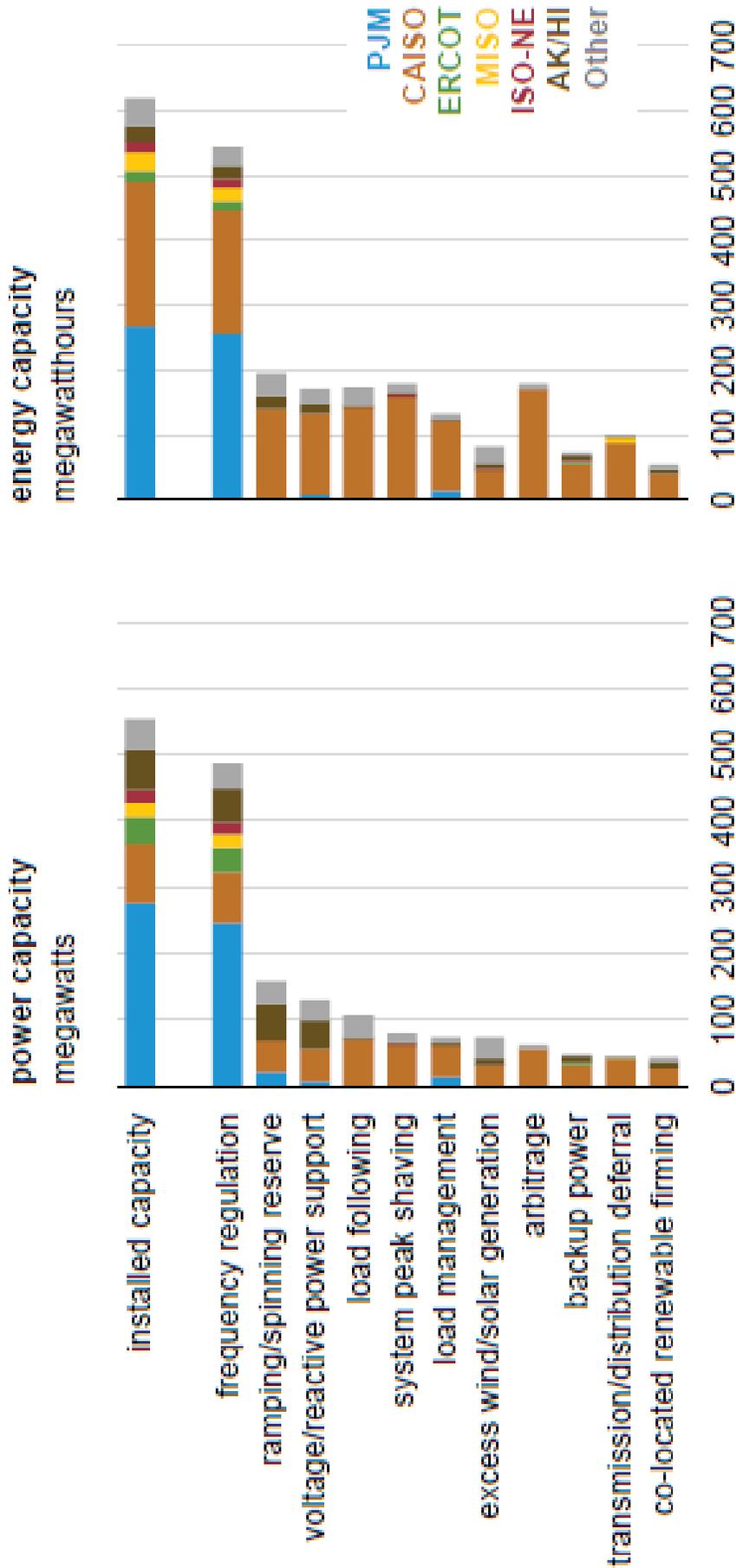
All battery storage installed 2003-2017:  
800 MW / 1200 MWh

Single PG&E battery in 2020:  
300 MW / 1200 MWh

DER storage aggregations to follow (largest today ~20 MW)



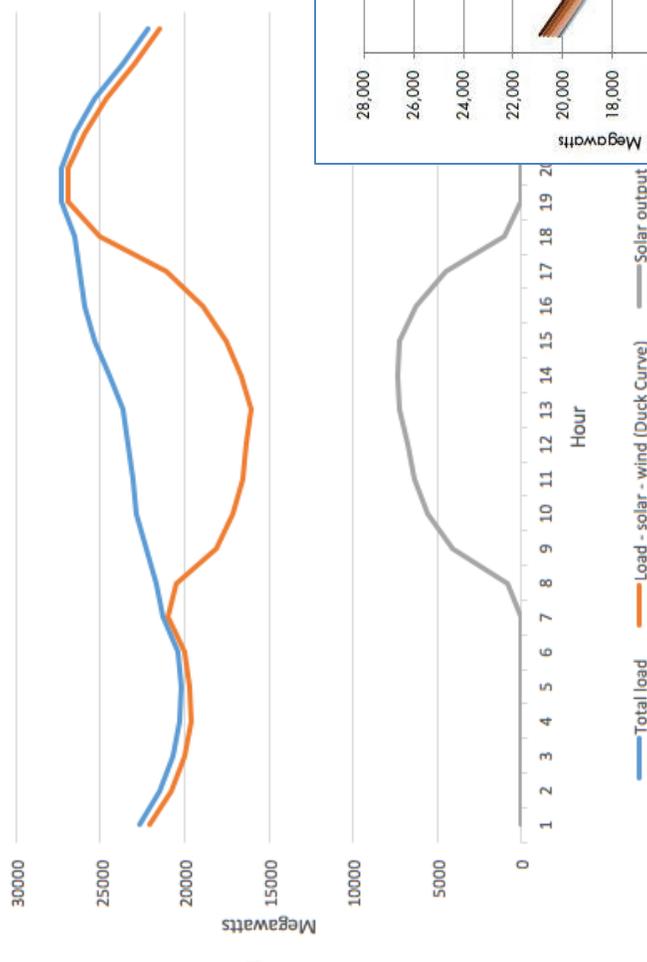
# Applications served by U.S. Large Scale BESSs (2016)



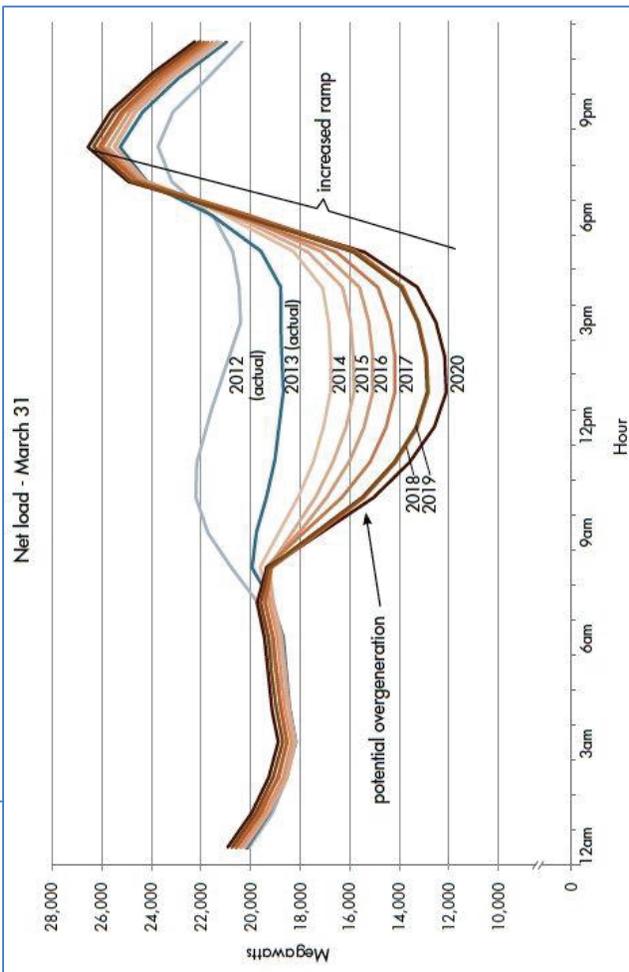


# The California Duck Curve

California hourly electric load vs. load less solar and wind (Duck Curve) for October 22, 2016



<http://www.caiso.com/market/Pages/ReportsBulletins/DailyRenewablesWatch.aspx>



<https://www.greentechmedia.com/articles/read/california-duck-curve-will-encourage-innovation#gs.OaaSnKE>



# Barriers to deployment



Cannot **VALUE** or compensate storage flexibility

**Solutions**

- Deployment targets
- Incentive programs
  - Tariff/rate design
- Wholesale market products
  - Cost-benefit studies



Unable to **COMPETE** in all grid planning and procurements

**Solutions**

- Long-term resource planning
  - Distribution planning
  - Transmission planning
- GHG/renewables standards
  - Wholesale market rules
- Resource adequacy rules



Cannot **ACCESS** grid or constrained to narrow use

**Solutions**

- Interconnection processes
- Multiple-use frameworks
  - Ownership rules



# NM Energy Transition Act



- 100% Carbon-Free Electricity by 2045
  - Senate Bill 489, Energy Transition Act, passed 44-22 on 03/12/2019
    - Provides process to close coal plants and provide economic relief and job training
    - Provides job training in renewables
    - Creates new Renewable Portfolio Standards
- Renewable Portfolio Standards in NM
  - 20% by 2020
  - 50% by 2030
  - 100% by 2045 (Co-ops by 2050)
- In December 2018 New Mexico Electricity was *produced* by the following sources: (<http://bber.unm.edu/energy>)
  - 48% coal, 33% natural gas, 19% renewable
- NM joins 8 other states, 141 cities, 11 counties with 100% goals
  - Hawaii, CA, Wash DC, Puerto Rico, Washington, Maine, NY, Nevada

## How do we get there?



# Optimal PV, wind, and ES capacity requirement for PNM to meet 100% carbon free goal

	<u>Now</u>	<u>Needed<sup>4</sup></u>
Energy Storage	3.75 MW <sup>1</sup> (0.00375 GW)	5 GW/25 GWh
Solar PV	818 MW <sup>2</sup> (0.818 GW)	10 GW
Wind	1,953 MW <sup>3</sup> (1.953 GW)	5 GW

<sup>1</sup> Global Energy Storage Database 2019; <sup>2</sup> Solar Energy Industries Association 2019

<sup>3</sup> American Wind Energy Assoc. 2019; <sup>4</sup> Copp et al., in press

Optimal Sizing of Distributed Energy Resources for 100% Renewable Planning

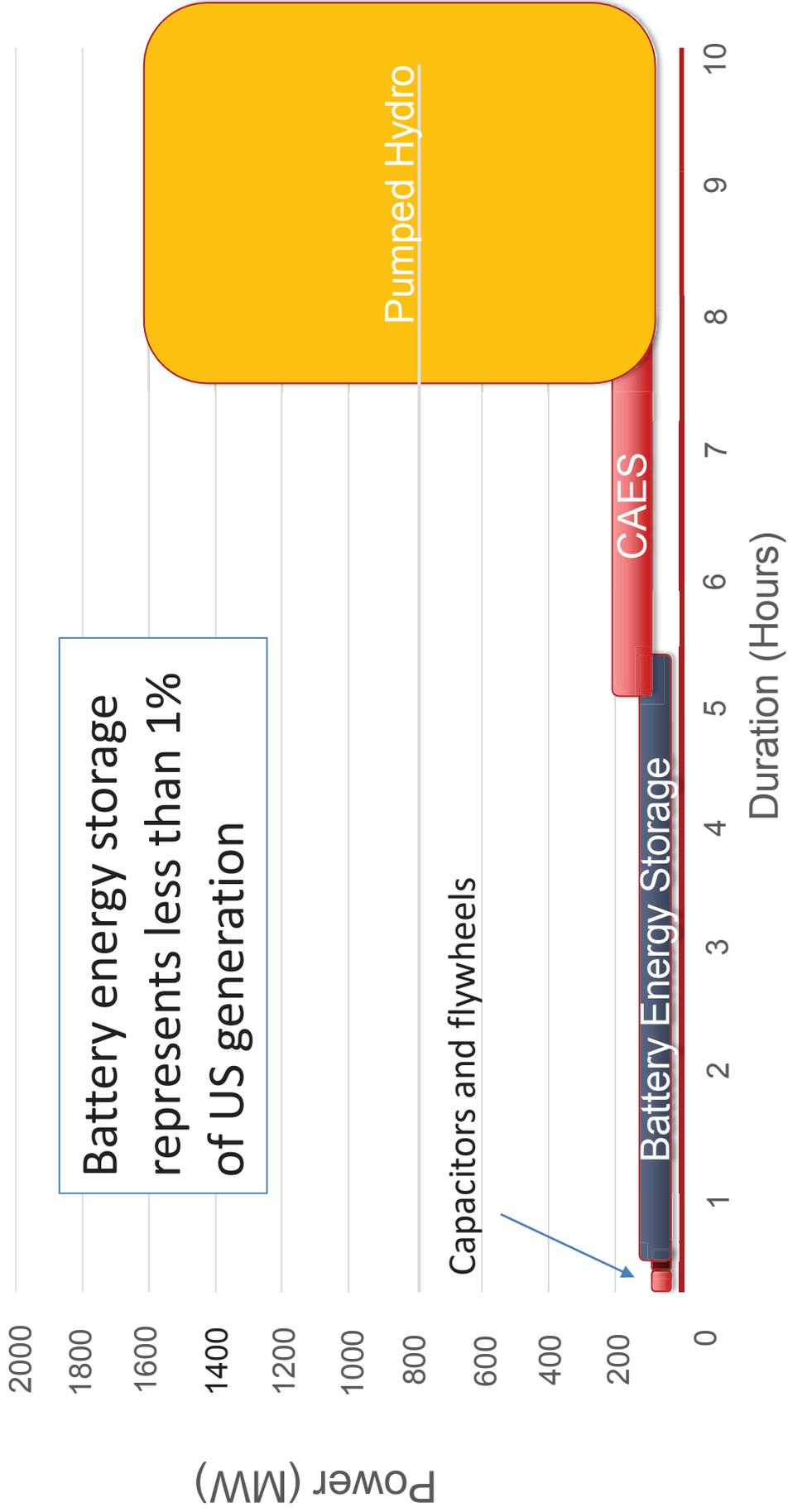
David A. Copp<sup>a,\*</sup>, Tu A. Nguyen<sup>a</sup>, Robb Thomson<sup>b</sup>, Raymond H. Byrne<sup>a</sup>, Babu R. Chalamala<sup>a</sup>

<sup>a</sup> Sandia National Laboratories, P.O. Box 5800, Albuquerque, NM 87185-1108, USA

<sup>b</sup> Retired Fellow, NIST, Gaithersburg, MD; Current address, 250 E Alameda Apt 523, Santa Fe, NM 87501, USA

# Electromechanical, Capacitor, and Thermal Technologies

# Energy Storage Technologies



# Pumped Hydro



- Characteristics
  - Large global and US capacity, but difficult to site new projects in the US
  - High energy capacity (4h – 22h)
  - High power capacity (GWs)
  - Slower response (seconds to minutes)
  - Very mature technology
  - Long Life (20+ years)
  - High initial costs
- Broad applications and services

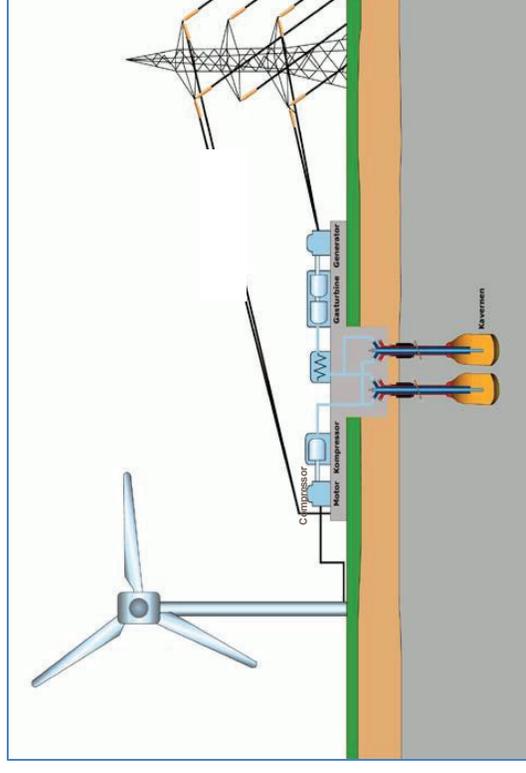


<https://www.windpowerengineering.com/pumped-hydro-storage-market-to-surpass-350-billion-by-2024/>

# Compressed Air (CAES)



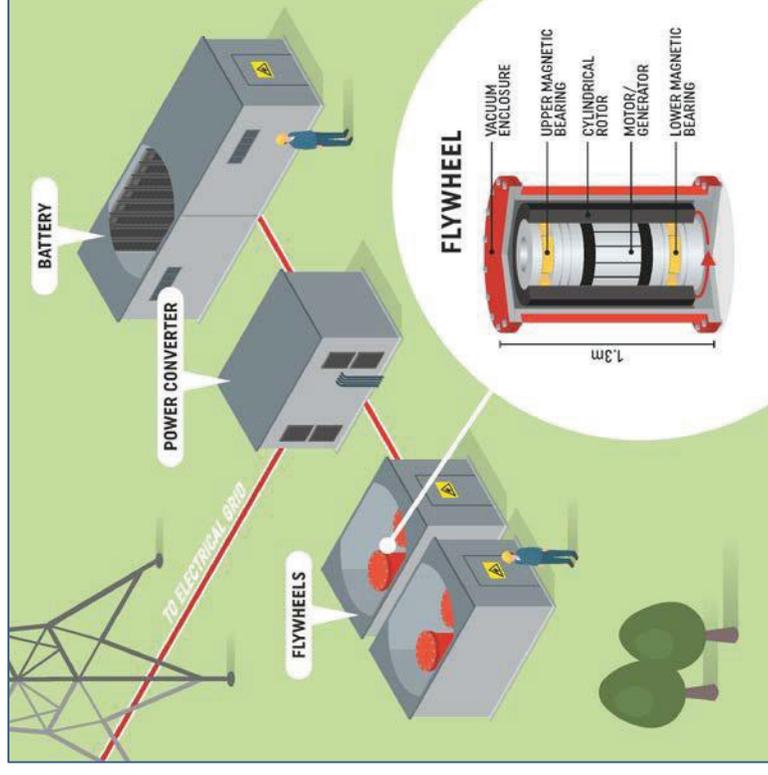
- Characteristics
  - High energy capacity (2h – 30h)
  - High power capacity (100s MW)
  - Long life (20 - 30 years)
  - Slower response (seconds)
  - Must be sited above geological repository (e.g., deep salt caverns)
  - Initial costs are high
- Broad applications



[https://www.uigmbh.de/images/referenzen/CAES\\_animiert.gif](https://www.uigmbh.de/images/referenzen/CAES_animiert.gif)

# Flywheels

- Characteristics
  - High power capacity (kW to MW per flywheel)
  - High cycle life (millions)
  - Very fast response (milliseconds)
  - Short term storage
- Limited applications
  - Frequency and voltage regulation, transient stability, stopping and starting electric trains



Courtesy of The University of Sheffield

# Super Capacitor

- Characteristics
  - Very long life
  - Fast discharge (milliseconds)
  - High round trip efficiency
  - High cost
- Limited applications
  - Power quality, frequency regulation, regenerative braking in vehicles



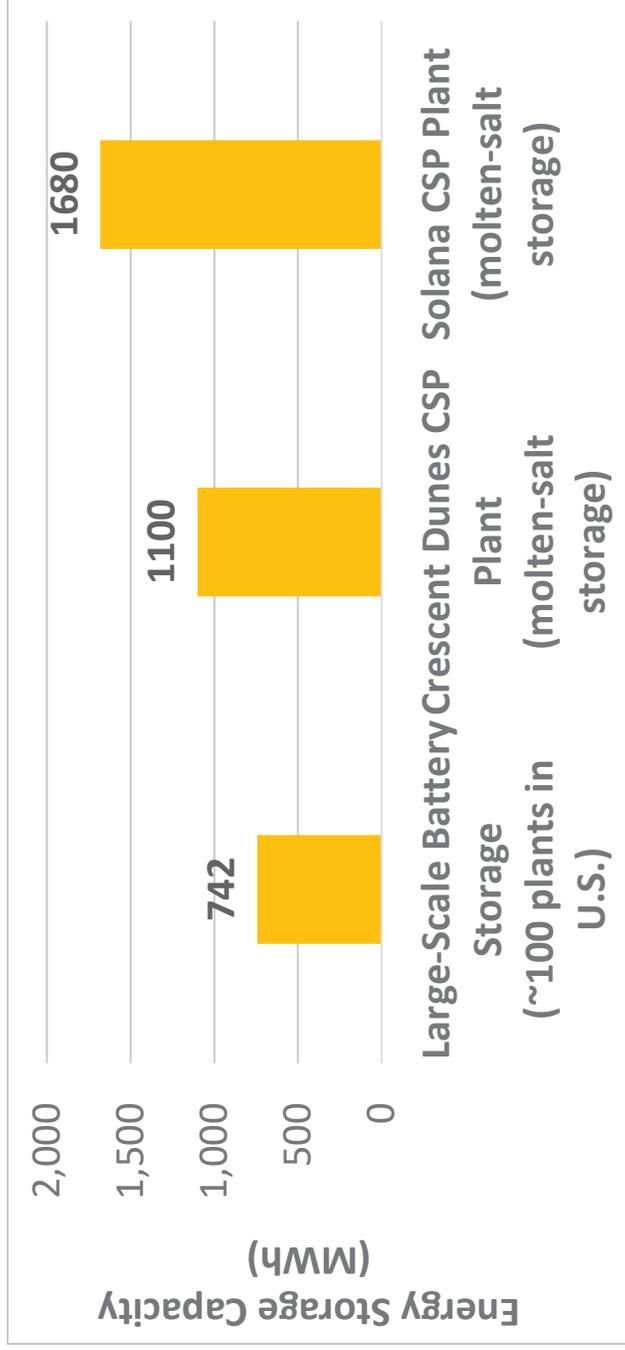
Ultra capacitor module, designed for vehicle applications (e.g., buses, trains)



# Concentrated Solar Power and Thermal Energy Storage



- Mirrors concentrate the sun's energy onto a receiver to provide heat to spin a turbine/generator and produce electricity
- **Hot fluid can be stored as thermal energy efficiently and inexpensively** for on-demand electricity production when the sun is not shining



Battery data from USEIA, 2018

CSP data from Cliff Ho, Sandia National Labs



# Battery Technologies

# How a battery works



- Redox (reduction – oxidation) chemistry drives all biological metabolism



Electrons move from oxygen to carbon

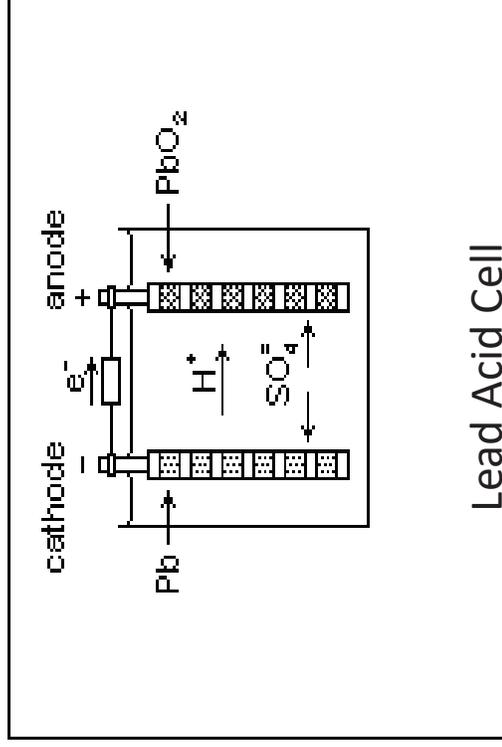
Electrons move from carbon to oxygen

- The same redox chemistry drives battery power

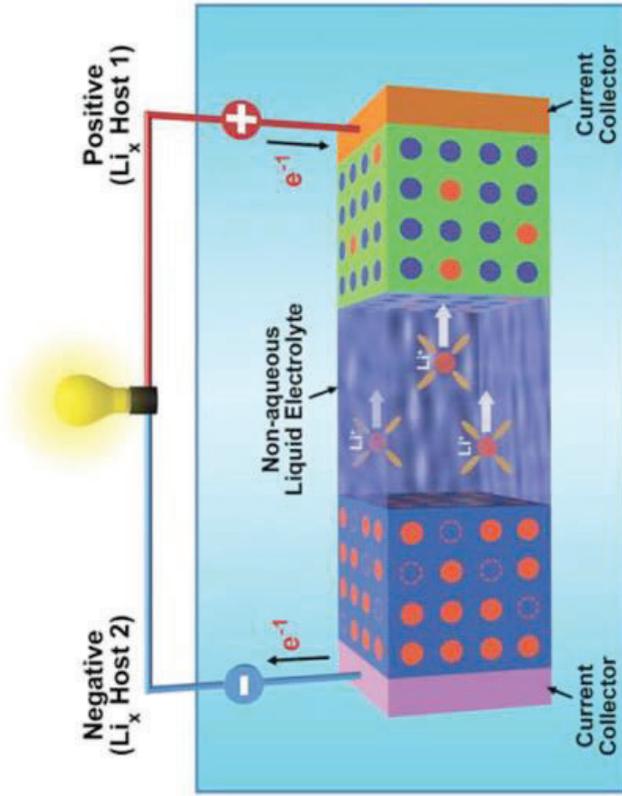
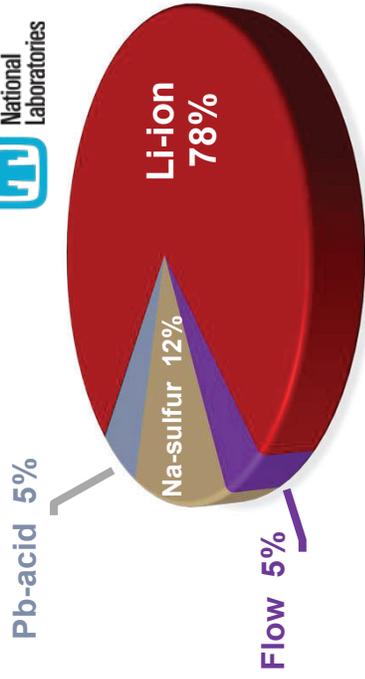


Reduced lead in the presence of oxidized lead, and in a sulfuric acid electrolyte, results in lead sulfate and water, and electrons and move with a force of 2 V.

Oxidation is defined as removal of electrons from an atom leading to an increase in its positive charge, and reduction as addition of electrons resulting in a decrease (reduction) in positive charge.



# Li-ion Batteries

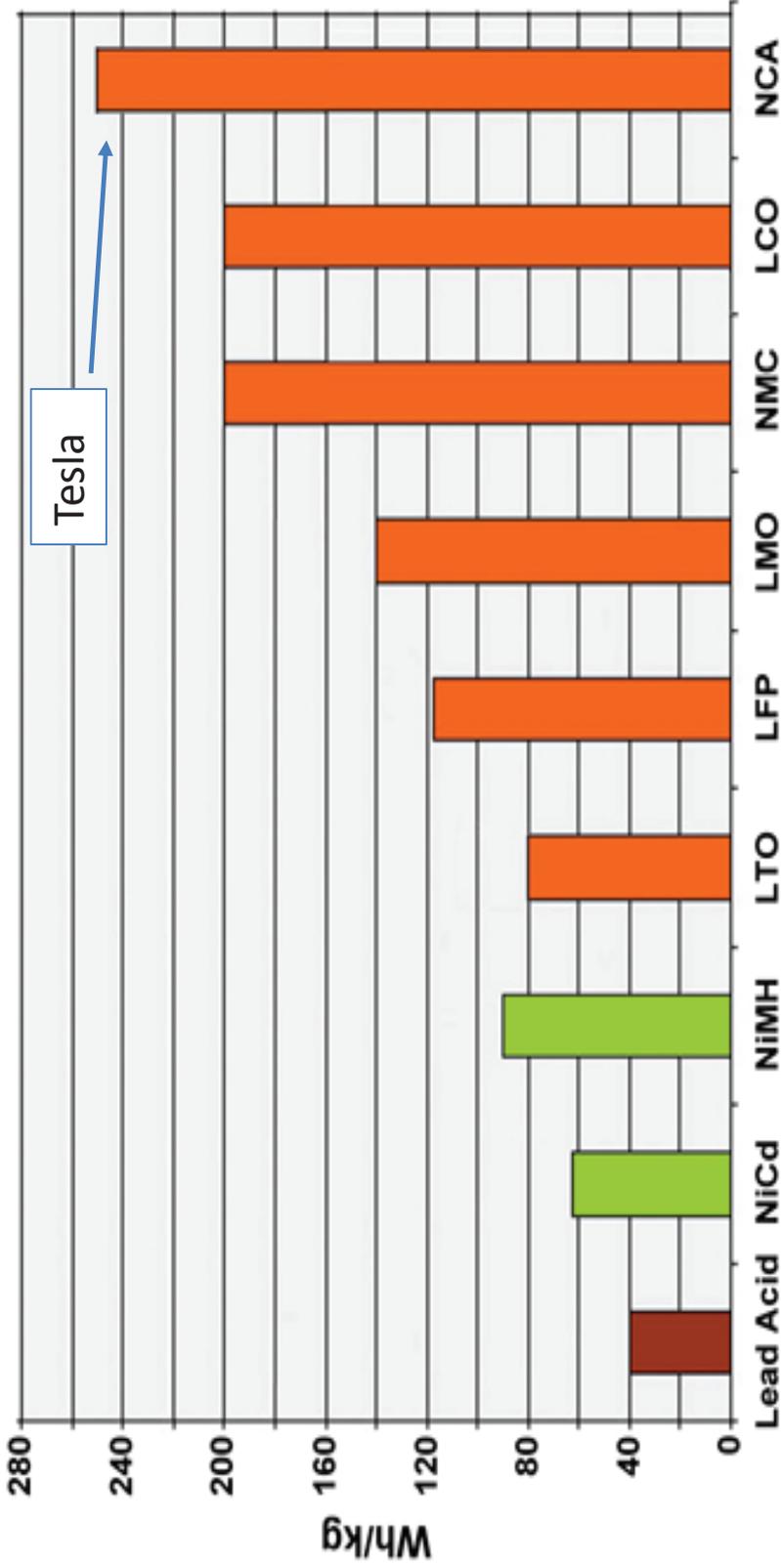


Chemistries	Device
LiCoO <sub>2</sub>	iphone
LiNiO <sub>2</sub>	
LiNi <sub>x</sub> Co <sub>y</sub> Mn <sub>z</sub> O <sub>2</sub>	Volt
LiNi <sub>x</sub> Co <sub>y</sub> Al <sub>z</sub> O <sub>2</sub>	Tesla
LiMn <sub>2</sub> O <sub>4</sub>	
LiMn <sub>1.5</sub> Ni <sub>0.5</sub> O <sub>4</sub>	
LiFePO <sub>4</sub>	
LiMnPO <sub>4</sub>	
LiNiPO <sub>4</sub>	
LiCoPO <sub>4</sub>	

Z. Yang [JOM](#) September 2010, Volume 62, [Issue 9](#), pp 14-23



# Li-ion chemistry energy density



Li-Al Oxide (NCA) enjoys the highest specific energy; however, Li-Mn Oxide (NMC) and Li-phosphate (LFP) are superior in terms of specific power and thermal stability. Li-titanate, LTO) has the best life span.

# Li-Ion Batteries

- High energy density
- Better cycle life than Lead-Acid
  - 5000-10,000 cycles at 100% DOD
- Decreasing costs
  - Stationary follows on coattails of EV battery development
- Ubiquitous – multiple vendors
- Fast response (milliseconds)
- Broad applications
- High efficiency (85-90%)
- Safety continues to be a significant concern
- Recycling is not available yet
- Uses non-domestic rare earth metals



SCE/Tesla 20MW - 80MWh Mira Loma Battery Facility



SCE Tehachapi Plant, 8MW—32MWh



# Tesla and the 18650 Li-ion cell



7104 cells



Tesla Model S Battery Pack

18650 cell format used  
in 85 kWh Tesla battery

An ESS like the 20  
mW – 80 mWh  
Mira Loma System  
would require 6.7  
million of the  
18650 cells

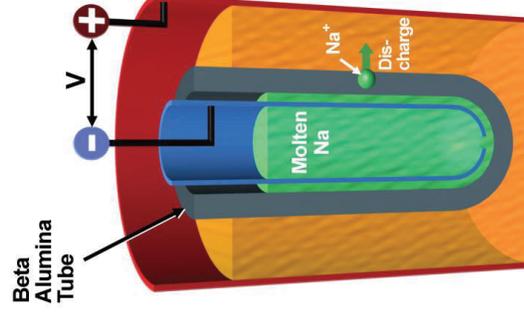
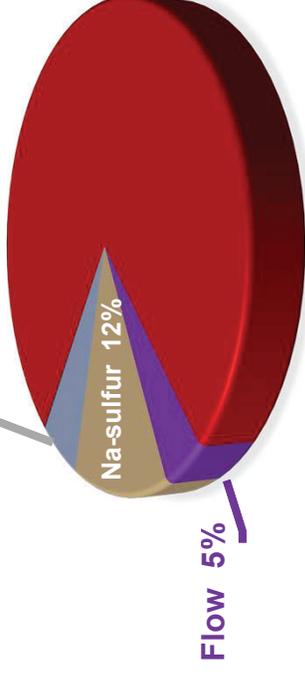


# Sodium (Na) -- Sulfur Batteries

- High energy density
- Life cycles
  - 2500 at 100% DOD
  - 4500 at 80% DOD
- Fast response (milliseconds)
- 85% round trip efficiencies
- Must be kept hot!
  - 300 - 350°C
  - Stand by losses are high, battery has to keep running or be heated up
- Longer term -- 4-6 hours
- Broad applications
- Low production volumes prevent economies of scale



Pb-acid 5%



# Lead Acid Batteries

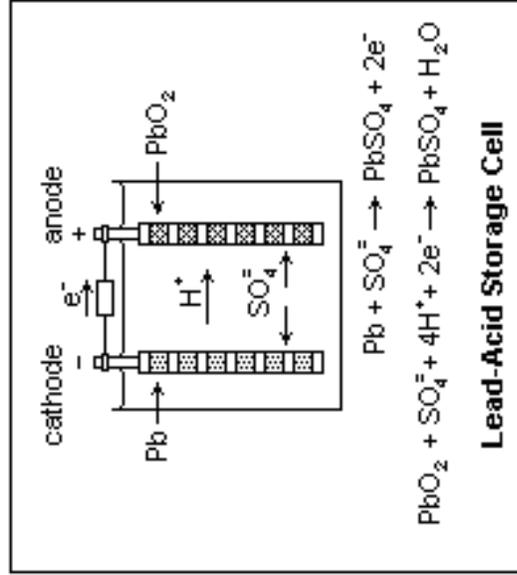
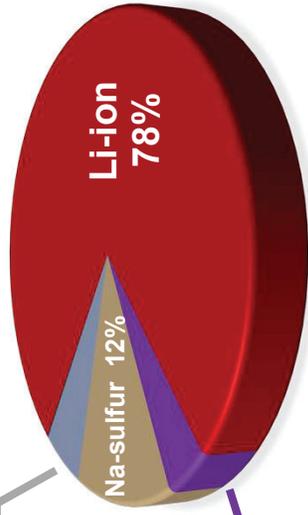


## Characteristics

- The most common batteries worldwide
- Limited life time (5~15 yrs)
- Limited cycle life (500~1000 cycles)
- Degradation w/ deep discharge (>50% DOD)
- Low energy density (30-50 Wh/kg)
- Overcharging leads to H<sub>2</sub> evolution
- Sulfation occurs with prolonged storage
- Recyclable
- Less expensive than the Li-ion
- New lead-carbon systems (“advanced lead acid”) can exceed 5,000 cycles

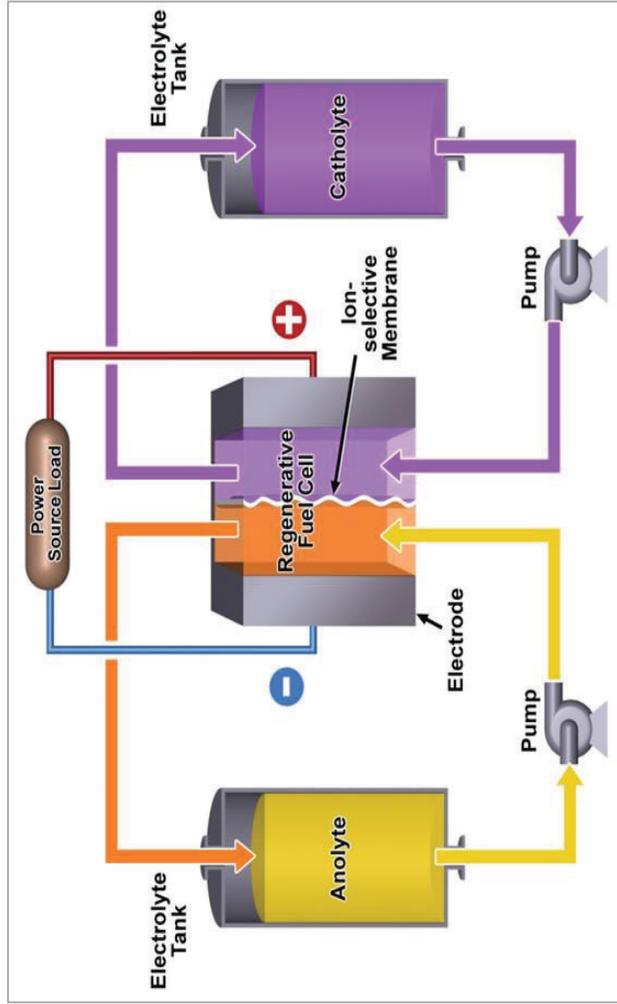
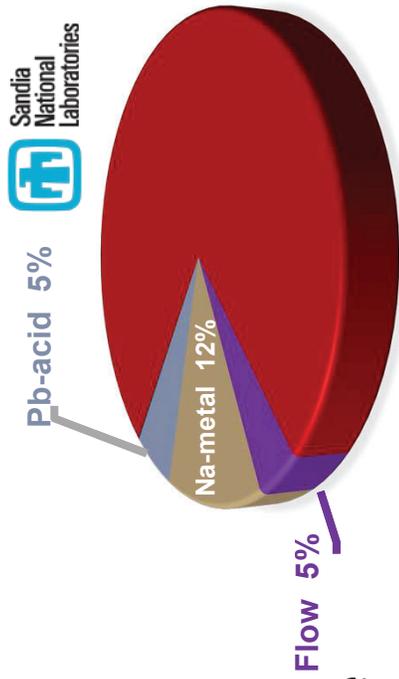


Pb-acid 5%

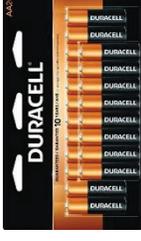


# Flow Batteries

- Wide range of chemistries available
  - Vanadium, zinc bromine, iron chromium
- Flexible -- increase volume of tanks to increase energy (no new racks, no new controllers)
- Suitable for wide range of applications, 5 kW to 10s MW
- Potential long cycle life (tens of thousands) and high duration (10 hours)\*
- Low energy density
- Lower round trip energy efficiency (50-70%)
- More expensive than Li-ion
- Safer than Li-ion
- Still nascent technology



# Zn-MnO<sub>2</sub> alkaline batteries

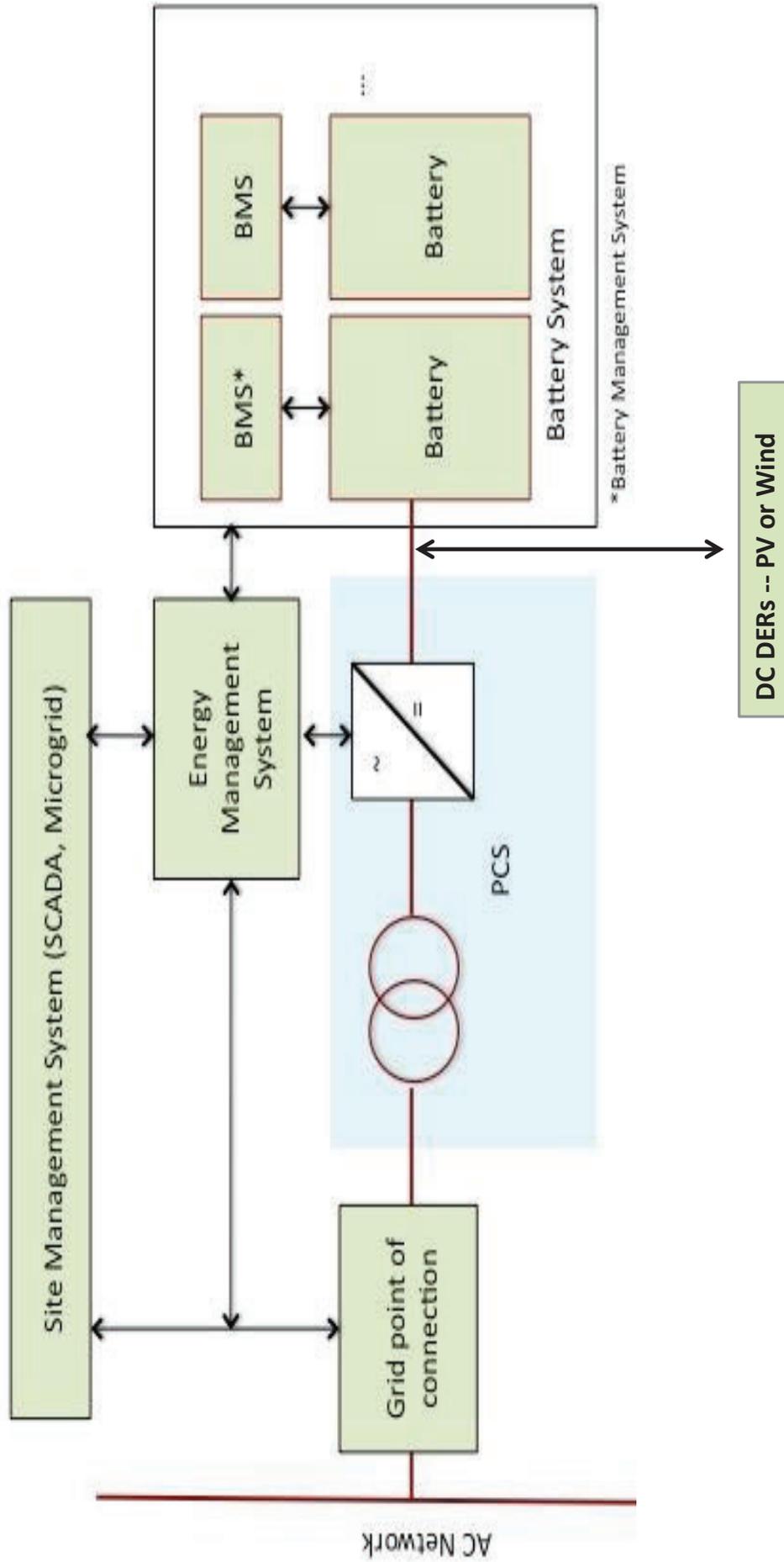


- Traditionally primary batteries, and ubiquitous
- Lowest bill of materials costs and manufacturing capital expenses
- Established supply chain for high volume
- Readily be produced in larger form factors for grid applications
- No temperature limitations of Li-ion or Pb-acid
- Environmentally benign -- EPA certified for landfill disposal
- Projected delivered costs at \$50/kWh
- Reversibility has been challenging
- Cycle life must be improved



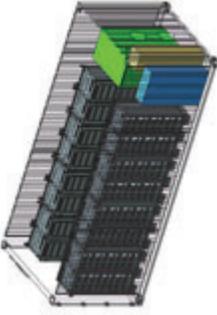
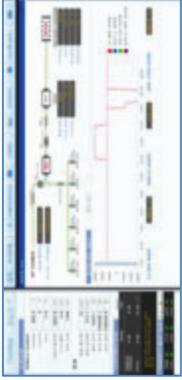
# Battery Energy Storage Systems (BESS)

# BESS topology



# BESS elements



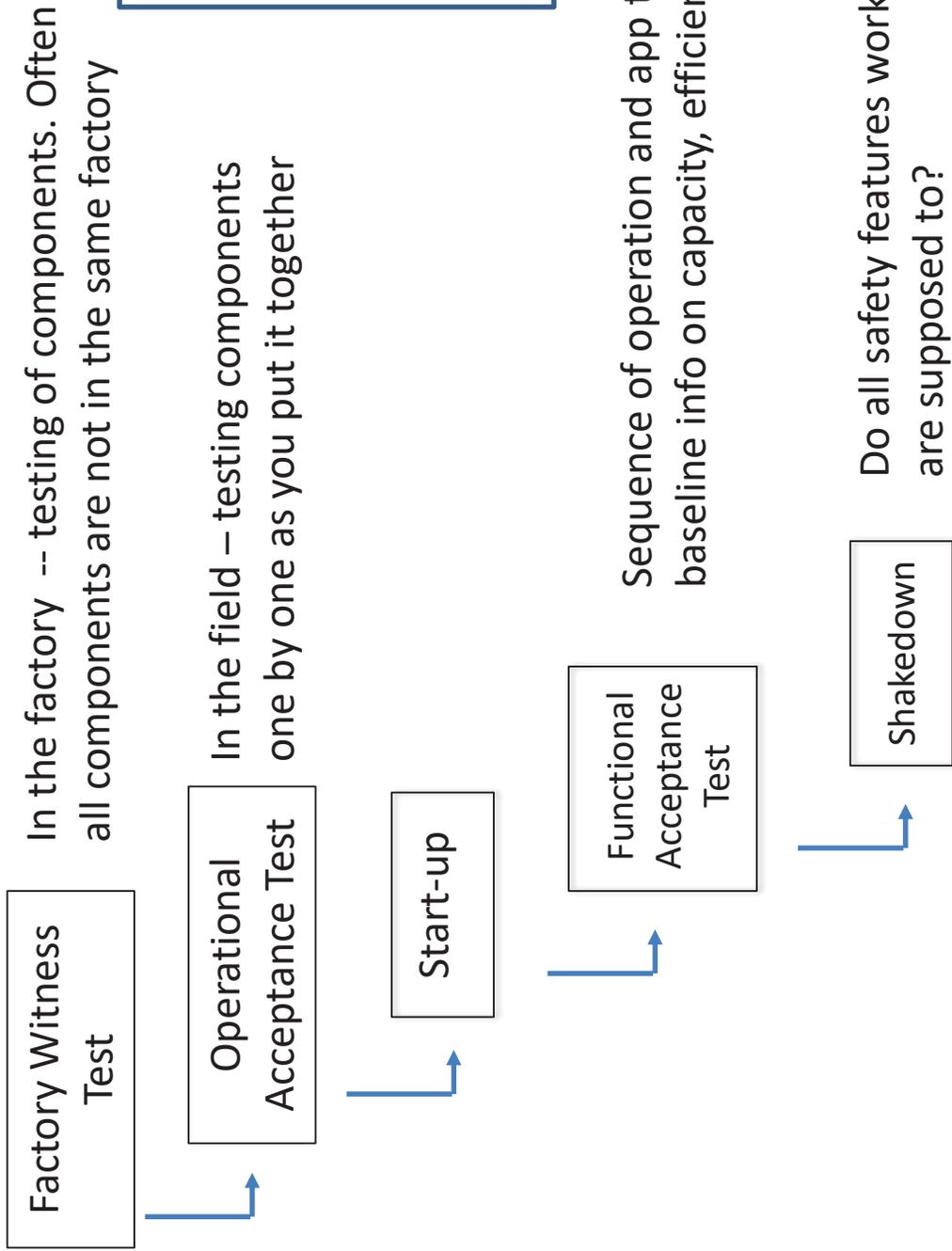
Battery Storage	Battery Management System (BMS)	Power Conversion System (PCS)	Energy Management System (EMS)	Site Management System (SMS)	Balance of Plant
<ul style="list-style-type: none"> <li>Batteries</li> <li>Racks</li> </ul> 	<ul style="list-style-type: none"> <li>Mgmt. of the battery</li> <li>Efficiency</li> <li>Depth of Discharge (DOD)</li> <li>Cycle life</li> </ul> 	<ul style="list-style-type: none"> <li>DC to AC, AC to DC</li> <li>Bi-directional Inverter</li> <li>Transformer, switchgear</li> </ul> 	<ul style="list-style-type: none"> <li>Optimal monitoring and dispatch for different purposes</li> <li>Charge/discharge</li> <li>Load management</li> <li>Ramp rate control</li> <li>Ancillary services</li> <li>Coordinates multiple systems</li> </ul> 	<ul style="list-style-type: none"> <li>Distributed Energy Resources (DER) control</li> <li>Synchronization with grid</li> <li>Islanding and microgrid control</li> <li>Interconnection with grid</li> </ul> 	<ul style="list-style-type: none"> <li>Housing</li> <li>HVAC</li> <li>Wiring</li> <li>Climate control</li> <li>Fire protection</li> <li>Permits</li> <li>Personnel</li> </ul> 

NOTE: Important to have single entity responsible for the ESS integration.

**Whole system installation can increase costs by 2-5x over cost of a cell.**



# Commissioning





# BESS Safety

Development of Inherently Safe Cells



- Safer cell chemistries
- Non-flammable electrolytes
- Shutdown separators
- Non-toxic battery materials
- Inherent overcharge protection

Safety Devices and Systems



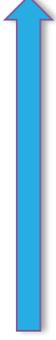
- Current interrupt devices
  - digital or mechanical
- Battery management system
  - Enforces limits on voltage, state of charge, and temperature

Effective Response to Off-Normal Events



- Suppressants
- Containment
- Advanced monitoring and controls

Policy, Codes, and Standards



- Testing and documenting
- Siting
- Interconnection



# Yet other topics



- Design of BESSs will vary depending on intended uses
- Impact of electric vehicles on the grid
- Economics
  - Energy Storage Applications & Revenue Streams
  - Stacking benefits
- Policy
  - ES landscape for states in the US
  - Policy issues
  - Developing an ES policy roadmap



# Many resources are available

[DOE Energy Storage Systems Program](https://www.sandia.gov/ess-ssl/)

<https://www.sandia.gov/ess-ssl/>

[DOE Global Energy Storage Database](https://www.energystoragedatabase.org/)

<https://www.energystoragexchange.org/>

[Clean Energy States Alliance \(CESA\)](https://www.CESA.org)

<https://www.CESA.org>

[Energy Storage Technology Advancement Partnership](https://www.cesa.org/projects/energy-storage-technology-partnership/)

<https://www.cesa.org/projects/energy-storage-technology-advancement-partnership/>

[The Energy Transition Show](https://xenetwork.org/ets/)

<https://xenetwork.org/ets/>

[Utility Dive](https://www.utilitydive.com/)

<https://www.utilitydive.com/>

[Energy Storage Association](https://energystorage.org/)

<https://energystorage.org/>



# Summary points

- Battery technology is improving, spreading, getting cheaper, getting safer, and is expected to boom
- MUCH more battery capacity is required to meet 100% carbon free goals in NM and across the country
- Li-ion overwhelms the market, but many other chemistries are in development
- Batteries can provide important services to the grid
- Batteries can provide many of value streams, but many of those values are hard to quantify, and markets for most don't exist
- PV + batteries is already outcompeting new and existing gas peaker plants

# Acknowledgements



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Dr. Imre Gyuk, Manager of the DOE Energy Storage Program.

Howard Passell – [hdpasse@sandia.gov](mailto:hdpasse@sandia.gov) – 505 284-6469





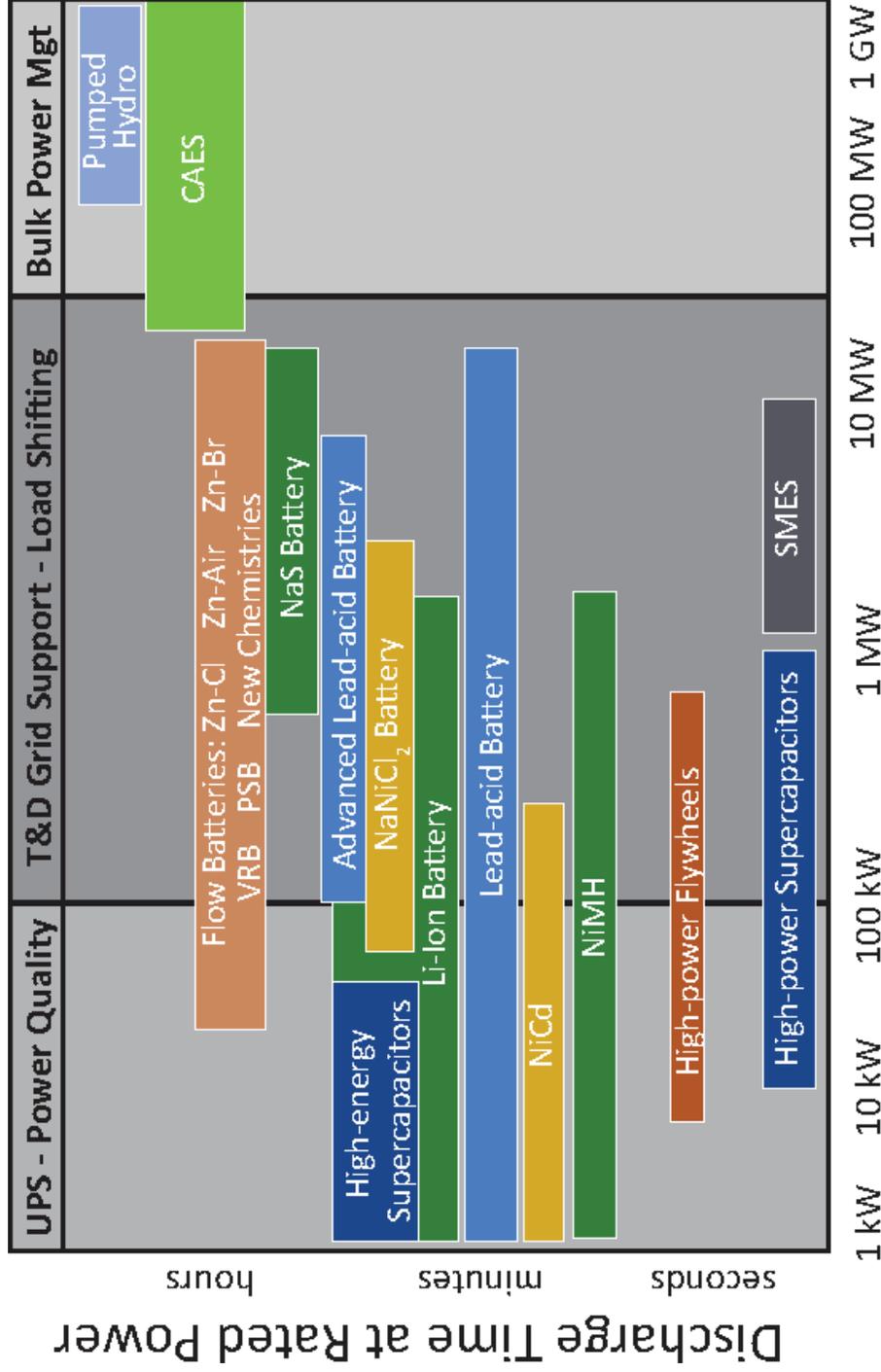
# Additional Slides



# ESS services and value streams

- **Frequency Regulation** – Provide \*up\* regulation by discharging and provide \*down\* regulation by charging
- **Power Quality** -- Mitigate voltage sags by injecting real power
- **Peak Shaving** - Discharge in on-peak periods and charge in off-peak periods
- **Renewables Firming** (PV, wind) -- Supplement RE to provide steady power output
- **Islanded Microgrids** – Support an electrical island separated from the grid
- **New Peakers and Transmission & Distribution Deferral** – Avoid construction of new infrastructure
- **Resilience/Reliability** – Provide power during and after natural disasters and hedge against malevolent attack

# Storage Technology and Applications Markets



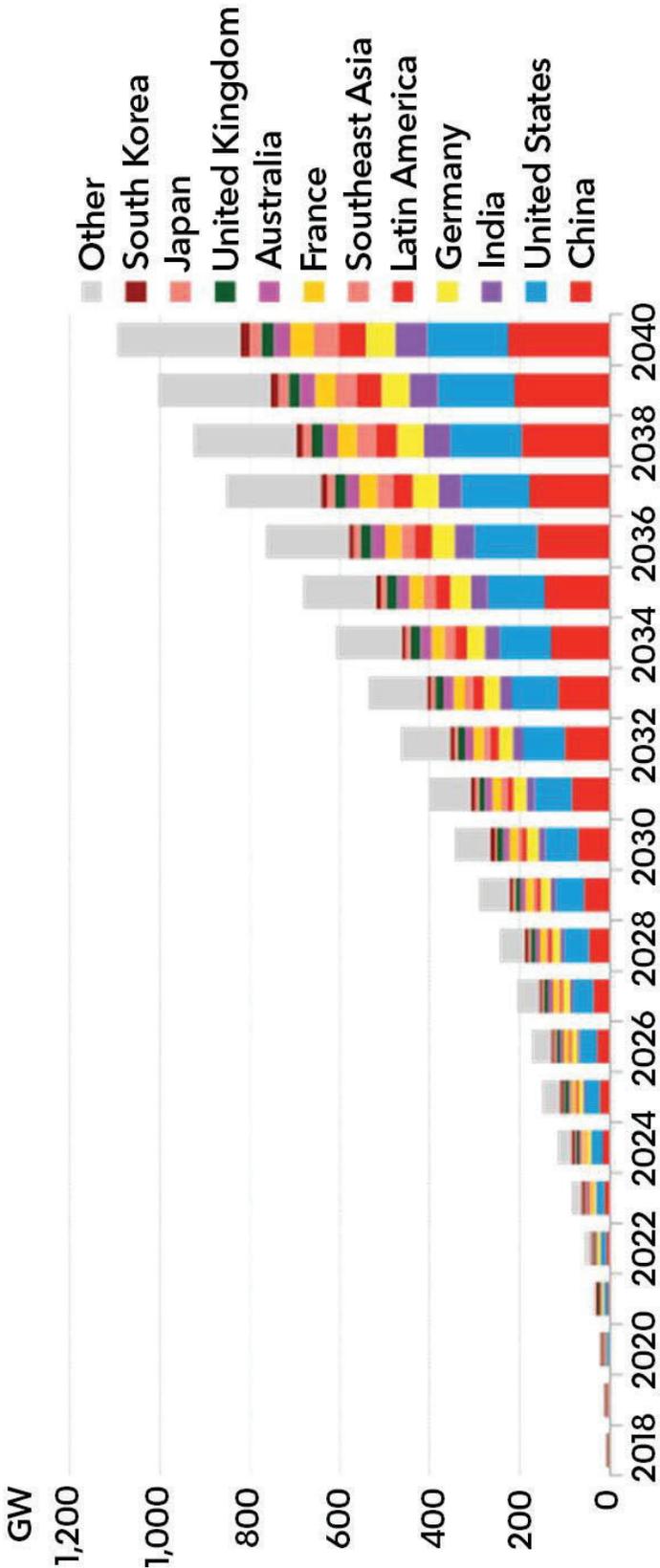
System Power Ratings, Module Size

Source: DOE/EPRJ Electricity Storage Handbook in Collaboration with NRECA, 2013  
50



# Global ES

Global cumulative energy storage installations



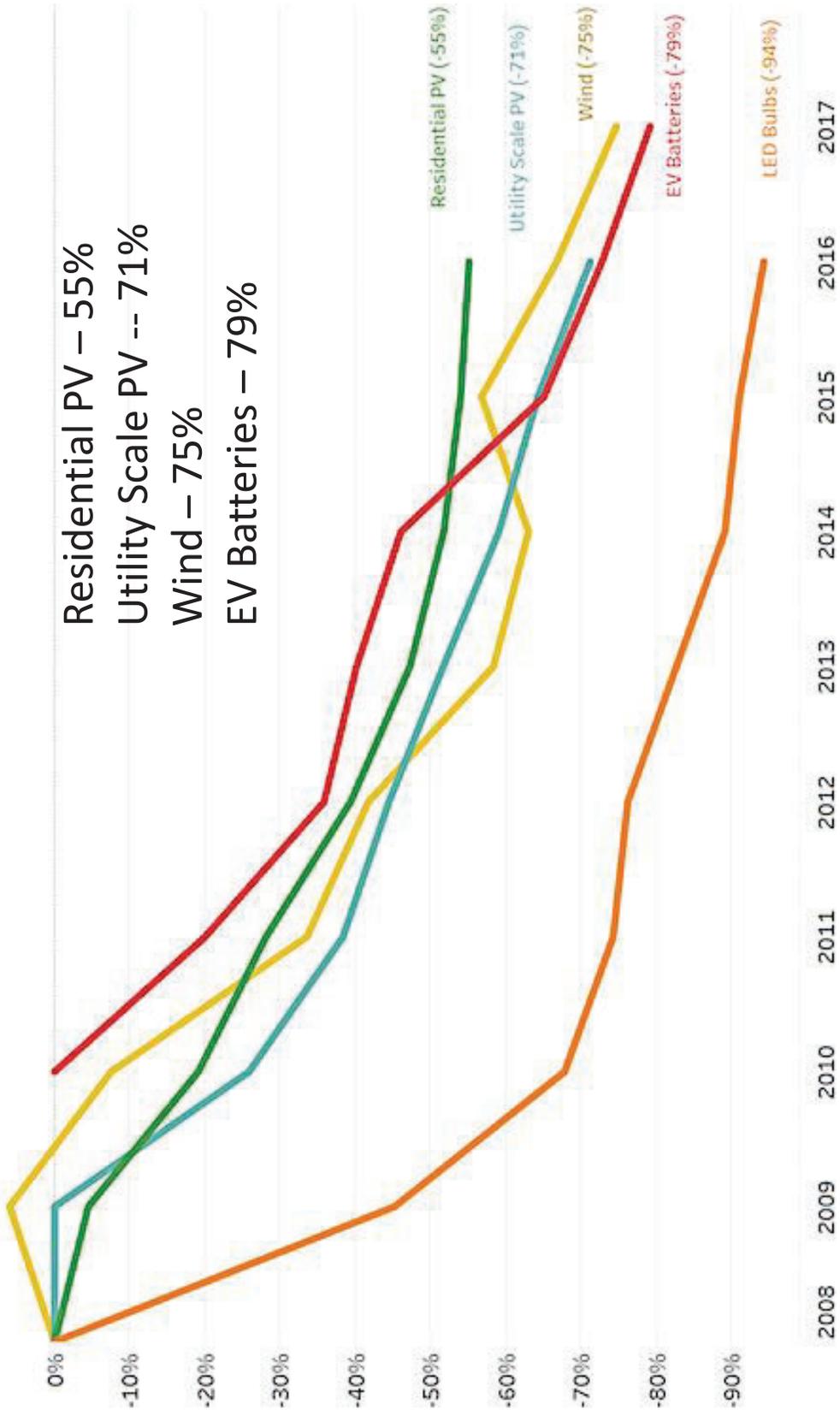
Source: BloombergNEF

<https://about.bnef.com/blog/energy-storage-investments-boom-battery-costs-halve-next-decade/>





# Cost reductions -- 2008-2017



<http://energyfreedomco.org/f4-costs.php>

# Safety through Codes and Standards

- Many ESS safety issues are identical or similar to other technologies
  - Voltage, arc flash, fire hazard, chemical toxicity are all conventional hazards
- Some safety issues are unique to ES in general, some only to particular ESSs
  - NFPA 70E, Standard for Electrical Safety in the Workplace – e.g., locking out or disconnecting energy in all storage systems for maintenance
  - DC voltage safety is associated with all battery types
- Current codes and standards define system safety
  - Tells a designer how far apart to space batteries or what alternative methods and materials criteria might be
- Codes and standards are being updated and new ones developed
- Sandia’s Energy Storage Safety Collaborative – national-scale collaborative addressing safety issues; [sandia.gov/energystoragesafety](https://sandia.gov/energystoragesafety)

# Comparison of Energy Storage Options

Cliff Ho, 2016. A review of high-temperature particle receivers for concentrating solar power. Applied Thermal Engineering.

	Energy Storage Technology					
	Solid Particles	Molten Nitrate Salt	Batteries	Pumped Hydro	Compressed Air	Flywheels
<b>Levelized Cost<sup>1</sup></b> (\$/MWh <sub>e</sub> )	10 – 13	11 – 17	100 – 1,000	150 – 220	120 – 210	350 – 400
<b>Round-trip efficiency<sup>2</sup></b>	>98% thermal storage ~40% thermal-to-electric	>98% thermal storage ~40% thermal-to-electric	60 – 90%	65 – 80%	40 – 70%	80 – 90%
<b>Cycle life<sup>3</sup></b>	>10,000	>10,000	1000 – 5000	>10,000	>10,000	>10,000
<b>Toxicity/ environmental impacts</b>	N/A	Reactive with piping materials	Heavy metals pose environmental and health concerns	Water evaporation/ consumption	N/A	N/A
<b>Restrictions/ limitations</b>	Particle/fluid heat transfer can be challenging	< 600 °C (decomposes above ~600 °C)	Very expensive for utility-scale storage	Large amounts of water required	Unique geography required	Only provides seconds to minutes of storage

<sup>1</sup>Ho, C.K., A Review of High-Temperature Particle Receivers for Concentrating Solar Power, *Applied Thermal Energy*, 2016; Kolb, G.J., Ho, C.K., Mancini, T.R., Gary, J.A., 2011, Power Tower Technology Roadmap and Cost Reduction Plan, SAND2011-2419, Sandia National Laboratories, Albuquerque, NM; Akhil et al., 2015, DOE/EPR Electricity Storage Handbook in Collaboration with NRECA, SAND2015-1002, Sandia National Laboratories, Albuquerque, NM. For solid particles and molten salt, we assume a 30 – 50% thermal-to-electric conversion efficiency and 10,000 lifetime cycles for the thermal-to-electric storage and conversion systems; the cost includes the storage media (bulk ceramic particles and sodium/potassium nitrate salts ~\$1/kg with  $\Delta T = 400\text{ }^\circ\text{C}$  and 9 hours of storage), tanks, pumps/piping/valves, other parts and contingency, and the power block at \$1000/kW<sub>e</sub> with 19 operating hours per daily cycle (including 9 hrs of storage) and 90% availability. For batteries, cost is based on sodium-sulfur, vanadium-redox, zinc-bromine/lead-acid, and lithium-ion batteries capable of providing large-scale electricity.

<sup>2</sup>Roundtrip efficiency defined as ratio of energy in to energy retrieved from storage; Djaadwinata, E. et al., 2014, Modeling of Transient Energy Loss from a Cylindrical-Shaped Solid Particle Thermal Energy Storage Tank for Central Receiver Applications, Proceedings of the ASME 8th International Conference on Energy Sustainability, 2014, Vol. 1.; Siegel, N.P., 2012, Thermal energy storage for solar power production, Wiley Interdisciplinary Reviews-Energy and Environment, 1(2), p. 119-131.; <http://energymak.net/round-trip-efficiency/>

<sup>3</sup>Siegel, N.P., 2012, Thermal energy storage for solar power production, Wiley Interdisciplinary Reviews-Energy and Environment, 1(2), p. 119-131.

Sandia National Laboratory Workshop on Energy Storage Policy

# PNM Exhibit WK-2 (Rebuttal)

Is contained in the following 49 pages.



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national  
interest*



# Energy Storage Policy Workshop



**Prepared for the New Mexico Public  
Regulatory Commission**

**Will McNamara, SNL**



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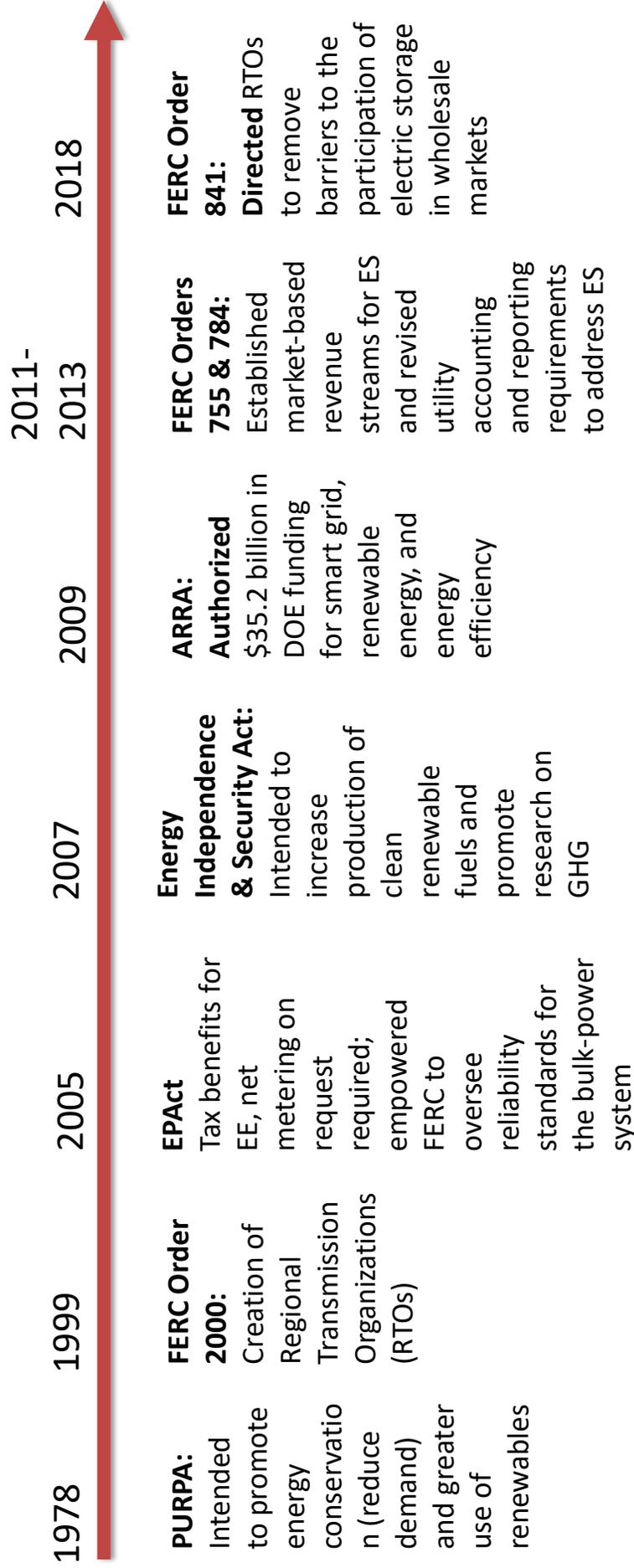
# Energy storage policy is the focus of this workshop.



- We will be covering the following topics:
  - Historical context of utility-industry policymaking
  - Overview of federal versus state responsibilities
  - Federal activity to date
  - The key energy storage policy issues at the state level
  - State activities to date
  - Considerations for state regulators
  - Q&A session

# Historical Context

- Policy development has been a consistent catalyst for reform in the risk-averse, slow-to-change utility industry.



# Federal Vs. State Responsibilities

## FEDERAL

FERC, Congress, potential for federal agencies to act (e.g., EPA)

- Rules governing wholesale markets / RTOs (FERC)
- Rules governing transmission lines (FERC)

## STATES

PUCs, state legislatures, executive directives from governors

- Retail markets
- Operations of distribution networks
- Utility rates

# Federal Activities



- FERC Order 841
- Directed RTOs to remove barriers to the participation of electric storage in wholesale markets
- RTOs must establish rules that open capacity, energy, and ancillary services markets to energy storage
- Obviously does not apply to Texas or vertically integrated, non-RTO markets
- Pending Congressional activity to define a storage ITC
- The Energy Storage Tax Incentive and Deployment Act, would extend to batteries and other electric storage systems the same 30% ITC offered to solar PV systems

# Development of energy storage policy varies greatly state to state.

According to the Energy Storage Association (ESA), U.S. states generally fall into four categories when assessing the current status of their energy storage policy development.

INVESTIGATING	CLARIFYING	ENERGIZING	PLANNING
States that have demonstrated an interest in storage through general investigations, workshops, or briefings.	States that are clarifying existing rules, through revising interconnection, net metering, fire and building codes, and other state standards as applicable.	States that are encouraging energy storage through procurement targets, pilot / demonstration project funding, or other mandates or incentives	States are that are addressing energy storage through broader long-term resource planning, resource valuation efforts, grid modernization or distribution system planning.

# Key Energy Storage Policy Issues—States



Each of the 50 U.S. states (plus territories) will need to develop policy on many energy storage issues:

- Procurement mandates
- Incentives / tax credits
- Utility ownership
- Inclusion of storage in utility IRPs
- Changes to net metering policies
- Changes to RPS programs
- Multiple use applications
- Cost / benefit analysis
- Distribution system modeling
- Rate design specific to BTM storage
- Changes to interconnection standards

# Policy Issues—*Procurement Mandates*



**The Issue:** Procurement targets are mandates set by a state that require utilities to acquire a specified quantity of energy storage, intended to provide more opportunities for energy storage.

## **PROS**

- Used to stimulate market development
- Provides cost recovery certainty for utilities
- Storage targets are “in the public’s best interest”
- A mandatory approach for storage is compatible with most RPS policies

## **CONS**

- Uncertainties about how to determine appropriate procurement levels & benefits
- Mandates allow the government to pick “winners” rather than the marketplace.
- Current resource planning is sufficient; 100% renewables will drive storage anyway

# Policy Issues—Procurement Mandates



Procurement mandates are still rather uncommon. Only five states have mandates, with others looking at the issue.

CA	MA	NJ	NY	OR	“In consideration mode”
1,825 MW by 2020	200 MW by 2020	2,000 MW by 2030	3,000 MW by 2030; interim goal of 1,500 MW by 2025	5 MW by 2020	AZ NV NM— considered and rejected
LEG & REG	LEG	LEG	REG	LEG	

# Policy Issues—*Procurement Mandates*



## *Policy Considerations:*

- Can procurement mandates be effective if other legal or regulatory hurdles to energy storage remain unaddressed?
- What is the best approach toward determining appropriate and realistic mandates?
- Should the mandates be state-wide or utility-specific?
- Should the mandates apply to IOUs only or munis and cooperatives as well?
- What steps can be taken to ensure that ratepayers do not incur increased costs for arbitrary procurement levels, or face increased costs without associated benefits?

# Policy Issues—*Incentives / Tax Credits*



**The Issue:** Regulatory frameworks typically prevent utilities & end-use customers from being able to monetize the value of ESS. Incentives can serve as a bridge to jumpstart a market while regulatory policies are finalized.

## **PROS**

- Pay-for-performance metrics that incentivize utilities to improve the utilization of existing assets can be very effective in deferring infrastructure investments
- Customer incentives can be tied to the economic value that is brought to the grid

## **CONS**

- Providing subsidies to ES can quickly become complicated--- e.g., determining if the battery is charged by renewable energy or grid electricity
- Undefined parameters create a gap allowing parties to “double dip”

# Policy Issues—*Incentives / Tax Credits*



- California, New Jersey, Maryland and Nevada are acting as leaders in this movement
  - CA: Smart Grid Incentive Program; incentives for customers who produce electricity through storage
  - MD: First state to provide an ITC for storage
  - NV: SESIP program; rebates for solar + storage
- Massachusetts, New York and Hawaii seem to be next in line
- So far, California is the only state in which an incentive program for storage has actually be implemented (the SGIP)

# Policy Issues—*Incentives / Tax Credits*



- While the debate continues whether or not state-level incentives for ES are necessary, some “best practices” are emerging.



- 1<sup>st</sup> state to adopt a state-level, 30 percent tax credit for energy storage devices

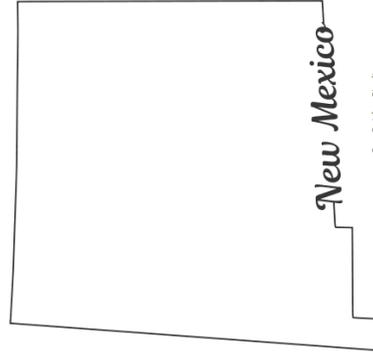


- 1<sup>st</sup> state to allow BTM batteries to be eligible for funding support from a large energy efficiency budget

# Policy Issues—Incentives / Tax Credits

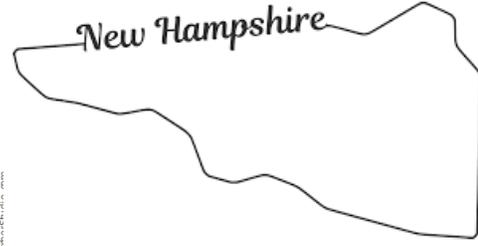


- Other notable states that offer a subsidy for energy storage , or are planning to do so, include:



- A taxpayer who holds an interest in a ESS can claim an advanced energy income tax credit in an amount equal to 6%

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- Innovative approach in which Liberty Utilities provides residential customers with Tesla Powerwall batteries—Customers get back-up power and TOU rates; the utility gets an alternative to more capital-intensive grid upgrades.

# Policy Issues—Incentives / Tax Credits



## Policy Considerations:

- Should a state develop unique incentive levels for energy storage paired with solar, energy storage intended to help boost behind-the-meter storage, etc.?
- From what funding sources will the incentive be supported?
- If ES is to be subsidized through existing EE budgets, how will that be justified (e.g., cost/benefit analysis)?

# Policy Issues—*Utility Ownership*



**The Issue:** Given that storage is typically classified as energy storage, should utilities be allowed to own storage assets in deregulated markets?

## **PROS**

- Opportunity for long-range, system-wide planning
- Opportunity to optimize the distribution system
- Enhanced flexibility to use cost-effective resources
- Enhanced economies of scale (i.e., prices drop with larger projects)

## **CONS**

- Market power concerns
- Utilities would have an advantage over 3<sup>rd</sup> parties, creating an unlevel playing field
- Uncertainties about utility cost recovery and equitable rate treatment among customers

# Policy Issues—*Utility Ownership*



## Point of Reference:



The Reforming the Energy Vision (REV) is the comprehensive energy strategy for the State of New York.

- Utilities operate a DER platform
- Utilities are neutral about which resources provide grid services
- New York PSC originally prohibited utilities from owning BTM DER, based on concerns about market power
- Subsequently, revisions to REV acknowledge the unique potential for storage, and exceptions for utility ownership can be pursued on a PBR basis

# Policy Issues—*Utility Ownership*



## Point of Reference:



*Texas has been a battleground on the issue of utility ownership. New law allows ownership only among public power entities.*

- Texas law defines ESS as generation.
- T/D utilities cannot own generation
- No capacity market or opportunity for frequency reg / arbitrage
- AEP Texas petitioned to own 2 battery storage assets. PUCT punted the issue to Texas Legislature
- New law allows munis and cooperatives to own ESS that sell energy and/or ancillary services

# Policy Issues—Utility Ownership



*Other points of reference:*

## Colorado



Xcel Energy's plan is to replace coal-fired generating plants with utility-owned storage.

## Oregon



Regulatory directive requires consideration of multiple options, including utility ownership.

# Policy Issues—*Utility Ownership*



## *Policy Considerations:*

- How can state regulators ensure that utilities do not gain the potential for market manipulation and / or stifling competition, growth, and innovation?
- How can state regulators ensure that a level playing field exists for third-party providers?
- Will the rate-basing of energy storage investments drive down market value of services?
- What are the regulatory limitations of rate-based investment process specific to energy storage?

# Policy Issues—*Inclusion in Utility IRPs*



**The Issue:** Because traditional IRP models do not consider many of the services that energy storage can provide, the technology does not fit neatly into IRP planning processes.

## **PROS**

- Thermal & electrochemical ES are competitive with natural-gas peaker plants in some cases, and should be considered as an alternative
- Long-term consideration of ES addresses other policy requirements (e.g., for renewables or clean energy)
- Provides certainty around the role that ES will play going forward

## **CONS**

- Lack of reliable cost data and “best practices”
- Lack of tools or protocols for analyzing storage
- Would only apply to vertically integrated utilities that are still responsible for generation resource plans (not restructured markets)
- Does not address local values and flexibility of storage

# Policy Issues—*Inclusion in Utility IRPs*



New Mexico is one among only a handful of states that have thus far explicitly required the inclusion of ES in IRPs (as opposed to voluntary inclusion).



**Colorado**



**New Mexico**



**Indiana**



**North Carolina**

# Policy Issues—*Inclusion in Utility IRPs*



## **Policy Considerations:**

- Ensure that storage is included as a eligible technology for IRPs (majority of states do not)
- How can utilities and regulators ensure that they have access to energy storage data on cost and performance of energy storage systems?
- How can utilities and regulators make sure that they are choosing a resource planning model that can fully represent the benefits of storage and how the technology functions?
- Does the method allow for sub-hourly and stacked benefits modeling?

# Policy Issues—Changes To Net Metering



**The Issue:** Pairing solar-plus-storage with NEM has received minimal policy attention to-date due to low level deployments. However, the issue is emerging as pairing energy storage with solar energy systems becomes more economical.

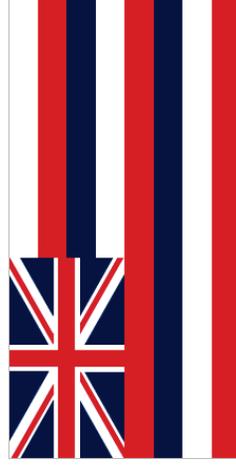
## **PROS**

- A strong market signal would be achieved if certifiably solar-powered batteries could get paid through NEM.
- Addresses the issue of states (e.g., California) reducing the value of traditional solar through TOU rates.
- Adding storage may be a prerequisite for a residential solar project to pencil out.

## **CONS**

- Utilities don't want to pay net metering (retail) rates to batteries charged by grid power
- Adding energy storage to a solar project adds a layer of complexity

# Policy Issues—Changes To Net Metering



## CALIFORNIA:

December 2017:  
NEM successor tariff modified virtual net metering to facilitate pairing eligible generation with energy storage.

## COLORADO:

1<sup>st</sup> state to adopt a consumer right to energy storage, which is prompting revision of NEM policy, among other policies.

## HAWAII:

Successor tariffs to NEM allow customers to choose a “smart export” option for solar + storage systems (among other non-exporting tariffs)

# Policy Issues—Changes To Net Metering



## Policy Considerations:

- Ensure that the credit given to storage is renewable energy produced and not energy purchased and resold from the grid.
- It is important to keep the bill credit separate from the rate itself.
- Are net metering programs obsolete? Instead of revising NEM, should NEM be replaced with successor tariffs?
- How can utilities and regulators address prices for energy storage that are based on location?

# Policy Issues—Changes To RPS Mandates



**The Issue:** Should an RPS require energy storage, or should objectives for ES be addressed separately?

## **PROS**

- Integrate intermittent renewable energy
- Help shift renewable generation to more closely match peak loads
- Provide generation and load balancing services
- Reduce the need for peaking and backup generators on the grid
- Reduce customer demand charges

## **CONS**

- Uncertain if regulators need to encourage storage specifically—encouraging renewables may be enough to stimulate storage
- Once an RPS is reopened, opponents of renewable energy could take the opportunity to revise, weaken or revoke the state’s obligations

# Policy Issues—Changes To RPS Mandates



Six states have each adopted an RPS of 50% or more; four of these states also have separate procurement targets for storage.

	CA	HI	NJ	NY	OR	VT
<b>RPS Mandate</b>	60% by 2030	100% by 2045	50% by 2030	70% by 2030	50% by 2040	75% by 2032
<b>Storage Mandate</b>	1,825 MW by 2020		2,000 MW by 2030	3,000 MW by 2030	5 MW by 2020	

## Policy Considerations:

- If energy storage is to be included in RPS mandates, which ES technologies should be covered? Just batteries...or CAES, flywheels, pumped hydro, hydrogen....others?
- Should eligibility for energy storage be based on performance characteristics, such as:
  - Minimum or maximum capacity?
  - Minimum duration the technology can hold a charge?
  - Whether or not the storage installation can be remotely controlled for dispatchability?
- Must energy storage be co-located or integrated with specific generation, or can it stand alone on the grid?

# Policy Issues—*Multiple Use Applications*

**The Issue:** The unique characteristics of ES (both load and supply) create flexibility to provide multiple uses or applications, sometimes simultaneously, and therefore layer on more than one revenue stream.

## **PROS**

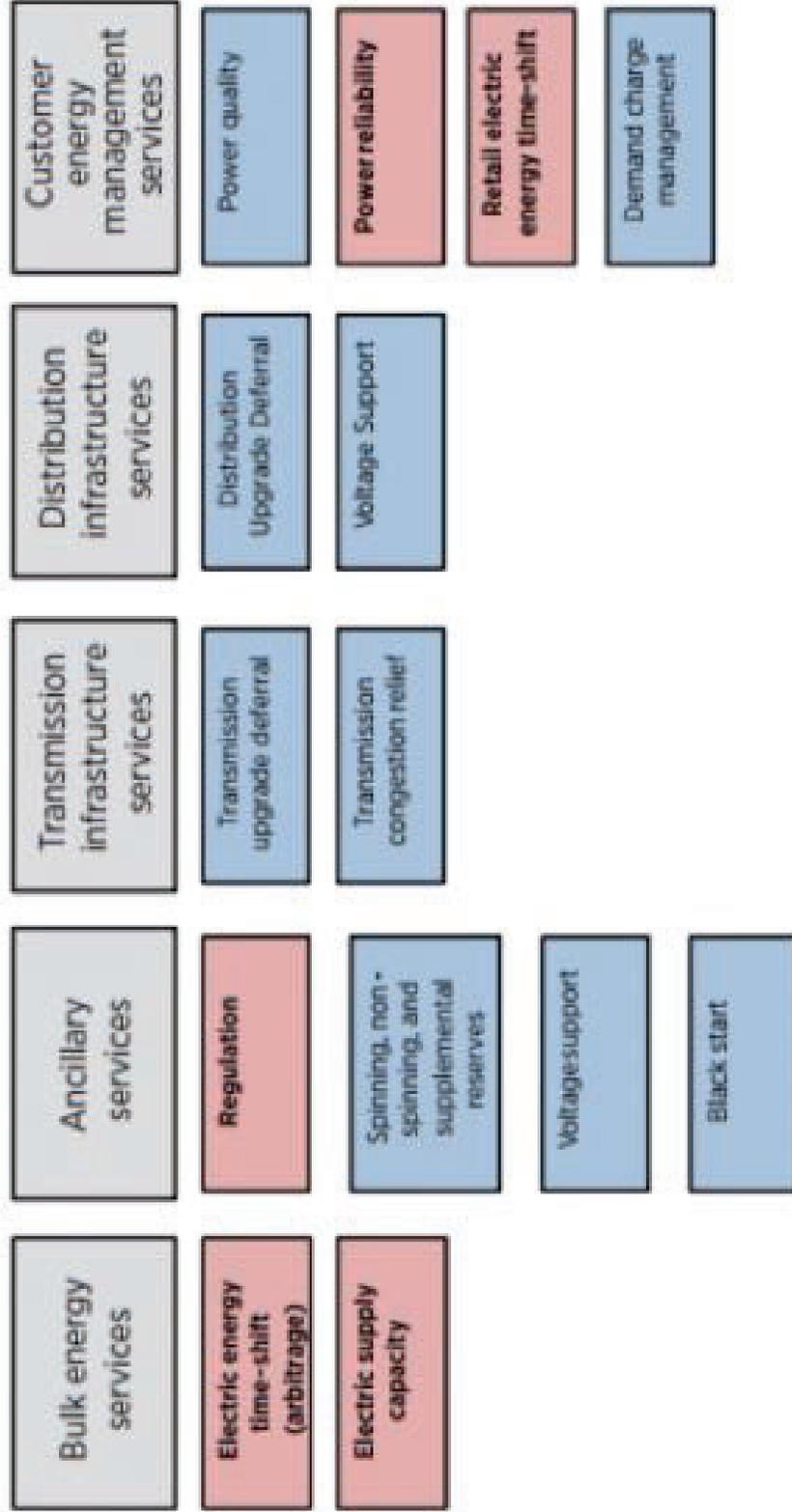
- Consideration of multiple uses allow ES to achieve its full economic potential
- Composite forms compensation can combine energy, capacity, environmental, location and temporally specific demand relief value

## **CONS**

- Most energy storage installations today consist of either behind-the-meter or grid-tied applications, but not both
- Some uses may have high priority than others (e.g., reliability), which may create conflicts in the marketplace

# Policy Issues—Multiple Use Applications

While this is an emerging area for policymaking in multiple jurisdictions, there are some trends:



# Policy Issues—*Multiple Use Applications*



In 2018, California became the first state to issue revenue stacking rules for energy storage projects.



- Developed a set of 11 rules on revenue stacking
- Series of dockets and working groups to address compensation for PUC jurisdictional services, appropriate metering and measurement of Multi-Use Applications, and PUC enforcement of Multi-Use Application rules

# Policy Issues—*Multiple Use Applications*



Oregon followed California's lead.... With guidelines for revenue stacking within the 5 MWh energy storage mandate.



- PUC guidelines encourage projects that “stack” revenues by being able to serve multiple applications.
- PGE responded that it is pursuing ES projects that provide:
  - Energy shifting and arbitrage
  - Ancillary services
  - Avoid renewable curtailment
  - System peaking and capacity value
  - Locational value

# Policy Issues—Multiple Use Applications



## Policy Considerations:

- How should multiple use applications be prioritized—for instance, does system reliability have a greater value than other services?
- How will the multiple values of energy storage be tracked? For instance, in CA resources interconnected in the transmission domain are restricted from providing services to distribution domains.
- How can BTM energy storage provide grid services, and how should they be priced?

# Policy Issues—*Cost/Benefit Analysis*



The Issue: Current market structures and policies lack clear mechanisms to identify and capture the full value of ES.

## PROS

- Cost-effectiveness is one of two tests that must be met to establish any energy storage procurement target
- Accurate cost and benefit modeling will help justify utility cost recovery applications
- Market participants need to identify and prioritize customers for whom storage is profitable

## CONS

- Currently there is no universal approach toward defining costs and benefits of energy storage
- Assessing the viability of ES is a challenge given that technologies vary in stages of development from traditional to advanced systems
- Wide range of performance create variances in efficiencies & costs

# Policy Issues—*Cost/Benefit Analysis*



- Legislation in MN has directed the state's Department of Commerce to conduct an energy storage C/B analysis, in order to determine the value of adding the resource to the electric grid.

# Policy Issues—Cost / Benefit Analysis



## Policy Considerations:

- Most cost/benefit analyses for energy storage are based solely on the energy benefits of storage, ignoring many non-energy benefits such as job creation, reduced land use, reduced grid outages, and higher property values. What steps can be taken to capture non-energy benefits?
- What steps can be taken to ensure that these non-energy benefits are captured?
- How can a cost/benefit analysis for ES ensure that multiple applications are included and address the unique configurations of ES based on where the EES facility is located?

# Policy Issues—*Distribution System Modeling*



**The Issue:** Much of new storage is expected to be connected to distribution feeders. However, distribution planners lack tools and methods to assess storage impact on distribution system capacity, reliability, and power quality.

## **PROS**

- Effective distribution system modeling supports optimal ESS sizing, placement, and operation are studied
- Distribution modeling provides location power quality improvements, mitigation of voltage deviation, frequency regulation, load shifting, etc.

## **CONS**

- Energy storage modeling requires sequential-time simulation, as opposed to more traditional static power flow calculations
- Mis-using or mis-locating ESSs in distribution networks can degrade power quality and reduce reliability as well as load control

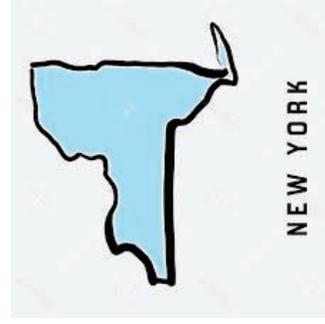
# Policy Issues—*Distribution System Modeling*



California and New York lead the way for requiring utilities to include energy storage in advanced distribution system modeling and planning.



- CPUC required 3 IOUs to submit Distribution Resource Plans that find opportunities to site, value and integrate renewable energy.
- The Plans include site specific evaluations for ES



- REV model envisions utilities acting as Distributed System Platform providers
- For the past three years, regulators, utilities and other stakeholders concentrated on filing proposals for the DSIP (Distribution Service Implementation Plans) process and rolling out pilot programs

# Policy Issues—Distribution System Modeling



## Policy Considerations:

- Long-term distribution planning usually requires large simulation durations in order to account for the uncertainties of system parameters. What planning model can be used to demonstrate distribution functions representing charging and discharging behavior that is unique to ES?
- Energy storage will continue to pose challenges for distribution planning: Insufficient resources, inadequate transmission corridors, high uncertainty and volatility of renewable resources. How will these challenges be addressed?

# Policy Issues—*Interconnection Standards*



**The Issue:** Interconnection standards that preceded renewables and ES technologies are likely in need of revision.

## **PROS**

- Interconnection is a critical step for any resource that operates while connected to a utility's grid
- Interconnection standards can be integrated with other policies covering net metering, distribution planning, integrated resource planning, and energy efficiency to support a comprehensive clean energy plan

## **CONS**

- ES technology is so nascent that interconnection standards can still not envision the full potential of services and benefits that storage can bring to the grid
- Integration of large amounts of DERs can negatively affect the reliability and operational stability of power system

# Policy Issues—*Interconnection Standards*



## A Tale Of Two States....



- The ACC has recognized that its legacy standards need to be revised to address the unique interconnection requirements of DERs and storage
- Draft rules were published in June 2015 but by late 2019 final statewide rules have not been adopted
- Utilities in Arizona have developed their own rules, but this has caused inconsistent requirements



- Interconnection rules have not been revised since 2004.
- New revisions include energy storage systems in the definition of eligible projects
- Modeled off of 2014 FERC SGIP
- Fast-track approval allowed for some ES projects

# Policy Issues—*Interconnection Standards*



## *Policy Considerations:*

- Does the state utilize the foundation provided by IEEE Standard 1547-2018 to support common design and component use?
- Do the Interconnection Standards ensure applicability to multiple services for storage (at minimum addressing storage as a generation source and load source)?
- Do the Standards provide rules for exporting, non-exporting, and limited exporting storage technologies?

# State Activities



- Approximately 15 U.S. states have developed substantive energy storage policy as of Nov 2019.
- At this time, these states represent “best practices” for state-level energy storage policies.

PM	I/TC	IRPs	NEM	RPS	C/B A	DSM	IC
CA	MD	CO	CA	CA	MIN	CA	AZ
MA		IN	CO	HI		NY	
NJ		NJ	HI	NJ			
NY		NM		NY			
OR				OR			
				VT			

# Regulatory Roadmap



- While it is difficult (and dangerous) to generalize across the 50 states, there are some common steps in the development of a regulatory roadmap for ES:
- Develop an ES Roadmap that identifies policy, technology and process changes to address challenges faced by the storage sector.
- Determine what specific policies make the most sense in a specific state.
- Ensure collaboration with all stakeholders.

# Regulatory Roadmap



- The ESA recommends the following approaches:

Capture the full value of energy storage technologies:

- *Policy initiatives:* Incentives, procurement targets, cost/benefit analyses, and new rate design

Enable competition in all grid planning and procurements:

- *Policy initiatives:* Inclusion of storage in IRPs, RPS, resilience planning, resource adequacy and distribution planning

Ensure fair and equal access for storage to the grid and markets:

- *Policy initiatives:* innovative ownership options, revised interconnection standards, multi-use applications

# Regulatory Roadmap—Considerations



- How can energy storage support broader clean energy goals adopted by the state?
- Do the current regulatory structures allow energy storage to compete on a level playing field?
- Are the right state agencies and stakeholders working together to address existing barriers for energy storage?

# Q&A Session





Thank you!

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**BEFORE THE NEW MEXICO PUBLIC REGULATION COMMISSION**

**IN THE MATTER OF PUBLIC SERVICE )  
COMPANY OF NEW MEXICO'S )  
CONSOLIDATED APPLICATION FOR )  
APPROVALS FOR THE ABANDONMENT, ) 19-00195-UT  
FINANCING, AND RESOURCE REPLACEMENT )  
FOR SAN JUAN GENERATING STATION )  
PURSUANT TO THE ENERGY TRANSITION ACT )**

**AFFIDAVIT**

STATE OF FLORIDA )  
 ) ss  
COUNTY OF SARASOTA )

**WILLIAM KEMP, Director, Roland Berger LLC** upon being duly sworn according to law, under oath, deposes and states: I have read the foregoing **Rebuttal Testimony of William Kemp** and it is true and accurate based on my own personal knowledge and belief.

SIGNED this 31<sup>st</sup> day of December, 2019.

William J Kemp  
WILLIAM KEMP

SUBSCRIBED AND SWORN to before me this 31<sup>st</sup> day of December, 2019.

Sherry L. Lane  
NOTARY PUBLIC IN AND FOR  
THE STATE OF FLORIDA

My Commission Expires:  
07/24/2021

