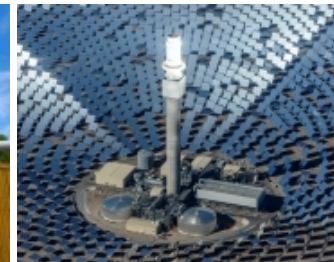
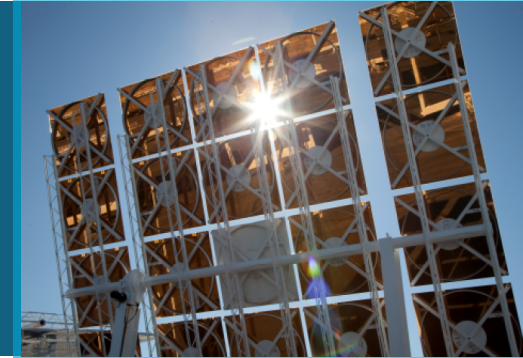




The Value of Long-Duration Energy Storage (LDES): Policy and Perception



PRESENTED BY

Clifford K. Ho

Sandia National Laboratories, Albuquerque, NM



Overview



- **Problem Statement**
- **Policy Overview**
- **Perceptions – LDES Survey Results**
- **Summary**

Go to [menti.com](https://www.menti.com) and use code 7508 1088



**Long-duration energy storage
(LDES) is not currently valued (or
needed) in existing energy
markets...**

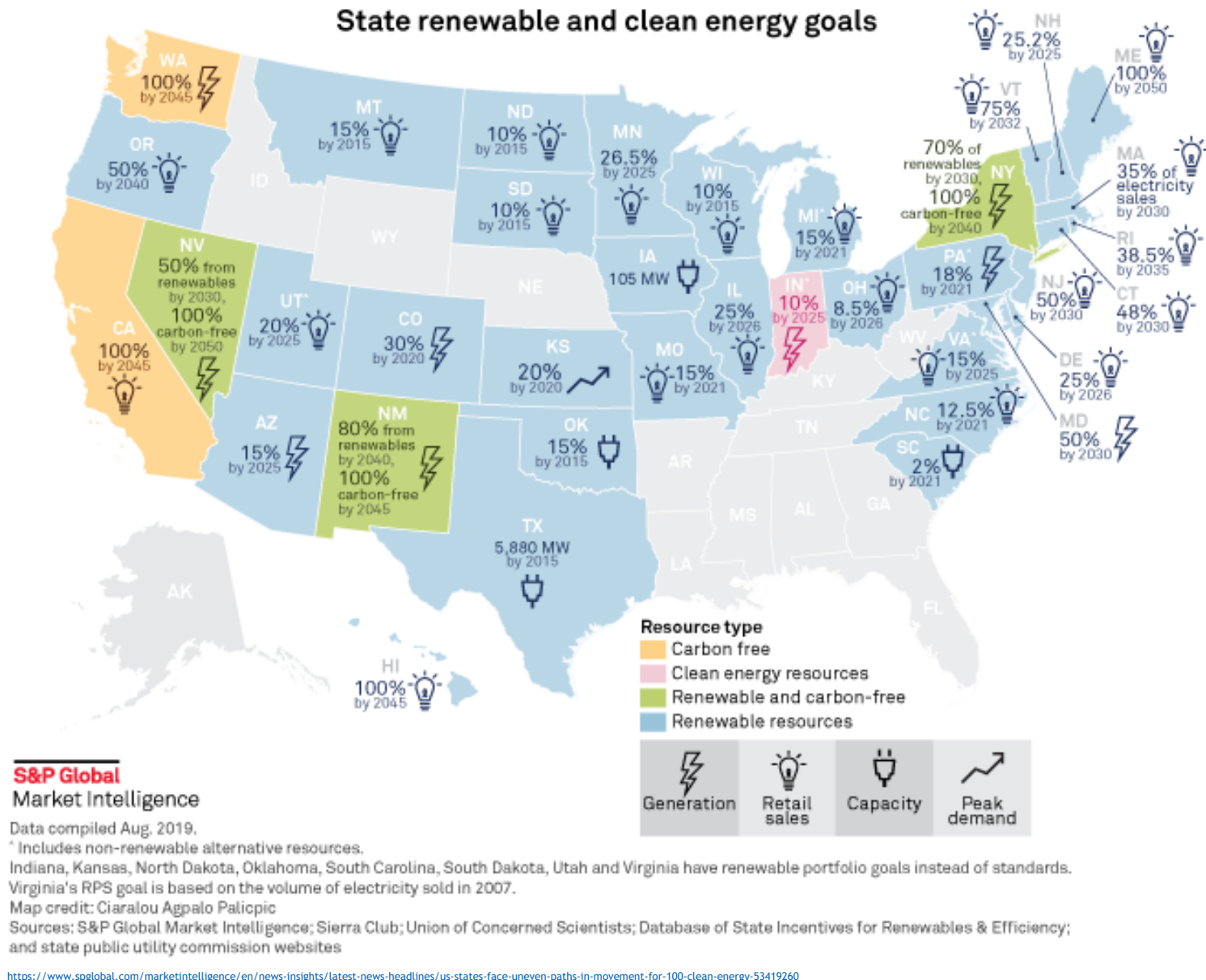
but it will be.

Go to menti.com and use code 7508 1088

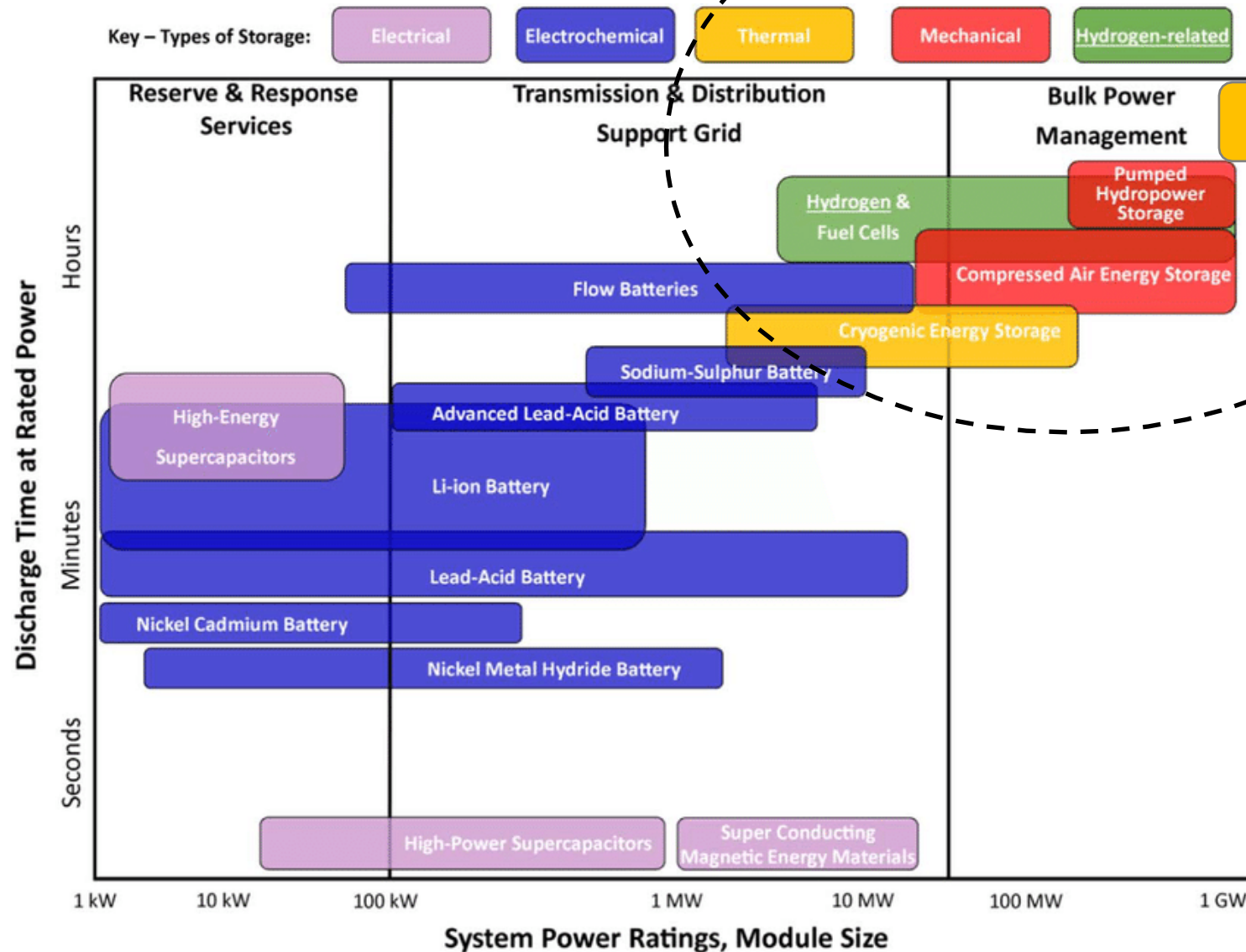
Problem Statement

New large-capacity, long-duration energy storage solutions are needed to ensure grid performance* with increasing intermittent renewables and threats that batteries alone cannot economically address

*Stability, reliability, and resilience



Problem Statement



High-temperature thermal storage often “left out”

Adapted from Moller, K.T., T.R. Jensen, E. Akiba, and H.W. Li, 2017, Hydrogen - A sustainable energy carrier, *Progress in Natural Science-Materials International*, 27(1), p. 34-40

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- How do you feel about the following statement? “Regulatory policies will play an important role in enabling the deployment and viability of long-duration energy storage technologies.”
 - 1) Strongly disagree
 - 2) Disagree
 - 3) Neutral
 - 4) Agree
 - 5) Strongly agree
- What is your current knowledge about regulatory policies that may impact energy storage technologies?
 - 1) No knowledge
 - 2) Very little knowledge
 - 3) Some knowledge
 - 4) Good amount of knowledge
 - 5) Significant amount of knowledge

Electricity Markets in the United States



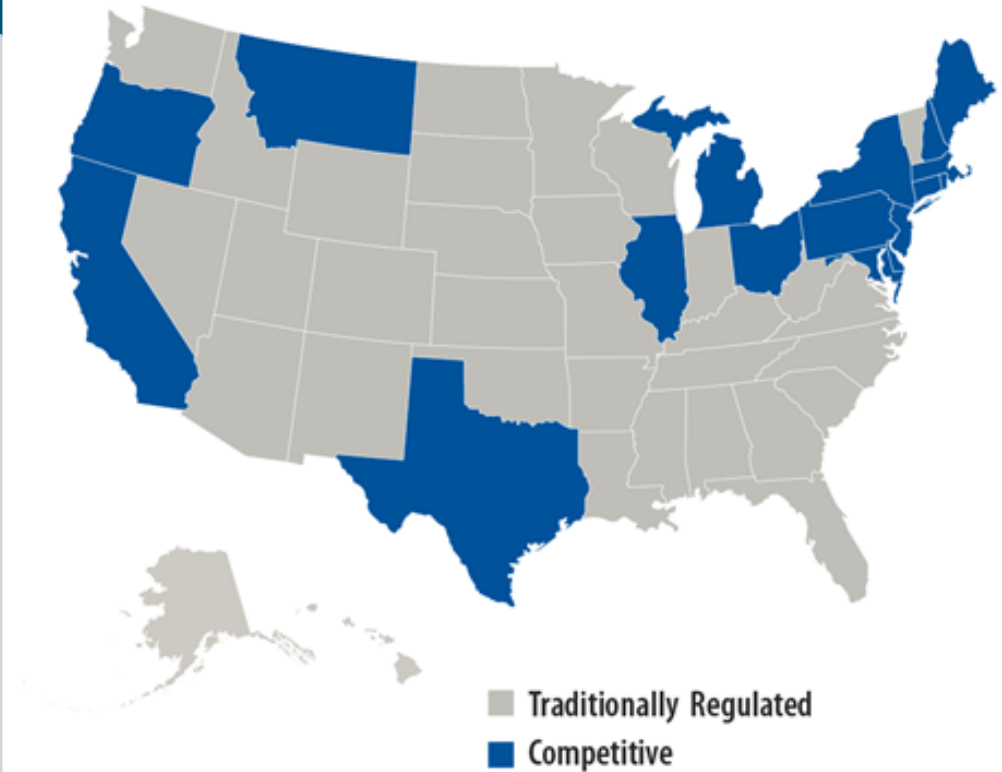
Regulated Market

- “Vertically integrated” utility **owns or controls** generation, transmission, and distribution
- **Regulated by states** (public utility commissions)
- Cost recovery via rates charged to customers
- **LDES needs to solve grid problem and be reliable, low-risk**

Deregulated (Restructured) Market

- Prohibited from owning generation and transmission
- RTOs* and ISOs* responsible for inter-/intra-state transmission, distribution, O&M
- Interstate transmission governed by **Federal Energy Regulation Commission (FERC)**
- Market is **competitive**
- **LDES needs to make money**

Retail Electric Power Markets



<https://www.epa.gov/repowertoolbox/understanding-electricity-market-frameworks-policies>

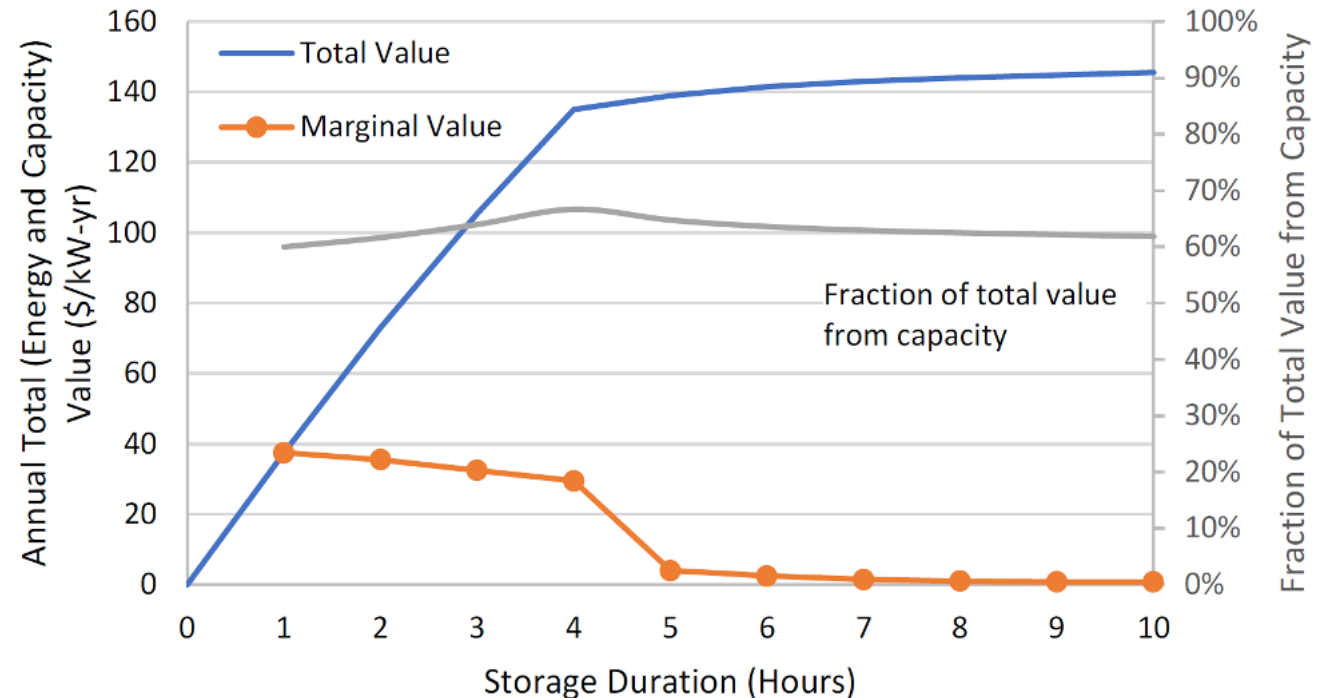
*RTO = Regional transmission operator, ISO = Independent system operator

“LDES Needs to Solve a Grid Problem”



- In 2018, **FERC Order 841** required RTOs and ISOs to establish market rules, including **energy storage durations** to receive full capacity or resource adequacy credit in wholesale electricity markets
 - Nearly all regions adopted 4 hour-or-less energy storage requirement*
 - Currently little need or value beyond 4 hours**
 - But need will increase
 - Strategen (2020) found that 45 – 55 GW of LDES needed**

*Denholm et al. (2021), NREL/TP-6A20-77480



Energy storage value as a function of duration assuming 4-hr duration requirement, \$90/kW-yr capacity payment, and 2019 market for energy time shifting.

“LDES Needs to Make Money”



- **Enable Value Stacking Policies**
 - Energy market (MWh) – Time shifting
 - Capacity market (MW) – Resource adequacy
 - Transmission asset (mitigate thermal overload and defer upgrades)
 - Ancillary services (short-term grid stability)
- **Resiliency policy** (insurance) for natural disasters and other threats
 - Utilize LDES for long-term resiliency *and* other value streams
 - Energy, capacity, ancillary, transmission

Hurricane Maria knocked out power in Puerto Rico for nearly a year



<https://www.nrdc.org/experts/rob-moore/disaster-aid-part-bi-partisan-budget-bill>

“LDES Needs to be Reliable and Low Risk”



- U.S. Federal Policies and Programs
 - 2020 BEST Act
 - Requires DOE to establish cross-cutting energy storage R&D to reduce cost and extend duration of energy storage systems
 - DOE Long Duration Storage and Hydrogen Earthshots
 - DOE ARPA-E DAYS and SETO CSP programs
- State Policies and Programs
 - California:
 - Governor Newsom recently proposed US\$350 million of support for “**pre-commercial long-duration storage projects**”
 - California Energy Commission (2020 GFO-19-308) - Assessing Long-duration Energy Storage Deployment Scenarios to Meet California's Energy Goals
 - Eight community choice aggregators (CCAs) launched a joint request for offers to procure up to 500 MW of long-duration storage
 - Other states (e.g., Arizona and New York) also have LDES-enabling policies

Policy – Equity and Justice



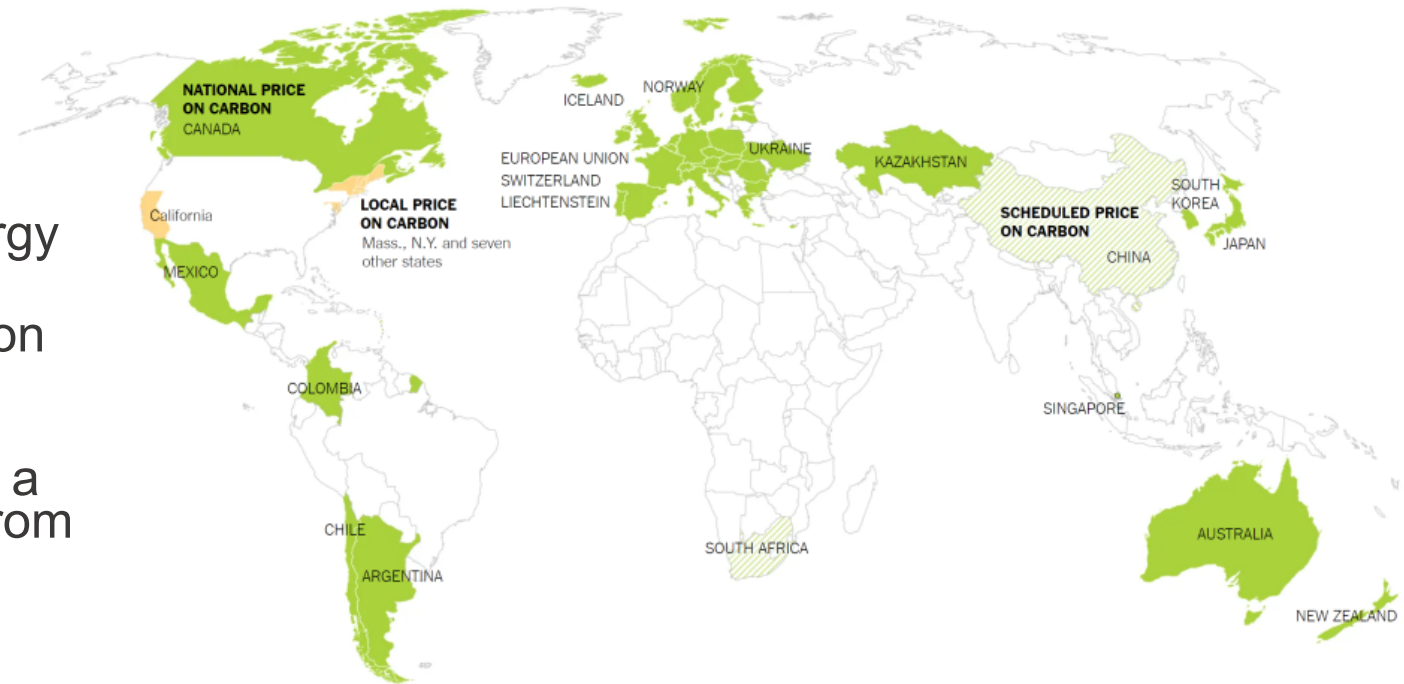
- **Justice40 Initiative**
 - 40% of the overall benefits from Federal investments in climate and clean energy to disadvantaged communities



International Policies



- European Union Electricity Market Design Directive (recast)
 - **Pros**
 - Aims to reduce barriers to energy storage
 - Encompasses both reconversion to electricity or conversion to another energy carrier
 - Energy storage recognized as a distinct asset class, separate from generation
 - **Cons**
 - Germany and France impose double taxation on energy storage systems for charging (consumer) and then discharging (generator)
- Carbon Pricing (Tax)
 - ~40 countries impose carbon pricing
 - Makes non-carbon LDES more competitive



Note: A local price on carbon is only highlighted where no national or European Union rules are in place. Some countries with a national price on carbon also have local-level programs that operate under separate rules. | Source: World Bank

<https://menloservice.sandia.gov/https://www.nytimes.com/interactive/2019/04/02/climate/pricing-carbon-emissions.html>

Overview



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Long Duration Energy Storage Workshop Survey



- 464 survey respondents

The screenshot shows a web browser window with the URL `sandia.gov/ess-ssl/ides/`. The page header includes the U.S. Department of Energy logo and a navigation menu with links like "DOE Global Energy Storage Database", "ES Safety Collaborative", "Conference Archive", "Events", "Publications", "Tools", "Resources", "Projects", and "About ESS".

The main content area features the following text:

DOE Long-Duration Energy Storage Workshop
March 9-10, 2021

**"BIG" Energy Storage:
Priorities and Pathways to Long-Duration Energy Storage**

Hosted by:

Logos for Sandia National Laboratories, Pacific Northwest National Laboratory, and Oak Ridge National Laboratory are displayed.

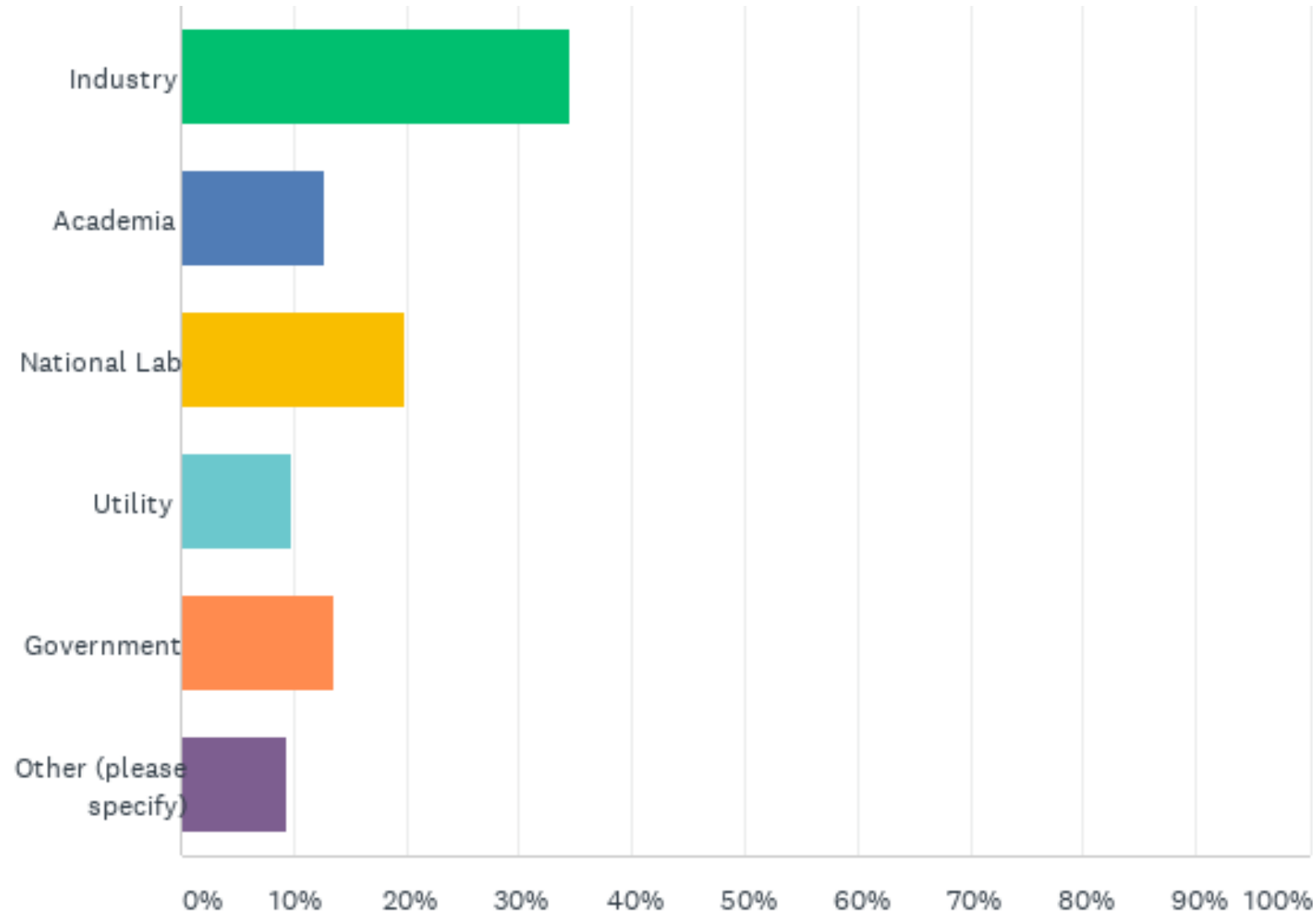
Join us for an interactive workshop!

- This workshop will define the unique challenges of "BIG" (large capacity (>100 MW_e) and long-duration (>6 hours) energy storage for grid applications, increase awareness in the energy storage community, and identify needs and gaps that must be addressed to realize the capability.
- The workshop will bring together researchers, representatives, and energy-storage stakeholders from utilities, industry (U.S. Domestic and International), U.S. Department of Energy, state and local government, national laboratories, and universities.
- The outcome of this workshop will be a summary of needs and gaps (scale and duration), use cases, potential technologies, and a framework for implementation through initiatives such as the U.S. DOE Energy Storage Grand Challenge.
- **NEW!** Want to get primed for the workshop? Please read our recently prepared [Issue Brief on Long-Duration Storage](#)

Q1: What best describes where you work?

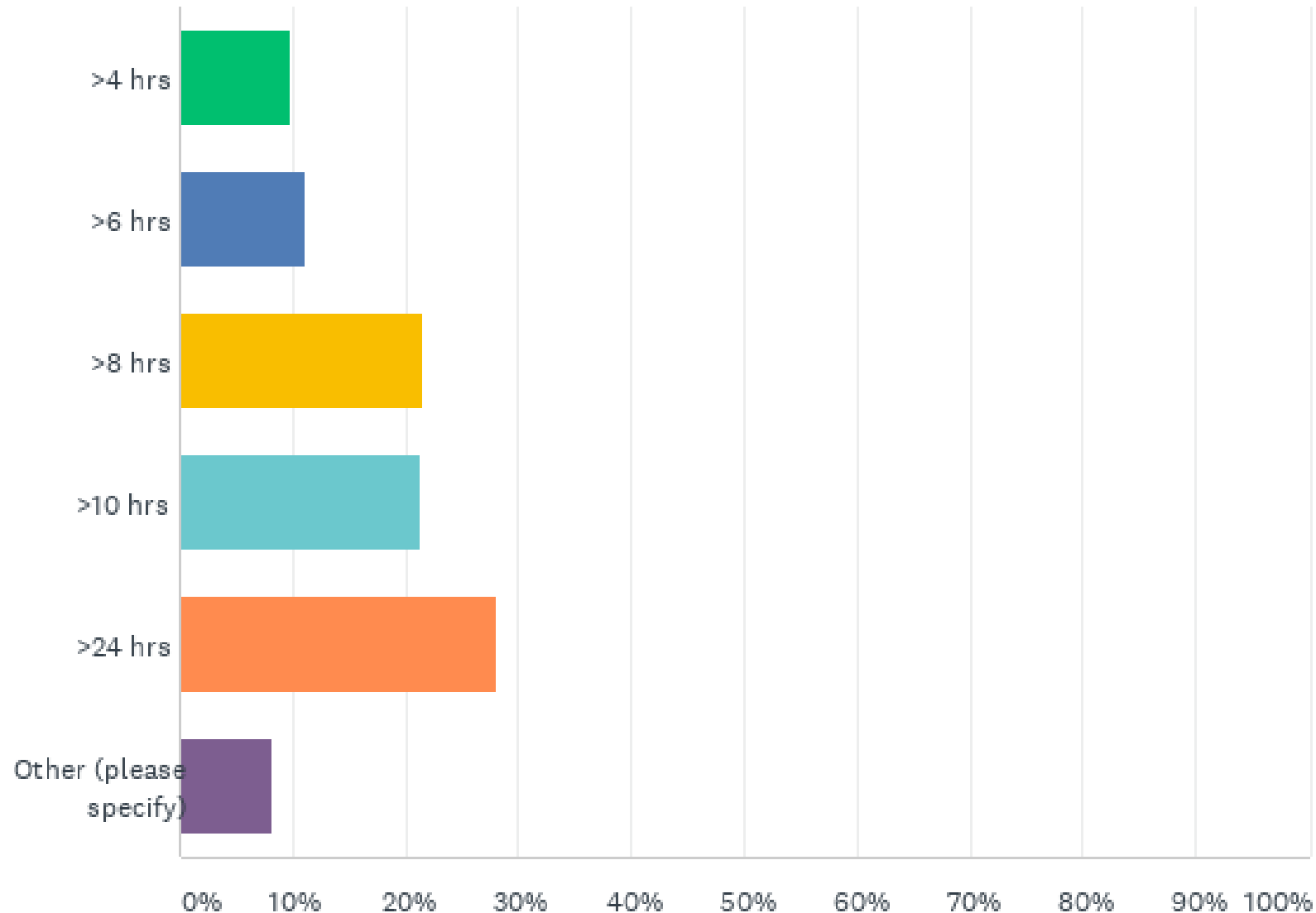


Answered: 464 Skipped: 0



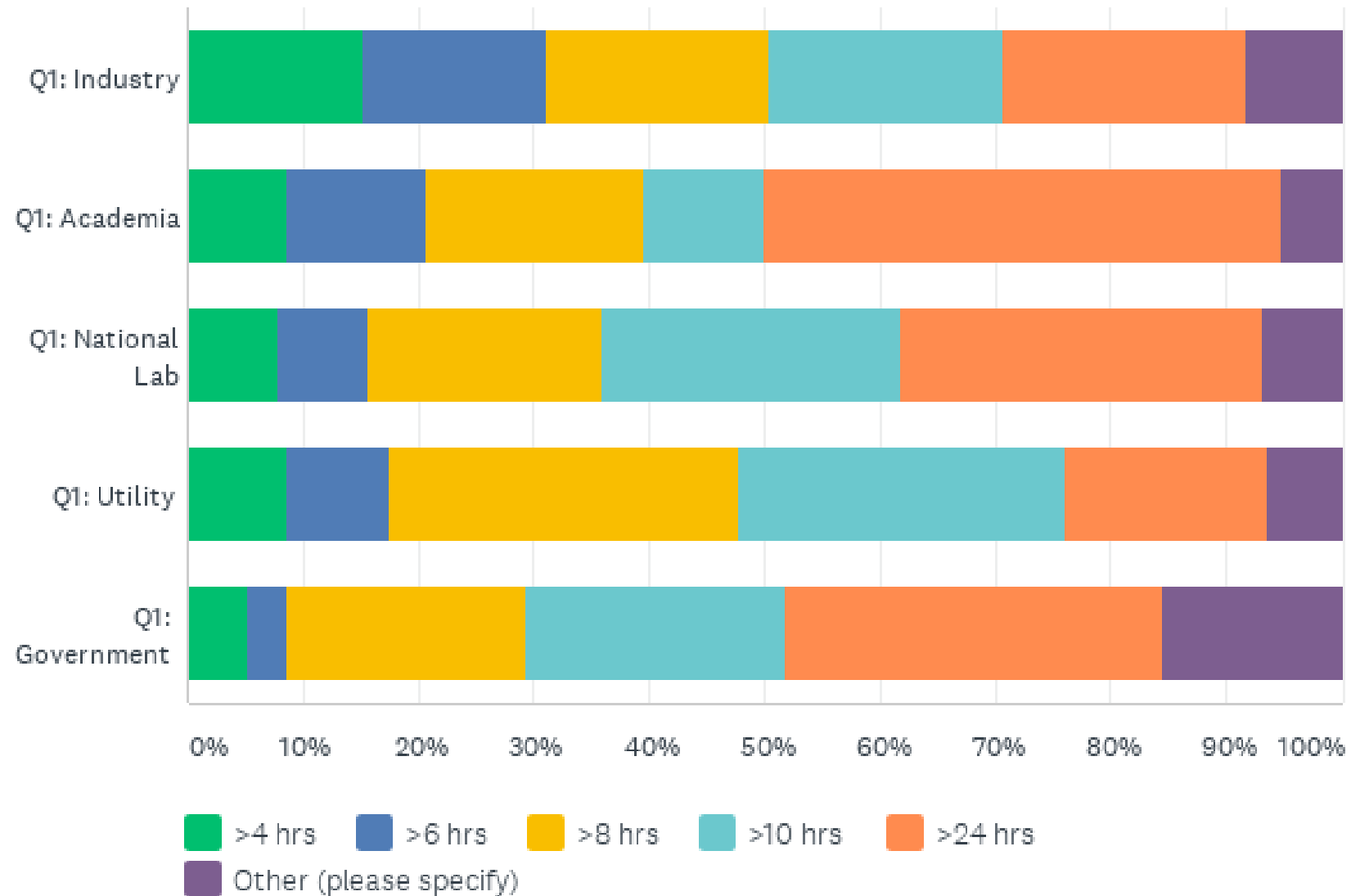
Q2: How do you define long-duration storage?

Answered: 449 Skipped: 15



Q2: How do you define long-duration storage?

Answered: 408 Skipped: 13



Q2: How do you define long-duration storage?

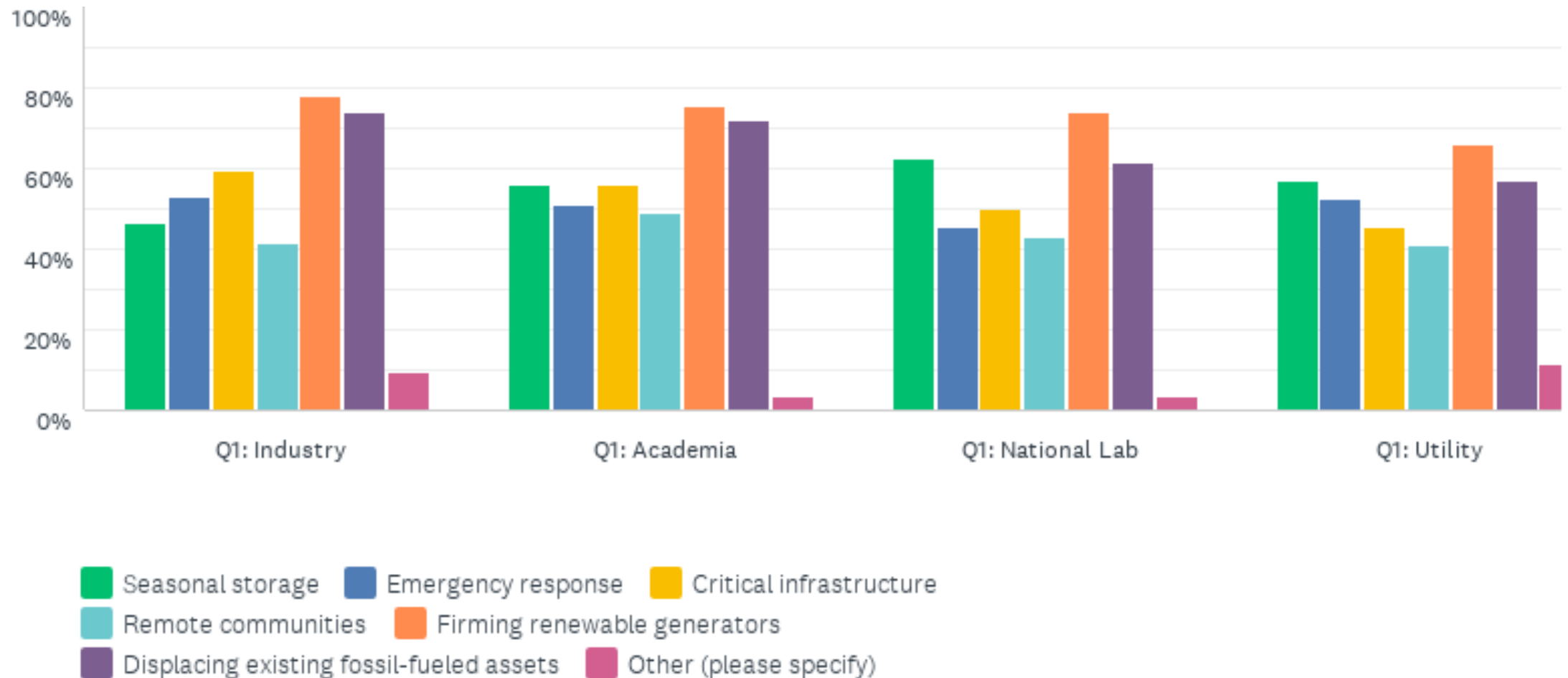


Answered: 408 Skipped: 13

	>4 HRS	>6 HRS	>8 HRS	>10 HRS	>24 HRS	OTHER (PLEASE SPECIFY)	TOTAL
Q1: Industry (A)	15.29% 24 E	15.92% 25 E	19.11% 30	20.38% 32	21.02% 33 B	8.28% 13 Responses	38.48% 157
Q1: Academia (B)	8.62% 5	12.07% 7	18.97% 11	10.34% 6 CD	44.83% 26 AD	6.90% 4 Responses	14.46% 59
Q1: National Lab (C)	7.87% 7	7.87% 7	20.22% 18	25.84% 23 B	31.46% 28	6.74% 6 Responses	21.81% 89
Q1: Utility (D)	8.70% 4	8.70% 4	30.43% 14	28.26% 13 B	17.39% 8 B	6.52% 3 Responses	11.27% 46
Q1: Government (E)	5.17% 3 A	3.45% 2 A	20.69% 12	22.41% 13	32.76% 19	15.52% 9 Responses	14.22% 58
Total Respondents	43	45	85	87	114	35	408

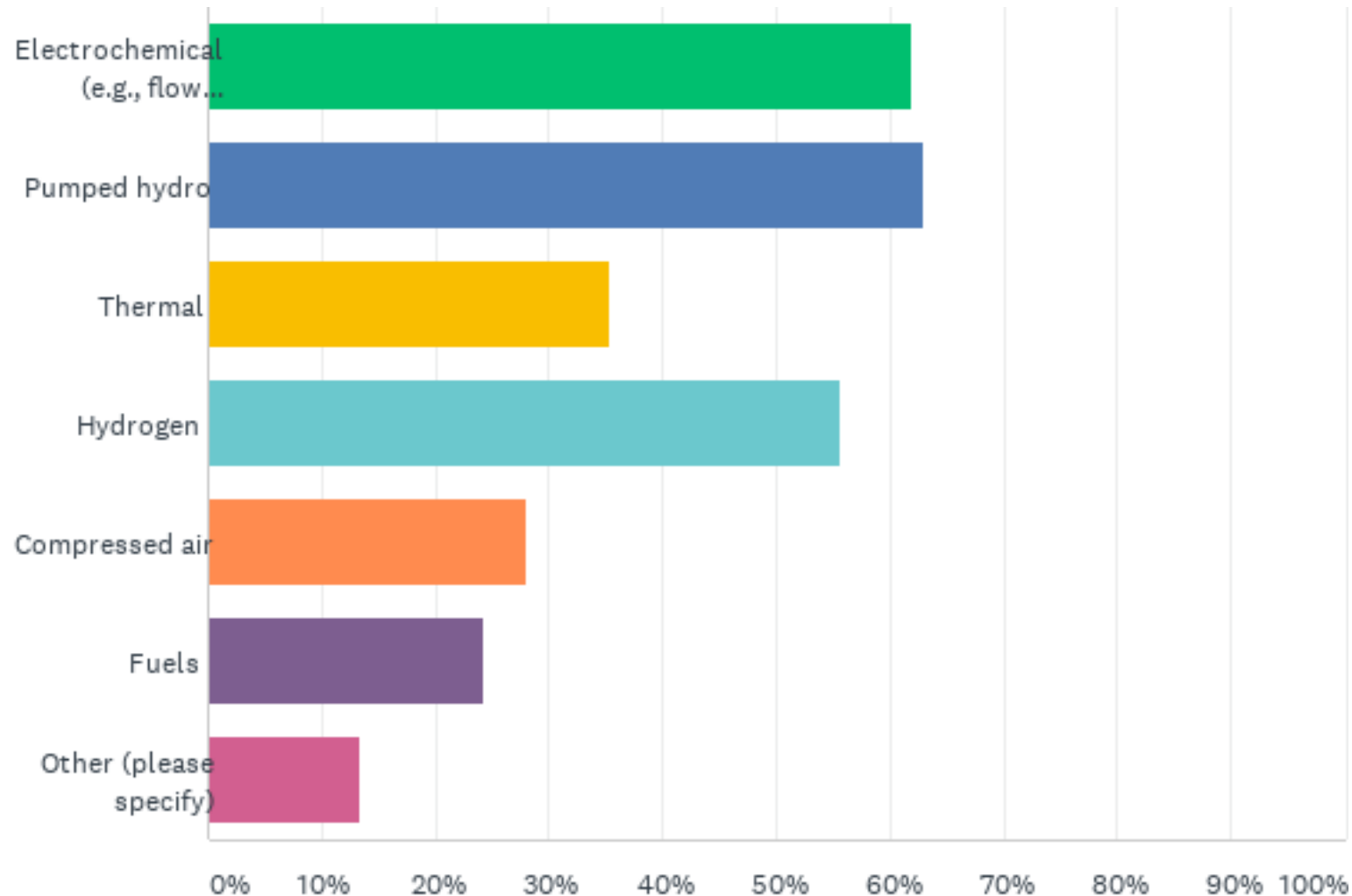
Q3: What use case(s) for long duration energy storage are you interested in?

Answered: 401 Skipped: 20



Q5: What technologies do you think are best suited to provide long duration energy storage?

Answered: 417 Skipped: 47



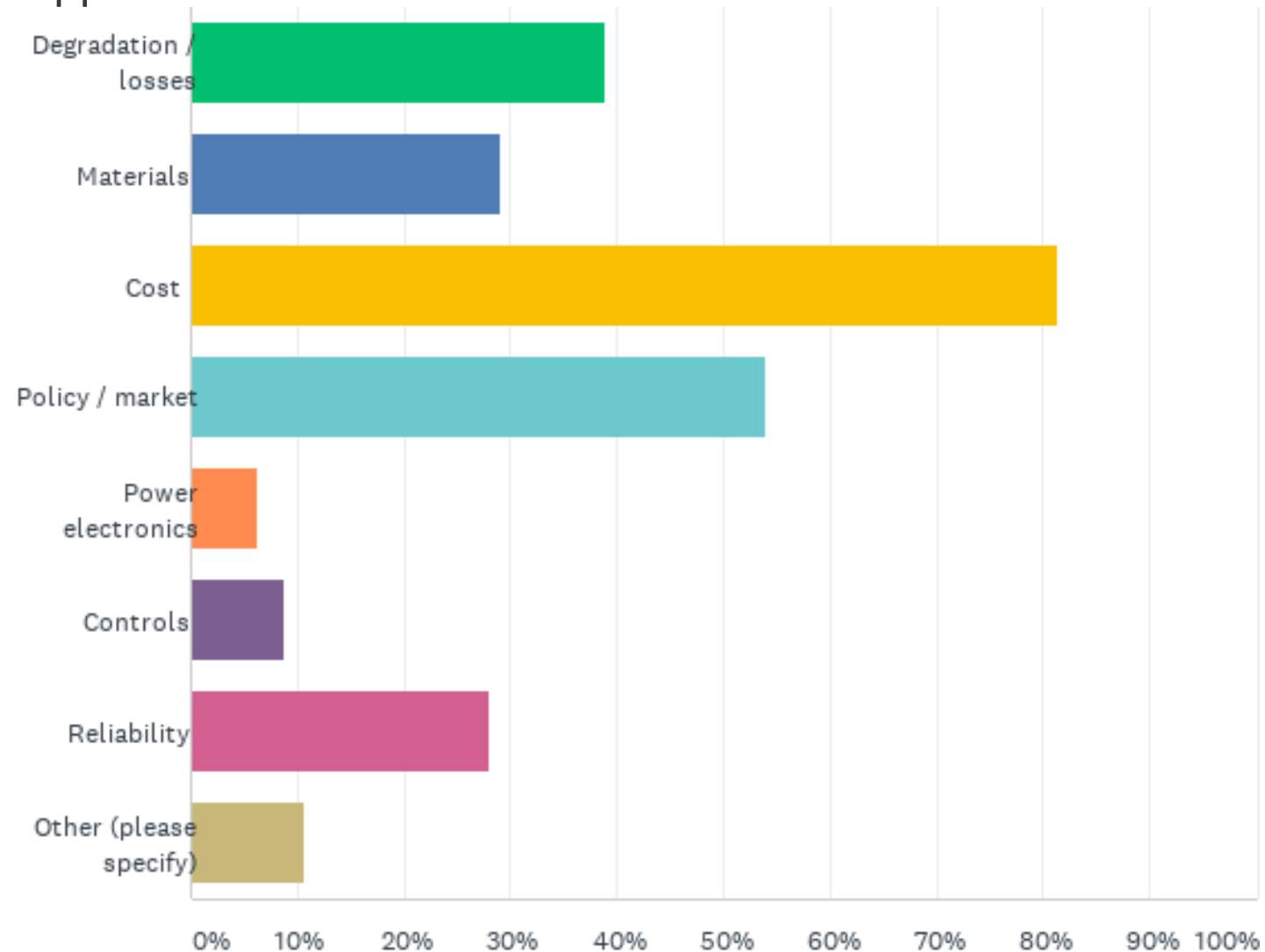
Q5: What technologies do you think are best suited to provide long duration energy storage?

Answered: 380 Skipped: 41

	ELECTROCHEMICAL (E.G., FLOW BATTERIES)	PUMPED HYDRO	THERMAL	HYDROGEN	COMPRESSED AIR	FUELS	OTHER (PLEASE SPECIFY)	TOTAL
Q1: Industry (A)	59.46% 88	63.51% 94	39.86% 59 D	51.35% 76	27.70% 41 D	22.30% 33	12.84% 19 Responses	107.89% 410
Q1: Academia (B)	73.21% 41	55.36% 31	21.43% 12	50.00% 28	16.07% 9 D	19.64% 11	12.50% 7 Responses	36.58% 139
Q1: National Lab (C)	60.71% 51	58.33% 49	39.29% 33	61.90% 52	17.86% 15 D	28.57% 24	8.33% 7 Responses	60.79% 231
Q1: Utility (D)	70.73% 29	70.73% 29	21.95% 9 A	56.10% 23	53.66% 22 ABC	21.95% 9	4.88% 2 Responses	32.37% 123
Q1: Government (E)	64.71% 33	70.59% 36	45.10% 23	56.86% 29	33.33% 17	27.45% 14	19.61% 10 Responses	42.63% 162
Total Respondents	242	239	136	208	104	91	45	380

Q6: What are the biggest challenges facing long duration storage?

Answered: 424 Skipped: 40



Q6: What are the biggest challenges facing long duration storage?

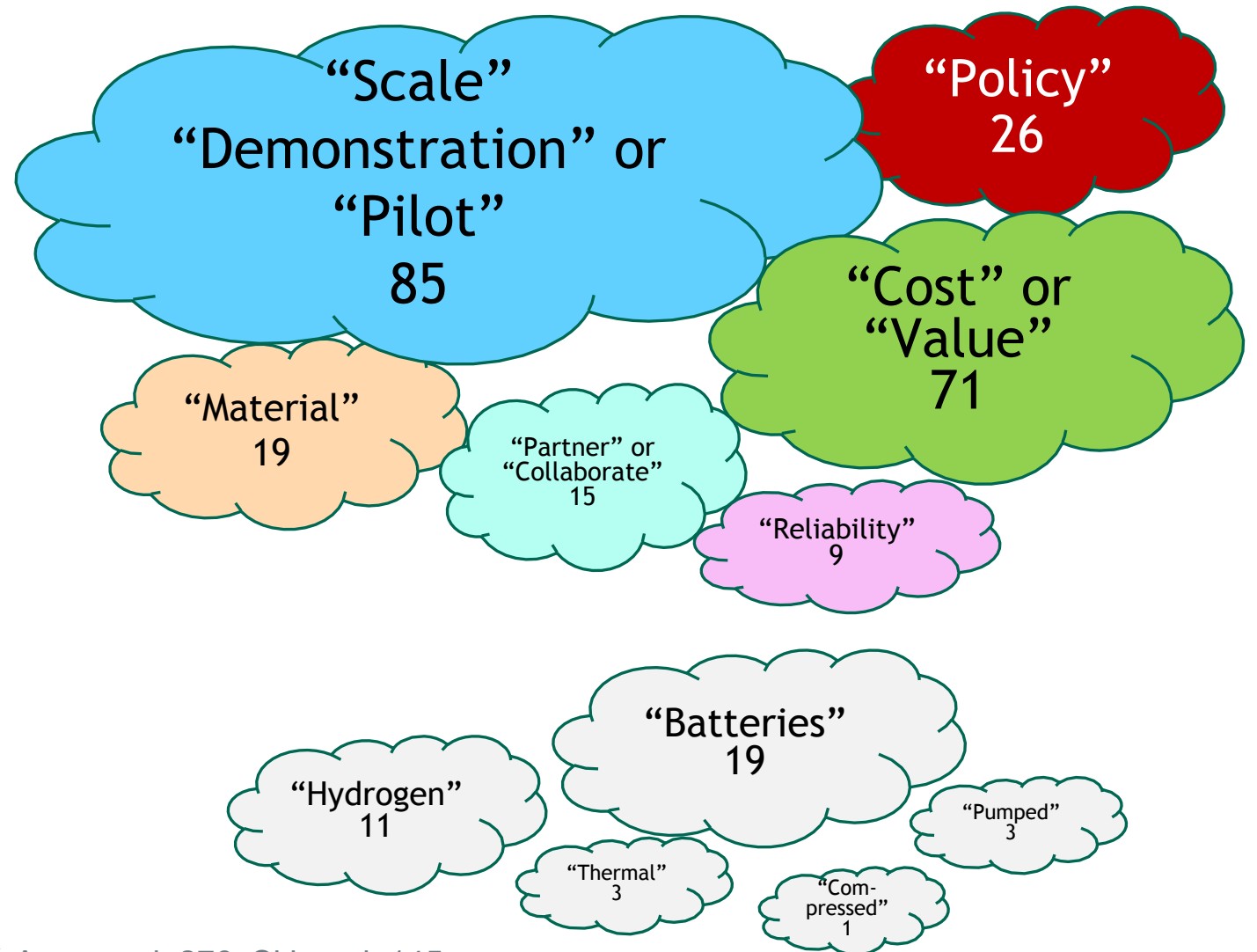
Answered: 424 Skipped: 40



	DEGRADATION / LOSSES	MATERIALS	COST	POLICY / MARKET	POWER ELECTRONICS	CONTROLS	RELIABILITY	OTHER (PLEASE SPECIFY)	TOTAL
Q1: Industry (A)	28.00% 42 C	24.67% 37	76.00% 114	64.00% 96 BCD	4.67% 7	7.33% 11 D	20.67% 31	12.67% 19 Responses	92.49% 357
Q1: Academia (B)	50.00% 28	39.29% 22	91.07% 51	44.64% 25 A	12.50% 7	14.29% 8	30.36% 17	8.93% 5 Responses	42.23% 163
Q1: National Lab (C)	48.81% 41 A	34.52% 29	82.14% 69	51.19% 43 A	7.14% 6	7.14% 6 D	38.10% 32	9.52% 8 Responses	60.62% 234
Q1: Utility (D)	41.86% 18	25.58% 11	83.72% 36	44.19% 19 A	11.63% 5	20.93% 9 ACE	34.88% 15	4.65% 2 Responses	29.79% 115
Q1: Government (E)	45.28% 24	24.53% 13	84.91% 45	47.17% 25	3.77% 2	5.66% 3 D	30.19% 16	5.66% 3 Responses	33.94% 131
Total Respondents	153	112	315	208	27	37	111	37	386

Q7: How can DOE and the national labs best address the challenges of long duration energy storage?

- Fund **demonstration** projects at **scale**; bridge valley of death to commercialization
- Assess **costs** and **value** of LDES in different use cases
 - Perform technoeconomic analyses for future carbon-free scenarios and architectures for individual utilities and regions
- Ensure **policy** enables LDES
- Foster **collaborations** between universities, national labs, and industry
- Improve LDES **technologies** to increase



Answered: 276 Skipped: 145

Summary



Summary – LDES and Relevant Policies



- **Policies for monetization and multiple value streams**

- Energy market (time shifting, MWh)
- Capacity market (meeting loads, MW)
- Transmission asset (prevent thermal overloads)
- Resilience/insurance (recovering from natural disasters)
- Elimination of double taxation (consumption and generation)
- Carbon tax (cost avoidance)



- **Technology demonstrations to lower risk of adoption**

- Federal assistance for technology development (e.g., DOE Storage and Hydrogen Earthshots, CSP program, ARPA-E Days)
- State mandates for storage deployment (e.g., California)



Summary –LDES Perceptions



- **LDES Perceptions**
 - **Different sectors** define duration, technologies, and challenges differently
 - Key **technologies** include pumped hydro, electrochemical, hydrogen, and thermal storage
 - Key **challenges** include cost, policy/market, degradation/losses, reliability/materials
 - **Government** should focus on **larger-scale demonstrations, cost reductions, and policies that enable LDES**

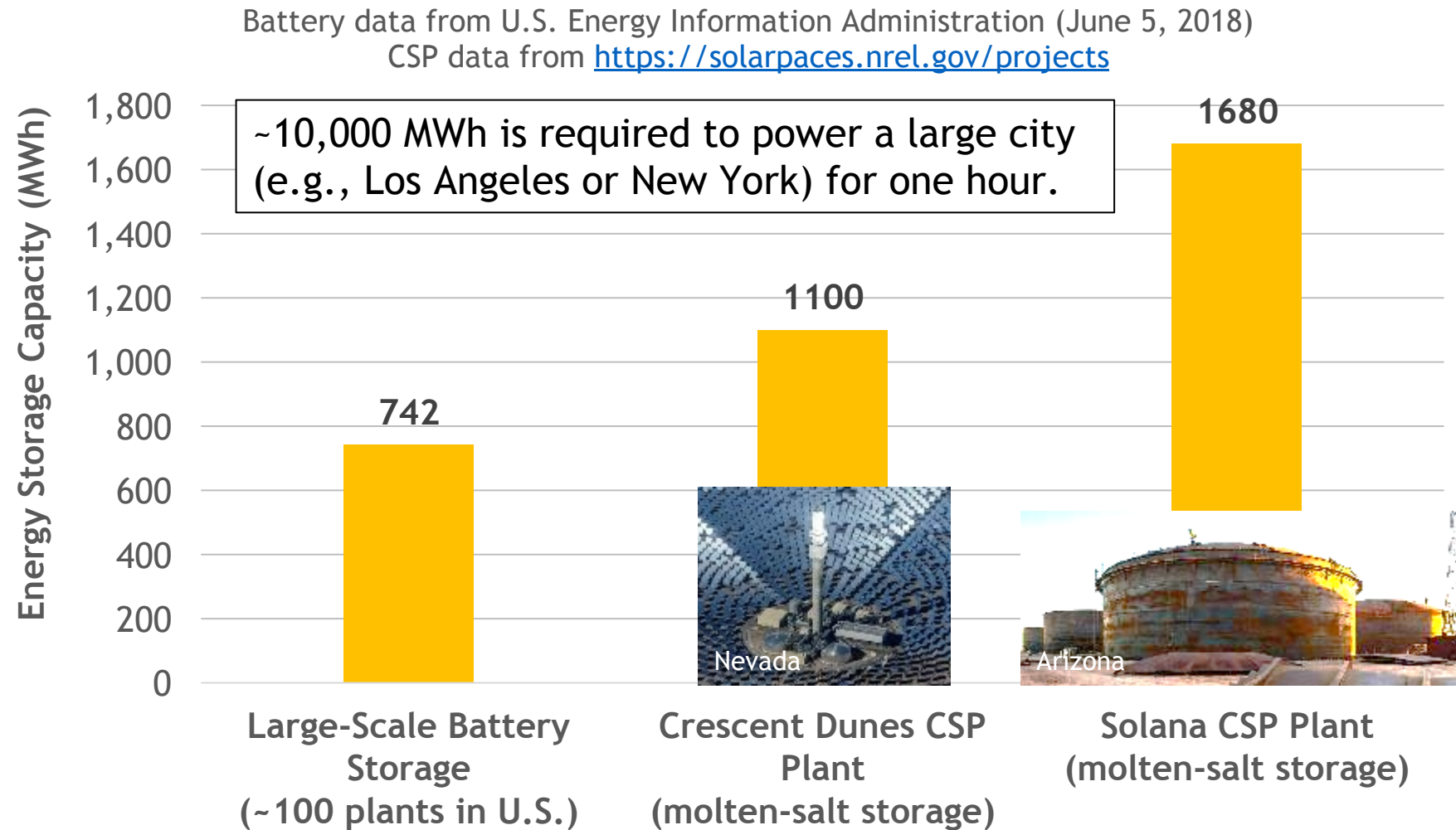




Cliff Ho, (505) 844-2384, ckho@sandia.gov

Backup Slides

Growing Need for Large-Scale Energy Storage



Q2: How do you define long-duration storage?



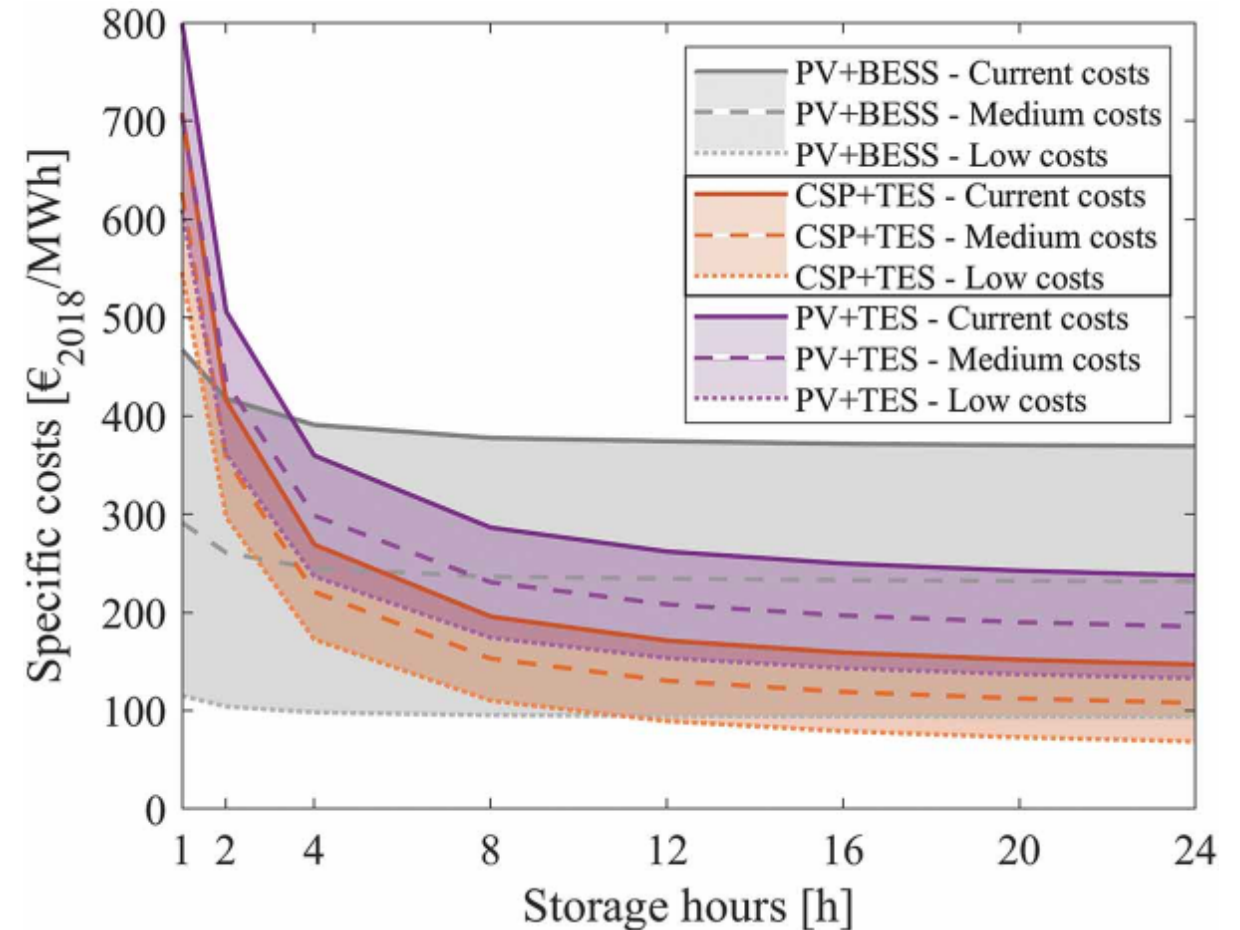
Answered: 408 Skipped: 13

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“LDES Needs to be Cost Competitive”



- E.g., CSP vs. PV + batteries
 - LCOS for long-duration thermal storage is competitive with PV + batteries after ~4 – 10 hrs

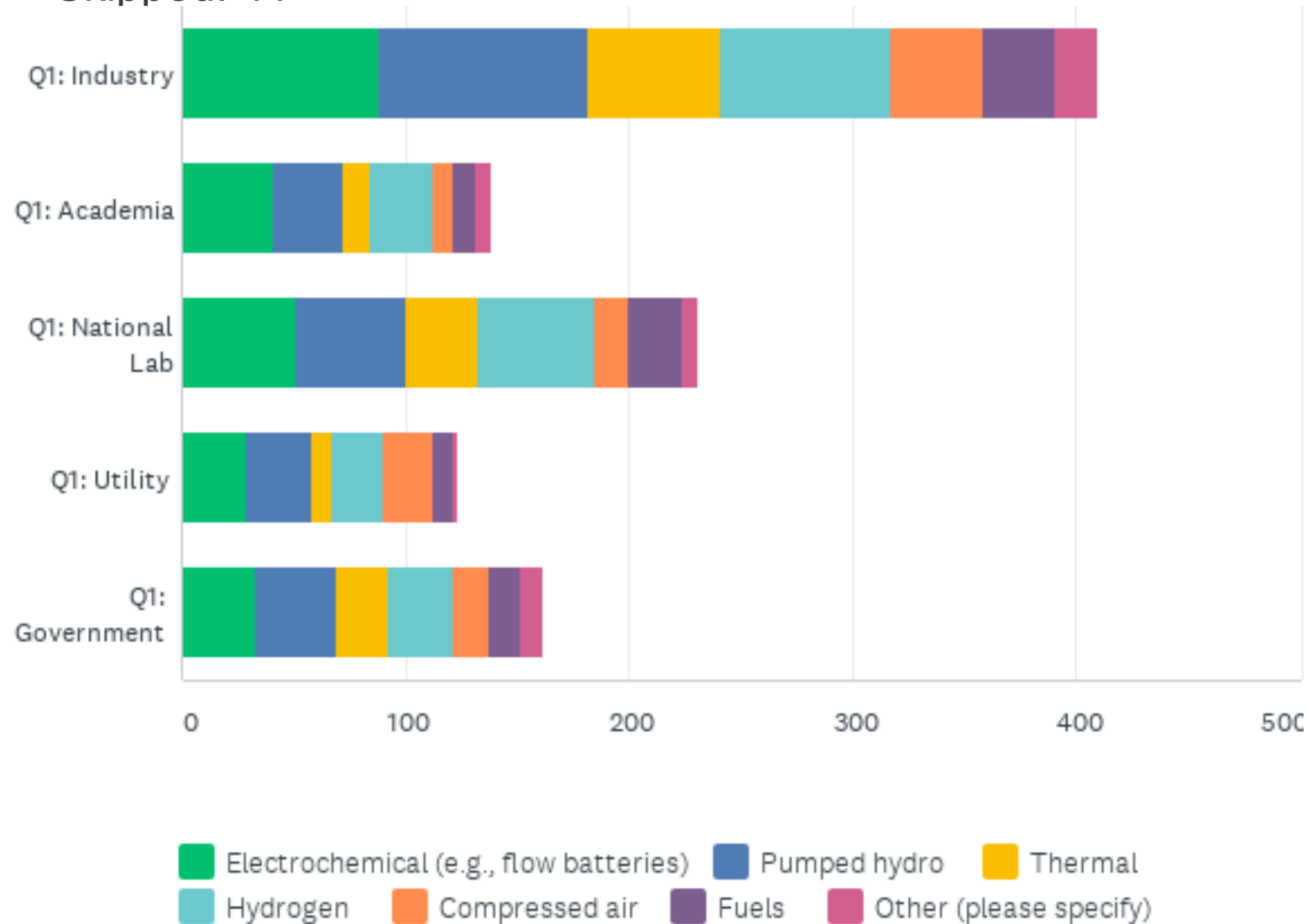


F. Schöniger, R. Thonig, G. Resch & J. Lilliestam (2021) Energy Sources, Part B: Economics, Planning, and Policy, 16:1, 55-74, DOI: [10.1080/15567249.2020.1843565](https://doi.org/10.1080/15567249.2020.1843565)

BESS = Battery Energy Storage System

Q5: What technologies do you think are best suited to provide long duration energy storage?

Answered: 380 Skipped: 41



Advantages and Disadvantages of Deregulated Markets



Advantages of Electricity Deregulation

1. More energy companies to choose from
2. Competition may lead to lower energy prices
3. Customers can support green companies; technological progress may be fostered

Disadvantages of Electricity Deregulation

1. Wholesale prices fluctuate
2. Lack of energy supply security; crucial services not ensured or controlled by governments
3. Rural and disadvantaged customers may suffer from energy shortages
4. Environmental problems



Texas multi-day power outage in Feb. 2021 affected 5M customers



Price of electricity rose over 7000% from \$0.12/kWh to \$9.00/kWh (NPR)