

A MORE SUSTAINABLE AND SECURE FORM OF BATTERY STORAGE: COMMERCIALIZING SODIUM-ION BATTERIES TO REPLACE LITHIUM-ION BATTERIES

Jennifer Gentile[*]

Synopsis: This article argues that lithium-ion batteries are a suboptimal storage solution and explores policies that can replace this technology with a more sustainable one, sodium-ion battery technology. Specifically, by analyzing the needs of the evolving energy grid, the benefits of storage batteries, and the drawbacks associated with lithium-ion batteries, this paper investigates the necessary qualities of a superior technology and identifies the nascent sodium-ion technology as the best alternative available. Further, this article examines current regulatory programs at the state and federal level, posits that these programs function to entrench lithium-ion batteries in the energy market, and recommends policy modifications encouraging commercialization and widespread deployment of sodium-ion batteries.

* Jennifer Gentile graduated from Lewis & Clark Law School in May 2025. In 2024, she published Adoption of a Circular Economy in the United States for the American Bar Association. Many thanks to Melissa Powers, Jeffrey Bain Faculty Scholar & Professor of Law at Lewis & Clark Law School, for all her guidance on this paper.

I. INTRODUCTION

The electric grid requires a constant equilibrium between supply and demand to avoid deterioration and blackouts.[1] Renewable energy generation — such as solar and wind — is variable, threatening the reliability of the grid.[2] Energy storage[3] can provide frequency regulation and other services to ensure that the grid remains in equilibrium.[4] To support our increasing dependency upon solar and wind-generated electricity, the United States largely relies upon lithium-ion (Li-ion) batteries. Indeed, almost all new storage installations use Li-ion.[5] As such, Li-ion batteries are currently integral to decarbonization goals.

However, Li-ion batteries are associated with environmental, social justice, safety, and supply chain concerns. These batteries rely upon rare minerals that are difficult to extract, scarring the land and depleting local water supplies.[6] Mining for cobalt, a mineral used in most Li-ion batteries, primarily occurs in the Democratic Republic of the Congo (DRC) and is often associated with human rights abuses.[7] Li-ion batteries pose fire and explosion hazards due to thermal runaway.[8] Furthermore, an overreliance on foreign materials and a lack of domestic infrastructure has constrained the United States' access to Li-ion batteries.[9] These issues create challenges for continued reliance on Li-ion batteries.

While investors and innovators are exploring many types of emerging technologies, sodium-ion (Na-ion) batteries have arisen as the most viable alternative to Li-ion batteries.[10] But there are challenges associated with such a transition. Na-ion batteries are not yet commercially available on a large scale.[11]

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1. *What is Grid Balancing? And How Does It Help the Climate?*, TRUE ENERGY: BLOG, https://www.trueenergy.io/blog/what-is-grid-balancing/ (last visited Mar. 10, 2024).

2. *Id*.

3. The Federal Energy Regulatory Commission (FERC) defines storage as "a resource capable of receiving electric energy from the grid and storing it for later injection of electric energy back to the grid." Order No. 841, *Electric Storage Participation in Markets Operated by Regional Transmission Organizations & Independent System Operators*, 162 FERC ¶ 61,127 P 29 (2018) (codified at 18 C.F.R. pt. 35) [hereinafter Order No. 841].

4. THOMAS BOWEN, ILYA CHEMYAKHOVSKIY & PAUL DENHOLM, NAT'L RENEWABLE ENERGY LAB'Y, GRID-SCALE BATTERY STORAGE FREQUENTLY ASKED QUESTIONS, GREENING THE GRID 2-3 (2019), https://www.nrel.gov/docs/fy19osti/74426.pdf.

5. *See* discussion *infra* Section III A.

6. *See id*.

7. *See id*.

8. *See id*.

9. *See* discussion *infra* Section III A.

10. Maider Zarrabeitia, Wenhua Zuo & Stefano Passerini, *Battery Types – Sodium Batteries – Low-Temperature Sodium Batteries | Cathode Active Materials*, *in* 4 ENCYCLOPEDIA OF ELECTROCHEMICAL POWER SOURCES 797, 797-816 (Yuichi Aihara et al. eds., 2d ed. 2025).

11. *See* discussion *infra* Section III B.

Moreover, once Na-ion batteries become available, experts expect Na-ion batteries to *complement* rather than replace Li-ion batteries.[12] Therefore, to change the trajectory of the storage market and improve the ability of the grid to rely on solar and wind-generated electricity, governments should take steps to accelerate the commercialization of Na-ion batteries and incentivize investment in the technology. If that is to happen, current government policy must change.

Today, federal and state policies are agnostic towards the issues associated with Li-ion batteries and do not prioritize developing sustainable alternative technologies.[13] Almost all federal and state policies seeking to increase battery deployment treat storage technologies the same, providing Li-ion batteries (the dominant technology) with a market advantage.[14] Even worse, some programs specifically act to increase deployment of Li-ion batteries.[15] Yet states are well-positioned to transition the storage market to Na-ion batteries. In fact, states are already leading the charge in battery deployment[16] and can largely rely upon modifying existing programs to commercialize Na-ion batteries and incentivize investment in the technology.[17] Additionally, states have wide discretion to adopt new policies to increase the market success of Na-ion batteries.[18]

Based on factors that drive innovation and programs that successfully grew solar, an analogous technology, this paper recommends state actions to commercialize Na-ion batteries and replace Li-ion batteries as the storage market leader. These actions consist of both financial and non-financial incentives, with a particular focus on increasing knowledge and demand of Na-ion technology.[19] Specifically, states should adopt a mixture of energy storage mandates, utility planning, education measures, public procurement, building codes, and storage-specific auctions.[20] For the most part, states have broad discretion in designing their energy storage programs as long as they avoid federal preemption.[21]

Section II explains why storage resources are integral to an energy system that increasingly relies upon variable generation from wind and solar facilities, and the benefits that those resources can provide to the grid generally. Section III describes the harmful consequences of Li-ion batteries and advocates that Na-ion batteries replace them once commercialized. Section IV shows how current state and federal policies promote battery deployment but fail to account for the costs associated with Li-ion batteries. Further, it explains why states, rather than the federal government, are best situated to lead the transition to Na-ion batteries. Section V recommends specific programs that states can implement to promote

12. Teo Lombardo et al., *Sodium-ion Battery Momentum Grows, but Challenges Remain*, INT'L ENERGY AGENCY (Feb. 17, 2026), https://www.iea.org/commentaries/sodium-ion-battery-momentum-grows-but-challenges-remain.

13. *See* discussion *infra* Section IV.

14. *Id*.

15. *Id*.

16. *Id*.

17. *See* discussion *infra* Section V.B.i.

18. *See* discussion *infra* Section V.B.ii.

19. *See* discussion *infra* Section V.A.

20. *See* discussion *infra* Section VB.

21. *See* discussion *infra* Section VI.

Na-ion batteries and phase Li-ion batteries from the energy market. Section VI evaluates the legality of the recommended programs. Finally, section VII concludes that the time is ripe for states to encourage Na-ion battery deployment.

II. The Need for Storage Batteries

Energy storage plays a critical role in achieving decarbonization of the electric grid. Efforts to reduce carbon emissions have increased the electric grid's reliance on wind and solar-powered generation.[22] The United States now has about 7,000 utility-scale solar plants and 84,000 wind turbines, generating almost 20% of its annual power needs.[23] Renewable generation, although necessary to decarbonize the grid, poses logistical challenges. First, renewable generation of electricity is variable. As the saying goes, solar arrays and wind farms cannot produce electricity when the sun doesn't shine or the wind doesn't blow.[24] That creates reliability issues because the electric grid requires a constant, almost perfect, equilibrium between supply (generation) and demand (load) to avoid deterioration and blackouts.[25] Second, renewable generation can result in an oversupply of energy when the renewable source is abundant,[26] for example, when the sun is shining at midday. An overabundance of electricity can throw the grid out of equilibrium, again threatening reliability, and can lead to financial losses.[27] To protect grid reliability, operators may need to curtail generation from renewable power plants, which wastes energy that otherwise could have been sold.[28] Oversupply also creates a "duck curve," which is especially a problem with solar generation.[29] A solar duck-curve represents the overabundance of solar generation at midday, which then quickly drops off in the late afternoon.[30] The fluctuation of energy production between day and night causes environmental concerns because fossil fuel plants often have to ramp up quickly to meet demand when renewable generation drops off,[31] emitting carbon dioxide in the process.

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22. *See* Chelsea Bruce-Lockhart, Claire Kaelin & Richard Black, *Why Wind & Solar are Key Solutions to Combat Climate Change*, EMBER (Feb. 9, 2024), https://ember-energy.org/latest-insights/why-wind-and-solar-are-key-solutions-to-combat-climate-change/ (describing reasons why wind and solar power outpace other types of generation in the effort to decarbonize the electric grid).

23. Michael Thomas, *Solar Farms in the United States*, CLEANVIEW (last updated Apr. 2026), https://cleanview.co/solar-farms/us; *Wind Power Facts*, AM. CLEAN POWER, https://cleanpower.org/facts/wind-power/ (last visited Apr. 1, 2026); *A Decade of Growth for U.S. Solar and Wind*, CLIMATE CENT. (Mar. 12, 2025), https://www.climatecentral.org/climate-matters/solar-and-wind-2025.

24. UNC ENERGY CTR. & KENAN INST. OF PRIV. ENTER., MEETING THE RENEWABLES INTERMITTENCY CHALLENGE 6 (2019), https://www.kenan-flagler.unc.edu/wp-content/uploads/2022/07/Meeting-the-Challenge-of-Renewables-Intermittency-General-Audience-Report.pdf.

25. *What is Grid Balancing? And How Does It Help the Climate?*, *supra* note 1.

26. Nick Wall, *Energy Storage: How States Are Leading the Charge*, 14 ALB. GOV'T L. REV. 28, 31 (2021) (internal citation omitted).

27. *Id*. at 32.

28. *Id*. at 31-32.

29. *As Solar Capacity Grows, Duck Curves are Getting Deeper in California*, U.S. ENERGY INFO. ADMIN. (June 21, 2023), https://www.eia.gov/todayinenergy/detail.php?id=56880.

30. *Id*.

31. *Id*.

Energy storage is integral to resolving renewable variability and overgeneration issues. Electrochemical technologies, like batteries, can store electrical energy,[32] prevent waste, and mitigate variability by capturing energy generated by renewables, storing it, and then injecting it to the grid when needed.[33] In other words, batteries can provide renewable energy to the grid when renewable resources are no longer generating electricity, helping achieve grid equilibrium and mitigating the grid's reliance upon fossil fuel plants. Batteries also mitigate overabundance issues by removing energy from the grid when capacity exceeds load, further regulating frequency.[34] The ability to dispatch electricity and ramp up quickly explains why storage has grown as a "necessary complement to intermittent renewable generation."[35] As a result, widespread deployment of batteries is essential to achieving decarbonization goals.[36]

The market for storage batteries is expected to survive recent setbacks in the domestic renewable energy transition described in section IV.B. The second Trump Administration's policies – including the earlier-than-expected phase-out of tax credits, new "foreign entities of concern" (FEOC) restrictions, suspending offshore wind leasing, and restricting the permitting of onshore wind and solar PV projects[37] – undermine the transition, but investment in renewables is still expected to increase, albeit more slowly than previous projections.[38] Between 2025 and 2030, the United States is projected to add almost 250 GW of renewable power capacity.[39] Meanwhile, global renewable power capacity during that same timeframe is expected to forge ahead with an additional 4,600 GW,[40] a massive amount of power capacity.

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32. GlobeNewswire, *Energy Storage Systems Market to Accumulate USD 542 Billion in Value by 2032, Registering an 9.2% CAGR: Market.us*, EIN PRESSWIRE (Jan. 9, 2024), https://www.einpresswire.com/article/679996228/energy-storage-systems-market-to-accumulate-usd-542-billion-in-value-by-2032-registering-an-9-2-cagr-market-us.

33. *Energy Storage: How It Works and Its Role in an Equitable Clean Energy Future*, UNION OF CONCERNED SCIENTISTS (last updated Oct. 4, 2021), https://www.ucs.org/resources/how-energy-storage-works.

34. *Battery Systems on the U.S. Power Grid Are Increasingly Used to Respond to Price*, U.S. ENERGY INFO. ADMIN (July 27, 2022), https://www.eia.gov/todayinenergy/detail.php?id=53199.

35. Neeraj Arora et al., *A 2024 Update on Utility-Scale Energy Storage Procurements*, MORGAN, LEWIS, & BOCKIUS LLP (Mar. 4, 2024), https://www.morganlewis.com/pubs/2024/03/an-update-on-utility-scale-energy-storage-procurements.

36. *Energy Storage: How It Works and Its Role in an Equitable Clean Energy Future*, *supra* note 33.

37. YASMINA ABDELILAH ET AL., RENEWABLES 2025: ANALYSIS AND FORECASTS TO 2030, at 18 (Int'l Energy Agency 2025), https://iea.blob.core.windows.net/assets/76ad6eac-2aa6-4c55-9a55-b8dc0dba9f9e/Renewables2025.pdf.

38. Michael Copley, *Clean Energy is Surging Despite Political Attacks. But a Slowdown May Be Looming*, NPR (Dec. 26, 2025), https://www.npr.org/2025/12/19/nx-s1-5638909/trump-ai-energy-electricity-demand-climate-change; *see also* discussion *infra* Section IV.C.

39. ABDELILAH ET AL., *supra* note 37, at 40; *cf.* YASMINA ABDELILAH ET AL., RENEWABLES 2024: ANALYSIS AND FORECAST TO 2030, at 43 (Int'l Energy Agency 2024), https://iea.blob.core.windows.net/assets/17033b62-07a5-4144-8dd0-651cdb6caa24/Renewables2024.pdf (stating that in 2024, the International Energy Agency predicted that the U.S. would add almost 500 GW of renewable energy capacity between 2024-2030, mostly driven by solar and wind).

40. ABDELILAH ET AL, *supra* note 37, at 16.

Furthermore, batteries offer a range of benefits that extend beyond support for renewable generation.[41] Those benefits include relieving congestion on the transmission grid, reducing or delaying costly transmission upgrades, improving reliability, and providing ancillary services.[42] As previously mentioned, batteries provide frequency regulation to help stabilize the grid, which complements all types of electric generation. Additionally, batteries provide backup power during outages, improving grid reliability.[43] Other services include voltage regulation, demand charge reduction, time-of-use arbitrage, demand response, and fast frequency response.[44]

Voltage regulation, as the name suggests, brings high or low voltages into equilibrium thereby stabilizing the grid, mitigating transmission wear, and protecting against the risk of fire and shock.[45] Demand charge reduction means that if the utility rate structure has demand charges, batteries can help consumers save money by replacing "electricity imported from the utility above a certain threshold to 'shave' the facility's load 'peaks.'"[46] If the utility rate structure has time-of-use charges, batteries' ability "to charge from the grid when prices are low and discharge to the facility when prices are high" means that batteries can provide further cost savings.[47] Batteries also improve demand response programs. Historically, demand response programs compensate consumers for reducing their electric usage during periods of high electricity demand to decrease strain on the grid and improve grid reliability.[48] Batteries allow participation in demand response by supplying surplus energy to the grid without reducing electricity usage.[49] Lastly, batteries provide fast frequency response because they can regulate grid frequency within milliseconds, making batteries an invaluable tool

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41. This paper is not intended to be a comprehensive analysis of all the benefits that energy storage provides. For a more complete analysis, please see David Schmitt & Glenn M. Sanford, *Energy Storage: Can We Get It Right?*, 39 Energy L.J. 447, 458-74 (2018).

42. *Id*. at 458.

43. GLEN ANDERSEN, LAURA SHIELDS & JEREMY TWITCHELL, ENERGY STORAGE FOR A MODERN ELECTRIC GRID: TECHNOLOGY TRENDS & STATE POLICY OPTIONS, NAT'L CONF. OF STATE LEGISLATURES (last updated Sep. 22, 2021), https://www.ncsl.org/energy/energy-storage-for-a-modern-electric-grid-technology-trends-and-state-policy-options.

44. *How Does the Battery Energy Storage System (BESS) Regulate the Frequency & Voltage of the Power Grid?*, HT INFINITE POWER (Oct. 21, 2024), https://www.infinitepowerht.com/how-does-the-battery-energy-storage-system-regulate-the-frequency-and-voltage-of-the-power-grid.html; Lucas Miller, *Value Stacking with Battery Energy Storage Systems,* MAYFIELD RENEWABLES (Aug. 22, 2025), https://www.mayfield.energy/technical-articles/value-stacking-with-battery-energy-storage-systems/.

45. *How Does the Battery Energy Storage System (BESS) Regulate the Frequency & Voltage of the Power Grid?*, *supra* note 44; Tina Reynolds, *Keeping it Steady: Voltage Limits & Regulation in the Low-Voltage Grid*, CLOU MIDEA ENERGY (last updated Oct. 8, 2025), https://clouglobal.com/keeping-it-steady-voltage-limits-and-regulation-in-the-low-voltage-grid/.

46. Miller, *supra* note 44.

47. *Id*.

48. Karsten Neumeister, *Cutting Peak Energy Costs with Demand Response*, ENV'T L. & POL'Y CTR. (Feb. 25, 2026), https://elpc.org/blog/cutting-peak-energy-costs-with-demand-response/.

49. *Demand Response 101: Understanding How Utilities Balance Energy Supply & Demand*, GRIDPOINT, https://www.gridpoint.com/blog/understanding-demand-response/ (last visited Jan. 10, 2026); *What is Demand Response?*, HAVEN, https://resources.havenenergy.com/what-is-demand-response (last visited Jan. 10, 2026).

for grid stabilization and reliability.[50] All of those services provide value no matter the source of generation. With electricity demand increasing substantially in the upcoming years – for example, Amazon, Google, and Microsoft each invested between $75 to $100 billion in data center construction in 2025 – energy storage systems are becoming fundamental to ensure the functionality of our grid.[51]

In sum, storage batteries provide a myriad of benefits, which means that investment in batteries will continue despite recent policy changes at the federal level undermining construction of additional wind and solar facilities. Put simply, we need storage batteries, and that need is growing. Thus, now is the time to consider a transition away from Li-ion batteries to avoid further proliferation and dependence upon that technology.

III. THE COSTS OF LI-ION BATTERIES AND SEEKING AN ALTERNATIVE

So far, Li-ion batteries have been the primary drivers behind the growth of the storage battery market. Battery power capacity rose from fifty-nine MW in 2010[52] to sixteen GW by the end of 2023.[53] In 2024, the battery storage market experienced unprecedented growth, pushing the nation's cumulative battery storage capacity to about twenty-six GW.[54] And by quarter three of 2025, the United States had another record-breaking year,[55] with battery storage capacity surpassing forty GW.[56] In other words, while batteries had the capacity to power about 39,000 homes in 2010, by the end of 2025 batteries had the potential to

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50. Diane Cherry, *Energy Storage's Role as a Fast Frequency Response*, MAREC ACTION: BLOG (Sep. 19, 2025), https://marec.us/energy-storages-role-as-a-fast-frequency-response/.

51. Andy Brownstein, *The Battery Storage Paradox: How Policy Changes Are Reshaping Energy Investment*, GREENEHURLOCKER (Aug. 28, 2025), https://greenehurlocker.com/the-battery-storage-paradox-how-policy-changes-are-reshaping-energy-investment/.

52. Tim Sylvia, *Battery Adoption Skyrocketed in the 2010s and Lithium-ion Reigns Supreme*, PV MAG. (July 15, 2020), https://pv-magazine-usa.com/2020/07/15/battery-adoption-skyrocketed-in-the-2010s-and-lithium-ion-reigns-supreme/.

53. Clarion Energy Content Directors, *U.S. Battery Storage Projected to Nearly Double in 2024*, POWER ENG'G (Jan. 11, 2024), https://www.power-eng.com/energy-storage/batteries/u-s-battery-storage-projected-to-nearly-double-in-2024/#gref.

54. Jennifer L., *U.S. Battery Storage Hits a New Record Growth in 2024*, CARBON CREDITS.COM (last updated May 21, 2025), https://carboncredits.com/u-s-battery-storage-hits-a-new-record-growth-in-2024/.

55. Diana DiGangi, *2025 on Track for Record Storage Deployments: WoodMac*, UTILITYDIVE (Dec. 17, 2025), https://www.utilitydive.com/news/energy-storage-installations-capacity-battery-obbba/808115/.

56. Ryan Kennedy, *Solar and Storage Represent 91% of Clean Power Additions in Q3 2025*, PV MAG. (Dec. 8, 2025), https://pv-magazine-usa.com/2025/12/08/solar-and-storage-represent-91-of-clean-power-additions-in-q3-2025/.

power almost thirty million homes.[57] That growth has relied primarily on Li-ion batteries, the dominant storage battery technology.[58]

Indeed, Li-ion batteries have been supporting grid decarbonization for decades. Li-ion batteries were first commercialized in 1991 and have since been used for powering large-scale energy storage, electrical vehicles (EVs), and personal devices, such as cellphones, tablets, and laptops.[59] Lithium is the lightest metal, which makes it an attractive option for EVs and personal devices, where excess weight either diminishes performance or is undesirable.[60] Due to lithium's multiple uses and ubiquity, production of Li-ion batteries expanded and costs dropped.[61] In fact, most Li-ion batteries used for energy storage can use the same supply chains and processes as EVs, which helped them achieve economies of scale.[62] Storage batteries also benefitted from technological developments across sectors.[63] Over time, climate mitigation efforts gained traction and renewable energy projects proliferated, increasing battery demand.[64] Given their low-cost and availability, utilities turned almost exclusively to Li-ion batteries to support the necessary transition away from fossil fuels. In fact, "[g]rid operators and

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57. These estimates are based on one MW powering 670 homes. *See* Jessica Taylor, *Expert Speaks on How Many Homes Can Be Powered by 1 MW, When Peak Demand Sits at 85,000+ MW*, CBS AUS. (Aug. 23, 2023), https://cbsaustin.com/news/local/expert-speaks-on-how-many-homes-can-be-powered-by-1-mw-when-peak-demand-sits-at-85000-mw ("one megawatt is enough to power 670 homes"); *but see also* WHAT IS A MEGAWATT?, U.S. NRC (2012), https://www.nrc.gov/docs/ML1209/ML120960701.pdf (explaining that there is some variability in how many homes one megawatt can power, depending on the energy source and the region that households are located).

58. Maciej Kolaczkowski & Debmalya Sen, *Explainer: The Role of Energy Storage Technologies in the Energy Transition*, WORLD ECON. F. (Nov. 22, 2024), https://www.weforum.org/stories/2024/11/the-role-of-energy-storage-technologies-in-the-energy-transition/; *see* Arora et al., *supra* note 35 (explaining that Li-ion batteries accounted for over 90% of storage installations in the United States in 2020 and 2021); *see also* Iola Hughes, *Global BESS Deployments Soared 53% in 2024*, ENERGY STORAGE NEWS: GUEST BLOG (Jan. 14, 2025), https://www.energy-storage.news/global-bess-deployments-soared-53-in-2024/ (explaining that Li-ion batteries account for 98% of energy storage deployments globally in 2024).

59. Yuliya Preger, Loraine Torres-Castro & Jim McDowell, *Lithium-Ion Batteries*, *in* U.S. DOE ENERGY STORAGE HANDBOOK 1, 2, 10 (2021), https://www.sandia.gov/app/uploads/sites/163/2021/09/ESHB-Ch3_Lithium-Batteries_Preger.pdf.

60. Dhruv Warrior, *Why Does Lithium-ion Dominate the Battery Market Today?*, COUNCIL ON ENERGY, ENV'T, & WATER (June 30, 2021), https://www.ceew.in/cef/quick-reads/explains/why-does-lithium-ion-dominate-the-battery-market-today.

61. Preger, Torress-Castro & McDowel, *supra* note 59, at 10.

62. Charlie Hoffs, *How Are Lithium-ion Batteries that Store Solar and Wind Power Made?*, UNION OF CONCERNED SCIENTISTS: EQUATION BLOG (Dec. 22, 2022), https://blog.ucsusa.org/charlie-hoffs/how-are-lithium-ion-batteries-that-store-solar-and-wind-power-made.

63. Daan Walter, Sam Butler-Sloss & Kingsmill Bond, *The Rise of Batteries in Six Charts and Not Too Many Numbers*, RMI (Jan. 25, 2024), https://rmi.org/the-rise-of-batteries-in-six-charts-and-not-too-many-numbers/.

64. *See* Teo Lombardo et al., *Global Battery Markets are Growing Strongly - and so are the Supply Risks*, INT'L ENERGY AGENCY (Feb. 13, 2026), https://www.iea.org/commentaries/global-battery-markets-are-growing-strongly-and-so-are-the-supply-risks ("As variable renewable generation expands in many markets, battery storage is becoming an important source of flexibility and resilience for power systems, while also representing a growing commercial opportunity for battery manufacturers."); *see also History of Climate Action*, COUNCIL ON FOREIGN RELS. (last updated Feb. 13, 2025), https://education.cfr.org/learn/timeline/history-climate-action (providing historical timeline of climate mitigation efforts).

utilities use [Li-ion] batteries for nearly every storage application."[65] As a result, Li-ion batteries became entrenched in the energy storage market as *the* battery application to provide grid stability and support renewable generation.

Li-ion batteries also serve decarbonization goals by (mostly) abating carbon emissions. A Li-ion battery running on 100% renewable energy does not emit carbon through its operation;[66] although, the process of *producing* a Li-ion battery does emit some carbon. Obtaining a precise estimate of the carbon footprint of lithium-ion battery production is difficult because the amount of carbon emitted in producing a battery varies depending on the materials used, how materials are sourced, and what energy sources are used in manufacturing.[67] That said, approximations are available. In general, one Li-ion battery with one kWh of storage capacity emits between forty and two hundred kilograms of carbon dioxide during production.[68] Utility-grade battery capacity ranges from several MWh to hundreds of MWh.[69] Therefore, a utility-grade battery with the capacity of 100 MWh can emit up to 20,000 metric tons of carbon in production.[70] However, while Li-ion battery production undermines decarbonization goals, those emissions are a significant improvement compared to the burning of fossil fuels; Li-ion batteries storing renewable energy emit carbon only once and a 100 MW

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65. TECHNOLOGY ASSESSMENT: UTILITY-SCALE ENERGY STORAGE, U.S. GOV'T ACCOUNTABILITY OFF., 23 (Mar. 2023), https://www.gao.gov/assets/gao-23-105583.pdf.

66. Renewable energy plants emit some carbon, but the amount is negligible; for example, a wind plant emits between 11-12 grams of CO_2 per kWh. *See Electricity Generation and CO2 Emissions*, PLANETE ENERGIES (last updated Dec. 4, 2023), https://www.planete-energies.com/en/media/article/electricity-generation-and-related-co2-emissions; *see also* Pankaj Sadavarte, Drew Shindell & Daniel Loughlin *Comparing the Climate and Air Pollution Footprints of Lithium-ion BEVs and ICEs in the US Incorporating Systemic Energy System Responses*, 4 PLOS CLIMATE, Oct. 29, 2025, at 1, 1, https://journals.plos.org/climate/article?id=10.1371/journal.pclm.0000714 ("lithium-ion battery electric vehicles (BEVs) produce no emissions during operation . . .").

67. Iris Crawford, *How Much CO_2 is Emitted by Manufacturing Batteries?*, CLIMATE PORTAL (last updated Aug. 8, 2025), https://climate.mit.edu/ask-mit/how-much-co2-emitted-manufacturing-batteries.

68. Georgette Kilgore, *Carbon Footprint of Lithium-Ion Battery Production (vs Gasoline, Lead-Acid)*, 8 BILLION TREES (Oct. 3, 2024), https://8billiontrees.com/carbon-offsets-credits/carbon-footprint-of-lithium-ion-battery-production/.

69. ARINA ANISIE & FRANCISCO BOSHELL, UTILITY-SCALE BATTERIES: INNOVATION LANDSCAPE BRIEF 6 (Int'l Renewable Energy Agency 2019), https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Sep/IRENA_Utility-scale-batteries_2019.pdf.

70. *See* Joe Sexton, *Megawatt-Hours to Kilowatt-Hours Converter*, INCH CALCULATOR, https://www.inchcalculator.com/convert/megawatt-hour-to-kilowatt-hour/ (last visited Apr. 18, 2025) (showing that 1 MWh = 1,000 kWh); Joe Sexton, *Kilograms to Metric Tons (Tonnes) Converter*, INCH CALCULATOR, https://www.inchcalculator.com/convert/kilogram-to-metric-ton/ (last visited Apr. 18, 2025) (showing that 1 kilogram = .001 metric tons). Utility-grade battery = (200 kilograms of carbon dioxide during production x 1,000 kWh x 100 MWh) / 1,000 kilograms per metric ton. As another example, the Tesla Model 3 battery pack holds an 80 kWh Li-ion battery, the production of which produces between 2,400 kilograms and 16 metric tons of carbon. *See* Crawford, *supra* note 67. If the battery pack produces 16 tons, a car with an internal combustion engine emits one ton per 2,500 miles, and the average person drives 12,500 miles per year, it would take about three years for an EV's production emissions to be offset by averted vehicle emissions. Memorandum from Melissa Powers, Jeffrey Bain Faculty Scholar & Professor of L., Lewis & Clark L. Sch. to Jennifer Gentile, Student, Lewis & Clark L. Sch. (Apr. 15, 2025) (on file with author).

natural gas power plant running at full capacity and full time emits about 380,000 metric tons *per year*.[71]

Despite the current function of Li-ion batteries to support decarbonization goals, a continued and increased reliance upon Li-ion batteries for energy storage entails a variety of costs that policymakers should consider.

A. *Costs of Li-ion Batteries*

Li-ion batteries are associated with environmental and social harms, safety risks, and supply chain constraints. First, Li-ion batteries are harmful to the environment. Most Li-ion batteries are composed of lithium, cobalt, manganese, nickel, and graphite.[72] Mining for lithium and cobalt degrades the land, pollutes the air, is extremely water-intensive, and risks polluting freshwater supplies.[73] Cobalt, in particular, is very rare and is mostly found in the DRC, which contains over 50% of global cobalt reserves and produces about 60% of the world's cobalt.[74] There, cobalt is mined using pickaxes and shovels to dig trenches, pits, and tunnels,[75] often with child labor[76] under dangerous conditions. In southern regions of the DRC where cobalt is co-located with uranium, miners and surrounding communities are exposed to high levels of radiation.[77] Mining activities also pollute drinking water supplies and emit dust that impairs breathing.[78] Deaths are common.[79] In 2019, a tunnel collapsed and killed sixty-

71. *How Much Carbon Dioxide is Produced per Kilowatthour of U.S. Electricity Generation?*, U.S. ENERGY INFO. ADMIN. (last updated Dec. 11, 2024), https://www.eia.gov/tools/faqs/faq.php?id=74&t=11 (showing that natural gas in 2023 produced 0.96 pounds of carbon dioxide per kilowatt hour). There are 1,000 kilowatt hours in a megawatt hour. *See* Joe Sexton, *supra* note 70. There are 2,204.623 pounds in one metric tonne. *Convert Lbs to Ton*, UNITCONVERTERS.NET, https://www.unitconverters.net/weight-and-mass/lbs-to-ton.htm (last visited Apr. 13, 2026). The emissions calculation for 100 MW natural gas power plant running at full capacity and full time therefore is as follows: (0.96 pounds of carbon dioxide per kilowatt hour *1000 kilowatt hours * 100 / 2,204.623) * 24 hours * 365 days = 381,452.97 metric tonnes of carbon dioxide per year.

72. BRANDON S. TRACY, CONG. RSCH. SERV., CRITICAL MINERALS IN ELECTRIC VEHICLE BATTERIES 8-17 (2022), https://crsreports.congress.gov/product/pdf/R/R47227; *see also* Hector Beltran, Pablo Ayuso & Emilio P . . . rez, *Lifetime Expectancy of Li-Ion Batteries Used for Residential Solar Storage*, 13 ENERGIES, Jan. 24, 2020, at 1, 3-4 (showing that $LiFePO_4$ batteries, otherwise known as LFP batteries, lack cobalt but still contain lithium).

73. Amit Katwala, *The Spiralling Environmental Cost of Our Lithium Battery Addiction*, WIRED (Aug. 5, 2018), https://www.wired.co.uk/article/lithium-batteries-environment-impact.

74. *Cobalt*, FRIENDS OF THE CONGO, https://friendsofthecongo.org/cobalt/ (last visited Apr. 13, 2026); March Zheng, *The Environmental Impacts of Lithium and Cobalt Mining*, EARTH.ORG (Mar. 31, 2023), https://earth.org/lithium-and-cobalt-mining/.

75. Terry Gross, *How 'Modern-Day Slavery' in the Congo Powers the Rechargeable Battery Economy*, NPR (Feb. 1, 2023), https://www.npr.org/sections/goatsandsoda/2023/02/01/1152893248/red-cobalt-congo-drc-mining-siddharth-kara.

76. Katwala, *supra* note 73.

77. Zheng, *supra* note 74.

78. *Id*.

79. Louise Boyle, '*Here it is Better Not to be Born': Cobalt Mining for Big Tech is Driving Child Labor, Deaths in the Congo*, INDEP. (Feb. 23, 2023), https://www.independent.co.uk/climate-change/news/phone-electric-vehicle-congo-cobalt-mine-b2277665.html.

three miners who were buried alive.[80] That is just one example; many more deaths are presumed as they are often not reported.[81]

Furthermore, lithium is either extracted from underground brine water pumped to evaporate on the Earth's surface, exposing lithium, or is mined out of open pits.[82] In both cases, lithium mining requires large amounts of water, sometimes using thousands of gallons per minute,[83] and is associated with water depletion in arid places.[84] For example, lithium mining in the Chilean Atacama region, one of the driest regions in the world, has depleted scarce water supplies and has forced surrounding communities to leave, in some cases requiring people to abandon their ancestral homes.[85] Lithium mining also scars the land[86] and exposes byproducts harmful to human health, including arsenic, lead, and cadmium.[87] Scars from open pit mines can last thousands of years, even if vegetation recovers.[88]

Additionally, 79% of known lithium deposits in the United States are located within thirty-five miles of Native American reservations.[89] Those reservations are generally subject to state and federal mining policies. While state mining policies vary – for example, Maine prohibited the mining of one of the only domestic hard-rock sources of lithium[90] and Utah is one of the most attractive mining jurisdictions in the world[91] – the federal government generally favors mining activities. The General Mining Act of 1872, a seriously outdated piece of legislation, governs the mining of federal public lands.[92] That Act essentially guarantees a mining permit for anyone who discovers a "valuable mineral deposit"

80. *Id*.

81. *Id*.

82. *How Is Lithium Mined?*, CLIMATE PORTAL (Feb 12, 2024), https://climate.mit.edu/ask-mit/how-lithium-mined.

83. Darren Orf, *Does the World Have Enough Lithium for Batteries?*, POPULAR MECHS. (Jan 6, 2023), https://www.popularmechanics.com/science/energy/a42417327/lithium-supply-batteries-electric-vehicles/.

84. *How Is Lithium Mined?*, *supra* note 82.

85. Datu Buyung Agusdinata et al., *Socio-Environmental Impacts of Lithium Mineral Extraction: Towards a Research Agenda*, 13 ENV'T RSCH. LETTERS, Nov. 27, 2018, at 1, 2, 9, https://iopscience.iop.org/article/10.1088/1748-9326/aae9b1/pdf.

86. Ben Pilkington, *Opportunities and Challenges of Lithium Mining,* AZOMINING (Oct. 31, 2022), https://www.azomining.com/Article.aspx?ArticleID=1722.

87. Jared Naimark, *Seeking Environmental Justice in California's "Lithium Valley"*, EARTHWORKS: BLOG (Nov. 11, 2023), https://earthworks.org/blog/seeking-environmental-justice-in-californias-lithium-valley/.

88. *Abandoned Mineral Lands: Reclamation and Restoration*, NAT'L PARK SERV. (last updated Dec. 3, 2021), https://www.nps.gov/subjects/abandonedminerallands/reclamation-and-restoration.htm.

89. THEA RIOFRANCOS ET AL., THE EFFECTS OF LITHIUM MINING, CLIMATE & CMTY. INST. (2023), https://www.climateandcommunity.org/effects-of-lithium-extraction.

90. Alana Semuels & Kate Cough, *Gem Hunters Found the Lithium America Needs. Maine Won't Let Them Dig It Up*, TIME (July 17, 2023), https://time.com/6294818/lithium-mining-us-maine/.

91. *See* JULIO MEJIA & ELMIRA ALIAKBARI, FRASER INSTITUTE ANNUAL SURVEY OF MINING COMPANIES 2023 15-16 fig. 4 (Fraser Inst. 2024), https://www.fraserinstitute.org/sites/default/files/2023-annual-survey-of-mining-companies.pdf (showing that in 2023, Utah was ranked as the most favorable mining jurisdiction in the world).

92. RIOFRANCOS ET AL., *supra* note 89.

on qualifying federal land,[93] and it contains no water or environmental safeguards nor tribal consultation requirements.[94] If lithium mining is permitted, tribes will disproportionately suffer the detrimental effects of lithium mining, including water depletion, land scarring, pollution, ecological destruction, damage or loss of access to cultural and spiritual land, and, eventually, abandoned mines.[95]

Li-ion batteries also pose safety concerns. The Environmental Protection Agency (EPA) recognizes that Li-ion batteries can qualify as hazardous materials because they are ignitable and reactive.[96] Li-ion batteries are sensitive to high temperatures;[97] if Li-ion batteries overheat,[98] they can ignite, explode, and emit toxic hydrogen fluoride gas.[99] Alarmingly, Li-ion battery fires are growing with "enormous frequency"[100] and accounted for 267 fires, eighteen deaths, and 150 injuries in New York City in 2023 alone.[101] While Li-ion batteries used in electric bicycles started those fires, the risk also applies for Li-ion batteries used for energy storage. To be sure, ignitability of Li-ion batteries is a "major concern for deployment."[102] Recently, a Li-ion battery facility at a power plant in Northern California caught on fire, causing the evacuation of 1,200 nearby residents.[103] And Li-ion battery fires are very difficult to extinguish;[104] for example, a 2013 storage battery fire in Port Angeles, Washington reignited one week after firefighters

93. Frank Erisman, *The Mining Law of 1872: How Does It Work & Where is It Headed?*, SCHWABE, WILLIAMSON & WYATT (March 14, 2013), https://enr.osbar.org/files/2016/09/Locating_Claim_Site_Erisman.pdf; *1872 Mining Law*, EARTHWORKS, https://earthworks.org/issues/1872-mining-law/ (last visited Jan. 10, 2026).

94. RIOFRANCOS ET AL., *supra* note 89.

95. *Id.*; *1872 Mining Law*, *supra* note 93.

96. *Lithium-Ion Battery Recycling Frequently Asked Questions*, EPA (last updated Aug. 6, 2025), https://www.epa.gov/hw/lithium-ion-battery-recycling-frequently-asked-questions#hazwaste.

97. Stephen Singer, *Fire Safety Lags Growth in Utility-Scale Battery Production, Duke Energy, Other Officials Say*, UTILITYDIVE (Feb. 15, 2023), https://www.utilitydive.com/news/battery-fires-protection-safety-utility-scale-duke-aps/642793/.

98. *How Do You Put Out a Lithium-Ion Battery Fire?*, HILLER, https://hillerfire.com/insights/how-do-you-put-out-a-lithium-ion-battery-fire/ (last visited Mar. 10, 2024).

99. Simon Lundin & Linus Lundin, Fire Properties of Electrolytes for Lithium-Ion Batteries 1-2 (2019) (B.S. thesis, Luleå University of Technology), https://www.diva-portal.org/smash/get/diva2:1276737/FULLTEXT01.pdf.

100. Samatha Murphy Kelly, *Lithium-ion Battery Fires are Happening More Often. Here's How to Prevent Them.*, CNN BUS. (last updated Mar. 9, 2023), https://www.cnn.com/2023/03/09/tech/lithium-ion-battery-fires/index.html.

101. *Lithium-Ion Battery Fires on the Rise, Destroying Properties, Taking Lives*, SENECA: BLOG (Jan. 22, 2024), https://www.senecainsurance.com/lithium-ion-battery-fires-on-the-rise-destroying-properties-taking-lives/.

102. MARIA FONESCA-GUZMAN ET AL., THE STATE OF GRID ENERGY STORAGE IN MASSACHUSETTS 11 (UMass Lowell & AIM Found. 2019), https://web.archive.org/web/20251214083123/https://www.uml.edu/docs/complete-the%20state%20of%20grid%20energy%20storage%20in%20massachusetts-final_tcm18-321989.pdf.

103. Dave Pehling, *Moss Landing Residents File Lawsuit Over Northern California Lithium Battery Facility Fire*, CBS NEWS (last updated Feb. 10, 2025), https://www.cbsnews.com/sanfrancisco/news/moss-landing-lawsuit-northern-california-lithium-battery-facility-fire/.

104. *Lessons Learned: Fires in Lithium-ion Batteries Can Be Difficult to Extinguish*, SAFETY4SEA (June 15, 2023), https://safety4sea.com/lessons-learned-fires-in-lithium-ion-batteries-can-be-difficult-to-extinguish/.

believed it had been extinguished.[105] Thus, Li-ion battery fires threaten damage to the transmission system and adjacent renewable power facilities.[106]

Lastly, Li-ion batteries are subject to significant supply chain constraints. As mentioned above, cobalt is scarce; the DRC contains and provides most of the global supply. Moreover, the Russo-Ukrainian war restricts the United States' access to nickel and graphite because Russia produces much of those materials.[107] But perhaps most critically, the lithium supply chain is constrained. Today, the United States sources most of its Li-ion batteries from China,[108] the global leader of the Li-ion battery market.[109] That is problematic because tenuous relations between the countries, based largely on trade disagreements,[110] threaten to derail domestic decarbonization goals. The second Trump Administration significantly increased tariffs on Chinese imports; specifically, while Li-ion storage batteries faced a 64.9% tariff in the beginning of 2025, tariffs escalated as high as 145% in April 2025.[111] Although tariffs on Li-ion batteries from China have recently decreased pursuant to a temporary "tariff truce" announced in November 2025,[112] the future of tariffs on Li-ion batteries is uncertain. What is certain is that the United States' unstable relationship with China has tightened our nation's access to storage batteries.

The United States has recognized the supply chain constraints associated with lithium and is beginning to turn inward to fulfill its demand.[113] However, it will be difficult, if not impossible, for the United States, which currently has only one active lithium mine,[114] to supply enough lithium to meet demand. While the

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105. Singer*, supra* note 97.

106. THE HARTFORD, FIRE HAZARDS OF BATTERY ENERGY STORAGE SYSTEMS 3-4 (2026), https://assets.thehartford.com/image/upload/fire_hazards_of_battery_energy_storage_systems.pdf.

107. Mark A. Lazaroff & Neeraj Arora, *Key Considerations for Utility-Scale Energy Storage Procurements*, MORGAN LEWIS (Mar. 8, 2023), https://www.morganlewis.com/pubs/2023/03/key-considerations-for-utility-scale-energy-storage-procurements.

108. Felix Richter, *Charted: Where Does the US Lithium Battery Supply Come From?*, WORLD ECON. F. (Mar. 15, 2023), https://www.weforum.org/agenda/2023/03/charted-where-does-the-us-lithium-battery-supply-come-from/.

109. Elizabeth N. Gallio, *Supply Chain Disruptions in the Energy Industry: Challenges with the Supply of Lithium-ion Batteries*, FOLEY: BLOGS (Sep. 1, 2022), https://www.foley.com/insights/publications/2022/09/supply-chain-disruptions-energy-lithium-ion/.

110. Patricia M. Kim, *The US-China Relationship in 2024 is Stabilized but Precarious*, BROOKINGS (Jan. 12, 2024), https://www.brookings.edu/articles/us-china-relations-in-2024-are-stabilized-but-precarious/.

111. *See The Tariff Tangle: China Trade & the Battery Industry in 2025*, ACCULON ENERGY (Aug. 26, 2025), https://acculonenergy.com/the-tariff-tangle-china-trade-the-battery-industry-in-2025/; *see also* Jonathon Gifford, *Tariff Uncertainty Grips US Battery Development*, ESS NEWS: PV MAG. (Apr. 23, 2025), https://www.ess-news.com/2025/04/23/tariff-uncertainty-grips-us-battery-development/ (noting that there is uncertainty surrounding the exact tariff percentage because the number is frequently changing).

112. *See The Tariff Tangle: China Trade & the Battery Industry in 2025*, *supra* note 111; *see also Fact Sheet: President Donald J. Trump Strikes Deal on Economic & Trade Relations with China*, THE WHITE HOUSE (Nov. 1, 2025), https://www.whitehouse.gov/fact-sheets/2025/11/fact-sheet-president-donald-j-trump-strikes-deal-on-economic-and-trade-relations-with-china/.

113. *See* discussion *infra* Section IV B.

114. Noel Lyn Smith & Pacey Smith-Garcia, *Tribes Face an Uphill Battle to Defend Their Sacred Land Against Lithium Mining*, LITHIUM LIABS. (Jan. 25, 2024), https://cronkitenews.azpbs.org/howardcenter/lithium/stories/indigenous.html.

United States sits on ample lithium reserves,[115] it lacks a robust infrastructure to extract, refine, and produce all the lithium it needs.[116] Consequently, the United States' production capacity of Li-ion batteries is forecasted to fulfill less than 50% of its projected demand through 2028.[117] The relatively short lifespan of Li-ion batteries (between eight to twelve years for residential uses[118] and ten to fifteen years for grid uses[119]) further exacerbates the issue. Moreover, the storage battery market must compete with the EV and personal device markets for the limited domestic supplies of lithium and Li-ion batteries that do exist.

Efforts underway to expand the domestic Li-ion battery supply chain have been met with community resistance, legal challenges,[120] and lengthy permitting processes.[121] Notably, resistance to lithium mining came to a head at Thacker Pass, Nevada, otherwise known by its Paiute name, *Peehee mu'huh*.[122] There, the Bureau of Land Management (BLM) approved a mining project that threatened to destroy sacred land[123] despite protests from local tribes.[124] Legal challenges seeking to halt Thacker Pass mining plans arose in response, and although challenges failed in 2023, the situation helped raise awareness of the need for mining reform.[125] Most recently, the Trump Administration has accelerated the permitting process for lithium mining in the United States pursuant to Executive Order (EO) 14241,[126] but that measure will likely also face resistance,[127] creating uncertainty in the Li-ion battery market.

Current efforts to recycle Li-ion batteries are failing to alleviate supply chain restraints. In general, Li-ion battery recycling occurs in three major stages –

115. Carly Anderson, *Does the U.S. Have Enough Lithium to Support the Growing EV Market?*, MEDIUM (May 18, 2022), https://medium.com/prime-movers-lab/does-the-u-s-have-enough-lithium-to-support-the-growing-ev-market-d73a44a969e5.

116. *U.S. Department of Energy Analysis Confirms California's Salton Sea Region to be a Rich Domestic Lithium Resource*, U.S. DEP'T OF ENERGY: OFF. OF ENERGY EFFICIENCY & RENEWABLE ENERGY (Nov. 28, 2023), https://content.govdelivery.com/accounts/USEERE/bulletins/37d1513.

117. FED. CONSORTIUM FOR ADVANCED BATTERIES, EXECUTIVE SUMMARY: NATIONAL BLUEPRINT FOR LITHIUM BATTERIES 2021-2030, at 15 (U.S. Dep't of Energy 2021) [hereinafter NATIONAL BLUEPRINT].

118. Beltran, Ayuso & P . . . rez, *supra* note 72, at 15.

119. *Grid Scale Energy Storage: An In-Depth Look*, ALSYM ENERGY (Feb. 11, 2024), https://www.alsym.com/blog/an-in-depth-look-at-grid-scale-energy-storage-systems/.

120. Bert Johnson, *Northern Nevada Lithium Mine Draws Native Resistance from Across the West*, KUNR (Jan. 10, 2023), https://www.kunr.org/energy-and-environment/2023-01-10/northern-nevada-thacker-pass-lithium-mine-native-american-western-resistance.

121. Tony Lenoir & Aude Marjolin, *Charging Up on Battery Energy Storage 101, US Market Outlook*, S&P GLOBAL (Apr. 5, 2023), https://www.spglobal.com/marketintelligence/en/news-insights/research/charging-up-on-battery-energy-storage-101-us-market-outlook.

122. Manuel Rodeiro, *Mining Thacker Pass: Environmental Justice and the Demands of Green Energy*, 16 ENV'T JUST. 91, 91 (2023).

123. *Id*.

124. Smith & Smith-Garcia, *supra* note 114.

125. *Id*.

126. *Trump Administration Adds Key Mining Projects to FAST-41*, U.S. DEP'T OF INTERIOR (last updated May 1, 2025), https://www.doi.gov/pressreleases/trump-administration-adds-key-mining-projects-fast-41.

127. *See* Theodore Quinn, *Trump's Mining Fast-Track: A Gold Mine for Investors?*, AINVEST (Apr. 18, 2025), https://www.ainvest.com/news/trump-mining-fast-track-gold-investors-2504/ (predicting regulatory battles in reaction to EO 14241).

collecting/sorting, disassembly/separation, and material recovery/regeneration – with the disassembly stage presenting the most significant hurdles.[128] Li-ion batteries are not designed for efficient recycling: disassembly and widely varied chemistries and configurations present technical, safety, and economic issues.[129] Because Li-ion batteries are not designed for end-of-life handling, they often retain high residual charge, risking thermal runaway, short-circuits, and toxic emissions during dismantling.[130] Further, the variety of Li-ion battery compositions and pack designs impede automation of the disassembly process (which requires standardized pack architectures) and result in labor-intensive, time-consuming, and costly manual disassembly.[131] Research is underway to improve end-of-life management of Li-ion batteries, but the road ahead is challenging.[132] Today, about 90% of Li-ion batteries end up in landfills, making material recovery impossible and risking fires and leakage of harmful heavy metals and chemicals into the environment.[133]

Amidst all the issues associated with Li-ion batteries, developers are exploring alternative battery technologies, and more sustainable alternatives are emerging.

B. Na-ion as an Alternative to Li-ion

Sustainable alternatives include compressed air energy storage (CAES), flow batteries, gravity-based storage, zinc-based technologies,[134] and Na-ion batteries.[135] While all those options may be viable candidates to replace Li-ion batteries, Na-ion batteries are "postulated as the most attractive economical and sustainable alternative to lithium-ion batteries" for large-scale stationary applications.[136]

As far as the mechanical options (CAES and gravity-based storage) go, Na-ion is a more versatile option. Utility-grade CAES stores energy by compressing air in underground caverns or above-ground vessels and releases that energy by

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128. Jaime Chacana-Olivares et al., *Lithium-ion Battery Recycling: A Perspective on Key Challenges & Opportunities*, 3 NPJ MATERIALS SUSTAINABILITY, Nov. 7, 2025, at 1, 2.

129. *Id*. at 1.

130. *Id*. at 2.

131. *Id*.

132. Chacana-Olivares et al., *supra* note 128, at 1.

133. Eduardo Enrique Martinez Jorges, António M.N. Quintino & Diogo M.F. Santos, *Economic Analysis of Lithium-ion Battery Recycling*, 11 AIMS ENERGY 960, 963 (2023); *Improper Disposal of Lithium Batteries Causing Fires at Fort Fairfield Landfill, Posing Major Safety & Environmental Risks*, FORT FAIRFIELD (Sep. 18, 2025), https://www.fortfairfield.org/improper-disposal-of-lithium-batteries-causing-fires-at-fort-fairfield-landfill-posing-major-safety-and-environmental-risks/.

134. Ben Cook, *4 Alternatives to Lithium-ion Batteries Currently Exciting Investors*, TAMARINDO (June 2, 2023), https://tamarindo.global/insight/analysis/4-alternatives-to-lithium-ion-batteries-currently-exciting-investors/.

135. *Sodium-ion Batteries as the Future of Renewable Energy Storage*, CLIMATE ADAPTATION PLATFORM (Mar. 12, 2023), https://climateadaptationplatform.com/sodium-ion-batteries-as-the-future-of-renewable-energy-storage/.

136. Zarrabeitia, Zuo & Passerini, *supra* note 10, at 797.

heating up the air to spin turbines.[137] Accordingly, CAES is often geographically limited to locations where underground caverns and/or gas turbines exist.[138] Gravity-based storage, which operates by hauling tons of weight upward and then releasing that weight to power a generator, also faces location and cost restrictions.[139] In order to operate, utility-grade systems require either underground shafts (like abandoned mine shafts) or massive above-ground structures that cost millions or billions of dollars to build (*e.g.* one prototype by Energy Vault stands twenty stories tall and is composed almost entirely of steel and concrete).[140] Conversely, Na-ion batteries are not location dependent and are relatively cheap to build.[141]

Furthermore, Na-ion battery technology has an edge over its electrochemical competitors, flow and zinc-based batteries. Na-ion batteries are safer, have better energy density, charge faster, operate at a wider temperature range, are more cost effective, and are more environmentally friendly than flow batteries.[142] Additionally, zinc-based batteries encounter technical challenges not suffered by Na-ion technology: relatively low power output, sensitivity to humidity and temperature changes, and recharging issues related to the formation of zinc dendrites, which can short-circuit the battery.[143] Based on the aforementioned considerations, other electrochemical and mechanical storage options are not competitive with Na-ion batteries.

Importantly, Na-ion batteries have significant advantages over Li-ion batteries. They rely upon cheaper, more abundant, and easier to extract materials (sodium and aluminum),[144] can be produced through more environmentally-

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137. *Renewable Energy Storage: Complete Guide to Technologies, Benefits & Future (2025)*, SOLARTECH (Oct. 15, 2025), https://solartechonline.com/blog/renewable-energy-storage-guide/.

138. Gergo Varhegyi & Mutasim Nour, *Advancing Fast Frequency Response Ancillary Services in Renewable-Heavy Grids: A Global Review of Energy Storage-Based Solutions and Market Dynamics*, 17 ENERGIES, July 29, 2024, at 1, 11.

139. Alasdair Lane, *Can Gravity Batteries Solve Our Energy Storage Problems?*, BBC (May 16, 2022), https://www.bbc.com/future/article/20220511-can-gravity-batteries-solve-our-energy-storage-problems; *see also* Christopher Bonasia, *Ontario Pours $285M into Studies for Controversial Pumped Storage Project*, THE ENERGY MIX (Feb. 26, 2025), https://www.theenergymix.com/ontario-pours-285m-into-studies-for-controversial-pumped-storage-project/ (describing the Ontario Pumped Storage Project, another mechanical storage option).

140. *See* Lane, *supra* note 139.

141. Oliver Gordon, *Exclusive: Sodium Batteries to Disrupt Energy Storage Market*, ENERGY MONITOR (July 1, 2024), https://www.energymonitor.ai/energy-storage/exclusive-sodium-batteries-to-disrupt-energy-storage-market/?cf-view.

142. *Sodium-ion Battery vs. Redox Flow – Which Technology Will Prevail?*, ALAS ENERGY: BLOG (Apr. 22, 2025), https://alasenergy.gr/2025/04/22/sodium-ion-battery-vs-redox-flow-which-technology-will-prevail/.

143. *Zinc-Air Batteries 101: Advantages, Limitations, & Use Cases*, EUREKA (June 20, 2025), https://eureka.patsnap.com/article/zinc-air-batteries-101-advantages-limitations-and-use-cases; Jared Sagoff, *Looking at Challenges to Zinc-ion Batteries*, ARGONNE NAT'L LAB'Y (Nov. 29, 2022), https://www.anl.gov/article/looking-at-challenges-to-zincion-batteries.

144. *Sodium-ion Batteries as the Future of Renewable Energy Storage*, *supra* note 135; *see* NICOLA DE BLASIO, SODIUM: AN ALTERNATIVE TO THE "WHITE GOLD" OF THE ENERGY TRANSITION? 6 (Harv. Kennedy Sch.: Belfer Ctr. for Sci. & Int'l Affs. 2024), https://www.belfercenter.org/sites/default/files/2024-08/PolicyBrief_ENRP_SodiumVsLithium_v4.pdf (discussing how the United States contains over 90% of the world's known soda ash reserves, which is the most cost-efficient source of sodium).

friendly processes such as seawater desalination,[145] operate at a higher temperature range without ignition risk, and charge faster than Li-ion batteries.[146] Na-ion batteries do not rely upon lithium or cobalt,[147] so they avoid the environmental and social justice issues previously described.[148] And although conflicting reports exist, at least one source indicates that Na-ion batteries have a life-cycle three times higher than Li-ion batteries,[149] meaning that a Na-ion battery can charge and discharge many more times than its competitors.[150] While Na-ion battery technology is still evolving, ongoing research and development has improved its energy density, cycle life, and safety features, positioning Na-ion batteries to effectively compete with Li-ion batteries in the storage battery market.[151] In fact, while Na-ion batteries are relatively new on the commercial scene,[152] some stakeholders predict that Na-ion batteries may be in mainstream use as early as 2027.[153]

Additionally, Na-ion batteries can be recycled in a simpler, safer, and potentially more energy-efficient manner than Li-ion batteries,[154] which is essential for reducing waste, promoting a circular economy, and improving the efficiency and sustainability of battery supply chains. Na-ion batteries are generally comprised of easier-to-recover materials than Li-ion batteries due to

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145. Meredith Rountree, *Sodium: Leading the Charge Toward Better Batteries*, ACS AXIAL (Dec. 26, 2022), https://axial.acs.org/energy/sodium-leading-the-charge-toward-better-batteries.

146. *Sodium-ion Batteries as the Future of Renewable Energy Storage*, *supra* note 135.

147. *See* Haegyeom Kim, *Sodium-Ion Battery: Can It Compete with Li-Ion?*, 3 ACS MATERIALS AU (SPECIAL ISSUE: 2023 RISING STARS) 571, 571 (2023) (stating that Na-ion batteries "avoid the use of expensive and less abundant elements such as lithium, cobalt, and nickel while also sharing similar operating principles with LIBs [Li-ion batteries]").

148. Many Na-ion batteries also do not contain nickel, avoiding supply chain constraints described in Section III.A, however, some Na-ion batteries, such as lithium nickel-manganese-cobalt (NMC), are partly comprised of nickel. *See id.* (stating the Na-ion batteries avoid the use of nickel); *A New Era for Batteries: Argonne Leads $50M Sodium-Ion Innovation Push*, ARGONNE NAT'L LAB'Y. (Nov. 21, 2024) https://www.anl.gov/article/a-new-era-for-batteries-argonne-leads-50m-sodiumion-innovation-push (stating that Na-ion batteries can eliminate using nickel as a component of their design); Joseph E. Harmon, *Cathode Innovation Makes Sodium-Ion Battery an Attractive Option for Electric Vehicles*, ARGONNE NAT'L LAB'Y (Jan. 8, 2024), https://www.anl.gov/article/cathode-innovation-makes-sodiumion-battery-an-attractive-option-for-electric-vehicles (describing sodium nickel-manganese-cobalt (NMF) oxide batteries).

149. Sanket Chipade, *Sodium-Ion v. Lithium-Ion Battery: Which is a Better Alternative?*, GEP (July 2, 2025), https://www.gep.com/blog/strategy/lithium-ion-vs-sodium-ion-battery.

150. *Sodium-Ion and Solar Power: A Match Made in Heaven*, ACCULON ENERGY (Feb. 27, 2024), https://acculonenergy.com/sodium-ion-and-solar-power-a-match-made-in-heaven/.

151. GlobeNewswire, *Global Sodium-Ion Battery Market to Expand at 13.2% CAGR, Fueled by Demand for Sustainable Energy Storage: Recent Report by Persistence Market Research*, EIN PRESSWIRE (Nov. 27, 2023), https://www.einpresswire.com/article/671159913/global-sodium-ion-battery-market-to-expand-at-13-2-cagr-fueled-by-demand-for-sustainable-energy-storage-recent-report-by-persistence-market.

152. *Sodium-ion Batteries: The Revolution in Renewable Energy Storage*, IBERDROLA, https://www.iberdrola.com/sustainability/environment/energy-efficiency/sodium-ion-batteries (last visited Feb. 22, 2025).

153. Gordon, *supra* note 141.

154. Mohammad Muhtasim Mashfy et al., *Sodium Ion Batteries: A Sustainable Alternative to Lithium-ion Batteries with an Overview of Market Trends, Recycling, & Battery Chemistry*, 10 Next Energy Oct. 27, 2025, at 1, 24.

their non-toxic natures.[155] Na-ion technology also has the benefit of learning from the recycling difficulties experienced by Li-ion technology, incorporating recycling considerations into its battery design.[156] Recycling Na-ion batteries is relatively straightforward, involving "crushing abandoned batteries, collecting stainless steel accessories via magnetic separation and flotation, and eliminating organic solvents from waste scraps via thermal vacuum."[157] Using a bipolar design, certain expensive electrode materials in Na-ion batteries can be inexpensively recycled in one step.[158] Na-ion batteries may even be able to achieve complete battery recyclability.[159] As such, Na-ion batteries can improve the sustainability and efficiency of the storage battery supply chain.[160]

A few drawbacks to Na-ion batteries exist, but they should not impede widespread adoption. Na-ion batteries have an approximately 30%[161] lower energy density than Li-ion batteries, meaning that a Na-ion battery cannot store as much energy as a Li-ion battery of the same size.[162] However, technological improvements are underway. Shirley Meng, a professor at The University of Chicago and Chief Scientist of the Argonne Collaborative Center for Energy Storage Science (ACCESS),[163] stated that she has "no doubt" Na-ion batteries will work just as well as Li-ion batteries by 2034.[164] Another concern is that Na-ion batteries are about three times heavier than Li-ion batteries,[165] but that is *mostly* a nonissue in the stationary energy storage context.[166] While weight and size do not pose problems once Na-ion batteries are installed, heavier and larger Na-ion batteries result in higher shipping costs due to bigger enclosures, more cooling, stronger mounting hardware, and potential vehicle modifications.[167]

In addition, production of Na-ion batteries currently emit more carbon dioxide than production of Li-ion batteries.[168] But note, the amount of emissions

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155. *Sodium Batteries: The Sustainable, Eco-Friendly Alternative to Lithium*, ELEVEN ENERGY (Sep. 9, 2024), https://www.elevenenergy.co.uk/post/sodium-batteries-the-sustainable-eco-friendly-alternative-to-lithium.

156. *See* Muhtasim Mashfy et al., *supra* note 154, at 21.

157. *Id*.

158. *Id*.

159. *Id*. at 23.

160. *See* Muhtasim Mashfy et al., *supra* note 154, at 4.

161. St . . . phanie Melançon, *Sodium-Ion Battery vs. Lithium-Ion Battery: Which One is Better?*, LASERAX: BLOG (Nov. 18, 2024), https://www.laserax.com/blog/sodium-ion-vs-lithium-ion-batteries.

162. DE BLASIO, *supra* note 144, at 5.

163. *Ying Shirley Meng*, ARGONNE NAT'L LAB'Y, https://www.anl.gov/profile/ying-shirley-meng (last visited Apr. 13, 2026).

164. Michael Schirber, *Sodium as a Green Substitute for Lithium in Batteries*, 17 PHYSICS MAG., Apr. 25, 2024), at 1, 2, https://physics.aps.org/articles/v17/73.

165. DE BLASIO, *supra* note 144, at 5.

166. *See* Grace Donnelly, *Batteries Beyond EVs – Everything You Need to Know About Stationary Storage*, TECH BREW (Apr. 19, 2022), https://www.emergingtechbrew.com/stories/2022/04/19/batteries-beyond-evs-everything-you-need-to-know-about-stationary-storage (stating that stationary storage batteries are less constrained by size and space considerations than batteries used in EVs).

167. *Why Sodium Batteries Might Cost You More Than Expected*, HIGH TAR: ABOUT US BLOG (Sep. 3, 2025), https://en.highstar.com/blog/why-sodium-batteries-cost-more-than-expected.

168. Schirber, *supra* note 164, at 3.

generated depends greatly upon the type of technology and the materials used; indeed, one study using a climate impact model found that some Na-ion battery technologies emit fewer emissions than a leading type of Li-ion battery technology, lithium nickel manganese cobalt oxide (NMC 811).[169] That same study predicted that Na-ion battery production may emit about the same or fewer carbon emissions per kWh as production of mainstream Li-ion battery technologies by 2030.[170] Even if Na-ion batteries emit the same level of carbon as Li-ion batteries, substituting Li-ion batteries with Na-ion batteries is more sustainable given the natural resource degradation and social justice issues associated with Li-ion batteries, described above.[171]

The biggest drawback to Na-ion batteries is that its industrial value chains are immature,[172] hindering widespread deployment of the technology until supply chains scale up. However, Na-ion batteries are well-situated to leverage existing processes to scale up quickly. Na-ion batteries use many of the same manufacturing processes as Li-ion batteries and they can take advantage of Li-ion economies of scale if manufacturers retrofit existing Li-ion battery plants (of which there are thirty-five within the United States)[173] to Na-ion technology.[174] Moreover, Li-ion and Na-ion batteries are similar in technology and chemistry, such that Li-ion and Na-ion batteries can be integrated into a single battery system.[175] This overlap means that Na-ion batteries can avoid issues associated with "lock-in," a phenomenon where existing infrastructure creates path dependencies for mature technologies and makes it difficult to transition to a new technology.[176]

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169. The study developed a climate model to compare the climate impact of Li-ion battery and Na-ion battery production using batteries of the same size. The Na-ion technologies used were layered oxide, vanadium-based polyanionic, and Prussian blue analogues, and were considered because of their technological readiness and market and research preference. The Li-ion technologies used were LFP and NMC 811 and were considered because they were deployed and used in similar applications as Na-ion batteries. Moreover, NMC 811 batteries are expected to dominate the future energy storage market. The study found that Na-ion batteries using layered oxide technology, vanadium-based polyanionic technology, and Prussian blue analogues emitted more carbon than Li-ion batteries using lithium-ion phosphate (LFP) technology, but that Li-ion batteries using lithium nickel manganese cobalt oxide (NMC 811) technology produced more emissions than Na-ion batteries using layered oxide and Prussian blue analogue technologies. *See* Shan Zhang et al., *Future Climate Impacts of Sodium-ion Batteries*, 202 RES., CONSERVATION & RECYCLING, Dec. 11, 2024), at 1, 2, 4.

170. *Id*. at 2, 5 fig. 2.

171. *See* discussion *supra* Section III.A. (describing the costs of Li-ion batteries).

172. DE BLASIO, *supra* note 144, at 5.

173. *Lithium Battery Manufacturing in the US – Number of Businesses (2006-2031)*, IBIS WORLD (last updated Sep. 2025), https://www.ibisworld.com/industry-statistics/number-of-businesses/lithium-battery-manufacturing-united-states/.

174. *Sodium-ion Batteries: The Revolution in Renewable Energy Storage*, *supra* note 152.

175. *See, e.g.* Charles Morris, *CATL's New Sodium-ion Battery Can be Mixed and Matched with Lithium-ion in the Same System*, CHARGED: EV ENG'G. NEWS (Aug. 2, 2021), https://chargedevs.com/newswire/catls-new-sodium-ion-battery-can-be-mixed-and-matched-with-lithium-ion-in-the-same-system/ (mixing-and-matching Li-ion batteries and Na-ion batteries within the same battery system); Jasper Biemolt et al., *Beyond Lithium-Based Batteries*, 13 MATERIALS, Jan. 16, 2020, at 1, 1 https://pmc.ncbi.nlm.nih.gov/articles/PMC7013668/pdf/materials-13-00425.pdf.

176. *See* Melissa Powers, *Natural Gas Lock-In*, 69 U. KAN. L. REV. 889, 891 (2021) (describing carbon lock-in as the "tendency for fossil fuel infrastructure to persist and create new path dependencies that could extend its use and lock out renewable resources"); *see also Top 5 Barriers to EV Adoption Reported by EV100*

As of 2026, Na-ion batteries have not been commercially deployed on a large scale in the United States.[177] In fact, there are currently no commercial manufacturers of Na-ion batteries in the United States.[178] The "world's first" grid-scale Na-ion project was launched in China as recently as 2023[179] and the United States' first grid-scale Na-ion battery installation powered up in 2025 at a test facility in Colorado.[180] Yet, despite its nascence, Na-ion battery technology is poised for expansion. Peak Energy, a domestic manufacturer, plans to launch commercial-scale projects as early as 2027.[181] And some experts forecast that Na-ion batteries will gain a significant share (23%) of the stationary battery market by 2030.[182] However, Na-ion batteries are expected to complement Li-ion batteries rather than replace them.[183] That is largely because lenders and financiers are often reluctant to invest in technologies that are not well-established.[184] Unless the government intervenes, Li-ion batteries will continue to maintain their dominance of the battery market.

IV. THE FAILURE TO ACCOUNT FOR LI-ION'S COSTS

While states and the federal government have sought to increase storage battery deployment, existing regulations fail to account for the costs associated with Li-ion batteries. As a result, government policy has enabled lithium's dominance of the battery storage market.

A. Current State Programs

States with energy storage programs have generally used one or more of the following mechanisms to encourage battery deployment: integrated resource planning, called IRPs (twenty states); utility procurement mandates, targets, or

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Member Companies, INT'L ENERGY AGENCY (last updated Apr. 29, 2021), https://www.iea.org/data-and-statistics/charts/top-5-barriers-to-ev-adoption-reported-by-ev100-member-companies (listing "lack of charging infrastructure" as the top barrier to EV adoption).

177. *See* Lombard et al., *supra* note 12.

178. Natron Energy, the nation's first commercial Na-ion battery manufacturer, shut down its operations in September 2025 citing funding issues. *See* Julia Tilton, *Natron's Failure May Not Spell Doom for Sodium-Ion Batteries – China is Still Surging Ahead in the Tech's Development*, IEEE SPECTRUM (Oct. 6, 2025), https://spectrum.ieee.org/natron-sodium-ion-battery-failure.

179. Cameron Murray, '*World-First' Grid-Scale Sodium-Ion Battery Project in China Launched*, ENERGY STORAGE NEWS (Aug. 3, 2023), https://www.energy-storage.news/world-first-grid-scale-sodium-ion-battery-project-in-china-enters-commercial-operation/.

180. Marija Maisch, *Peak Energy Announces Operation of First Large-Scale Sodium Ion Battery in US*, PV MAG. (Sep. 26, 2025), https://www.ess-news.com/2025/09/26/peak-energy-announces-operation-of-first-large-scale-sodium-ion-battery-in-us/.

181. *Id*.

182. SPOERKE, DURVASULU & BALLIET, TECHNOLOGY STRATEGY ASSESSMENT: FINDINGS FROM STORAGE INNOVATIONS 2030, at 5 (U.S. Dep't of Energy: Energy Earthshots 2023); *Sodium-ion Batteries: The Revolution in Renewable Energy Storage*, *supra* note 152.

183. Laura Lander, *Guide to Sodium-Ion Batteries: Are They Ready to Replace Lithium?*, ACCURE: BLOG, https://www.accure.net/battery-knowledge/sodium-ion-batteries-role-in-energy-storage (last visited Apr. 10, 2026).

184. Einar Rasmussen & Roger Sorheim, *How Governments Seek to Bridge the Financing Gap for University Spin-offs: Proof-of-Concept, Pre-Seed, & Seed Funding*, 24 TECH. ANALYSIS & STRATEGIC MGMT. 663, 664 (2012); *see* discussion *infra* Section IV.A.

goals, called Energy Storage Performance Standards or ESPSs (ten states); state-funded demonstration projects (five states); and incentives or subsidies (four states).[185] This section discusses each in turn.

Though IRP requirements vary by state, they generally require utilities to develop long-term plans on how to meet future energy demand[186] via reliable means and at the lowest practical cost.[187] In states that currently require IRPs, utilities typically must create plans based on ten-to-twenty year horizons subject to updates every two-to-three years.[188] During planning, states may require utilities to make decisions based on a list of considerations, often including risk and cost.[189] Other considerations, such as environmental performance, resilience, and customer empowerment, are gaining prevalence.[190] For example, Oregon has a "least-cost, least-risk" planning method while California requires utilities to account for emission reduction targets in communities disproportionately impacted by pollution.[191] Utilities must file plans with their state agencies that may acknowledge (or not) their IRPs and that basic requirements have been met.[192] Some states require formal approval of IRPs, others do not.[193] States may accept or reject all or portions of an IRP, identify areas of concern, and provide suggestions.[194] Despite the nonbinding nature of many IRPs, they tend to influence utilities' resource decisions by creating guidance and setting expectations.[195]

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185. Will McNamara, *Energy Storage Policy: Observations*, SANDIA NAT'L LAB'YS, at 4 (Oct. 26, 2023), https://www.sandia.gov/app/uploads/sites/82/2023/10/PR2023_1005_McNamara_Will_Regulatory-Environment.pdf; Mark A. Lazaroff & Maggie E. Curran, *State By State: An Updated Roadmap Through the Current US Energy Storage Policy Landscape*, MORGAN LEWIS (Mar. 7, 2025), https://www.morganlewis.com/pubs/2025/03/state-by-state-an-updated-roadmap-through-the-current-us-energy-storage-policy-landscape#_ftn7.

186. CELINA BONUGLI & HEIDI RATZ, INTEGRATED RESOURCE PLAN (IRP) SUPPORT PACKAGE, AM. CITIES CLIMATE CHALLENGE RENEWABLES ACCELERATOR 3-4, https://cityrenewables.org/wp-content/uploads/edd/2021/06/Integrated-Resource-Plan-Support-Package.pdf (last visited Mar. 31, 2024).

187. RACHEL WILSON & PAUL PETERSON, A BRIEF SURVEY OF STATE INTEGRATED RESOURCE PLANNING RULES AND REQUIREMENTS 3 (Synapse Energy Econ., Inc. 2011), https://www.synapse-energy.com/sites/default/files/SynapseReport.2011-04.ACSF_.IRP-Survey.11-013.pdf.

188. Alan Cooke, Senior Rsch. Economist, Pac. Nw. Nat'l Lab'y, Presentation at the South Carolia Office of Regulatory Staff: Integrated Resource Planning in the U.S. Overview, at 7 (Mar. 1, 2021), https://eta-publications.lbl.gov/sites/default/files/sc_commission_day_1_irps_in_us_review_of_requirements_final.pdf.

189. BONUGLI & RATZ, *supra* note 186, at 3-4.

190. *Id*.

191. EPA OFF. OF ATMOSPHERIC PROGRAMS: STATE & LOC. CLIMATE & ENERGY PROGRAM, STATE ENERGY & ENVIRONMENTAL GUIDE TO ACTION: ELECTRICITY RESOURCE PLANNING AND PROCUREMENT 16, 30 (2022), https://www.epa.gov/system/files/documents/2022-08/Electricity%20Resource%20Planning%20and%20Procurement_508.pdf.

192. WILSON & PETERSON, *supra* note 187, at 4.

193. *See, e.g.*, Hraciela Etchart, *States that Approve or Reject Integrated Resources Plans*, No. UE-030423, at 2, 4 (Wa. Utils. & Transp. Comm'n Apr. 15, 2024) (explaining that Hawaii approves rather than merely acknowledges utilities' IRPs while Florida's determination of an IRP as suitable or unsuitable has no binding effect on the utility).

194. *Id*. at 1-5.

195. BONUGLI & RATZ, *supra* note 186, at 4.

Depending on IRP considerations, IRPs may be more or less agnostic to the costs associated with Li-ion batteries. Consider, in a state that has adopted least-cost planning, the historically low economic cost of Li-ion batteries influences utilities to adopt Li-ion batteries as the preferred storage technology.[196] Least-cost planning can be especially conducive to Li-ion battery entrenchment because planning horizons are generally long, ranging from ten-to-twenty years.[197] On the other hand, states that require utilities to consider risk or environmental impact *may* have more flexibility in encouraging their utilities to incorporate Na-ion batteries into their IRPs. To date, states have failed to define risk or environmental impact to promote sustainable battery alternatives over Li-ion batteries in any significant way.

Another state program, ESPS, has promoted widespread deployment of batteries. ESPSs require (or in some cases encourage) utilities to procure a defined amount of energy storage capacity.[198] The stringency of ESPSs varies depending on the procurement amount and whether the ESPS is a mandate, target, or goal. A mandate subjects a utility to liability for non-attainment; a target is a defined goal with measures for follow-though; and a goal is merely a number with no defined accountability.[199] ESPSs can be successful in expanding battery deployment. California, the first state to mandate procurement of energy storage systems in 2013,[200] became a global leader of battery deployment partly due to its procurement mandates.[201]

Without differentiating between technology-types, ESPSs cannot account for costs associated with different battery technologies and thus are ineffective at incentivizing investment in Na-ion batteries over Li-ion batteries. That is the case even when states purport to account for environment impacts during deployment. New York, which has a technology-neutral ESPS,[202] adopted a complementary non-binding Guidebook recommending that local governments minimize their environmental footprint during battery deployment.[203] Yet, New York is primarily focused on expanding its deployment of Li-ion batteries rather than investing in more sustainable technologies like Na-ion.[204] Absent technological

196. Kate Stuzin, *NW Utilities Increase Development of Battery Storage Systems*, NEWSDATA (Aug. 18, 2023), https://www.newsdata.com/clearing_up/supply_and_demand/nw-utilities-increase-development-of-battery-storage-systems/article_90f1efcc-3e0b-11ee-8c09-1f656a71c7ae.html. That is in the case when least-cost planning does not account for social or environmental costs and accounts for economic cost only. *See* discussion *infra* Section V.C.i.

197. Cooke, *supra* note 188, at 7.

198. WILL MCNAMARA, HOWARD PASSELL & TODD OLINSKY-PAUL, STATES ENERGY STORAGE POLICY: BEST PRACTICES FOR DECARBONIZATION 23-24 (Sandia Nat'l Lab'ys & Clean Energy States All. 2023), https://www.cesa.org/wp-content/uploads/State-Energy-Storage-Policy-Best-Practices-for-Decarbonization.pdf.

199. *Id*. at 23.

200. *Id*. at 24.

201. *How California Is Driving the Energy Storage Market Through State Legislation*, THE CLIMATE GROUP, at 2 (Apr. 2017), https://www.theclimategroup.org/sites/default/files/2020-11/under2_coalition_case_study_etp_california.pdf.

202. MCNAMARA, PASSELL & OLINSKY-PAUL, *supra* note 198, at 24.

203. Wall, *supra* note 26, at 49.

204. Kavya Balaraman, *New York Proposes 15 Safety Recommendations for Battery Energy Storage Facilities*, UTILITYDIVE (Feb. 8, 2024), https://www.utilitydive.com/news/new-york-battery-energy-storage-

differentiation, utilities tend to fulfill their capacity requirements with the most readily available battery, Li-ion.[205]

Current demonstration projects also fail to properly account for the adverse costs of Li-ion batteries. Demonstration projects evaluate the technical and economic performance of storage technologies for a variety of applications, including load frequency regulation and grid integration with renewable resources.[206] The goal is to develop and disseminate information to a variety of stakeholders about the operations, uses, benefits, and potential issues of certain technologies.[207] For instance, a market operator may discover that a certain technology provides a service that previously went unrecognized or a developer may discover that certain technological changes could be made to improve battery performance. Demonstration projects work to accelerate innovation, market validation, and customer demand.[208]

The level of state involvement in demonstration projects varies; states may authorize, fund, facilitate, or develop projects.[209] For example, Massachusetts funded a demonstration project in 2017 called Advancing Commonwealth Energy Storage (ACES) to increase deployment of storage technologies by identifying valuable and replicable combinations of value streams.[210] While the ACES program included two projects for flow batteries and flywheels, twenty-three out of its twenty-five projects focused on Li-ion batteries.[211] Thus, rather than accounting for the costs of Li-ion batteries, the ACES program acted to increase

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lithium-ion-safety/706947/; *but see NSF Energy Storage Engine in Upstate New York*, U.S. NAT'L SCI. FOUND. (last visited Apr. 19, 2025), https://www.nsf.gov/funding/initiatives/regional-innovation-engines/portfolio/upstate-new-york-energy-storage-engine (noting that New York is investing in some sustainable measures, such as removing forever chemicals from the battery manufacturing supply chain and improving battery recycling).

205. *See New York's First State-Owned Utility-Scale Energy Storage System Now in Operation*, T&D WORLD (Aug. 29, 2023), https://www.tdworld.com/electric-utility-operations/article/21272654/new-yorks-first-state-owned-utility-scale-energy-storage-system-now-in-operation (noting that in 2023, New York opened its first state-owned utility-scale battery energy storage project running on Li-ion batteries).

206. *Recovery Act: Energy Storage Demonstration Project*, SMARTGRID.GOV, https://web.archive.org/web/20240525102644/https://www.smartgrid.gov/archive/recovery_act/program_impacts/energy_storage_technology_performance_reports (last visited Feb. 23, 2025).

207. *About the Energy Storage System Program*, U.S. DEP'T OF ENERGY, https://www.sandia.gov/ess/about (last visited Mar. 31, 2024).

208. *The Value of Demonstration Projects*, ACCELERA: CUMMINS (Jan. 24, 2024), https://www.accelerazero.com/news/value-demonstration-projects.

209. *See* Mark A. Lazaroff & Maggie E. Curran, *State by State: A Roadmap Through the Current US Energy Storage Policy Landscape*, MORGAN LEWIS (Mar. 4, 2024), https://www.morganlewis.com/pubs/2024/03/state-by-state-a-roadmap-through-the-current-us-energy-storage-policy-landscape (stating that states explicitly authorize and sometimes fund demonstration programs, and describing how New York facilitates its demonstration projects); *State-by-State Overview: Navigating the Contemporary U.S. Energy Storage Policy Terrain*, ENERGYTREND (Mar. 28, 2024), https://www.energytrend.com/news/20240328-46222.html (noting that Utah works with utilities to create demonstration programs via legislation and Maryland initiated a program allowing utilities to develop projects).

210. *Energy Storage*, MASS. CLEAN ENERGY CTR., https://www.masscec.com/energy-storage (last visited Mar. 31, 2024).

211. FONESCA-GUZMAN ET AL., *supra* note 102, at 15.

Li-ion battery deployment. Other states, including Maryland,[212] New York,[213] Utah,[214] and Washington,[215] have also focused on improving Li-ion battery technology through their demonstration projects.

Finally, state financial incentive policies in the form of direct subsidies or tax credits are typically provided to end users installing behind-the-meter (BTM) resources,[216] which are technologies that help customers, such as homeowners or businesses, store electricity for use at a later time.[217] State financial incentives generally do not distinguish between technology type, contributing to the proliferation of Li-ion batteries. California implemented the nation's largest financial incentive policy, the Self-Generation Incentive Program (SGIP), setting aside $450 million in funding for BTM.[218] Maryland became the first state to offer state income tax credit for energy storage subject to a program cap of $750,000 per year.[219] Much of this money funnels into the Li-ion battery market because Li-ion batteries comprise the majority of new BTM installations.[220]

In contrast, few subsidies are available to front-of-meter (FTM) resources, which are resources that provide applications required by system operators and are connected to distribution networks, transmission networks, or with generation assets.[221] One policy for FTM subsidies proposed by the New Jersey Board of Public Utilities (NJBPU) in 2022 would have compensated FTM resources for carbon emissions abated through the operation of storage devices.[222] Because both Li-ion and Na-ion batteries abate emissions through operation, NJBU's proposal would have incentivized deployment of both Li-ion and Na-ion batteries. Again, financial incentives that fail to differentiate between technologies fail to encourage commercialization of Na-ion batteries.

In sum, state storage policies do not differentiate between battery technologies, and given Li-ion dominance of the energy storage market, enable the proliferation of Li-ion batteries. That hinders the commercialization of Na-ion batteries because stakeholders prioritize investing in Li-ion batteries.

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212. *Solid-State Lithium-Ion Battery with Ceramic Electrolyte*, ARPAE, https://arpa-e.energy.gov/technologies/projects/solid-state-lithium-ion-battery-ceramic-electrolyte (last visited Mar. 31, 2024).

213. *Governor Hochul Announces New York's First State-Owned Utility-Scale Energy Storage System Now Operating in North Country*, N.Y. STATE (Aug. 25, 2023), https://www.governor.ny.gov/news/governor-hochul-announces-new-yorks-first-state-owned-utility-scale-energy-storage-system-now.

214. *Ongoing Projects*, UTAH STATE UNIV.: POWER ELECS. LAB, https://engineering.usu.edu/ece/power/research/ (last visited Mar. 31, 2024).

215. *Glacier Battery Energy Storage System (BESS)*, PUGET SOUND ENERGY, https://www.pse.com/en/pages/grid-modernization/glacier-demo-project (last visited Mar. 31, 2024).

216. Lazaroff & Curran, *supra* note 209.

217. THOMAS BOWEN & CARISHMA GOKHALE-WELCH, BEHIND-THE-METER BATTERY ENERGY STORAGE: FREQUENTLY ASKED QUESTIONS, GREENING THE GRID 1 (Nat'l Renewable Energy Lab'y 2021), https://www.nrel.gov/docs/fy21osti/79393.pdf.

218. Lazaroff & Curran, *supra* note 209.

219. *Id*.

220. BOWEN & GOKHALE-WELCH, *supra* note 217, at 5.

221. ANISIE & BOSHELL, *supra* note 69, at 6.

222. Lazaroff & Curran, *supra* note 209.

B. Current Federal Programs

1. In General

The federal government's stance on storage technology has not been consistent. Previously, under the Biden Administration, the federal government was heavily invested in clean energy technology (including storage) to support climate initiatives and reduce the country's reliance on foreign battery materials. In pursuing those initiatives, the government acted to deploy both Li-ion and alternative battery technologies. The Biden Administration's most influential act to deploy storage came from the Inflation Reduction Act (IRA).[223] The IRA included several tax, grant, and loan programs intended to induce investment in clean energy technologies.[224] Those programs provided $64.8 billion in renewable energy and clean energy investment tax credits, $62.8 billion in renewable energy and clean energy production tax credits, and reserved $36.85 billion for clean manufacturing.[225] IRA tax credits sent strong signals to battery developers to invest, stimulating tremendous growth of the energy storage market.[226] Because the IRA's incentives were technology-neutral, Li-ion batteries were best positioned to take advantage of the program, although other storage technologies

223. *See generally Inflation Reduction Act*, MORGAN LEWIS, https://www.morganlewis.com/topics/inflation-reduction-act-of-2022 (last visited Mar. 10, 2024).

224. BUILDING A CLEAN ENERGY ECONOMY: A GUIDEBOOK TO THE INFLATION REDUCTION ACT'S INVESTMENTS IN CLEAN ENERGY AND CLIMATE ACTION 9 (The White House 2023), https://bidenwhitehouse.archives.gov/wp-content/uploads/2022/12/Inflation-Reduction-Act-Guidebook.pdf.

225. *IRA Renewables Impact: At a Glance*, BLACK & VEATCH, https://www.bv.com/en-US/perspectives/ira-renewables-impact-at-a-glance (last visited Mar. 10, 2024).

226. Arora et al., *supra* note 35.

benefitted, as well.[227] Other Biden-era programs included demonstration projects,[228] R&D,[229] and efforts to expand lithium mining.[230]

Federal energy policy changed dramatically with the start of the second Trump Administration in 2025. The Trump Administration reversed or abandoned many Biden-era climate initiatives.[231] Significantly, Trump's One Big Beautiful

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227. *See* Jakob Fleischmann et al., *Battery 2030: Resilient, Sustainable, and Circular*, MCKINSEY & CO. (Jan. 16, 2023), https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/battery-2030-resilient-sustainable-and-circular (forecasting that the Li-ion battery supply chain will grow over 30% between 2022-2030, reaching a value of more than $400 billion and a market size of 4.7 TWh by 2030).

228. Federal demonstration projects focused on increasing deployment of both Li-ion and alternative battery technologies. For example, the Department of Energy (DOE) solicited applications between July and December 2023 to engage in demonstration projects aimed at improving discharge duration and lifetime of storage technologies. *See Energy Storage Demonstration & Validation*, INTERAGENCY WORKING GRP. ON COAL & POWER PLANT CMTYS. & ECON. REVITALIZATION, https://web.archive.org/web/20230330175207/https://energycommunities.gov/funding-opportunity/energy-storage-demonstration-and-validation/ (last visited Mar. 31, 2024). The program, called Energy Storage Demonstration and Validation (ESDV), offered up to $5 million in funding and 50% cost share per applicant. *Id*. The program consisted of three demonstration projects, one of which was reserved for Li-ion batteries. *Id*.

229. In 2021, former-President Biden issued EO 14017 which, in pertinent part, required the DOE to research and develop strategic processes to improve the battery supply chain, specifically storage batteries and EVs. *See FACT SHEET: Biden-Harris Administration Announces Supply Chain Disruptions Task Force to Address Short-Term Supply Chain Discontinuities*, THE WHITE HOUSE (June 8, 2021), https://web.archive.org/web/20240208150426/https://www.whitehouse.gov/briefing-room/statements-releases/2021/06/08/fact-sheet-biden-harris-administration-announces-supply-chain-disruptions-task-force-to-address-short-term-supply-chain-discontinuities/ [hereinafter *FACT SHEET*]. EO 14017 sought to grow the domestic battery market and decrease reliance on foreign sources for battery materials. *Id*. To achieve this goal, the DOE invested in battery alternatives, including loaning $400 million to a manufacturer researching a zinc-based battery alternative, and investing $15.7 million in R&D in next-generation batteries with a particular focus on sodium-ion. Andrew Paul, *This Alternative to Lithium-Based Batteries Could Help Store Renewable Energy*, POPULAR SCI. (Sep. 6, 2023), https://www.popsci.com/technology/zinc-bromine-battery/; Joelle Anselmo, *Energy Department Opens Battery R&D Funds for Sodium-ion*, UTILITY DIVE (Feb. 7, 2024), https://www.utilitydive.com/news/dept-of-energy-to-fund-15-million-for-battery-manufacturing-research-projects/706827/. EO 14017 also sought to strengthen the Li-ion supply chain and expand domestic lithium mining, leading the Departments of Energy, Defense, Commerce and State to collaborate on a national blueprint aimed to "establish[] a domestic supply chain for lithium-based batteries." *See* NATIONAL BLUEPRINT, *supra* note 117, at 6. Former-President Biden's agenda also spurred the DOD to invest $90 million in re-opening a lithium mine in Kings Mountain, North Carolina. *DoD Enters Agreement to Expand Domestic Lithium Mining for U.S. Battery Supply Chains*, U.S. DEP'T OF WAR (Sep. 12, 2023), https://www.war.gov/News/Releases/Release/Article/3522657/dod-enters-agreement-to-expand-domestic-lithium-mining-for-us-battery-supply-ch/ [hereinafter *DoD Agreement*]. Additionally, in 2023, the DOE announced that it was allocating $3.5 billion to "boost domestic production of advanced batteries and battery materials nationwide" on a technologically nondiscriminatory basis. *Biden-Harris Administration Announces $3.5 Billion to Strengthen Domestic Battery Manufacturing*, ENERGY.GOV (Nov. 15, 2023), https://web.archive.org/web/20240304153708/https://www.energy.gov/articles/biden-harris-administration-announces-35-billion-strengthen-domestic-battery-manufacturing.

230. EO 14017 also sought to strengthen the Li-ion supply chain and expand domestic lithium mining, leading the Departments of Energy, Defense, Commerce and State to collaborate on a national blueprint aimed to "establish[] a domestic supply chain for lithium-based batteries." *See* NATIONAL BLUEPRINT, *supra* note 117, at 6. The DOE also invested $90 million in re-opening a lithium mine in Kings Mountain, North Carolina. *DoD Agreement*, *supra* note 229.

231. MADELINE CRAIG-SCHECKMAN & SCOTT MOORE, BATTLING FOR BATTERIES: LI-ION POLICY & SUPPLY CHAIN DYNAMICS IN THE U.S. & CHINA 2 (Kleinman Cntr for Energy Pol'y 2025), https://kleinmanenergy.upenn.edu/wp-content/uploads/2025/10/KCEP-Digest-82-Battling-for-Batteries.pdf; *see*

Bill Act (OBBBA) rapidly phases out investment and production tax credits for many clean-energy technologies under the IRA; for example, credits will no longer be available to wind and solar facilities placed into service after December 31, 2027 unless construction begins within twelve months of the OBBBA's enactment.[232] The Trump Administration also cancelled almost $8 billion in clean energy grants, although the fate of those funds is uncertain after a federal judge ruled on January 12, 2026 that the cancellation was illegal.[233] Additionally, EO 14154, "Unleashing American Energy," seeks to replace clean energy with fossil fuels by doing the following: calling agencies to "suspend, revise, and rescind" existing regulations and other actions that unduly burden domestic energy sources, particularly fossil fuels; revoking Biden EOs related to the environment and climate change; revoking EO 11991, the Council on Environmental Quality's (CEQ's) authority for its National Environmental Policy Act (NEPA) regulations; and prompting the EPA to rescind its 2009 Endangerment and Cause or Contribute Findings for Greenhouse Gases.[234]

Interestingly, the OBBBA treats storage better than solar and wind projects, reflecting a growing recognition that energy storage is critical to grid infrastructure beyond the context of the renewable transition.[235] Unlike the accelerated phase-out of tax credits faced by solar and wind, energy storage retains its full investment tax credit value through 2033, followed by reductions of 75% in 2034, 50% in 2035, and a final-phase-out in 2036.[236] Additionally, EO 14241, "Immediate Measures to Increase American Mineral Production," seeks to facilitate domestic production of critical minerals, including lithium,[237] in the name of "national and economic security."[238]

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also Sharon Lerner, *Trump's Anti-Green Agenda Could Lead to 1.3 Million More Climate Deaths. The Poorest Countries Will be Impacted Most*, PROPUBLICA (Nov. 19, 2025), https://www.propublica.org/article/trump-climate-rollbacks-heat-deaths.

232. *Tax Bill Significantly Changes Clean Energy Credits & Incentives*, RSM US (July 15, 2025), https://rsmus.com/insights/services/business-tax/obbba-tax-clean-energy.html.

233. Ryan Kennedy, *Court Rules Trump Administration Funding Cut to Clean Energy Projects Unlawful*, PV MAG. (Jan. 13, 2026), https://pv-magazine-usa.com/2026/01/13/court-rules-trump-administration-funding-cut-to-clean-energy-projects-unlawful/.

234. *Executive Order Unleashing American Energy*, VAN NESS FELDMAN LLP (Jan. 30, 2025), https://www.vnf.com/unleashing-american-energy. For more implications of EO 14154, *see id*.; *see also Final Rule: Recission of the Greenhouse Gas Endangerment Finding & Motor Vehicle Greenhouse Gas Emission Standards Under the Clean Air Ac*t, EPA (last updated Apr. 9, 2026), https://www.epa.gov/regulations-emissions-vehicles-and-engines/final-rule-rescission-greenhouse-gas-endangerment.

235. Brownstein, *supra* note 51.

236. *Id*.

237. *See Executive Order 14241: What It Means for Domestic Mineral Projects*, MCALLISTER & QUINN (Mar. 28, 2025), https://jm-aq.com/executive-order-14241-what-it-means-for-domestic-mineral-projects/ (noting that lithium is a critical mineral); Off. of Commc'ns & Publ'g, *Interior Department Releases Final 2025 List of Critical Materials*, USGS (Nov. 14, 2025), https://www.usgs.gov/news/science-snippet/interior-department-releases-final-2025-list-critical-minerals (noting a list of critical mineral and sodium not being included).

238. Exec. Order 14241, 90 Fed. Reg. 13673 (Mar. 20, 2025); *see also Summary of Executive Order 14241*, FREDRIKSON (Apr. 3, 2025), https://www.fredlaw.com/alert-summary-of-executive-order-14241; *see* discussion *supra* Section III.A.

Despite some support for energy storage, the Trump Administration likely cannot be relied upon to facilitate growth of the storage market. While all storage, including Na-ion batteries, can benefit from federal tax credits, the federal government has cancelled other programs to the detriment of energy storage, including a $30 million award for battery storage at a children's hospital in California.[239] Rapidly reducing tax credits for other clean energy technologies also adversely impacts batteries, which are commonly paired with renewable energy generation.[240] Additionally, efforts to expand lithium mining probably cannot alleviate the supply chain constraints that Li-ion batteries face. As previously described, the United States lacks infrastructure for mining lithium and new mining projects are likely to encounter community and legal resistance.[241] Even if efforts to expand lithium mining end up being successful, restricting access to foreign battery materials before a domestic mining infrastructure is in place risks stagnating growth of the battery market. FEOC restrictions under the OBBBA that deny tax credits to storage projects sourcing materials from designated countries[242] and the looming threat of escalating tariffs on lithium and Li-ion batteries from China tighten our nation's access to critical battery materials.[243]

Both former-President Biden and President Trump converge on their perspectives to reduce the United States' dependence on China for lithium and Li-

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239. Michael C. Anderson, *Trump Administration's Clean Energy Policy: 1 Step Forward, 2 Steps Back for Battery Industry*, BATTERY TECH. (Oct. 6, 2025), https://www.batterytechonline.com/market-analysis/trump-administration-clean-energy-policy-1-step-forward-2-steps-back.

240. *Large Battery Systems are Often Paired with Renewable Energy Power Plants,* U.S. ENERGY INFO. ADMIN. (May 18, 2020), https://www.eia.gov/todayinenergy/detail.php?id=43775; *see also* Scott Gillam, *Top 10 Energy Storage Investors in the World*, PF NEXUS (July 14, 2025), https://www.pfnexus.com/top-10-energy-storage-investors-in-the-world (noting that the top 10 global investors in energy storage are also invested in renewable energy projects).

241. *See* discussion *supra* Section III.A. Additionally, doubling down on mining may end up hurting domestic manufacturing of batteries if mining in the United States is not cost competitive and manufacturers are confined to using domestically sourced materials. *See* BENTLEY ALLAN & JONAS GOLDMAN, SECURING AMERICA'S CRITICAL MINERALS SUPPLY 7-8 (Carnegie Endowment for Int'l Peace 2025), https://assets.carnegieendowment.org/static/files/Allan%20and%20Goldman_US%20CM%20Supply.pdf.

242. FEOC restrictions under the OBBBA deny tax credits to new energy storage projects using materials over a certain threshold that are sourced from designated countries. *"Prohibited Foreign Entity" Restrictions in the OBBBA Restrict Tax Credits in Connection with Chinese Investment in US-Based Energy Storage Projects*, HERBERT SMITH FREEHILLS KRAMER (July 21, 2025), https://www.hsfkramer.com/notes/sanctions/2025-posts/prohibited-foreign-entity-restrictions-in-the-obbba-restrict-tax-credits. Those thresholds are called Material Assistance Cost Ratio thresholds. Brownstein, *supra* note 51. For new energy storage projects, thresholds begin at 55% and climb to 75% for projects starting construction after 2029, although there are different thresholds for different materials. *Id.*; *see also* Doug Jones & Jacob Stephens, *OBBBA Renewable Energy Provisions: Frequently Asked Questions*, HUSCH BLACKWELL (Sep. 22, 2025), https://www.huschblackwell.com/newsandinsights/obbba-renewable-energy-provisions-frequently-asked-questions-1 ("The material assistance cost ratio is calculated as the total cost of manufactured products minus the cost of manufactured products from a specified foreign entity or foreign-influenced entity, divided by the total cost of manufactured products. If a project's material assistance cost ratio exceeds the required threshold amount for a particular year, then the project will be treated as complying with the Material Assistance Provision. There are different required threshold amounts for different types of projects for each year.").

243. *See* discussion *supra* Section III.A.

ion batteries,[244] but their approaches to foster a market for energy storage greatly diverge. Former-President Biden casted a wide net investing in all battery types and took a measured approach in imposing restrictions on the United States' access to lithium and Li-ion batteries sourced from China. Alternatively, President Trump is rolling back and reversing incentives to invest in clean energy technology, including energy storage. Moreover, President Trump's domestic mining approach faces significant hurdles and FEOC restrictions and tariffs risk thwarting the ability of the United States to compete in the battery market. As a result, energy storage deployment is growing at a slower rate than originally anticipated.[245] At least $24.3 billion in clean energy industrial projects were cancelled in 2025, three-quarters of which consisted of battery storage and EV projects.[246]

In sum, the federal government under the Biden Administration sought to increase energy storage resources but was agnostic towards the costs of Li-ion batteries. Current federal policy under the Trump Administration is hostile towards clean energy, although less so towards energy storage. Investment in lithium mining cannot grow the Li-ion battery market alone considering community and legal resistance towards mining and a lack of domestic mining and manufacturing infrastructure. Moreover, trade tensions with China and OBBBA restrictions undermine incentives to invest in the storage battery market. Critically, for the purposes of this paper, the Trump Administration is not investing in Na-ion battery technology.[247] Therefore, the federal government cannot be relied upon to help commercialize Na-ion batteries.

2. FERC Regulation and Market Rules

The Federal Energy Regulatory Commission (FERC), the federal agency charged with regulating competitive wholesale energy markets,[248] has acted to increase battery deployment in a manner indifferent to the costs of Li-ion batteries. Most relevant to the discussion is FERC's landmark rule, Order No. 841, which seeks to promote large-scale deployment of energy storage resources by removing barriers to participation in wholesale energy markets operated by Regional Transmission Organizations (RTOs) and Independent System Operators (ISOs).[249] Under Order No. 841, RTOs and ISOs can craft market rules that better

244. ALLAN & GOLDMAN, *supra* note 241, at 3.

245. *US Energy Storage Installations through Q3 2025 Surpass 2024 Totals*, WOOD MACKENZIE (Dec. 16, 2025), https://www.woodmac.com/press-releases/us-energy-storage-installations-through-q3-2025-surpass-2024-totals/; *see also* Jonathan Touriño Jacobo, *U.S. Solar & Wind to be 100GW Lower by 2030 without Tax Credits – WoodMac*, PV TECH (July 14, 2025), https://www.pv-tech.org/us-solar-and-wind-to-be-100gw-lower-by-2030-without-tax-credits-woodmac/.

246. Mark Jaffe, *Clean Energy Investments to Plummet in the Face of Trump Administration Policies*, EUCI (Nov. 11, 2025), https://www.euci.com/clean-energy-investments-to-plummet-in-the-face-of-trump-administration-policies/.

247. Note, funding that was provided to many clean energy projects, including projects involving Na-ion batteries, under the Biden administration were cancelled under the Trump administration, but the fate of that funding is uncertain after a federal judge ruled that the cancellation was illegal. *See* Kennedy, *supra* note 233.

248. *Energy Markets*, FERC (last updated Aug. 18, 2025), https://www.ferc.gov/opp/energy-markets.

249. Order No. 841, *supra* note 3, at PP 1, 20.

compensate batteries through the creation of new revenue streams,[250] stimulating competition in the market and leading to more battery deployment. Order No. 841 is intentionally technology-neutral to maximize market participation.[251] As described earlier, technical neutrality can enable entrenchment of Li-ion batteries, which are the dominant and established technology in the energy storage market[252] and the best positioned to take advantage of rules. Nascent alternative technologies, such as Na-ion batteries, have difficulty competing with Li-ion batteries under rules that treat the technologies the same. In other words, FERC policies permit Li-ion batteries to maintain the headstart they have on Na-ion batteries in the race to deploy.

However, design issues, legal challenges, and market rules implementing Order No. 841 have diminished the rule's influence and have hindered the deployment of all battery technologies, including Li-ion batteries (although to a lesser extent). First, while removing some barriers to participation, Order No. 841 is not designed as a radical push to deployment.[253] For example, batteries that can respond to the grid's energy needs in seconds compete in the same wholesale markets as generators that take up to thirty minutes to reach their full output, and are afforded no market advantage for their quick ability to respond.[254] Thus, the market is designed to favor incumbent generators that often have more resources to compete over batteries, which are newer to the market. Moreover, legal challenges brought by utilities arguing that FERC exceeded its jurisdiction by promulgating Order No. 841 created uncertainty and likely slowed down implementation of the Rule until 2020 when the D.C. Circuit ruled in FERC's favor.[255] But most importantly, RTOs and ISOs have generally been resistant towards fully complying with Order No. 841's directives.

Some RTOs and ISOs have delayed compliance with Order No. 841. The California Independent System Operator (CAISO) was the first to obtain an approved compliance filing from FERC with an effective date of December 3,

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250. Matthew Bandyk, *FERC's Order 841 'Essential' for Energy Storage to Cut Emissions, Attorneys General Argue*, UTILITYDIVE (Feb. 11, 2020), https://www.utilitydive.com/news/fercs-order-841-essential-for-energy-storage-to-cut-emissions-attorneys/572050/; *see also* Mike O'Boyle & Ron Lehr, *Trending Topics – How Market Rules are Holding Back Energy Storage*, ENERGY INNOVATION (Jan. 31, 2019), https://web.archive.org/web/20200922234500/https://energyinnovation.org/2019/01/31/trending-topics-how-market-rules-are-holding-back-energy-storage/ (proposing revisions in market rules to compensate batteries for attributes such as ability to quickly change output, reduction of air pollution, and quick and modular deployment pace).

251. William D. Kissinger & Arjun P. Ramadevanahalli, *Storage Participation in Wholesale Markets*, MORGAN LEWIS (Mar. 8, 2023), https://www.morganlewis.com/pubs/2023/03/storage-participation-in-wholesale-markets.

252. *What Is Battery Storage?*, NATIONAL GRID (last updated May 9, 2023), https://www.nationalgrid.com/stories/energy-explained/what-is-battery-storage.

253. Sean Baur, *Going Beyond Order 841 to More Meaningful FERC Storage Policy*, UTILITYDIVE (Sep. 1, 2020), https://www.utilitydive.com/news/going-beyond-order-841-to-more-meaningful-ferc-storage-policy/584129/.

254. *Id*.

255. *See* Nat'l Ass'n of Regul. Util. Comm'rs v. FERC, 964 F.3d 1177, 1184-90 (D.C. Cir. 2020) (denying utilities' request for review that FERC exceeded its jurisdiction by banning states from "broadly prohibiting" local storage from participating in wholesale markets and clarifying that Order No. 841 did not usurp state power).

2019.[256] But the Independent System Operator – New England (ISO-NE) did not become fully compliant until January 2026, and the Midcontinent Independent System Operator (MISO) requested FERC to defer compliance twice, although its second request was denied.[257] In addition, with the exception of CAISO and the New York Independent System Operator (NYISO), RTOs and ISOs have undermined Order No. 841 by proposing market rules that arbitrarily impede battery deployment.[258] For example, ISO-NE proposed rules that failed to recognize all the services that batteries can provide and limited their use to a single discharge each day without reasonable justification.[259] Additionally, MISO defined fast-start resources, generators that can quickly deliver electricity to the grid when needed, to exclude batteries.[260] While FERC rejected these proposals, they exemplify a general resistance towards Order No. 841 that hinders FERC's efforts to broadly increase battery deployment.[261]

That said, the rules that RTOs and ISOs have implemented under Order No. 841 are skewed towards deploying Li-ion batteries. Despite FERC's instruction to implement neutral rules that do not favor incumbents and allow new technologies to fairly compete in wholesale energy markets,[262] several RTOs and ISOs have adopted four-hour capacity rules that favor Li-ion batteries' shorter duration capacity.[263] In fact, Li-ion batteries generally can run between two to four hours before risking degradation in performance and lifespan.[264] Four-hour duration rules favor Li-ion batteries by providing full compensation for the first four hours of discharge but provide only limited value for storage durations beyond four hours, disincentivizing investment in longer-duration storage technologies,[265] such as CAES.[266]

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256. JESSICA R. BELL & HAMPDEN T. MACBETH, ARE WE THERE YET? GETTING DISTRIBUTED ENERGY RESOURCES TO MARKETS 8 (State Energy & Env't Impact Ctr.: N.Y.U. 2021), https://stateimpactcenter.org/files/AreWeThereYet-GettingDistributedEnergyResourcestoMarkets-TheStateImpactCenter.pdf.

257. *Id*. at 8-10.

258. Oleg Kozel, *Governing the Grid: Reforming Regional Transmission Organizations on the Heels of Order No. 841*, 49 ECOLOGY L.Q. 259, 276-77 (2022); *see also* O'Boyle & Lehr, *supra* note 250 (finding that almost all ISOs/RTOs failed to fully comply with Order No. 841's directives).

259. Kozel, *supra* note 258, at 274.

260. *Id*. at 275-76.

261. *Id*. at 274-79.

262. U.S. ENERGY INFO. ADMIN., BATTERY STORAGE IN THE UNITED STATES: AN UPDATE ON MARKET TRENDS 24 (2021), https://www.eia.gov/analysis/studies/electricity/batterystorage/pdf/battery_storage_2021.pdf.

263. PAUL DENHOLM, WESLEY COLE & NATE BLAIR, NAT'L RENEWABLE ENERGY LAB'Y, MOVING BEYOND 4-HOUR LI-ION BATTERIES: CHALLENGES AND OPPORTUNITIES FOR LONG(ER)-DURATION ENERGY STORAGE 6 (Liz Breazeale, Madeline Geocaris & Mike Meshek eds., 2023), https://www.nrel.gov/docs/fy23osti/85878.pdf.

264. Jeff St. John, *Tracking Energy Storage Market Participation Under FERC Order 841*, GREEN TECH MEDIA (Oct. 16, 2018), https://web.archive.org/web/20250213094218/https://www.greentechmedia.com/squared/dispatches-from-the-grid-edge/tracking-energy-storage-under-ferc-order-841.

265. DENHOLM, COLE & BLAIR, *supra* note 263, at vi.

266. Cook, *supra* note 134.

Notably, in 2019, Pennsylvania-New Jersey-Maryland Interconnection (PJM) proposed a ten-hour duration rule in which the value of storage technologies would be calculated based on the capacity they could provide over ten continuous hours.[267] That proposal received backlash primarily because most of the available storage technologies had capacities below ten hours, making it unrealistic to quickly replace shorter duration storage with longer duration storage and risking diversion of investment away from storage towards cheaper fossil fuels.[268] Those concerns were valid and PJM ultimately removed the ten-hour requirement.[269] However, RTOs can encourage development of longer-duration storage without undermining decarbonization goals by valuing services that longer-duration storage uniquely provide.[270] For example, assigning value to transmission investment deferral and congestion management tends to favor longer-duration storage.[271] Moreover, as longer-duration technologies become more available, longer-duration rules may feasibly promote deployment of longer-duration storage technologies.

Furthermore, RTOs and ISOs often fail to adequately compensate for blackstart services,[272] which are services provided by generators or storage resources to restart the grid in case of a blackout and inherently favor longer-duration storage resources.[273] For instance, Lake Lynn hydropower station in West Virginia earns about $51,000 per year for blackstart services under PJM's rules, but spends about $65,000 per year on regulatory compliance, operating at a loss.[274] While there are no doubt environmental and justice consequences associated with hydropower plants,[275] Lake Lynn's situation illustrates how market rules disincentivize stakeholders from investing in longer-duration storage services, enabling Li-ion battery dominance despite Order No. 841's claim of neutrality.

In sum, FERC's technology-neutral approach towards storage provides Li-ion batteries, the dominating technology in the market, with a headstart over Na-

267. David Thill, *With New Study, Critics Push Back on PJM's Proposed 10-Hour Storage Rule*, CANARY MEDIA (July 30, 2019), https://www.canarymedia.com/articles/enn/with-new-study-critics-push-back-on-pjms-proposed-10-hour-storage-rule.

268. *Id.*; *Taking Aim at PJM's 10-Hour Duration Capacity for Energy Storage*, LIST SOLAR (July 24, 2019), https://list.solar/news/taking-aim-at/.

269. *See* PJM: SYS. PLANNING DEP'T, PJM MANUAL 21: RULES & PROCEDURES FOR DETERMINATION OF GENERATING CAPABILITY 5 (16th rev. 2021), https://www.pjm.com/-/media/DotCom/documents/manuals/archive/m21/m21v16-rules-and-procedures-for-determination-of-generating-capability-08-01-2021.pdf.

270. *See* DENHOLM, COLE & BLAIR, *supra* note 263 at 21.

271. *See id*. at 22.

272. NAT'L ASS'NS OF STATE ENERGY OFFS., THE BLACK BOX OF BLACKSTART: ELECTRICITY RELIABILITY AND INTERDEPENDENCY CONSIDERATIONS FOR STATE ENERGY OFFICES 8, https://www.naseo.org/data/sites/1/documents/publications/NASEO_The%20Black%20Box%20of%20Blackstart_FINAL.pdf (last visited Mar. 31, 2024).

273. *Id*. at 4-5.

274. *Id*. at 8.

275. *Environmental Impacts of Hydroelectric Power*, UNION OF CONCERNED SCIENTISTS (Mar. 5, 2013), https://www.ucsusa.org/resources/environmental-impacts-hydroelectric-power.

ion batteries. Additionally, RTO rules are skewed towards facilitating Li-ion battery entrenchment.

V. RECOMMENDATIONS

The federal government and RTOs and ISOs are not likely to lead the transition to Na-ion batteries. The Trump Administration does not support decarbonization goals,[276] which have historically spurred investment in energy storage.[277] Despite the fact that energy storage was left mostly unscathed by the OBBBA, the battery storage market is expected to grow more slowly than originally anticipated under the current administration's energy policies.[278] Moreover, evidence suggests that the Trump Administration supports Li-ion batteries and a domestic supply chain of same over battery alternatives.[279] To date, the administration has not taken action to increase deployment of Na-ion batteries and there is no indication that it will.[280]

Furthermore, because FERC is primarily an energy agency,[281] not an environmental agency, it is unlikely to consider the lifecycle impacts of Li-ion batteries. While one could argue that FERC should take more responsibility in protecting the environment, it is unlikely to do so. FERC's mission is to provide "Reliable, Safe, Secure, and Economically Efficient Energy for Consumers at a Reasonable Cost,"[282] which illustrates that FERC's concerns lie outside the environmental context.[283] Indeed, despite indisputable evidence that carbon dioxide contributes to climate change,[284] FERC continues to approve natural gas pipelines.[285] Additionally, RTO and ISO resistance to Order No. 841 generally

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276. *See* CRAIG-SCHECKMAN & MOORE, *supra* note 231, at 7-8; *see also USA: Country Summary*, CLIMATE ACTION TRACKER, https://climateactiontracker.org/countries/usa/ (last visited Jan. 18, 2026) (noting that the Trump Administration pulled out of the Paris Agreement).

277. *See* Arora et al., *supra* note 35 (noting that the IRA spurred "tremendous growth" of the domestic energy storage sector); Owen Reith, *Five Key Objectives of the Inflation Reduction Act*, PBS (Aug. 10, 2022), https://www.pbs.org/wnet/peril-and-promise/2022/08/five-key-objectives-of-the-inflation-reduction-act/ (noting that one of the main objectives of the IRA was to help the United States meet international climate goals by reducing greenhouse gas emissions).

278. *US Energy Storage Installations through Q3 2025 Surpass 2024 Totals*, *supra* note 245; *see also* Jacobo, *supra* note 245.

279. *See* discussion *supra* Section IV.A.i.

280. *See id*.

281. *What is FERC?: What FERC Does*, FERC (last updated June 18, 2025), https://www.ferc.gov/what-ferc-does.

282. FERC, FY 2024 CONGRESSIONAL JUSTIFICATION 6 (2023), https://www.ferc.gov/sites/default/files/2023-03/FERC%20FY%2024%20Congressional%20Justification.pdf.

283. *See also* Alexandra B. Klass et al., *Grid Reliability Through Clean Energy*, 74 STAN. L. REV. 969, 1060 (2022) ("RTOs have no clear mandate to promote renewable energy, given that the primary legal authority under which they operate is the assurance of 'just and reasonable rates'") (internal citation omitted).

284. Rebecca Lindsey, *Climate Change: Atmospheric Carbon Dioxide*, CLIMATE.GOV (May 21, 2025), https://www.climate.gov/news-features/understanding-climate/climate-change-atmospheric-carbon-dioxide.

285. *See, e.g., Saguaro Connector Pipeline*, OIL & GAS WATCH, https://oilandgaswatch.org/pipeline/5975 (last visited Feb. 23, 2025) (noting that in 2024 FERC approved the Saguaro Connector Pipeline, which will transport almost three billion cubic feet of natural gas daily); *see also* Alex Baumhardt, *Fed. Regulators Approve Natural Gas Pipeline Expansion through Oregon, Washington*, OR. CAP. CHRON. (Oct. 19, 2023), https://oregoncapitalchronicle.com/2023/10/19/federal-regulators-approve-natural-gas-pipeline-expansion-

undermines battery deployment. In the event that RTOs and ISOs develop market rules promoting battery deployment, rules are neutral (providing Li-ion batteries a headstart on Na-ion batteries) or even favor Li-ion batteries.[286] In any event, RTOs and ISOs oversee only 60% of the electricity market, thus their influence is limited.[287]

States are best positioned to drive the transition from Li-ion batteries to Na-ion batteries. In fact, states are already leading the charge in battery deployment,[288] so even adjusting existing state programs can have a large impact on the energy storage sector. States should also be incentivized to commercialize Na-ion batteries. As Na-ion technology develops, Na-ion batteries are increasingly becoming more affordable[289] and reliable than Li-ion batteries;[290] thus, commercialization of Na-ion batteries can help states keep electricity prices low for consumers while achieving decarbonization goals.[291] Since states are responsible for ensuring utilities provide end users with adequate and efficient supplies of energy at just and reasonable rates,[292] affordable and reliable Na-ion batteries should become an attractive electric storage resource. Finally, state programs can shelter the battery storage market from federal policy changes stemming from administrative turnover[293] as long no federal preemption exists.

Additionally, many states have experience in growing solar, an analogous technology to energy storage. That experience, combined with research on fostering innovation, can guide states in revising or creating storage policies to encourage the commercialization of Na-ion batteries.

The discussion below first evaluates important considerations in promoting technological innovation. Then, it evaluates the rise of solar (an analogous technology). Finally, it applies takeaways to recommend specific programs that states can implement to commercialize and transition to Na-ion batteries.

through-oregon-washington/ (noting that in 2023, FERC approved expansion of the Gas Transmission Northwest pipeline, which is already 1,400 miles long and pumps billions of cubic feet of natural gas to utilities).

286. *See* discussion *supra* Section IV.B.ii.

287. Max Luke, *Why We Need Bigger Electricity Markets*, WORLD ECON. F. (Feb. 27, 2015), https://www.weforum.org/stories/2015/02/why-we-need-bigger-electricity-markets/.

288. Wall, *supra* note 26, at 28.

289. Gordon, *supra* note 141 (noting that as of 2024, the average cost for Na-ion cells is already cheaper than Li-ion cells at $87/kWh compared to $89/kWh and is expected to become increasingly more affordable than Li-ion cells at $10/kWh by 2028).

290. *See* discussion *supra* Section III (describing how Li-ion batteries are subject to supply chain constraints and fire safety risks while Na-ion batteries are comprised of more abundant and accessible materials and are less vulnerable to fire hazards); *see also* discussion *infra* Section V.A (describing how "innovation snowballing" reduces costs of new technologies).

291. *See State Climate Policy Maps*, CTR. FOR CLIMATE & ENERGY SOLS., https://www.c2es.org/content/state-climate-policy/ (last visited Feb. 23, 2025) (noting that as of 2024, twenty-four states and the District of Columbia have adopted specific targets to reduce greenhouse gas emissions to mitigate climate change).

292. U.S. EPA: STATE CLIMATE & ENERGY PROGRAM, STATE CLIMATE AND ENERGY TECHNICAL FORUM BACKGROUND DOCUMENT: AN OVERVIEW OF PUCS FOR STATE ENVIRONMENT AND ENERGY OFFICIALS 1 (2010), https://www.epa.gov/sites/default/files/2016-03/documents/background_paper.pdf.

293. *See* discussion *supra* Section IV.B.I. (discussing second-Trump administration).

A. How Innovation Happens

Market forces often direct innovators towards the path of least resistance: that is, the most productive and profitable technology in the market.[294] In the storage battery context, Li-ion battery technology draws investors because Li-ion batteries are the dominant technology.[295] As technology matures, its knowledge stock grows and its profitability increases, creating an innovation "snowballing" effect where innovation begets more innovation.[296] Zachary Liscow and Quentin Karpilow[297] of Yale Law School dubbed this phenomenon "innovation snowballing" to describe the process "by which earlier innovations can lead to similar but more advanced innovations, causing a snowballing of innovation in a particular technology area."[298]

Government policy may influence the velocity of the metaphorical "snowball." The government directly contributes to Li-ion's market dominance by investing in Li-ion itself.[299] Additionally, the government indirectly facilitates Li-ion dominance by adopting technology-neutral policies, like Order No. 841, because failing to account for Li-ion's historical advantage over other technologies permits innovators to continue on the path of least resistance.[300] These policies help entrench and secure Li-ion's dominate position in the storage battery market. Technological entrenchment causes stakeholders to innovate in dominant technologies even when it is clear that superior alternatives exist.[301]

Strategic government intervention can divert resources away from the existing dominant technology (Li-ion) and towards an alternative (Na-ion). Indeed, innovation snowballing can also work to "redirect innovators" by increasing the knowledge stock of newer technologies and changing the relative profitability of technology types.[302] As the new technology improves and production becomes cheaper, it will begin its own "snowball," drawing in more innovators and increasing profitability.[303] As more resources divert from the mature technology and into the newer technology, the velocity of innovation snowballing in the mature technology slows down until eventually the newer technology snowballs at a greater rate than its competitors, usurping the mature technology's dominant market position.[304]

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294. Zachary Liscow & Quentin Karpilow, *Innovation Snowballing & Climate Law*, 95 WASH. U. L. REV. 387, 426 (2017).

295. Evelina Stoikou, *Lithium-Ions Grip on Storage Faces Wave of Novel Technologies*, BLOOMBERGNEF (June 4, 2024), https://about.bnef.com/blog/lithium-ions-grip-on-storage-faces-wave-of-novel-technologies/.

296. Liscow & Karpilow, *supra* note 294, at 439.

297. *Zachary Liscow*, YALE L. SCH., https://law.yale.edu/zachary-liscow (last visited Feb. 23, 2025); *Quentin Karpilow*, YALE CNTR. FOR BUS. & THE ENV'T, https://cbey.yale.edu/our-community/quentin-karpilow (last visited Feb. 23, 2025).

298. Liscow & Karpilow, *supra* note 294, at 404.

299. *See* discussion *supra* Section IV.B.

300. Liscow & Karpilow, *supra* note 294, at 410.

301. *Id*. at 405.

302. *Id*. at 404.

303. *See id*. at 294, at 412 (noting that as technology becomes cheaper and closer to commercialization, more people will use it, increasing the scale over which innovators can deploy and make a profit).

304. Liscow & Karpilow, *supra* note 294, at 412-13.

Therefore, government programs can use innovation snowballing to bring production of Na-ion batteries up to scale. To harness innovation snowballing and grow Na-ion batteries, government programs must prioritize: (1) increasing the technology's knowledge stock; and (2) lowering its production costs.[305]

B. Lessons Learned from Solar Technology

Solar technology provides a model for how climate-related technologies can effectively scale-up.[306] The cost of solar PV modules has decreased by more than a factor of 10,000 since initial commercialization[307] and currently remains one of the fastest growing sources of energy despite the rapid phase-out of solar tax credits under the OBBBA.[308]

Beginning with the United States' technological breakthrough of solar technology in 1954, which significantly improved solar technology's efficiency,[309] five countries – the United States, Australia, Japan, Germany, and China – adopted measures to improve solar and lower costs.[310] Although solar technology's upward trajectory has not been linear, often corresponding with fossil fuel shortages,[311] solar's path to widespread deployment provides valuable insight into policies that can grow Na-ion batteries. In general, a combination of financial and non-financial incentives have been key to driving adoption of solar.[312]

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305. An important benefit of innovation snowballing to note is that, even if government programs promoting innovation of battery alternatives are canceled, their effects are difficult to reverse: the market cannot "unlearn" knowledge, and future governments cannot reclaim money already spent on R&D. *Id*. at 457-58. This "stickiness" helps create stability in the market since the benefits of innovation do not depend upon future government commitments, further motivating private investors to participate. *Id*.

306. GREGORY F. NEMET, HOW SOLAR ENERGY BECAME CHEAP: A MODEL FOR LOW-CARBON INNOVATION 19 (Routledge ed. 2019).

307. *Id*. at 1.

308. *Renewable Energy*, CTR. FOR CLIMATE & ENERGY SOLS., https://www.c2es.org/content/renewable-energy/ (last visited Feb. 23, 2025); Daniyal Ahmed, *U.S. Solar Market Trends (September 2025) – Record Growth Amid Headwinds*, SUNHUB (Sep. 26, 2025), https://www.sunhub.com/blog/us-solar-market-trends-2025/.

309. *See* NEMET, *supra* note 306, at 30-31 (describing Bell Lab's technological breakthrough and certain milestones that led to solar's widespread deployment including R&D, public procurement, rebates, feed-in tariffs, and investment in manufacturing); Sourav Mandal, *Evolution of Silicon Based Solar Cell Technologies for Future Sources of Energy*, UWI: ST. AUGUSTINE CAMPUS, https://sta.uwi.edu/fst/physics/evolution-silicon-based-solar-cell-technologies (last visited Apr. 14, 2026). (noting that the silicon solar cells developed by Bell Labs were a "huge improvement" over previous versions of the technology).

310. *See* NEMET, *supra* note 306, at 2, 31.

311. *See* Bernadette Del Chiaro & Rachel Gibson, *Government's Role in Creating a Vibrant Solar Power Market in California*, 36 GOLDEN GATE U. L. REV. 347, 368-69 (2006) ("the initial push for solar came after the oil crisis of the 1970s"); *id*. at 369 (noting that after the federal tax credit expired in 1985 and its own state tax credit expired a few years later, it was not until the mid-1990s that California looked to solar again to lower energy cost in response to fossil fuel shortages).

312. NEMET, *supra* note 306, at 162.

Financial incentives, including tax credits, rebates, net-metering[313] and feed-in-tariffs, have helped and continue to help deploy solar technology by enhancing demand for solar and reducing prices that adopters face.[314] Other government actions that have catalyzed innovation in solar technology include R&D, early stage public procurement, promoting sharing and codification of knowledge, and training a workforce.[315] Below examines the types of programs that have been the most effective in growing solar and takes a close look at California, the national leader in solar adoption.[316]

1. Financial Incentives

The push for solar power first began after the 1970s oil crisis when nations across the globe looked to develop alternative energy sources.[317] Initially, the federal government led the initiative to adopt solar in the United States,[318] however, in 1980 the Reagan Administration systematically dismantled its solar program.[319] From there, California took up the mantle to grow solar technology by adopting a medley of financial and non-financial incentive programs.

Starting in 1980, California began offering solar tax credits, which are dollar-for-dollar deductions in tax liability.[320] California's tax credits provided financial

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313. *See* Agustin J. Ros & Sai Shetty Sai, *Residential Rooftop Solar Demand in the U.S. & the Impact of Net Energy Metering & Electricity Prices*, 118 ENERGY ECON., Jan. 9, 2023, at 1, 1 (noting that net-metering has a large positive impact on residential solar rooftop demand).

314. NEMET, *supra* note 306, at 165.

315. *Id*. at 185-88.

316. *See* DAVID C. FESSLER, THE ENERGY DISRUPTION TRIANGLE: THREE SECTORS THAT WILL CHANGE HOW WE GENERATE, USE & STORE ENERGY 9 (Wiley ed. 2019) ("what really got solar off the ground in the United States has been a continuing series of state mandates for renewable energy"); *see also State Overview – California*, SOLAR ENERGY INDUS. ASS'N (last updated Mar. 2026), https://seia.org/state-solar-policy/california-solar/ (stating that California has the largest solar market in the U.S.); CAL. PUB. UTILS. COMM'N, NO. A.22-05-022 ET AL., ENERGY DIVISION FACT SHEET: DECISION EXPANDS EXISTING COMMUNITY SOLAR PROGRAM FOR LOW-INCOME CUSTOMERS & ADOPTS NEW COMMUNITY SOLAR PROGRAM 1 (2024), https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/energy-division/documents/community-solar-in-california/fact-sheet-comm-solar-053024.pdf [hereinafter ENERGY DIVISION FACT SHEET] (noting that solar resources generate 30% of California's electricity compared to a national average of 5%); *Leading States Based on Cumulative Solar Photovoltaic Capacity in the United States as of March 2025*, STATISTA, https://www.statista.com/statistics/183531/renewables-in-the-us-leading-states-in-pv-capacity/ (last visited Feb. 23, 2025) (comparing California's cumulative capacity of 52.27 gigawatts to the state with the next highest capacity, Texas, with 43.56 gigawatts).

317. Del Chiaro & Gibson, *supra* note 311, at 368; NEMET, *supra* note 306, at 65.

318. *See* Del Chiaro & Gibson, *supra* note 311, at 369 (noting that in combination, federal and California tax credits were instrumental in the early growth of solar); *see also* Energy Tax Act of 1978, Pub. L. No. 95-618, 92 Stat. 3174; NEMET, *supra* note 306, at 17, 65 (noting that the U.S. adopted federal R&D programs for solar from 1974-1981, investing $1.7 billion, to help reduce the cost of solar technology).

319. NEMET, *supra* note 306, at 66.

320. *Solar Rebates & Incentives*, SOLAR.COM, https://www.solar.com/learn/solar-rebates-incentives/ (last visited Feb. 23, 2025). From 1980 to1983, California offered homeowners a tax credit up to $3,000 for any solar energy system installed on homes, creating 19,000 solar installment jobs by 1984. *See* Del Chiaro & Gibson, *supra* note 311, at 368-69. California also enacted other solar credits including a program helping property owners finance solar installations through special assessments on property taxes, and an investment tax credit (ITC). *California Solar Tax Credits, Incentives & Rebates (2024)*, UNDERSTANDSOLAR (June 8, 2024), https://web.archive.org/web/20250421164207/https://understandsolar.com/california-solar-tax-credits-

support that contributed towards a 300% surge in solar installations within a decade.[321]

In addition, rebates have been vital in deploying solar technology. Rebates are financial incentives offered to energy users for solar installations.[322] Over the years, California has adopted multiple solar rebates.[323] The most noteworthy rebate program is the California Solar Initiative (CSI), the nation's largest solar program.[324] As part of the CSI, California offered rebates from 2006 to 2016 to help reach its goal of installing 3,000 MW of solar on one million homes, businesses, farms, schools, and municipal buildings.[325] Overall, that program was

incentives-and-rebates-2024/; Brett Stadelmann, *The Role of Government Incentives in Promoting Solar Energy Adoption*, UNSUSTAINABLE MAG. (Nov. 26, 2024), https://www.unsustainablemagazine.com/solar-energy-adoption-incentives/.

321. Stadelmann, *supra* note 320; *see also* Ben Zientara, *2025 California Solar Incentives, Tax Credits, Rebates & Exemptions,* SOLARREVIEWS (last updated Apr. 2026), https://www.solarreviews.com/solar-incentives/california (California no longer offers any solar-specific tax credits).

322. *Solar Rebates & Incentives, supra* note 320.

323. The first was an $180 million solar rebate adopted in 1996 for small-scale solar less than 30 kW and primarily installed on homes. *See* Del Chiaro & Gibson, *supra* note 311, at 370-71; *see also* 1996 Cal. Stat. 4488, 4531 (allowing customers to "receive a rebate"). In 2002, California extended this rebate through 2007 and made available an additional $118 million. *See* Del Chiaro & Gibson, *supra* note 311, at 371; *see also* 2002 Cal. Stat. 2911, 2929 ("program shall provide monetary rebates").

324. In 2000, Self-Generation Incentive Program (SGIP) authorized $138 million in incentives for large distributed-generation technologies between 30 kW and 1 MW. *See* Del Chiaro & Gibson, *supra* note 311, at 371; *see also* 2000 Cal. Stat. 2713, 2722 (permitting financing options to encourage development of self-generation and cogeneration resources). California extended SGIP in 2018. *See Residential Solar Incentives for California Homeowners*, ENACT SOLAR (Nov. 20, 2024), https://enact.solar/residential-solar-incentives-for-california-homeowners/ (noting that California extended the SGIP to promote the use of energy storage devices with solar installations through January 1, 2026); 2018 Cal. Legis. Serv. ch. 839 (West) (extending administration of SGIP through January 1, 2026). In 2020, the California Public Utility Commission (CPUC) used its authority under SGIP to spend an additional $1 billion to support energy storage. Anna Fero & Patrick J. Ferguson, *Evolution of the Self-Generation Incentive Program*, DAVIS WRIGHT TREMAINE, LLP (June 17, 2020), https://www.dwt.com/blogs/energy--environmental-law-blog/2020/06/california-sgip-wildfire-power-shutoffs#footnote12; *see also Self-Generation Incentive Program Revisions Pursuant to Senate Bill 700 & Other Program Changes,* No. 20-01-021 (Cal. Pub. Utils. Comm'n 2020).

325. Del Chiaro & Gibson, *supra* note 311, at 350-51, 384; *see Interim Order Adopting Policies and Funding for the California Solar Initiative*, No. 06-01-024 (Cal. Pub. Utils. Comm'n 2006) (establishing the California Solar Initiative); *Opinion Adopting Performance-Based Incentives, an Administrative Structure, and Other Phase One Program Elements for the California Solar Initiative*, No. 06-08-028 (Cal. Pub. Utils. Comm'n 2006) (implementing the California Solar Initiative); *Opinion Modifying Decision 06-01-024 and Decision 06-08-028 in Response to Senate Bill 1*, No. 06-12-033 (Cal. Pub. Utils. Comm'n 2006) (modifying the California Solar Initiative to accommodate Senate Bill 1); *California Solar Initiative (CSI)*, CAL. PUB. UTILS. COMM'N, https://www.cpuc.ca.gov/industries-and-topics/electrical-energy/demand-side-management/california-solar-initiative (last visited Feb. 23, 2025) (stating that CSI closed on Dec. 31, 2016). For more context, CSI structured rebates based on actual output of installed systems rather than an upfront rebate, which encouraged the production of more efficient solar panels and installations. *See* Del Chiaro & Gibson, *supra* note 311, at 388. CSI also provided additional subsidies to low-income households to help relieve the financial burden associated with solar adoption and increase deployment. *California Solar Initiative (CSI)*, CAL. PUB. UTILS. COMM'N, https://www.cpuc.ca.gov/industries-and-topics/electrical-energy/demand-side-management/california-solar-initiative (last visited Feb. 23, 2025).

a huge success. By the end of 2021, over one million homes had installed solar, including about eighty-seven MW attributed to low-income households.[326]

Net-metering has also been highly effective in deploying solar technology, but challenges with the design of net-metering caution against its adoption. Net-metering is a program that provides participating energy customers with credits for excess electricity generated (*e.g.* through solar panels) and supplied back to the grid.[327] These credits are then used to reduce the energy bills of participating customers.[328] In 1995, California passed its first net-metering program (NEM 1.0), establishing a key financial driver for energy customers to invest in small solar power systems and reduce their electricity bills.[329] As solar technology improved and prices fell, net metering prompted hundreds of thousands of energy customers to install solar.[330] In 2016, California extended its net-metering program and adopted NEM 2.0[331] which led to a record-breaking 700,000 residential solar installations in 2022.[332]

While net-metering has undoubtedly been effective in increasing solar adoption, it is also associated with significant challenges.[333] A study finding that NEM 2.0 negatively impacted non-participating customers, was not cost-effective,

326. BRETT PALMER ET AL., 2020 CALIFORNIA SOLAR INITIATIVE ANNUAL PROGRAM ASSESSMENT 6 (Cal. Pub. Utils. Comm'n 2022), https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/energy-division/documents/csi-progress-reports/2022-csi-apa.pdf.

327. *See, e.g.*, *California's NEM 2.0 vs NEM 3.0: A Comprehensive Comparison*, EXRO, https://web.archive.org/web/20260206023652/https://www.exro.com/industry-insights/california-net-energy-metering-policies (last visited Feb. 23, 2025).

328. ASHLEY J. LAWSON, NET METERING: IN BRIEF 2 (Cong. Rsch. Serv. 2019), https://crsreports.congress.gov/product/pdf/R/R46010.

329. Del Chiaro & Gibson, *supra* note 311, at 369; *see* CAL. PUB. UTIL. CODE § 2827(c)(1) (West 2023) (requiring every utility to adopt net energy metering). Applying to all utilities in the state, NEM 1.0 required a utility to provide a financial credit to residential and commercial systems with solar installation capacity of one megawatt or below until solar generation comprised 5% of that utility's power demand. *Id*. §§ 2827(c)(4)(B), 2827(h)(9)(i); *Net Energy Metering 2.0: A California Solar Update*, BRIGHTEN SOLAR CO., (May 9, 2017), https://brightensolarco.com/net-energy-metering-2-0-california-solar-update/.

330. Del Chiaro & Gibson, *supra* note 311, at 369.

331. *The History of Net Metering & How to Combat NEM3 Policies*, VECKTA (Dec. 7, 2022), https://veckta.com/2022/12/07/the-history-of-net-metering-and-how-to-combat-nem3-policies/; *see* CAL. PUB. UTIL. CODE § 2827.1(b)(6) (West 2022) (requiring utilities to extend their net metering programs upon reaching the statutory maximum of NEM 1.0 or by July 1, 2017, whichever comes earlier).

332. Faith Foushee, *Net Metering Changes in California: How Will They Impact You?*, CNET (last updated Feb. 18, 2023), https://www.cnet.com/home/energy-and-utilities/net-metering-changes-in-california-how-will-they-impact-you/; *Solar Market Insight Report 2022 Year in Review*, SOLAR ENERGY INDUS. ASS'N (Mar. 9, 2023), https://seia.org/research-resources/solar-market-insight-report-2022-year-review/; *see also California's NEM 2.0 vs NEM 3.0: A Comprehensive Comparison*, *supra* note 327 (crediting NEM 2.0 with significantly boosting solar adoption in California). Importantly, NEM 2.0 removed the one megawatt size limitation to qualify many more customers. *Net Energy Metering 2.0: A California Solar Update*, *supra* note 329.

333. Different sources dispute the significance of net-metering challenges. *See* Tony Clark, *Hard Truths About Net Metering and the Perils of Regulatory Nihilism*, UTILITYDIVE (June 24, 2020), https://www.utilitydive.com/news/hard-truths-about-net-metering-and-the-perils-of-regulatory-nihilism/580390/ (stating that net-metering is "overwhelmingly regressive" and allows high-income solar adopters to "dump their costs" onto non-adopting low-income customers); *The Myth of the Solar "Cost Shift" and the True Value of Solar*, SOLAR UNITED NEIGHBORS, at 2, https://solarunitedneighbors.org/wp-content/uploads/2021/01/Myth-of-the-Solar-Cost-Shift-FINAL.pdf (last visited Feb. 23, 2025) (stating that cost shift claims are false).

and disproportionately harmed low-income customers[334] motivated California to water down its latest net-metering iteration, NEM 3.0 (although, legal challenges against NEM 3.0 have rendered its future uncertain).[335] Specifically, the study found that NEM 2.0 disproportionately harmed lower-income customers because they were burdened with the additional expense (82-91%) of the cost of service bypassed by predominately wealthier NEM 2.0 customers.[336] In other words, non-participating customers paid more in electricity to supplement participating customers' avoided costs.[337] In addition, lower electricity costs may have reduced energy conservation,[338] and that energy is often supplemented by fossil fuels.[339]

Another policy, feed-in tariffs (FiTs), has been highly effective in other countries, like Germany,[340] but less so in the United States. FiTs guarantee renewable generators the right to connect to the grid and require utilities to purchase electricity from renewable generators at above-market rates for a specified duration of time.[341] Two noteworthy FiTs in California are the Renewable Market Adjusting Tariff (ReMAT)[342] and the Green Tariff Shared Renewables Program (GTSR).[343] While those programs share admirable goals of

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334. *Decision Revising Net Energy Metering Tariff and Subtariffs*, No. 22-12-056, at 2-3 (Cal. Pub. Utils. Comm'n 2022).

335. *California's NEM 2.0 vs NEM 3.0: A Comprehensive Comparison*, *supra* note 327; *see generally Decision Revising Net Energy Metering Tariff and Subtariffs*, *supra* note 334.; *see also October 24, 2024, Statewide Call – Appeal of the PUC's NEM 3.0 Decision at the California Supreme Court – The Last Chance to Make the PUC Follow the Law!*, CAL. ALL. FOR CMTY. ENERGY, https://cacommunityenergy.org/portfolio-item/october-31-2024-statewide-call-appeal-of-the-pucs-nem-3-0-decision-at-the-california-supreme-court-the-last-chance-to-make-the-puc-follow-the-law/ (last visited Feb. 23, 2025) (noting that the California Supreme Court is expected to address the legality of NEM 3.0 in 2025); Foushee, *supra* note 332 (noting that under NEM 3.0, the CPUC reduced the credit value for energy supplied to the grid by 75%); *The CPUC is Not Above the Law: The State Supreme Court Kicks NEM3 Lawsuit Back to Court of Appeal*, SOLAR RIGHTS ALL.: BLOG (Dec. 5, 2025), https://solarrights.org/blog/2025/12/05/nem3appeal/ [hereinafter *CPUC is Not Above the Law*] (NEM 3.0 is currently undergoing legal challenges with a ruling expected by the middle of 2026).

336. *Decision Revising Net Energy Metering Tariff and Subtariffs*, *supra* note 334, at 209-10.

337. LAWSON, *supra* note 328, at 7.

338. *Net Metering: What is it and How Does it Impact Utility Bill Management*, ENGIE IMPACT (Aug. 18, 2019), https://www.engieimpact.com/insights/net-metering-becoming-controversial.

339. *See Rapid Expansion of Batteries Will Be Crucial to Meet Climate & Energy Security Goals Set at COP28*, INT'L ENERGY AGENCY (Apr. 25, 2024), https://www.iea.org/news/rapid-expansion-of-batteries-will-be-crucial-to-meet-climate-and-energy-security-goals-set-at-cop28 (noting that batteries are necessary to supplement variable renewable generation).

340. In 2000, Germany adopted a FiT that quadrupled its solar market and massively scaled production. *See* NEMET, *supra* note 306, at 178.

341. Felix Mormann, Dan Reicher & Victor Hanna, *A Tale of Three Markets: Comparing the Renewable Energy Experiences of California, Texas, & Germany*, 35 STAN. ENVT'L L.J. 55, 79 (2016).

342. ReMAT allows small renewable generators producing less than three MW to sell renewable energy to IOUs under contracts that are ten, fifteen, or twenty years in length with prices set and annually adjusted by the CPUC based on market needs. *Renewable Market Adjusting Tariff (ReMAT)*, CAL. PUB. UTILS. COMM'N (last updated Mar. 21, 2024), https://www.cpuc.ca.gov/industries-and-topics/electrical-energy/electric-power-procurement/rps/rps-procurement-programs/renewable-market-adjusting-tariff; *see* CAL. PUB. UTIL. CODE § 399.20(d)(1) (West 2022).

343. GTSR enables customers to pay a premium and in exchange receive 50-100% renewable energy or purchase a share of a community renewable project (typically solar) directly from a developer and receive a credit for avoided generation. *See* ENERGY DIVISION FACT SHEET, *supra* note 316, at 3; *Green Tariff/Shared Renewables Program (GTSR)*, CAL. PUB. UTILS. COMM'N, https://www.cpuc.ca.gov/industries-and-

getting solar online, they both suffer from flaws that undermine their efficacy. Low prices and short contracts dissuade clean energy developers from using ReMAT; in fact, only one solar project has been built under the program since 2021.[344] And high administrative fees, low solar bill credits, and floating charges hinder large-scale use of GTSR.[345]

In all, direct financial incentives are crucial in growing immature markets,[346] and tax credits and rebates are better than net-metering and FiTs.

2. Non-financial Incentives

As mentioned above, other government actions that have increased solar technology deployment include: R&D; early-stage public procurement; promoting knowledge sharing and codification; and training a workforce.[347]

R&D and demonstration projects have been vital in lowering production costs and improving the market's understanding of solar technology. R&D is "the most direct action" to accelerate adoption of a new technology because it steadily progresses innovation while training scientists and engineers.[348] By attracting participants from different backgrounds, R&D programs help to build an industry consortia invested in developing solar technology that shares knowledge.[349] California's CSI includes a provision for the Research, Development and Demonstration Program (CSI RD&D).[350] Among its most successful outcomes are the numerous knowledge benefits that CSI RD&D has achieved by bringing together diverse stakeholders, leading to lower production costs.[351]

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topics/electrical-energy/electric-rates/green-tariff-shared-renewables-program (last visited Feb. 23, 2025); *see* CAL. PUB. UTIL. CODE § 2832 (West 2014); *see generally Decision Modifying Green Access Program Tariffs and Adopting a Community Renewable Energy Program*, No. 24-05-065 (Cal. Pub. Utils. Comm'n 2024).

344. Jeff St. John, *California Regulators Torpedo Popular Plan to Boost Community Solar*, CANARY MEDIA (May 30, 2024), https://www.canarymedia.com/articles/solar/california-regulators-torpedo-popular-plan-to-boost-community-solar.

345. *See* Eli Goldman, *A Guide to Community Solar in California*, SOLSTICE (Apr. 20, 2020), https://solstice.us/solstice-blog/community-solar-california/ (noting that only 27% of the program's available generation has been allocated and fewer physically built); *but see Decision Modifying Green Access Program Tariffs and Adopting a Community Renewable Energy Program*, *supra* note 343, at 19, 168-76 (noting that the CPUC recently updated GTSR in June 2024 and the effects of its latest revision are yet to be seen).

346. McNamara, *supra* note 185, at 10.

347. Some overlap exists between R&D, public procurement, and programs that promote sharing and codification of knowledge, and training a workforce. *See infra* pp. 42-47.

348. NEMET, *supra* note 306, at 185, 214.

349. *Id*. at 215.

350. CSI R&D has devoted $50 million to fund research, development, and demonstration projects to support integration of solar into the California grid, increase solar technology performance, reduce solar costs, and improve knowledge stock of solar within the industry. GRETCHEN B. JORDAN & VARUN RAI, CALIFORNIA SOLAR INITIATIVE RD&D PROGRAM PROCESS EVALUATION: FINAL REPORT 1 (Evergreen Econs. 2017), https://www.calmac.org/publications/CSI_RD&D_Program_-_Program_Evaluation_.pdf. CSI RD&D has funded thirty-seven projects, involving multiple stakeholders, and has been successful in reaching its goals. *Id.* at 1, 109.

351. *Id*. at 50, 115. For example, CSI RD&D awarded $850,000 to the Clean Power Research project, which brought together CAISO, utilities, nonprofits, research institutes, and universities to predict solar power variability caused by cloud cover. *See* Press Release, CSI RD&D Grant Awarded to Clean Power Research Brightens Future of PV Grid Integration, Clean Power Rsch. (Mar. 12, 2012),

Programs, like R&D and demonstration projects, not only increase the knowledge stock of solar, but also disseminate cost-saving measures that have stimulated technology adoption as prices decline.[352] Knowledge sharing can occur within and between industries; indeed, solar technology benefitted from technological advancements in other industries, such as the computer industry, by incorporating outside expertise into its own material, equipment, and production processes.[353] Although solar stakeholders initially did not codify their knowledge stock, programs should codify knowledge to ensure that knowledge is not lost amongst the quick turnover that tends to occur within the technology industry.[354] During solar's growth from the 1950's to 2000, tacit knowledge was lost as people pursued careers outside of the industry,[355] delaying innovation. To codify, programs may create reporting requirements and mandate that information be made publicly available.[356] In contrast, programs that incentivize safeguarding information, such as patents, hinder widespread deployment.[357]

Further, programs intentionally targeted at building and training a workforce have been necessary in driving the adoption of solar technology. Training scientists, engineers, and businesses has been crucial to the innovation and cost-reduction of solar technology.[358] In addition, public support of education helped avoid bottlenecks that emerged as the industry scaled.[359] Demonstration projects have been useful in training a workforce and facilitating learning by doing.[360] Governments have also promoted education through scholarships, internships, and fellowships.[361]

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https://www.cleanpower.com/resource/csi-rdd-grant-awarded-to-clean-power-research-brightens-future-of-pv-grid-integration/.

352. NEMET, *supra* note 306, at 166.

353. *Id*. at 187. For instance, one demonstration project under CSI worked with Siemens, a technology company, to provide the computer interface and collect data. *See* FINAL PROJECT REPORT: SUPERVISORY CONTROLLER FOR PV & STORAGE MICROGRIDS 5 (Cal. Solar Initiative 2016), https://www.calmac.org/publications/CSI-RDD_Sol5_Tri-Technic_FinalReport_2016-03-01.pdf; *About Us*, SIEMENS, https://www.siemens.com/us/en/company/about.html (last visited Feb. 23, 2025).

354. NEMET, *supra* note 306, at 214.

355. *Id*. at 186.

356. *Id*. at 214.

357. *See* Liscow & Karpilow, *supra* note 294, at 394 (noting that patents slow down the snowballing process because they hinder the use of others' innovations, therefore they are not a compelling tool to spur cleantech innovation).

358. NEMET, *supra* note 306, at 186.

359. *Id*. at 214.

360. U.N. HUM. SETTLEMENTS PROGRAMME & U.N. DEV. PROGRAMME, GUIDE TO IMPLEMENTING MDG DEMONSTRATION PROJECTS: A HANDS-ON AND PARTICIPATORY KNOWLEDGE DEVELOPMENT STRATEGY FOR MEETING THE MILLENNIUM DEVELOPMENT GOALS 3 (2007), https://www.local2030.org/library/72/Guide-to-Implementing-MDG-Responsive-Demonstration-Projects.pdf.

361. *See Scholarships, Internships, & Fellowships*, U.S. DEP'T OF ENERGY, https://www.energy.gov/eere/fuelcells/scholarships-internships-and-fellowships (last visited Feb. 23, 2025) (providing a list of Department of Energy scholarships, internships, and fellowships). California provides about $130 million in grants annually under the California Sustainable Energy Entrepreneur Development Initiative (CalSEED) and has awarded grants for eighteen solar-related generation projects since 2016. *CalSEED Awards Two Early-Stage Startups 450k Each*, CALSEED (Jan. 25, 2023), https://calseed.fund/calseed-awards-two-early-stage-startups-450k-each/; CAL. PUB. RES. CODE § 25711.5 (West 2025) (authorizing the CEC to award grants for CalSEED under the Electric Program Investment Charge (EPIC)); *see also Entrepreneur Directory:*

Additionally, public procurement has stimulated the consistent demand needed for the solar industry to make investments in scale, learn through experience, and train a workforce.[362] That is because when the government buys a technology, it creates market confidence and drives private investment.[363] For example, the U.S. Block Buy Program from 1975 to 1985 was instrumental in improving the efficiency of solar technology production.[364] Effective public procurement may take the form of power purchase agreements, holding auctions for set quantities of goods, or guaranteeing prices for specified quantities of a good.[365] To combat policy changes and establish market credibility for a new technology, governments should agree to long-term contracts.[366] Moreover, public procurement can counter any delays in innovation that may result from market participants waiting for others to develop cost-effective measures for them.[367] California has successfully used public procurement to drive solar innovation and deploy solar for over twenty years.[368] By the end of 2014, state

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Awardees, CALSEED, https://calseed.fund/awardees/ (last visited Feb. 23, 2025) (listing CalSEED awardees); *Our Network: Our Story*, CALSEED, https://calseed.fund/about/ (last visited Feb. 23, 2025) (CalSEED Initiative began in 2016).

362. NEMET, *supra* note 306, at 214.

363. *How Cities Can Use Procurement to Create & Shape Markets.*, C40 KNOWLEDGE (Sep. 2024), https://www.c40knowledgehub.org/s/article/How-cities-can-use-procurement-to-create-and-shape-markets?language=en_US.

364. NEMET, *supra* note 306, at 71, 185-86.

365. *Id*. at 214.

366. *Id*. at 214-15 (noting that Germany committed to 20-year long contracts for feed-in-tariffs to accelerate innovation of solar technology).

367. *Id*. at 166-67.

368. In 2001, California adopted a program requiring new and existing state-owned buildings and parking facilities to install solar systems where cost-effective by 2007. Del Chiaro & Gibson, *supra* note 311, at 375; CAL. GOV'T. CODE § 14684(a) (West 2003). In 2007, California extended the program to apply to state-owned buildings and parking facilities constructed after January 1, 2008. *Green Building Action Plan for State Facilities*, ENERGYBOT (June 18, 2024), https://web.archive.org/web/20250619220914/https://www.energybot.com/incentives/california/green-building-action-plan-for-state-facilities-1776.html; *see* CAL. GOV'T CODE § 14684.1(b) (West 2008). Although not solar-specific, California also implemented multiple executive orders that indirectly encouraged public procurement of solar. In 2004, California Governor Schwarzenegger issued EO S-20-04, which created the Green Building Action Plan to "improve the energy performance of all state buildings," including a requirement for buildings to obtain a Leadership in Energy and Environmental Design (LEED) Silver Certification. *Green Building Action Plan for State Facilities*, ENERGYBOT (June 18, 2024), https://web.archive.org/web/20250619220914/https://www.energybot.com/incentives/california/green-building-action-plan-for-state-facilities-1776.html; CAL. EXEC. ORDER NO. S-20-04 (Dec. 14, 2004), https://www.library.ca.gov/wp-content/uploads/GovernmentPublications/executive-order-proclamation/279-280.pdf; *see also* Kara Anderson, *LEED Certification: Meaning & Requirements*, LEAF: GREENLY (last updated June 19, 2024), https://greenly.earth/en-us/blog/company-guide/leed-certification-meaning-and-requirements (noting that LEED certification is a point-based rating system issued by the Green Building Council based on factors such as energy consumption, greenhouse gas emissions, site sustainability, and water efficiency). Further, in 2012, California Governor Brown issued EO B-18-12, updating EO S-20-04 to require that all state entities reduce their grid energy use 20% compared to 2003 levels by 2018. *Green Building Action Plan for State Facilities*, ENERGYBOT (June 18, 2024), https://web.archive.org/web/20250619220914/https://www.energybot.com/incentives/california/green-building-action-plan-for-state-facilities-1776.html; CAL. EXEC. ORDER NO. B-18-12 (Apr. 25, 2012), https://www.library.ca.gov/wp-content/uploads/GovernmentPublications/executive-order-proclamation/39-B-18-12.pdf. California's latest public procurement measure, effective January 1, 2024, mandates all state agencies

agencies had installed about thirty-eight MW of solar power, potentially enough energy to power 25,000 homes,[369] at their facilities.[370] And in 2021, local governments in California installed 207 MW of solar power on brownfields.[371]

Like public procurement, building codes have also subsidized demand for solar technology, which fosters innovation, lowers production costs, and trains a workforce. California was the first state in the nation to adopt a green building standards code,[372] resulting in the CALGreen program.[373] CALGreen's largest impact on solar has been the California Solar Mandate which first took effect in 2020 and requires solar installations on most new single-family homes and multifamily dwellings.[374] This mandate has significantly contributed to solar growth in California with solar powering about 17% of the state's electricity generation by 2023.[375] California's Solar Mandate updates every three years;[376] in 2023, California expanded its scope to include high-rise residential buildings

constructing new buildings or major renovations larger than 10,000 square feet to obtain LEED Gold Certification. Maria Balzer-Pisciotta, *California's 2023 Policy Year: Building Decarbonization & Climate Action*, U.S. GREEN BLDG. COUNCIL (Jan. 16, 2024), https://www.usgbc.org/articles/californias-2023-policy-year-building-decarbonization-and-climate-action; *see* CAL. GOV'T. CODE § 8316(a)(1) (West 2024).

369. *See* Taylor, *supra* note 57 ("one megawatt is enough to power 670 homes").

370. Press Release, California Adds Additional Solar Power at State Facilities, Cal. Dep't of Gen. Servs. (Aug. 18, 2014), https://www.dgs.ca.gov/Press-Releases/Page-Content/News-List-Folder/California-Adds-Additional-Solar-Power-at-State-Facilities.

371. Sara Carbone, *The Promise & Challenge of Solar on Government-Owned Property*, SOLAR POWER WORLD (Jan. 16, 2024), https://www.solarpowerworldonline.com/2024/01/the-promise-and-challenge-of-solar-on-government-owned-property/.

372. *History of the California Green Building Standards Code (CALGreen): 2007 to Present*, CAL. DEP'T OF GEN. SERVS., https://www.dgs.ca.gov/BSC/About/History-of-the-California-Green-Building-Standards-Code-CALGreen (last visited Feb. 24, 2025) [hereinafter *CALGreen*].

373. California adopted the California Global Warming Solutions Act of 2006 to help reduce the state's greenhouse gas emissions to 1990 levels by 2020. *Id.*; *California Climate Policy Fact Sheet: Building Energy Efficiency*, BERKELEY L., https://www.law.berkeley.edu/wp-content/uploads/2019/12/Fact-Sheet-Building-Energy-Efficiency.pdf (last visited Feb. 24, 2025); CAL. HEALTH & SAFETY CODE § 38500 (West 2007); *see also CALGreen*, *supra* note 372 (noting that California achieved its goal of reducing greenhouse gas emissions below 1990 levels in 2018). The Act directed the California Building Standards Commission (CBSC) to develop green building standards for commercial buildings and the Department of Housing and Community Development (HCD) to develop standards for residential structures. *Id.*; *California Climate Policy Fact Sheet: Building Energy Efficiency*, BERKELEY L., https://www.law.berkeley.edu/wp-content/uploads/2019/12/Fact-Sheet-Building-Energy-Efficiency.pdf (last visited Feb. 24, 2025); CAL HEALTH & SAFETY CODE § 38500 (West 2007). This program, known as CALGreen, first went into effect in 2009, and has undergone continuous updates between 2010 and 2025. *CALGreen*, *supra* note 372; CAL. CODE REGS. tit.14, § 18989.1 (2008); Aileen Carroll, *CALGreen: A Comprehensive Guide to Title 24, Part 11 Regulations*, ONE CLICK LCA (Sep. 30, 2025), https://oneclicklca.com/en-us/resources/articles/calgreen-a-comprehensive-guide-to-title-24-regulations.

374. *Solar on New Homes in California: All You Need to Know in 2024*, SOLARGRAF: BLOG (last updated Mar. 2024), https://www.solargraf.com/blog/solar-on-new-homes-in-california-all-you-need-to-know-in-2024.

375. *2023 Total System Electric Generation*, CAL. ENERGY COMM'N, https://www.energy.ca.gov/data-reports/energy-almanac/california-electricity-data/2023-total-system-electric-generation (last visited Apr. 14, 2026).

376. *Title 24 California Solar Mandates: Empowering Homeowners with Sustainable Energy Solutions*, SOLAR TECHS. (Feb. 10, 2024), https://solartechnologies.com/title-24-california-solar-mandates-empowering-homeowners-with-sustainable-energy-solutions/.

and some commercial structures[377] and became the first state to mandate both solar and energy storage systems on all new and some retrofit commercial buildings.[378]

Beyond the above-described programs, accountability measures have been vital to ensure that utilities adhere to state renewable policy goals. Three effective measures include RPSs, renewable auctions, and IRPs. RPS is a program that has been a key driver of demand for solar technology in the United States.[379] California first adopted an RPS in 2003 to promote the build out of renewable technologies, including solar.[380] Over the years, California has updated its RPS program to keep up with energy policy goals.[381] California uses RECs to track compliance.[382]

Renewable auctions have been another mechanism facilitating utility procurement of solar technologies. California adopted a Renewable Auction Mechanism (RAM) program, that provides a platform for investor-owned utilities (IOUs) to procure renewable electricity and fulfill renewable energy capacity targets.[383] RAM is a reverse auction process where generators submit bids and IOUs select the lowest-cost option to fulfill energy demand.[384] Initially, from 2010 to 2015, RAM was confined to small distributed generation (DG)[385] projects producing between three MW and twenty MW and required participation from the three largest IOUs in California.[386] However, after 2015, the CPUC lifted size restrictions and RAM became available to utilities on a voluntary basis.[387] RAM

377. Sarah Lozanova, *California Solar Mandate: Is Solar Required on New Homes?*, GREENLANCER (last updated Nov. 22, 2025), https://www.greenlancer.com/post/california-solar-mandate.

378. *CEC Energy Code to Require Solar + Storage in 2023*, REVEL (Jan. 12, 2023), https://revel-energy.com/cec-energy-code-to-require-solar-storage-in-2023/.

379. NEMET, *supra* note 306, at 42.

380. Mormann, Reicher & Hanna, *supra* note 341, at 78.

381. For example, the Clean Energy and Pollution Reduction Act of 2015 codified an RPS mandate of 50% electricity from renewables by 2030 that the CPUC must implement. *Id*. at 78–79; 2015 Cal. Legis. Serv. ch. 547 (West). Further, California updated its mandate when it passed the Clean Energy, Jobs, and Affordability Act of 2022 requiring LSEs to provide 100% renewable and carbon neutral electricity to end users by 2045. Nathan Barbara & Paul Kaufman, *2022 in Review – California Climate Change Policy & Legislation*, JDSUPRA (Jan. 5, 2023), https://www.jdsupra.com/legalnews/2022-in-review-california-climate-7770900/; CAL. PUB. UTIL. CODE § 454.53(a) (West 2025).

382. Mormann, Reicher & Hanna, *supra* note 341, at 78-79.

383. Jessica Wentz, *Balancing Economic & Environmental Goals in Distributed Generation Procurement: A Critical Analysis of California's Renewable Auction Mechanism (RAM)*, 5 J. ENERGY & ENV'T L. 30, 30 (2014), https://gwjeel.com/wp-content/uploads/2014/06/v5i2-wentz-article.pdf; *Renewable Auction Mechanism*, CAL. PUB. UTILS. COMM'N, https://www.cpuc.ca.gov/industries-and-topics/electrical-energy/electric-power-procurement/rps/rps-procurement-programs/rps-renewable-auction-mechanism (last visited Feb. 24, 2025); *see generally Decision Adopting the Renewable Auction Mechanism*, No. 10-12-048 (Cal. Pub. Utils. Comm'n 2010).

384. Wentz, *supra* note 383, at 30; *see Decision Adopting the Renewable Auction Mechanism*, *supra* note 383, at 3.

385. *See* Wentz, *supra* note 383, at 30 (defining distributed generation (DG) as "the generation of electricity from installations that are located at or in close proximity to the point of consumption").

386. *Id*.

387. *Renewable Auction Mechanism*, *supra* note 383; *Renewable Auction Mechanism (RAM)*, ENERGYBOT (Nov. 18, 2022), https://web.archive.org/web/20250913044144/https://www.energybot.com/incentives/california/renewable-auction-mechanism-ram-4979.html; *Decision Conditionally Accepting 2014 Renewables Portfolio Standard*

has proven successful at promoting procurement of solar projects. Thirteen of the fifteen winning projects in the first auction were solar.[388]

Lastly, IRPs have been an important mechanism for facilitating utility procurement of solar technologies. California required IOUs to adopt IRPs by 2019[389] to help utilities attain the state's RPS goals.[390] California does not require utilities to incorporate solar in their IRPs; however, almost half of the current total planned resource investment between 2024 and 2045 consists of solar for all California load-serving entities (LSEs).[391] This high level of investment in solar to achieve renewable energy targets is likely spurred by state mandates on solar, customer demand driven by financial incentives,[392] and solar's low cost.[393] In this way, IRPs have proven to be effective tools in aligning utilities with state policy goals and for increasing deployment of technologies by creating a stable market for them.

In sum, a combination of tax credits and rebates are the most effective financial incentives to grow a new technology while avoiding equity and conservation concerns. Furthermore, other important incentives include R&D,

Procurement Plans and an Off-Year Supplement to 2013 Integrated Resource Plan, No. 14-11-042, at 93 (Cal. Pub. Utils. Comm'n 2014) (eliminating the project size requirements from RAM).

388. Wentz, *supra* note 383, at 43; *see* Mormann, Reicher & Hanna, *supra* note 341, at 79 (describing RAM as a noteworthy policy tool used to achieve RPS targets); *see also Decision Adopting the Renewable Auction Mechanism*, *supra* note 383, at 20 (the CPUC determined that RAM does not conflict with FERC jurisdiction because it does not set a market price; rather it "rel[ies upon] a market-mechanism that is compatible with FERC's rate-setting in wholesale markets").

389. *Publicly Owned Utility Integrated Resource Plans (IRPs)*, CAL. ENERGY COMM'N, https://www.energy.ca.gov/rules-and-regulations/energy-suppliers-reporting/clean-energy-and-pollution-reduction-act-sb-350-0 (last visited Feb. 24, 2025); STAFF REPORT: SENATE BILL 350 INTEGRATED RESOURCE PLANNING ELECTRICITY SECTOR GAS PLANNING TARGETS, CAL. AIR RES. BD. 7-8 (2018), https://ww2.arb.ca.gov/sites/default/files/2020-06/sb350-full-report-2018.pdf [hereinafter STAFF REPORT: SENATE BILL 350]; 2015 Cal. Legis. Serv. ch. 547 (establishing California's IRP requirement); *see* CAL. PUB. UTIL. CODE §§ 454.51-52 (West 2015) (detailing CPUC directives and establishing utility filing requirements); *see* CAL. PUB. UTIL. CODE § 9621 (West 2022) (listing IRP requirements).

390. STAFF REPORT: SENATE BILL 350, *supra* note 389, at 7-8. While not required to accept CPUC recommendations, IOUs must update their IRPs every five years. BRIAN MCCOLLOUGH & MELISSA JONES, PUBLICLY OWNED UTILITY INTEGRATED RESOURCE PLAN SUBMISSION & REVIEW GUIDELINES 17 (Cal. Energy Comm'n 3d ed. rev., 2022), https://www.energy.ca.gov/publications/2022/publicly-owned-utility-integrated-resource-plan-submission-and-review-guidelines; Mark Specht, *The Basics of Integrated Resource Planning in California*, THE EQUATION (May 23, 2019), https://blog.ucsusa.org/mark-specht/integrated-resource-planning-california/'. IOUs must consider cost-effectiveness, reliability, GHG reduction goals, the impact of air pollution on disadvantaged communities, and state mandates. STAFF REPORT: SENATE BILL 350*, supra* note 389, at 8; *Workshop: ALJ Ruling on Centralized Procurement of Specified Long Lead-Time Resources in Integrated Resource Planning*, CAL. PUB. UTIL. COMM'N, at 6 (May 7, 2024), https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/energy-division/documents/integrated-resource-plan-and-long-term-procurement-plan-irp-ltpp/ab1373/staff-workshop-on-alj-ruling-on-central-procurement.pdf; CAL. PUB. UTIL. CODE § 454.52 (West 2015).

391. *See Decision Adopting 2023 Preferred System Plan & Related Matters, & Addressing Two Petitions for Modification*, No. 24-02-047, at 2, 68 (Cal. Pub. Utils. Comm'n 2024).

392. *How & Why California Leads the Way in Solar Power Going into 2023*, SIMPLYSOLAR (Dec. 2, 2022), https://simplysolar.com/blog/how-why-california-leads-solar-power/.

393. Ivan Penn, *California Invested Heavily in Solar Power. Now There's So Much That Other States are Sometimes Paid to Take It*, L.A. TIMES (June 22, 2017), https://simplysolar.com/blog/how-why-california-leads-solar-power/.

education programs (like demonstration programs and scholarship grants), public procurement, building codes, RPSs,[394] auctions, and IRPs.

C. Recommended State Action

While researchers are currently working to improve Na-ion battery technology,[395] states should take action to accelerate the commercialization of Na-ion batteries and divert investment from Li-ion batteries towards Na-ion batteries. State programs promoting innovation have proven effective in growing solar, an analogous technology.[396] The discussion below first proposes modifications to the most common state energy storage programs before suggesting other programs with less prevalence in the energy storage context. In addition, this paper cautions against using net-metering and FiTs.

1. Modifying Common Programs to Promote Battery Alternatives

The most common state programs involving battery deployment are financial incentives, IRPs, ESPSs, and demonstration projects.[397] First, states can directly improve the affordability and profitability of emerging battery technologies through financial incentives. In designing incentive programs, states should tailor tax credits and rebates to Na-ion batteries.[398] Currently, states mostly provide BTM subsidies and tax incentives.[399] While many financial incentives do not differentiate based on energy storage technology today, they could. For example, California has implemented various solar-specific tax credits since 1980.[400] Moreover, both California and Oregon offer rebates to residential customers installing solar panels with energy storage.[401] Thus, states can offer financial incentives based on technology-type and give partiality to Na-ion batteries.

While rarer, states could also adopt rebates for FTM resources with positive environmental impacts, such as the subsidy proposed by the NJBPU in 2022.[402] To incentivize Na-ion battery adoption, the rebate should be designed to compensate for: (a) the abatement of emissions through battery operation; *and* (b) the abatement of natural resource degradation (or a like benefit that Na-ion batteries offer). While a rebate for the abatement of emissions through battery operation would reward buyers of both Li-ion and Na-ion batteries, compensation based on the abatement of natural resource degradation would reward buyers of Na-ion batteries because Na-ion batteries are comprised of more abundant

394. The storage equivalent of RPS is ESPS.

395. *See* discussion *supra* Section III.B.

396. Similar to how states took up the mantle to grow solar after former-President Reagan dismantled federal solar programs, states now can take up the mantle in deploying Na-ion batteries. *See* discussion *supra* Section V.B.

397. *See* discussion *supra* Section IV.A.

398. Financial incentives are crucial to growing immature markets. McNamara, *supra* note 185, at 10.

399. BOWEN & GOKHALE-WELCH, *supra* note 217, at 4.

400. *See* discussion *supra* Section V.B.i.

401. *Oregon Solar + Storage Rebate Program*, OREGON.GOV, https://www.oregon.gov/energy/Incentives/Pages/Solar-Storage-Rebate-Program.aspx (last visited Mar. 31, 2024); *see* discussion *supra* Section III.B.

402. *See* discussion *supra* Section IV.A.

materials.[403] Accordingly, Na-ion batteries would have a market advantage over Li-ion batteries.

Second, states with procurement mandates, targets, or goals can modify their ESPSs by imposing a carveout requiring utilities to procure a certain proportion of their energy storage from Na-ion batteries. ESPSs are flexible in that they can differentiate between storage technologies. California already treats storage technologies differently in its ESPS; consider, California caps the amount of pumped storage to fifty MW of the total procurement goal.[404] Requiring utilities to procure fixed amounts of storage from Na-ion batteries sends a strong signal to stakeholders to invest in that market,[405] accelerating Na-ion commercialization and increasing deployment.

Moreover, states should consider adopting credit tracking programs as one option to monitor compliance with ESPSs and further drive deployment of Na-ion batteries.[406] For instance, a state could offer a credit for each MWh of energy stored and delivered to the grid, and utilities and businesses could purchase these credits to prove compliance with ESPSs or sustainability targets. This credit mechanism would emulate current REC systems, which assign credits to renewable generators for each MWh produced that can then be sold to utilities and businesses.[407] While REC programs vary by state, RECs have largely been successful in both ensuring compliance and increasing investment in renewable generation.[408] While the need for a tracking mechanism is less pronounced in the energy storage context than the renewable energy context,[409] it could still be useful as a method to simplify compliance and increase Na-ion battery investment.

To date, tracking mechanisms for energy storage have not been widely implemented.[410] Moreover, implementation of a credit system benefits all batteries, including Li-ion batteries. Thus, states considering tracking mechanisms for storage should take steps to provide Na-ion batteries with an advantage. First, states could assign a multiplier to Na-ion batteries, which would increase their value to buyers, incentivizing investment. Although, it is important to note that multipliers can potentially stagnate deployment because utilities could purchase fewer credits to achieve the same procurement targets. On the other hand, states

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403. *See* discussion *supra* Section III.B.

404. Lazaroff & Curran, *supra* note 209.

405. *Id*.

406. ASHLEY J. LAWSON, ELECTRICITY PORTFOLIO STANDARDS: BACKGROUND, DESIGN ELEMENTS, AND POLICY CONSIDERATIONS 6-8 (Cong. Rsch. Serv. 2020), https://crsreports.congress.gov/product/pdf/R/R45913.

407. *Renewable Energy Credits (RECs), Explained*, WATCHWIRE: TANGO ENERGY & SUSTAINABILITY (Feb. 19, 2021), https://watchwire.ai/renewable-energy-credits-recs-explained/.

408. Eric Mack & Andrew Blok, *Renewable Energy Certificates: How You Can Prove How Green You Are,* CNET (last updated Nov. 2, 2023), https://www.cnet.com/home/energy-and-utilities/renewable-energy-certificates-how-anyone-can-enter-the-green-energy-market/.

409. Utilities use RECs to prove that they have purchased energy from renewable sources because electricity co-mingles on the grid, making it impossible to determine whether renewable sources or fossil fuels generated the energy actually received. *Id*.

410. E. RSCH. GP. INC. & ED HOLT & ASSOCS., INC., STATUS & TRENDS REPORT ON U.S. ENERGY ATTRIBUTE TRACKING SYSTEMS 26, 46, 48 (U.S. Env't Prot. Agency: Green Power P'ship 2025), https://www.epa.gov/system/files/documents/2025-01/status_and_trends_report_us_energy_attribute_tracking_systems.pdf (last visited Feb. 24, 2025).

could create a credit distinct to Na-ion batteries. For example, some states already include a solar renewable energy carveout (SRECs) in their REC programs to ensure that utilities procure a certain portion of their energy from solar.[411] Separate certificates would allow the market to properly value Na-ion batteries; however, it is important to note that while Na-ion batteries are still nascent and not widely available, the cost of Na-ion-specific RECs would likely be high.[412]

Next, states can increase procurement of Na-ion batteries through their IRPs. As previously mentioned, several states have already adopted regulations requiring utilities to account for energy storage in their IRPs.[413] States with IRPs can better account for the costs of Li-ion batteries in multiple ways. Most obviously, state agencies may revise their planning considerations to mandate that utilities consider Na-ion batteries. However, if that option is unavailable or infeasible – for instance, if the state public regulatory commission (PUC) is restricted to considerations passed by the state legislature – reframing interpretations of cost, risk, and environmental impact could encourage utilities to adopt Na-ion batteries in their IRPs.

When utilities adopt least-cost plans, they typically interpret cost to mean economic cost. For example, some interpret New Hampshire's least-cost IRP (LCIRP) requirement to mean that utilities must save customers "as much money as possible."[414] However, if states reinterpreted cost to include not just economic cost, but also the environmental and social costs of Li-ion batteries, states could internalize the adverse externalities associated with Li-ion batteries. That would raise Li-ion "prices" and encourage utilities to invest in less harmful Na-ion batteries.

Furthermore, a least-risk metric focuses on minimizing the "regret" of procurement plans, meaning that utilities weigh the likelihood and consequence of risks and challenges that could surface and choose the procurement plan that is relatively low cost for the utility no matter how the future unfolds.[415] Utilities that consider risk *should* account for the fire safety hazards associated with Li-ion batteries because battery fires can be particularly dangerous.[416] Yet some utilities that account for risk do not recognize the fire risks that Li-ion batteries pose. Utah requires least-cost, least-risk planning,[417] but in 2023, Pacific Corp. (a utility

411. Mack & Blok, *supra* note 408.

412. *See RECs Are Expensive. Now What?*, USOURCE (Sep. 23, 2023), https://www.usourceenergy.com/resource-center/insights/recs-are-expensive-now-what-alternatives-to-meeting-your-sustainability-metrics.html (noting that when demand for RECs surpasses supply, RECs become a scarce resource and REC prices increase).

413. Lazaroff & Curran, *supra* note 209.

414. Donald M. Kreis, *Warning: A Pillar of Utility Regulation May Be About to Topple*, INDEPTHNH.ORG (Mar. 2, 2023), https://indepthnh.org/2023/03/02/warning-a-pillar-of-utility-regulation-may-be-about-to-topple/.

415. Patrick Bean & David Hoppock, *Least-Risk Planning for Electric Utilities* 5-6 (Duke Nicholas Inst. for Env't Pol'y Sols., Working Paper No. 13-05 2013), https://nicholasinstitute.duke.edu/sites/default/files/publications/ni_wp_13-05.pdf.

416. *See* Pehling, *supra* note 103 (describing how Li-ion batteries caught on fire at a power plant in California).

417. 2023 INTEGRATED RESOURCE PLAN (AMENDED FINAL) 9 (PacifiCorp vol. 1 eds., 2023), https://pscdocs.utah.gov/electric/23docs/2303510/3281812023IRPFnlVlmI5-31-2023.pdf.

operating within the state) neglected to differentiate between the ignitability risks of different types of battery technologies even though it accounted for wildfire risks associated with weather events.[418] In other words, Pacific Corp.'s IRP represents a blind-spot where utilities recognize that the risk of fire must be mitigated, and prepare for fires caused by weather events, but fail to consider how Li-ion batteries contribute to that risk. In that case, states should decline to acknowledge an IRP for failing to account for fire risks associated with Li-ion batteries. This could motivate utilities to explore safer alternatives, such as Na-ion batteries.

In addition, states that require utilities to consider environmental impacts could expand their purview to include natural resource degradation. California's goal for its 2019 to 2021 IRP cycle was to ensure that the electricity sector helped reduce greenhouse gas emissions to meet state climate goals.[419] California's limited focus on emissions reductions[420] made Li-ion an attractive storage technology. Therefore, LSEs in California invest heavily in Li-ion to provide capacity, second only to investments in solar.[421] If states such as California expanded their environmental considerations to account for natural resource degradation in addition to emission abatement, utilities would be more likely to invest in Na-ion batteries.

Furthermore, states could adopt programs specific to Na-ion batteries to educate stakeholders and disseminate information. In the past, demonstration projects have focused on deploying Li-ion batteries throughout the energy sector.[422] But some states have started to engage in demonstration projects focused on understanding alternative battery technologies. Between 2021 and 2023, California facilitated a demonstration project, called the Eos Energy Storage: Utility Demonstration of Non-Flammable, Aqueous-Zinc Battery Storage project, to test the commercial application of zinc aqueous electrolyte technology.[423] Published findings can help disseminate information to stakeholders and are may help with deployment of zinc batteries. Given the nascence of Na-ion battery technology and the fact that investor inexperience is a common barrier to deployment,[424] states should create Na-ion specific demonstration programs to improve investors' confidence in Na-ion battery technology.

418. *Id*. at 130-43.

419. *CPUC Integrated Resource Planning (IRP)*, CAL. PUB. UTILS. COMM'N, at 2 (June 2021), https://ww2.arb.ca.gov/sites/default/files/2021-06/cpuc-irp_sp_kickoff-electricity_june2021.pdf.

420. *Id*.

421. *Decision Adopting 2023 Preferred System Plan & Related Matters, & Addressing Two Petitions for Modification*, *supra* note 391, at 68.

422. *See* discussion *supra* Section IV.B.

423. COLBY MURDOCK & EOS ENERGY STORAGE, EOS ENERGY STORAGE: UTILITY DEMONSTRATION OF NON-FLAMMABLE AQUEOUS-ZINC BATTERY STORAGE 1 (Cal. Energy Comm'n 2023), https://www.energy.ca.gov/publications/2023/eos-energy-storage-utility-demonstration-non-flammable-aqueous-zinc-battery.

424. DHRUV BHATNAGAR ET AL., MARKET AND POLICY BARRIERS TO ENERGY STORAGE DEPLOYMENT 32 (Sandia Nat'l Lab'ys 2013), https://www.sandia.gov/ess-ssl/publications/SAND2013-7606.pdf.

2. Other Effective Programs

Other, less common programs adopted by states in the energy storage context include R&D, education programs, public procurement, building codes, and storage-specific auctions. Starting with R&D, it is important that states consider adopting their own programs. In general, the federal government has driven R&D for energy storage technologies; in 2024, the DOE's R&D budget for energy efficiency and renewable energy was almost $3.5 billion.[425] However, federal administration changes can threaten the longevity of energy storage R&D programs even if states favor them.[426] Therefore, states should adopt R&D programs specific to Na-ion batteries to ensure that innovation, industry training, and knowledge dissemination do not stall if and when the federal government changes its priorities.[427] R&D is a beneficial vehicle to drive growth of Na-ion battery technology because it can be geared towards very specific learning objectives.[428] While Na-ion batteries have benefited from some R&D so far, notably by Argonne Laboratory,[429] more R&D is needed to commercialize Na-ion batteries to the point where Na-ion can replace Li-ion.

Relatedly, states should adopt education programs, such as scholarships and grants, to draw innovators into the Na-ion battery market. Education measures can be designed to redirect innovators away from Li-ion batteries and towards Na-ion batteries, thereby increasing the knowledge stock of Na-ion batteries and changing the relative profitability between the technology-types.[430] Like R&D, scholarships and grants often target very specific objectives – *e.g.*, the University of North Carolina at Chapel Hill offered a scholarship to optimize performance of electrodes in fluoride-ion batteries.[431] Research to improve Na-ion battery technology can help build its knowledge stock and attract investors.

States should also engage in public procurement to create consistent demand for Na-ion batteries and establish market credibility.[432] Directly, states can

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425. LAURIE HARRIS, FEDERAL RESEARCH AND DEVELOPMENT (R&D) FUNDING: FY2025 24 (Cong. Rsch. Serv. 2024), https://crsreports.congress.gov/product/pdf/R/R48307/2.

426. *See* Kate Magill, *Trump Freezes IRA Funding*, UTILITYDIVE (last updated Jan. 23, 2025), https://www.utilitydive.com/news/president-trump-inflation-reduction-act-executive-order-ev-mandate/738001/; Brian Martucci, *Potential Trump Policies Pose Risks for US Storage Sector, with Musk Impact Uncertain, Analysts Say*, UTILITYDIVE (Nov. 12, 2024), https://www.utilitydive.com/news/trump-policies-risks-energy-storage-sector-tesla-musk-impact/732713/ (noting that twenty congressional republicans opposed the repeal of energy tax credits available under the IRA); *see generally* Exec. Order No. 14,154, 90 Fed. Reg. 8353 (2025) [hereinafter Exec. Order No. 14,154].

427. *See* discussion *supra* Section V.B.ii (describing benefits of R&D programs).

428. *See, e.g.*, *id*. (noting that California invested in a R&D program that sought to predict solar power variability caused by cloud cover).

429. *A New Era for Batteries: Argonne Leads $50M Sodium-ion Innovation Push*, ARGONNE NAT'L LAB'Y (Nov. 21, 2024), https://www.anl.gov/article/a-new-era-for-batteries-argonne-leads-50m-sodiumion-innovation-push.

430. *See* discussion *supra* Section V.A. (noting that innovation snowballing can "redirect" innovators towards a new technology).

431. Dave DeFusco, *APS Student Receives Scholarship for Research on Promising Battery Technology*, UNIV. N.C. CHAPEL HILL: APPLIED PHYSICAL SCIS. (May 30, 2024), https://aps.unc.edu/home-page-news-item/aps-student-receives-scholarship-for-research-on-promising-battery-technology/.

432. *See* discussion *supra* Section V.B.i. (explaining the benefits of public procurement).

mandate their agencies to install Na-ion batteries on state-owned buildings.[433] Indirectly, states can require that state-owned buildings attain certain clean energy standards. For example, California mandated that state-owned buildings attain LEED certification, a rating system that evaluates buildings on sustainability, which prompted solar adoption.[434] However, while LEED certification encourages adoption of renewable technologies and storage batteries, it does not differentiate based on technology type, thus, there is a risk that this indirect method of public procurement could incentivize adoption of Li-ion adoption as well as Na-ion batteries.

The best public procurement directive would direct state agencies to enter into long-term contracts with Na-ion battery manufacturers for a specified amount of power in order to create steady demand for Na-ion batteries. Because of Na-ion's nascency in the market, public procurement initiatives could create bottlenecks in the supply chain while the industry scales up.[435] However, as market credibility for Na-ion batteries improves, more manufacturers and investors are expected to enter the market, which should relieve supply chain bottlenecks that may arise. As competition intensifies and knowledge of Na-ion technology improves, production costs should lower and profitability improve, thereby accelerating innovation and increasing deployment.[436]

Adopting building codes is another effective way that states can subsidize demand for Na-ion batteries. Paralleling the California Solar Mandate, states can require that certain dwelling types adopt Na-ion batteries, functioning as distributed energy resources or accompanying other renewable energy technologies.[437] If a mandate is infeasible or unpractical, states can also develop building performance standards that incentivize Na-ion battery adoption. For example, all fifty states have incorporated some form of the National Fire Protection Association (NFPA) standards, which assign fire resistance ratings to building materials to minimize the effects of fires.[438] States can encourage builders to adopt Na-ion batteries by assigning fire resistance ratings to battery

433. *See, e.g. id*. (noting that California required state agencies to install solar systems on new and existing state-owned buildings and parking facilities where cost-effective).

434. Paul Walsh, *The LEED Rating System Explained*, CIM (Mar. 19, 2026), https://www.cim.io/blog/the-leed-rating-system-explained#areas%20of%20LEED%20performance; *see* discussion *supra* Section V.B.ii. (describing how California required state-owned buildings to attain LEED certification, leading to increased solar deployment).

435. Currently, only one commercial manufacturer in the United States, Peak Energy, is poised to launch Na-ion battery storage projects starting in 2027. *See* discussion *supra* Section III.B. Thus, by default, states purchasing Na-ion batteries domestically would necessarily contract with Peak Energy to fulfill demand once Na-ion batteries are available.

436. *See* discussion *supra* Section V.A. (describing the process of "innovation snowballing").

437. *See* discussion *supra* Section V.B.ii. (describing how the California Solar Mandate requires that all new and some retrofit commercial buildings install solar and energy storage systems).

438. *NFPA 101: Life Safety Code*, NAT'L FIRE PROT. ASS'N, https://docinfofiles.nfpa.org/files/AboutTheCodes/101/NFPA101FactSheet0809.pdf (last visited Feb. 24, 2025); *What Is the NFPA 101 Life Safety Code?*, ALTUS: FIRE & LIFE SAFETY, https://www.altusfire.com/life-safety-resources/nfpa-101-life-safety-code/ (last visited Feb. 24, 2025).

materials; since Li-ion batteries pose a risk of thermal runaway,[439] builders may prefer to use safer Na-ion batteries.[440]

Additionally, states can adopt green building standards that encourage the adoption of Na-ion batteries. Green building standards generally set minimum benchmarks for performance based on metrics such as energy efficiency, indoor air quality, sustainable site selection, and materials and resource use.[441] Optimizing the use of materials and resources requires reducing waste and using materials that can be recovered or recycled.[442] If a state adopted green building standards that considered the natural resource degradation associated with the extraction and production of building materials, then states could incentivize builders to adopt Na-ion batteries, which have a smaller environmental impact than Li-ion batteries.[443] Additionally, if building code standards were interpreted to consider the recycling difficulties associated with Li-ion batteries, then states could incentivize builders to adopt Na-ion batteries, which are more easily recycled.

Lastly, it is a good idea for states to adopt storage-specific auctions. Auctions provide a convenient forum for LSEs to purchase renewable energy and help utilities meet ESPS mandates, targets, and goals.[444] As seen by RAM in California, states can design auctions by energy type, like renewable energy.[445] While renewable energy auctions could potentially foster growth of battery alternatives such as Na-ion batteries, competition with incumbent renewable generators would likely impede battery deployment.[446] A storage-specific auction would reduce competition and give Na-ion batteries a better chance to compete. And given that auctions can be designed by energy-type, there is no reason that auctions cannot be designed by technology-type. As Na-ion battery technology improves and costs drop, Na-ion battery manufacturers could likely bid their storage at lower prices than Li-ion batteries since Na-ion batteries are comprised

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439. *See* discussion *supra* Section III.A. (describing how Li-ion batteries pose fire safety risks).

440. Indeed, forty-two states and two U.S. territories have adopted the International Fire Code (IFC) to regulate businesses storing Li-ion batteries and require adoption of a fire safety plan. *Where to Store Lithium-Ion Batteries*, JUSTRITE, https://www.justrite.com/storing-li-ion-batteries/where-to-store-lithium-ion-batteries (last visited Feb. 24, 2025). Some states have also adopted codes regulating residential energy storage systems, but they do not specifically address the flammability of li-ion batteries. *See* Justine Sanchez, *Fire Codes & NFPA 855 for Energy Storage Systems*, MAYFIELD RENEWABLES (Dec. 16, 2021), https://www.mayfield.energy/technical-articles/fire-codes-and-nfpa-855-for-energy-storage-systems/. The logical next step is to adopt building codes regulating Li-ion storage batteries since states already recognize that these batteries pose fire-safety risks.

441. *Green Building Codes, Standards & Rating Systems*, DURABLE BLDG. SOLS., https://durablebuildingsolutions.org/building-future/green-building-codes-standards-rating-systems/ (last visited Feb. 24, 2025).

442. *Green Communities Criteria and Certification: Materials*, ENTERPRISE, https://www.greencommunitiesonline.org/materials (last visited Apr. 14, 2026).

443. *See* discussion *supra* Section III.A. (explaining the costs of Li-ion batteries). Note, that if a state adopted a form of the recommended building codes, codes would also apply to state-owned buildings.

444. *Renewable Energy Auctions*, SUSTAINABILITY DIRECTORY, https://energy.sustainability-directory.com/area/renewable-energy-auctions/resource/1/ (last visited Apr. 15, 2026).

445. *See* discussion *supra* Section V.B.ii.

446. *See* discussion *supra* Section IV.B.ii. (discussing how RTO and ISO auctions frustrate widespread battery deployment).

of cheaper materials, thereby benefitting the most from a reverse-auction mechanism.

3. Cautioning Against Net-Metering and FiTs

As described above, although net-metering was effective in widely deploying solar technology, it is associated with equity concerns. Indeed, in response to concerns that net-metering left non-participating and lower-income energy customers with higher rates, California took steps to weaken its net-metering program.[447] Therefore, this paper cautions against adopting net-metering to increase deployment of Na-ion batteries.

This paper also does not recommend FiTs. Despite the success of FiTs in Germany, they have been largely unsuccessful in growing solar in the United States, often due to poor design.[448] FiTs suffer from high administrative burden, such as setting the correct price to incentivize development, and require periodic revision to keep up with market and technological changes.[449] Even Germany is moving away from FiTs and replacing them with competitive market measures.[450] Moreover, in 2010, FERC issued two decisions that endorse a strong preemption regarding FiT prices under Public Utility Regulatory Policies Act (PURPA), leaving states with "very limited paths" to implement their own FiTs.[451] Consider, in 2019, the Ninth Circuit ruled that Re-MAT violated PURPA's requirements, prompting California to modify Re-MAT's design.[452] While FiTs may be effective under certain policy designs,[453] in light of the other policy options and jurisdictional difficulties associated with FiTs, it is not recommended for states to adopt their own.

In sum, government intervention is required to disrupt Li-ion's dominance of the storage battery market and encourage commercialization of Na-ion batteries. States are best positioned to drive this change. To help Na-ion batteries reach commercialization and divert investment from Li-ion batteries towards Na-ion batteries, states should focus on programs that: (1) increase the technologies' knowledge stock; and (2) lower production costs. Solar technology's rise to

447. *See* discussion *supra* Section IV.B.i.; *CPUC is Not Above the Law*, *supra* note 335 (noting that ongoing legal challenges regarding NEM 3.0 make the future of that program uncertain).

448. *See* discussion *supra* Section IV.B.i..

449. KARLYNN CORY, TOBY COUTURE & CLAIRE KREYCIK, FEED-IN TARIFF POLICY: DESIGN, IMPLEMENTATION, AND RPS POLICY INTERACTIONS 11 (Nat'l Renewable Energy Lab'y 2009), https://www.nrel.gov/docs/fy09osti/45549.pdf.

450. *Solar Incentives for End-Users in Germany*, ENACT SOLAR (Dec. 10, 2024), https://enact.solar/solar-incentives-for-end-users-in-germany/.

451. Jim Rossi, *Clean Energy and the Price Preemption Ceiling*, 3 SAN DIEGO J. CLIMATE & ENERGY L. 243, 250 (2012); *Cal. Pub. Utils. Comm'n*, 132 FERC ¶ 61,047 P 67 (2010) (Order on Petitions for Declaratory Order); *see, e.g.*, *Cal. Pub. Utils. Comm'n*, 133 FERC ¶ 61,059 PP 25-30 (2010) (Order Granting Clarification and Dismissing Rehearing).

452. *See* Winding Creek Solar LLC v. Peterman, 932 F3d 861, 862 (9th Cir. 2019) ("Re-MAT violates PURPA's requirements"); *Decision Resuming and Modifying the Renewable Market Adjusting Tariff Program*, No. 20-10-005 (Cal. Pub. Utils. Comm'n 2020) (adopting a modified version of Re-MAT to comply with PURPA).

453. *See* CORY, COUTURE & KREYCIK, *supra* note 449, at 10 (providing recommendations on designing FiTs).

market dominance provides a blueprint of programs that states can emulate in driving Na-ion battery deployment. As described, states need not take drastic action. Indeed, states with current energy storage policies can modify existing policies to help effectuate the transition to Na-ion batteries.

VI. PASSING LEGAL MUSTER

The shared regulatory scheme between the federal government and states in energy law adds a layer of complexity in determining whether state programs are legal. Some of the recommended state programs clearly pass legal muster while others are more ambiguous. States plainly have the authority to implement ESPSs, RECs, and IRPs because states retain jurisdiction over energy procurement and resource planning.[454] Moreover, it is clear that states may create their own demonstration projects, R&D, and education programs because no federal preemption exists to bar states from improving the knowledge stock of energy technology.[455] Building codes may also pass legal muster as long as states are cognizant not to override federal law.[456] On the other hand, state authority to implement financial incentives and storage-specific auctions is more ambiguous. Nonetheless, this paper argues that if these programs comply with the legal requirements identified below, they ultimately should pass legal muster.

Beginning with financial incentives, states can subsidize clean energy technology only through measures "untethered" to wholesale market participation.[457] In the seminal case, *Hughes v. Talen Energy Marketing, LLC*, Maryland promulgated an order requiring LSEs to contract with a specific generator and agreed to pay that generator the difference between the contract price and auction clearing price.[458] As a result, Maryland's program guaranteed

454. *See* Coal. for Competitive Elec., Dynergy Inc. v. Zibelman, 906 F.3d 41, 50 (2018) ("the states are authorized to regulate energy production"); *id.* at 54 ("FERC has confirmed that REC programs fall within the jurisdiction of the states").

455. Three types of federal preemption exist: express, field, and conflict. Express preemption exists when a federal statute explicitly indicates that it intends to displace state law. Cessna v. REA Energy Coop., 258 F.Supp.3d 566, 575 (2017). Field preemption exists when federal regulation is so pervasive in a particular area as to occupy the entire field, leaving no room for state regulation. *Id*. An example of this is immigration law. *See* United States v. Texas, 719 F.Supp.3d 640, 663-65 (2024). Conflict preemption exists when a state law either makes compliance with both state and federal law impossible or acts as an obstacle to the implementation of federal law. *Cessna*, 258 F.Supp.3d at 575. None of these applications of preemption concern state efforts to improve knowledge of energy technology.

456. There is no national or federal building code because under the U.S. Constitution states control the regulation of construction. FED. EMERGENCY MGMT. AGENCY, BUILDING CODES TOOLKIT FOR HOMEOWNERS AND OCCUPANTS: FEDERAL ROLE IN STATE AND LOCAL BUILDING CODES AND STANDARDS 32, https://www.fema.gov/sites/default/files/documents/fema_federal-role-state-local-building-codes-standards.pdf (last visited Apr. 19, 2025). However, local building codes sometimes conflict with federal law, like in *California Restaurant Association v. City of Berkeley* where the Ninth Circuit ruled that the Energy Policy & Conservation Act (EPCA) preempted a local ordinance barring developers from including gas infrastructure in most new buildings. *Gloom Not Doom: The Latest in the Berkeley Decarbonization Case*, PUB. HEALTH L. CNTR. (Jan. 3, 2024), https://www.publichealthlawcenter.org/commentary/240103/1/3/24-gloom-not-doom-latest-berkeley-decarbonization-case; *see* 42 U.S.C. § 6297(c). This paper does not provide an analysis of EPCA because it is beyond the scope of this paper.

457. Hughes v. Talen Energy Mktg., LLC, 578 U.S. 150, 166 (2016).

458. *Id*. at 158-59.

the generator a price for its energy despite its bid into the wholesale energy auction overseen by PJM.[459] The Supreme Court determined that although states can implement programs that "incidentally affect areas within FERC's domain," Maryland's "contract-for-differences" program "intrude[d]" on FERC's jurisdiction to set wholesale electricity rates."[460] In other words, the contract-for-differences program was "tethered" to wholesale market participation because its subsidies were conditioned upon the generator's sale of capacity into a FERC-regulated auction, and was thus invalid.[461]

Coalition for Competitive Electricity, Dynergy Inc. v. Zibelman,[462] provides an example of a state-run financial incentive program that was "untethered" from the wholesale energy market and, therefore, legally permissible. In that case, New York developed a Zero Emissions Credit (ZEC) program that subsidized qualifying nuclear power plants.[463] The plaintiffs argued that the ZEC program improperly influenced prices in the wholesale market auction overseen by NYISO because it enabled nuclear generators to sell capacity even if the market-clearing price was below the cost of production.[464] To be clear, if the ZEC program did not exist, then nuclear generators could not profitably sell their capacity into the wholesale auction, and only economically viable competitors could participate, resulting in a different market-clearing price. Yet the court ruled that even if the ZEC program indirectly influenced wholesale market prices, it was permissible because ZECs were based on nuclear energy *production* independent of a generator's participation in the wholesale market, and *Hughes* prohibited state programs tethered to "wholesale market *participation*," not prices.[465] Consolidating the holdings of *Hughes* and *Zibelman*, state rebates and tax credits should pass legal muster if they are based on battery production and are not conditioned upon participation in wholesale energy markets.

In a similar vein, while state-run wholesale market auctions appear to toe the jurisdictional line, states should be able to implement storage-specific auctions if prices are set competitively. In designing RAM, California's state-run auction where renewable generators sell capacity to IOUs to help IOUs achieve their RPS goals,[466] the CPUC deliberately used a market-based approach because FERC mandates market-based rates for wholesale sales of energy, capacity, and ancillary services.[467] In fact, the CPUC considered jurisdiction in depth before adopting RAM. In response to comments that FERC had "exclusive jurisdiction over sales of electric energy in wholesale transactions," the CPUC decided that employing

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459. *Id*. at 159.

460. *Id*. at 164.

461. *Hughes*, 578 U.S. at 165.

462. Coal. for Competitive Elec., Dynergy, Inc. v. Zibelman, 906 F.3d 41 (2018).

463. *Id*. at 45.

464. *Id*. at 46-47.

465. *Id*. at 51, 54.

466. *See* discussion *supra* Section IV.A.

467. *See* Wentz, *supra* note 383, at 40 ("CPUC decided to pursue the market-based approach in order to avoid any potential legal disputes with FERC"); Order No. 697, *Market-Based Rates for Wholesale Sales of Electric Energy, Capacity and Ancillary Services by Public Utilities*, 72 Fed. Reg. 39,904, 39,907 (2007) (codified at 18 C.F.R. pt. 35) [hereinafter Order No. 697].

competitive solicitation yields market-based prices "compatible with FERC's rate-setting in wholesale markets" and avoids the issue of a state setting wholesale market prices.[468] Although FERC has not expressly sanctioned California's RAM program, the CPUC's argument seems to hold water. After implementation, no party has yet legally challenged California's jurisdiction to implement RAM, although parties have challenged the program on other grounds.[469] Moreover, state-run auctions are consistent with the holding in *Hughes*, which rejected Maryland's contract-for-differences program "only because it disregards an interstate wholesale rate required by FERC."[470] A state-run auction does not disregard a wholesale rate set by FERC, rather it sets market-based rates in compliance with FERC's mandate.[471] As such, states should be authorized to implement storage-specific auctions.

In sum, states could adopt ESPSs, RECs, IRPs, demonstration projects, R&D, education programs, and building codes to support the energy storage market's transition to Na-ion batteries. Furthermore, states can support Na-ion batteries through financial incentives "untethered" from the wholesale energy market and through storage-specific auctions with competitive prices.

VII. CONCLUSION

This paper contemplates two major problems encountered by the energy sector in the United States: first, the evolving energy grid increasingly needs and relies upon battery storage; and second, the market currently relies upon less optimal and problematic Li-ion batteries. This paper posits that the solution to those problems is to replace Li-ion batteries with Na-ion batteries. States, rather than the federal government, are best positioned to lead this transition. To accomplish this, states should adopt programs designed to commercialize Na-ion batteries and divert investment from Li-ion batteries to Na-ion batteries, enabling Na-ion to attain the dominant position in the storage market. Effective programs include rebates, tax incentives, ESPSs, IRPs, demonstration projects, R&D, education programs, public procurement, building codes, and storage-specific auctions.

State-level policies can improve the sustainability, equity, and security of the renewable energy transition. With the need for decarbonization becoming more apparent every day, the strain on the grid worsening, and battery technology improving, the time is ripe for states to encourage deployment of Na-ion batteries.

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468. *Proposed Decision of ALJ Mattson*, Rulemaking No. 08-08-009, at 35, 40 (Cal. Pub. Utils. Comm'n 2008).

469. Three IOUs requested modification of RAM related to potential security concerns associated with making certain transmission and distribution system information publicly available. *Regulatory Update for July 19, 2022 (Week of July 11, 2022)*, STOEL RIVES, LLP, at 2 (July 19, 2022), https://www.stoel.com/assets/htmldocuments/uploads/files/article%20pdfs/energy_regulatory_updates/jul19-2022.pdf.

470. Hughes v. Talen Energy Mktg., LLC, 578 U.S. 150, 166 (2016).

471. Order No. 697, *supra* note 467, at 39,906.