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FAQ Dr Mark Jacobson Stanford University - Energy Transition (Presented on June 25th, 2025)

1. What are the primary motivations for a rapid global transition to 100% Wind, Water, and Solar (WWS) energy?

A rapid global transition to 100% WWS is urgently needed due to severe problems caused by fossil fuels and bioenergy. These include approximately 7.4 million air pollution deaths annually worldwide, costing an estimated $30 trillion per year. Global warming is projected to cost a similar amount by 2050. Furthermore, the increasing scarcity of fossil fuels will lead to higher energy prices and contribute to economic, political, and social instability. The drastic nature of these problems necessitates immediate and comprehensive solutions like the WWS plan.

2. How does the WWS solution propose to meet global energy demands across all sectors?

The WWS solution aims to meet all energy demands by electrifying or providing direct heat for every sector (electricity/heat, transportation, buildings, industry) and supplying this energy with 100% wind, water, and solar sources. This involves a comprehensive set of technologies. For electricity and heat generation, it includes wind, solar PV/CSP, geothermal, hydro, tidal/wave, and solar/geo heat. For transportation, it focuses on battery-electric and H2 fuel cell vehicles. Buildings will utilize heat pumps, LED lights, insulation, and induction cooktops. Industry will adopt arc furnaces, induction furnaces, resistance furnaces, dielectric heaters, and electron beam heaters.

3. What types of energy storage are crucial for a 100% WWS system to ensure grid stability?

To ensure a stable grid with 100% WWS, various types of energy storage are crucial. These include:

- Electricity Storage: CSP with storage, pumped hydro storage, existing hydroelectric, batteries, flywheels, compressed air, gravitational storage, and grid hydrogen/fuel cells.
- Hot/Cold Storage: Water tanks, ice, underground storage, borehole storage, water pit storage, aquifer storage, and building materials like firebricks.
- Hydrogen Storage: Non-grid hydrogen storage. This diverse portfolio of storage solutions helps manage the intermittency of renewable sources and ensures continuous energy supply.

4. What significant reductions in energy demand and costs are projected with a global transition to WWS by 2050?

A global transition to WWS by 2050 is projected to lead to a significant 54.2% reduction in end-use power demand compared to business-as-usual (BAU). This efficiency gain comes from:

- 19.8% from the higher efficiency of battery-electric (BE) and hydrogen fuel cell (HFC) vehicles versus internal combustion engines (ICE).
- 4.1% from the efficiency of electric industrial processes.
- 13.1% from the efficiency of heat pumps.
- 10.6% from eliminating the energy used in fuel mining, moving, and processing. In terms of costs, WWS is projected to reduce annual energy costs by 61% and total economic (social) costs (including fuel, health, and climate) by 92% compared to BAU, saving trillions of dollars annually worldwide.

5. What is the estimated capital cost for the worldwide WWS transition, and what is its payback period?

The estimated capital cost for a worldwide transition to 100% WWS for all purposes across 150 countries is $60.0 trillion. For the U.S., it's $6.5 trillion, and for California, it's $517 billion. Despite these significant upfront capital costs, the WWS plan offers substantial annual energy cost savings. For California, the capital cost of $517 billion is projected to be offset by annual energy savings of $129 billion, resulting in an energy cost payback time of approximately 4 years.

6. What is the land footprint required for a 100% WWS system globally and in specific regions, and how does it compare to current land use for biofuels?

The land footprint required for a 100% WWS system is remarkably small.

- For 150 countries globally, it would require 0.39% of land for onshore wind (spacing) and 0.18% for utility PV+CSP (footprint), totaling 0.57%.
- For the U.S., it's 0.36% for onshore wind and 0.69% for utility PV+CSP, totaling 1.05%.
- For California, it's 0.47% for onshore wind and 0.33% for utility PV+CSP, totaling 0.80%.
- This is significantly less than the 1.24% of U.S. land currently used for corn ethanol alone.

7. What progress has California made towards 100% WWS, and what specific examples demonstrate this progress?

California has made significant progress towards 100% WWS in its electric power sector. Examples include:

- On April 8, 2024, during a solar eclipse, batteries effectively filled the gap in electricity supply, demonstrating their role in grid stability.

- On May 5, 2024, WWS supply met 162.3% of demand for 5 minutes and exceeded demand for 9.9 hours.
- On May 25, 2025, WWS supply exceeded 100% for 10.5 hours, and 82% of the 24-hour demand was met by WWS, peaking at 158.3%.
- On June 9, 2025, a record battery discharge rate of 10.144 GW was achieved.
- From January 1 to June 12, 2025, 79% of days saw WWS exceeding 100% of demand, with significant increases in solar (18.4%) and battery (66%) capacity compared to the previous year.

8. Beyond energy benefits, what are the broader societal advantages of transitioning to 100% WWS?

Transitioning to 100% WWS offers substantial broader societal advantages:

- Job Creation: It is projected to create 28 million more jobs worldwide than are lost, and 300,000 more long-term, full-time jobs in California.
- Public Health: It avoids approximately 7 million air pollution deaths per year globally by eliminating fossil fuel emissions.
- Climate Change Mitigation: It effectively slows and then reverses global warming.
- Economic Savings: Annual energy costs are 61% less than those of fossil fuels, and annual total social costs (energy, health, climate) are 92% less, leading to massive global economic savings.
- Grid Stability: Stable electric grids can be maintained throughout the world with 100% WWS.

FAQ Dennis Dyc-O'Neal – Central Coast Community Energy

(Presented on June 25th, 2025)

What is Central Coast Community Energy (3CE) and what is its mission?

Central Coast Community Energy (3CE) is a public community choice aggregator (CCA) that serves 30 cities and five counties from Santa Cruz to Santa Barbara, excluding King City, the city of Santa Barbara, and the city of Lompoc. As a CCA, 3CE's primary role is to source clean and renewable energy for its customers. They partner with Investor-Owned Utilities (IOUs) like Pacific Gas and Electric and Southern California Edison for energy delivery. Beyond just sourcing energy, 3CE also designs and implements dynamic electrification programs, aiming to empower customers to participate in the energy transition. Their long-term vision is to cease burning fossil fuels for energy due to their detrimental impacts on health and the environment. 3CE strives to provide reliable, affordable, clean electricity and innovative electrification programs that reduce greenhouse gas emissions and strengthen local economies.

How does 3CE compare to traditional Investor-Owned Utilities (IOUs) in terms of operations and benefits?

Unlike IOUs, 3CE's rates are solely based on the cost of serving customers, aiming for fair and justifiable pricing. They commit about $15 million annually to community investment programs. A significant difference is their governance structure: 3CE is governed by elected officials on its policy board, not a board of shareholders, providing local control and direct engagement opportunities for the community with board members and staff. In Santa Cruz County, 3CE has consistently offered cheaper rates than incumbent IOUs and has invested over $5 million in local programs. 3CE is also on an aggressive path to 100% clean and renewable energy by 2030, 15 years ahead of California's statewide goal of 2045, and they achieve this by incrementally adding to the renewable mix without relying on carbon offsets or credits.

Why is battery storage crucial for achieving California's renewable energy goals?

Battery storage is essential because renewable energy sources like solar and wind are intermittent; solar generates electricity when the sun shines, and wind power when the wind blows, but not consistently. Batteries balance these intermittent renewables by storing excess energy generated during peak production times (e.g., midday for solar) and dispatching it during high-demand, low-generation periods (e.g., evening hours). This process helps stabilize the grid, reduces reliance on expensive and polluting combustion-based generation, and captures curtailed (wasted) solar energy, which would otherwise be lost. For California to meet its 100% renewable goal by 2045, it is estimated that 52,000 megawatts of battery storage will be needed. Without sufficient storage, the state cannot transition off fossil fuels affordably, as customers would revert to cheaper gas alternatives.

How does 3CE integrate battery storage into its operations and customer programs?

3CE actively invests in and contracts for battery storage projects. They have 110 megawatts of operational battery storage, including California's first solar-plus-storage project, and another 728 megawatts contracted. These projects include large-scale initiatives like the world's largest compressed air storage facility. 3CE is also strategically placing hybrid battery projects at existing combustion facilities, effectively taking over their interconnection capacity to reduce their run hours and associated emissions. Furthermore, 3CE has launched a residential battery program that incentivizes customers (with or without solar) to install batteries, offering $300 per kilowatt (up to 26 MW) and $500 for income-qualified customers. Participants commit to dispatching at least 50% of their battery's capacity during evening hours, which helps reduce overall energy costs for all customers by lessening the need to purchase expensive, gas-generated power.

What are the main challenges and safety considerations associated with battery storage?

Challenges include market complexities, regulatory delays, and federal policy changes. A significant issue is the rapid increase in load due to 3CE's expansion, requiring them to constantly adjust their energy procurement to stay on target for their 2030 clean energy goal. From a safety perspective, the industry is addressing incidents, which EPRI defines as any need for emergency safety response. While there have been incidents, primarily involving older magnesium cobalt battery technology, the overall rate of incidents has dramatically reduced in the United States (97% drop). Key safety design changes include internally cooled systems, separate fire suppression within battery containers, the ability to derate individual modules to prevent thermal runaway, and increased spacing between outdoor battery modules (from 18 inches to 6.5-10.5 feet, with some new facilities opting for 28 feet). The industry has also largely shifted to more stable lithium iron phosphate batteries.

How has the regulation and technology of battery storage evolved to address safety concerns?

Following incidents, particularly at Moss Landing, the battery storage industry and regulators have implemented significant changes. The California Public Utilities Commission (CPUC) approved General Order 167C, bringing battery energy storage facilities under the same regulatory structure as other generating facilities, with additional requirements. This includes mandates for approved maintenance and operation plans, coordination with local fire response (as per SB 1383 and SB 38), comprehensive audits, and incident reporting. Technologically, the industry has moved away from less stable magnesium cobalt batteries towards lithium iron phosphate batteries, which are more stable even if less efficient. New installations are exclusively outdoor and incorporate design features like independent fire suppression systems, derating capabilities, and significant separation between modules to prevent thermal runaway and fire spread.

Beyond batteries, what other energy storage technologies are being considered or implemented?

While batteries are a primary focus, other forms of energy storage are also being explored. One notable alternative is pumped hydro storage, which involves using excess electricity during low-demand periods to pump water uphill into a reservoir. When electricity is needed, the water is released downhill through turbines to generate power. Another emerging concept is gravity storage, which functions similarly to an elevator, lifting heavy objects (like bricks or rocks) using cheap electricity and then slowly lowering them to generate electricity during high-demand times. 3CE itself has a contracted compressed air storage project, a large-scale facility located outside Bakersfield, which stores compressed air and releases it to generate electricity. The feasibility of these alternative technologies depends on their cost-effectiveness for customers and their ability to integrate into the grid.

How does battery storage contribute to community resilience and equity?

Battery storage significantly enhances community resilience by providing backup power during outages caused by power safety shutoffs, grid failures, or natural disasters. For individual residences, a battery coupled with solar ensures power during outages. For community facilities like cooling centers, on-site battery backup is critical. From an equity standpoint, 3CE prioritizes affordability, recognizing that electricity is a non-negotiable expense for struggling families. By displacing expensive and polluting gas-fired "peaker plants"—which are often located in underserved communities and contribute to health issues like asthma and lung disease—battery storage provides significant health benefits to these populations. For example, 3CE's battery projects are curtailing emissions from high-polluting facilities, directly reducing the energy burden on environmental justice communities. Additionally, by capturing curtailed solar energy and making it available at lower costs, batteries help ensure that the benefits of renewable energy are broadly distributed.

FAQ Scott Murtishaw Long Duration Energy Storage

(Presented on July 30th, 2025)

Why do lithium-ion batteries currently dominate the energy storage market?

Lithium-ion batteries currently dominate the energy storage market primarily due to significant advancements in their performance and durability, coupled with a dramatic 90% decline in costs between 2010 and 2023. This cost reduction was driven by massive investment and economies of scale fueled by demand from consumer goods, battery energy storage systems (BESS), and electric vehicles (EVs). They boast high round-trip efficiency (85%-90%), excellent energy density, improved durability, and fast response times. Currently, out of nearly 16,000 MW of operating energy storage in California, only about 10-20 MW are non-lithium technologies.

What are the main limitations of lithium-ion batteries that create a need for alternative storage technologies?

While lithium-ion batteries excel in many areas, their primary limitation is that they become less cost-effective at longer durations of energy discharge. This is where non-lithium energy storage technologies, often referred to as long-duration energy storage (LDES), become more competitive. As California's grid integrates higher shares of variable renewable energy and reduces reliance on dispatchable gas-fired resources, longer durations of storage are increasingly necessary to maintain grid reliability, which lithium-ion batteries are less suited for economically.

How is the increasing need for long-duration energy storage (LDES) being projected and addressed in California?

The need for LDES in California is being projected through various analyses aiming to meet the statewide 100% net-zero GHG target by 2045. The 2021 SB 100 Joint Agency Report projected a need for 4 GW of pumped hydro, while a 2023 CPUC analysis identified a need for 17 GW of 8-hour LDES for the CAISO territory. Further 2023 CEC reports modeled needs ranging from 5 GW to 37 GW of 12, 24, 48, and 100-hour LDES, depending on assumptions about gas plant retirements and LDES costs. To address this, the CPUC has issued procurement orders, including reserving 1,000 MW for LDES in 2021 and, more recently in August 2024, recommending solicitations for 1,000 MW of 12+ hour ES and 1,000 MW of "multi-day" ES, specifically excluding lithium-ion technologies for these longer-duration procurements.

What are the different categories of non-lithium energy storage technologies?

Energy can be stored in four main ways, which encompass the various non-lithium technologies:

- Electrochemically: This includes non-flow (static electrolyte) chemical batteries, like those using iron or zinc, with durations from 6 to 100 hours and efficiencies of 50-85%. It also includes flow chemical batteries, where active material is in electrolyte fluid in large tanks, ideal for 4-24 hour renewable storage.
- Chemically: This involves producing synthetic fuels, such as hydrogen, for combustion or oxidation.
- Mechanically: This stores potential energy by elevating mass (e.g., pumped hydro, lifting solid mass on cables) or compressing gases (e.g., compressed air, liquid air, liquid CO2). These systems typically offer 8-24 hour durations, 50-75% efficiencies, and very long lifetimes of 40-60 years.
- Thermally: This involves heating salts, metals, or other materials to store energy.

How do flow batteries compare to lithium-ion batteries in terms of characteristics and ideal use cases?

Flow batteries and lithium-ion batteries have distinct characteristics and ideal use cases. Flow batteries utilize electrolyte fluid in large tanks as their active material, while lithium-ion batteries use nanoscale solid materials. Flow batteries are ideally suited for longer-duration applications, such as 4-24 hour renewable storage, ancillary services, peak shaving, and resiliency, with a battery lifetime of 20+ years and potential for domestic supply chains. Their installed cost is globally averaged at $444,000/MWh. Lithium-ion batteries, conversely, are ideal for shorter durations like 10 minutes to 4 hours, primarily for ancillary services, peak shaving, and frequency regulation, with a faster response time (microseconds vs. milliseconds for flow batteries). Their installed cost is lower at $304,000/MWh, and they typically last 15-25 years, relying on international supply chains.

What are some examples of recent procurement orders and projects for long-duration energy storage in California?

Following the 2020 blackouts, the CPUC ordered utilities to procure 1,000 MW specifically for LDES, initially assumed to favor non-lithium technologies. However, recent procurements have shown a strong presence of lithium-ion solutions, with a consortium of Community Choice providers executing contracts for over 100 MW of 8-hour lithium-ion batteries, and SCE securing 400 MW of 8-hour Li-ion capacity. Despite this, some non-lithium projects are emerging: Central Coast Community Energy signed a contract for 200 MW of 8-hour advanced compressed air energy storage from Hydrostor (designed for 500 MW), and SMUD executed an agreement with ESS (iron flow) for 4 MW, with an option to expand to 200 MW. Additionally, a 2023 law (AB 1373) and an August 2024 CPUC decision are driving future procurements of 1,000 MW of 12+ hour ES and 1,000 MW of "multi-day" ES, with Li-ion technologies specifically deemed ineligible for these longer-term resources expected online between 2031 and 2037.

What is the long-term outlook for non-lithium energy storage technologies in California?

While lithium-ion batteries are expected to dominate energy storage deployment for the next 5 to 10 years, the long-term outlook for non-lithium energy storage technologies in California is very positive. As the state's grid incorporates higher shares of variable renewable energy, the increasing need for longer-duration storage becomes critical for maintaining reliability and achieving environmental goals. Legislative mandates and CPUC procurement orders, particularly those targeting 12+ hour and multi-day storage where lithium-ion is deemed ineligible, are specifically designed to foster the growth and deployment of non-lithium solutions. This indicates that in the medium to longer term, non-lithium energy storage technologies will play a significantly larger and more crucial role in California’s evolving energy portfolio.

FAQ Mike Nicholas Battery Energy Storage Systems

(Presented on July 30th, 2025)

What is Battery Energy Storage System (BESS) and why is fire safety a critical concern?

BESS refers to systems that store electrical energy in batteries for later use. Fire safety is a critical concern due to the potential for thermal runaway in batteries, which can lead to fires. While BESS failure rates have significantly decreased (by 97% between 2018 and 2023) due to improved codes and manufacturing, the inherent risks necessitate rigorous safety measures.

What are the key safety standards and codes that govern BESS installations?

Several key safety standards and codes govern BESS installations to ensure safety and prevent hazards:

- UL 9540: Covers integrated systems, battery management systems, inverters, and interconnection equipment.
- UL 9540A: A standard test method for evaluating thermal runaway fire propagation in BESS at cell, module, and unit levels.
- NFPA 855: Provides guidelines for the installation of stationary energy storage systems, including proper setbacks to prevent fire propagation.
- NFPA 69: Focuses on explosion prevention systems, often involving hydrogen sensors and active ventilation.
- NFPA 72: The National Fire Alarm and Signaling Code, which dictates fire alarm system design and monitoring.
- International Fire Code (IFC) and National Electrical Code (NEC): Provide broader safety requirements.

What information should developers include in a BESS submission to fire authorities?

To ensure a thorough review and approval, developers must include comprehensive documentation in their BESS submission to fire authorities. This includes a Hazard Mitigation Analysis (HMA) with a Fire Risk Analysis (FRA) specific to the chosen technology, a Failure Modes and Effects Analysis (FMEA), and details on NFPA 69 compliant systems, including their performance in large-scale fire tests. Crucially, burn test results from UL 9540A and other large-scale fire tests, along with technology listings, are required. Furthermore, the submission should encompass Emergency Response Plans for all phases (construction, commissioning, operations, decommissioning), incident reporting procedures, triggers for notifying fire authorities when safety systems are offline, and detailed Testing and Maintenance Plans for fire life safety systems, including auxiliary backup power. Site layout plans are also vital, showing the Incident Command Post location, fire water tank size and location, auxiliary backup power design and refueling considerations, and proper enclosure spacing based on burn test results.

What are the best practices for managing a BESS fire incident?

In the event of a BESS fire, industry best practices prioritize containment and monitoring rather than direct suppression of the involved unit. The recommended approach is to monitor adjacent exposures and allow the involved unit to consume itself safely. This strategy addresses concerns about stranded energy and helps safely consume many of the toxic byproducts of the fire. Current code direction emphasizes not including suppression systems within the battery containers themselves, with water primarily used for cooling adjacent exposures. The primary fire safety emphasis is on early gas or smoke detection combined with integrated exhaust system activation. All fire alarm devices are monitored 24/7 by a UL Central Station, which then contacts fire dispatch upon detector activation.

How do first responders manage a BESS incident, and what information do they need?

Upon arrival, first responders will first seek site contact information at the entrance to establish direct communication with a site representative. Site representatives are crucial as they can provide valuable diagnostic information on the status of the involved and adjacent battery enclosures. Sites also have the capability to remotely disconnect the BESS from the grid to enhance safety. A multi-agency command post can be established once the site representative meets with emergency response personnel. The Large-Scale Fire Test data, which is a required part of the battery technology's code compliance, is vital for first responders. This test demonstrates that a fire in one unit will not propagate to adjacent enclosures, providing critical insight for managing the incident within a finite fire area.

What ongoing testing and maintenance are required for BESS fire safety systems?

Maintaining operational readiness of BESS fire safety systems is crucial and often required for annual operational permit approval. This includes consistent documentation of maintenance reports for local Fire Departments. Recent regulations, such as those from the California Public Utility Commission (SB38 and General Order 167-C), mandate BESS operators to collect and submit documentation regarding ongoing fire system testing and maintenance. While fire codes specify intervals for many components, some, like louver maintenance, exhaust CFM output, and filter changes, rely on manufacturer-suggested intervals. However, due to environmental exposures, more frequent service schedules may be necessary. Specific requirements include testing all fire alarm initiation and notification devices, servicing and maintaining fire pumps per manufacturer and code requirements, and ensuring all concentration reduction system components (exhaust fans, louvers, air filters) are operational.

How often should BESS operators and fire departments conduct multi-agency incident response training?

Ongoing multi-agency incident response training is essential to ensure alignment between BESS operators and first responders, especially as new technologies are introduced or compound phases change. It is recommended that contact lists for operations staff are updated and shared with the local Fire Department at least semi-annually. Site staff must be trained on incident reporting procedures and prepared to provide critical information to first responders. An annual tabletop multi-agency drill with the local Fire Department and operations staff is crucial to keep emergency response procedures current and expectations clear. Additionally, it is beneficial for operations staff to be trained in the Incident Command System to ensure common terminology and a reliable organizational structure for safe and timely incident mitigation.

What role do concentration reduction systems play in BESS fire safety, and what standards apply to them?

Concentration reduction systems are critical in BESS fire safety for managing combustible gas concentrations, particularly hydrogen, to prevent explosions. These systems typically utilize hydrogen sensors in conjunction with active ventilation to purge any gas buildup, keeping the concentration below 25% of the Lower Explosive Limit (LEL). NFPA 69, the Standard on Explosion Prevention Systems, governs the design and performance of these systems. It's crucial that these systems are designed in conjunction with a site controller, and often include an Uninterrupted Power Supply (UPS) and a small generator to ensure they are not reliant on grid power for operation. The fire alarm design also needs to monitor key points within the concentration reduction system.