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# Exploring Emerging Battery Technology

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Continuing Education AIA

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Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation.

# Learning Objectives

**At the end of this course, participants will be able to:**

- Identify the limitations of traditional energy systems in remote, off-grid, and extreme environments.
- Explain innovations in battery design, including geothermal-cooled, rugged, and safe systems.
- Analyze real-world applications of advanced battery technologies in military, disaster relief, and off-grid settings
- Evaluate California's battery storage expansion and policy landscape, and its implications for global energy resilience and decarbonization.

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This presentation concludes The American Institute of Architects Continuing Education Systems Course

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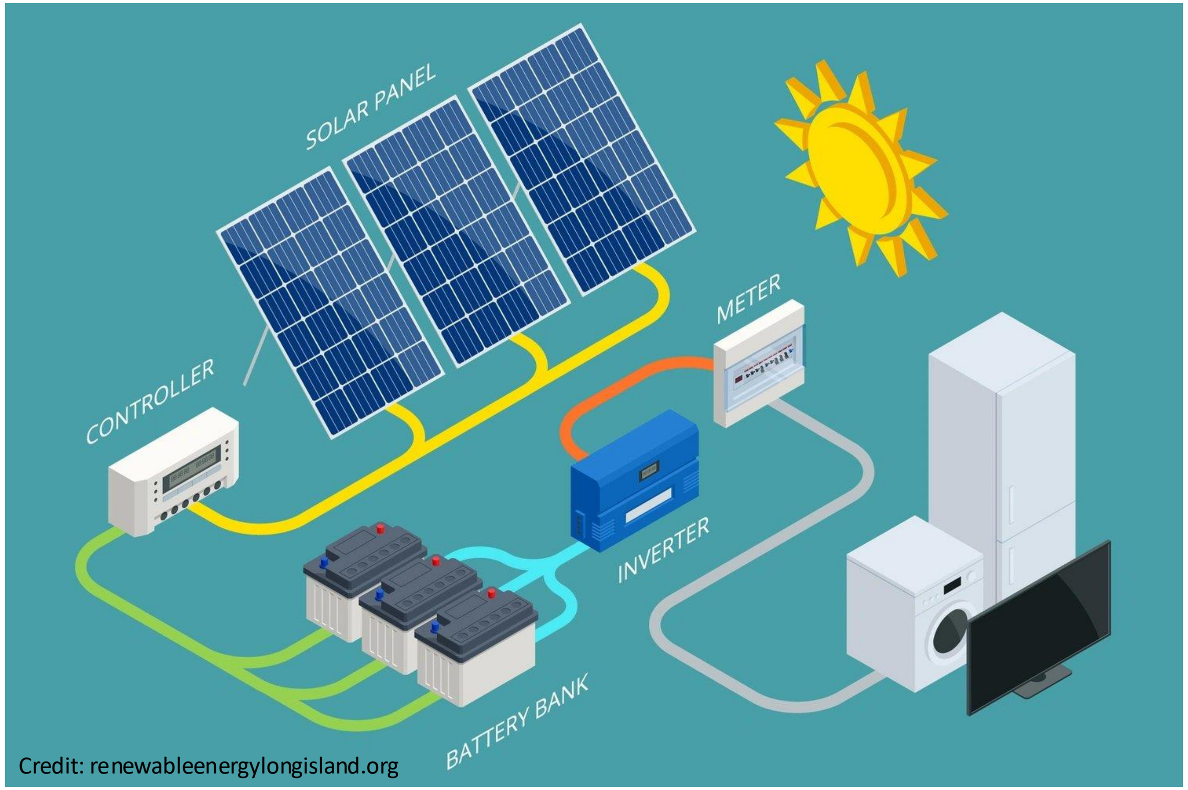
# Introduction: Lighting the Future Through Energy Innovation

World is increasingly becoming more dependent on uninterrupted power; the lighting we design is only as resilient as the energy that feeds it. Integration of the renewable energy source into transportation infrastructure, we need to investigate a multi-criterial assessment framework to identify the most suitable renewable source for street lighting in any location. The framework evaluates the key metrics are cost friendly, reliability, and power generation potential.


Credit: holdenluntz.com

# Powering Resilience: Battery Storage and Microgrids for Critical Times

The long history of fossil fuel use has supported industrial and economic growth, but it has also created significant environmental challenges, including greenhouse gas emissions, air and water pollution, and habitat loss. As awareness of these impacts has increased, there is a growing need for cleaner and more resilient energy solutions. For this reason, our presentation highlights battery energy storage and microgrids as part of the transition to more sustainable energy systems. These technologies can store renewable energy, reduce dependence on fossil fuels, and provide reliable power during emergencies or grid failures, making them especially valuable in challenging conditions.



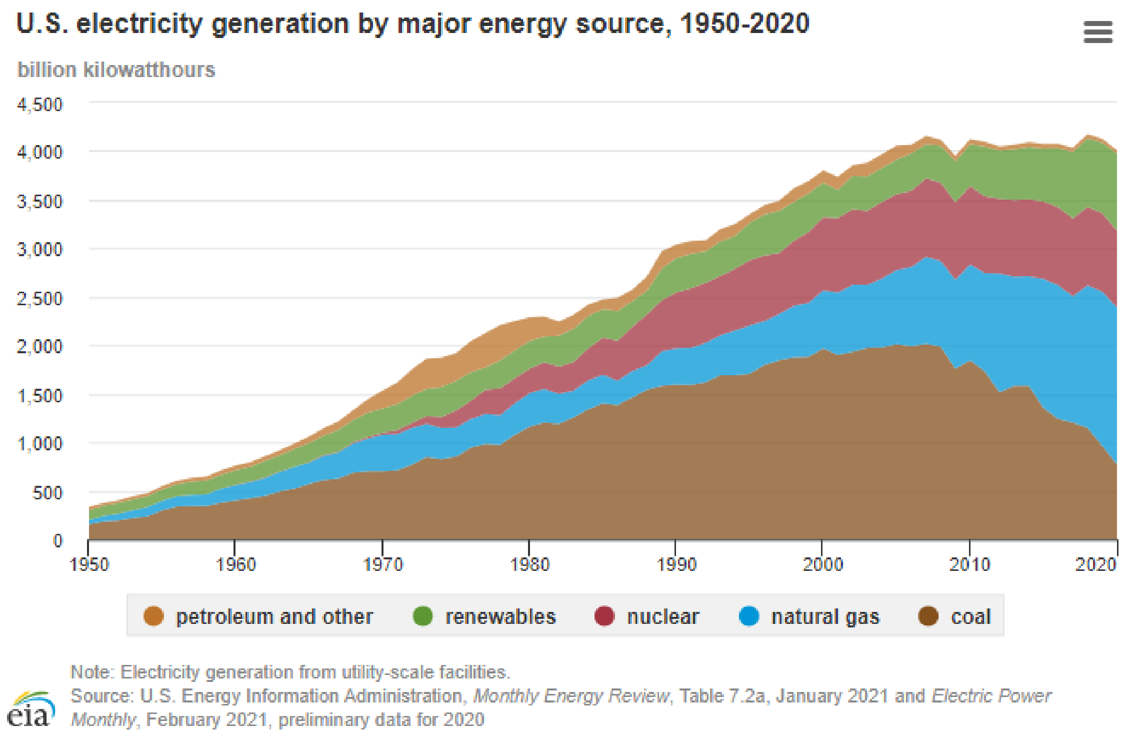
Credit: renewableenergylongisland.org

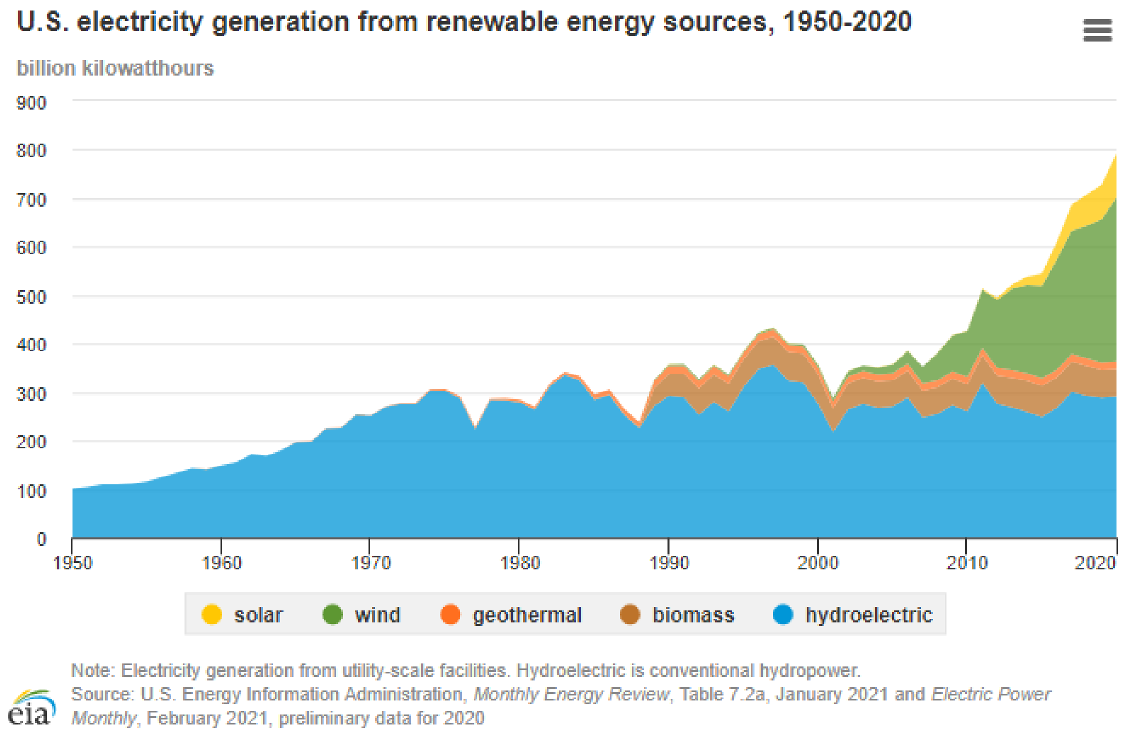
# The hardest places to deliver energy are exactly where reliability matters most

- Remote Area
- Wildfire PSPS Outage (Power Safety Power Shutoff)
- During high-risk wildfire weather conditions, PSE may
- temporarily shut off power lines in some areas to help prevent wildfires. This is called a **<u>Public Safety Power Shutoff</u>** (PSPS), and it's a measure of last resort to keep the community safe.
- forward operating bases
- Disaster field hospitals
- Traffic lights

Credit: PNNL.gov

# The hardest places to deliver energy are exactly where reliability matters most

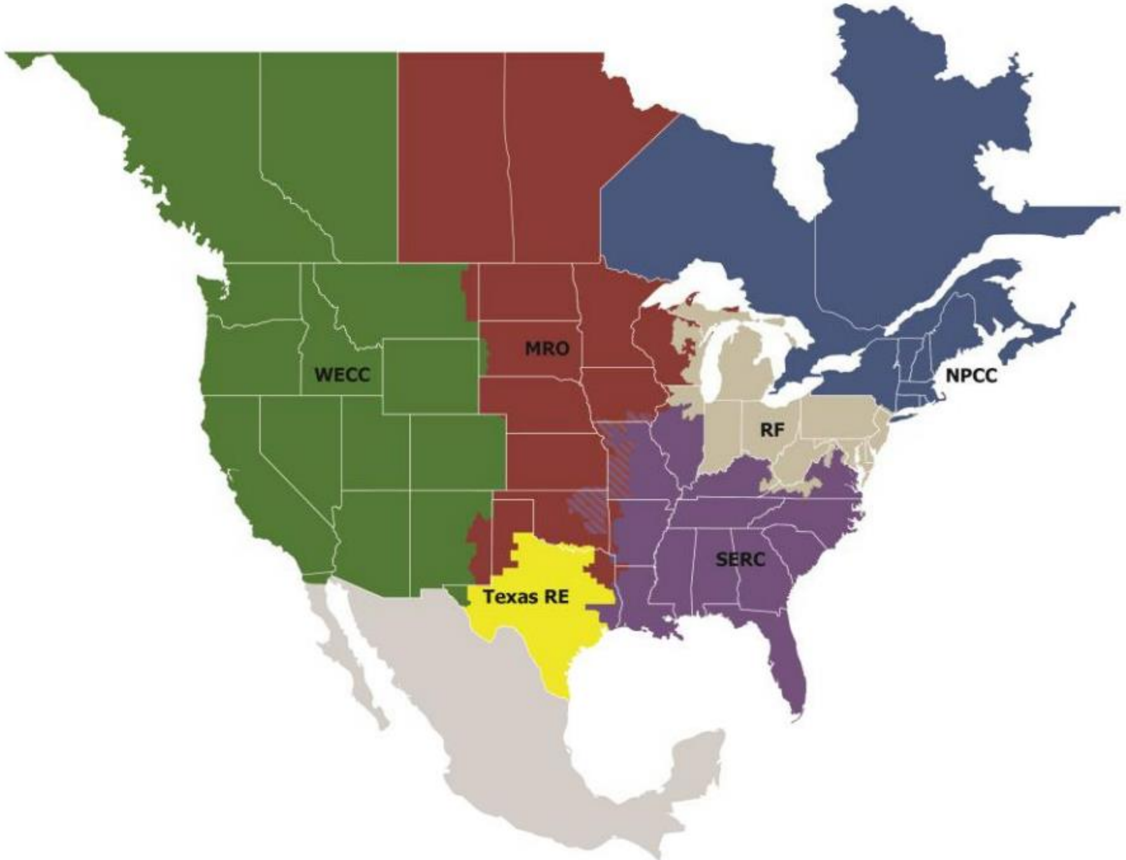



Credit: U.S. Environmental Protection Agency

# The hardest places to deliver energy are exactly where reliability matters most

•**Isolated/Complex Grids:** California acts as an "energy island" with limited pipeline access, relying on imports. The Western US grid is highly complex, split into 38 different balancing authorities.

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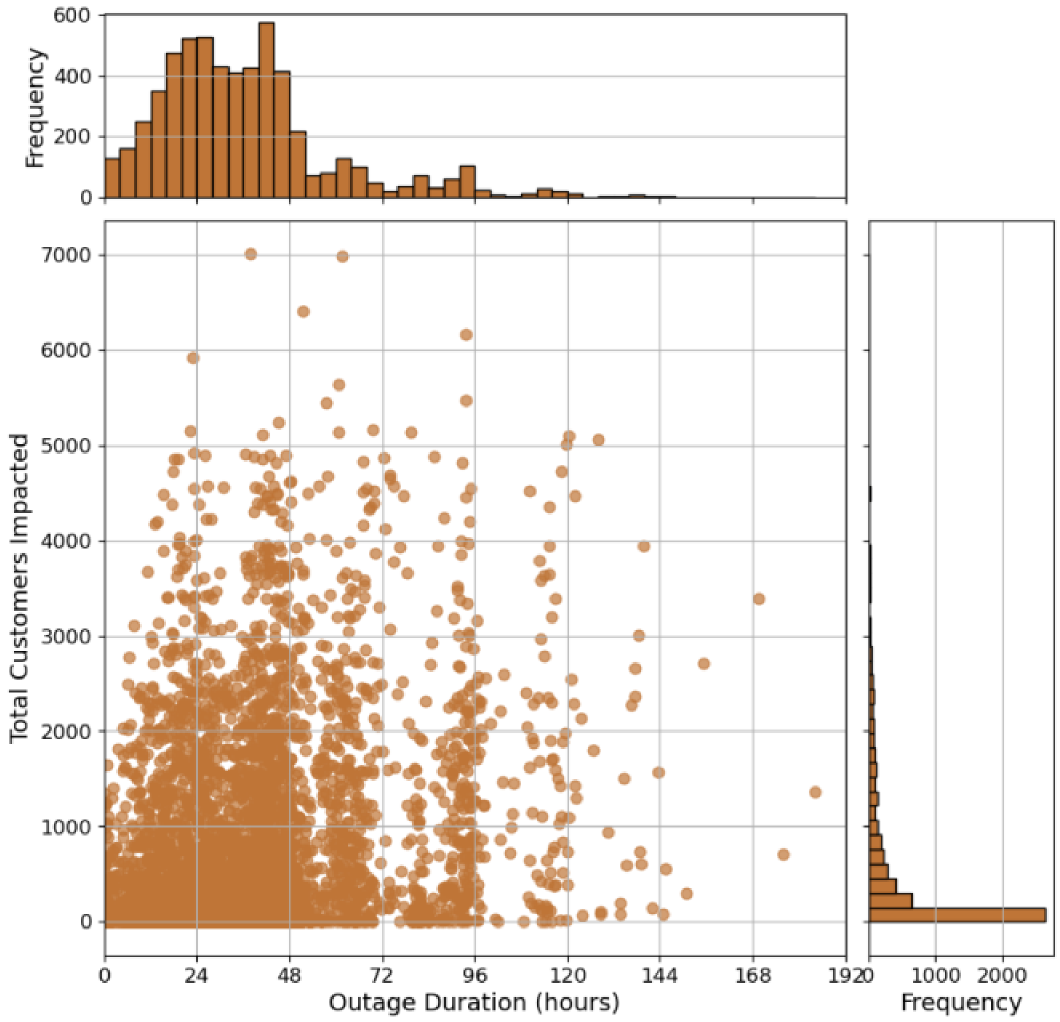
# PSPS Event Reporting Data Availability

## *California*

- Since 2013, most events lasted less than 48 hours, with 32% of events lasting less than 24 hours, and an additional 49% lasting between 24 and 48 hours.
- Long-duration events (greater than 48 hours) tend to affect smaller, likely rural, customer bases.
- 92 circuit de-energizations (1.4%) are reported to have impacted zero customers.




Source: California Public Utilities Commission

**Grid shutoffs** can significantly affect public safety and traffic operations. When power is lost, traffic signals, street lighting, and communication systems may stop functioning, increasing the risk of accidents and congestion. Emergency response can also be delayed as first responders face limited visibility and disrupted transportation systems. These challenges highlight the importance of resilient energy systems that can maintain critical infrastructure during power outages.

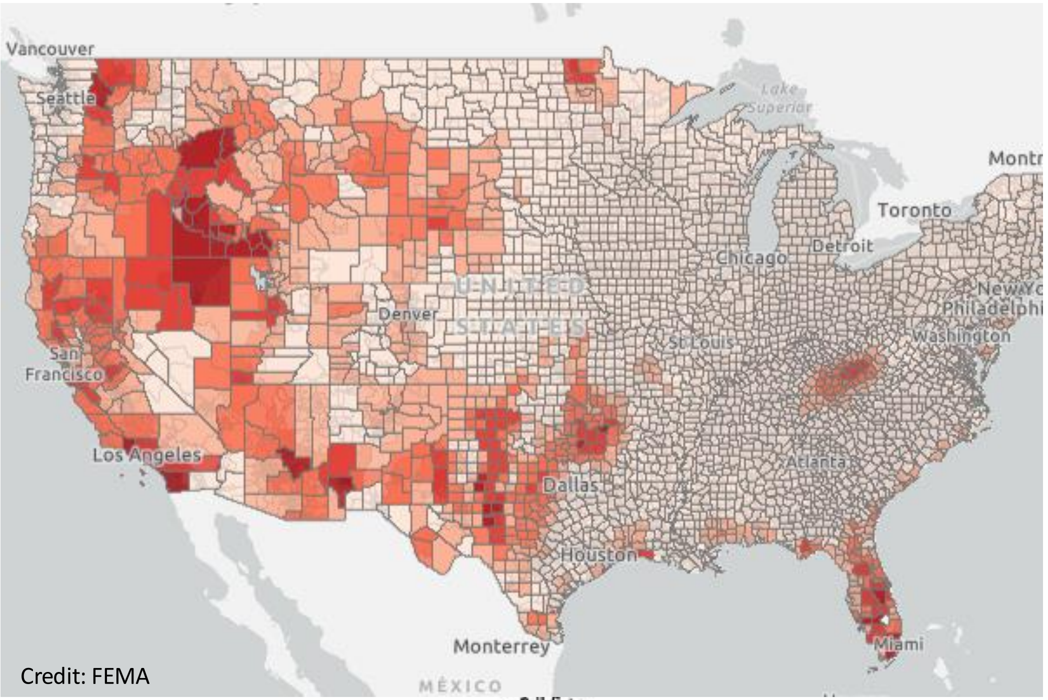
Credit: KQED. Vehicles are left stranded off the side of the road after residents tried to flee from the Palisades Fire in the Pacific Palisades neighborhood of Los Angeles on Tuesday, Jan. 7, 2025. *(Etienne Laurent/AP Photo)*

**Loss of Public Lighting: Power shutoffs mean streetlights, stoplights, and exterior lighting are deactivated, creating safety risks at night for first responders and civilians, although residents may be advised to keep some lights on to be visible.**

Credit: theatlantic.com

Credit: scmp.com

**Severe weather** events such as strong winds, storms, and hurricanes can significantly impact the electrical grid. High winds and falling trees may damage power lines and poles, while flooding and heavy rain can disrupt substations and other critical infrastructure. These conditions often lead to widespread power outages and can take hours or even days to repair, highlighting the need for more resilient energy systems.



Credit: FEMA

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# Extreme environments: why conditions break assumptions

Cold: reduced starting reliability, fuel gelling, battery power limits without thermal design.

Heat: derating, cooling load, accelerated component aging.

Dust/salt fog/humidity: corrosion, filter clogging, connector failures.

Altitude: combustion efficiency changes; cooling changes; logistics worsen.

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# Harsh environmental stress on energy systems or infrastructure

**Harsh Environment**

Cold

Heat

Dust, Salt

**First responders and traffic management**

Emergency response Centers

Traffic Signals and Intersection controls

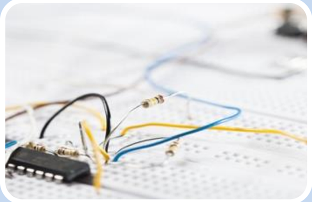
Communication Towers

**Remote Area**

Arctic and Antarctic

Logistically difficult

Desert



**Corroded Equipment**

Rusted Connectors

Dust-Clogged filters

Heat-Damaged Components, Iced Equipment

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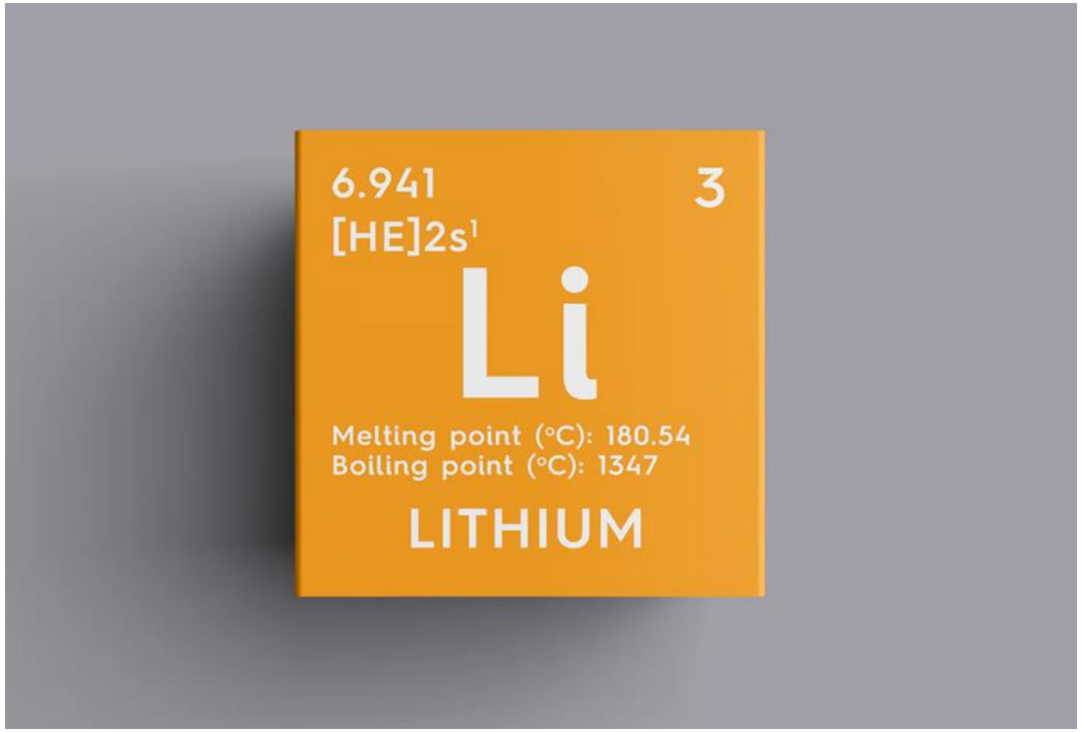
# Evaluating Lithium-Ion Batteries as an Efficient Solution for Harsh Environments




Lithium batteries are widely used today because they combine strong performance with flexibility across many applications. They store more energy in a smaller, lighter form, last longer over repeated charge cycles, and recharge more quickly than older battery types such as nickel-metal hydride (NiMH) and lead-acid batteries. These advantages make lithium batteries especially well suited for modern technologies, including portable devices, electric vehicles, and renewable energy systems.

# Resilience gap

Traditional systems optimize for availability of **fuel**, not availability of **power**.

**Energy resilience = Logistics resilience + Equipment resilience + Safety resilience.**

Micro-case : Remote medical clinic
Power failures = spoiled vaccines+ Interrupted Oxygen Concentrators+ communication System Failing

Innovations in battery design: rugged + safe systems

⇒ require less fuel logistics
⇒ can be more reliable in remote locations
⇒ improve safety and durability

# Advanced Batteries

It is not just one specific technology: Lithium-ion variation, Lithium iron phosphate, …

Grid/off-grid storage is increasingly optimized for:

1- Cycle life

2- Thermal stability

3- Manufacturability

4- Safety

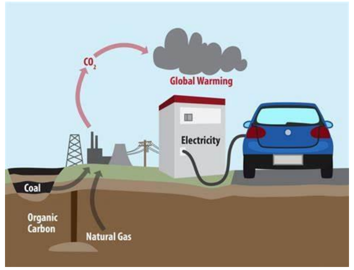
Credit: Department of Energy

**Grid storage**: Batteries connected to the electrical grid to store energy from power plants or renewables.
**Off-grid storage:** Batteries used in places without a power grid, like remote clinics, villages, research stations, or emergency systems.

# Failure modes (remote/off-grid)

- Fuel logistics as the real "grid": delivery constraints, storage, theft/spoilage, single-point failures.
- Maintenance burden: skilled labor + spare parts + downtime.
- Low-load inefficiency: gensets run poorly when lightly loaded; more wear, worse fuel burn.
- Noise + heat signature + air quality: operational/security + health impacts
- Volatile operating cost: delivered fuel cost (especially remote) dominates LCOE.

Credit: fifewa.gov



Credit: green.org

Credit: efinancialmodels.medium.com

# Different battery chemistries, Different strengths and weaknesses

**Lithium-ion batteries Advantages:** (the general category used in phones, laptops, EVs, and many energy storage systems)
**High energy density:** They can store a lot of energy in a relatively small and light battery, which is why they are widely used in electronics and electric vehicles.
**High efficiency:** They charge and discharge with very little energy loss (often over 90% efficiency).
**Good cycle life:** They can be recharged many times compared to older battery technologies.
**Fast charging capability:** Many lithium-ion batteries can charge relatively quickly compared with other chemistries.

**Lithium-ion batteries Limitations:**
**Thermal stability / fire risk:** Lithium-ion batteries can overheat or catch fire if damaged, overcharged, or poorly designed.
**Degradation over time:** They lose capacity gradually as they age and go through charge cycles.
**Material cost and supply chain issues:** Some lithium-ion chemistries rely on cobalt, nickel, and lithium, which can be: expensive, geographically concentrated, vulnerable to supply disruptions.
**Temperature sensitivity:** Performance drops in very cold temperatures, and heat can accelerate degradation.
**Recycling challenges:** Recycling lithium-ion batteries is complex and still developing at scale.

# Summary of Major Risks

| Risk | What Happens |
|---|---|
| Thermal runaway | Chain reaction overheating |
| Fire | High heat, difficult to extinguish |
| Toxic gases | Dangerous emissions during failure |
| Electrical hazards | Shock or arc flash |
| Explosion | Gas ignition in enclosure |
| Environmental damage | Chemical leakage |
| Physical damage | Disaster impacts |

# Battery Energy Storage Systems (BESS) safety risks and hazards

**1. Thermal Runaway**
It happens when a battery cell overheats and triggers a chain reaction that causes nearby cells to overheat as well. Can lead to fires or explosions.
Causes: Overcharging, Internal short circuits, Manufacturing defects, Physical damage, High temperatures

**2. Battery Fires**
Lithium-ion batteries can burn very intensely and are difficult to extinguish.
Fires may reignite hours or days later.
Produces large amounts of heat and toxic gases.

**3. Toxic Gas Release**
During battery failure or fire, batteries can release harmful gases such as: Hydrogen, Carbon monoxide, Hydrogen fluoride
These gases can be dangerous for first responders and nearby communities.


Credit: mitsubishicritical.com


Credit: sandiegouniontribune.com


Credit: www.bloomberg.com

**4. Electrical Hazards**
Battery systems operate at high voltage and high current, which can cause: Electric shock, Arc flash, Equipment damage, Improper handling or faulty wiring

**5. Explosion Risk**
Gas buildup inside battery enclosures can lead to explosions if: Ventilation is poor, Sparks or ignition sources are present.

**6. Control Software failure**
Large BESS installations rely on software and communication systems. Risks include: System control failures, Cybersecurity attacks, Incorrect charging or discharging commands

**7. Temperature Sensitivity**
High heat: accelerates battery degradation and increases fire risk.
Cold temperatures: reduce performance and may cause charging issues.

**8. Physical Damage**
Impacts from: Earthquakes, Flooding, Vehicle collisions, Debris during storms
can damage battery systems and trigger failures.

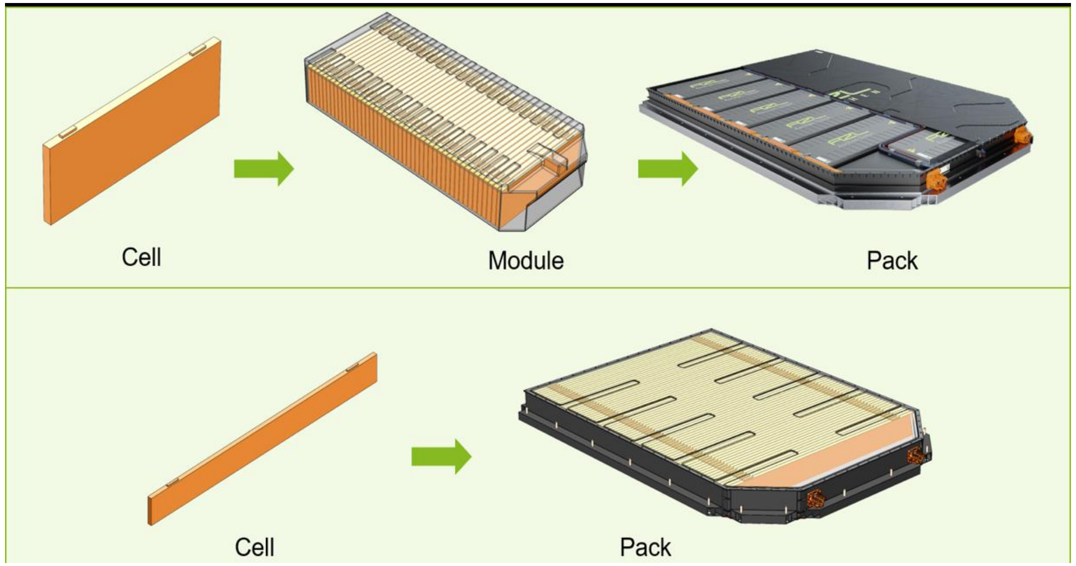
**8. Environmental Risks**
If damaged, batteries may leak chemicals that can contaminate: Soil, Water systems

# Design improvements in battery systems design and management

Battery innovation today is not only about chemistry. Engineers are also improving battery architecture, thermal management, electronic monitoring, and durability so batteries can be safer, easier to manufacture, and reliable in harsh environments.

Traditional battery systems are built like this:
- **Cells** = small individual battery units
- **Modules** = groups of cells
- **Pack** = the full battery system

New designs reduce or eliminate modules:
- **Cells** = small individual battery units
- **Pack** = the full battery system



Credit: compositesworld.com

**Benefits:**

- Fewer Part
- Lower Manufacturing Cost
- Higher Efficiency
- Better Energy Density

# Layered safety design defense in depth

**1. Cell-Level Safety**
**Thermal stability:** Choosing chemistries less prone to thermal runaway (e.g., LiFePO4 vs. Li-ion NMC).
**Internal protection:** Fuses or current interrupters inside cells to stop overcurrent.
**Electrochemical design:** Limiting maximum charge/discharge rates to prevent overheating.

**2. Module/ Pack-Level Safety**
**Module enclosure:** Fire-retardant and mechanically robust casing.
**Cell balancing & monitoring:** Ensures no single cell is overcharged or overheated.
**Ventilation and heat dissipation:** Passive or active cooling channels to remove heat.

**3. System-Level Safety**
**Battery Management System (BMS):** Monitors voltage, current, temperature, and state-of-charge. Able to disconnect faulty modules or the entire system in emergencies.
**Redundant sensors and controls:** Multiple temperature or voltage sensors to avoid false readings.
**Emergency shutdown:** Automated switches to isolate the system in case of fire or short circuit.

**4. Facility / Site-Level Safety**
**Fire suppression:** Sprinklers, inert gas systems, or foam to contain fires.
**Thermal & gas management:** Venting for smoke, hydrogen, or other gases produced under failure.
**Physical separation & barriers:** Prevents thermal runaway in one module from spreading to others.
**Access control:** Limits exposure to unauthorized personnel.

**5. Operational / Procedural Layer**
**Maintenance protocols:** Regular inspection, cleaning, and firmware updates for the BMS.
**Monitoring & alarms:** Remote monitoring for early detection of anomalies.
**Emergency response plan:** Clear procedures if thermal events or leaks occur.

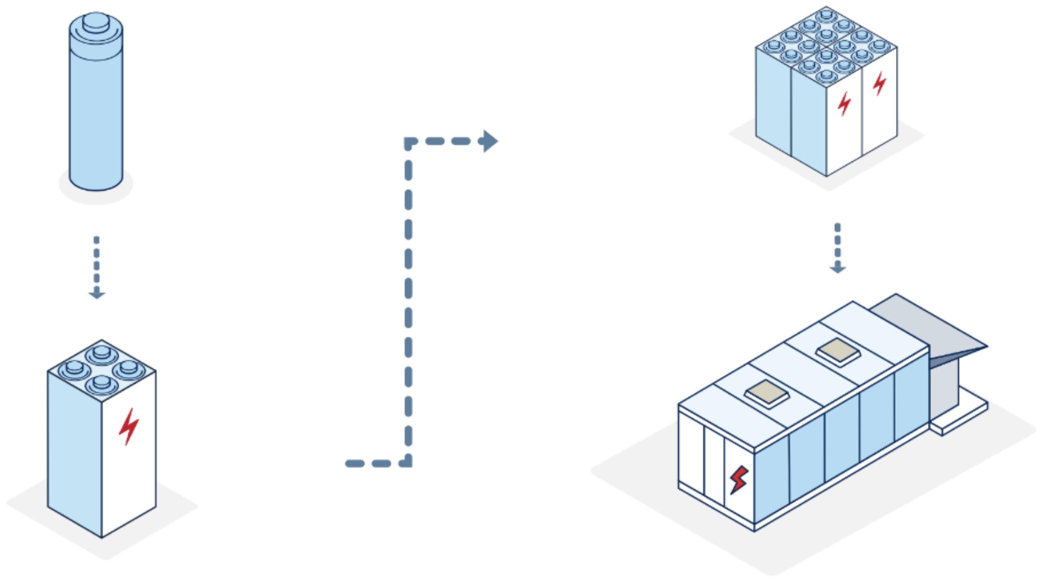
## Standards and test methods

UL 9540A is an ANSI/CAN/UL standard test method used to evaluate thermal runaway fire propagation in Battery Energy Storage Systems (BESS). It tests lithium-ion batteries at cell, module, and unit levels to analyze gas generation, heat release, and fire spread, helping to meet safety standards like NFPA 855.

NFPA 855 and alignment with model fire codes (e.g., 2024 IFC provisions)

**Cell-level test**
Cell-level testing evaluates the thermal runaway characteristics of the cell as well as the composition and flammability of the gases.

**Unit-level test**
Unit-level testing evaluates the likelihood of fire spread between modules, the unit's heat and gas release rates, and the potential for deflagration or re-ignition.



**Module-level test**
Module-level testing evaluates the tendency of cell thermal runaway propagation, the heat and gas release rate of the module, and the potential danger of ignition or deflagration.

**Installation-level test**
Installation-level mainly evaluates the effectiveness of the fire protection system, as well as the heat and gas release rate of the system and the danger of deflagration or re-ignition.

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# Microgrids and Backup Power for Emergency Response

First responders serve as the first line of community protection during disasters. Therefore, safety, risk awareness, and operational reliability are critical considerations when designing energy systems that support their work. In recent years, some critical facilities have adopted **microgrids**, which are localized energy systems capable of operating independently from the main power grid during outages.


Credit: drawdownga.org

# Microgrid Trailer Brings Clean Energy to Disaster Response

A typical microgrid system may include:

**Solar panels** for electricity generation

**Battery energy storage** for backup power

**Smart control systems** that manage energy flow and maintain stable power supply.

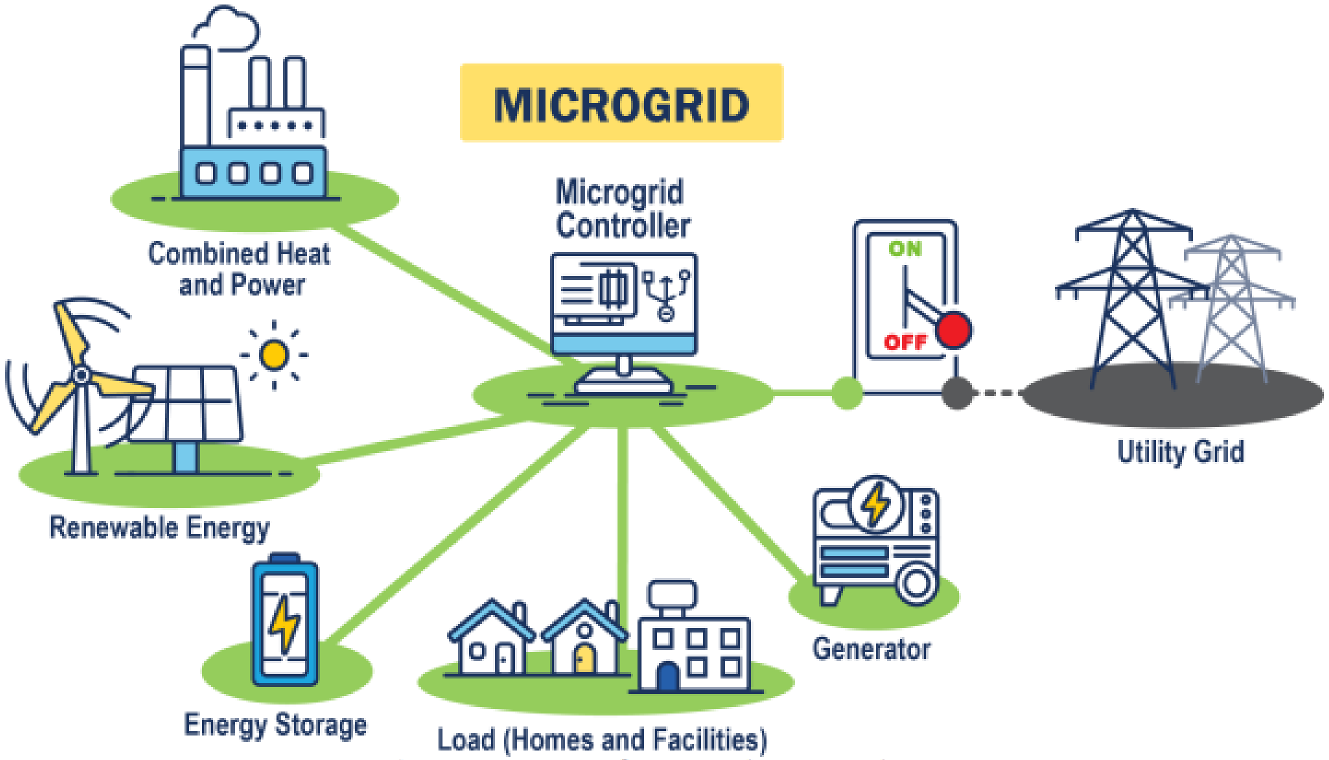
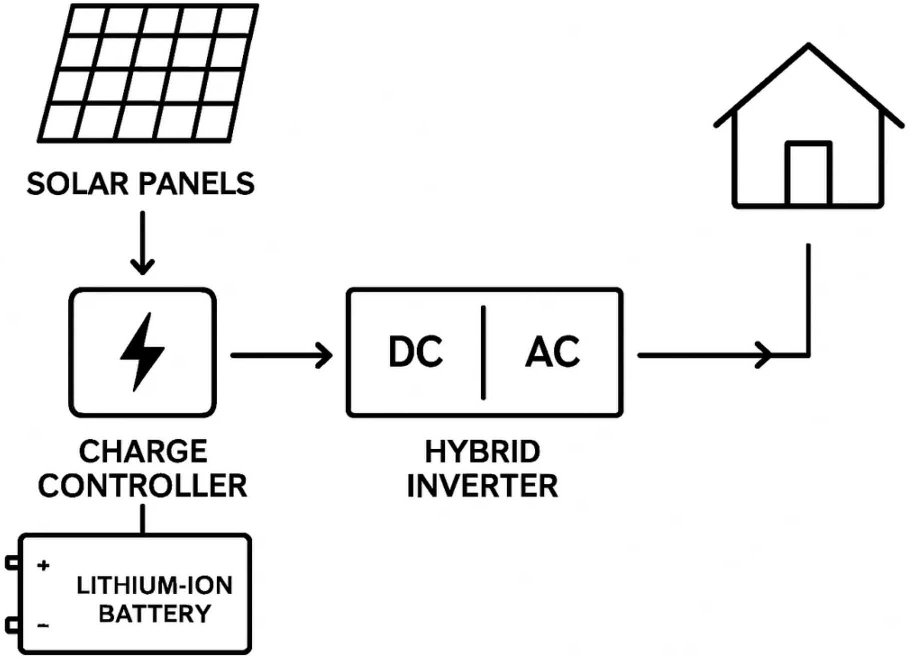



**Figure 1:** Features of an example microgrid.

**Battery:** Most systems utilize high-capacity lithium-ion batteries to store electrical energy for later use. Energy is stored in the form of direct current (DC).

**Charger:** Dedicated charging electronics regulate and manage the safe charging of the battery when connected to an external power source, such as a utility grid connection or a photovoltaic system.

**Inverter:** This component converts the stored DC power into alternating current (AC), which is required for the operation of standard household and commercial electrical devices.




Source: anernstore.com

**Power Outlets:** These interfaces enable the connection of devices to the system. Battery backup systems typically provide standard AC outlets, as well as specialized outlets designed to support a range of AC and DC devices with varying plug configurations.

Source: oksolar.com

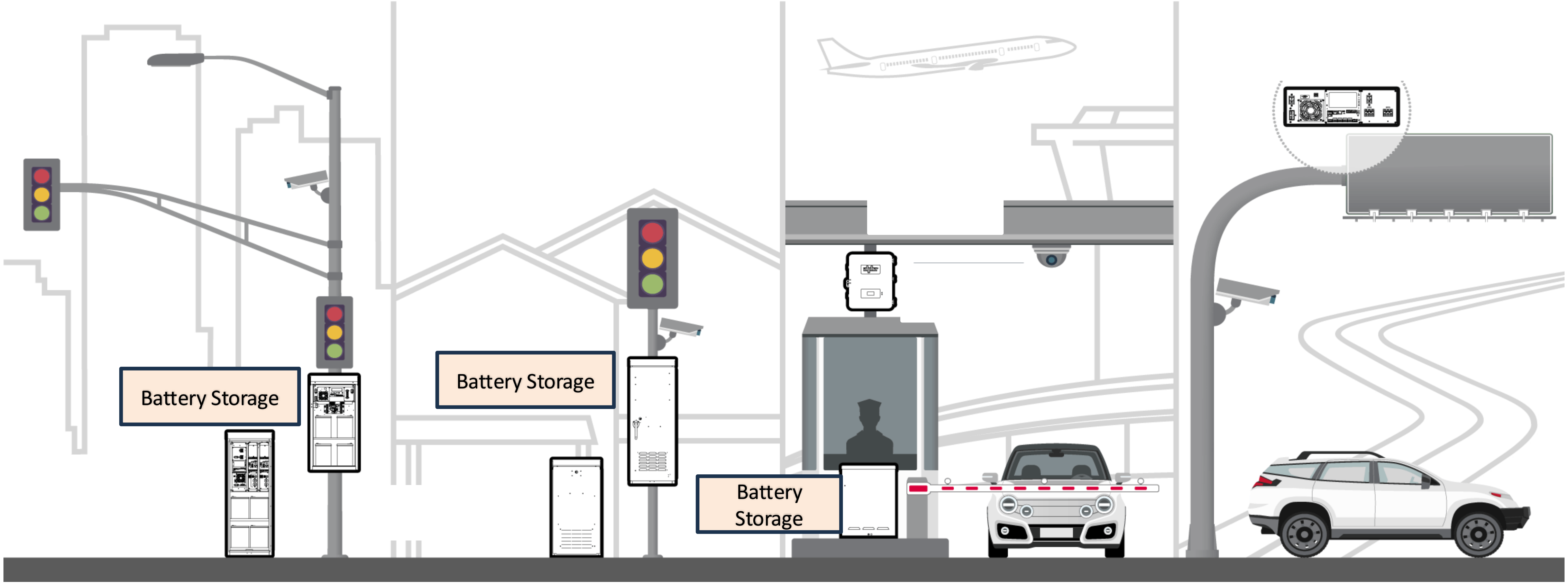
## What is clean energy? Why is it important? And what is the significance of the connection between battery storage and clean energy?

“Clean” energy is energy that emits little to no greenhouse gas emissions and includes renewable and carbon-free sources. This contrasts with fossil fuels, which produce a significant amount of greenhouse gas emissions, including carbon dioxide and methane. *sanjosecleanenergy.org*

Credit: DOE.gov

# Resilient Energy Systems

# Traffic and Intelligent Transportation Systems



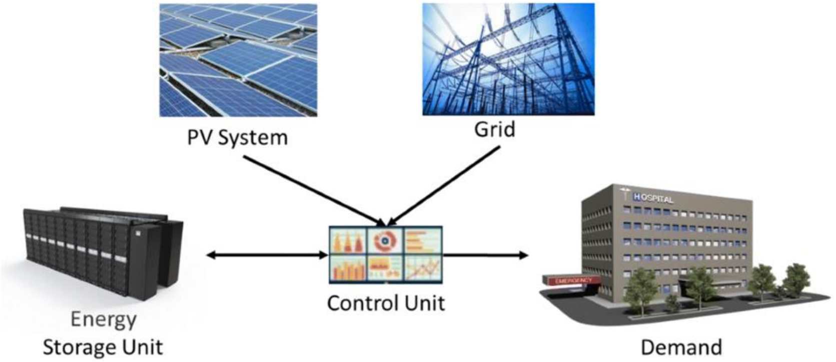

Credit: Alpha.ca

# Battery Energy Storage for the cities, urban areas, and Critical Public Safety

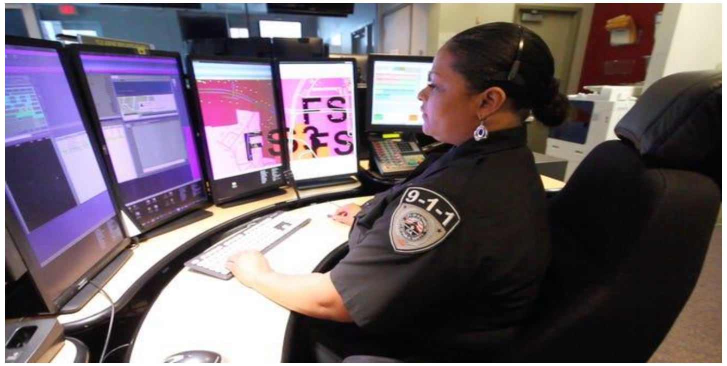


# Battery Energy Storage for Critical Infrastructure

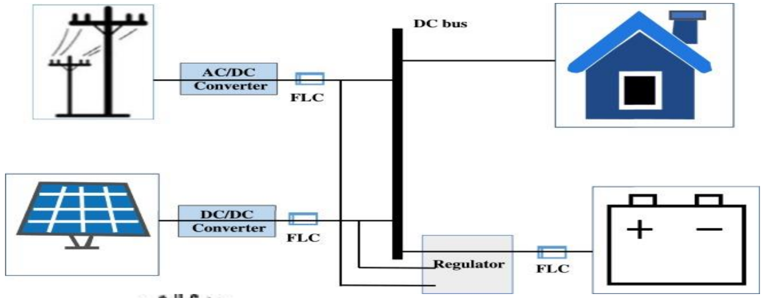
Battery Energy Storage Systems (BESS) play a vital role in strengthening public safety by ensuring a reliable and continuous power supply for critical infrastructure. Facilities such as emergency call centers, hospitals, and essential communication networks depend on uninterrupted electricity, particularly during natural disasters or grid failures.



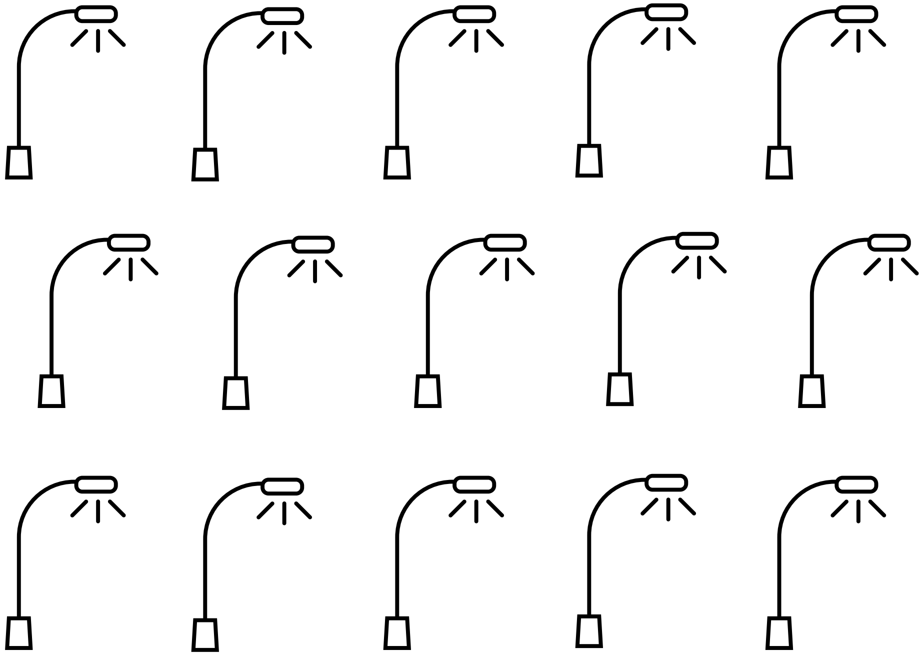

Credit: Springer.com




Credit: usatoday.com



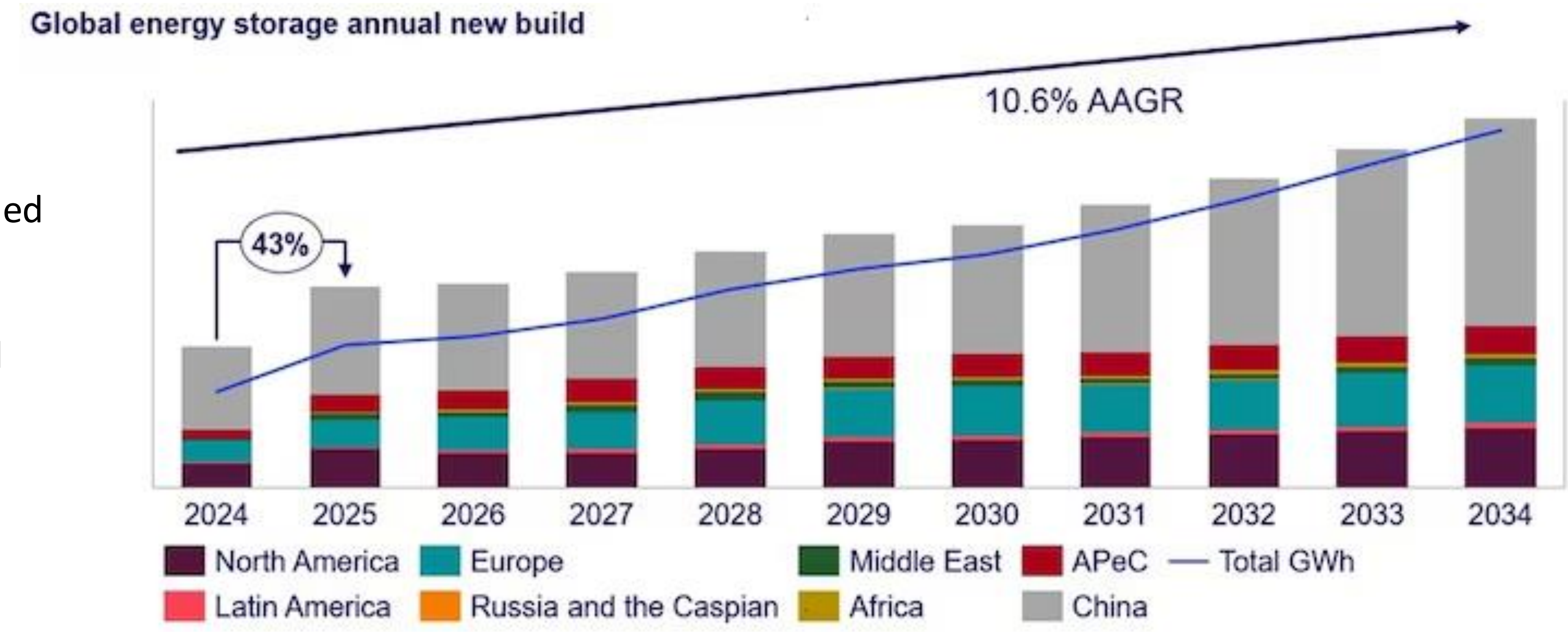

Credit: sciencedirect.com



By stabilizing the electrical grid and reducing peak strain, BESS help prevent widespread outages. In addition, they support the development of microgrids, allowing communities and essential services to operate independently when disconnected from the main grid. This resilience ensures that communication systems, data networks, and life-sustaining equipment remain operational when they are needed most.

# Battery Safety in Action: Global Adoption and Progress

**NEMA** recently published a comprehensive new guide, Plan Review and Inspections of Battery Energy Storage System (BESS) Installations.




Credit: reuters.com

This document provides critical insights for authorities having jurisdiction (AHJs), fire officials, and industry professionals. To amplify the reach of this important guidance, NEMA is exploring a partnership with the IAFC.

# Traffic Signal Resiliency Case: Dublin California

Dublin has experienced several Public Safety Power Shutoff (PSPS) events in response to severe weather conditions to help prevent wildfires. These events can last up to 3-4 days, during which traffic signals typically lose functionality. Regardless of the length of the power outage, safety at signalized intersections is compromised.

To mitigate future PSPS events during the wildfire season or other power outage events and natural disasters, the City of Dublin is installing batteries and fuel cells that will provide backup power to maintain full operation of the City's traffic signal system at 22 key intersections. These improvements will supply up to 72 hours of backup power that will automatically turn on during power outages.

This project aligns with the goals in the City's *Climate Action Plan 2030 and Beyond* by implementing microgrids to enable uninterrupted power during times of grid instability in support of Measure CF-2. The batteries and fuel cells will also support the City's efforts to reduce greenhouse gas emissions as current backup power is provided by diesel generators.

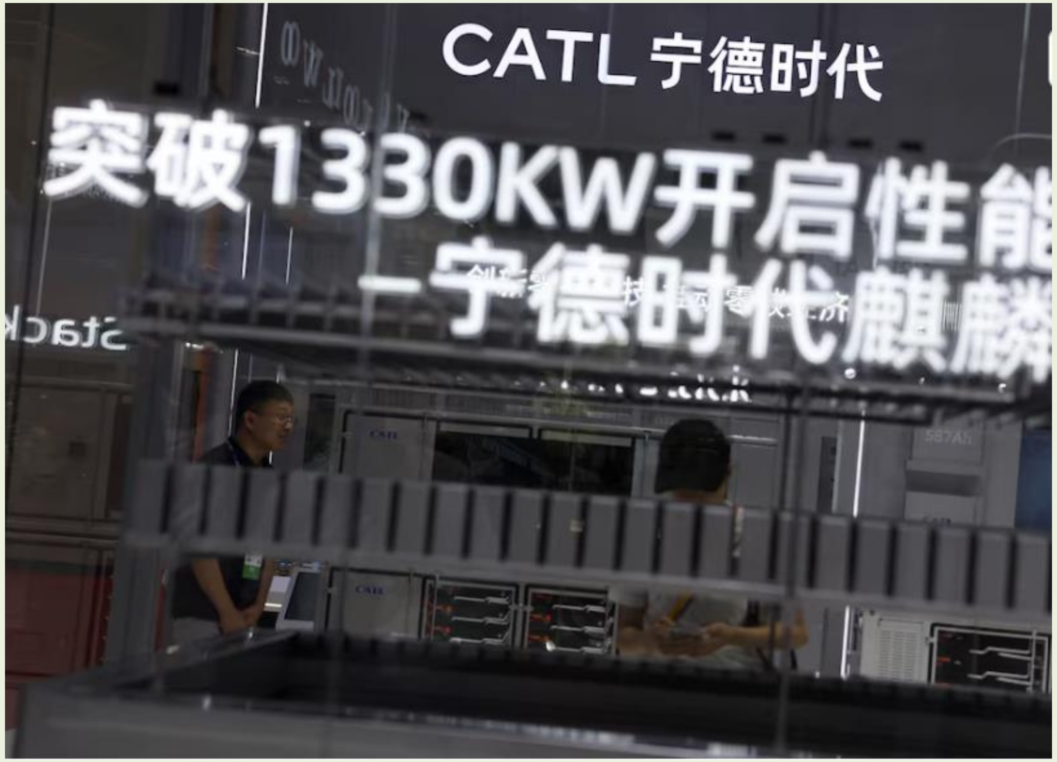
# Backup Batteries at Traffic Lights in Saratoga

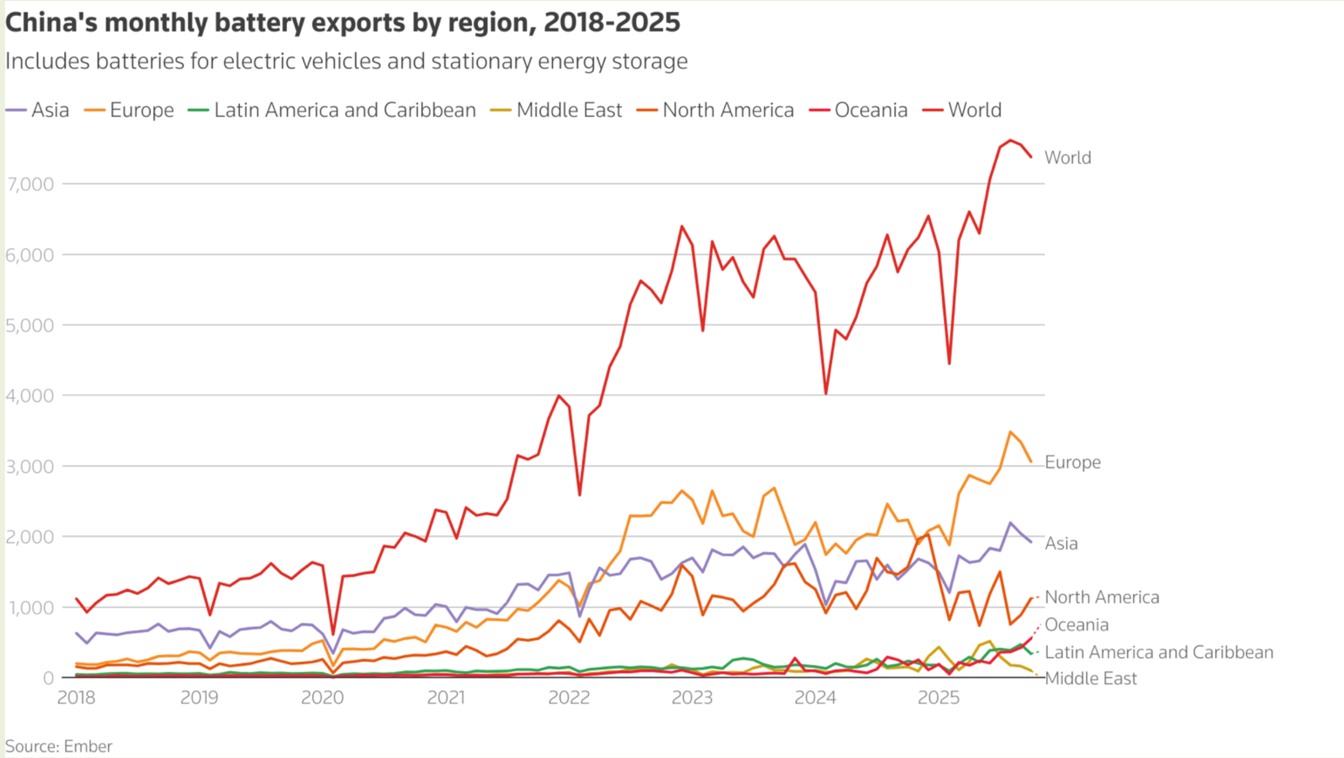
The City of Saratoga in 2022 installed backup battery systems at 14 traffic light intersections to increase safety. If a power outage occurs, the backup batteries will switch on to power traffic lights and allow the city to maintain access to the signals.

Credit: svcleanenergy.org

# China's power reforms, global data center buildout usher in battery boom

China lithium-ion battery cells for energy storage tipped to jump 75% this year
China dominates production as global, domestic demand climb
Surge driven by data centers', China renewables and reforms




Credit: People visit the booth of battery giant CATL during the China International Supply Chain Expo in Beijing, China July 16, 2025. REUTERS

**Germany:** A growing number of homeowners in Germany are installing batteries to store solar power. As prices for energy storage systems drop, they are adopting a green vision: a solar panel on every roof, an EV in every garage, and a battery in every basement.

In 2022, one out of every two orders for rooftop solar panels in Germany is now sold with a battery storage system.


Credit: e360.yale.edu

# ASSESSMENT OF THE U.S. BATTERY MANUFACTURING INDUSTRY

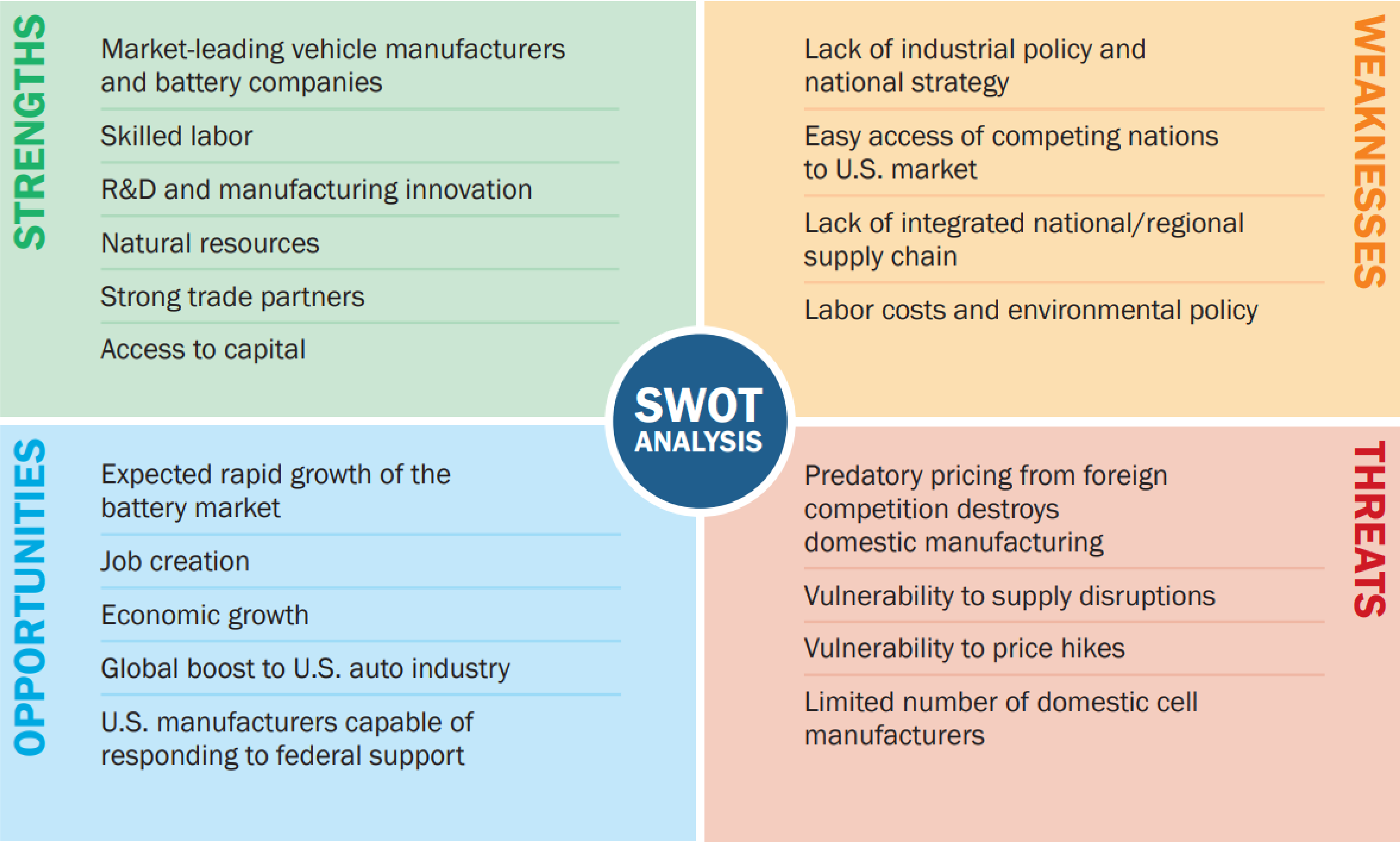



**FIGURE 4. Strengths, Weaknesses, Opportunities, and Threats (SWOT) Analysis of the U.S. position in global battery manufacturing.**

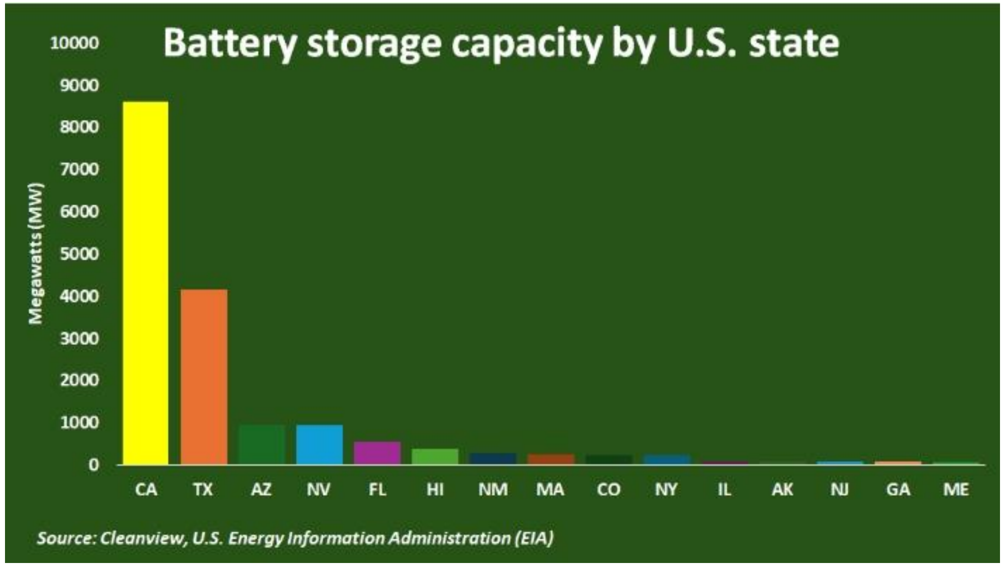
Credit: DOE, FEDERAL CONSORTIUM FOR ADVANCED BATTERIES

# California as a live lab

California is acting like a real-world testing environment for modern energy systems, especially systems with large amounts of solar power and battery storage

Because solar power only produces electricity during the day, the grid uses battery storage to store excess solar energy and release it later.

Credit: www.ecowatch.com




Total battery storage capacity in the U.S. is currently estimated at around 17.5 GW (World-energy.org, 2024), according to the U.S. Energy Information Administration and Cleanview.

Credit: A drone view shows California's largest battery storage facility, as it nears completion on a 43-acre site in Menifee, California, U.S., March 28, 2024. REUTERS/Mike Blake/File Photo Purchase Licensing Rights

# Battery Energy Storage: A Technology Rapidly Evolving


New Power production facility in Richmond, California, moves forward with securing a $9.3 million grant from the California Energy Commission (CEC). This funding marks a major milestone in mission to revolutionize energy storage and reinforces California's leadership in clean energy innovation.

Manufactures like Viridi and OnLine Power are the commercial-scale BESS to be installed in existing, occupied spaces, and is deployed nationwide for indoor, behind-the-meter installations across industrial, medical, commercial, and municipal buildings. California's evolving energy landscape.

# Conclusion:

Battery energy storage technologies are continuing to improve in terms of performance, safety, and reliability. Advances in battery chemistry, system architecture, and safety management have made modern storage systems more stable and better suited for both grid and off-grid applications.

Today, many established companies design and manufacture battery energy storage systems that meet strict engineering and safety standards. As these technologies mature, they are becoming a reliable component of resilient energy infrastructure, supporting critical facilities, renewable energy integration, and emergency preparedness while maintaining strong safety and operational performance.

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# Questions? Thank you!

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