Overview of Battery Energy Storage (BESS) commercial and utility product landscape, applications, and installation and safety best practices

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TESLA’S MISSION

Accelerate the world’s transition to sustainable energy
TESLA EXPERIENCE OVERVIEW

1,500 Supercharger stations
15,000 Superchargers
275 GW Power Electronics

920,000 Vehicles Deployed
6 Billion Miles Driven on Autopilot
65 GWh Li-ion Battery Systems

3 GWh Powerpack/Powerwall/Megapack
3.2 GW Solar
VERTICALLY INTEGRATED WORLD CLASS MANUFACTURING

Tesla Model S/X/3/Y Production Facility
Fremont, CA

Gigafactory 1
Reno, NV

Gigafactory 2
Buffalo, NY
ESS LANDSCAPE
Energy Storage Technologies

- Electrochemical
  - Batteries
    - Lead Acid
    - NiCd
    - NiMh
    - NaS
    - NaNiCl
    - Li-Ion
    - Metal Air
    - PbSb Liquid
  - Flow Batteries
    - Vanadium
    - ZnBr
    - PSBr
  - Hydrogen
    - Electrolyser
    - Fuel Cells
  - Electric
    - Capacitors
    - Supercaps
  - Magnetic
    - SMES
  - Pressure
    - CAES

- Electromagnetic
  - Pressure + Heat
    - Adiabatic - CAES

- Thermodynamic
  - Heat
    - Thermo - Electric

- Mechanical
  - Gravity
    - Pumped - Hydro
  - Kinetic
    - Flywheels

Source: https://www.mpoweruk.com/grid_storage.htm
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**GLOBAL ENERGY STORAGE FORECAST**

- **2018:** 12 GWh
- **2024:** 158 GWh (est)

*Source: BloombergNEF, GTM*
GROWTH OF LITHIUM ION ESS

Benefits of Li-ion:
- Gravimetric density
- Volumetric density
- Depth of discharge
- Cyclability
- → Cost

Source: AVICENNE ENERGY, 2017
PRODUCT LANDSCAPE

Commercial & Industrial (behind the meter)  
< 500 – 2000 kWh products

Cabinet Solution:
- Small footprint, easier to transport
- Includes inverter, thermal management
- Indoor/Outdoor
- Not suitable for larger projects due to added EPC costs

Utility (front of the meter)  
2000 – 6000+ kWh products

Container Solution:
- ISO or similar form factor
- Support module depopulation to customize power/energy ratings
- Can be coupled together for larger project sizes

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SolarEdge  
All-In-One

Samsung Sungrow
COMMERCIAL (C&I) PRODUCT LANDSCAPE

- **Tesla Powerpack** – 232 kWh
- **BYD** – 210kWh
- **SolarEdge** – 400kWh
- **Sungrow/Samsung** – 584kWh
- **NEC** – 510kWh
UTILITY PRODUCT LANDSCAPE

6MWh+ per unit
Figure 8: 2019 average survey costs for a utility-scale energy storage system with 4-hour duration

Source: BloombergNEF, survey participants. Note: Delivery year is 2019. Battery rack here is on a $/kWh of usable capacity.
BATTERY STORAGE COSTS ARE DROPPING

Source: BloombergNEF  Note: See Figure 10 for full note.
ESS APPLICATIONS
ENERGY STORAGE APPLICATIONS

- BACK-UP
- SOLAR SELF-CONSUMPTION
- PEAK SHAVING
- LOAD SHIFTING
- DEMAND RESPONSE
- VOLTAGE SUPPORT
- CAPACITY SUPPORT
- OTHER GRID SERVICES
**PEAK POWER SHAVING**

Discharging during peak demand time to avoid or reduce demand charges

Lower peak demand charges  
Reduce grid connection costs  
Hedge against rising charges
Avoid peak price periods and reduce energy costs

Protect your business from future energy price increases

Maximizes value of energy generated by on-site solar
Maximize your ability to use your renewable energy generation sources

Reduce costs for energy and grid connection

Protect your business from future energy price increases

Drive sustainability and reduce CO₂ emissions
DEMAND RESPONSE PROGRAMS

Maximize revenues by using storage as an asset to help decongest the grid

Generate revenue by participating in a demand response program
Support integration of solar on the grid
Improve grid stability
FREQUENCY/VOLTAGE GRID ANCILLARY SERVICES

Provide voltage support and participate in frequency regulation to help maintain a stable grid.

- Provides reactive power control
- Lowers risk of grid outage
- Provides additional revenue stream
Renewable Power Production Firming

Smooth out variability and increase certainty in renewable energy production

- Controls ramp rates and smooths generation profile
- Enables continuous power despite fluctuations in power supply
- Avoids renewable curtailment and increases energy output
MICROGRIDS
ENABLING FACILITIES TO ISLAND

Reduce energy costs and use of diesel for generation
Lower maintenance costs by reducing generator run hours
Protect against diesel supply constraints and price changes
ESS PRODUCT FEATURES, INSTALLATION, AND SAFETY
MEGAPACK

An all-in-one AC energy storage system for utility market optimized for cost and performance
## MEGAPACK SPECIFICATIONS

<table>
<thead>
<tr>
<th></th>
<th>2 Hour</th>
<th>4 Hour</th>
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</thead>
<tbody>
<tr>
<td>Rated AC Energy [kWh]</td>
<td>2,529</td>
<td>2,964.8</td>
</tr>
<tr>
<td>Rated AC Power [kW]</td>
<td>1,264.5</td>
<td>741.2</td>
</tr>
<tr>
<td>Round Trip Efficiency (at STC)</td>
<td>87.5%</td>
<td>90%</td>
</tr>
<tr>
<td>AC Power (kVA @ 480V) [Max]</td>
<td>Scalable up to 1540</td>
<td>Scalable up to 910</td>
</tr>
<tr>
<td>Maximum Mass (kgs / lbs)</td>
<td>21,500 / 47,400</td>
<td>23,500 / 51,800</td>
</tr>
<tr>
<td>Dimensions W x D x H (m / ft)</td>
<td>7.12m x 1.6m x 2.52m / 23'-5&quot; x 5'-3&quot; x 8'-3&quot;</td>
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</table>
Each unit is fully assembled and tested at the Tesla Gigafactory and ships ready to install.
Utility-specific ESS products enable the lowest cost, highest density utility-scale projects.

- Megapack is cost optimized for projects sized >2MWh
- Megapack requires more space and bigger crane to install

C&I-sized ESS products are versatile and best suited for a whole range of locations and applications

- Powerpack is generally less expensive than Megapack on an installed basis for projects <2MWh
- Powerpack’s modularity makes it easier to transport and install in locations with difficult access
# Megapack vs Powerpack Energy Density

Megapack yields a 63% more energy density and requires >10x fewer enclosures vs Powerpack.

<table>
<thead>
<tr>
<th>Powerpack</th>
<th>51 kWh/m²</th>
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<tbody>
<tr>
<td>Megapack</td>
<td>83 kWh/m²</td>
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![Diagram showing Megapack and Powerpack energy density comparison]
ESS INSTALLATION

- Megapack is designed to be installed close together to improve on-site energy density
- Connects directly to a transformer, no additional switchgear required (AC breaker & included in ESS unit)
- All AC conduits run underground
- No DC connections required

Typical 4-Hour AC Transformer Block Layout
ESS INSTALLATION

- Typical ESS AC terminal voltage: 480V
- Connect directly to MV transformer
- Can also connect directly to 480V switchgear for smaller sites
BESS SAFETY STANDARDS

Product Functional Safety

• UL 1642 – Standard for Lithium Batteries (cell level certification)
• UL 1973 – Standard for Batteries for Use In Stationary Applications (module level certification)
• UL 9540 – Standard for Energy Storage Systems and Equipment (system level certification)
• UL 9540A – Test Method for Evaluating Thermal Runaway Fire Propagation in Battery ESS ➔ NEW
• UL 1741 – Standard for Inverters, Controllers, Converters, and Interconnection Equipment for DER
• UL 1998 – Standard for Software in Programmable Components
• UL 991 – Standard for Tests for Safety-Related Controls Employing Solid-State Devices
• IEC 62619 – Standard for Battery Safety in Stationary Applications
• + more

Electrical, Fire, and Safety Codes and Standards

For commercial applications: new code and standard requirements for ESS >20kWh
• NFPA 855 – Standard for the Installation of Stationary Energy Storage Systems (2020) ➔ location, separation, hazard detection, etc
• NFPA 70 – NEC (2020), contains updated sections on batteries and energy storage systems
• International Fire Code 2018 and 2021 – Dedicated sections on energy storage, language is harmonized with NFPA 855
SITE LEVEL CONSIDERATIONS

Code requirements:

- Large-scale fire testing and report may be required to meet exemptions in new codes and standards around:
  - Maximum allowable quantities (>600kWh)
  - Fire suppression sprinkler density
  - Size and separation of ESS
  - Means of egress

- IFC and NFPA language does not require detection or suppression for outdoor locations (except walk-in container ESS)
- Indoor locations require smoke detection / IR and fire suppression (water sprinkler)
QUESTIONS?

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Visit:
tesla.com/megapack