Energy Storage Battery- Industry Combing

Sep. 2016
### News

<table>
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<th>No.</th>
<th>Date</th>
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<td>1</td>
<td>May 26, 2016</td>
<td>CLOU Electronics to Co-found JV with LG Chem</td>
<td>evpartner.com</td>
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<tr>
<td></td>
<td></td>
<td>CLOU Electronics announced on May 26, 2016 that it signed a Sino-foreign Joint Venture Contract with LG Chem, planning to co-found Shenzhen CL New Energy Technology in China. The registered capital is $3.5 million, with CLOU Electronics investing $2.45 million, 70% stake in the JV. It was the first time that LG Chem co-founded with a Chinese enterprise in the energy storage field. Its planned production scale on Phase is over 400MWh battery packages per year, and it will realize mass production in early 2017. However, these two companies just signed the cooperation contract but have not completed other related procedures as to the JV, which require approval by relevant government departments.</td>
<td><img src="https://example.com/image1.jpg" alt="Image 1" /></td>
</tr>
<tr>
<td>2</td>
<td>June 29, 2016</td>
<td>First Largest Commercial Optical Storage Power Station in China Put into Operation</td>
<td>escn.com.cn</td>
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<td></td>
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<td>The Geermu New Energy 50MWp grid-connected PV power station, the first largest commercial optical storage power station in China which constructed by TBEA Sunoasis, completed system adjustment and was put into operation on June 28, 2016. The station sets an example as to ensure new energy power heavily used in power generation system via energy storage technology smooth and controlling power supply fluctuation, which symbolizes the new era of “photovoltaic+ energy storage” coming.</td>
<td><img src="https://example.com/image2.jpg" alt="Image 2" /></td>
</tr>
<tr>
<td>3</td>
<td>August 10, 2016</td>
<td>Electricity Energy Storage Dominates in Peak Load Shifting Auxiliary Service of the Northern China, Northeastern China and Northwestern China Regions</td>
<td>CNESA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>In July, 2016, National Energy Administration of China released Notice on Fostering Electricity Energy Storage to Involve in Electric Power Auxiliary Service Compensation Mechanism Trial in Northern China, Northeastern China and Northwestern China Regions. As the first substantial supportive policy for energy storage industry this year, it is pivotal in terms of building up auxiliary service sharing mechanism for energy storage, making electricity energy storage technology fully take advantages of peak load shifting and frequency modulation, and propelling the steady development of domestic energy storage industry.</td>
<td><img src="https://example.com/image3.jpg" alt="Image 3" /></td>
</tr>
</tbody>
</table>
Among various types of energy storage battery, lead-carbon battery, lithium-ion battery and flow battery show superiorities in aggregative indicator.

- Mainstream energy storage batteries include lead-acid battery, lead-carbon battery, lithium-ion battery, Ni-MH battery, sodium-sulfur battery and flow battery.
- On technology and cost front, lead-carbon and lithium-ion battery show strong superiority and go more smooth in commercialization. However, flow battery is promising in the long run.

Energy storage technological utilization in China is mainly focused in power system field.

- Energy storage technological utilization is mainly focused in power system (e.g., renewable resources and smart grid), new energy vehicles, UPS (Uninterrupted Power Supply), electric tools and electronics.
- Power system accounts for 70% of China’s energy storage technology utilization, distributed micro-grid as the major demand side.

Lithium-ion battery keeps leading energy storage market

- Global energy storage market developed noticeably in 2015. Specifically, chemical energy storage battery market boomed 80% YoY.
- Both in global and domestic chemical energy storage market, the amount of installation of lithium-ion battery tops other types of batteries. In the enormous domestic energy storage utilization market, Li-ion battery is expected to keep the upward trend in the foreseeable future.

Accelerating pace of the policy publication benefits energy storage industry

- Opinions on further deepening power system reform (2015) clarifies key tasks of power system reform. With the establishment of power transaction platform, the reform gradually enters into the practice period.
- Notice on promoting electric storage to participate in electricity energy storage in northern China, northeastern China and northwestern China regions started pilot promotion, encouraging investment in constructing energy storage facilities, especially in the user-side, which will foster the policy subsidy afterwards.
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Energy Storage Technical Route

1. Concept

This report discusses narrow sense of energy storage: the storage of electric energy, with a series of techniques and methods (i.e. chemical and physical) to store and release when needed.

2. Principle

- **Electric energy**
  - Energy storage facility
  - Electric energy
  - Other energy

1. Comparison of main technical routes

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<th>Categories</th>
<th>Physical energy storage</th>
<th>Electromagnetic energy storage</th>
<th>Electrochemical energy storage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technical routes breakdown</td>
<td>Pumping energy storage, compressed air energy storage, flywheel energy storage, etc.</td>
<td>Superconducting electromagnetic energy storage, super capacitor energy storage, etc.</td>
<td></td>
</tr>
<tr>
<td>Feature</td>
<td>Using water, air and etc., as storage medium, and is the most mature large-scale energy storage technology</td>
<td>The current technology is still not mature</td>
<td></td>
</tr>
<tr>
<td>Strength</td>
<td>Suitable for large-scale, long cycle life, low running costs, high safety, less need for maintenance, and non-polluting</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weakness</td>
<td>Constrained by geographical conditions, long construction duration, low energy density</td>
<td></td>
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</tr>
</tbody>
</table>

2. Electrochemical energy storage classification

- Energy storage batteries include lead-acid battery, lithium-ion battery, NI-MH battery, sodium-sulfur battery and flow battery. Specifically, flow battery can be subdivided into vanadium redox flow battery, zinc-bromine flow battery and iron-chromium battery. In addition, lead-carbon battery, added activated carbon in lead-acid battery’s cathode, has characteristics of both lead-acid batteries and super capacitors.
- Performance of lead-acid battery and NI-MH battery is inferior to other types. Market share of the two will be gradually eroded in the long term. Therefore, as to the field of electrochemical energy storage, SMM focuses on lead-carbon battery, lithium-ion battery, sodium sulfur battery and flow battery.

Low cost, wide range of applications, with universal applicability

Low energy density, with pollution

SMM focuses on electrochemical energy storage which is more mature in technology and is widely applicable
Comparison of Main Techniques for Energy Storage Battery

Comparison of key parameters of energy storage battery

- Energy density
- Commercialization degree
- Cycle index
- Power
- Producing cost
- Safety
- Charge/discharge efficiency
- Self-discharge
- Cost per kwh
- Battery recycling

Source: ZHESHANG SECURITIES, Great Wall Securities, SMM

- Comprehensive performance of Lithium-ion battery is superior but the cost is high

Comparison of traditional batteries and energy storage battery in cost

RMB/KWh

- Lead carbon battery's cost advantage is obvious. Costs of lithium-ion battery and vanadium redox battery are high

Analysis of technical features and development trend of energy storage batteries

①Lead-acid batteries
- Features: most mature in technology, complete industry chain, widely used
- Trend: holding a certain market share in the short-term, being replaced in the long-term

②Lead-carbon batteries
- Features: low cost and fast recharging
- Trend: relying on the complete industry chain of lead-acid battery, optimistic in short-term

③Lithium-ion Battery
- Features: thoroughly superior performance, high cost
- Trend: power battery echelon utilization to reduce the costs of energy storage

④Sodium-sulfur battery
- Features: high theoretical energy density, domestic market still in R&D period
- Trend: hard in short-term promotion, expected to be applied in some areas in the long-term

⑤Ni-MH batteries
- Features: high memory effect, high self-discharge level
- Trend: gradually replaced by lithium-ion battery, further narrowing market share
- Trend: owning intellectual property in China, expected to develop rapidly

⑥Flow battery
- Features: high cycle index for vanadium redox flow battery, low self-discharge level

Note: Detailed technical indicators of energy storage batteries in Appendix 1, "comparison of variety of chemical energy storage battery main performance parameters"
Energy Storage Technology Application

• Currently, energy storage technology is mainly used in five major areas: power systems, new energy vehicles, UPS (uninterruptible power supply), power tools and electronic products.

Application fields breakdown of energy storage technology in China

Distribution of energy storage technology application fields in China, 2015

- Power systems accounted for 70% of China’s energy storage technology applications, with great market attention.

Application of energy storage battery in power system

- Currently, energy storage battery is mainly used in distributed micro-grid and renewable energy fields.

Comparison of energy storage batteries in power application

Application of energy storage battery in power utilization

Application of energy storage technology in China’s power system

Note: other refers to UPS, power tools and electronic products.

Application of energy storage technology in China's power system

- Currently, energy storage in China’s power system accounts for 70% of China’s energy storage technology applications, with great market attention.

Currently, energy storage battery is mainly used in power generation and transmission and distribution.

Power systems accounted for 70% of China’s energy storage technology applications, with great market attention.

Application of energy storage technology in China’s power system

Sources: IEA, SMM

Note: for detailed requirements corresponding to detailed technical indicators, see appendix 2 "technical indicators of energy storage battery in power applications"
Industrial Chain Flow

Upstream raw materials

Mining and metallurgy industry

- Nickel
- Cobalt
- Lithium
- Lead
- Sodium, sulfur
- Vanadium
- Zinc-bromine
- Ferrochrome

Midstream manufacturer

Battery manufacturer

- NI-MH battery
- Lithium-ion battery
- Lead-acid battery
- Lead-carbon battery
- Sodium-sulfur cell
- Flow battery

- Corun
- Byd
- Sunwoda electronics
- Lishen
- Nandu power
- Sacred sun
- NGK (Japan)

Downstream application

Automobile, electricity, electronics

- First auto-mobile group
- SAIC motor
- Byd
- China mobile
- China unicom
- China telecom
- Datang corporation renewable power
- Wind power, PV operator
- Distributed microgrid developers
- Communication base station
- Longyuan power
- Cpi
- Ztt
- Ieslab
- Ari-technology
- 3C electronic products
- Canon
- Philips
- UPS
- Electric tools

Note: UPS refers to uninterruptible power supply

- Note:
  - Technology of lithium-ion battery and lead-carbon battery is more mature, and already has commercial operating conditions.
  - In the downstream application field, the power system has a huge room to develop. Specifically, distributed micro-grid is the major demand composition.
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Market Development Stage

1. Comparison of electrochemical energy storage market at home and abroad

The global energy storage industry is growing significantly, with large potential afterwards. United States and Japan dominate the market. China started late, and needs policy planning and subsidies support.

2. Development of domestic energy storage industry

During the period of the 12th five-year plan, corresponding policy and guidance concerning energy storage industry have been released. However, they were all framework policies, and do not involve development targets, capacity planning, cost planning and subsidy of specific energy storage industry.

At the end of the 11th five-year plan period, Chinese government began to give support by official policy to encourage the development of energy storage industry.

During the 13th five-year plan period, detailed policies will be put into execution. Domestic investment scale in the construction energy storage industry is expected to be RMB 140 - 230 billion 2016-2020, with the average annual investment of about RMB 28-46 billion.

China's energy storage industry is in the introduction stage, with considerable growth expected in the foreseeable future.
Market Size

Global installed capacity

- In terms of installed capacity in 2015, global electrochemical energy storage, other mechanical energy storage and thermal energy storage developed rapidly, with thermal energy storage accounting for 43%.
- In 2015, the growth rate of electrochemical energy storage nearly touching 80%. Growth in Japan's and China's chemical energy storage far exceeded the global average, and is expected to boom in the future.

Global electrochemical energy storage capacity structure

- Lithium-ion batteries, sodium-sulfur batteries, lead-acid batteries and flow batteries have high market share among global electrochemical energy storage market.
- The proportion of lithium-ion batteries and sodium-sulfur batteries reached 40% and 38%, respectively.

Energy storage capacity structure of electrochemical storage in china

- Lithium-ion battery and sodium-sulfur battery take a lion’s share in global electrochemical energy storage market. In china, lithium-ion battery installed capacity takes the largest market share, and might continue to lead the energy storage market.

Note:
- Lithium-ion battery and sodium-sulfur battery take a lion’s share in global electrochemical energy storage market. In china, lithium-ion battery installed capacity takes the largest market share, and might continue to lead the energy storage market.
Policy Interpretation

<table>
<thead>
<tr>
<th>Policy category</th>
<th>Time</th>
<th>File names</th>
<th>Main contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planning target</td>
<td>2005</td>
<td>Renewable energy industry development guide directory</td>
<td>Propose that two battery projects should be one of the key development projects to promote the pilot application of energy storage technology</td>
</tr>
<tr>
<td></td>
<td>2011</td>
<td>&quot;12th Five-Year Plan&quot; for National Energy Technology (2011-2015)</td>
<td>Clarify research direction for the 10-MWh-class mega-scale air energy storage equipment and MWh-class sodium-sulfur battery energy storage systems</td>
</tr>
<tr>
<td></td>
<td>2014</td>
<td>Strategic Plan of Action for Energy Development (2014-2020)</td>
<td>Energy storage for the first time was identified as one of the “9 key areas of innovation” and “20 key innovation directions”</td>
</tr>
<tr>
<td></td>
<td>2016</td>
<td>13th Five-Year Plan Outline</td>
<td>The eight projects include energy storage stations, energy storage facilities; focus on accelerating large-scale energy storage technology</td>
</tr>
<tr>
<td>Technical guidelines</td>
<td>2006</td>
<td>National Medium and Long-term Science and Technology Development Plan 2006-2020</td>
<td>Propose “high-efficiency energy conversion and energy storage material system, and pushing the development of energy storage materials technology from the perspective of science and technology</td>
</tr>
<tr>
<td></td>
<td>2013</td>
<td>General specification for electrochemical energy storage system of power system</td>
<td>Improve domestic energy storage technology standard system</td>
</tr>
<tr>
<td></td>
<td>2016</td>
<td>Energy Technology Revolution Innovation Action Plan (2016-2030)</td>
<td>Support large-scale energy storage, and supporting distributed energy storage, micro-grid and other energy storage applications</td>
</tr>
<tr>
<td>Pilot reform</td>
<td>2009</td>
<td>Provisional Measures for the management of financial subsidies of Golden Sun Demonstration Project</td>
<td>Propose to support the construction of national scenery storage and transportation demonstration project</td>
</tr>
<tr>
<td></td>
<td>2010</td>
<td>Smart grid planning for the 12th five-year plan period</td>
<td>Propose distributed power, energy storage and micro-grid access and coordination pilot</td>
</tr>
<tr>
<td></td>
<td>2015</td>
<td>Opinions on further deepening power system reform</td>
<td>Emphasize the necessity of power reform and the development of integrated energy storage, information technology, micro-grid and smart grid technology</td>
</tr>
<tr>
<td></td>
<td>2016</td>
<td>Notice on promoting electric storage to participate in Electricity Energy Storage in Northern China, Northeastern China and Northwestern China Regions</td>
<td>Encourage investment in energy storage facilities, the user side of the building energy storage facilities, and emphasizing the scheduling operation of electricity storage</td>
</tr>
</tbody>
</table>

Opinions on further deepening power system reform ([2015] 9)

<table>
<thead>
<tr>
<th>Core content</th>
<th>Planned target</th>
</tr>
</thead>
<tbody>
<tr>
<td>First: the power system reform problems to be solved</td>
<td>Lack of transaction mechanism; price relationship is not straighten out; government functions are not in place, and various planning and coordination mechanisms are imperfect</td>
</tr>
<tr>
<td>Second: the key tasks of the power system reform</td>
<td>Rationalize the electricity price formation mechanism; improve the market-oriented trading mechanism; form fair and standardized market trading platform; orderly release the electricity sales to social capital business; the establishment of distributed power development mechanism</td>
</tr>
<tr>
<td>Third: strengthening the organization and implementation of the power system reform</td>
<td>Strengthening organization and coordination; creating an active atmosphere; secure and orderly manner</td>
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</tbody>
</table>

Note:
- Chinese government evidently pays more close attention to energy storage industry
- In 2005-2011, energy storage planning focused on a few areas, which will expand to other fields during 2014-2016
- Power trading platform was established, and policy reform was gradually executed
- At present, there is no subsidy policy. SMM expects subsidy policy will unlikely be released at the beginning of the 13th Five-Year Plan period.
Problems and Bottlenecks

- Compared with foreign energy storage industry, China started late, and policy planning and subsidy support are inadequate.
- Most of the domestic energy storage projects are still functional demonstration projects, and promotion in different regions are not in the same pace, giving limited boost to the industry development.

- Subsidy cheating affected the production of some new energy vehicle enterprises, **which will drag down the demand for energy storage batteries.**
- Subsidies for new energy vehicles will recede, and market activity will also slide. It will dampen consumption of new energy vehicles.
- The consistency of the policies afterwards will be affected.

- Energy storage technology is still faced with a variety of **practical problems** when utilized, such as large-scale grid—facing the issues of power shifting, power security and power quality.
- Some promising energy storage technologies such as vanadium redox battery, is still in the **R&D stage**, and is far from commercialization.
- Energy storage products are not **economical efficiency enough.**
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<td>Industry Opportunity</td>
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</table>
### Overview of Mainstream Domestic and Foreign Enterprises

<table>
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<tr>
<th>Role</th>
<th>Company</th>
<th>Application field</th>
<th>Major product</th>
<th>Micro-grid/Energy storage projects</th>
<th>Investment cooperation</th>
<th>Advantage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Battery manufacturer</td>
<td>Narada</td>
<td>Large-scale energy storage system, distributed micro-grid energy storage system, household energy storage system, commercial energy storage system</td>
<td>Lead-acid batteries (lead carbon, lead-acid), lithium batteries, optical storage integrated micro-grid energy storage, LSJ, REX</td>
<td>45 projects were put into operation, with total installed capacity of 150MWh, and 7 to be built, with total installed capacity of 108.64MWh</td>
<td>Acquired a 25% stake of Canada SPS in 2015, receiving large orders of energy storage lithium battery.</td>
<td>The first to step into the field of energy storage, and formulated the &quot;investment + operating&quot; business model</td>
</tr>
<tr>
<td>SACRED SUN</td>
<td>Distributed energy storage, household energy storage, large-scale energy storage, communication base station energy storage</td>
<td>Lead-acid batteries, lithium-ion batteries, power plants, modular container energy storage system</td>
<td>Winning bid for telecom base station new energy storage power supply system from China Tower’s subsidiaries in Tibet, Qinghai and Inner Mongolia in 2015.</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Rongke Power</td>
<td>Large-scale new energy grid, smart micro-network, independent power supply</td>
<td>Flow battery (all vanadium flow battery), container-type energy storage</td>
<td>Winning bid from Liaoning Electric Power Research Institute for distributed photovoltaic energy storage micro-grid system research and demonstration project in June, 2013.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Battery supporting facilities suppliers</td>
<td>Sungrow</td>
<td>Distributed energy storage, household storage, etc.</td>
<td>Energy storage converters, lithium-ion batteries, energy storage systems, energy storage accessories</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CLOU Electronics</td>
<td>Household energy storage systems, industrial / commercial energy storage systems, grid-level energy storage systems, EMS energy management systems, electric vehicle battery energy storage</td>
<td>Home storage system, battery management system, box-type mobile storage power station, energy storage bi-directional converter, optical storage machine, large-scale energy storage power station system</td>
<td>The 30-mile Jingzi scenery grid integration demonstration project in Yumen City was completed; Build commercial-grade power station in Hawaii, and government-level micro-grid demonstration projects in Cameroon, Africa.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Car enterprises, multi-roles coverage in the industry chain</td>
<td>BYD</td>
<td>Energy storage on the generating side, energy storage on the transmission side, and energy storage on the distribution side</td>
<td>Various products</td>
<td>The first to enter US energy storage market, Chinese enterprises. BYD’s new energy storage business accounted for more than 50% of the US energy market segments share; won the largest US energy storage projects in 2015</td>
<td>In September 2014, BYD and Switzerland’s ABB developed new battery energy storage system solutions</td>
<td>Leading enterprise of lithium-ion battery energy storage project construction</td>
</tr>
<tr>
<td></td>
<td>Tesla</td>
<td>Household energy storage systems, for household usage, commercial energy storage systems commercial public electricity solutions Powerpack</td>
<td>Powerwall battery equipment, Powerpack total equivalent to 600MWh, or 3% of the global 3C orders, and won 500MWh energy storage system AMS order in June.</td>
<td>Planned to acquire SolarCity, but the progress is hindered.</td>
<td></td>
<td>&quot;Photovoltaic power + energy storage &quot;layout</td>
</tr>
</tbody>
</table>

Note: Those marked in red are domestic listed companies.

Green Partnership Program: Encouraging green partnership between local governments, enterprises, academia, research, management, training institutions, and other organizations at different levels in China and the United States. Capitalizing on characteristic and innovation-type projects to carry out technical cooperation, exchange of experience and capacity building and other forms of cooperation activities. At present, China’s lead department is the National Development & Reform Commission, and the US side is the State Department and the Department of Energy.

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# Domestic Representative: Narada

## Basic profile
- **Headquarters:** Hangzhou, Zhejiang
- **Market value:** RMB 17 billion
- **Core Business:** R & D, manufacturing, sales and service of communication back-up power supply, power supply, storage power supply, system integration and related products.
- **Partner:** State Grid, China Southern Power Grid, Guodian, Sifang Power, Zhonhen, etc.

## Energy storage strategy
- **“Investment + operation” business model (expansion accelerating period)**
  - The company invests in the construction of energy storage power station. Via signing contracts with clients, it provides them with a set of energy-saving services, and recoups investment and gains profits from energy-saving benefits obtained from the energy-saving renovation for the clients.

  The core is to utilize the characteristics of “peak load shifting”, storing power in the trough and selling power at peak. Then, the clients can take a share of the profit from the peak-to-valley electricity spreads.

- **Competitors**
  - **Lithium energy storage areas:** BYD, ATL, etc.
  - **Lead-carbon energy storage areas:** There exist competitors in the demonstrative projects. In commercial projects, competition is not fierce, and the company is willing to see others involved.

## Energy storage projects
- **Under operation**
  - Narada 2MWh optical storage integrated micro-grids energy storage power station

- **Under installation and commission**
  - Xinjiang Turpan renewable demo city pilot project
  - Zhejiang Luxi Island 4MWh micro-grid pilot project
  - Zhuhai Wanshan Island 6MWh demo micro-grid project

**Project winning bid in 2016**
- jointly constructs a 120MWh power storage station with Wuxi Xingzhou Keyuan

## Highlights
- With the breakthrough of research and development, energy storage per kWh cost has declined significantly, and the economy and reliability of the energy storage programs has been fully validated.
Domestic Representative: Tesla

**Basic profile**

- **Headquarters:** California, US
- **Market value:** USD 33.22 billion
- **Core business:** electric vehicle R & D, manufacturing, sales and service
- **Partner:** Jointly developing Gigafactory with Panasonic; 1/3 of lithium battery capacity will be used for Powerwall and Powerpack by 2020.

**Energy storage strategy**

- "Photovoltaic power generation + energy storage" layout
- On July 21, 2016, Tesla released its second blueprint, covering four directions—integration of energy regeneration and storage, diversification of product portfolio, automatic driving and sharing. The core of the first direction is "photovoltaic power + energy storage"

**Energy storage projects**

- **Household-level:** Powerwall
  Specification: 7kWh, 10kWh (halt in production)
  Application: provide home users with photovoltaic storage and emergency power supply

- **Grid-level:** Powerpack
  Specification: Minimum capacity of 100kWh, able to extend to MWh level on demand
  Application: Adjusting the peak and valley power, controlling power transmission and distribution delay, providing continuous and stable power supply, and participating in grid service

**Creating vertical industrial chain: Tesla**

- Powerwall and Powerpack are cost efficient, helping accelerate the cost reduction of energy storage
- foster the transformation from electric vehicle manufacturer to energy enterprise

**Competition:** Tesla is aimed to dominate the emerging market of energy storage batteries, but it faces numerous rivals and competitive technology challenges

- Bosch, General Electric and Samsung are all doing business of electronic energy storage system
- Nissan Leaf’s used batteries are applied in the residential and commercial energy storage equipment

**Highlights**
## Domestic and Foreign Energy Storage Demonstration Projects

- During 2008 - 2015, domestic and foreign energy storage demonstration projects were conducted gradually, mainly by United States, Japan, Chile and China and lithium batteries as well as lead-acid batteries played a major role in the technical route.

<table>
<thead>
<tr>
<th>Project</th>
<th>Place</th>
<th>Time</th>
<th>Technology</th>
<th>Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sendai substation lithium-ion battery pilot project</td>
<td>Sendai city, Miyagi prefecture, Japan</td>
<td>Commissioning in Feb. 2015</td>
<td>Lithium-ion battery</td>
<td>20mwh</td>
</tr>
<tr>
<td>Canadian wind energy research institute durathon sodium salt battery project</td>
<td>Prince Edward island, Canada</td>
<td>Commissioning in Feb. 2014</td>
<td>Sodium nickel chloride battery</td>
<td>20mwh</td>
</tr>
<tr>
<td>PRIMUS power company wind stable electric field</td>
<td>Modesto, California</td>
<td>Constructed in Jan. 2013</td>
<td>Zinc oxide redox flow battery</td>
<td>75mwh</td>
</tr>
<tr>
<td>Auwahi wind farm battery storage system</td>
<td>Hawaii Kula</td>
<td>Commissioning in Dec. 2012</td>
<td>Lithium-ion battery</td>
<td>4.4mwh</td>
</tr>
<tr>
<td>Duke energy corporate services norris wind energy storage demonstration project</td>
<td>Goldsmiths, Texas</td>
<td>Commissioning in Oct. 2012</td>
<td>Advanced lead-acid battery</td>
<td>24mwh</td>
</tr>
<tr>
<td>Angamos</td>
<td>Mejones, Chile</td>
<td>Commissioning in Dec. 2011</td>
<td>Lithium-ion battery</td>
<td>6.7mwh</td>
</tr>
<tr>
<td>Mount laurel</td>
<td>Elkins, West Virginia</td>
<td>Commissioning in Sep. 2011</td>
<td>Lithium-ion battery</td>
<td>8mwh</td>
</tr>
<tr>
<td>Rokkasho wind power plant</td>
<td>Rokkasho, Japan</td>
<td>Commissioning in May 2008</td>
<td>Sodium-sulfur cell battery</td>
<td>245mwh</td>
</tr>
<tr>
<td>Kelu Electronics Sanshili Jingzi scenery storage grid integration demonstration project</td>
<td>Jiuquan, Gansu</td>
<td>Commissioning in Jun. 2016</td>
<td>Lithium-iron phosphate energy storage technology</td>
<td>10mw</td>
</tr>
<tr>
<td>China southern power grid FGC scenery storage integrated substation demonstration projects</td>
<td>Shenzhen, Guangdong</td>
<td>Commissioning in Nov. 2015</td>
<td>Lead-carbon battery, phosphoric acid iron battery energy storage system</td>
<td>3mwh</td>
</tr>
<tr>
<td>Guodian and Fengbei town Fengchang energy storage projects</td>
<td>Jinzhou city, Liaoning</td>
<td>Demonstration operation in Nov. 2015</td>
<td>Phosphoric acid iron battery, vanadium redox flow battery, super-capacitor</td>
<td>14.083mwh</td>
</tr>
<tr>
<td>Zhongneng Silicon energy storage station implementation project</td>
<td>Jiangsu</td>
<td>Winning bid in Dec. 2015</td>
<td>Lead-carbon storage battery</td>
<td>12mwh</td>
</tr>
<tr>
<td>CGN network photovoltaic power station in Gonghe county</td>
<td>Gonghe county, Jiangsu</td>
<td>Started in May 2014</td>
<td>Lithium battery, lead-acid battery</td>
<td>3/28mwh</td>
</tr>
<tr>
<td>CGN micro-grid photovoltaic power plant in Qilian county</td>
<td>Qilian county, Qinghai</td>
<td>Completed in Oct. 2013</td>
<td>Lithium battery, lead-acid battery</td>
<td>1.2/4mwh</td>
</tr>
<tr>
<td>Longyuan Faku Wuniushi wind power plant project</td>
<td>Shenyang, Liaoning</td>
<td>Completed in 2012</td>
<td>Vanadium redox flow battery energy storage technology</td>
<td>10mwh</td>
</tr>
<tr>
<td>Zhangbei scenery storage and transportation demonstration project (phase I)</td>
<td>Zhangjiakou city</td>
<td>Completed in Dec. 2011</td>
<td>Phosphoric acid iron battery, lithium-titanic battery, vanadium redox flow battery, lead-acid battery</td>
<td>83.5mwh</td>
</tr>
<tr>
<td>Zhejiang Luxi island Micro-grid project zhejia</td>
<td>Wenzhou, Zhejiang</td>
<td>Commissioning in Jan. 2014</td>
<td>Lead-acid battery</td>
<td>4mwh</td>
</tr>
</tbody>
</table>

Sources: public information, SMM
Domestic Representative Case: State Grid Zhangbei Wind/Solar Energy Storage and Transmission Project

**Background**
- **Address:** Zhangbei County and Shangyi County, Zhangjiakou City, Hebei Province
- **Time:** launched in 2009
- **Status:** the first key project of the “Golden Sun Project” jointly launched by the Ministry of Finance, Ministry of Science and Technology, the National Energy Board and the State Grid Corporation; the only power project of the first batch of key strong smart grid projects built by State Grid; the world’s largest renewable energy project, which integrates wind power, photovoltaic power generation, energy storage and transmission engineering

**Project scale**
- Total planned capacity is: 500MW of Wind power, 100MW of photovoltaic power, and 70MW of energy storage system, constructed in two phases.
- **Phase I:** 9.8MW of Wind power, 4MW of photovoltaic power generation, and 2MW of energy storage system → Phase I was commissioned in 2011
- **Phase II:** 400MW of wind power, 60MW of photovoltaic power generation, and 50MW of energy storage system → Phase II was commissioned in late 2013

**1st phase of energy storage program**
- Project winning the bids in Phase I
  - **Bid time** | Successful bidder | Energy storage technology | Total capacity | Bid amount (RMB 10,000)
  - 2011/4/13 | BYD | LiFePO6 | 6MW*6h | 14839.73
  - 2011/4/13 | Dongguan ATL | LiFePO4 | 4MW*4h | 8456
  - 2011/4/13 | CALB | LiFePO3 | 3MW*3h | 6090.99
  - 2011/4/13 | Wanxiang | LiFePO1 | 1MW*2h | 1443.576

**2nd phase of energy storage program**
- Phase II is equipped with the world's largest multi-type chemical energy storage power station, with installed capacity of 20MW.
  - Adopt various types of chemical batteries, including 14MW of lithium battery, 2MW of flow battery, 2MW lead-acid battery.
  - Specifically, there are 9 energy storage units of lithium battery,
  - Equipped with 46 units of PCS of different brands and topological structures
  - Storage battery power conversion exceeds 70 times a day. Remaining capacity is generally between 45-65%. The project runs for three years, with very limited battery attenuation, 274,568 cells in total

**Highlights**
- Since commissioning in December 25, 2011, the project has remained safe and stable operation for nearly 5 years. The cumulative output of high-quality and safe green power is more than 1.65 billion kwh.
- Currently, lithium battery of this energy storage power station powers costs RMB 0.6-0.7/kWh.
- Built up the world's largest lithium battery storage power station, and initiated large-scale energy storage in China.
- All kinds of batteries in the power station are made domestically. Meanwhile, it enables the centralized management, unified coordination and real-time control, and realizes the unified control of lithium battery, flow battery and sodium-sulfur cell battery. Smooth output, tracking plan, peak load shifting and frequency modulation, these four major functions, are also implemented.

Note: PCS: power conversion system, an important component for battery energy storage system, which helps realize two-way energy transfer between DC and AC power grid.

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### Industry Chain Opportunities

#### Energy storage battery manufacturing

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<tr>
<th></th>
<th></th>
</tr>
</thead>
</table>
| 1 | Lithium-ion battery  
- Lithium-ion battery products tend to enter into the maturity stage, and will penetrate into various fields. Policy support is expected to accelerate the development of this industry afterwards. |
| 2 | Lead-carbon battery  
- Lead-carbon battery is an upgraded version of lead-acid battery, able to be used in lead-acid battery field. Its market is mature and stable, with limited policy effects. It has realized commercialized operation. Currently, the market is profitable but potential is limited. |
| 3 | Flow battery  
- Immature technology in some dimensions leads to high cost and to hard commercialization. However, future policy support and technical breakthrough will foster the maturity of flow battery market. Power market reform in China is probable to help the market expansion in the near term. |

#### Distributed micro-network, new energy vehicles

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
</table>
| 1 | Power market - distributed microgrid  
- China’s power market is accelerating the pace of reform, with high stock and incremental market. China is expected to execute subsidy policy later. Incremental micro-network market is estimated to reach 20-30 billion during the 13th five-year plan period. Differentiated needs will benefit the diversification of business operation models. |
| 2 | New energy vehicles  
- Automotive unmanned systems and new energy systems lead the automotive market reform. China's auto market growth will keep the upward trend, and new energy vehicles is still a hot point.  
- The recent new energy vehicle subsidy cheat has an impact on new energy vehicles industry. Chinese government tightened the subsidy policy, and the market temporarily returned to a wait-and-see stance. |

### Companies to be focused on

- **Narada**: Its company performance improved significantly in 2016. The closed-loop of batteries, energy storage power plants and recycling business were established. It evidently plays a leading role in the energy storage industry covering lead-carbon battery and lithium-ion battery.

- **Tianqi Lithium**: It has obvious advantages in resource, and newly invested RMB 80 million in 20,000 mt of battery-grade lithium hydroxide, so as to appeal for the strict overseas production system, in full preparation for entering the international market.

- **Beijing prudent**: It acquired Canadian VRB power system assets, and has over ten years of experience in vanadium battery research and development, making breakthroughs in stack construction, key materials and system integration.

- **NARI technology**: It is a research and development institution directly under national power department, and has advantages in intelligent power grid, micro-grid and distributed control technology. Of the distributed hybrid energy storage device has been widely applied in the field of distributed energy and micro-network. The research and development of the distributed energy storage device is based on the research of intelligent power grid, micro-grid and distributed control technology. The company successfully self-developed distributed hybrid energy storage, which has a broad application prospect in distributed energy and micro-grid.

- **BYD**: The company is one of the world's leading manufacturers of secondary rechargeable batteries, and one of the world's most competitive handset component and assembly business suppliers. Its capacity continues to expand. New energy vehicles and energy storage development serve as supplement for each other.
Appendix 1: Comparison of Chemical Energy Storage Battery Key Performance Parameters

<table>
<thead>
<tr>
<th>Performance index</th>
<th>Lead-carbon battery</th>
<th>Lead-acid battery</th>
<th>NI-MH battery</th>
<th>Lithium-ion battery</th>
<th>Sodium-sulfur battery</th>
<th>Flow battery</th>
<th>Vanadium redox battery (VRB)</th>
<th>Zinc-bromine battery</th>
<th>Ferrochrome battery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scale level</td>
<td>MW</td>
<td>10MW</td>
<td>kW ~ MW</td>
<td>10MW</td>
<td>10MW</td>
<td>5MW/10MWh</td>
<td>1MWh/4MWh</td>
<td>&gt;10000</td>
<td>250kW/1MWh</td>
</tr>
<tr>
<td>Cycle life</td>
<td>1000-5000</td>
<td>600-1000</td>
<td>500-1800</td>
<td>2000-5000</td>
<td>2500</td>
<td>&gt;10000</td>
<td>2000-5000</td>
<td>2000-5000</td>
<td>&gt;10000</td>
</tr>
<tr>
<td>Energy density</td>
<td>30-60Wh/kg</td>
<td>30-50Wh/kg</td>
<td>75-150Wh/kg</td>
<td>130-200Wh/kg</td>
<td>150-240Wh/kg</td>
<td>15-30Wh/L</td>
<td>430Wh/kg</td>
<td>15-30Wh/L</td>
<td></td>
</tr>
<tr>
<td>Charge-discharge efficiency</td>
<td>&gt;90%</td>
<td>80~90%</td>
<td>0.66</td>
<td>&gt;90%</td>
<td>75-90%</td>
<td>80-85%</td>
<td>65-75%</td>
<td>80-85%</td>
<td></td>
</tr>
<tr>
<td>Self-discharge</td>
<td>0.1~0.3%/day</td>
<td>0.1~0.3%/day</td>
<td>0.1~1%/day</td>
<td>0.1~0.3%/day</td>
<td>Low</td>
<td>Very low</td>
<td>Low</td>
<td>Very low</td>
<td></td>
</tr>
<tr>
<td>Commercialization difficulty</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
<td>Hard (constistency)</td>
<td>Medium (ceramic material)</td>
<td>Easy</td>
<td>Medium (plate technology)</td>
<td>Easy</td>
<td></td>
</tr>
<tr>
<td>Operating temperature</td>
<td>Environment temperature affects lifetime</td>
<td>Environment temperature affects lifetime</td>
<td>Environment temperature affects lifetime</td>
<td>Poor performance in low temperature</td>
<td>300-350°C</td>
<td>5-40°C</td>
<td>20-50°C</td>
<td>-10-70°C</td>
<td></td>
</tr>
<tr>
<td>Safety</td>
<td>Lead pollution</td>
<td>Lead pollution</td>
<td>Relatively safe</td>
<td>Risk of overheating explosion</td>
<td>Sodium leakage risk</td>
<td>Relatively safe</td>
<td>Risk of bromine steam leakage</td>
<td>Relatively safe</td>
<td></td>
</tr>
<tr>
<td>Battery recycling</td>
<td>Recyclable, renewable</td>
<td>Recyclable, renewable</td>
<td>Recyclable, renewable</td>
<td>Hard</td>
<td>Medium</td>
<td>Electrolyte solution</td>
<td>Hard</td>
<td>Electrolyte solution</td>
<td></td>
</tr>
<tr>
<td>Advantages</td>
<td>No memory effect, low cost, good uniformity</td>
<td>Low price, good recyclability</td>
<td>Long cycle life, high specific energy</td>
<td>High energy density, large output power, no memory effect, fast charge and discharge speed</td>
<td>High Specific energy, high current, high-power discharge, low cost</td>
<td>High voltage consistency, high reliability, long cycle life, large scale</td>
<td>Low cost, long life 100% deep cycling, super power, momentary charge</td>
<td>Low cost, theoretical cost lower than VRB, zinc-bromine batteries</td>
<td></td>
</tr>
<tr>
<td>Disadvantages</td>
<td>Low specific energy, corroding environment</td>
<td>Low specific energy, not suitable for fast charge and high-current discharge, short lifetime</td>
<td>With memory effect, hot when charged, short life</td>
<td>High cost, poor overcharge and over-discharge durability</td>
<td>Dangerous when operating temperature is high or over-charged</td>
<td>High cost and low energy density</td>
<td>Corrosive to battery materials, more severe self-discharge</td>
<td>Toxic, low energy density, operation and maintenance difficulties</td>
<td></td>
</tr>
<tr>
<td>The most suitable application</td>
<td>Hybrid electric vehicles, electric bicycles, wind energy storage</td>
<td>Communications equipment, power tools, electric control locomotives</td>
<td>Portable electronic equipment, hybrid, pure electric vehicles, vehicle braking</td>
<td>Electronic products, electric bicycle, military, aerospace, wind power</td>
<td>Military, aerospace, wind power, solar energy, telecommunication s base stations</td>
<td>Smart grid, large-scale solar, wind power, standby power</td>
<td>Solar, wind power, electric vehicles</td>
<td>Solar, wind power, standby power, research into a halt</td>
<td></td>
</tr>
</tbody>
</table>

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## Appendix 2: Technical Indicators for Energy Storage Batteries Application

<table>
<thead>
<tr>
<th>Object</th>
<th>Output power</th>
<th>Discharge duration</th>
<th>Charge-discharge frequency</th>
<th>Response time</th>
<th>Energy storage battery installation location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seasonal storage</td>
<td>500-2000</td>
<td>Day, month</td>
<td>1-5 times/day</td>
<td>Day</td>
<td>generation √, transmission √, distribution √, utilization √</td>
</tr>
<tr>
<td>Charge and discharge arbitrage</td>
<td>100-2000</td>
<td>8-24 hours</td>
<td>0.25-1 times/day</td>
<td>&gt; 1 hours</td>
<td>√</td>
</tr>
<tr>
<td>FM</td>
<td>1-2000</td>
<td>1-15 minutes</td>
<td>20-40 times/day</td>
<td>1 minutes</td>
<td>√</td>
</tr>
<tr>
<td>Load tracking</td>
<td>1-2000</td>
<td>15 minutes-1 day</td>
<td>1-29 times/day</td>
<td>&lt; 1 minutes</td>
<td>√</td>
</tr>
<tr>
<td>Voltage stability</td>
<td>1-40</td>
<td>1s-1 minute</td>
<td>10-100 times/day</td>
<td>&lt; 1 second</td>
<td>√</td>
</tr>
<tr>
<td>Black-start</td>
<td>0.1-400</td>
<td>1-4 hours</td>
<td>Below 1 time/day</td>
<td>&lt; 1 hour</td>
<td>√</td>
</tr>
<tr>
<td>Transmission and distribution congestion relief</td>
<td>10-500</td>
<td>2-4 hours</td>
<td>0.14-1.25 times/day</td>
<td>&gt;1 hour</td>
<td>√</td>
</tr>
<tr>
<td>Demand adjustment and peak clipping</td>
<td>0.001-1</td>
<td>minutes- hours</td>
<td>0.75-1.25 times/day</td>
<td>&lt; 15 minutes</td>
<td>√</td>
</tr>
<tr>
<td>Off-grid demand</td>
<td>0.001-0.01</td>
<td>3-5 hours</td>
<td>0.75-1.5 times/day</td>
<td>&lt; 1 hour</td>
<td>√, √</td>
</tr>
<tr>
<td>Variable supply resource integration</td>
<td>1-400</td>
<td>1 minutes- hours</td>
<td>0.2-2 times/day</td>
<td>&lt; 15 minutes</td>
<td>√</td>
</tr>
<tr>
<td>Waste heat utilization and heat and power cogeneration</td>
<td>42379</td>
<td>minutes- hours</td>
<td>1-20 times/day</td>
<td>&lt; 15 minutes</td>
<td>√, √</td>
</tr>
<tr>
<td>Thermal equipment and cooling equipment</td>
<td>10-2000</td>
<td>15 minutes-2 hours</td>
<td>0.5-2 times/day</td>
<td>&lt; 15 minutes</td>
<td>√</td>
</tr>
</tbody>
</table>

Sources: IEA, SMM
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