Biweekly 005 Sep/30

Energy Storage Battery- Industry Combing

Sep. 2016

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SMM
Shanghai Metals Market

News

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1 CLOU Electronics to Co-found JV with LG Chem

May 26,2016 Source: evpartner.com

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.

2 First Largest Commercial Optical Storage Power Station in China Put into Operation

June 29,2016 Source: escn.com.cn

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.

3 Electricity Energy Storage Dominates in Peak Load Shifting Auxiliary Service of the Northern China, Northeastern China and Northwestern China Regions

August 10, 2016 Source: CNESA

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.

Highlight

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1

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.**

2

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.

3

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.

4

Accelerating pace of the policy publication benefits energy storage industry

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

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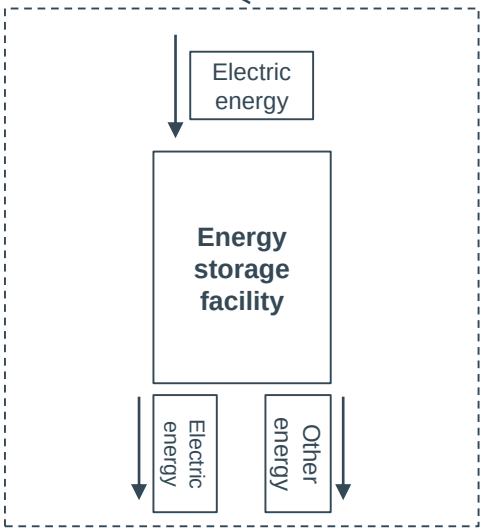
Concept and principle

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



Classification of the techniques

1. Comparison of main technical routes

Categories	Physical energy storage	Electromagnetic energy storage	Electrochemical energy storage
Technical routes breakdown	Pumping energy storage, compressed air energy storage, flywheel energy storage, etc.	Superconducting electromagnetic energy storage, super capacitor energy storage, etc.	Lead-acid batteries, vanadium redox flow batteries, lithium-ion batteries, etc.
Feature	Using water, air and etc., as storage medium, and is the most mature large-scale energy storage technology	The current technology is still not mature	The charge-discharge process is accompanied by chemical reaction of the storage medium. The technology is relatively mature
Strength	Suitable for large-scale, long cycle life, low running costs, high safety, less need for maintenance, and non-polluting	High power density, high current charge-discharge performance, long cycle life, fast response, high conversion efficiency	Low cost, wide range of applications, with universal applicability
Weakness	Constrained by geographical conditions, long construction duration, low energy density	Low energy density, high cost, difficult to maintain, and insufficient technical maturity	Low energy density, with pollution

SMM focuses on electrochemical energy storage which is more mature in technology and is widely applicable

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 than 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.**

Comparison of Main Techniques for Energy Storage Battery

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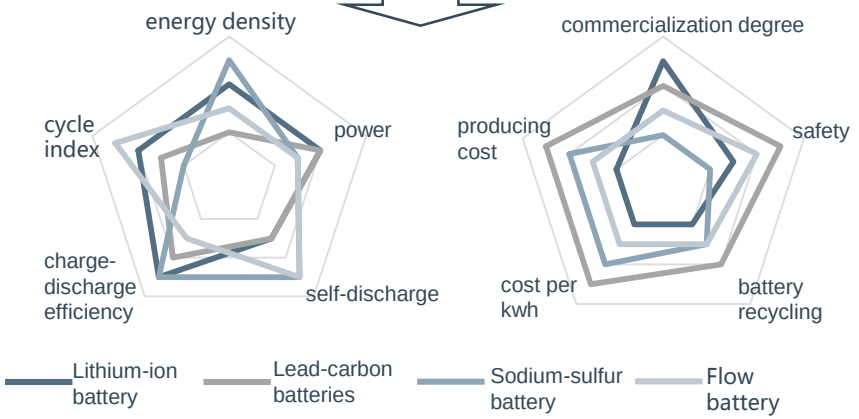
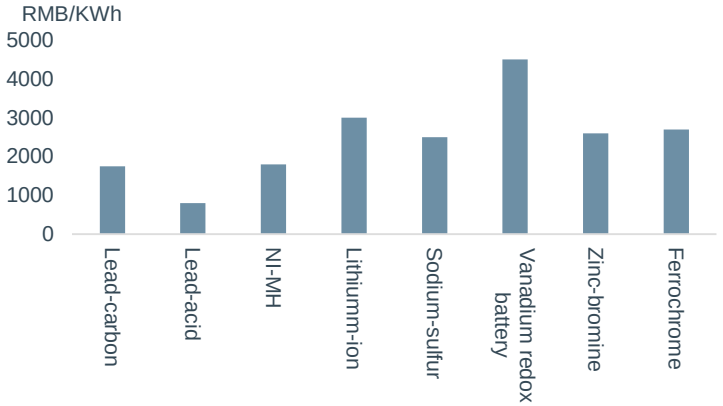
Comparison of key parameters of energy storage battery



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



- 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

⑤ Ni-MH batteries

- **Features:** high memory effect, high self-discharge level
- **Trend:** gradually replaced by lithium-ion battery, further narrowing market share

⑥Flow battery

- **Features:** high cycle index for vanadium redox flow battery, low self-discharge level
- **Trend:** owning intellectual property in China, expected to develop rapidly

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

Note:

- ***Regarding of the technology and the cost, lead-carbon battery and lithium-ion battery are promising currently, while flow battery will see a bright future.***

Energy Storage Technology Application

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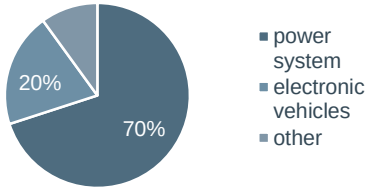
- Currently, energy storage technology is mainly used in five major areas: power systems, new energy vehicles, UPS (uninterruptible power supply), power tools and electronic products

Application fields breakdown of energy storage technology in China

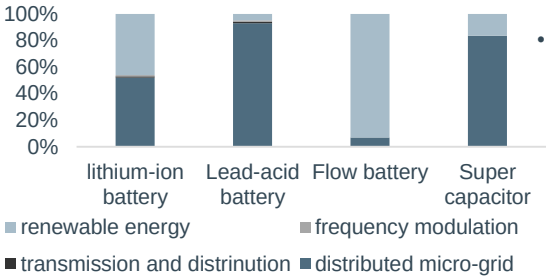
Distribution of energy storage technology application fields in China, 2015



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

- 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.

Application of energy storage technology in China's power system

Comparison of energy storage batteries in power application

Demand	Storage battery installation location			
	Generation	Transmission	Distribution	Utilization
Seasonal storage			√	√
Charge-discharge arbitrage	√	√	√	
FM	√		√	
Load tracking			√	
Voltage stability			√	√
Black start	√			
Transmission and distribution congestion relief		√	√	
Demand adjustment & peak clipping			√	
Off-grid demand		√	√	
Variable supply resource integration			√	
Waste heat utilization and heat and power cogeneration	√		√	√
Thermal and cooling equipment			√	√

Sources: IEA , SMM

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

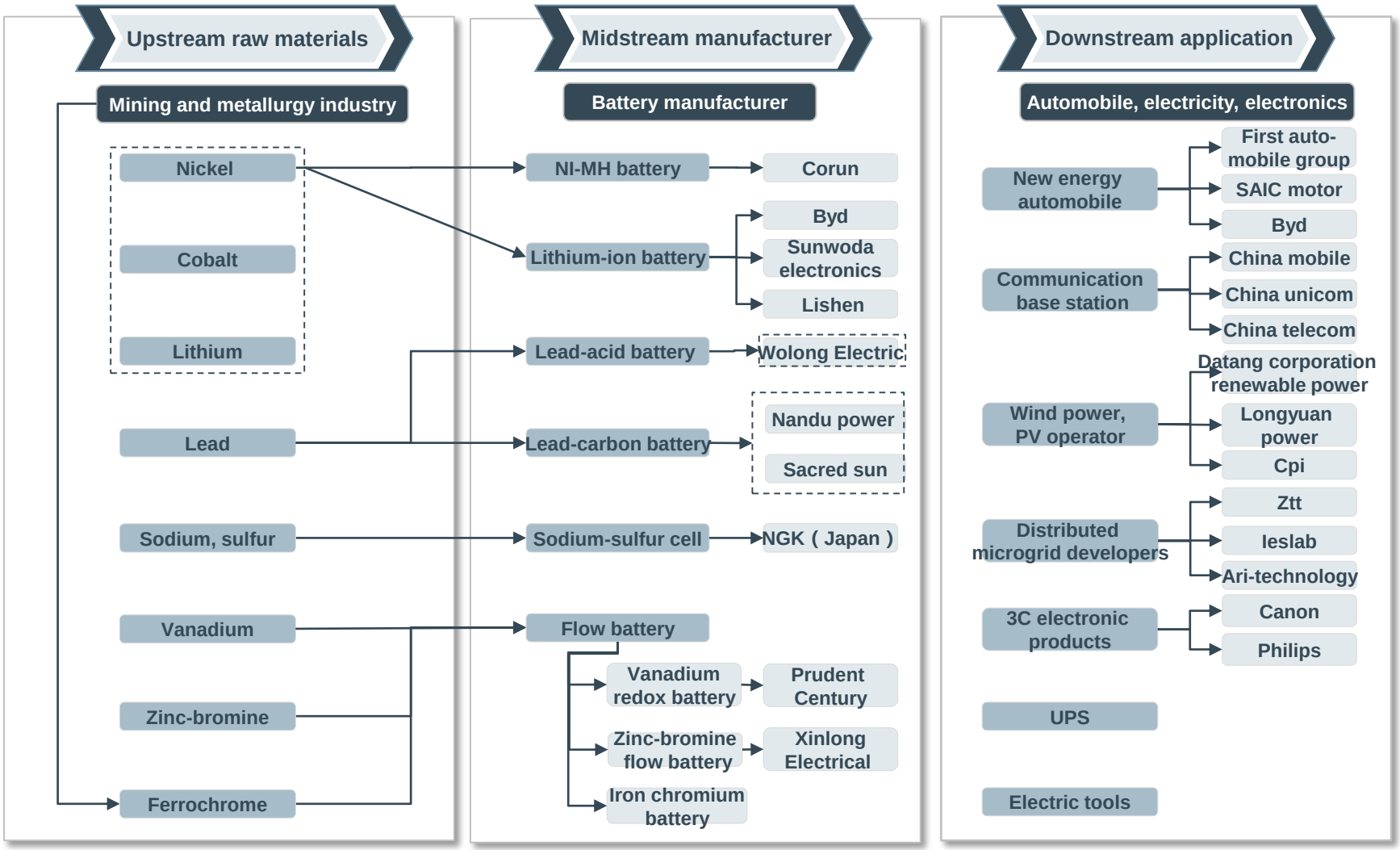
Application of energy storage battery in power utilization

Application	Advantage	Cost impact
Power-Generation side	Help reduce system's installed capacity requirements; improving the utilization rate of power generation equipment and planned power generation by renewable energy	Reducing power plant investment and operating costs, reducing generation costs, and increasing power generation efficiency
Power transmission and distribution	Delaying transmission and distribution investment; improving asset utilization; increasing access to renewable energy sources	Investment in transmission and distribution equipment decreased, Network loss reduced
User-side	Demand side management; improving allocation of electrical equipment resources	Reducing electricity cost reduction; increasing power quality and reliability

Note:

- ***Power market is the main application of energy storage in China. Storage battery performance indicators vary, and distribution needs diversify, which benefits business differentiation***

Industrial Chain Flow



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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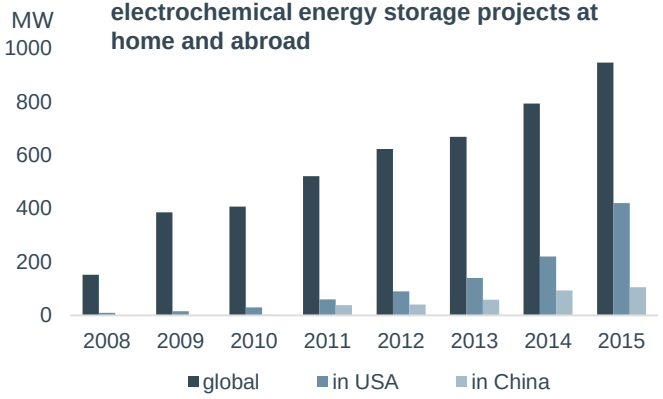
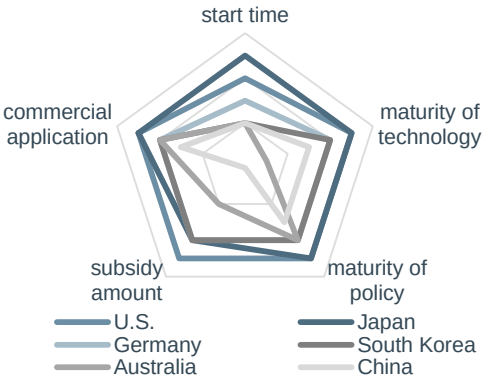
Market Development Stage

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

Comparison of installed capacity of electrochemical energy storage projects at home and abroad



Comparison of energy storage market in different countries



- **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.

"11th five-year" plan (2006-2010) → **12th five-year" plan (2011-2015)** → **13th five-year" plan (2016-2020)**

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

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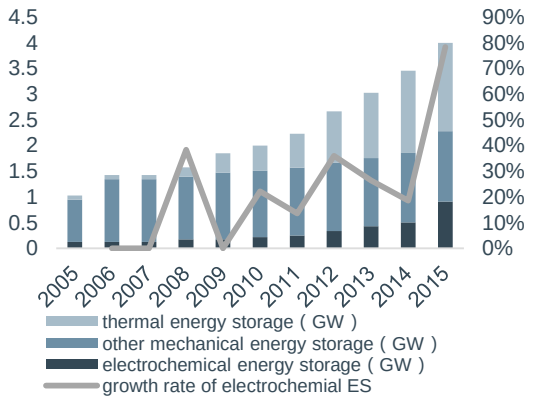
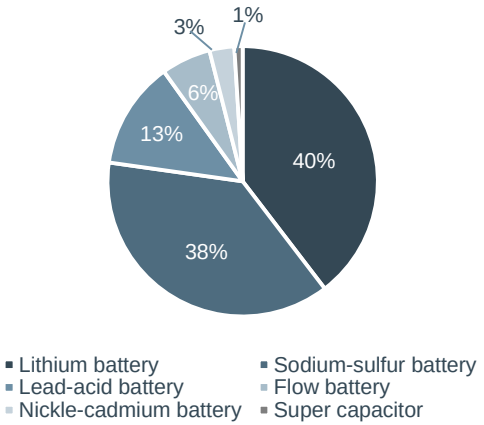
Global installed capacity



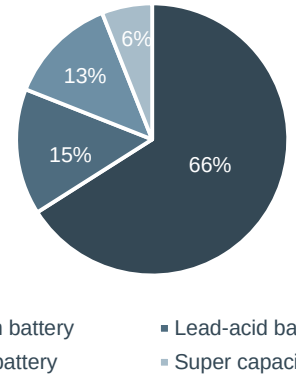
- In terms of installed capacity in 2015, global electrochemical energy storage, other mechanical energy storage and thermal energy storage developed rapidly, with thermal energy storage accounting for 43%.
- In 2015, the growth rate of electrochemical energy storage nearly touching 80%. Growth in Japan's 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



- In China's electrochemical energy storage market, lithium-ion battery installed capacity comes up to 66%, followed by lead-acid batteries (15%) and flow batteries(13%).
- Domestic energy storage capacity is expected to reach about RMB 200 billion by 2020. Lithium-ion battery materials industry will step into large-scale industrialization. With the formulation of the relevant standards and the publication of afterward policy, the market is still expected to grow.

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

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

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

Core content	Planned target
First: the power system reform problems to be solved	**Lack of transaction mechanism**; price relationship is not straighten out; government functions are not in place, and various planning and coordination mechanisms are imperfect
Second: the key tasks of the power system reform	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
Third: strengthening the organization and implementation of the power system reform	Strengthening organization and coordination; creating an active atmosphere; secure and orderly manner

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

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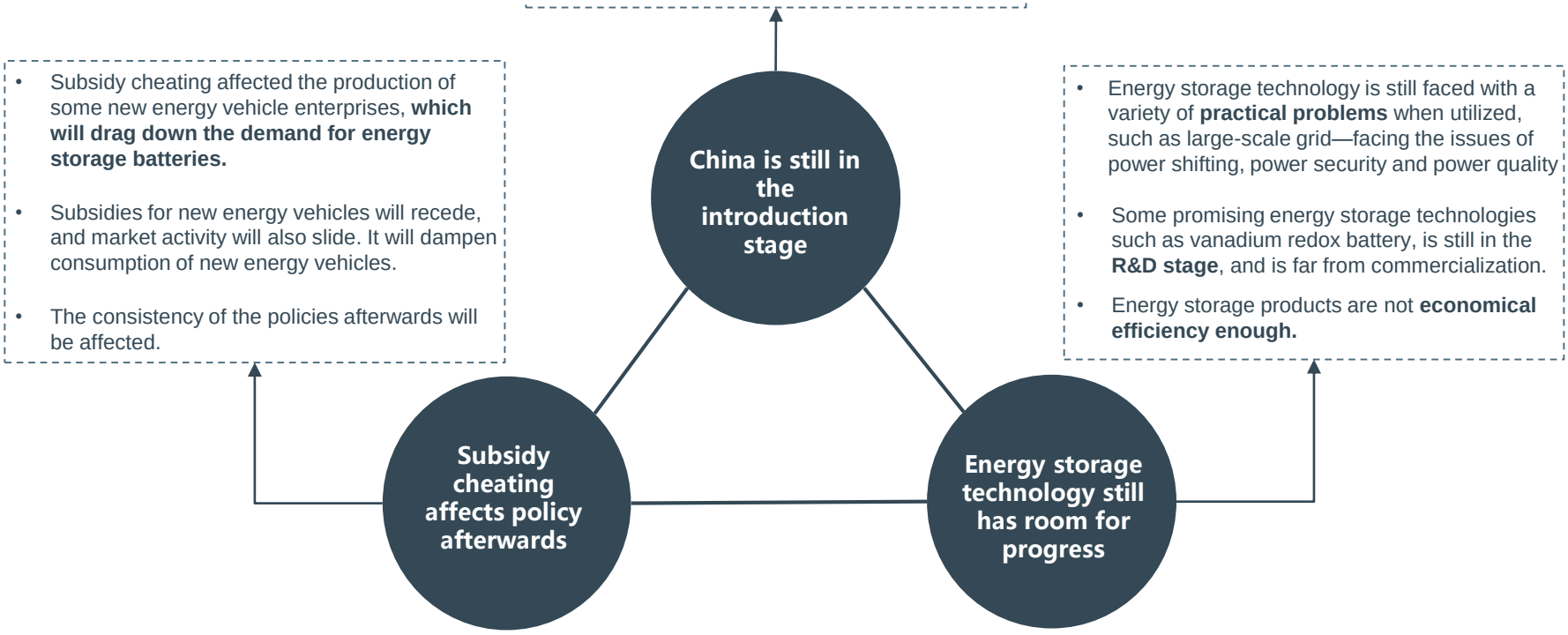
- **Compared with foreign energy storage industry, China started late, and policy planning and subsidy support are inadequate.**
- **Most of the domestic energy storage projects are still functional demonstration projects**, and promotion in different regions are not in the same pace, giving limited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

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Role	Company	Application field	Major product	Micro-grid/Energy storage projects	investment cooperation	Advantage
Battery manufacturer	Narada	Large-scale energy storage system, distributed micro-grid energy storage system, small household energy storage system, independent off-grid energy storage system, commercial energy storage system	Lead-acid batteries (lead carbon, lead-acid), lithium batteries, optical storage integrated micro-grid energy storage, LSJ, REX	45 projects were put into operation, with total installed capacity of 150MWh, and 7 to be built, with total installed capacity of 108.64MWh	Acquired a 25% stake of **Canada SPS** in 2015, receiving large orders of energy storage lithium battery.	**The first** to step into the field of energy storage, and formulated the **"investment + operating"** business model
	SACRED SUN	Distributed energy storage, household energy storage, large-scale energy storage, communication base station energy storage	Lead-acid batteries, lithium-ion batteries, power plants, modular container energy storage system	**Winning bid for telecom base station new energy storage power supply system from China Tower's subsidiaries in Tibet, Qinghai and Inner Mongolia in in 2015.**	In June 2014, gaining lead carbon battery production right from **Japan**'s Furukawa in April 2014.	The introduction of **Furukawa** battery technology, the battery cycle life reached 4,200 times, significantly reducing the cost of energy storage battery
	Rongke Power	Large-scale new energy grid, smart micro-network, independent power supply	Flow battery (all vanadium flow battery), container-type energy storage	Winning bid from Liaoning Electric Power Research Institute **for distributed photovoltaic energy storage micro-grid system** research and demonstration project in June, 2013.	Invested in **Dalian Hengliu Storage Power Station Co., Ltd**. in September 2016	Focused on liquid battery energy storage projects; selected for the China-US Green Partner Program in 2016
Battery supporting facilities suppliers	Sungrow	Distributed energy storage, household storage, etc.	Energy storage converters, lithium-ion batteries, energy storage systems, energy storage accessories	The State Grid's **Zhangbei wind/solar storage** demonstration projects in 2015 Aikang Jinchang Qingneng 100MW **photovoltaic storage power station**, the East African camp **smart micro-grid project**, Xi'an Samsung factory **peak-valley price adjustment projects** in 2016	Announced in November 2014 economic **cooperation with Samsung** to set up two joint ventures to strengthen cooperation on energy-efficient lithium-ion battery packages for power facilities, converters and integrated systems	Possess Sungrow's new **energy power conversion technology** and Samsung SDI world-class **lithium battery technology**
	CLOU Electronics	Household energy storage systems, industrial / commercial energy storage systems, grid-level energy storage systems, EMS energy management systems, electric vehicle battery energy storage	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	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.	Signed a Sino-foreign Joint Ventures Contract with LG Chemical in May 2016 to establish Shenzhen Kelo New Energy Technology Co., Ltd., and holding a 70% stake in the JV.	Taking the geographical advantage of Shenzhen, build a complete energy industry chain of the Internet; **Leader of large energy storage system integration business**
Car enterprises, multi-roles coverage in the industry chain	BYD	Energy storage on the generating side, energy storage on the transmission side, and energy storage on the distribution side	Various products	**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	In September 2014, BYD and Switzerland's ABB developed new battery energy storage system solutions	Leading enterprise of lithium-ion battery energy storage project construction
	Tesla	Household energy storage systems, commercial energy storage systems	Powerwall battery equipment for household usage, commercial public electricity solutions Powerpack	In May 2016, booking of Powerwall and Powerpack totaled equivalent to 600MWh, or 3% of the global 3C orders, and won 500MWh energy storage system AMS order in June.	Planned to acquire SolarCity, but the progress is hindered.	"**Photovoltaic power + energy storage "layout**

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

Domestic Representative: Narada

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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.

The pioneer in energy storage field：Narada

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.

- **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.

Domestic Representative: Tesla

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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"

Creating vertical industrial chain: Tesla

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 of100kWh, 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

Highlights

- 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

Domestic and Foreign Energy Storage Demonstration Projects

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- 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.

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

Sources: public information, SMM

Domestic Representative Case: State Grid Zhangbei Wind/Solar Energy Storage and Transmission Project

Shanghai Metals Market

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:** → Phase I was commissioned in 2011
  9.8MW of Wind power, 4MW of photovoltaic power generation, and 2MW of energy storage system
- **Phase II:** → Phase II was commissioned in late 2013
  400MW of wind power, 60MW of photovoltaic power generation, and 50MW of energy storage system

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	LiFePO	6MW*6h	14839.73
2011/4/13	Dongguan ATL	LiFePO	4MW*4h	8456
2011/4/13	CALB	LiFePO	3MW*3h	6090.99
2011/4/13	Wanxiang	LiFePO	1MW*2h	1443.576

Bid time	Successful bidder	Energy storage technology	Total capacity	Bid amount (RMB 10,000)
2011/9/07	Beijing Prudent	vanadium redox battery	2MW*4h	Negotiation
2013/7/16	Altairnano	Lithium-titanate battery	1MW*0.5h	1498
2013/7/16	Jiangsu Shuang deng	Colloid lead-acid battery	1MW*6h	795
2013/7/16	Narada	Colloid lead-acid battery	1MW*6h	768

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 power **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

Shanghai Metals Market

Energy storage battery manufacturing

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

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

Shanghai Metals Market

Performance index	Lead-carbon battery	Lead-acid battery	NI-MH battery	Lithium-ion battery	Sodium-sulfur battery	Flow battery		
						Vanadium redox battery(VRB)	Zinc-bromine battery	Ferrochrome battery
Scale level	MW	10MW	kW ~ MW	10MW	10MW	5MW/10MWh	1MW/4MWh	250kW/1MWh
Cycle life	1000-5000	600-1000	500-1800	2000-5000	2500	>10000	2000-5000	>10000
Energy density	30-60Wh/kg	30-50Wh/kg	75-150Wh/kg	130-200Wh/kg	150-240Wh/kg	15-30Wh/L	430Wh/kg	15-30Wh/L
Charge-discharge efficiency	>90%	80~90%	0.66	>90%	75-90%	80-85%	65-75%	80-85%
Self-discharge	0.1~0.3%/day	0.1~0.3%/day	0.1~1%/day	0.1~0.3%/day	Low	Very low	Low	Very low
Commercialization difficulty	Medium	Medium	Medium	Hard (consistency)	Medium (ceramic material)	Easy	Medium (plate technology)	Eesy
Operating temperature	Environment temperature affects lifetime	Environment temperature affects lifetime	Environment temperature affects lifetime	Poor performance in low temperature	300-350℃	5-40℃	20-50℃	-10-70℃
Safety	Lead pollution	Lead pollution	Relatively safe	Risk of overheating explosion	Sodium leakage risk	Relatively safe	Risk of bromine steam leakage	Relatively safe
Battery recycling	Recyclable, renewable	Recyclable, renewable	Recyclable, renewable	Hard	Medium	Electrolyte solution	Hard	Electrolyte solution
Cost of electricity (RMB/ KWh)	1500-2000	600-1000	1800	2000-4000	2000-3000	4500-5000	1800-3500	1800-3500
Advantages	No memory effect, low cost, good uniformity	Low price, good recyclability	Long cycle life, high specific energy	High energy density, large output power, no memory effect, fast charge and discharge speed	High Specific energy, high current, high-power discharge, low cost	High voltage consistency, high reliability, long cycle life, large scale	Low cost, long life 100% deep cycling, super power, momentary charge	Low cost, theoretical cost lower than VRB, zinc-bromine batteries
Disadvantages	Low specific energy, corroding environment	Low specific energy, not suitable for fast charge and high-current discharge, short lifetime	With memory effect, hot when charged, short life	High cost, poor overcharge and over-discharge durability	Dangerous when operating temperature is high or over-charged	High cost and low energy density	Corrosive to battery materials, more severe self-discharge	Toxic, low energy density, operation and maintenance difficulties
The most suitable application	Hybrid electric vehicles, electric bicycles, wind energy storage	Communications equipment, power tools, electric control locomotives	Portable electronic equipment, hybrid, pure electric vehicles, vehicle braking	Electronic products, electric bicycle, military, aerospace, wind power	Military, aerospace, wind power, solar energy, telecommunications base stations	Smart grid, large-scale solar, wind power, standby power	Solar, wind power, electric vehicles	Solar, wind power, standby power, research into a halt

Appendix 2: Technical Indicators for Energy Storage Batteries Application

Shanghai Metals Market

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

Sources: IEA, SMM

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