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Energy Storage Technologies and Business Model

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Abstract: As the demand for renewable energy sources continues to grow, the importance of energy storage technologies and the development of sustainable business models for energy storage services have become paramount. This paper explores the various energy storage technologies available in the market and their unique characteristics, including battery storage systems, pumped hydro storage, compressed air energy storage, and more. Additionally, it investigates the evolving landscape of energy storage services and the potential business models that can be employed to maximize the utilization and economic viability of energy storage systems. The paper analyses the key factors influencing the deployment and adoption of energy storage technologies, such as cost, regulatory frameworks, grid integration, and the role of energy market stakeholders. Moreover, it delves into the emerging trends and 1the existing energy infrastructure. By examining the current state of energy storage technologies and providing insights into the development of sustainable business models, this paper aims to contribute to the understanding of the role of energy storage in enabling the transition towards a cleaner and more reliable energy future.
Keywords: Battery, Storage, Energy, Power Supply, Grid Storage.

I. INTRODUCTION

There are several types of energy storage technologies available today, each with its own unique characteristics and applications.

Here are some of the most commonly used energy storage types:

1) *Battery Storage Systems:* Battery storage is one of the most versatile and widely adopted energy storage technologies. It involves the use of rechargeable batteries to store electrical energy. Lithium-ion batteries are commonly used due to their high energy density and efficiency.
2) *Pumped Hydro Storage:* Pumped hydro storage is a well-established and mature technology. It works by pumping water from a lower reservoir to an upper reservoir during times of excess electricity generation. When electricity is needed, the stored water is released from the upper reservoir, passing through turbines to generate electricity.
3) *Compressed Air Energy Storage (CAES):* CAES involves compressing air and storing it in underground caverns or pressurized tanks. When electricity demand rises, the compressed air is released and expanded through turbines to generate electricity.
4) *Flywheel Energy Storage:* Flywheel energy storage systems store energy in the form of kinetic energy by spinning a rotor at high speeds. When energy is required, the rotor's kinetic energy is converted back into electricity.
5) *Thermal Energy Storage:* Thermal energy storage systems store energy in the form of heat or cold. They can use various media such as water, molten salts, or phase-change materials to store and release thermal energy for applications such as heating, cooling, or power generation.
6) *Hydrogen Storage:* Hydrogen can be produced through electrolysis or other methods and stored for later use. Hydrogen storage technologies include compressed hydrogen gas, liquid hydrogen, or hydrogen chemically bound to materials such as metal hydrides.
7) *Supercapacitors:* Supercapacitors, or ultracapacitors, store energy electrostatically. They have high power density, quick charge and discharge capabilities, and a long cycle life. They are often used for short-duration energy storage and applications requiring high power output.

Energy storage devices play a crucial role in various applications such as uninterruptible power supply (UPS) and transmission and distribution (T&D) system support.

Among the different types of energy storage devices, those focused on UPS and T&D system support have received significant attention. Examples of representative technologies in this domain include redox flow batteries, sodium-sulfur (Na-S) batteries, lead-acid batteries (including advanced lead-acid), supercapacitors, lithium batteries, and flywheel batteries. Currently, lithium batteries are widely used.

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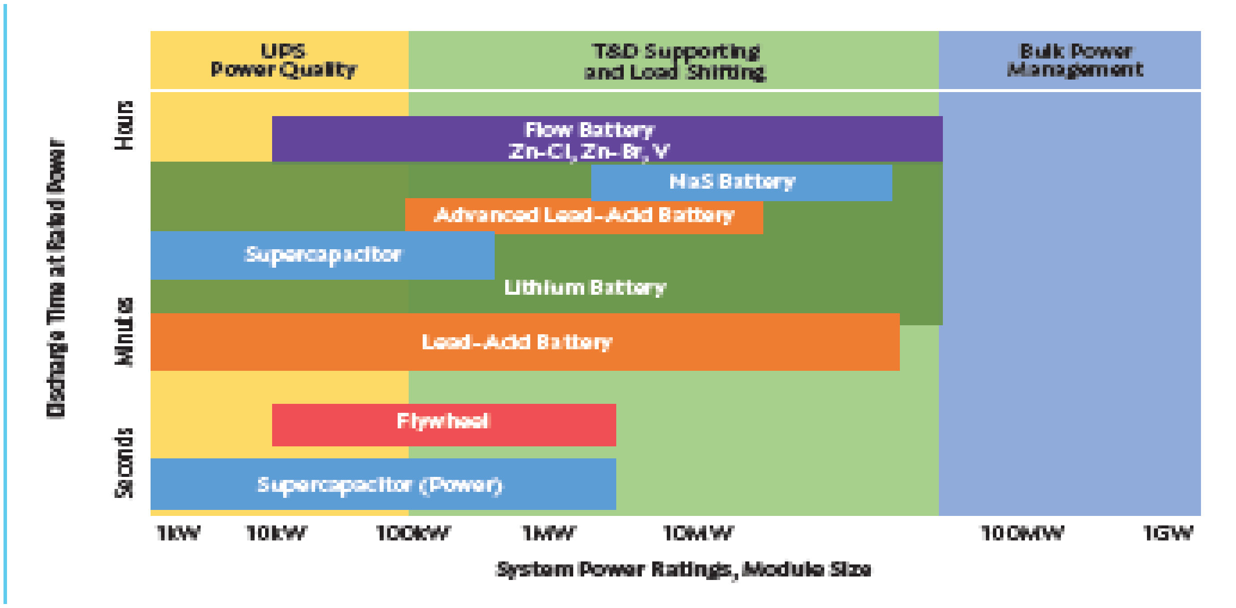

Differentiating battery technologies for energy storage devices involves considering factors such as energy density, charge and discharge efficiency (round trip efficiency), life span, and environmental impact. Energy density refers to the amount of energy that can be stored per unit volume or weight. Lithium secondary batteries typically have an energy density of 150-250 watt-hours per kilogram (Wh/kg), surpassing Na-S batteries by 1.5-2 times, redox flow batteries by 2-3 times, and lead storage batteries by approximately five times.

Charge and discharge efficiency is a measure of battery performance that assesses how efficiently a battery can be charged and discharged. Lithium secondary batteries exhibit the highest charge and discharge efficiency, typically around 95%. In comparison, lead storage batteries have an efficiency of about 60-70%, while redox flow batteries have an efficiency of approximately 70-75%.

These differentiating factors play a crucial role in determining the suitability of battery technologies for specific energy storage applications, enabling stakeholders to select the most appropriate solution based on their specific requirements

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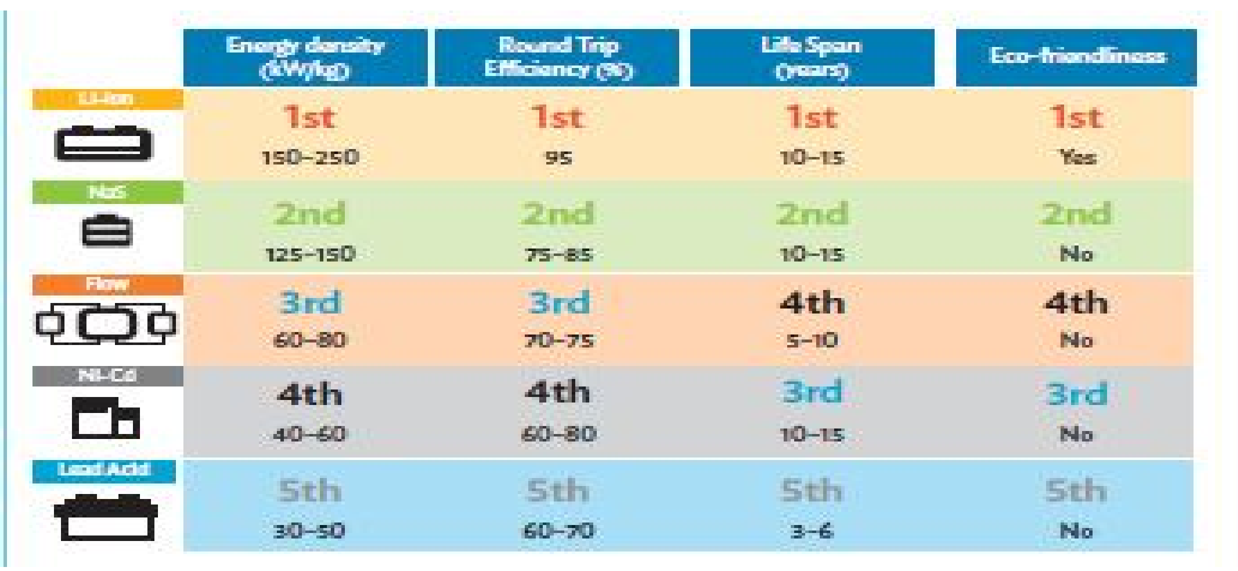

	Energy density (Wh/kg)	Round Trip Efficiency (%)	Life Span (years)	Eco-friendliness
Li-Ion	1st 150–250	1st 95	1st 10–15	1st Yes
NaS	2nd 125–150	2nd 75–85	2nd 10–15	2nd No
Flow	3rd 60–80	3rd 70–75	4th 5–10	4th No
Ni-Cd	4th 40–60	4th 60–80	3rd 10–15	3rd No
Lead Acid	5th 30–50	5th 60–70	5th 3–6	5th No

Advancements in battery technology are driving progress towards higher energy density, as depicted in Figure 1.5. Next-generation battery technologies, such as lithium-ion, zinc-air, lithium-sulfur, and lithium-air, are expected to surpass the energy density of current lithium secondary batteries (rechargeable batteries). Furthermore, these advancements are anticipated to be accompanied by cost reductions, aiming for prices below $50 per kilowatt (kW).

The applications of energy storage devices vary based on factors such as the time required for connection to the generator, transmitter, and energy consumption location. Different timeframes and energy requirements dictate specific applications. For instance, black start technology, which enables generators to restart after blackouts without relying on the external power grid, can supply energy within 15-30 minutes. Power supply for maintaining frequency typically needs to be provided within a quarter-hour to an hour of system operation. Similarly, power supply for maintaining voltage levels is required within shorter operating intervals. The grid storage needs can be categorized according to network function, power market, and duration of use, as illustrated in Figure 1.6. These categories help in understanding the specific requirements of energy storage in the grid. Table 1.1 provides a comparison of different battery technologies based on their discharge time and energy-to-power ratio, which are crucial factors for determining their suitability in various applications.

These models include service-contracting without owning the storage system to outright purchase of the battery energy storage system (BESS). The specific option chosen depends on the needs and preferences of the service user. The following sections describe some of these business models:

II. THIRD-PARTY OWNERSHIP

In this model, a third-party owns, operates, and maintains the energy storage system (ESS) and provides storage services under a contractual agreement. It is similar to power purchase agreements signed with independent power producers. Key terms of third-party ownership contracts typically include:

1) The off-taker (customer) holds the dispatch rights for charging and discharging the ESS.
2) The seller (third-party) earns a fixed capacity payment ($/kW-month) and a variable payment for operation and maintenance (O&M) per MWh delivered ($/MWh).
3) The seller provides an assurance of a specified degree of availability of the ESS.
4) The seller provides an efficiency guarantee.

III. OUTRIGHT PURCHASE AND FULL OWNERSHIP

In this model, the customer outright purchases and fully owns the energy storage system. There is a clear distinction between the procurement and installation processes for different technologies. Pumped hydro and compressed-air energy storage (CAES) technologies differ significantly from batteries and flywheels in terms of size and functionality.

IV. ELECTRIC COOPERATIVE APPROACH TO ENERGY STORAGE PROCUREMENT

Electric cooperatives (co-ops) have a different approach to energy storage procurement compared to investor-owned utilities (IOUs). Co-ops are not-for-profit entities that exist to serve their owner-members living in the co-op service area. They typically rely on loans, grants, and private financing for operation, maintenance, and modernization. Surplus revenue is returned to the members as patronage dividends based on their electricity consumption. Co-ops have voting rights and involvement in setting policies and running the business. This approach may differ from the for-profit structure of IOUs.

The specific entity benefiting from the energy storage system will depend on the chosen business model and contractual arrangements.

In the context of energy storage projects, conducting financial and economic analysis is essential. According to the Guidelines for the Economic Analysis of Projects by the Asian Development Bank (ADB), both project economic analysis and financial evaluation involve identifying project benefits and costs over their respective timeframes and converting future cash flows into present value through discounting. These analyses aim to generate indicators such as net present value (NPV) and internal rate of return (IRR).

However, it's important to note that the perspectives and objectives of financial evaluation and project economic analysis differ:

1) *Financial Evaluation:* Financial evaluation focuses on assessing the project's ability to generate sufficient incremental cash flows to cover financial costs (both capital and recurrent costs) without relying on external support. The primary goal is to evaluate the project's financial sustainability and determine if it can recover its costs and generate returns on investment.
2) *Project Economic Analysis:* Project economic analysis, as shown in Figure 2.2, aims to assess the project's overall economic viability for the country or region where it is implemented. It takes into account broader economic factors and considers the project's contribution to the overall economy, such as job creation, economic growth, environmental benefits, and social welfare. This analysis helps determine if the project aligns with the country's economic objectives and if the benefits outweigh the costs on a societal level.

By conducting both financial evaluation and project economic analysis, stakeholders can gain a comprehensive understanding of the project's financial viability and its broader economic impacts. These analyses provide valuable insights into whether the project is financially sustainable and economically beneficial for the country or region.

When identifying project benefits for economic analysis, it is crucial to consider two key distinctions:

a) *Incremental vs. Non-Incremental Output:* The first distinction pertains to whether the project benefits are derived from incremental or non-incremental output. Incremental output refers to the additional output or production that occurs directly as a result of the project. These are the outputs that would not have been generated in the absence of the project. On the other hand, non-incremental output refers to the existing output that would have been produced regardless of the project. It is important to differentiate between these two types of output to accurately assess the project's impact on the economy.

b) *Market Prices and Valuing Project Benefits:* The second distinction is related to whether the project output is sold in markets and whether there are market prices available that can be used as a starting point for valuing the project benefits. Market prices provide a reference point for determining the value of project benefits. If the project output is sold in markets and market prices exist, these prices can be used to estimate the value of the additional output generated by the project. However, if the project output does not have readily available market prices, alternative methods such as contingent valuation or stated preference techniques may be used to estimate the value of the benefits.

Considering these distinctions is crucial for accurately assessing the benefits of a project in economic analysis. It allows for a proper evaluation of the project's impact on output and provides a basis for valuing those benefits in monetary terms, whether they are derived from incremental output and whether market prices exist for the project's output.

V. CONCLUSIONS

In conclusion, energy storage technologies and business models are expected to play a vital role in the future of the energy sector as we transition towards a more sustainable and renewable energy system. Advancements in battery technologies, grid-scale storage, distributed energy storage, hydrogen storage, and second-life battery applications are some of the areas that hold promise. Business models are likely to evolve to meet the growing demand for energy storage solutions. Energy Storage as a Service (ESaaS) can provide customers with the benefits of energy storage without the upfront capital investment. Companies can monetize energy storage through various grid services, including capacity services, frequency regulation, and demand response. The integration of advanced software and AI algorithms will optimize the operation and management of energy storage systems, enabling real-time energy trading, predictive maintenance, and energy arbitrage. This will lead to more efficient and intelligent energy storage systems.

However, the future of energy storage technologies and business models will be influenced by factors such as policy support, technological advancements, market dynamics, and consumer preferences. Continued research, development, and collaboration between various stakeholders will be crucial to drive innovation and accelerate the adoption of energy storage solutions in the years to come.

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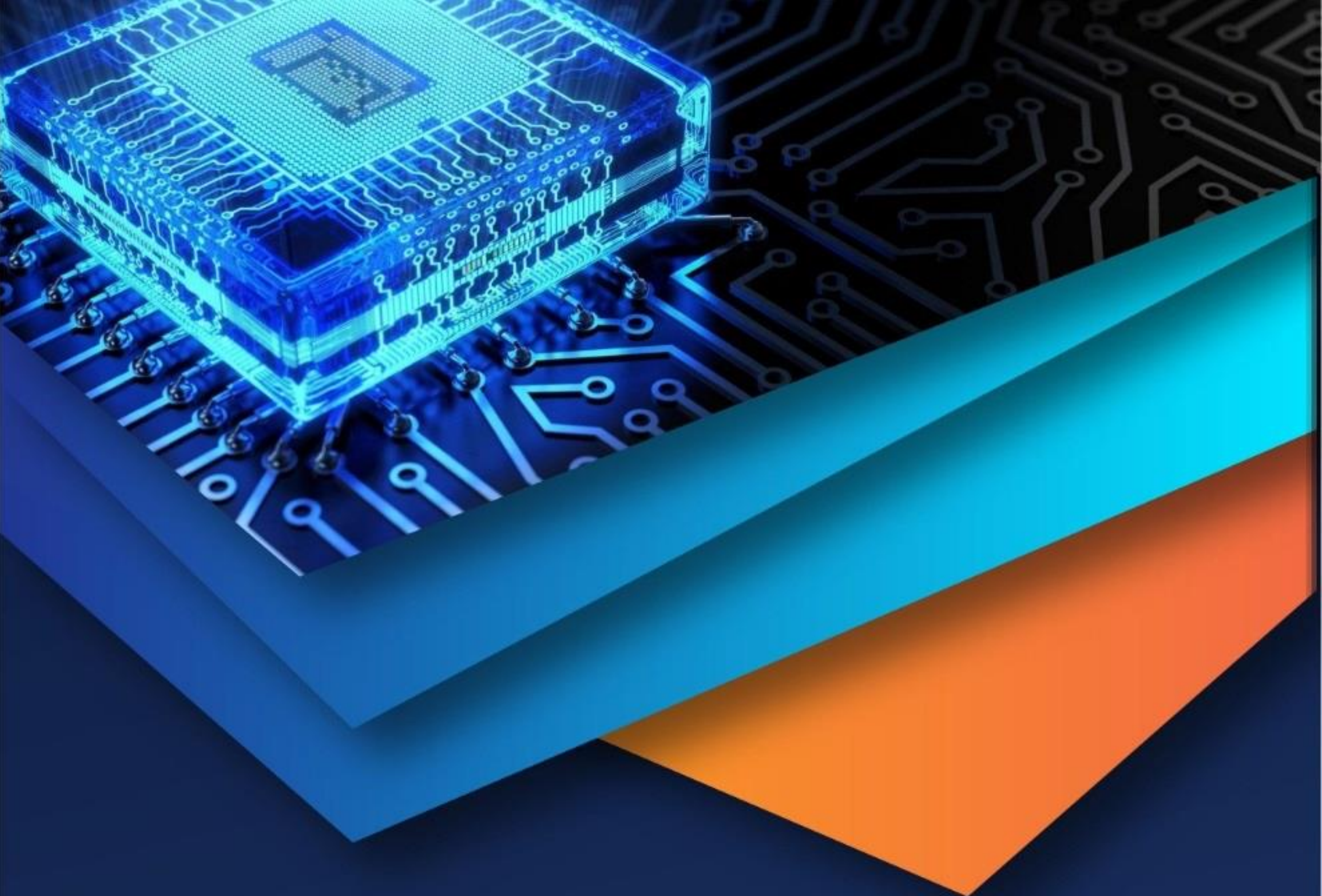

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