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COMPARATIVE COST-BASED ANALYSIS OF ENERGY STORAGE UNITS FOR SMALL AND LARGE SCALE RENEWABLE ENERGY SOURCES

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Abstract

The development of renewable energy sources (hereinafter RES) is increasing day by day and many countries are setting their own indicators as a result of the Paris Agreement. Energy storage devices, known as cogeneration devices, can contribute to the achievement of the targets set for the green economy, including the renewable energy sector. However, the concern is economic and financial viability, taking into account the centralised infrastructure of the Central Asian countries revealing a number of challenges with grid congestion, capacity maneuvering and grid failures that require grid transformation in the initial phase with a planned transition to modernisation. It is also noteworthy that for the transition to a green economy, introducing green technologies in enterprises is a time-consuming and long-term process. An important step in the development of a green economy is the deployment of the renewable energy sector. Therefore, it is proposed to consider the classification of energy storage units, resulting in a relief from grid interruptions and power shortages. In this connection, it is recommended to consider the classification of energy storage, which would make it possible to relieve the grid from interruptions, shortages of electricity during peak times of the day and avoid penalties for inaccurate renewable energy generation estimates.

Keywords: renewable energy sources, the classification of energy storage units.

Energy storage devices do not involve the generation of energy, but rather the storage of energy and the transmission of energy to the electricity grid. The classification of energy storage units is classified as follows: electrochemical, electrical, mechanical, thermal and hydrogen-based storage. Thus, in order to identify the most efficient of the five listed energy storage units in the RES sector from a financial perspective, it is necessary to analyse the consumer and supplier market, to take into account the prices for transportation of the units, including the marginal cost price. This analysis will provide the reader with an analytical overview and a recommendation for later use. In this respect, this article will aim at an analysis of energy storage units. Novelty and problem statement Generation of renewable energy inherently involves the use of many resources that are not dwindling but are constantly renewed. Wind and solar energy are the most widely used in the world today, but energy sources that are clean which is renewable have one major disadvantage. The disadvantage is the inaccessibility in relation to the periods of the following seasons. Likewise, solar energy is only available during the day, whereas wind does not regularly blow. Thus, solar energy is mostly available, when there is less demand for lighting in the household, so it is vital to store energy so that it can be used when needed, and it is in these cases that batteries must be used to store the energy. In the last few years, the market for stationary battery storage has significantly increased due to a growing demand for backup power solutions coupled with power supply security issues. Lack of power grid infrastructure along with frequent power outages in Central Asia will drive demand for stationary battery storage systems. To tackle more relevance on the benefits of the energy battery storage, it is significant to highlight that the use of batteries nowadays necessity. This is due to power supply that can be used at any time when it is necessary. With the use of batteries, excess energy is stored in a battery storage system, and e.g. during bad weather, when the solar power plant does not produce as much energy as required or as planned according to weather forecasts, it is possible to extract energy from the batteries that has been stored during low demand for an energy supply. Energy storage batteries systems allow to solve difficulties by eliminating on-demand charges from a company's utility bill or by providing reliable backup in the event of an emergency. The energy storage battery's annual revenue will be more than $23 billion in 2020 and is expected to rise by an estimated 25.1% on average by 2030 [5], driven by increased investment in sustainable energy sources.

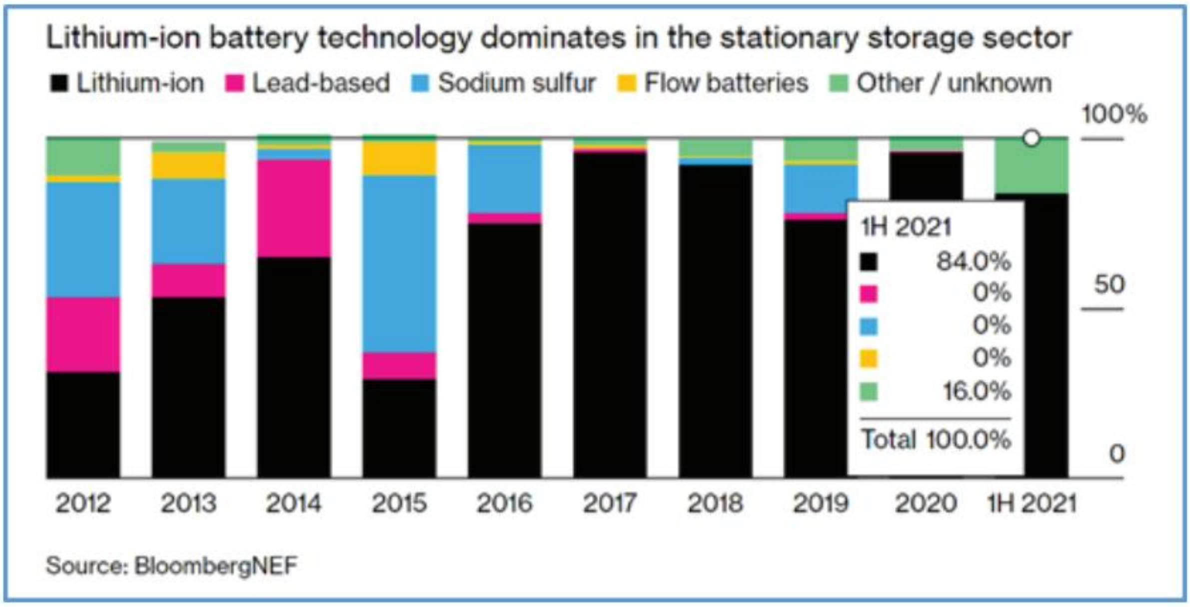

Figure 1 – Lithium-ion battery technology dominates in the stationary storage sector [12]

Energy

According to the Bloomberg (2021) the most dominant energy storage battery at the stationary market is Lithium-ion battery summed at 84% based on stationary storage sector utilization (Refer to Figure 1) [12]. According to Gupta A. (2021) sodium-sulphur batteries and lead-acid batteries are taking the place in the global market after lithium-ion batteries by demand (Refer to Table 1). Sodium-sulphur batteries are expected to evolve due to their high operational safety along with improved temperature stability. High energy density, long battery life cycle duration and improved safety prospects are high priority features contributing to the demand for the products over the projected timeframe.

Table 1. Global Market by battery 2017-2018 (MW & USD million) [5]

Battery	2017 (MW)	2018 (MW)	2017 ($)	2018 ($)
Lithium-ion	2,228.6	3,906.0	3,929.6	6,668.7
Sodium-sulphur	573,6	883.6	1,879.5	2,798.8
Lead-acid	847.9	1375.9	1,703.1	2,706.6
Flow-batteries	103.1	175.0	360.5	582.7
Others	269.6	484.0	611.3	1,065.6
Total	6,824.5	6,824.5	8,484.0	13,822.2

International stock-take examples & experimental part

Gupta A. (2021) cited that the following major players have been included in the stationary battery market study (table 1) such as Tesla, Duracell, Toshiba Corporation, Panasonic Corporation, Samsung and etc. For instance, Tesla, Inc. is an American company that manufactures and sells electric vehicles and energy storage systems. It installs, operates and services solar energy and energy storage products. The company has installed more than 3,100 Tesla wall jacks in more than 1,800 locations worldwide. It was previously known as Tesla Motors Inc. until it changed its name to Tesla, Inc. in February 2017.

In 2017, Tesla partnered with Panasonic [10] to start manufacturing lithiumion batteries to catalyse the shift to sustainable energy. In 2018, Tesla was awarded a project power package in 2018 for assisting in the development of energy storage (lithium-ion batteries) in Australia. Under the energy storage initiative, the Australian Renewable Energy Agency (ARENA) [1] has announced a $25 million co-investment by the Victorian government to fund large-scale batteries connected to the Victorian grid. Tesla has provided power units for a 25MW/ 50MWh battery installed on a 60MW solar farm in Gannawarra. The project is the company's second largest company's energy storage project in Victoria and will strengthen its business in Australia. In addition, it may supply energy for 20,000 households in one hour. In 2019, Tesla unveiled and deployed Megapack, the world's largest lithiumion battery using the company's power unit batteries in Hornsdale, South Australia which was designed for utility scale projects. Recent developments assisted the region to balance, stabilise and support the grid system. Lithium ion batteries - on discharge, lithium ions are deintercalated and transferred to the cathode and the released electrons form an electric current in the external circuit. This type of battery is characterised by high energy capacity, deep charge-discharge cycles and no memory effect.

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Lithium ion battery utilises organic lithium carbonates (LiPF6) [7] as the electrolyte. The negative electrode is commonly a metallic lithium oxide including Limno2, LiCoO2 and LiNiO2, whilst the positive electrode is made from graphite carbon. The sodium-sulphur battery - is a heat-resistant rechargeable battery. The battery works at 300°C and uses a solid electrolyte, which makes it unique among conventional secondary cells. One electrode is molten sodium and the other is molten sulphur, and it is the response between these two electrodes that is the basis of the cell's function. Whilst reagents, and particularly sodium, have the potential to behave in an explosive manner, modern cells are generally reliable [14].

Table 2 – The cost benefit analysis on energy storage batteries [2, 3, 6, 8, 11, 13]

Battery	Cost ($/kW/h) average	Round trip efficiency	Charge and discharge rate	Cycles lifitime of a battery	System size
Lithium-ion	140	80-95%	0.3-6C	10-20 years	140 kWh and more
Sodium-sulphur	10-30	75-90%	0.05-0.8C	20 years	50kWh-400kWh
Lead-acid	100-37	81%	0.02-2C	10 years	140 kWh and more
Flow-batteries	30-100	60%	0.16-0.5C	10 years	1kwh-10MW

Conclusion Information provided in this article is mainly concentrated on international stock-take and examples of the costs on batteries per Kw/h. All individual financial model costs designed for the renewable power plants are mostly disclosed information. An energy storage battery in practice shall be connected to an inverter. In order to be able to provide a comparative cost base analysis to be precise in calculation of batteries quantities, it is necessary to be aware of the inverters' characteristics. This could be charge cycle, bulk charging voltage and cut off voltage power, as well as for instance solar connected cells quantity. Since there is no case study or a renewable power plant capacity being verified by the researcher, the comparative cost analyses can be provided to capacity of the battery storage as 1 Kw/h USD as written above in Table 2. Therefore, it is concluded in order to be able to make a calculation: 1. Solar/wind/hydro power plant needs to be chosen in the country/city. Preferably to contact an organization that would be interested in implementation of energy battery storage. 2. In the chosen company - the inverters characteristics and capacity of the renewable station need to be clarified. With lack of this information, there could be a risk arising in installation of the energy battery storage in terms of compatibility. It is necessary to know, especially, the characteristics of inverter in order to be aware of how much Amper needed for battery and inverter to operate without burning or getting out of the system. 3. Request information on previous year energy generation figures to identify the required battery capacity. By knowing electricity production and considering expensive price of the battery, it will be possible to purchase only 30-50% capacity battery storage. Recommendations An inverter converts direct current into standard alternating current and is divided into these three types: on grid, off grid and hybrid. There is a possibility that an on-grid inverter may not be suitable for the battery, as on-grid inverters normally feed power into the grid system directly. However, due to the need for inverter specifications, the following information is worth considering: the type of the inverter (on-grid, off-grid, and hybrid) which depends on the solar or any other renewable power plant. This means that the on-grid inverter works in contact with the primary electrical grid, acting not only as a converter but also as a corrector for network parameters, such as amplitude variations, purity readings and others. If there is a fault in the external electrical network, the on-grid inverter is automatically switched off. Off-grid is used, where there is no contact with the external power grid, with direct current coming not only from solar panels, but also from the battery.

Meanwhile, a hybrid inverter incorporates both attributes and is used as a redundant system to connect uninterrupted equipment and system operation. Inverter specifications - input voltage, nominal and peak loads, efficiency, temperature rating and overload protection (single-phase or three-phase inverter). Number of trackers, availability of built-in monitoring, i.e. all technical specifications should be considered in order to select a battery pack. In connection with the aforesaid, it is advisable to determine the number of Ampere/hours required to cover the load for the day, in which case it is necessary to know the output voltage of the battery according to the characteristics of the inverter. It is also necessary to consider the lifetime of the batteries, which depends on the degree of discharge, the deeper the discharge, the shorter the lifetime. Batteries must be connected in sequence and in parallel, with series connection the nominal voltage increases and the capacity does not change. The number of batteries to be connected in sequence as well as in parallel should be calculated. The five types of features of inverters were described above where one of them is temperature, it is also recommended to choose the right load controller, as it is responsible for the discharge and charging current. The Controller is the most important element in a solar energy system, which is responsible for the battery tension and prevents the battery itself from failing to operate and failing before the expected time. In this connection, it is recommended to investigate the model of the inverter, determine the daily and peak load capacity of the facility, knowing the type of inverter and based on the peak load data, the number of batteries can be determined. Given the voltage, capacity and current parameters, the batteries will also need to be connected in sequence and in parallel order. For the most part, however, one is frequently looking for those batteries that will be somewhat more inexpensive and suitable. In a comparative analysis, all calculations regarding the inverter should be made, and only after the data is obtained, it is possible to make calculations for the choice of battery. Likewise, with batteries for renewable energy facilities, it is worth selecting a facility and making certain calculations, only afterwards it is feasible to make calculations on the cost of levelised energy and the return on investment on the energy storage battery.

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Резюме

СРАВНИТЕЛЬНЫЙ АНАЛИЗ ЗАТРАТ ЕДИНИЦ НАКОПЛЕНИЯ ЭНЕРГИИ ДЛЯ МАЛЫХ И КРУПНЫХ ИСТОЧНИКОВ ВОЗОБНОВЛЯЕМОЙ ЭНЕРГИИ

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Развитие возобновляемых источников энергии (далее ВИЭ) растет с каждым днем, и многие страны устанавливают свои собственные показатели в рамках Парижского соглашения. Устройства накопления энергии, известные как когенерационные устройства, могут способствовать достижению целей, поставленных перед зеленой экономикой, включая сектор возобновляемых источников энергии. Тем не менее, вызывает беспокойство экономическая и финансовая жизнеспособность, принимая во внимание централизованную инфраструктуру стран Центральной Азии, выявляющую ряд проблем, связанных с перегрузкой сети, маневрированием мощности и сбоями в сети, которые требуют трансформации сети на начальном этапе с запланированным переходом к модернизации. Примечательно также, что для перехода к зеленой экономике внедрение зеленых технологий на предприятиях является трудоемким и длительным процессом. Важным шагом в развитии зеленой экономики является развертывание сектора возобновляемой энергетики. Поэтому предлагается рассмотреть классификацию накопителей энергии, позволяющую избавиться от перебоев в сети и дефицита электроэнергии. В связи с этим рекомендуется рассмотреть классификацию накопителей энергии, которая позволит избавить сеть от перебоев, дефицита электроэнергии в часы пик и избежать штрафных санкций за неточные оценки выработки возобновляемой энергии.

Ключевые слова: возобновляемые источники энергии, классификация накопителей энергии.

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