TECHNOLOGY DEVELOPMENT FOUNDATION OF TÜRKİYE

PIONEER PROJECT INVESTMENT PROGRAM

LONG-TERM, GRID SCALE ELECTROCHEMICAL

ENERGY STORAGE

IN ORDER TO INCREASE THE AMOUNT OF RENEWABLE ENERGY IN OUR COUNTRY'S ENERGY MİX

DEEP DIVE STUDY

December 2022

INTRODUCTION

Activities for Climate Change increase in number in line with various global initiatives and practices such as the Green Deal and carbon border adjustment etc and stand out as an opportunity for change, which will foster the international competitiveness of our industry. **Climate Technologies** refer to technologies intended to slow down or prevent the climate change; to increase adaptation and/or resilience to its impacts; or to support the management of its consequences. Climate Technologies, in which $5 trillion is predicted to be invested annually on a global scale in the coming period, is regarded as one of the areas for a major paradigm shift of the next 20 years. As TTGV, a Pioneer Project Investment Program has been developed in the field of climate technologies, which will be our primary focus in the next 5 years (2023-2028), in an attempt to prove by implementing on site 'one-of-a-kind' technological solutions with high sampling and multiplier effect, which has not been applied in our country before and to contribute to domestic capacity development, market penetration and scaling processes.

For the development of the Preliminary Projects, a process was created starting from the creation of the project idea all the way to the project investment and scaling stage, and **"Long-Term, Grid Scale Electrochemical Energy Storage in order to Increase the**

Amount of Renewable Energy in Our Country's Energy Mix" was chosen as the first/pilot topic. Recent Deep Dive study focused on the following aspects:

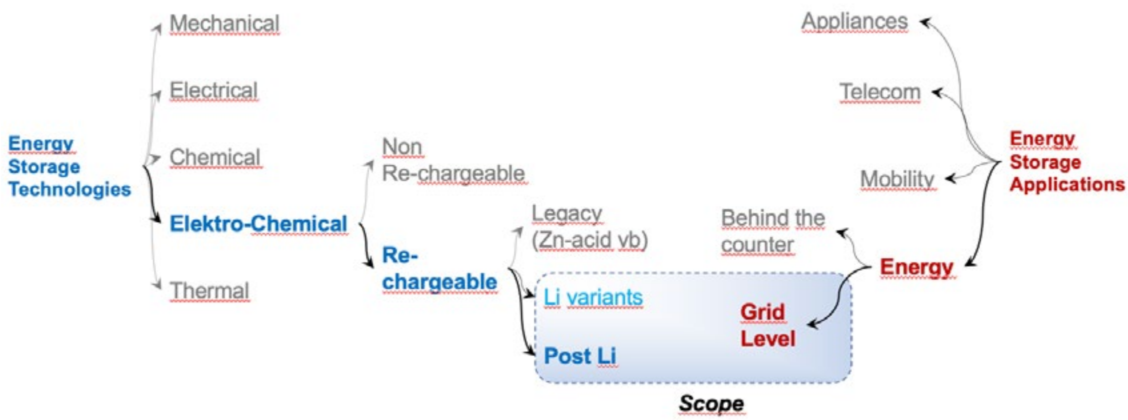

Figure: Focus of Deep-Dive Study

A **Deep Dive** analysis study was performed in an effort to conduct a due diligence on the subject selected in the period of September-December 2022 and create potential project scenarios for the purposes of raising awareness about innovative energy storage technologies in our country, developing our country's high-tech capacity and contributing to the reduction of the country's energy import by ensuring the integration of more renewable energy generation into the electricity grid. In this study, comprehensive examinations were carried out in terms of technology and legislation, and a number of organizations and experts both in Turkey and abroad were contacted for exchange of information. Below are the findings of this study and concise evaluation of the results obtained.

1. As in all over the world, the demand for energy and therefore energy production are increasing day by day in Turkey. Turkiye is a net importer in terms of fossil fuel-containing energy sources, such as oil, coal and natural gas, and dependency on these external sources causes an increase in the current account deficit.
2. Turkiye has a great potential to meet the energy demand in the field of renewable energy, especially with solar and wind. On the other hand, renewable energy sources

cannot provide a continuous and consistent energy supply at all times due to their nature. Emerging energy storage technologies offer a great opportunity to make more use of these resources more effectively and more efficiently.

Cell/Battery Technologies and Energy Storage Systems

3. In general, mechanical, electrical, chemical, thermal and electrochemical energy storage technologies have been used for different applications for many years and they keep evolving. Electrochemical energy storage technologies can be grouped under four key headings in terms of their working principles: conventional batteries (e.g. lead acid, nickel cadmium, Lithium-ion, Sodium-ion), high-temperature batteries (e.g. Sodium sulfide (NaS), Sodium nickel chloride ($Na\text{-}NiCl_2$)), flow batteries (e.g. Vanadium redox, zinc bromine, iron chromium), metal-air batteries (e.g. Lithium-air, zinc-air, iron air)

4. Battery (or cell) technology, which is the major component of electrochemical energy storage, is a challenging and multi-disciplinary subject that requires many years of dedication in order to get reliable results. Technical success at the laboratory scale does not always guarantee any success at industrial scale.

5. Various complementary aspects to be considered in building an appropriate battery industry and technology ecosystem are as follows:

    a. In cell, battery and electrochemical energy storage, training and retaining **highly qualified human resources**, building the industrial ecosystem and the availability/localization of materials/components are the most critical issues for the future.

    b. **Material**, mining and recycling are becoming more and more critical in battery technologies.

    c. It is not only the cell and battery that are needed as the final product, but it also requires the acquisition of **test infrastructure and test knowledge**.

6. **Battery/cell design and chemistry, material selection, production, conversion of batteries to energy storage system, etc**. are all separate areas of specialisation, which are closely associated. While the battery/cell technology is very critical, the

energy storage system is more than a battery. Energy storage system is about system integration and requires the integration of many different subsystems, such as battery pack management, power management, energy management, air conditioning, remote monitoring and management, cyber security, etc.

What problem do the batteries solve?

7. Today, lead acid dominate the electrochemical energy storage market, while it is followed by Lithium-ion technologies. On the other hand, it is still unclear which new technology will come to the fore as a favourite one in the future. With the measures for carbon emissions and the rise in electrification, it is considered that all storage technologies have the "potential to find themselves an area for application" and each technology will be needed at different rates. **There is no single type of battery that fits all scenarios and can prove successful in all performance criteria**. Even for the same field of application, different conditions can highlight different technologies economically. Therefore, in the selection of optimum battery chemistry and storage technology, it is important to know for which applications/scenarios and under which conditions the battery will be used.

8. To give an example, even in mobility applications, it is considered that there might be differences in choosing the right technology between intensive urban usage and intensive intercity usage. There are also significant differences in life cycle management between the batteries exposed to intense vibration in mobility and (for the same battery technology) the ones used in stationary applications. Speaking of the grid scale, the technology to be preferred will change due to the factors such as whether it is used on distribution or production side, the renewable energy resource to which it is integrated (solar/wind, etc.), cold/temperate climate, high/low quality grid (or in other words, less and frequent outage) and voltage stability, etc. Different usage scenarios require different storage economics because different technologies will also require some variations in maintenance and operation. In summary, **usage requirements and environmental/usage conditions must be taken into account in selecting the optimum battery chemistry and storage system design**.

Various Cell Technologies

9. Considering alternative cell technologies very briefly, electrochemical energy storage (especially Lithium-ion based) technologies have made significant developments recently especially in the sectors of mobility (especially electric cars) and electronic device sectors. Lithium-ion stands out (despite low temperature performance and various safety and environment-related problems, Asian domination in the market, raw material availability, fluctuating and high raw material costs, etc.) in meeting the requirements for fast response time and instant high energy, in addition to high TRL (Technology Readiness Level) level and high energy density, and this technology continues to be further developed. There are various investments on this subject in Turkiye, as well (domestic production via transfer of technology) and these investments continue to be made.

10. Also the new technologies (flow, sodium-ion, metal air technologies, etc. other than Li-ion batteries), some of which are still under development and some of which have already been put into use in the field, are promising. High energy capacity, long-term storage, long discharge times and high number of cycles in particular highlight (despite their relatively lower energy efficiency) the flow batteries that have recently been put into use in the field. Besides, while Sodium-ion, which has not yet reached the energy densities as high as Lithium-ion, has the potential to eliminate several handicaps of Lithium-ion, existing energy densities points to stationary application areas in the first place. In addition, metal air battery technology, which has a relatively low TRL level, has the potential to be an option for high performance and long-term energy storage. Although all these different technologies are studied at between TRL 4-9 around the world, there are a wide variety of studies on the laboratory scale (TRL 3-5) in Turkiye.

11. Lithium-ion batteries, the most common option, have high performance and energy efficiency. Although the use of Lithium-ion for mobility is increasing, it is still controversial that it has become “cheap” enough for use at grid-scale. Apart from lithium-ion, commercial applications of flow batteries for fixed storage needs have started to be seen in the field. Sodium-ion batteries and metal-air batteries (R&D yet to be completed) also have a high potential to be strong alternatives in mid and long term. Moreover, it is expected that the use of different energy storage systems collectively as hybrids as required by the application will become widespread in order

to create cost-effective solutions. Furthermore, it will be required **to research non-electrochemical technologies** for long-term storage, as well.

Applications and Scenarios

12. Judging by the area of application, there are numerous needs and scenarios in the use of **grid-scale energy storage system**. In Deep Dive Analysis, most of these scenarios are discussed under two main scenario groups requiring quite different energy storage systems.

13. **First one** is the scenario group, which is also referred to as "ancillary services" shortly and aims to keep the grid ready and in high quality at all times. This scenario aims to solve the problem by stepping into the grid as quickly as possible with the available power kept in the energy storage system. The basic requirements of the energy storage system that will support this scenario: very fast response time, high power density and relatively short discharge time. As a critical note; some scenarios and requirements have been tested for this purpose in KEDEP Project using Lithium-ion technology, which was then an already available battery solution, in Turkiye in the 2020-2021 period. The results obtained through this project have shaped and continue to shape the current and emerging strategies and regulations.

14. **Second one** is the scenario that can shortly briefly defined as "renewable energy integration", in which the energy obtained from sources of irregular supply, especially high-potential solar and wind energy, is stored during production hours and made available when there is no/low production, in principle. In order to increase the ratio of renewable energy in the energy mix, it is necessary to enable the use of solar and wind energy, which can be produced irregularly or intermittently, as some sort of "base load", and therefore they should be integrated with large-scale (grid-scale) energy storage offering long discharge times. Basic requirements of energy storage system, which will support this scenario, are: high energy density, long discharge time and relatively high number of cycles. These requirements move Lithium-ion technology away from being "cost-effective" over time, **considering the entire life cycle of the energy system** under current conditions, and instead it highlights other technological solutions that are more suitable for long-term storage, as fit-for-purpose technologies.

15. Experiments on the second scenario have not yet been conducted in Turkiye, yet. It is considered that there may be a need for conducting large-scale trials and raising awareness of demonstration project(s) which will be implemented for that matter as well as improving the practices and technical capacity, developing a policy set and creating a relevant legislation.

16. In this Deep Dive analysis phase, various project setups have also been studied for grid-scale electrochemical energy storage. TTGV continues its efforts for planning/development and feasibility studies for demonstration projects within the framework of project setups.

CONCLUSION

While the fact that the impacts of global climate change become more perceptible day by day increase the amount investments in existing climate technologies on the one hand, it also give rise to the research for innovative solutions and new technologies, on the other. In the future, climate technologies such as energy production from renewable sources, energy storage, carbon capture, hydrogen, etc. will be vital components for decarbonization, energy independence, economic improvement and development. So, it is fair to say that the technologies for electrochemical energy storage will play a key role in energy systems at all levels and scales (national, regional, organization/enterprise/business, grid, household, etc.) as part of the comprehensive transformation which is required to achieve decarbonization and net zero targets.

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