TECHNOLOGICAL CAPABILITIES ANALYSIS WITHIN THE SCOPE OF ELECTRICAL VEHICLE AND ENERGY STORAGE TECHNOLOGIES: THE CASE OF TÜRKİYE

A THESIS SUBMITTED TO
THE GRADUATE SCHOOL OF SOCIAL SCIENCES
OF
MIDDLE EAST TECHNICAL UNIVERSITY

BY

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IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR
THE DEGREE OF MASTER OF SCIENCE
IN
THE DEPARTMENT OF SCIENCE AND TECHNOLOGY POLICY STUDIES

OCTOBER 2024

Approval of the thesis:

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ABSTRACT

TECHNOLOGICAL CAPABILITIES ANALYSIS WITHIN THE SCOPE OF ELECTRICAL VEHICLE AND ENERGY STORAGE TECHNOLOGIES: THE CASE OF TÜRKİYE

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October 2024, 98 pages

This thesis investigates Türkiye's technological capabilities in the automotive sector, with a particular focus on electric vehicles (EVs) and energy storage technologies. The study utilizes a qualitative research methodology involving semi-structured interviews with stakeholders from the industry, including R&D managers from EV and battery companies, experts from academia and a representative from a technology development platform. Designed as a case study, this study adopts the Dynamic Capabilities and National Innovation System (NIS) approach as the theoretical framework. The data was analyzed using thematic analysis technique to understand the perspectives, knowledge, and experiences of these stakeholders to find recurring patterns. The findings reveal that Türkiye has significant potential in the development of EV and Battery Technologies but faces some challenges to fully utilize this potential. Which technological capabilities are needed to overcome these challenges and how they are formed are objectives of the research. Among the findings of the study is that Türkiye's dynamic capabilities in EV and battery technology should be developed at the firm level. In addition, there are policy recommendations for increasing inter-institutional co-operation and interaction based on the NIS approach of the innovation ecosystem required for innovation. The analysis contributes to the existing studies in terms of showing the existence of possible threats that may hinder the growth and global competitiveness of the sector. The market position of the Turkish automotive industry as one of the most important economic powers will change depending on the developments in new technologies brought about by the transition to clean energy.

Keywords: Decarbonization, Technological Capability, EV, Battery

ÖZ

ELEKTRİKLİ ARAÇLAR VE DEPOLAMA TEKNOLOJİLERİ KAPSAMINDA TEKNOLOJİK YETENEK ANALİZİ: TÜRKİYE ÖRNEĞİ

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Bu tez, özellikle elektrikli araçlar (EA) ve enerji depolama teknolojilerine odaklanarak Türkiye'nin otomotiv sektöründeki teknolojik yeteneklerini incelemektedir. Çalışma, elektrikli araç ve batarya şirketlerinden Ar-Ge yöneticileri, akademiden uzmanlar ve teknoloji geliştirme platformundan bir temsilci de dahil olmak üzere sektörden farklı paydaşlarla yarı yapılandırılmış görüşmeler içeren nitel bir araştırma metodolojisi kullanmaktadır. Bir vaka çalışması olarak tasarlanan bu çalışma, teorik çerçeve olarak Dinamik Yetenekler ve Ulusal İnovasyon Sistemi (NIS) yaklaşımını benimsemektedir. Veriler, bu paydaşların bakış açılarını, bilgilerini ve deneyimlerini anlamak ve tekrar eden örüntüleri bulmak amacıyla tematik analiz tekniği kullanılarak analiz edilmiştir. Bulgular, Türkiye'nin elektrikli araç ve batarya teknolojilerinin geliştirilmesinde önemli bir potansiyele sahip olduğunu, ancak bu potansiyeli tam olarak kullanmak için bazı zorluklarla karşı karşıya olduğunu ortaya koymaktadır. Bu zorlukların üstesinden gelmek için hangi teknolojik yeteneklere ihtiyaç duyulduğu ve bunların nasıl oluşturulduğu araştırmanın hedeflerindendir. Çalışmanın bulguları arasında, Türkiye'nin elektrikli araç ve batarya teknolojisindeki dinamik kabiliyetlerinin firma düzeyinde geliştirilmesi gerektiği yer almaktadır. Ayrıca, inovasyon için gerekli olan inovasyon ekosisteminin NIS yaklaşımına dayalı olarak geliştirilmesi için kurumlar arası iş birliği ve etkileşimin artırılmasına yönelik politika önerileri de bulunmaktadır. Analiz, sektörün büyümesini ve küresel rekabetçiliğini engelleyebilecek olası tehditlerin varlığını göstermesi açısından mevcut çalışmalara katkı sağlamaktadır. En önemli ekonomik güçlerden biri olan Türk otomotiv endüstrisinin pazardaki konumu, temiz enerjiye geçişin getirdiği yeni teknolojilerdeki gelişmelere bağlı olarak değişecektir.

Anahtar Kelimeler: Karbonsuzlaşma, Teknolojik Yetenekler, Elektrikli Araçlar, Batarya.

To my sister

&

To the sisterhood

ACKNOWLEDGMENTS

First of all, I would like to thank my advisor Prof. Dr. Erkan Erdil for his interest, support and understanding from the day I decided to apply to the department until the day I defended my thesis. I was very lucky to have such a generous advisor with his attention and time. I learned a lot from him and was inspired. This thesis could not have been possible without his guidance and encouragement. I am grateful to have chosen this topic and to have worked with him, thank you for everything Erkan Hocam.

I would like to thank my dear co-supervisor Res. Asst. Dr. Yelda Erden Topal for patiently guiding me in every way. I am so glad we met. You came to me like a godsend every time I thought I couldn't do it and gave up. This thesis would not have happened without you. You are an inspiration to me as both a loving mother and a successful woman. May your beautiful energy never fade, thank you from the bottom of my heart.

Also, I would like to thank Prof. Dr. Özgül Keleş for doing everything she could to collect data from the beginning. Without her, I could not have collected this much information. Her comments and suggestions improved me a lot and brought the thesis to its current state. I would like to thank her for helping me produce an interdisciplinary study.

The most difficult issue I had throughout the thesis process was to list my priorities. My dear siblings Didem and Eren, without you, this thesis would never have been a priority for me, and I would not have been able to succeed. You always said, "you can do it" and "we are here". You never complained and did not make me feel alone. Your sister succeeded and thanks to you. I am so glad you exist curly ones, I love you. And Didem, my wonderwall. I know you are always there, and I will always be there for you. I can't wait to be in the acknowledgements section of your thesis in 2 years. My darling Baran, I am so lucky to have you with me. You have been stressed with me all summer and I know how difficult it is for you. We got through the hardest times, there are better days ahead And my chosen family. All those beautiful and successful women surrounding me. For the last 2 years, whenever I have been struggling with something on my own, you have come running and hugged me. Meryem, Ece, Ayşegül, Melek and Begüm; I love you my girls, thank you for everything. Finally, I wanted to thank little Ilgın. Please, always stay a cheerful and angry girl, you have achieved and will achieve everything you want. Love you.

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LIST OF ABBREVIATIONS

COP21	Conference of the Parties
COVID-19	Coronavirus Disease
EV	Electrical Vehicle
GGE	Greenhouse Gas Emissions
IEA	International Energy Agency
Int.	Interviewee
KPMG	Klynveld Peat Marwick Goerdeler
Li-ion	Lithium-Ion Battery
MaxQDA	Qualitative Data Analysis Software
MENR	Ministry of Energy and Natural Resources
Mt CO2	Million tonnes carbondioxide
NGOs	Non-Governmental Organizations
NIS	National Innovation System
R&D	Research and Development
RE	Renewable Energy
REE	Rare Earth Elements
TUBITAK	Türkiye Bilimsel ve Teknolojik Araştırma Kurumu
SCT	Special Consumption Tax
TC	Technological Capability
TURKSTAT	Türkiye Bilimsel ve Teknolojik Araştırma Kurumu
UNDP	United Nations Development Program

CHAPTER 1

INTRODUCTION

The transportation sector, which played a major role in the birth of civilization and its transformation into what it is, is now causing one of the biggest problems that could end civilization: Climate Crisis. Today, humanity has a hard time imagining a world without land, air and sea transportation, and for the future, it must find the least damaging form of all these transportation types to the environment. Road transportation, which plays a major role in the increase of greenhouse gas emissions with internal combustion engines and fossil fuels, has had to go back to where it started: Electrification. Electric engines, which entered other places such as trains and subways much earlier, are trying to reach their best version for cars today. In the 1800s, electric engines were developed by different people in many different places and integrated into rail systems, but they were not at the desired level in terms of power and efficiency. Electric vehicles, which experienced their most successful period between 1900-1910 with the developments in rechargeable batteries, were called "women's cars" at that time because they were quiet and slow (Guarnieri, 2012). While it had a greater market share than internal combustion vehicles in continental Europe and America, it lost its popularity at the same rate when the need for range and speed was revived by the development of highways with asphalt works and the discovery of oil reserves and the decrease in the price of gasoline (Guarnieri, 2012). After 1920, it remained as an "experiment" that disappeared. What was seen here was that any innovation and invention prevented its adoption and spread when the development in infrastructure and production technologies was not parallel. For this reason, the world, which is re-engaging in the story of electric vehicles today, must also approach infrastructure problems such as storage technologies and charging stations/grid power in a holistic manner. The global fight against climate change began in 1992 with the "United Nations Framework Convention on Climate Change"[1] and continued with the Kyoto Protocol[2] in 1997. In 2015, the Paris Agreement was signed at the COP21 held in Paris, which committed to limiting human-induced greenhouse gas emissions below 2 degrees Celsius. As of 2023, there are 196 countries that have become

[1] Source: https://unfccc.int/process-and-meetings/what-is-the-united-nations-framework-convention-on-climate-change
[2] Source: https://unfccc.int/kyoto_protocol

parties to this agreement. With this agreement, each country has taken responsibility according to its own development and submitted its national contribution declarations. The target for net zero carbon emissions set for the global energy sector is also 2050. Türkiye has also become a party to this agreement in 2021 as a developing country. With this step, the "Climate Change Mitigation Strategy and Action Plan" and the "2053 Long-Term Climate Change Strategy" were prepared with the support of the United Nations Development Program (UNDP). Türkiye, which set a 21% reduction target in its national contribution declaration, updated this target in 2023 and increased it to 41%[3]. Türkiye, which has chosen 2053 for its net zero carbon target, is developing strategies with development programs, action plans and climate councils and has roadmaps for the green transformation of basic sectors.

According to Global Carbon Project data, the biggest decrease in global emissions since 1960 was experienced in 2020 (5.4%)[4]. It is seen that this decrease occurred because the mandatory closures in the Covid-19 pandemic restricted air and land transportation. However, it was seen that the emissions increased again in 2021 and continued their upward trend and reached record levels in 2022 (IEA, 2022a). According to the IEA report, global CO2 emissions from the energy sector broke a record with 37 billion tons in 2022, exceeding the situation before the pandemic by 1% (IEA, 2022a). The top 10 countries with the largest share in global emissions are a list led by the People's Republic of China, the United States and India; followed by European countries, Russia, Japan and Brazil, Indonesia, Iran and Canada. The first three of these countries have a share of 42.6% in total emissions[5]. The energy sector has been the largest source of greenhouse gas emissions since 1990[6]. For this reason, the removal of fossil fuels from the global energy sector and clean energy technologies are becoming increasingly important. For this reason, the transition from energy systems with coal and fossil fuels to systems with electricity and renewable energies is progressing rapidly all over the world.

With the Russia-Ukraine war that started in 2022, concerns about energy security have increased and prices have increased in the inflationary environment that emerged after the

[3] Source: https://iklim.gov.tr/db/turkce/haberler/files/T%C3%BCrkiye%20Cumhuriyeti%20G%C3%BCncellenmi%C5%9F%20Birinci%20Ulusal%20Katk%C4%B1%20Beyan%C4%B1.pdf

[4] Source: https://www.globalcarbonproject.org/carbonbudget/22/highlights.htm

[5] Source: https://www.wri.org/insights/interactive-chart-shows-changes-worlds-top-10-emitters

[6] Source: https://www.wri.org/insights/interactive-chart-shows-changes-worlds-top-10-emitters

pandemic. This whole process has increased the investments of countries in renewable energy sources to become independent of natural gas and oil. At this point, renewable energy sources such as solar and wind energy and electric vehicles come to the fore. With the rapidly increasing state support in recent years, the installed capacity in solar and wind energy has increased, while mass production and standardization have begun to be achieved in electric vehicles and storage technologies. For example, Electric car sales in 2023 are expected to increase by 35%, with 3.5 million more units than in 2022 (IEA, 2023a). Rising EV sales are fueling global demand for batteries. According to IEA data, demand for EV batteries increased by 40% in 2023 compared to 2022, reaching over 750 GWh, with the growth rate slowing on an annual basis (2024). Costs seem to have increased in 2022 due to fluctuating prices for battery materials. According to BloombergNEF's annual battery price survey, prices increased by 7% in 2022[7]. 95% of the growth rate in demand for batteries is driven by electric cars (IEA,2024). In Türkiye, this situation is growing rapidly as in the world. In 2023, the number of EVs seems to have increased 5 times compared to the previous year (Table 1). However, hybrid vehicles dominate EVs. Due to the concerns of end-users in Türkiye about this technology, hybrid vehicles may be an intermediate stopping point in the transition to electric vehicles for a long time, with 222,328 units sold in 2024.

Table 1. EV Numbers in Türkiye

Change in the Number of Electric Vehicles Registered in Türkiye (2019-2023)	
2019	1.176
2020	2.797
2021	6.267
2022	14.552
2023	80.043
Source: TURKSTATA	

This is evidence that developments in the sector have been accelerating in recent years. Considering all these developments, innovation is essential to achieve net zero carbon in electric vehicle and storage technologies to reduce costs and grow the industry. Considering the scarcity of low-emission technologies and infrastructure deficiencies; considering the supply and processing processes of critical raw materials in battery technologies; user needs such as range and charging time, which are important for the widespread use of electric cars, require technologies that can quickly produce solutions to all these.

[7] Source: https://about.bnef.com/blog/lithium-ion-battery-pack-prices-rise-for-first-time-to-an-average-of-151-kwh/

Considering the energy transition process that the whole world is rapidly entering, there is a danger that a country like Türkiye, which has a certain competence and position in the automotive industry, may lose its competitive power. Asia-Pacific countries that are quite advanced in electric vehicles and storage technologies may affect Türkiye's sales power in Europe. A country like China, which has only a 10% share in global sales of internal combustion engine cars, has produced more than half of all electric cars sold worldwide in 2023 (IEA,2024). Türkiye should take its place in this transformation with its existing human resources, investments, and automotive production capacity. What needs to be done on this path is to first determine its current situation, determine its potential and the technological areas where it stands out from other countries and can make a difference, and then develop industrial strategies in areas that require international cooperation. In this process, where the state must be an active actor, it has many responsibilities regarding investments, incentives, and cooperation. This technological transformation process, which requires national efforts, is important for it to be able to position its future position now. It needs technological innovations to maintain its competitive power and international position as one of the export centers for both its dynamic local market and Europe and Africa. In this context, science and technology policies in the country should be worked on especially for Türkiye to increase its innovation capacity. With policies that identify technological capabilities, target what is needed to increase them, and impose responsibility and cooperation on all stakeholders on this path, Türkiye can prove its strategic importance in the electric vehicle market.

Turkish automotive industry, which started its activities in the 1960s, has increased and diversified its production capacity by growing more and more every day with 60 years of experience and large investments of local and foreign partners. In addition to automobiles, the automotive industry, which ranks first in Europe especially in light commercial vehicles, consists of 6 vehicle groups including trucks, buses, midibuses and tractors and exports to 82 countries (OSD,2022). The automotive sector, which plays a major role in economic development, not only creates a large part of the employment in the country, but also has created many different sectors with its suppliers and sub-industries. This sector, which has succeeded in developing domestic products such as all components and its own engine, seems to have succeeded in becoming an effective international player with its exports to other countries. In 1995, with the Customs Union Agreement signed with the EU[8], Türkiye managed to use its geographical position strategically and became the largest exporter in

[8] Source: https://trade.ec.europa.eu/access-to-markets/en/content/eus-custom-union-Türkiye

Europe. Today, Türkiye is the 14th largest automotive production center in the world and the 4th largest in Europe and is a strong link in the global automotive chain (KPMG, 2023). According to OSD data, this sector, which has reached an annual production capacity of approximately 2 million units, is in a new transformation process to keep up with the developments in the world (2022). The Republic of Türkiye, which aims to contribute to carbon zero targets, should support the automotive industry, which is both one of the country's locomotive industries and responsible for a considerable amount of carbon emissions, to undergo this transformation without losing its strengths and in a way to create new opportunities for itself.

Although the growth rates of the automotive sector decreased in many countries due to the crisis in chip supply after the pandemic, Türkiye saw an increase in growth in 2022 compared to the previous year due to the base effect (KPMG, 2023). However, due to the inability of production to meet demand in recent years, prices have tended to increase gradually and especially high SCT rates put pressure on prices. For example, according to ODMD data, compared to 2023, sales of electric cars below 160 kW increased by 453.1 per cent to 84.2 per cent, while sales of electric cars above 160 kW increased by 34.5 per cent to 15.8 per cent (2024, January). The reason for this is that the SCT rate for electric vehicles below 160 kW is 10 per cent, while the rate for electric vehicles above 160 kW is 50-60 per cent. Thus, according to 2024 data, the market share of electric vehicles in the total automotive market increased to 6.2% (ODMD, 2024).

It is seen that global automotive manufacturers are trying to provide many technological developments with the themes of digitalization and sustainability to comply with carbon neutrality targets. With the emergence of Tesla and its dominance in the market, countries such as China have tried to launch their own domestic brands, while existing brands have brought many technological innovations by working on new electric models. In this context, Türkiye needs to develop not only its production capacity but also its human resources and research and development activities. Technological capability analysis is an issue that needs to be studied and considered for developing countries such as Türkiye. Although electric vehicles and storage technologies pose challenges, they also offer many opportunities for Türkiye. This process is not only a process of importing and adapting new technologies, but also a process of becoming a country that produces and develops innovations by leveraging its technological capabilities. For Türkiye's automotive industry to maintain and improve its position in the global market, this study will try to understand Türkiye's potential based on the technological capability literature and provide policy recommendations to create a roadmap.

This dissertation is structured in 6 chapters in total. The main purpose of the thesis is to analyze Türkiye's technological capabilities within the scope of electric vehicles and storage technologies. In this context, first, the birth of electric vehicles, carbon zero targets and Türkiye's place in this transformation are explained. In Chapter 2, the literature on technological capabilities is reviewed and the theoretical framework is determined. The subject of technological capabilities will be examined with specific studies from the literature. In Chapter 3, a discussion was conducted on battery raw materials specific to electric vehicles and storage technologies. Critical raw materials, which are seen as the biggest factor in the development of these technologies, were explained by examining the actors in the market. Türkiye's situation on this issue was summarized. In Chapter 4, the research methods and design of the thesis are explained. Qualitative research methods were used while collecting data in this thesis. For this reason, 10 semi-structured interviews were conducted. The interviewees included electric vehicle and battery manufacturers in Türkiye and the academics, which is one of the important stakeholders of this network. The data was analyzed using MaxQDA and a constructivist perspective prevails. In Chapter 5, the findings obtained because of the analysis of the data will be presented. Based on these findings, thematic analysis is conducted, and answers are sought to the research questions. In the last section, the results obtained will be discussed and Türkiye's science and technology policies will be reviewed. Based on the research results, a series of policy recommendations have been presented and it is aimed to contribute to Türkiye's science and technology policies.

In addition to the transformation process of the automotive industry, Türkiye, which has entered the green transformation process with its decarbonization targets, is facing many different challenges. In this context, the research questions of the thesis are aimed at understanding how companies adapt to this transformation, what difficulties they encounter in this process, and what policies are needed to overcome these difficulties. While searching for answers to these questions, previous examples such as Togg and other countries were examined to reveal the aspects of the process specific to Türkiye. This case study, which focuses on the example of Türkiye, analyzes the technological capabilities that must be possessed for the development and spread of electric vehicles and battery technologies based on the literature. In this context, the dynamic capabilities of companies were examined in terms of adapting to rapidly changing environmental conditions. The existence of complementary capabilities was questioned. The science and technology policies that the state should implement for the capabilities that need to be developed were discussed within the scope of NIS. This study aims to contribute to the literature by addressing this double transformation process, which is a new and rapid process for Türkiye, analyzing technological capabilities, and summarizing the current situation for future studies. It shares important findings so that Türkiye can emerge from these bottlenecks by creating opportunities by showing the bottlenecks in electric vehicles and storage technologies.

In summary, this thesis aims to provide a comprehensive analysis of Türkiye's technological capabilities in the rapidly transforming automotive industry in the field of electric vehicles and battery technologies. After showing the current situation, the study will serve as a guide to overcome the obstacles to the production, development and adoption of electric vehicles and storage technologies and to evaluate the opportunities, thus contributing to Türkiye's place as a competitive player in the global automotive and energy markets.

CHAPTER 2

LITERATURE REVIEW

The technological capability literature, which started to emerge in the 1970s, has been expanding its scope with an increasing number of studies. Studies that analyze and try to understand the source of technological development by looking at developed countries have evolved both conceptually and practically from past to present. Many studies have exemplified the technological capabilities of countries such as Korea, Brazil, India, Latin America, and Hong Kong, which enabled them to be internationally competitive despite their late industrialization. However, there are not enough studies on technological capability analysis for a developing country like Türkiye. Countries that can analyze their technological capabilities, compensate for deficiencies, and use them correctly can achieve economic development. For this reason, technological capability literature, with its past and present, is of great importance for developing country economies such as Türkiye as the key to their sustainability.

With the transition to Industry 4.0 and the increasing complexity of information technologies, economic growth theories have also diverged from external growth theories that treat knowledge and its practical equivalent, technology, as exogenous factors. Unlike neo-classical economics, evolutionary theory recognizes that there is information asymmetry between firms. Taking knowledge as one of the factors of production, scholars such as Roomer, Aghion and Howitt developed endogenous growth theories that explain the effect of innovation and technological development on economic growth by including knowledge-based factors (see: A Model of Growth Through Creative Destruction). After these studies, technological development, human capital, and R&D activities emerged as determinants of the economic growth process. Thus, the need for state intervention (such as resource allocation) and policy development in this field has emerged from the free-market economy to increase technological developments.

According to Schumpeter (1934), firms seek new ways of producing a good or service or new ways of creating new markets to gain a competitive advantage over their competitors.

This leads to obsolescence or even extinction of existing economic activities (Schumpeter, 1942). Innovations that increase productivity in the production process cause creative destruction, which is the process of industrial mutation that continuously revolutionizes the economic structure from within, continuously destroying the old and continuously creating the new. (Schumpeter, 1942) Thus, evolutionary economics considers innovation as the driving force of long-term and sustainable economic growth. Innovation according to the Oslo Guidelines (2018, p.20):

> Innovation is a new or improved product or process (or combination thereof) that is significantly different from the unit's previous products or processes and that is offered to potential users (product) or taken up by the unit (process).

According to this definition, innovation considers both the process and the result of that process as innovation. The technological capability (TC) literature investigates the sources and consequences of these technological innovations, which emphasize the importance of technological developments with the goal of economic growth and development to maintain the competitiveness of firms at the micro scale and countries at the macro scale. The literature, the theoretical foundations of which are based on concepts such as innovation, absorptive capacity, and core competence, started with the definition of (TC) by researchers such as Bell and Pavitt, Linsu Kim, Jorge Katz and Sanjaya Lall and the inferences about industrialization in developing countries. In the early studies, especially the distinction between industrialized-late industrialized and developed-developing countries, technology producing and technology importing countries stand out. Since this study will analyze the technological capability of electric vehicles and storage technologies in the case of Türkiye, the literature review will start with an overview of the conceptualization of TC and then focus on studies on the sources, types, measurement, and evaluation of TC. After mentioning the state of the art in the field of electric vehicles and batteries, studies on the current technological capability of the automotive industry in Türkiye will be presented and finally, conclusions that answer the research questions of this thesis will be presented.

2.1. Technological Capability Concept

Technological capability (TC) is a set of resources, skills, knowledge, structures, organizational ties, and prior experience that contribute to the process of generating and managing technological change (Bell&Pavitt, 1993). According to Winter, a capability is "a high-level routine that, together with its implementing input flows, confers upon an organization's management a set of decision options for producing significant outputs of a particular type" (2000: 983). Technological capability includes a range of skills and competences. The main difference between them is that Çetindamar and Günsel define skills as individual abilities to complete a task, while competence is defined as collective skills that have risen above a certain level that the enterprise has (2009). A capability is the ability of an enterprise to perform a set of coordinated tasks in a conventional manner using the resources of the organization to achieve specifically defined results (Çetindamar and Günsel, 2009).

Technological capability is the ability to develop new technologies or to use new technologies effectively to ensure the competitiveness of countries at the macro scale and firms at the micro scale. Technological capability has been defined in different ways by many different authors, and the meaning it has carried since its first emergence and the themes it is associated with reflect the areas where it is most needed. Gamarra&Oliveira (2020), who present a bibliometric study on the technological capability literature, examined how the theoretical foundations of technological capability have evolved from past to present, and compiled the authors and studies that have shaped this field through co-citation analysis and bibliographic coupling method. This study, which presents the theoretical foundations of TC and the research areas it is related to in 3 periods as past, present, and future is a good magnifying glass to look at the literature in terms of its scope and originality. Accordingly, in the past co-citation analysis, the theoretical foundations of TC emerged in 3 clusters: absorptive capacity, innovation, and core competence (Gamarra&Oliveira, 2020). The above theoretical foundations will provide a comprehensive framework for understanding the differentiation of technological developments accelerated by globalization according to the development level of countries. In today's world, where multinational companies and joint ventures are gaining momentum, the following clusters can help to understand how technological capabilities differ at the firm level. Today, technological capability is almost perceived as the ability to innovate. While the clusters that emerged in the bibliographic coupling of the studies that form the current theoretical foundations are innovation capacity, firm performance, and knowledge transfer, it has been observed that the current TC is mostly linked to innovation capacity (Gamarra&Oliveira, 2020). As this thesis analyses the technological capabilities of electric vehicles and storage technologies, the complexity and diffusion of sustainability and climate technologies require predictions on which technological capabilities will be prominent. In this context, the future perspectives presented in the study are a roadmap for the analysis. The clusters found in the keyword co-occurrence combination of future perspectives are as follows: business development, sustainability, and future technologies (Gamarra&Oliveira, 2020).

States that want to maintain their competitive advantage in the international arena, manufacturers who do not want to fall behind in the sustainability race of companies, and academics who will take part in the development of new climate technologies for the world will not be a part of this transformation without identifying their technological capabilities and eliminating the gaps. From this point of view, this thesis aims to contribute to the literature in terms of showing the shape that technological capability analysis will take in the future for all stakeholders.

Table 2. Bibliometric Method of TC Literature

	Theoretical bases in the past	Theoretical bases at present	Future perspectives
Cluster1	*AC* (Absorptive Capacity)	*IC* (Innovation Capacity)	*BD* (Business Development)
Cluster2	*I* (Innovation)	*FP* (Firm Performance)	*S* (Sustainability)
Cluster3	*CC* (Core Competence)	*KT* (Knowledge Transfer)	*FT* (Future Technologies)
Key Authors	Pavitt, Teece, Bell, Lall, Kim	Chen, Wang, Garcia-Villaverde,Liu,Parra-Requena	Wu, Sumrin, Figueiredo et al.
Derived From: Gamarra&Oliveira, 2020			

2.1.1. Pioneers of the Literature

In developing countries, it can be developed with imported technology (Kim, 1980) or through technological learning (Lall, 1992; Bell&Pavitt, 1993). Kim's study (1980), which provides a model of the stages of development for firms in developing countries, includes examples from the electronics industry in Korea. The study summarized the stages of technology development in three phases: first the introduction of imported technology to local firms, then the experience accumulated in the production and design phase with local efforts to assimilate this technology, and finally the increased capability of local staff and the assimilation of technology through export-oriented strategies. This study exemplifies both technology imports, knowledge utilization and production strategies, and the importance of human capital in the acquisition of technological capabilities through government policies that encourage export-oriented competition. There are both successful and unsuccessful examples where technology transfer has improved technological capabilities because the main issue is not importing technology, but selecting, assimilating, and mastering the technology to be imported correctly. Technological capability capacity provides these.

In his study of the technology production processes of the manufacturing industry in Latin America, Katz (1987) concluded that technology imports in the industrialization process negatively affected the production capacity of the local industry. Due to limited R&D activity and lack of established technological capabilities, Latin American industry failed to adapt and adopt imported technology to the local context (Katz, 1987). Criticisms of neo-classical economics, which argues that technology is freely available, have increased with the weak technological development in late industrialized countries as globalization has increased. The way out of the understanding that only developed countries can produce and export technology and other countries are the buyers and users of these technologies has led to the development of many different strategies in the TC literature.

Lall (1992), who stands out with his studies emphasizing the importance of technological learning and technology exports, developed a framework based on the interaction of incentives, institutions, and capabilities. He criticized the view that firm-specific learning and technical effort are unnecessary and irrelevant (Nelson 1987) and underlined that not all firms operate in a common structure with an evolutionary economics approach (Lall, 1992). With this understanding, he brought new definitions to technological change and innovation at the firm level. Technological change at the firm level is understood as a continuous process involving the assimilation or creation of know-how, determined both by external inputs and by existing skills and knowledge within the firm (Lall, 1992). Innovation at the firm level is any kind of search and improvement effort, whether it is adapting technology to new conditions, making small improvements, or achieving significant advances (Lall, 1992). Not all technological capabilities have the same impact on economic performance. Lall attributes this differentiation to the technological learning process that requires skill, effort, and investment after technology transfer (1992). This learning process requires detailed strategy as a transition phase from mastery to professionalism. An area of expertise can be developed and deepened through experience and effort. Lall says that only on-the-job training and familiarity with technological activities are not enough for the labor force that will carry out this experience and effort, pointing out that as technology becomes more sophisticated, the level of education should also increase (1992). For industrialization, the value given to secondary and higher education in science and technology is indispensable for producing high technology.

Another common definition is that TC is the knowledge, experience and skills required to search for suitable technological alternatives, to master the technology to transform these alternatives into output, to adapt and price the technology according to the local market, to institutionalize R&D activities and to perform further technological activities (Costa&Queiroz, 2001). Developing countries can implement different policies to increase their technological capabilities. They try to overcome their deficiencies in physical and human capital through foreign investment. In this article, which tries to explain how foreign investment affects technological capabilities in Brazil, technological capabilities are considered in two different scopes: knowledge utilizing and knowledge producing (Costa&Queiroz, 2001). Producing this knowledge is possible by increasing R&D activities. Factors such as the number of R&D personnel, R&D facility competences, R&D investments will also affect knowledge production processes. Low number of R&D personnel indicates that technological effort is not at the desired level. Although being able to use existing technologies well is also a technological skill, it is understood that technological effort is low because it is on the side that does not produce knowledge (Costa&Queiroz, 2001). As exemplified in this study, increasing technological efforts can be possible with foreign investors.

The characteristics that distinguish knowledge from other production factors can be expressed as non-competitiveness, non-excludability, and accumulative (Saygılı, 2003). Knowledge, which is the source of technological capability, does not lose value as it is used, its use is not limited to the people or institutions that produce it, it increases cumulatively and allows to produce new ones as it increases. (Tiryakioğlu, 2013). According to the accumulation approach adopted by Bell and Pavitt, technological developments are too complex to be limited to codified knowledge and physical capital (1995). Technological development means the production of accumulated knowledge and this knowledge may be codified or tacit. What is important here is to discover the tacit knowledge contained in technological developments. According to Bell and Pavitt, even if late industrialized countries import technological changes, it is not possible without TC to create and manage these changes (1995). Unlike codified knowledge, it emerges through trial-and-error processes and these processes systematically lead to the accumulation of knowledge and experience (Bell&Pavitt, 1995). These accumulations are the building blocks of technological capabilities. For this reason, it has been emphasized that developing countries need capabilities to nurture and manage technological change to move from being mere recipients of technology to innovators.

As technological developments progress very rapidly, the economic environment and conditions also change. To adapt to this change, it is possible to make the right decisions at the right time with TC. Maintaining competitiveness in price and quality is possible by using technological knowledge effectively. This capability enables the development of new products and processes or the creation of new technologies in response to changing environmental conditions (Kim, 2001). According to Kim, the process of creating and accumulating technological capability means technological learning (2001). Looking at the differences between developed and developing countries, Kim put forward the concepts of duplicative imitation and creative imitation (2001). While developed countries obtain technological knowledge through research, developing countries can accumulate knowledge and experience through learning by doing to obtain technological knowledge. Developing countries, which reveal creative imitations with the TC acquired after sufficient accumulation, can move towards original innovation with R&D, human capital, and investments (Kim, 2001).

2.1.2. Absorptive Capacity

This educated and qualified human capital increases the capacity of the firm's absorptive capabilities through experience and skill accumulation. The answer to which capabilities and how they emerge on the road to technological development has been linked to the innovation and absorptive capacity of firms with core competencies. The reason for this situation is the widespread view that for late industrialized countries the way to catch up with technological changes is not sufficient by importing technology alone. Absorptive capacity is the ability of firms to recognize the value of new, external knowledge, absorb it and apply it to business purposes, which is a function of the firm's prior level of relevant knowledge (Cohen&Levinthal, 1990). According to this view, firms should be able to recognize technological or scientific developments, market innovations, assimilate them and adapt them to the local market. While the general view is that the flow of information between the internal units of the firm (R&D, production, marketing) will increase innovation activities, this study also emphasized the importance of external sources of information because it is possible to realize the value of external information only if the firm has prior knowledge. At the most basic level, this prior knowledge includes basic skills and even a common language, but it may also include knowledge of the latest scientific or technological developments in a particular field (Cohen&Levinthal, 1990). Their argument is that firms that do their own R&D, are active in production and invest in issues such as staff training will improve the firm's absorptive capacity as they improve the cognitive learning process behind absorption (1990).

Absorptive capacity can be summarized as a set of capabilities required to manage knowledge. Zahra and George (2002) try to understand the effects of absorptive capacity, which consists of capabilities with different and complementary roles, on the firm's outputs. Accordingly, absorptive capacity is a set of organizational routines and processes that the firm employs to build dynamic capabilities (Zahra & George, 2002). These processes are acquired, assimilate, transform, and exploit, where absorptive capacity creates the knowledge needed to build other capabilities (i.e., marketing). (Zahra&George, 2002) By building on each other, these capabilities put absorptive capacity in a more dynamic framework and emphasize its importance for creating and sustaining the firm's competitive advantage. Unlike previous studies, it has discovered dimensions that will help to analyze absorptive capacity better and has shown that changes to be made on these dimensions can reveal more competitive capabilities.

2.1.3. Innovation&Innovation Capacity

The theoretical foundations of technological capability have of course also evolved with perspectives on innovation. Before the emergence of the concept of dynamic capabilities in 1997, complementary assets were mentioned by Teece. This concept is the first version of complementary capabilities, which later enabled dynamic capabilities to work better. It was discussed how and to whom innovation brings benefits. According to Teece, innovation is know-how, i.e., technical knowledge on how to do things better than the way things are currently done (1986). Turning this technological success into commercial success is possible with the complementary assets mentioned here. Firms may produce, copy, or follow the technology according to their position in the market, and it is not always the technology producer who reaps the profits (Teece, 1986). Those with complementary assets in specialized or critical areas succeed in successfully commercializing innovation. Examples include services such as marketing, competitive production, and after-sales support (Teece, 1986). Another important element in this study is the public policy of governments that want to increase innovation is not only R&D incentives but also the removal of obstacles to the development of complementary assets and infrastructure.

Another study that defines complementary assets as strategic assets and provides insights into their relationship with innovation is the study by Amit and Schoemaker in 1993, which links the sources of a firm's competitive advantage to the use of resources and capabilities. This study, which generally refers to these as strategic assets, investigated the factors (such as brand value) that make the firm unique. It pointed out that capabilities can be developed, transferred and portable through human resources (Amit & Schoemaker, 1993). It says the following about capabilities: “They can be abstractly thought of as ‘intermediate goods’ generated by the firm to provide enhanced productivity of its resources, as well as strategic flexibility and protection for its final product or service." (Amit & Schoemaker, 1993, p. 35) For this reason, innovation is conceptualized as a critical capability that protects the competitiveness of firms.

Another study that reveals important findings on innovation capability is Guan&Ma's 2003 study investigating the relationship between export capacity and innovation capacity of Chinese firms. In this study, the export performances of 213 Chinese industrial firms were analyzed by looking at innovation and firm characteristics. T-test, multiple regression and correlation analyses were used in this empirical study. The study presents 7 dimensions of innovation capability and reveals that investment in other than production capacity will also improve export performance (Guan & Ma, 2003). In this case, it can be concluded that not all firms that invest in technological capabilities will be innovative, but those that invest in innovation capability will have a competitive advantage. This proves the importance of innovation capability and its 7 dimensions for the technological capability literature. These 7 dimensions are as follows: manufacturing capability, learning, R&D, marketing, organizational, resource exploiting, and strategic capability. (Guan&Ma,2003) Although R&D is one of the most well-known ones, it cannot be said whether it alone without the others will improve export performance. It is a noteworthy study in terms of drawing attention to capabilities other than R&D.

Innovation management has become increasingly important in terms of technological capabilities as well as innovation capacity. Accordingly, total innovation management proposed by Xu et al. (2006), which presents a new innovation management paradigm, discusses the time-space dimension of innovation that has not been mentioned before. The approach, which sees all employees as innovators, proposes to increase the synergy between all technological and non-technological processes and, moreover, to create a culture of collective and organizational innovation that includes mechanisms that can bring out innovation anytime, anywhere, anything (Xu, et al., 2006). In contrast to previous studies, a more dynamic and strategic understanding of innovation has been developed that moves away from the 'uncertain' understanding of innovation as a major research and development process that may or may not emerge in the long run to a more improvised and dynamic understanding that distributes responsibility equally to everyone in the organization. This study reminds us once again that in an international market where the competition in innovation is becoming more and more difficult, growth is possible through continuous innovation, innovation in organizational processes and innovation in marketing and globalization and that competitive advantage cannot be achieved without the accumulation and development of technological capability (Xu, et al., 2006).

2.1.4. Core Competence

Another theoretical basis of technological capability is core competence. After the competitive forces and strategic conflict approaches that try to sustain the competitive advantage of firms, the dynamic capabilities paradigm has been put forward. Developed by Teece, Pisano and Shuen in 1997, this paradigm emphasizes that firms need to develop their dynamic capabilities to sustain their existence and competitiveness in a rapidly changing environment. Dynamic capabilities can be defined as the firm's ability to develop, deploy, and protect internal and external competences to keep pace with rapidly changing environments (Teece et al., 1997). This approach, which finds the previous approaches inadequate in explaining the sources of competitive advantage, contributes to the literature by answering the question of why and how dynamic capabilities emerge. Another important contribution is the foundation of 'core competence' which adds a new dimension to the conceptualization of technological capabilities. The seeds of experience, knowledge and skill accumulation that constitute technological capabilities are sown in certain activities of firms and sprout as these activities are repeated. Similar to this analogy, dynamic capabilities consider the quality of repeated routines and the difficulty of imitation as the core competence of a firm. Like the importance of tacit knowledge leading to technological change, differences in the core competences that germinate dynamic capabilities between firms also differentiate their competitive advantages.

Teece emphasized that many organizational routines are tacit in nature. (1982) This approach, which emphasizes the importance of organizational, functional, and technological skills (R&D management, product and process development, technology transfer, intellectual property, production, human resources, and organizational learning etc.), which are difficult to imitate, for dynamic capabilities and the development of management capabilities for this purpose, provides a more holistic and understandable framework (Teece et al., 1997). Competitive advantage does not only come from a strong position in the market or the efficiency of firms. It is also possible to perceive opportunities and threats to survive in the market and to develop dynamic capabilities of weaknesses accordingly. In this approach, the firm should be in harmony with its environment. Teece et al. argue that the way to achieve this is through integration, learning and restructuring; the integration of the firm's internal environment into the external environment, the assimilation of new information coming from this integration and the restructuring process because of this assimilation (1997). The point that draws attention here is that, unlike technological capabilities, dynamic capabilities can produce rapid responses to rapid changes.

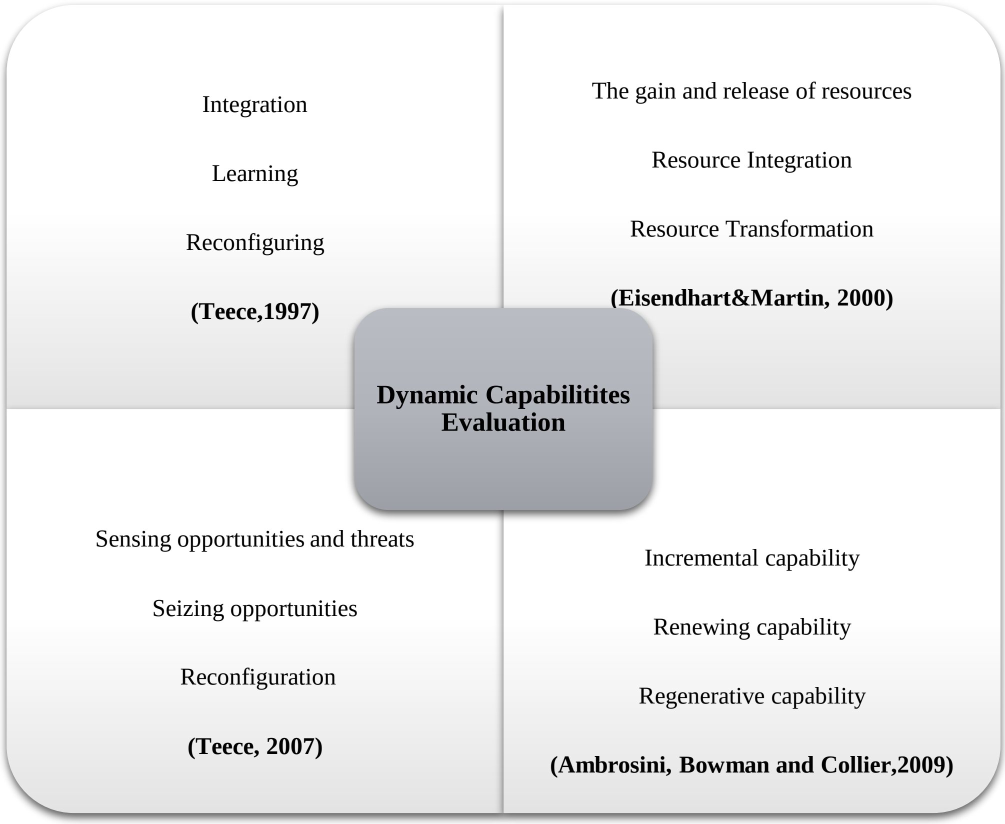

Figure 1. Dynamic Capabilities Evaluation

Source: Elaborated from authors.

2.1.5. Firm Performance

After technological capabilities have been associated with the ability to innovate for a long time, studies on how to make innovation more, more profitable, and more sustainable have also increased. The intensity of R&D studies, R&D investments and the number of patents is seen as the natural result of innovation capacity. However, the new state of competition has revealed the need to measure technological capabilities in a different way by examining examples that failed despite innovating. In this context, Coombs & Bierly's 2006 study, which explains why R&D expenditures and the number of patents not valid measures is for understanding the existence and effectiveness of technological capabilities, has an important place in the literature. The most important conclusion is that measurement systems used alone (accounting or market-based) will not give accurate results, and that multiple measurement systems can make accurate inferences about the result between technological capability and performance. The study challenges the belief that R&D expenditure will be successful and produce technological capability when R&D funds are ‘wasted’ on products or processes that are later abandoned, when an excessive proportion of funds are spent on administrative activities, or when the implementation of new products and processes fails (Coombs & Bierly, 2006). Since this situation will have a negative impact on accounting measures, it will lead to misperception of firm performance and the relationship between technological capability and performance cannot be established correctly (Coombs & Bierly, 2006). The importance of R&D activities can be seen in technological capabilities, which are used by Coven and Levinthal in the absorptive capacity approach as finding external knowledge valuable, using, and exploiting it. Since patents require the ability to innovate, the number of patents is often a misconception that the firm is performing well, but it is more important how they are strategically protected and utilized than the number of patents. Similarly, while patents often have no financial value, the fact that patents are important for investors; in other words, the fact that firms that spend for patents cannot obtain rent in return reflects negatively on firm performance; however, since patent studies indicate the existence of technological capabilities, the technological capability-performance relationship cannot be established correctly based on patents (Coombs & Bierly, 2006). Since the relationship between technological capabilities and firm performance contains layers that are difficult to understand, the firm's determination of the capabilities and competencies that will distinguish itself from others has opened the door for further studies.

2.1.6. Knowledge Transfer

Another different perspective on technological capabilities is knowledge transfer. Studies on this basis analyze the differences in technological capability between start-up and established firms, learning practices, and the process of upgrading of late-comer firms. The importance of this theoretical foundation for the literature is that it provides insights for junior firms in developing countries to find their place in a sufficiently large and complex market. In one of these studies, Aeron & Jain conceptualized different degrees of innovation (creation, modification, and extension) as possible manifestations of different levels of technological capability. (2015) They also stated that they need to discover the technological resources necessary for innovation and develop innovative products through technological learning (Aeron & Jain, 2015). Here, in fact, it is seen that the theoretical foundations of the literature in the past period are reconnected with the absorptive capacity capabilities are still in effect. The previous view that technology transfer will leave firms in developing countries as followers of technology unless they build their own knowledge base has gained new dimensions with the insights of recent studies. Chuang&Lin (2013), who draws heavily on Kim's work, argues that technological partnerships between late-comer firms in developing countries and top-tier firms in developed countries positively affect the competitive advantages of both parties in the market. (2013) The study, which draws heavily on Kim's work, shows that when the technological partnership is established on the R&D side, the knowledge accumulation process, which takes place in the form of technological assimilation, knowledge generation and strategic innovation, benefits the top-tier firm by expanding its knowledge base and providing production capacity, while the lower-tier firm benefits from a more senior position in the market (Chuang&Lin, 2013). The study is important in terms of understanding how knowledge transfer can take place on a global scale, how the parties can mutually benefit and the critical meaning of the role of learning & assimilation capabilities in knowledge transfer.

2.1.7. Future Perspectives in the Literature

The foundations on which the literature has in the past established what technological capabilities are, have now turned into research that looks at how technological capabilities are formed and their sources. As the bibliometric study shows, technological capabilities continue to build on the theoretical foundations of the past and do not dissipate. Innovation in the past appears today as innovation capacity and firm performance. As technologies become more sophisticated and faster, technological capabilities are increasingly sought in the fields of innovation and technology management, which are viewed from a strategic management perspective. In this context, the foundations that have the potential to be researched for the future are important for the technological capabilities’ literature. A bibliometric study mapping technological capability studies revealed the following three pillars: business development, sustainability, and future technologies. It is useful to examine these three pillars to look at the differences in perspective in technological capability research in recent years. In addition, when we consider that electric vehicles and battery technologies are among the future technologies, it is obvious that they can be a theoretical reference for the outputs of this thesis.

2.1.8. Business Development

Hunteler et al. (2016), in their study focusing on Thailand's electricity sector, argue that the barrier to investments due to the high cost required for new technological activities will be overcome with the concept of technological learning. Accordingly, the capacity of developing countries to absorb and adapt new technologies in the process of transition to clean technologies will reduce the cost of these technologies and bring economic growth (Huenteler et al, 2016). The transformation of clean energy technologies into a global industry causes most of the technology to be imported by developed countries and certain components to be produced in developing countries (Huenteler et al., 2016). This has been termed local and global learning. This study shows that for late industrialized countries, the absorptive capacity in the TC literature retains its place because it is concluded that local rather than global learning is the driving force in technological development (Huenteler et al., 2016). What matters in local learning is whether firms have the skilled workforce and organizational processes to absorb the technological knowledge generated. In cases where they do not, these capabilities should be consciously developed. The importance of this paper is that it links the development of such capabilities with a sustainable business model. Hunteler et al. argue that technological learning capability will not develop for firms that do not have this business model and that the state should contribute to this process through regulatory frameworks (2016).

Patents, which are seen as an output of technological activities and are considered noteworthy for understanding the development of technological capabilities, are another study in which technological capabilities are evaluated within the scope of the business model in Leiponen&Delcamp's 2019 study. Accordingly, a licensing firm can only recognize high-quality patents with strong technological expertise (Leiponen&Delcamp, 2019). This strong technological expertise is specific to firms with advanced technological capabilities. Not only knowledge generation and production capacity but also the commercialization of the product requires a technological capability. From this point of view, when a firm with technological expertise adopts an innovation-oriented business model, it acquires patents that other firms cannot recognize (Leiponen&Delcamp, 2019). This study brings innovation to the past understanding that the number of patents is used to distinguish technological capabilities at the firm level and emphasizes the importance of the business model.

2.1.9. Sustainability

The increasing importance of climate technologies and developments in this field have obliged companies to develop competition in the field of sustainability. Both government commitments to decarbonization and public awareness of the climate crisis have turned the steering wheel of technological developments towards the theme of sustainability. Especially environmentally sensitive technologies are desired both by customer demand and international funds. Innovations developed in this context are defined as eco-innovation. Claude Fussler and Peter James used this term in their book “Driving Eco-Innovation” (1996). James later defined eco-innovation as ‘new products and processes that provide customer and business value but significantly reduce environmental impacts’ (1997). One of the studies in which both product and service innovation and environmentally sensitive innovations are examined within the scope of sustainability is ‘Eco-innovation for environment and waste prevention’ by Sumrin et al. (2020) The use of mostly plastic materials in packaging has been made recyclable and biodegradable by customer demands. This is a good example that innovation can arise from customer demands and needs. Sumrin, who examined this eco-innovation in packaging, mentioned that managerial environmental awareness; technological capabilities, human capabilities, and organizational capabilities both contribute to technological developments in waste prevention and gain competitive advantage by improving the brand values of companies in the context of sustainability (2020).

Studies on how eco-innovation affects firm performance are important studies in terms of understanding the necessity of technological capabilities. For example, in Cai and Li's article published in 2018, data were obtained from 442 Chinese firms through a survey. Based on the resource-based view and institutional theory, the study tested hypotheses about the drivers of eco-innovation in the light of the data obtained and found that technological capabilities, environmental organizational capabilities, market-based tool, customers' green demand, competitive pressure triggered eco-innovation (Cai&Li, 2018). The positive relationship between eco-innovation and technological capabilities is based on the previous environmental management system that firms' environmental awareness and operational efficiency make them more innovative (Horbach, 2008; Wagner, 2008). Environmental organizational capabilities help firms to promote operating efficiency by developing organizational capabilities and practices that include a systematic, comprehensive, planned, and documented approach to environmental programs and practices that focus on reducing a firm's environmental impacts (i.e., pollution prevention, recycling, and green product design), aiming for better environmental quality at lower costs. (Cai&Li, 2018, p. 111) In this context, one of the important findings of the study is that firms with an environmental management system have the power to influence the network they are in and direct their stakeholders towards eco-innovation. The competitive advantage provided by eco-innovation thus illustrates that firms with sustainability awareness and goals should develop their technological capabilities in this context.

2.1.10. Future Technologies

In the context of future technologies, areas such as renewable energy technologies, 3D printing, nanotechnology, nanotechnology, smart cities, and biotechnology seem to include the technological capability studies of the future (Gamarra&Oliviera, 2020). However, in the context of the subject of this thesis, this section will focus on studies that analyze technological capabilities within the scope of batteries and electric vehicles.

Wu et al.'s research on NEV vehicles is based on data from 127 firms from the Chinese automotive industry (2020). China, which dominates the market in terms of product, sub-industry, and raw material supply, especially in the field of battery technologies, is a difficult competitor in terms of price and quality in the international arena. The economic and political underpinnings of this are discussed in the section of the literature review on EV and Storage Technologies (See Chapter 3). In this context, the findings presented in this study are important for making sense of the Turkish case. The paper explores the role of technological capability in the R&D of new energy vehicles (NEVs) and its interaction with external resources such as government support and cooperation (Wu et al., 2020). The concepts of sustainability and eco-innovation have been explained above with case studies. In Cai & Li's study described above, eco-innovation is associated with technological capabilities, environmental organizational capabilities, competitive pressures, green customer demand, market-based instruments (2018). In Wu et al.'s study, with a similar approach, the driving forces of eco-innovation are analyzed in 2 groups as internal (technological capabilities i.e., financial capability and size) and external (R&D subsidies, cooperation, environmental regulation, market demand) factors (2020). The interaction between these two factors has been the subject of many different studies. As a result of these studies:

1. The impact of the firm's internal resources on strategic actions depends on external conditions (Boyd et al., 2012),
2. The link between technological capacity and NEVs' R&D is related to the fact that government support develops technological capacity as an external resource (Whitmarsh& Köhler, 2010),
3. Government subsidies affect the cost-effectiveness of R&D investment (Tsai&Liao, 2019),
4. It has been observed that government subsidies, with their impact on cost, have led to the formation of external partnerships, enabling firms to develop internal or collaborative R&D in the R&D of NEVs (Schmiedeberg, 2008).

In this context, Wu et al. argue that very few studies have empirically investigated the role of the firm's technological capability in the R&D of NEVs, which is emphasized in the eco-innovation literature, and emphasize its contribution to the literature (2020). Looking at previous studies, it is concluded that increasing technological capability through R&D promotes eco-innovations (Horbach, 2008) and that the endogenous factor of technological capabilities is more relevant to eco-innovation than other innovations (Del Rio et al., 2015).

Wu et al.'s study confirms the following hypotheses: that R&D investment as a technological capability enhances eco-innovation, the positive relationship between eco-innovation and technological capabilities as government ownership of R&D investments increases cost-effectiveness, and finally that technologically lagging firms may benefit more from government subsidies for R&D outputs of NEVs compared to technology-leading firms. These results are valuable as a reminder of the unpredictable nature of R&D. It is obvious that firms need to acquire more resources so that asymmetric information does not alienate them from the R&D process (Tsai&Liao, 2017).

As for the results of the study, eco-innovation patents, which are seen as the output of R&D expenditures, once again emphasize the importance of government support and external cooperation in terms of the cost-effectiveness of R&D investment. (Wu et al., 2020) Since this study, which is a rare study on NEVs in terms of examining the relationship between technological capability and eco-innovation, adds the insufficiency of empirical evidence, it is understood that the literature will require more strategic studies on NEVs in the future.

After this study, which clearly demonstrates the impact of government subsidies and ownership on the technological capabilities that drive innovation, it is important to look more deeply into the National Innovation System approach.

2.2. Sources of Technological Capability

This section discusses the sources from which technological capabilities come and the characteristics of these sources. Technological capabilities, which determine the competitiveness of a country in the international arena, are a critical element especially for developing countries like Türkiye. It is known in the literature that this element is developed through sources such as national innovation system, technology transfer and labor transfer.

2.2.1. National Innovation System

NSI was defined by Freeman in his book 'Technology, Policy, and Economic Performance: Lessons from Japan' in 1987 as 'network of institutions in the public and private sectors whose activities and actions initiate, import, modify and diffuse new technologies' (Freeman, 1987). The NIS includes a systemic approach to understanding innovation, with contributions by authors such as Dosi et al. (1988), Lundvall (1992), Lall (1992), Nelson (1993), Edquist (1997) and validated by OECD reports on science policy. It mainly focuses on the interaction between technology, institutions, and organizations. It has an important place especially in policy studies. Since policy design will be done in the last part of this thesis, it is important to examine it in this study as a theoretical framework.

NIS, which has developed in two different branches looking at the knowledge-based economy and the interaction of institutions, is basically what governments should do for firms to increase innovation. Authors such as Nelson, who examined institutions as a unit of analysis down to their rules and wondered how NIS is organized, looked at the interaction of each actor that constitutes the system. As the output of this interaction, R&D and patent performance are associated with innovation. According to Nelson, a NIS "is a set of institutions whose interactions determine the innovative performance of national firms" (Nelson, 1993, p.4).

The approach that focuses on knowledge and learning processes is closer to the knowledge-based economy approach. For example, Lall (1992) criticized the difficulties faced by developing countries by criticizing the neo-classical model and emphasized that technology cannot be easily taken and transferred from developed countries, and that each country requires assimilation and adaptation of technology in its own conditions. Firms that can only carry out this learning and assimilation process through accumulation of technological capabilities need some national technological efforts. His study, which discusses these technological efforts in the context of technology transfer and labor transfer, put forward criteria such as the ratio of total R&D expenditures to GDP, the number of patents, the number of scientists and engineers required for R&D (Lall, 1992). Looking at examples of advanced economies, Lall sees technological capabilities as 'the best that can be achieved' (1992, p. 7), associated with the provision of human capital, savings, and existing capital stock, as well as the technical and organizational skills to use them (1992). In terms of the role of institutions here, they seem to have a complementary role. The behavior of firms within the national system depends to some extent on the attitudes of institutions. Lall discusses the interaction between capabilities, incentives, and institutions in the context of whether there are institutions to provide incentives or not, and that these will affect the technological capabilities of industries as an exogenous effect. For this reason, we can consider incentives as supporting the technological capabilities that create innovation with the incentives provided by institutions. The view that there are institutions to provide these incentives, or that they should be created if they do not exist, clearly suggests that government intervention is necessary for innovation and technological endeavors. For this reason, this study has explained to policy makers that 'careful' and 'selective' interventions are necessary for innovation success (Lall, 1992). Lall furthered the work in this field under the name of national technology system. This approach, which refers to the processes of assimilation, adaptation and learning of knowledge, is valuable for developing countries as it shows that the transfer of technology and labor on the road to industrialization should be fed by local capabilities.

Another study that gives importance to knowledge processes is Lundvall's approach that sees the NIS as a knowledge-based network. For Lundvall, NIS "is constituted by elements and relationships which interact in the production, diffusion and use of new, and economically useful, knowledge" (Lundvall, 1992, p.2). Emphasizing the importance of learning and knowledge sharing to innovate, Lundvall argues that innovation arises not only from individual inventions but also from social and institutional interactions (1992). This study is holistic in the sense that it shows which actor plays what role in a complex innovation system in which there are many actors and all of them come together to form a strong innovation ecosystem. R&D activities required for innovation are affected by the education system as much as they are affected by government policies. In a way, he sees these interactions as complementary capabilities that increase the function of the main inputs of innovation. The study, which contributes to development policies with the term learning economy, considers knowledge as the basic source of innovation and learning process as the basic process for innovation with the aspect of university-industry cooperation that increases the accumulation of knowledge in R&D processes (Lundvall, 1992). Furthermore, organizations innovate and learn through their interactions with users, suppliers, competitors, universities, or regulators in innovation systems (Fagerberg et al., 2007; Lundvall et al., 2009). In contrast to Lall, he argued that the indicators for performance measurement of NIS are 'not yet' developed.

With the rapid development of information technologies and the increasingly unpredictable nature of innovation, it has become difficult for firms and countries to keep pace with this rapid transformation. According to the OECD, the complexity and dynamism of the innovation-driven economy has forced governments to explore new directions for innovation management, even if this does not require a major system design in innovation policy (2002). Related to this view is the view that the NIS approach lacks the theory and methodology for systemic empirical comparisons (Balzat & Hanusch, 2004). Moreau argued that the diversity of ‘national idiosyncrasies’ needs to be considered and that elements of NIS need further theoretical development to be more useful in policy making (Groenewegen& Van der Steen,2006; Moreau, 2004). According to Malerba (2005), the literature on innovation systems has struggled to explore the dynamics of the system. Understanding how new systems emerge and how they relate to their predecessors requires in-depth efforts. These dynamic innovation and economic systems that constitute NISs are quite complex.

Therefore, the NIS, which provides insights for countries to develop unique policies and improve their innovation performance, is quite compatible with the technological capability analysis of Türkiye's case in EV and battery technologies, which is the subject of this thesis with its complex and up-to-date structure. The National Innovation System is the policies that enhance the interaction of actors in the network to increase the efficiency of technological endeavors such as R&D activities and the innovation capacity of countries. In this context, the NIS plays a vital role in the development of technological capabilities required for innovation performance and the competitiveness of countries.

2.2.2. Technology Transfer

The importance of technology transfer in the context of NIS, especially discussed in Kim's work and in the absorptive capacity section, is that it is the source of technological capabilities, but without national technological endeavors it is not useful in developing and enhancing capabilities. The imitation processes, absorptive capacity, acquisition, and adaptation of the transferred technology require effort on the part of both human resources and physical capital. Failure to assimilate the acquired technology in a way that contributes to the re-knowledge production through learning processes may lead to a vicious circle where countries are left standing while trying to improve their capabilities through technology transfer. For this reason, technology transfer can be put into practice in a more effective framework for developing countries by increasing education from primary to secondary and higher education, returning qualified personnel to brain drain, developing export strategies, intensive corporate R&D activities, setting competitive international targets, importing capital goods instead of importing technology (Kim, 1998: Kim, 2001).

2.2.3. Labor Transfer

Labor transfer is seen as another source for developing technological capabilities. This perspective argues that knowledge and skills transfer is achieved through the transfer of skilled labor. Lall (1992) emphasized this point and stated that if labor transfer is supported at the national level (NTS), such transfers of knowledge and skills will contribute to local technological capacity. Due to the tacit nature of knowledge, transferring labor with technological knowledge rather than transferring technology may reduce risks. Moreover, labor transfer plays a decisive role not only through the direct transfer of knowledge and skills, but also in the training of the local labor force and the management of R&D activities (Bell & Pavitt, 1993). Organizations need to make conscious technological efforts to create capabilities in the form of a skilled workforce and organizational processes to absorb the new knowledge and experience they generate (Cohen and Levinthal, 1989). This is because the previous view that the production and effective use of knowledge and technology at the national level can be realized through the assimilation and adaptation of imported technologies is only possible through the accumulation of human capital with these skills. Freeman and Soete (1997) emphasize that the global mobility of skilled labor plays a role in enhancing technological capabilities, especially for developing countries. For example, India's growth in the information technology sector has been accelerated largely by the transfer of highly skilled labor from the West (Saxenian, 2005). Moreover, labor transfer not only provides knowledge accumulation but also strengthens local innovation ecosystems, which is important for NSI.

The inevitable necessity of absorptive capacity also applies to technology transfer. Adapting technology to local conditions is at least as important as transferring it and the labor force capable of using it. In other words, the individual technological capabilities of the labor force should work in harmony with the technological capabilities of the firms in the local context.

CHAPTER 3

TÜRKİYE'S CURRENT SITUATION IN EV AND STORAGE TECHNOLOGIES

Despite the challenges of the transition to ‘clean energy’ and zero carbon emission targets set out in documents such as the Green Deal and the Paris Agreement, most countries have pledged to achieve these targets by 2050. The transport sector, which has one of the largest shares of carbon emissions, is also moving towards the target in the middle of this transformation thanks to electric vehicles. Although electric vehicles have become increasingly widespread in recent years, they are more costly than conventional internal combustion vehicles due to their high-tech components. In addition to obstacles such as vehicle range, infrastructure deficiencies such as the scarcity of charging stations and the length of charging time, the most important problem in front of the adoption and further spread of this technology is battery raw materials and production, which directly affect the cost. Disruptions in the supply chain of these raw materials cause price fluctuations and production efficiency is low in terms of reserve and processing. In this section, which aims to determine the sectoral status of critical materials used in Li-ion batteries and Türkiye's position in terms of these materials, critical materials are first introduced.

3.1. Definition and Importance of Critical Materials

In the report titled ‘The Role of Critical Minerals in Clean Energy Transitions - World Energy Outlook Special Report’ published by the International Energy Agency (IEA) in 2022, the establishment of reliable, sustainable, and durable systems for the transition to clean energy is discussed in a multifaceted manner. In this report, it is stated that electric vehicles require 6 times more mineral inputs compared to conventional vehicles (IEA, 2022b). These minerals are listed as lithium, nickel, cobalt, manganese, graphite, silicon, rare earth elements, copper, and aluminum. To define the functions of these minerals simply;

- **Lithium:** It is the main component of the battery cell. Lithium ions provide storage and transport of electrical energy in the battery cell.
- **Nickel, cobalt, and manganese:** These are the materials in the cathode of the battery cell. These materials help to increase the energy density and performance of the battery cell.

- **Iron:** Another material found in the cathode of the battery cell. Iron helps to reduce the cost of the battery cell.
- **Aluminum:** A material found in the cathode of the battery cell. Aluminum helps to reduce the cost of the battery cell.
- **Copper:** A material found in the anode of the battery cell. Copper helps to increase the conductivity of the battery cell.
- **Graphite:** A material found in the anode of the battery cell. Graphite helps to improve the charge and discharge performance of the battery cell.
- **Silicon:** It can be used as a high-capacity anode material in the battery cell. It can store more lithium ions than graphite, which allows the battery to store more energy. This allows the battery to have a higher power density. However, this anode material has not replaced graphite due to the volumetric changes that occur during use and is used as an additive material to graphite by some electric vehicle companies.
- **Rare Earth Elements (REE):** REE can be used as an additive to the electrolyte of the battery in R&D studies on batteries such as nickel, cobalt, and manganese.

These minerals are essential not only for electric vehicles but also for solar power plants and wind turbines. Therefore, it is possible to create a new dependence on these minerals while trying to decarbonize or reduce dependence on oil and natural gas, and it is also possible to encounter consequences such as water and soil pollution because of mining activities. Accordingly, critical minerals can be defined as raw materials that are increasingly demanded in terms of their vital role in the production of new technologies and the risks, they harbor in the supply process since alternatives in battery production are not sufficiently available or more costly in terms of battery storage technologies.

According to Article 7002 of the Energy Act[9] of 2020 in USA, critical minerals are defined as follows: “Any element, substance, or material that carries the risk of interruption in the supply chain, is not a fuel, and has an essential function for technologies used in generating, transmitting, and storing energy.”

In addition, the United States Geological Survey (USGS) published a list of critical minerals for the United States in 2022. Similarly, the European Union has a list of 30 items. The demand for these minerals will increase as the EV market continues to grow. Therefore, as the demand for batteries increases, the demand for these minerals also increases. According

[9] Source: https://www.iea.org/policies/16065-energy-act-of-2020-critical-minerals-provisions

to the IEA's Global EV Outlook 2023 report, Li-ion battery demand increased by 65% in 2022 compared to 2021 (IEA, 2023a). At this point, one of the factors affecting demand is the determination of state policies to implement climate targets. Although demand continues to increase in 10-year scenarios such as 2030, 2040 and 2050, it is highly probable that the carbon neutral target will not be achieved in 2050. In addition, as demand continues to increase, supply security becomes equally important. Especially when it comes to minerals, the geopolitical positions of countries should also be considered. The upward movement of demand until 2040; If the demand for minerals increases and eventually results in insufficient supply, the future of climate targets will become debatable because of a technology that has increased in cost. The demand and supply of critical minerals are quite open to being affected by global developments. The Covid-19 Pandemic, which emerged in 2020, has also hit the mining sector and caused disruptions in the supply chain. In many countries that process and produce critical minerals, from Peru to China, mines, refineries, and factories have been closed (Akçil et al. 2020). This situation has caused countries investing in renewable energy to stock up due to supply concerns and prices, including rare earth elements, to increase. Therefore, a fully competitive sector has not yet been formed. According to the article[10] published by McKinsey & Company in January 2023, the entire lithium-ion battery chain market from mining to recycling is expected to increase by 30% each year from 2022 to 2030, reaching 4.7 TW. It is expected to reach a size of 1.5 billion and a value of more than 400 billion dollars. For a market that will grow this much not to experience a supply shortage, investment and large-scale industrialization are required.

3.2. Leader of the Market China

China is today a leader in the market for clean energy technologies. It controls at least 60% worldwide production capacity in many areas such as solar energy, wind systems and batteries. A quarter of the batteries for electric vehicles and other electronic devices and almost all the solar panels and fuel cells are imported from China (IEA, 2023b). The consequences of China's long-term clean energy strategy and its dominance in critical minerals are now clearly visible in the supply chain. According to Goldman Sachs Research[11], China now accounts for 85% to 90% of global REE refining and 92% of global REE magnet production. Similarly, it refines 68% of the cobalt, 65% of the nickel and 60%

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[10] Source: https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/battery-2030-resilient-sustainable-and-circular

[11] Source: https://www.goldmansachs.com/insights/articles/resource-realism-the-geopolitics-of-critical-mineral-supply-chains.html

of the lithium required for electric vehicle batteries (Goldman Sachs, 2023). Neither the US nor any other country is currently able to overtake China in these areas (Shirley and Svensson, 2023). Following China's requirement to obtain export licenses for the rare earth elements gallium and germanium in August 2023, the US and the Netherlands made similar decisions on the export of certain materials[12]. The US has particularly restricted the export of these materials to China. On 20 October 2023, China also officially announced an export license for graphite. This restriction on graphite will directly affect the battery sector, as China dominates the graphite market with a 65% share in natural graphite production, over 75% in synthetic graphite and over 90% in spherical graphite, the type used in batteries[13]. It also produces more than 90% of the world's anodes. For this reason, the decision may cause problems in the graphite supply chain and negatively affect the price. Since this situation hinders the development of electric vehicle and battery technology and the reduction of costs, China, which has an active role in all stages of the supply chain in global competition, will be able to maintain its advantage.

When the prices of both minerals that are important in the transition to clean energy and minerals used in battery technologies are calculated according to the worldwide import and export rates, China, which is the exporter of most minerals, has a great influence on prices. Even for the minerals that it does not have the most reserves, it does not have a strong competitor in the refining and battery readiness stages. Therefore, even resource-rich countries must import these materials since they do not have the ability to process them. In the case of Türkiye, although it has significant resources in graphite, it does not have any control over the prices since there is no satisfactory and desired quality production volume. In addition, since some minerals are not traded on the stock exchange, the factors affecting the price are formed on the initiative of the producer based on supply and demand. For this reason, when it comes to changes in the prices of these materials, there is not yet a country with a price advantage that can compete.

Table 3. China Domination

Minerals of China's Share	Extraction (%)	Processing (%)
Copper	8	40
Nickel	5	35

[12] Source: https://www.mayerbrown.com/en/insights/publications/2023/07/china-imposes-new-export-controls-on-two-minerals-critical-to-the-manufacture-of-semiconductors

[13] Source: https://www.energypolicy.columbia.edu/chinas-latest-move-in-the-critical-mineral-and-technology-trade-war/

Table 3. (continued)

Cobalt	1,5	65
Rare Earth Elements	60	87
Lithium	13	58
Source: https://elements.visualcapitalist.com/visualizing-chinas-dominance-in-clean-energy-metals/		

As seen in Table 3, China meets half or more of the world's need for most minerals through its processing and production capacity, even for minerals that are not rich in reserves.

3.3. Factors Affecting Battery Material Prices

In addition to the availability and supply of critical minerals for the battery market, the ease of processing is also one of the factors that make up the cost. In addition to mining a mineral, the most economical choices in processes such as purification also affect battery technology and prices. For example, while nickel sulphate is one of the cathode materials in the battery, when it is not accessible in terms of availability and processability, it is preferred to obtain it from high purity nickel (van Bommel & Dahn, 2009). While nickel and cobalt are expensive cathode materials, manganese and iron are more affordable as they are sufficient in terms of resource and production volume and can be processed. Unless alternatives to nickel and cobalt are developed, battery prices are expected to be 60% more expensive between 2040 and 2050, dominated by these two materials and their chemicals (Vaalma et al., 2018). More than 20% of the overall cost of Li ion batteries is the cathode part consisting of lithium, nickel, manganese, and cobalt. Since the concentration of these materials is important for ease of processing, their prices are inversely proportional to their concentration (Murdock et al., 2021).

Lithium, on the other hand, is the most expensive battery material, although prices have recently started to fall due to the shortage of supply, including chemicals. Apart from lithium carbonate and lithium hydroxide, some lithium salts are also used in batteries. Therefore, there is a need for quite a lot of lithium and chemicals. This situation has led to the importance of processing processes rather than mining activities. This sector, which is between the raw material supplier and the battery manufacturer, is also affected by price fluctuations on both sides. Since there are few players in this field and the field does not carry a competitive advantage for new entrants, pricing is risk-averse to manage price fluctuations in the raw material supply and battery market (IEA, 2023c).

In this context, to reduce the cost of batteries and gain price favorability, minerals must first be abundant and economically processable. Then, it is necessary to discover chemicals that will provide higher density energy with less cell production. In short, battery prices will become cheaper if critical materials are used to provide high performance at an affordable price and alternatives are discovered (Turcheniuk et al., 2021).

Research on post-Li ion batteries shows that sodium ion batteries can be an example of this situation. It is estimated that batteries using sodium instead of lithium without any change in cell production can reduce material costs by up to 1.5-3% (Vaalma et al., 2018). However, it is a known fact that its performance is lower than Li ion batteries due to its energy density.

As can be seen in Table 4, the materials with the highest prices that increase the battery cost are cobalt, nickel, and lithium. Although the reserves of nickel and cobalt are high, due to their low concentrations, more materials need to be processed, which creates additional costs due to the technologies used (Vaalma et al., 2018).

Table 4. Current Prices of Some Minerals in Lithium-ion Batteries

Material		**Price ($)**
Aluminum	LME %99,7	2.113
Copper	LME	8.366
Iron	Fine ore, %58 Fe high quality, China Ports	100,34-107,2
	Fine ore, %62 Fe, China Ports	114,18
	Pellet ore, %65 Fe, China Ports	139,02
Phosphate	DAP (Diammonium phosphate) FOB US Ports	625
	%70 BPL Morocco Casablanca	300
Cobalt	Metal, free market	51.015
	Cobalt Sulfate, free market, ton	8.863
Manganese	Free market, electrolytic %99,7	2.275
	Metallurgical %32Mn index, dmtu metal content	4,64-4,72
	Metallurgical %38Mn index, dmtu metal content	5,70
	Metallurgical %44-45Mn index, dmtu metal content	6,2-6,49
Nickel	LME	30.400
	Nickel ore %1,8, CIF China %15-20 Fe, Water Content: %30-35 Si:Mg ratio <2	103-105
	Laterite %1,5 Ni content CIF China	70-73
	Nickel sulfate, battery quality	5369-5456
Lithium Minerals	Lithium carbonate, %99,5 LiC2O3 for battery	72.773
	Lithium hydroxide 56,5% LiOH Europe	74.225
	Spodumene conc. min %6 LiO2 CIF China	5.400-5.600
	Metal Lithium, min. %99 Li	424.454
Rare Earth Elements	Cerium Oxide, %99, FOB China	965
	Lanthanum Oxide, %99,9, FOB China	987
	Neodymium Oxide, %99,5, FOB China	113.187

Table 4. (continued)

	Samarium Oxide %99,9, FOB China	2.177
	Lanthanum/Cerium metal for battery	3.990
Derived from: Basic mineral prices from https://www.mapeg.gov.tr/Sayfa/Madenistatistik		

3.4. Current Situation in Türkiye

Türkiye has started to take steps to stay ahead of the global 'clean energy' race. In addition to its renewable energy targets, it has strategic plans (see: Green Deal Action Plan, MENR 2019-2023 Strategic Plan) on carbon regulations at the border and nuclear energy. Türkiye, which aims to reduce external dependence on energy and thus aims to achieve economic development by closing the foreign trade deficit, seems to be behind other countries in terms of critical minerals. While most countries have published their own list of critical minerals, it is important for Türkiye to develop a strategy for the production, export and import of these minerals to ensure a secure supply chain. Türkiye's foreign trade partners in minerals are given in Table 5 published by MTA (MTA, 2022c).

Table 5. Türkiye's Foreign Trade Partners

Leading Countries in Mineral Exports	Leading Countries in Mineral Imports
• China • USA • Bulgaria • Spain • Italy • Belgium • India • Germany • Israel • Romania	• Russian Federation • Colombia • Australia • USA • Brazil • India • South Africa • Sweden • China • Canada

In the 2019-2023 Strategic Plan, increases in the prices of cobalt and lithium minerals used in the batteries of electric vehicles are considered as a risk due to the limited production of these minerals. Among the strategies determined to mitigate the impact of this risk is the identification of the country's potential for lithium and cobalt (MENR, 2019).

Türkiye aims to make a rapid entry into the electric vehicle sector with TOGG and aims to produce 1 million vehicles in 10 years and to start domestic battery production with the Chinese company Farasis. Another step in domestic battery production is the establishment of Aspilsan's factory, which aims to produce 21 Li-ion batteries per year. All these developments show that Türkiye's demand for critical materials will increase many times over.

Although Türkiye is rich in mineral reserves, its processing and production capacity is not at the desired level. As seen in Table 6, the foreign trade deficit in mining is quite high. Production is required to close this deficit and for economic development. Reducing foreign dependency in raw material needs also depends on production. Türkiye, which wants to stand out in the field of electric vehicle and battery technology, lacks concrete strategies and policies in this regard. There is no comprehensive study on critical minerals yet. The Soil Elements Research Institute (NATEN) was established within MENR on 28 December 2019. NATEN aims to carry out studies to obtain rare earth elements and other critical minerals. Laboratory studies are carried out for various rare earth elements such as rare uranium, thorium, lanthanum, praseodymium, neodymium, cerium, and heavy rare earth oxides.

When the world prices of Critical Materials and Türkiye's import-export prices are compared, it is observed that there is a foreign trade deficit in most minerals. Although it is seen that import prices have increased after the pandemic in parallel with world prices, a general trend cannot be mentioned. As in the world, prices are fluctuating in Türkiye as well. Türkiye, which is lacking in production and therefore exports, has a significant potential in terms of reserves. Although it is rich in reserves in some specific minerals such as graphite and boron, it does not have the production and processing capacity to utilize them. For this reason, materials that do not have a worldwide supply risk with their own specific criteria rather than global supply of critical minerals may be critical for Türkiye in the future.

As seen in Table 6, there has been a significant increase in the foreign trade deficit between 2021 and 2022, and the 2022 rate is the largest deficit to date. A major reason for this may be the increase in the exchange rate. Turkey must urgently change its export strategy and give importance to domestic production as much as imports. For this reason, mining and raw material studies can be considered a strategic area and investment activities here can be prioritized.

Table 6. Foreign Trade Deficit of Türkiye in Mining

Türkiye Mining Sector		
Year	**Coverage Rate (%)**	**Foreign Trade Deficit ($)**
2022	68,75	106.932.227.365
2021	81,96	47.030.820.266
2020	76,69	48.841.892.309
2019	84,61	31.202.410.183
2018	75,33	55.015.647.368
2017	67,17	76.736.291.499

Table 6. (continued)

2016	85,54	601.831.798
2015	81,39	857.665.438
2014	84,49	1.564.878.887
2013	87,26	711.087.831
2012	59,13	2.785.873.477
2011	57,45	2.581.075.492
2010	69,49	1.459.650.105
2009	51,62	-
2008	60,45	-
Derived from: https://www.mta.gov.tr/v3.0/bilgi-merkezi/maden-dis-ticaret		

Considering that there will be an even greater demand for critical minerals for electric vehicles and renewable energy storage in the coming years, finding a new export item that will balance import costs may be one of the primary solutions. Otherwise, it will not be possible to keep the promises made for both electrification and green transformation and to be competitive in the global market.

CHAPTER 4

RESEARCH METHODOLOGY

In this chapter, the research organization and design of the thesis will be explained. For this purpose, it will be explained in detail how a data generation process was followed to answer the research questions, the methodology chosen and the research methods suitable for this methodology and why this methodology was chosen. Since the study aims to analyze the technological capability of electric vehicles and storage technologies in Türkiye, qualitative research methodology was chosen and the knowledge and experiences of key stakeholders of the sector were identified as the primary data source. In this thesis, which focuses on the case of Türkiye and tries to explain a complex phenomenon, case study was chosen as the research method. The interview technique, which is an important data generation tool of qualitative research method, was applied in a semi-structured manner. These semi-structured interviews included 20 open-ended questions. These interviews were conducted with key stakeholders who have decision-making and steering positions in the EV and storage technologies sector in Türkiye. In the case of Türkiye, this sector, which is well equipped in terms of production capacity and human capital, needs to develop technological capabilities to be competitive in the international market. Therefore, actors directly involved in technological capability development were selected as different perspectives are needed to answer the research questions on the current state and potential of these capabilities and consequently to formulate science and technology policy. In this sense, the sampling strategy of the research methodology is purposive sampling to benefit from the experiences of actors who are likely to have the most knowledge about the technological capabilities of electric vehicles and storage technologies.

In the first section, the theoretical foundations of research methods are briefly mentioned, and the main principles of qualitative and quantitative research methods are explained. The 3.1 discusses why the qualitative research method was used in this thesis. The second section presents the design of the study and the research questions and theoretical framework. 3.3 describes the data collection process and provides a detailed description of the interview form. The last section explains the techniques used in data analysis and their operation.

4.1. Theoretical Foundations of Research Methods: Quantitative and Qualitative Research Methods

Research methods are how scientific research is built on solid foundations such as reliability and validity. Popper (1959) argued that scientific knowledge is based on whether it is falsifiable or not, not on whether it is verified, and believed that scientific methods require a systematic understanding of skepticism. Kuhn, who put forward his own philosophy of science, in his theory of scientific revolutions (1962), states that science does not progress linearly and that research methods are shaped by paradigms. Feyerabend (1976), who differs from these two views, argues that scientific methods cannot be confined within strict rules and that the researcher should be flexible and creative for scientific knowledge. All these theories are important foundations that constitute the epistemological stance and methodological preference of scientists, which show their critical presence in choosing and applying research methods. In this context, qualitative and quantitative research methods are the product of a specific scientific paradigm and are selected and adapted in accordance with the purpose of the research (Creswell, 2014).

Bryman defined research methods as refer to the techniques and procedures that are applied in the process of data gathering and analysis. They are how researchers collect and analyze data to answer research questions or test hypotheses. These methods can be quantitative, focusing on numerical data and statistical analysis, or qualitative, focusing on exploring meanings, experiences, and social phenomena (2012).

This guide, which contains a set of guidelines for the researcher, shows the paths to be followed throughout the research process to understand, make sense of and transfer reality. These paths shape the research according to the nature of the questioner and the questioned. Research has three different dimensions: epistemological, ontological, and theoretical. The ontological paradigm, which investigates the nature of reality, is based on the reality of the researched in the social world, the epistemological paradigm, which investigates the nature of knowledge, is based on the relationship between the researcher and the researched, and the theoretical paradigm is based on which methods and how they will be used in the research, quantitative or qualitative research method can be used (Guba & Lincoln, 1994). According to Creswell et al. (2003), qualitative and quantitative approaches are familiar and conventional research models that exist simultaneously. In the literature, quantitative research is interpreted as a research strategy that emphasizes quantification in data collection and data analysis, requires a deductive approach in the relationship between theory and research, and attaches importance to the testing of theories, while qualitative research is a strategy based on theory generation that attaches importance to words in the data collection and analysis process, and deals with the link between theory and research with an inductive approach. (Bryman, 2012) While social reality is external and objective in quantitative research, it is a creation of individuals who constantly change and reoccur in qualitative research. The strategy in which these two methods are used together is called mixed method research. In qualitative research, the researcher produces context-dependent results to explain and understand reality, and the research process is influenced by his/her worldview, which is his/her beliefs and attitudes about the world he/she lives in (Corbin&Strauss, 2008). According to Guba & Lincoln, data collection and hypothesis formation processes are independent in quantitative research, whereas data and reality are interdependent in qualitative research (1994). In qualitative research, the researcher is not objective but sensitive in the data and analysis process (Patton, 2002). This constant interaction between the researcher and the data in the research process deepens, expands, and clarifies the data (Patton, 2002). As a result, while quantitative research proceeds with hypotheses that are independent of the researcher and aim to test the universal knowledge outside, qualitative research is a method that tries to understand and explain all the interactions and values between the social entities that are the source of the data, in which the researcher is involved at every point of the process.

The research topic of this thesis is to understand the role of technological capabilities in the development of emerging electric vehicles and storage technologies and to make science and technology policy recommendations to increase these capabilities. My semi-structured interviews with the participants aim to understand their perceptions, experiences, and knowledge about the objectives of the research topic. In this context, reality is a socially constructed reality and cannot be separated from the context that collectively manifests knowledge. Therefore, I will construct the role of theory inductively and the theoretical framework of the thesis will be the Dynamic Capabilities Theory and the National Innovation System. With the empirical research aspects of the study and the analytical framework provided by the theoretical background, I will abstract the reality filtered through the data and make it generalizable and transferable. Instead of testing existing hypotheses with data, I will try to interpret the reality carried by the data using the inferences offered by the theory and enrich the existing theoretical framework by adding Türkiye-specific findings. Since electric vehicles and storage technologies in Türkiye are still new technologies, I will interpret the data within the scope of dynamic capabilities literature and develop policy recommendations with the National Innovation System theory.

4.2. Research Design

According to Yin, a case study is an empirical form of investigation that is used to investigate a current phenomenon in-depth and in a real-world context and is used when the boundary between phenomenon and context is not clear (2017), and Walsham (1995) argued that the most appropriate method for empirical research in the interpretivist tradition is the in-depth case study. This investigation, which includes a unique research design, involves multiple sources of evidence and data triangulation (Yin, 2017). The development of electric vehicles and battery technologies in the automotive sector in Türkiye is a current and rapidly developing phenomenon. At the same time, it is one of the objectives of the research to try to understand the current situation and to provide policy recommendations to ensure the development of these technologies. To do so, it is necessary to analyze the multi-actor structure of the sector, its dynamics, government policies and contextual factors such as technological infrastructure. In this context, Yin's approach is ideal to conduct an in-depth technological capability analysis of Türkiye's EV and battery technologies.

The case study brings its own recommendations for data collection, research design and analysis. Accordingly, in this study, where I chose the unit of analysis as a firm, I applied a single case study design, and I will examine more than one firm. Yin suggests interviews, documents, or observations for data collection. In this study, I chose semi-structured interviews and supplemented these interviews with archival information to increase the validity and reliability of the study. I conducted document analysis using written material such as companies' annual reports, strategy documents, sectoral reports, government policies, industry standards, research papers, news articles, etc. I used sectoral data and statistics as the third data source. The primary thing I did for the case study was to identify the problem. How can technological capabilities for electric vehicle and battery technologies in Türkiye be improved? For this, I used my research questions which also helped me to do the literature review. Accordingly, my research questions are as follows:

1. Why and how have firms in Türkiye developed their technological capabilities in the field of electric vehicle and battery technologies?
2. Why did Türkiye's challenges in the field of EVs and battery technologies emerge and how were these challenges overcome?
3. What policies and incentives does Türkiye need for electric vehicles and battery technologies?

According to Yin, to understand processes and mechanisms, the question of how should be asked. To identify how the accumulation of technological capability in the automotive and battery sector in Türkiye has occurred and the steps it has followed, I have created questions 1,2. Questions 2,3 are needed to understand why the current situation has emerged in this way and to find the motivations of the companies. Since I tried to understand the perceptions of the interviewees regarding the policy recommendation, which is one of the objectives of the thesis, I tried to understand the internal dynamics and decision-making processes of the decision makers by creating question number 3. In the light of these questions, I aim to identify the technological capabilities that Türkiye's automotive industry already has in EV and battery technologies, to understand its potential and to find out which policies are needed to help overcome the obstacles to this potential.

The existing technological capabilities literature has helped me to take an explanatory approach to my research, helping me to find the reflections of existing theory and hypotheses in my case. It has enabled me to formulate research questions based on the studies in the literature to explain whether these theories are proved or disproved and what kind of phenomenon it is. Afterwards, I prepared an interview form within the scope of the objectives I aimed to find.

4.3. Data Collection

The main data sources of the research are people in managerial positions of electric vehicle and battery manufacturers in Türkiye. These actors have significant experience, approaches, and perspectives in their field of expertise. In the case study of how technological capabilities develop, it is necessary to conduct interviews to obtain this kind of qualitative data based on the experiences of key actors. This data collection technique, which is frequently used in qualitative research, gives the interviewees the opportunity to express themselves first-hand, while allowing the researcher to understand in depth the meaning worlds, perspectives, feelings, thoughts, and experiences of the interviewees with the help of their own expressions (McCracken, 1988). For this purpose, semi-structured interviews were planned by preparing open-ended questions. With this data collection technique, implicit information that is explicitly referred to by the actors during the interview and whose relationship with the data can be analyzed by the researcher helps us to understand the overall picture from the worldviews of key actors.

The interview form I prepared in line with my research questions consists of 20 questions. The interviewer's profile and the introduction & warm-up section are excluded from these questions. I divided the questions into 5 categories: production process, knowledge production process, international targets, technological development, and policy recommendations. I started the interview with questions related to the production process and these questions explored innovation, R&D, human capital, technology transfer and cooperation with other actors. Considering that the interviewees were in managerial positions, I tried to understand their innovation capabilities and how they built this capacity through their answers to these questions. The other category was related to the knowledge production process, which I created to measure tacit knowledge, which was one of the most striking and difficult to answer questions of the interview. The questions in the category of international goals were aimed at understanding how much the interviewees were aware of the developments in the world and how they kept up with them to understand the competitive structures of the organizations they were affiliated with. Here, I asked about the firm's vision and mission regarding carbon zero targets. I prepared the questions in the technological development category to question the infrastructure required for the spread and adoption of electric vehicle and battery technology, whether the firm has a production area or not. The answers to the questions in this section were clearer and concrete. Finally, the category of policy recommendations allowed me to measure the interviewees' insights on how they would make decisions if they were policy makers. In this context, I investigated how their relationship with the government and its policies affected their perspectives on the technology they produce. I contacted the interviewees via e-mail and requested an appointment by attaching an information note explaining the purpose of the study, a voluntary participation form and my permission document from the ethics committee. At the beginning of the interview form, I added a short introduction introducing myself and the purpose of the thesis.

Table 7. Interview Design

Categories	Objectives of Questions	Number of Questions
Introduction	• Personal Information • Experience	2
Production Process	• R&D • Technology Transfer • Innovation Perception • Human Capital • Cooperation	7
Knowledge Production Process	• Absorbing Capabilities • Technological Learning	2

Table 7. (continued)

International Goals	• Awareness of International Agreements • Mission • Vision	2
Technological Development	• Spread of Technology • Technological Adoption • Obstacles in Technological Adoption	7
Policy Proposal	• Which policy making tools are needed?	2

The interviewees were selected through purposive sampling. Firstly, based on the analysis of the automotive sector in Türkiye, it started with the detection of companies with developed production capacity. Then, battery companies were listed for battery manufacturers, and I selected those who have invested/received investments especially in lithium-ion batteries and have actions and targets in this regard. Since the knowledge and experience of the selected people and their reflections on the innovation capability of their knowledge and experience are important for the study, I determined the managers of R&D departments as the first target. During the preliminary studies, the bottlenecks, and costs of battery technologies on a global scale were observed and an expert opinion was needed on this indispensable component for EV. Therefore, I interviewed 2 academicians specialized in the field of batteries. Finally, to understand how the development of these technologies depends on the interaction of stakeholders with each other, I interviewed an actor from a platform established for technology development in the field of automotive. In total, I conducted 10 interviews.

Table 8. Interviewees' Profile

Interviewees	Title	Experience	Type of Organization	Duration
A	Prof. Dr. (Academic)	17 years	University	1h 11m
B	R&D Manager (New Technologies Dept.)	11 years	Profit	27m
C	New Systems Team Lead (R&D Dept.)	6 years	Profit	45m
D	Director	40 years	NGO	1h 31m
E	Prof. Dr. (Academic)	33 years	University	38m

Table 8. (continued)

F	Senior Cell Development Engineer (R&D)	9 years	Non-Profit	Did not consent to voice recording
G	Manager of R&D Center	22 years	Profit	58m
H	Regional Manager of R&D Center	30 years	Profit	1h 3m
I1 - I2	Executive of Electrification Control and Component Part (i1) - Executive of Power Train Control Calibration Electrification (i2) (R&D Dept.)	13 years	Profit	46m
J	Battery Systems Department Manager	11 years	Profit	1h 42m

The interviews were conducted online through applications such as google meet/teams/zoom. Before the interview started, I asked each interviewee for their consent on whether the interview could be audio recorded. I then transcribed these audio recordings verbatim. The duration of the interviews lasted an average of 1 hour. The longest interview lasted 102 minutes and the shortest interview lasted 27 minutes. Interviewees skipped the questions they did not want to answer. In some interviews, the selected interviewer was accompanied by experienced colleagues from the firm (3 interviewees). Interviews started in December 2023 and snowball sampling was used to increase the number of interviewees through the network of the technology development platform (Patton, 2002). Since I chose the firm as the unit of analysis, I also tried to reach people from different companies that produce and develop the same technology. While this strengthens the credibility of the research, I think that the interviews with academics, who are not only firms but also important actors of the network, enriched my source of information.

4.4. Data Analysis

Qualitative data analysis is managed with an inductive approach (Strauss & Corbin, 1998). ‘Inductive analysis means that the patterns, themes and categories of analysis come from the data; they emerge from the data rather than being imposed on them prior to data collection and analysis’ (Patton, 1980, p. 306). In qualitative research methods, texts that are data sources are not evaluated with predefined criteria. The environment or people who produce this text are tried to capture their own definitions. When analyzing qualitative data, important categories, patterns, and relationships in the data are also tried to be identified, but these do not emerge spontaneously. They emerge according to what the researcher wants to know and from which theoretical frameworks and perspectives he/she filters what he/she wants to know and his/her ontological or epistemological stance while interpreting. In this way, the setting and participants are represented from their own perspectives, through the researcher's filter. Qualitative data analysis is an iterative and reflexive process that starts from the moment data collection begins, not after the data collection process ends (Stake 1995). The researcher constructs a 'reality' with his/her interpretations of a text obtained from individuals. Therefore, the text, which is the source of data, may have more than one and different realities. The text is only one of many interpretations (Patton, 2002, p. 114). In qualitative data analysis, the researcher actively participates in the process by reporting and interpreting. To better understand this active participation, Patton prepared some question sets. (2002) In this approach, which the researcher calls triangular reflexive enquiry, the questions that the researcher asks themselves are what they know and how they know, and this is self-reflexivity. The questions to be asked about the research subjects through which the data is filtered are what they know and how they know, and how they make sense of the findings of the research about the target audience (reflexivity) (Patton, 2002). These reflexivity questions are a systematic approach for the analyst to make the data comprehensible in the reporting phase. In the interpretation part, the analyst is expected to 'explain the findings, answer "why" questions, attribute meaning to particular results, and place patterns in an analytical framework' (Patton, 2002, p.438). Patton suggests 3 approaches for this reporting process: storytelling, case study and analytical framework (2002).

In this thesis, analytical framework is used. I was assisted in analyzing the data by MaxQDA software. My empirical evidence is data which is coming from the thematic analyses. As Maxwell (1996) comments, 'hypotheses in qualitative research are based on data and are developed and tested in interaction with the data, rather than simply being preliminary ideas tested against the data' (p.53). I coded the interviewer's word as relatable with the findings that I wish to reach. Then, codes bring together and they formed clusters. Clusters have signs what theme will be occur. For example, I found out the pattern for example "subsidiary industry" and it is the answer to my research question about obstacles in technological capability accumulation on EV and battery technologies. This is also complementary capabilities form the literature of Dynamic Capabilities.

Table 9. Regulations About Clean Energy

Regulations in Türkiye
2011- 2023 National Climate Change Action Plan
Updated First National Contribution Statement
Climate Change Mitigation Strategy and Action Plan Covering the Years 2024-2030 - Planning 7 Main Reduction Sectors
Climate Change Adaptation Strategy and Action Plan
Climate Finance Strategy-Preparation Phase
National Green Taxonomy-Preparation Phase
2053 Long-Term Climate Strategy-Preparation Phase
Climate Law 2024
Climate Technologies Pioneer Project, Climate Lab Community, Eco-Production Transformation Programs
11. Development Plan (2019-2023)
Industry and Technology Strategy Document (2023)
National Smart Cities Strategy and Action Plan (2020-2023)
Electric Scooter Regulation (Ministry of Transport and Infrastructure, Ministry of Interior and Ministry of Environment, Urbanization and, Climate Change) (2021)
Regulation on the Control of Waste Batteries and Accumulators (Environmental Legislation)
National Development Plan for Charging Infrastructure for Electric Vehicles (2021)
2. National Energy Efficiency Action Plan (UEVEP II)

To understand the current situation of Türkiye and the steps taken by the government in this regard, I examined some regulations and development plans. These documents showed me what has already been done and what is planned to be done. Türkiye, which is a signatory to the Paris Climate Agreement in its carbon neutrality goals, has adopted an approach where it prioritizes renewable energy sources by prioritizing its dependence on fossil fuels. Although it has increased its installed solar and wind energy capacity to a certain level in the last 10 years, it still has a long way to go. Although it has goals in the Green Deal Action Plan for the transportation sector, it seems that it has difficulty in turning them into concrete action plans. While it aims to follow certain strategies, there is no roadmap, and it is not developed regarding which policy tools it will use to achieve this. In the Mobility Vehicles and Technologies Roadmap Report (2022) published by the Ministry of Industry and Technology, it was stated that 379 companies, 294 of which are TEYDEB, applied for mobility software and hardware systems project support, and the project budget of these applications was 677 million TL in total, 84% of which was EU. Battery technologies, which rank second in project support, include TEYDEB and ARDEB supports with a budget of approximately 150 million TL.

The report, which presents ambitious strategic goals on electric vehicles and batteries such as becoming a "Regional Battery Production Center", 35% electric vehicle market share and 251 thousand charging sockets (35% of which are DC), being the leader in Europe and in the top 5 in the world in light and heavy commercial vehicles, and "producing Level 1-2 companies in electric and electronic components", has organized the roadmap for three years as 2023-2025-2030. While there is a target for each of the 42 action plans for these goals, including MTV and SCT reduction, low-interest financing support, tax exemption in new investments and public procurement guarantee, actions such as supporting investments in the battery field and supporting projects that will develop university-industry cooperation and projects aimed at training human resources are also listed.[14]

When looking at sectoral reports other than regulations, the SHURA Türkiye Energy Transformation Outlook Report (2023)[15] offers some important points regarding Türkiye's energy efficiency, use of domestic energy resources and the transformation that makes technological innovations indispensable. The report, which undeniably presents the role of electrification and new technologies, emphasizes that meeting the additional electricity demand from renewable energy sources with the introduction of electric vehicles instead of gasoline vehicles in transportation is one of the basic strategies for decarbonization. For this reason, it can be inferred that the widespread use of electric vehicle technology is also dependent on the development of all other renewable energy sectors. This situation forces Türkiye to undergo a twin transformation at the same time. While decarbonizing, it will need technological innovations, and technological innovations will have to develop rapidly in the field of climate technologies with decarbonization targets. This situation shows that Türkiye's electric vehicle and battery technology is realized from the top down. The electrification of the transportation sector, the increase in energy efficiency and the electricity consumption rate in the final energy consumption of the sector have reached 0.44% (SHURA, 2023). In this rapid transformation, it is known that demand for electric

[14] Source: https://www.sanayi.gov.tr/plan-program-raporlar-ve-yayinlar/strateji-belgeleri/mu0906011618

[15] Source: https://shura.org.tr/wp-content/uploads/2024/04/SHURA-2024-04-Rapor-outlook-2023-2.pdf

vehicles has increased in Türkiye and that there will be 80,000 vehicles registered in traffic in 2023. As of the end of 2023, the number of electric vehicles charging sockets in 81 provinces of Türkiye is approximately 12,000. The number of charging stations in Türkiye is 5,614 (SHURA, 2023). In UEVEP 2, actions were determined to carry out R&D studies to reduce the grid load of electric vehicles and charging stations and to develop applications for optimization according to the results. This situation emphasizes the importance of cooperation and simultaneous work of infrastructure and technology complementary sectors, which is another problem that Türkiye needs to solve quickly.

According to all these documents, Türkiye's ability to not fall behind in the global competition in terms of climate technologies and to achieve economic development can be achieved by determining science and technology policies that will increase technological development in innovations in a holistic manner. In order to create an innovation ecosystem, critical points such as the electricity grid, infrastructure works of charging stations, state incentives and supports for the feasibility of investment costs, R&D projects that will increase university-industry cooperation and attracting foreign investments to the country that will increase production capacity and the joint growth of electrification through renewable energy systems for the ability of all processes to produce and store clean energy can be listed.

Based on the literature and documents summarizing the status of the sector, the extent to which Türkiye can use its technological capabilities in electric vehicle and battery technologies, its open aspects, obstacles to development and solutions were questioned and analyzed with the experiences of the interviewees.

CHAPTER 5

RESULTS

After the collected data were extracted and cleaned, they were transferred to MaxQDA and thematic analysis was applied. Thematic analysis is the process of identifying, organizing, and interpreting qualitative data into recurring themes or patterns (Braun & Clarke, 2006). Thematic analysis provides a flexible and comprehensive qualitative research method for the researchers and helps to explore the hidden truths by digging deeper into the data. As emphasized by Patton (2002), the analysis of qualitative data begins in an inductive way so that the collected data can be analyzed in an open and unbiased way. In addition, as Braun and Clarke suggest, thematic analysis is a process that can be done cyclically in 6 stages. Gaining familiarity with the data, creating initial codes, identifying themes, reviewing themes, defining, and naming themes, and finally the reporting process (2006). Accordingly, in this thesis, I created the first themes by transcribing the interview texts, separating them into paragraphs, removing the irrelevant parts, and then reading and coding them line by line. Then, I changed the codes and themes several times and changed the sub-codes. I tried many different coding until I reached the reporting stage. The codebook provided by MaxQDA is given in the appendix.

The technological capability analysis of electric vehicles and battery technologies in Türkiye has been analyzed using qualitative research methods and empirical data in line with these data by conducting interviews with electric vehicle and battery manufacturer companies from the sector and expert opinions. The data were analyzed in a way to answer the research questions 'Why and how have technological capabilities for electric vehicles and battery technologies developed in Türkiye?' and 'What are the obstacles to the development of technological capabilities for electric vehicles and battery technologies in Türkiye?', as well as clues to be used in policy design, reflecting the perspectives of the interviewees. In this section, in the light of the core capabilities and complementary capabilities obtained from the literature review, the developed and undeveloped capabilities of the firms are identified and how and why these capabilities are developed/undeveloped is tried to be explained by filtering the data.

After revealing Türkiye's current situation and potential in these technologies, the science and technology policy proposals needed in the context of technological capabilities were also identified.

Firstly, I coded the interviews with sub-codes such as ‘name-surname, age, educational background, work experience’ to distinguish the personal information of the interviewees. Thus, I had convincing findings about the experience and competence of my interviewee profile. In particular, the interviewees whose expert opinions I received had much more experience than the company employees (17,33,40 years). However, others had managerial roles since they had been working in R&D since the beginning of their careers and the responsibilities imposed by their current positions. Except for 1 company, the others were companies that had already been in the automotive sector for many years and had significant knowledge and experience in the fields of production capacity, human resources, and R&D, in other words, technological capabilities related to automotive. The interviewees representing the companies were 3 battery companies, 3 automotive groups and 1 consultancy firm providing R&D services. Although these companies have high production capacity and R&D centers in their respective fields, not all of them were yet active in the production of batteries and electric vehicles. There were different situations, including those that were operational but not yet offering commercial products, those that were operational and launching products, and those that were not operational but only at the project design stage. Investigating the main reasons for this helped me to analyze technological capabilities. In addition, listening to the structure of the companies from the interviewees and the fact that most of them have foreign capital ventures or partnerships contributed to the view that capital is the main resource that Türkiye needs in the transition to electric vehicle and battery technology. The potential answers to questions such as whether the foreign partnerships of the companies also affected their innovation and R&D cultures, whether there are processes that they accelerated or slowed down, and whether there is know-how provided by the foreign partner enabled me to analyze technology transfer and technological learning processes from the National Innovation System literature. Dynamic capabilities, which offer an important perspective on technological capabilities, helped me to analyze the capabilities that exist in Türkiye but are currently lacking complementary features. In this context, especially those interviewees who did not engage in production activities proved that complementary capabilities have a critical role in providing the necessary conditions for the development and diffusion of a technology.

All the interviewees are engineers and all but two of them have a postgraduate degree. 40% of the interviewees are women and 60% are men and the average age of the interviewees is

34. This cluster, which represents different branches of the Turkish automotive industry, is young and educated in line with the demographics of Türkiye.

5.1. Production Process

The answers I obtained in this section helped me to identify the interviewees' perspectives on R&D and innovation. In addition, there were important insights for understanding the differences in the difficulties they experienced in production processes specific to electric vehicles and battery technology. Therefore, different sub-themes such as ‘investment, production cost, factory requirement, human resource requirement, scale problem... etc.’ generally emerged in the coding. The interviewees, who attribute the difficulties they face in production to such reasons, have problems due to the newness and small size of the sector rather than know-how in terms of producing technology. This situation gives clues as to why electric vehicle and battery technology has not developed in Türkiye and identifies problems. One of the most recurrent and frequently mentioned problems is the lack of a subsidiary industry. The subsidiary industry, which is a complementary capability for production capacity, has not been able to reach a position to make active production in the country due to the high raw material supply and initial investment costs of batteries. Although the process continues with R&D studies and projects, today even the batteries of Togg, which is presented as a national and domestic production mission in Türkiye, are supplied from abroad. This situation emerged as two separate codes during the interviews.

Localization and foreign dependency problems. In the transformation of the transport sector, which was set out with the aim of reducing dependence on fossil fuels and decarbonizations, the procurement of battery cells and only packaging them here has revealed a technology that has moved away from localization and a new foreign dependency. In this context, the interviewees think that especially raw material production, reserve resources in the country should be well utilized and material science studies should be increased. China's uncompetitive production capacity in the world market causes the prices of batteries to be fluctuating and unpredictable and to remain a major cost item. While Europe has not yet been able to offer alternative solutions to this situation, Türkiye's ability to become an exporter for Europe requires a large amount of investment and government support to produce battery technologies. The obstacles to the development of battery technology can be summarized as Türkiye's inability to develop complementary capabilities that cause the production capacity and investments to not grow.

5.2. Knowledge Production Processes

The answers to this question, which I asked during the interviews to understand the technological endeavors and the development in knowledge production in the country, helped me to define the perspective of the companies on R&D and innovation. In this regard, companies that have accumulated technological knowledge thanks to the R&D support of TUBITAK and HORIZON projects and foreign collaborations have not yet fully established technological learning processes that will improve their absorption capacity. **Interviewee G**, who stated that they do not transfer technology, shared the following about how they produce their own solutions:

> "Together with our suppliers, we come up with our own solution, that is, our authentic, new, original design. While doing this, we sometimes benchmark. We examine what our competitors have done. Sometimes we manage by talking to those who do not fit and understanding what solutions they have. But basically, we produce our own solutions. We do not transfer technology, but sometimes we can get outsource support from other engineering companies if the competence and competence of the internal human resources is not suitable for that job, or if the purpose of the internal human resources is not suitable, if the intensity is not suitable, I can get outsource support from other engineering companies. Or we try to come up with solutions with the support of suppliers by evaluating their own products, but we do not have a process called technology transfer."

The benchmark studies that emerged from this transfer was a point also mentioned by another company. The lack of human resources was mentioned in 3 more interviews as an area that needs to be improved because these technologies are new and software intensive. The conclusion I draw from this is that human resources, which is an important element of technological capability capacity, will accumulate in this area as these technologies are needed and still need to be developed. Interviewee F, who is a company that has made its own production, exemplified how human resources and know-how are developed by explaining that the company sent them to the Far East for training in battery production. **Interviewee C**, another company that has launched an electric bus, explained about the existing know-how and human resources:

> "Actually, there is an accumulation of know-how in this business. That know-how accumulation is left aside and goes to a completely different place. In that completely different place, the number of people who can lead is very few, because it is very new, so specific departments, the departments we call electrical and electronic systems, need to lead these issues. It is changing now. It is leaving automotive companies and turning into a technology company, and at this point, the perspectives of people who come from automotive culture are shifting from mechanics to electronics."

This situation has shown that as the technology becomes more specific, the staff that will assimilate and produce that technological knowledge can also adapt to innovations and accumulate experience. The fact that the rapidly transforming automotive industry in Türkiye brings solutions mostly in the field of software development is a good example to understand where this human resource is concentrated.

As a result, Türkiye, which participates in knowledge production processes as a follower of technology, must use its existing human resources wisely while having the basic competencies to realize R&D projects, foreign collaborations, and technology transfer in the context of innovative imitation, not just copying. This situation has produced answers to my questions about why and how electric vehicle and battery technology has developed in Türkiye.

5.3. International Goals

In this section, where we talk about international conventions and I try to measure the awareness of companies about them, I start from the references made by the literature in recent years to the sustainability, eco-innovation, and future technologies of technological capabilities. Here, by listening to the mission and vision of the companies, I tried to collect clues about their technological capabilities in terms of how much they can turn their decarbonization targets into a business model, how much they have sustainability goals and objectives, and their own insights into possible eco-innovations. I have seen that most of the companies have set targets and action plans, but they are still at a very early stage to realize them. Unfortunately, reflecting their sustainability targets to the product could not be realized due to the obstacles in their production capacities. Especially the electrification of all processes is a major transformation for the automotive industry and their efforts in this regard remain limited. **Interviewee C,** who was able to produce buses, stated that the company installed solar panels on all buildings and made huge investments to decarbonize electricity generation, which is the biggest carbon emission in production processes. **Interviewee G** said that the company has identified its current carbon footprint and set targets for where it should be in 2030 and 2050. The company has an action plan and believes that producing electric tractors is the first and most important step towards realizing these targets. **Interviewee J**, a company that provides consultancy and engineering solutions as an R&D center, stated that they do not need to adopt a separate mission for this, and that they have built their entire vision on this and gave the following example:

> “We already have innovation projects on how to do this because we are constantly following the laws, that is, we are constantly following the laws on decarbonization. For example, hydrogen vehicles, hydrogen engines, fuel cell vehicles. We follow these directly on a regular basis and work on them in advance because they will be requested anyway. So yes, I can say that our mission is our vision. But we have been doing these things until today because we are not in the mindset of directly buying and producing such a vehicle. ... A new regulation called Battery Passport will come. Will it come in 2026 or 27 or what? It hasn't even arrived in Europe yet. But I'm sitting right now, trying to come up with solutions on how to ensure that regulation. I'm doing this in advance, so you can call it mission, vision. Because tomorrow and the day after tomorrow, when it becomes compulsory, it will be compulsory in Türkiye and Europe. But right now, I will make my prototype application or prototype product by the end of this year, and I will come up with a product that I will solve this problem in this way. And I will go to my customers with a product next year. Because we already include these in innovation.”

In this respect, we can say that eco-innovations have started to be achieved to a certain extent. Although each company specifies its mission and vision, another issue is that it is not possible to realize these targets on the dates stated, but they continue on their way by saying that 1 is better than zero. How and why the technological capabilities of EV and battery technologies in Türkiye have developed is based on the reasons triggered by both sustainability as a business model and international regulations, and companies are rapidly developing new technological innovations.

5.4. Technological Development

With these questions, in which I questioned the reasons for the obstacles to technological development, I tried to find concrete examples of ‘which technological capabilities can eliminate these reasons based on the answers I received. This stage of the analysis, in which quite a lot of codes emerged, revealed the concrete shortcomings of a systematic transformation process in Türkiye, as well as the aspects that these new technologies bring in their own nature and pose problems for the whole world. The theme of obstacles to the development of these technologies has 12 sub-themes and exactly 30 codes. Some of the codes are very repetitive, while others are mentioned less frequently, but I believe that this is not because the less frequently mentioned codes are unimportant, but because they require a more in-depth perspective. First of all, if we look at the sub-theme of the disadvantages of the technology, which I associate with the lack of complementary capabilities, the charging capacity, life span, reliability, weight, reusability (recycling) and range of the batteries are areas that the whole world is trying to overcome, and some progress has been made. However, the scarcity of charging stations, insufficient network power and urbanization, where individual charging station use is not possible, emerge as problems specific to this country. The companies' point of view that customer demands do not rise to the desired level due to these disadvantages, and that this situation does not increase investments by affecting the sales potential, is that the state should take a hand in this situation as a solution. It is a common opinion that this sector will grow, and demand will increase with the projects and supports to be made by the state to solve infrastructure problems and this will increase the supply. This situation shows that Türkiye needs policy instruments to be developed, while technological capabilities can be achieved by developing a national innovation system based on inter-institutional co-operation and interaction.

Other factors hindering technological development are the lack of investment and the fact that production is still not feasible because it is not scaled up. This sector, which requires strategic and large investments, is unable to produce solutions in the domestic market due to the fear that production units will not meet sales targets. In this context, the work of Kim (2001), who emphasizes the importance of export strategies for the development of technological capabilities, is key for Türkiye. As in the case of Togg, this technology, in which large investments were made, could not become widespread due to the low purchasing power in the country. To solve this problem, the state needed to find foreign markets to encourage exports and develop sales capabilities. Local companies, which have seen the Togg example, think that opening to these areas will help overcome many obstacles in the country, especially by reminding the automotive power in the European market. Production should be increased, but technological capability should not be limited to production capacity and R&D studies. When the marketing and sales policy processes of innovation, which are always forgotten, are also technological capabilities developed through exports, these technologies can be developed and spread in our country.

As a developing country, Türkiye must transform into an economy that produces technology, not just consumes it. **Interviewee A** from the expert **Interviewee I** conducted on this subject summarizes this situation as follows:

> ‘We are always in the position of giving money because we are always in the position of being a consumer as a country. What are we financing? We enable them to earn today's money for the R&D work they have done in previous years, so that they can start investing in another project, so that it becomes sustainable. We do not have such a concept. When we don't have such a concept, we can't produce technology anyway. Now, my assumption is that they have produced the technology, they have reached sufficient maturity in terms of batteries, and they have put it on the market for years. Now, using the climate crisis as an excuse...so we are now financing their R&D investments. While this electric vehicle financing passes, he is financing another technology with the money he receives here now. Therefore, that

> technology will come to us, and then we will start to cover what it does there. There is a cycle, I think we are experiencing that cycle right now ... As this cycle goes on like this, at the end of the business, in my opinion, after 30 years, we will start financing another technology. Or we will start investing its money. That is our problem, we are now, for example, a society that always consumes because we do not invest in the future already.'

As it is understood from this conclusion, the obstacles to technological development will be possible with technological capabilities related to innovation that invest in future technologies today. To develop these capabilities, the state needs to trigger the interactions that the innovation eco-system will create by developing division of labor and cooperation policies that will increase the national technological effort as dominated in the national innovation systems literature.

The solution to many of the obstacles to technological development was found in state policies by the interviewees. These were coded with the following two sub-codes: misuse of resources and lack of incentives and support. Due to the economic instability in Türkiye, the lack of foreign investment necessitates the strategic use of the financial resources available to us. Their ideas on this:

> 'I think that the state definitely does not support, we are one of the weakest countries in terms of financial resources, the private sector needs to invest in this business. For example, there is North Volt in the world, they invested 1 billion dollars in this business. This is not a job that can be done with 20-50-100 million dollars. Big things cannot be done.'

Interviewee F was also one of the 2 interviewees who mentioned the issue of merit.

> 'There is no upper mind in Türkiye. Everyone works for their own benefit, Tübitak says let us learn everything rather than making a distribution. If there is someone without merit in these institutions, it cannot be done.'

He believed human resources, money and organizations with merit are vital for this country. Institutionalization, which is one of the technological capabilities, can play an important role in solving this problem. Regarding institutionalization, **Interviewee A** contributed with his expert opinion by saying that the fact that there are people without competence at the head of the institutions

> 'Institutionalization is more important than people, and it is important to work efficiently, not to work hard....There are also cases where good results are obtained if resources are used correctly.'

The interviewees maintained their negative view that decarbonization targets will not be realized when they say they will be, also for the scenario in which Türkiye switches to all-electric vehicles. They think there are basically two reasons for this. That it will not become widespread due to customer concerns about this technology and that it has already lost the power to compete with China. The prevailing opinion in Türkiye is that this sector will stagnate in hybrid vehicles for a certain period of time, and perhaps in the future, if these problems are solved, electric vehicles will be more widespread. In the second-hand market, they predict that the second-hand market will develop more due to the decrease in the value of the vehicles in this technology (battery life). This is a problem related to the low level of purchasing power in the country, i.e., GDP per capita. The recent unfavorable situation of GDP per capita affects customer demand. **Interviewee D** emphasized one of the responsibilities of the state by saying

> ‘We should increase our GDP, increase our income, policies should be policies that will increase our income, mainly.’

In his views on the obstacles to the diffusion of new technologies, he said:

> ‘First, the country will be productive, increase its welfare level, and raise its income level. Then it will happen. Therefore, as long as these are obstacles in front of us, we cannot move as fast as some countries.’

He emphasized that economic policies should be formulated with the aim of economic development.

Finally, another sub-theme that emerged from the coding related to technological development was the theme of new needs brought by technology, which evaluates the challenges that the world is trying to overcome as areas that can create a potential competitive power for Türkiye. The first thing I would like to mention in this section is recycling and waste management. Due to the short lifespan of battery materials and the cost of the raw materials used, most interviewees attach great importance to the materials to be obtained from recycling. **Interviewee J** stated that:

> ‘If investments were made and incentives were given to them (battery producers), I think it would contribute to a very large economy in the electric vehicle sector if they took those unavailable lithium vehicles from dead vehicles and dead batteries for recycling and used them for recycling. Costs would also decrease a little.’

And exemplified this situation. She sees investment in recycling as a role and strategic investment belonging to the state. Similarly, **Interviewee B** said,

> 'Like recycling processes. I think an opportunity can be created in Türkiye for recycling.'

Interviewee A, from whose expert opinions I benefited, looks at this issue from the employment side and said:

> 'Therefore, we are conducting research for more waste and recycling in this field as much as we can. It seems that it will be a place where Europe will destroy the jobs it does not want to do, but it can create new job opportunities.'

Interviewee H, who has not yet started battery production activities, emphasized that recycling is critical and shared the following:

> 'But the biggest thing is resources and recycling. Recycling is very critical. As you know, in Europe, since these electrified processes will be very fast, within the scope of two changes and due to the targets in emission values, resources are at the limit, so they have set targets for recycling. As you know, when we look at the new European Union projects in nickel, cobalt and lithium, recycling is always on the agenda in Horizon Europe.'

Recycling can be considered as a door of opportunity for Türkiye, which has difficulties in price competition with China in the field of batteries, to create a new strategic power for itself and realize its potential, and state policies can ensure that it does not fall behind in the race by using the human resources in this field correctly.

5.5. Policy Proposals

The last part of the questions, in which I collected solution suggestions from the interviewees for the existing problems and asked them about the steps they would take if they were in a decision-making position in this context, guided me in the science and technology policy design, which is one of the main outputs of the thesis. The answers I found based on the analysis of the data to the question of which technological capabilities can overcome the obstacles to the development of technology and how these capabilities can be developed are given respectively.

Strategic investment, division of labor between companies, university-industry cooperation, meritorious institutions, competitive export strategy, scaling to reduce production costs, large factories and foreign investment, growth of the subsidiary industry to reduce foreign dependency and increase localization, proper use of human resources accumulated in software technologies, and infrastructure development to ensure the diffusion of technology were frequently mentioned in both problem identification and solutions to problems. The solutions proposed for most of these problems were such as to prove that the state has an active responsibility in the transformation of electric vehicle and battery technology.

When we categorize state policies into two separate sub-themes, we see that they emerge as regulations and supports. **Interviewee B** stated that regulations should be in line with decarbonization targets but not in a way that penalizes the end user, and that they have to wait for the commercialization of their products depending on the situation in the country. After R&D and patent studies, they follow market opportunities to scale the product and develop a sales strategy. This situation can be seen as a reflection of the country's economic instability on the domestic market. In addition to regulations, those who mentioned government support mentioned policy instruments to prioritize these technologies for investment and to improve the production capacity of the auxiliary industry through certain incentives (tax reduction, purchase guarantee for foreign investors, etc.). Infrastructure development and increasing co-operation are other examples of state support. **Interviewee E**, whose expert opinion I obtained, expressed his views on this issue as follows:

> ‘First of all, for these technologies to become widespread, university-industry collaborations need to be done very well. Secondly, there are regulations, incentives, especially for renewable energy for vehicles, but these incentives should be increased. The infrastructure needs to be established throughout the country, such as fuel cell, hydrogen technology, infrastructure, hydrogen filling station, I don't know what kind of things, that kind of network needs to be established as infrastructure. For the battery, especially charging stations, if the battery has completed its life, rapid change and the development of those infrastructures are essential. The country needs to increase incentives in this regard, especially by policy makers.’ she stated, emphasizing their cooperation.

In the section where I questioned the examples of disruptive technologies in Türkiye and how they are realized, striking examples of state policies brought the defense industry to mind. **Interviewee D** argue that:

> ‘Incentives can be given; better facilities can be provided. Incentives can be given to research laboratories where people can go more. I mean, Türkiye has a certain budget, and it spends this budget in certain places, right? You can balance this expenditure in such a way that you can allocate more budget to these technologies. For example, if we do not have a problem of threats from outside, will we be able to allocate a significant portion of the budget we have to allocate for defense to technological developments? We have spent a lot of money on the defense industry to protect ourselves. I mean, there can be policies in that direction.’

Interviewee G agrees with this statement.

> ‘Yes, for example, this is how I see the drone production of the defense industry. For example, the US or Israel had drones for years, and we used them, but with disruptive technology, Türkiye's drones are being used in Ukraine today. Because we have changed the dimensions of the product, we have changed the flight time in the air, and that area is now placed in one of the most critical areas for war. A serious investment was made there, it was a transformation partnership, and in Türkiye, not individuals, but even the flattest institutions have become very critical. There are institutionalized structures. I see the innovations in the defense industry not as the product of an individual, but as an institutional success.’

5.6. Conclusion

Türkiye's current situation as a developing country has some handicaps regarding the development of electric vehicle and battery technologies. The interview questions, which were prepared in conjunction with the research questions, were designed to understand whether the key stakeholders of the sector lack the skills to identify these problems and find solutions to them. In particular, production and investment costs, which stand as a major obstacle to the development of new technologies, delay the technologies from reaching economies of scale and becoming feasible. Türkiye, which is trying to close this gap through R&D studies and technology transfer, has to cooperate and distribute tasks in order to use its human resources and all stakeholders of the sector in the right way. As in the defense industry, there are technologies that are prioritized and developed with state support, but here the country needs to set its targets well and develop the ability to identify areas that will be an investment for the future. Technological capabilities that will provide international competitive advantage play an indispensable role in this regard. It is clear that these capabilities need to be developed especially in line with dynamic capabilities and national innovation system. While the development of the sub-industry, which is one of the complementary capabilities, seems to be the solution to the problems of foreign dependency and localization, the economic policies of the country should be shaped to ensure the export-import balance. The co-operation of all institutions and companies and the distribution of tasks wisely will make the national technological effort meaningful and efficient. In this context, Türkiye should take meaningful steps to institutionalize all the structures that will contribute to the knowledge production processes and act within the framework of the principle of merit to become a producer and pioneer country from its position as a follower and consumer of technology.

Türkiye, which has reached an important position in the world because of 60 years of development in the automotive industry, should not lose its competitive power by lagging the rapidly changing new technologies. In this context, it seems possible to compete with countries such as China, which has a monopolizing share in the market, by investing in areas that will create opportunities for itself from crises and where it can reflect its own potential. It is understood from the interviews that Türkiye, which has reached a certain standard in terms of both money and human resources, can improve its technological capabilities and consequently increase its competitiveness by using its resources correctly and aiming for economic development, especially by bringing its exporter position in the European market to much better levels.

CHAPTER 6

CONCLUSIONS AND POLICY RECOMMENDATIONS

This section will discuss the outputs of the qualitative data analysis and the documentary analysis of Türkiye's current situation in the context of the literature, with the ultimate goal of policy discussions. After presenting the limitations of the thesis, points that can be the subject of future studies will be summarized.

6.1. Implications of the Thesis

According to the Global Innovation Index[16], Türkiye, which is in the upper middle-income group, ranks 39th among 132 countries in the world in terms of innovation performance and 3rd in its region after Israel and UAE. Although Türkiye is one of the middle-income economies that has made the most progress in innovation in the last 10 years, it is still below the EU average in innovation performance. Technological capabilities, one of the biggest sources of innovation performance, is a topic that needs further study for Türkiye. One of the most popular theoretical frameworks of technological capabilities literature with a strategic management approach is Dynamic Capabilities. Teece, Pisano and Shuen (1997) claim that technological capabilities, which they define as dynamic capabilities, increase the competence of firms to gain competitive advantage while adapting to changing market conditions. The direct relationship between these capabilities and innovation performance can be summarized as follows: Dynamic capabilities are capabilities that integrate, build, and restructure the firm's internal and external capabilities to adapt to rapidly changing environments and define the firm's ability to achieve innovative forms of competitive advantage. The emphasis on dynamic is used here to emphasizes the flexibility of firms in a rapidly changing environment. Based on the literature, the decarbonization transformation of Turkish firms in electric vehicles and battery technology is an example of this rapidly changing environment.

When we evaluate the internal and external capabilities of electric vehicle and battery companies in Türkiye based on Teece (2007);

[16] Source: https://www.wipo.int/en/web/global-innovation-index

1. The ability to perceive opportunities and threats, which is the transformation of assimilation capacity into perception capacity today, can be called the ability of companies to be aware of the crises that may arise in tidal market conditions and to turn these crises into opportunities. The ability of electric vehicle and battery companies in Türkiye to adapt to the market conditions of Türkiye and the world requires exactly such a capability. While they are aware of potential threats, the solutions they develop to address them are not innovative or unique. They have the capacity to coordinate with sustainability goals and to transfer and adapt limited technologies that are not available here.

2. As mentioned above, although the companies have an insight in capturing opportunities, which is another dynamic capability, they do not have an entrepreneurial attitude. Although they have perceived the importance and opportunities created by recycling and battery charging capacity, there is no economic initiative to seize these opportunities. The companies, which need the encouraging attitude of the state in this regard, are afraid of the initial investment and production costs due to limited opportunities. The academia side is already aware of this situation and continues its research as an investment for the future, especially in the material unit, and creates knowledge accumulation. At this point, the government's bringing together companies and academy stakeholders working in the field of materials and supporting them with funds to increase R&D studies will contribute to the ability to seize opportunities. Finally, the perceived and captured opportunity should be evaluated with analytical thinking. The perspectives of the company employees and the corporate culture should be able to respond to the skills that need to be developed in line with the needs of these opportunities. Based on the inferences I made from the interviews, although individuals have these skills, not all of them are successful in transferring them to the company level. In fact, this is one of the important technological capabilities in terms of companies' ability to reveal their unique differences.

3. After detection and capture, the restructuring phase covers possible threats. This dynamic capability, which Teece (2007) underlines the integration of new resources and assets into the organization, means the collective sharing of the information obtained in the first two stages. According to Teece (1982), since the new knowledge created by learning is hidden in the individuals themselves, the knowledge needs to be shared, that is, integrated at a collective level. Thanks to this dynamic capability, firms will be able to keep themselves up to date continuously

and will be able to take competitive advantage of the rapid changes in the market (Teece, 2007).

In this context, McKinsey's study on Türkiye's sustainability transformation in 2024 provides a good base for combining interview data and theoretical framework. The study, titled Net zero opportunity, presents a projection of Türkiye's promised 2053 targets.[17] Accordingly, to realize the targets, Türkiye needs to spend about 7% of its GDP, i.e., $3.1 trillion, on energy, materials, and land use, as well as infrastructure development by 2053. It argues that the transformation process, which requires such a large resource, can only be realized through cooperation between stakeholders. These stakeholders range from financial institutions that will provide green funds to consumers with green demands. The point where this report and the dynamic capabilities literature are compatible is that it addresses this transformation process from both a crisis and an opportunity perspective.

Accordingly, the crisis is that Europe's Carbon Border Adjustment Mechanism (CBAM)[18], which will enter into force in 2026, will levy a tax on imports of high-carbon materials such as steel, cement, aluminum, fertilizer, hydrogen, and electricity into the European Union. This mechanism, which aims to incentivize clean industrial production by putting a price on emissions from the production of carbon-intensive goods entering the European Union, will push the Turkish automotive industry, which has an important place in the European market, to strive to reduce their carbon footprint. Interviewee J, one of the companies that made similar remarks during the interviews, stated that they aim to reach their potential customers in 2026 with a product that offers solutions to this issue through their studies on battery passport. Interviewee C, an electric bus manufacturer, stated that they are trying to make electricity generation clean by equipping all factory buildings with solar panels regarding their mission and vision. We see that these companies have entered a restructuring process to resolve the possible crises that CBAM and the EU Emissions Trading System[19] will create within their own organizations. In this context, although we can say that they have dynamic capabilities**,** we cannot say that they have an initiative to turn the crisis into an opportunity. This is a situation related to both the product portfolio and export items of the firms. The fact that they state that the state should take a hand in recycling emphasizes the need for the

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[17] Source: https://www.mckinsey.com/capabilities/sustainability/our-insights/turkiyes-sustainability-transformation-the-net-zero-opportunity#/

[18] Source: https://taxation-customs.ec.europa.eu/carbon-border-adjustment-mechanism_en

[19] Source: https://climate.ec.europa.eu/eu-action/eu-emissions-trading-system-eu-ets_en

formation of a complementary and auxiliary industry in this field. Accordingly, the crisis is that Europe's Carbon Border Adjustment Mechanism (CBAM), which will enter into force in 2026, will levy a tax on imports of high-carbon materials such as steel, cement, aluminum, fertilizer, hydrogen, and electricity into the European Union. This mechanism, which aims to incentivize clean industrial production by putting a price on emissions from the production of carbon-intensive goods entering the European Union, will push the Turkish automotive industry, which has an important place in the European market, to strive to reduce their carbon footprint. Interviewee J, one of the companies that made similar remarks during the interviews, stated that they aim to reach their potential customers in 2026 with a product that offers solutions to this issue through their studies on battery passport. Interviewee C, an electric bus manufacturer, stated that they are trying to make electricity generation clean by equipping all factory buildings with solar panels regarding their mission and vision. We see that these companies have entered a restructuring process to resolve the possible crises that CBAM and the EU Emissions Trading System will create within their own organizations. In this context, although we can say that they have dynamic capabilities, we cannot say that they have an initiative to turn the crisis into an opportunity. This is a situation related to both the product portfolio and export items of the firms. The fact that they state that the state should take a hand in recycling emphasizes the need for the formation of a complementary and auxiliary industry in this field. Accordingly, it emerges that the sectors with high emissions should enter the transformation process as prioritized and fast as possible. According to TURKSTAT data, while the total greenhouse gas emissions in 2021 was 564 Mt Co2, 91 Mt Co2 of this is accounted for by the transport sector.[20] This share is sufficient to prioritize transport. In these areas, it is necessary to build technological capabilities and strategically redistribute resources to transition to green technologies with sustainable business models. Recycling batteries of electric vehicles can contribute to Türkiye's competitiveness in terms of potential opportunities.

6.2. Policy Recommendations

There are many different studies in the field of science and technology policy from many different perspectives. These studies, which are basically divided into two theoretical frameworks, are gathered in the neo-classical movement, which is used to state intervention only when the market fails, and in the evolutionary economics understanding that rejects the

[20] Source: https://enerji.gov.tr/Media/Dizin/EVCED/tr/%C3%87evreVe%C4%B0klim/%C4%B0klimDe%C4%9Fi%C5%9Fikli%C4%9Fi/UlusalSeraGaz%C4%B1EmisyonEnvanteri/Belgeler/Ek-1.pdf

assumption that knowledge is accessible and the same for everyone from the moment it is produced. The tacit nature of knowledge and the fact that innovation does not emerge from a linear process have been fed by studies endeavoring to understand the knowledge production processes and the sources of innovation. In this direction, approaches such as the national innovation system have emerged by questioning the effectiveness of the processes in the transfer of knowledge as well as the emergence process. Each actor that puts forth technological endeavors is an important part of this innovation system approach and the processes arising from the interaction between them contribute to the cumulative progressive structure of knowledge. While policy instruments such as incentives and tax exemptions aimed at increasing R&D are cost-oriented and can be useful to increase knowledge production in situations where resources are not fairly distributed in the market; however, based on the work of Coombs&Bierly in the literature review (see chapter 2), many points are overlooked in measuring existing technological capabilities and presenting them as a solution to improve them, since investing in R&D does not always result in innovation (no competitive quality). Policies aimed at increasing the effectiveness of knowledge flow processes one step beyond knowledge production, on the other hand, try to increase the impact of these processes directly or indirectly through the participation and contribution of each actor constituting the innovation system. When we look at the theoretical foundations of the concept of technological capabilities in the literature, the assimilation capacity, which started from knowledge production capabilities, has evolved into dynamic capabilities, which are the ability to perceive opportunities and threats, which see the ability to respond quickly to changes, that is, to stay in interaction as a capability. The increasing complexity of production processes for the firm and the impact of each actor on the process has also revealed the need for innovation systems policies. Accordingly, the state, which has an active role in the innovation system, is not only a regulatory and supervisory power that removes rough edges, but also a key that enables all actors in the innovation system to interact and increase interaction. Based on this, as a result of the research and analysis I conducted in my own thesis, I see these two policy approaches as complementary for a developing country like Türkiye. With the conclusion I have reached from the literature, I realize that National Innovation System policies are lacking in this country, and I have confirmed the undeniable contribution of state support and incentives for costs in terms of providing a basic competence for the knowledge production processes of each actor involved in the national innovation system with interview data.

The fact that the production and initial investment costs of electric vehicle and battery technologies, which are the most frequently mentioned problems of the companies because of the interviews, are too high, is an obstacle to the formation of the knowledge to be transmitted in the knowledge flow process. Therefore, government supports and incentives for costs may make less sense only as the level of development of the country increases. It should not be overlooked that unless state support and incentives are directed to the right areas, the use of resources is wasted. After the formation of knowledge, the expansion of its quality with the contributions of each actor will emerge as a product of joint work in co-operation. For this reason, rather than increasing the number of university-industry collaborations, establishing the right collaborations will contribute more to technological development.

In this context, I have formulated my science and technology policy recommendations for the development of the technological capabilities of electric vehicles and battery technologies by following these steps;

1. Determining the sectors that will contribute the most to the realization of Türkiye's 2053 carbon neutrality targets
2. The transport sector, which should be considered as one of these sectors, should enter the transformation process without losing the current competitiveness of the Turkish Automotive Industry
3. Recognizing the handicaps of this transformation process as potential opportunities for Türkiye and identifying the technological capabilities required by these potentials
4. Making efforts at the national level to increase the effectiveness of these identified technological capabilities and to overcome their deficiencies
5. These are the policies needed to realize national level efforts with the participation and interaction of all sector stakeholders.

The policy tools to be used for the realization of these policies can be listed as the creation of a development plan with realistic and systematic targets to create infrastructure, preparation of regulations to include renewable energy resources in production processes in order to produce low-emission technology, development of action plans that adopt strategic task distribution and cooperation among sector stakeholders in order to reduce investment costs, development of projects that shift university-industry collaborations to these two areas in order to invest in the future in recycling and battery materials, and directing investments that will feed innovation ecosystems in accordance with the nature of the transition to clean energy.

At this point, all the problems mentioned above, and the suggested policies are summarized in Table 10. When this table is examined, the priority problems in Turkey's ability to develop and innovate EV and battery technologies are listed. The solutions to be developed for these problems and the technological capabilities required for these solutions are explained. The steps that the state should take for these solutions are listed in the policy recommendations section. Then, examples of policy tools suitable for these recommendations are presented. The classification of these policy tools is given in the last column. Although production capacity and R&D are the areas that stand out as the first to be developed, as mentioned in the previous chapters, the organizational counterparts of technological capability, marketing and discovering new markets, are another area emphasized in this study. The ability of the produced technologies to find buyers is important both for the return on investment and for the technology to be adopted and spread. In the next stage, the customer's demand will be another important element that will develop the product and technology and can be examined from this perspective in future studies. Apart from this, the mentioned cooperation, strategic investment and merit-oriented suggestions are the most important data obtained from the participants of this study.

In summary, Turkey can use its competitive power by setting realistic goals with a systematic and strategic roadmap in which all stakeholders take an active role in the process, using its existing human resources and accumulated talent in the automotive industry.

Table 10. Policy Tools

Policy Implications for Development of EV and Storage Technologies in Türkiye				
Obstacles to the Development of Technology	**Solutions**	**Policy Recommendations**	**Policy Tools**	**Policy Tool Types**
Lack of Complementary Technological Capabilities	Infrastructure Sub-Industry	The necessary infrastructure work should be carried out to integrate the technological capabilities that Türkiye has accumulated in the automotive sector with new technologies; the sub-industry should be supported; external dependency should be reduced, and production costs should be lowered.	Providing incentives and loans for the installation of charging stations Allocating suitable areas for charging stations Providing tax breaks to sub-industry manufacturers, especially for battery technologies	Financial Regulatory

Table 10. (continued)

High Production and Investment Costs	Strategic Investment Foreign Direct Investment	A strategic roadmap should be determined for these technologies and rational investments should be supported, and foreign investors and joint ventures should be supported to the extent that they do not harm the competitiveness of local companies.	Organizing studies to determine technologies that are a priority for Türkiye Conducting Feasibility Studies Taking steps for cooperation with potential rival countries Creating stable and secure economic policies to attract foreign investors	Financial Regulatory Soft Tools
Difficulty of Raw Material Supply and Costs	Locality Partnership	R&D should be conducted for critical raw materials, especially considering renewable energy technologies such as solar and wind energy, Türkiye's reserves should be investigated in detail and processing capacity should be improved. Foreign dependency on raw materials should be reduced or cooperation should be developed with countries that play an important role in the supply process. Export and import balance should be achieved.	Developing a roadmap to accelerate material and mineral studies in Türkiye Utilizing inter-institutional cooperation and university staff Developing R&D activities for lithium, specifically for Salt Lake To prepare a specific critical material list and mineral mapping for Türkiye	Regulatory Soft Tools

Table 10. (continued)

Economies of Scale	Marketing New Markets	Larger production capacities should be targeted to reduce production costs. Delivering new technologies to customers should be a goal as much as producing them, new markets should be explored, and efforts should be made to establish international cooperation where local manufacturers can market their products.	Developing an export strategy for EV to European and Middle Eastern countries Implementing monetary policies to encourage exports Developing marketing strategies to promote the product well enough Taking steps to develop foreign relations with potential customer countries Establishing joint working consortiums	Financial Regulatory Soft Tools
Strong competitor in the Market	Focus on niche areas Prioritize these investments	Opportunities should be created by focusing on areas where there is still little competition, such as recycling, and investors and producers who focus on such niche areas should be supported.	Developing TUBITAK and European Union projects for recycling, Providing state support and tax exemption to manufacturers and investors related to recycling, Determining expert staff on recycling and developing cooperation projects with industry	Financial Soft Tools

Table 10. (continued)

Failure to utilize qualified human resources in the country	University Industry Collaborations Merit	Academics working in the EV and battery field should be brought together with manufacturing companies and academicians should be included in projects according to their fields of study. Institutionalized R&D projects and supports should be implemented to use strong and qualified human resources efficiently. Division of labor and cooperation should be encouraged	Supporting R&D and scientific studies conducted within the university by the state Providing financial and physical resources Organizing workshops that will bring together academics working in this field Organizing award-winning competitions to support new ideas and entrepreneurs	Financial Soft Tools

6.3. Future Research and Limitations

The qualitative data collected in this study could be improved in terms of the number of interviewees because the presence of non-production firms in the mindset of the transformation process allowed me to understand their current technological capabilities but may not reflect the reality to understand their renewed capabilities specific to electric vehicle and battery technology. Their existing capabilities and R&D know-how represent their capabilities specific to these technologies. One of the things I observed while collecting data was that companies did not want to share their personal opinions about the topics covered by their unannounced projects, which they considered to be within the scope of company confidentiality. This made it difficult for some interviews to focus on specific questions and to identify firm differences in other questions. Another observation and constraint were that a significant number of the interviewed firms were joint ventures, as they were reluctant to share information due to the dominance of their foreign partners in decision-making processes. From time to time, there were interviewees who wanted to stop the recording or asked me not to add my notes to the transcript. Despite all these, there were very recurrent matches, especially on the obstacles to the development of technology. One of these was the high investment costs and the lack of a subsidiary industry. As a solution to these obstacles, there was a common opinion that foreign investors should come. However, after the interviews, I wonder whether their opinions on this issue have changed due to a development in Türkiye during the preparation of this study. The arrival of BYD investment and the extent of the competitive advantages recognized may be the subject of future studies in terms of the link between foreign investment and technological capability development. To elaborate on this development, the Presidential Decree on the Amendment to the Decree on the Amendment to the Decree on the Application of Additional Customs Duty on Imports entered into force after being published in the Official Gazette on 5 July 2024. With the new article added to the Decree, it has been decided not to impose additional financial obligation on imports of Chinese origin automobiles, which are realized by benefiting from customs exemption within the scope of investment incentive certificate. Accordingly, Chinese companies investing in Türkiye were exempted from additional customs duty. Following this decision, an agreement was signed on 8 July 2024 with the Chinese automotive company BYD to establish a factory in Manisa with an investment of approximately USD 1 billion. It was announced that the factory, which will start production at the end of 2026, will employ 5 thousand people and will have an annual production capacity of 150 thousand vehicles. It was added that these vehicles will be electric and hybrid vehicles, and that a center will be established to carry out R&D studies on sustainable technologies. Even though a foreign investor has arrived after a long time with tax exemption, the fact that BYD will be able to sell the vehicles it imports tax-free without starting production in the country may have more negative than positive effects on both other Chinese competitors and the Turkish local market. The newly emerging competitive advantage of local firms in Türkiye carries the risk of completely disappearing in the domestic market. Therefore, while vehicle imports to Türkiye will increase, local firms will need to find new markets to increase exports. In addition to this, local companies may not have any price advantage against BYD, which will benefit from the 10 per cent SCT advantage, with SCT rates that can go up to 60 per cent for internal combustion vehicles and 80 per cent for electric vehicles depending on engine power. The arrival of foreign investors in the country, which was emphasized especially in the interviews, will increase competition, and cause the sector to grow, but it may adversely affect the import-export balance until BYD starts production here. For this reason, it is important to balance the competitive advantages of domestic companies so that they do not lose their production capacity. In particular, the approximately 2.5 billion TL investment made in Togg so far may be wasted due to the inability to increase the sales share in the domestic market and the lack of sales to Europe. Considering that BYD, which aims to expand into the European market, has positioned Türkiye as a production base, China's dominance of its own brands in the European market may lead local companies to leave more production share for commercial vehicles and products such as electric buses and electric tractors instead of passenger cars. With Tesla's falling shares, it may also hinder America's competitiveness. Time will show the benefits and drawbacks of BYD for Türkiye, which causes customer hesitation about quality even though it has a price advantage.

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APPENDICES

A. APPROVAL OF THE METU HUMAN SUBJECTS ETHICS COMMITTEE

[redacted]

B. QUESTIONNAIRE FORM

ELEKTRİKLİ ARAÇ VE ENERJİ DEPOLAMA TEKNOLOJİLERİ KAPSAMINDA TEKNOLOJİK YETENEK ANALİZİ: TÜRKİYE ÖRNEĞİ

Mülakat Rehberi

Merhaba, ben Ilgın İrem Gündüz. ODTÜ TEKPOL'de yüksek lisans öğrencisiyim. Tezimde elektrikli araç ve batarya teknolojilerinin, teknolojik yetenekleri üzerine çalışıyorum. Türkiye için yeni ve hızlı gelişen bu teknolojinin önemini belirten, üretim aşamasının zorlukları ve bilgi yayılım süreçleri gibi konuları açıklığa kavuşturan bir çalışma yapmak amacındayım. Bu sebeple sektörden mühendisler ve yöneticilerle derinlemesine görüşmeler yapmak istedim. Yaklaşık bir saat sürecek bu görüşmede sizin görüş ve deneyimlerinizden bahsedeceğiz. Lütfen detaylı cevap vermekten kaçınmayın, anlamadığınız ya da geçmek istediğiniz sorular olursa her zaman bana sorabilirsiniz. Daha sonra dinleyip cevaplarınızı detaylı şekilde yazıya dökebilmek adına izninizle ses kaydı almak istiyorum. Bu görüşmeye katıldığınız için teşekkürler.

Görüşmeci Profili

Kısaca kendinizden bahseder misiniz?

- Ad-Soyad, Yaş, Mezun olduğu okul ve bölüm

Çalıştığınız şirket ve pozisyonunuz nedir?

- Bu alana nasıl ilgi duymaya başladınız, kaç yıllık bir iş tecrübeniz var?

Üretim Süreci

1. Elektrikli araç/batarya/şarj cihazı üreten bir firma olarak innovasyon sizce nedir ve kendinizi/şirketinizi bu alanda innovatif olarak tanımlar mısınız?
2. Elektrikli araç/batarya/şarj cihazı ARGE sürecinizden bahsedebilir misiniz?

3. Elektrikli araç/batarya/şarj cihazı üretimi için varsa yaptığınız teknoloji transfer sürecinden bahseder misiniz?
4. Elektrikli araç/batarya/şarj cihazı üretiminde çalışacak personeli nasıl ve hangi kriterlere göre seçtiniz? (Yönetici Pozisyon)
5. Elektrikli araç/batarya/şarj cihazı üretim sürecinde herhangi bir kurum (okul, kamu kurumu, özel sektör) ile iş birliği yaptınız mı?
6. Firmanızın Türkiye'de diğer ülkelerdeki üretim sürecinden farklı bir aşaması var mı? (örn. Çok Uluslu Şirketler)
7. Elektrikli araç/batarya/üretimi/tasarımı sırasında karşılaştığınız en belirgin sorun neydi?

Bilgi Yayılım Süreci

8. Elektrikli araç/batarya/şarj cihazı teknolojileri ile bilgi üretim süreçleri arasındaki ilişkiyi nasıl tanımlarsınız?
9. Bir mühendis olarak elektrikli araç/batarya/şarj cihazı projesi geliştirirken bu alanda çalışırken hiç zımni (tacit) bilgiye (*yazıya aktarılmamış, yalnızca görerek öğrenebileceğiniz bilgi türü i.e: yüzmek*) rastladınız mı?

Uluslararası Hedefler

10. Elektrikli araç/bataryaların AB Yeşil Mutabakat Belgesi için ifade ettiği anlam sizce nedir?
11. Karbonsuzlaştırmaya dair misyon ve vizyonlarınız var mı, varsa nelerdir? (Yönetici Pozisyon)

Teknolojik Gelişim

12. Türkiye'deki elektrikli araç ve batarya/şarj cihazı sektöründe ilk aklınıza gelen sorun nedir?
13. Elektrikli araçların/şarj cihazı yaygın kullanımı ile çözülecek problemler nelerdir?
14. Türkiye'de bu teknolojinin ne kadar sürede yaygın kullanımına kavuşacağını öngörürsünüz?
15. Elektrikli araç/bataryaların/şarj cihazlarının size göre dezavantajları var mı varsa nelerdir?
16. Elektrikli araç/bataryaların/şarj cihazlarının şarj kapasitesi hakkında ne düşünüyorsunuz?

17. Elektrikli araçların/şarj cihazlarının gelecekte sahip olacağı en önemli özelliği tahmin edebilir misiniz?
18. Şu anki haliyle ürünlerinize talep var mı? Bu talebin süreç içinde nasıl değişeceğini düşünüyorsunuz?

Politika Önerileri

19. Sizce elektrikli araç/batarya/şarj teknolojilerinin yayılması için hangi politikalara ihtiyaç vardır?
20. Siz politika yapıcı/karar verici olsaydınız elektrikli araç/batarya teknolojisinin geleceği adına hangi adımları atardınız?

C. TURKISH SUMMARY / TÜRKÇE ÖZET

Uygarlığın doğuşunda ve bugünkü haline gelmesinde büyük rol oynayan ulaştırma sektörü, bugün uygarlığın sonunu getirebilecek en büyük sorunlardan birine neden oluyor: İklim Krizi. Bugün kara, hava ve deniz ulaşımının olmadığı bir dünyayı hayal etmekte zorlanan insanlık, gelecek için tüm bu ulaşım türlerinin çevreye en az zarar veren şeklini bulmak zorunda. İçten yanmalı motorlar ve fosil yakıtlarla sera gazı emisyonlarının artışında büyük rol oynayan karayolu taşımacılığı, başladığı yere geri dönmek zorunda kaldı: Elektrifikasyon. Tren ve metro gibi başka ulaşım türlerine çok daha önce giren elektrikli motorlar, bugün otomobiller için en iyi versiyonuna ulaşmaya çalışıyor. 1800'lü yıllarda elektrikli motorlar birçok farklı yerde farklı kişiler tarafından geliştirilmiş ve raylı sistemlere entegre edilmişti ancak güç ve verimlilik açısından istenilen seviyede değillerdi. Şarj edilebilir bataryalardaki gelişmelerle 1900-1910 yılları arasında en başarılı dönemini yaşayan elektrikli araçlar, sessiz ve yavaş olmaları nedeniyle o dönemde “kadın arabası” olarak adlandırılıyordu (Guarnieri, 2012). Kıta Avrupası ve Amerika'da içten yanmalı araçlardan daha büyük bir pazar payına sahipken, asfalt çalışmaları ile otoyolların gelişmesi ve petrol rezervlerinin keşfi ile benzin fiyatının düşmesinden sonra menzil ve hız ihtiyacı yeniden canlanınca elektrikli otomobiller de popülerliğini yitirmiştir (Guarnieri, 2012). 1920'den sonra ise ortadan kaybolan bir “deney” olarak kalmıştır. Burada görülen, herhangi bir yenilik ve buluşun, altyapı ve üretim teknolojilerindeki gelişme paralel olmadığında benimsenmesini ve yaygınlaşmasını engellemesidir. Bu nedenle bugün elektrikli araçların hikayesine yeniden dahil olan dünyanın, depolama teknolojileri ve şarj istasyonları/şebeke gücü gibi altyapı sorunlarına da bütüncül bir şekilde yaklaşması gerekmektedir.

İklim değişikliği ile küresel mücadele 1992 yılında “Birleşmiş Milletler İklim Değişikliği Çerçeve Sözleşmesi” ile başladı ve 1997 yılında Kyoto Protokolü ile devam etti. 2015 yılında Paris'te düzenlenen COP21'de insan kaynaklı sera gazı emisyonlarının 2 santigrat derecenin altında sınırlandırılmasını taahhüt eden Paris Anlaşması imzalandı. 2023 yılı itibariyle bu anlaşmaya taraf olan 196 ülke bulunmaktadır. Bu anlaşma ile her ülke kendi gelişmişliğine göre sorumluluk almış ve ulusal katkı beyanlarını sunmuştur. Küresel enerji sektörü için belirlenen net sıfır karbon emisyonu hedefi de 2050 yılıdır.

Türkiye de gelişmekte olan bir ülke olarak 2021 yılında bu anlaşmaya taraf olmuştur. Bu adımla birlikte Birleşmiş Milletler Kalkınma Programı (UNDP) desteğiyle “İklim

Değişikliği Azaltım Stratejisi ve Eylem Planı” ile “2053 Uzun Vadeli İklim Değişikliği Stratejisi” hazırlanmıştır. Ulusal katkı beyanında %21 azaltım hedefi koyan Türkiye, 2023 yılında bu hedefi güncelleyerek %41'e yükseltmiştir. Net sıfır karbon hedefi için 2053 yılını seçen Türkiye, kalkınma programları, eylem planları ve iklim konseyleri ile stratejiler geliştirmekte ve temel sektörlerin yeşil dönüşümü için yol haritalarına sahiptir.

Küresel Karbon Projesi verilerine göre 1960 yılından bu yana küresel emisyonlarda en büyük düşüş 2020 yılında yaşanmıştır (%5,4). Bu düşüşün Covid-19 pandemisindeki zorunlu kapatmaların hava ve kara ulaşımını kısıtlaması nedeniyle gerçekleştiği düşünülmektedir. Ancak 2021 yılında emisyonların tekrar arttığı ve yükseliş eğilimini sürdürerek 2022 yılında rekor seviyelere ulaştığı görülmüştür (IEA, 2022a). IEA raporuna göre, enerji sektöründen kaynaklanan küresel CO2 emisyonları 2022 yılında 37 milyar ton ile rekor kırarak pandemi öncesindeki durumu %1 oranında aşmıştır (IEA, 2022a). Küresel emisyonlarda en büyük paya sahip ilk 10 ülke Çin Halk Cumhuriyeti, Amerika Birleşik Devletleri ve Hindistan'ın başını çektiği bir liste olup; bu ülkeleri Avrupa ülkeleri, Rusya, Japonya ve Brezilya, Endonezya, İran ve Kanada takip etmektedir. Bu ülkelerin ilk üçü toplam emisyonlarda %42,6'lık bir paya sahiptir. Enerji sektörü 1990 yılından bu yana sera gazı emisyonlarının en büyük kaynağı olmuştur.

Bu nedenle fosil yakıtların küresel enerji sektöründen çıkarılması ve temiz enerji teknolojileri giderek önem kazanmaktadır. Kömür ve fosil yakıtlı enerji sistemlerinden elektrik ve yenilenebilir enerjili sistemlere geçiş tüm dünyada hızla ilerlemektedir. 2022'de başlayan Rusya-Ukrayna savaşı ile birlikte enerji güvenliğine ilişkin endişeler de artmış ve pandemi sonrası ortaya çıkan enflasyonist ortamda fiyatlar yükselmiştir. Tüm bu süreç ülkelerin doğalgaz ve petrolden bağımsızlaşmak için yenilenebilir enerji kaynaklarına yatırımlarını artırmıştır. Bu noktada güneş ve rüzgâr enerjisi ile elektrikli araçlar gibi yenilenebilir enerji kaynakları ön plana çıkmaktadır. Son yıllarda hızla artan devlet desteği ile güneş ve rüzgâr enerjisinde kurulu kapasite artarken, elektrikli araçlar ve depolama teknolojilerinde de seri üretim ve standardizasyon sağlanmaya çalışılmaktadır. Örneğin, 2023 yılında Elektrikli otomobil satışlarının 2022 yılına göre 3,5 milyon adet daha artarak %35 oranına yükselmesi beklenmektedir (IEA, 2023). Artan elektrikli araç satışları, bataryalara yönelik küresel talebi körüklemektedir. IEA verilerine göre, elektrikli araç bataryalarına olan talep 2023 yılında 2022 yılına kıyasla %40 artarak 750 GWh'in üzerine çıkmış, büyüme hızı ise yıllık bazda yavaşlamıştır (2024). Batarya malzemeleri için dalgalanan fiyatlar nedeniyle maliyetler 2022'de artmış görünmektedir. BloombergNEF'in yıllık batarya fiyat araştırmasına göre, fiyatlar 2022 yılında %7 oranında artmıştır. Batarya talebindeki büyüme oranının %95'i elektrikli otomobillerden kaynaklanmaktadır (IEA,2024). Türkiye'de de bu durum dünyada olduğu gibi hızla büyümektedir. 2023 yılında elektrikli araç sayısı bir önceki yıla göre 5 kat artmış görünmektedir (Tablo 1). Ancak hibrit araçlar EA'ları domine etmektedir. Türkiye'deki son kullanıcıların bu teknolojiye ilişkin endişeleri nedeniyle, hibrit araçlar 2024 yılında 222.328 adetlik satışla uzun bir süre elektrikli araçlara geçişte bir ara durak noktası olabilir. Bu da sektördeki gelişmelerin son yıllarda hızlandığının bir kanıtıdır. Tüm bu gelişmeler göz önünde bulundurulduğunda, elektrikli araç ve depolama teknolojilerinde net sıfır karbona ulaşmak, maliyetleri düşürmek ve sektörü büyütmek için inovasyon şarttır. Düşük emisyonlu teknolojilerin azlığı ve altyapı eksiklikleri düşünüldüğünde; batarya teknolojilerindeki kritik hammaddelerin tedarik ve işleme süreçleri göz önüne alındığında; elektrikli otomobillerin yaygınlaşması için önemli olan menzil ve şarj süresi gibi kullanıcı ihtiyaçları, tüm bunlara hızla çözüm üretebilecek teknolojiler gerektirmektedir.

Tüm dünyanın hızla girdiği enerji dönüşümü süreci dikkate alındığında, Türkiye gibi otomotiv sektöründe belirli bir yetkinliğe ve konuma sahip bir ülkenin rekabet gücünü kaybetme tehlikesi bulunmaktadır. Elektrikli araçlar ve depolama teknolojilerinde oldukça ilerlemiş olan Asya-Pasifik ülkeleri, Türkiye'nin Avrupa'daki satış gücünü etkileyebilir. Çin gibi içten yanmalı motorlu otomobillerin küresel satışında sadece %10'luk bir paya sahip olan bir ülke, 2023 yılında dünya çapında satılan tüm elektrikli otomobillerin yarısından fazlasını üretmiş gözükmektedir. (IEA,2024).

Türkiye mevcut insan kaynağı, yatırımları ve otomotiv üretim kapasitesi ile bu dönüşümde yerini almalıdır. Bu yolda yapılması gereken öncelikle mevcut durumunu tespit etmek, potansiyelini ve diğer ülkelerden öne çıktığı ve fark yaratabileceği teknolojik alanları belirlemek, ardından uluslararası iş birliği gerektiren alanlarda sanayi stratejileri geliştirmektir. Devletin aktif bir aktör olması gereken bu süreçte yatırımlar, teşvikler ve iş birlikleri konusunda birçok sorumluluğu bulunmaktadır. Ulusal çaba gerektiren bu teknolojik dönüşüm süreci, gelecekteki konumunu şimdiden konumlandırabilmesi için önemlidir. Hem dinamik yerel pazarı hem de Avrupa ve Afrika için ihracat merkezlerinden biri olarak rekabet gücünü ve uluslararası konumunu korumak için teknolojik yeniliklere ihtiyaç duymaktadır. Bu bağlamda, özellikle Türkiye'nin inovasyon kapasitesini artırması için ülkedeki bilim ve teknoloji politikaları üzerinde çalışılmalıdır. Teknolojik kabiliyetleri belirleyen, bunların artırılması için gerekenleri hedefleyen ve bu yolda tüm paydaşlara sorumluluk ve iş birliği yükleyen politikalar ile Türkiye elektrikli araç pazarındaki stratejik önemini kanıtlayabilir.

1960'lı yıllarda faaliyetlerine başlayan Türk otomotiv sanayi, 60 yıllık tecrübesi, yerli ve yabancı ortakların büyük yatırımları ile her geçen gün daha da büyüyerek üretim kapasitesini artırmış ve çeşitlendirmiştir. Otomobilin yanı sıra özellikle hafif ticari araçlarda Avrupa'da ilk sırada yer alan otomotiv sanayi, kamyon, otobüs, midibüs ve traktör olmak üzere 6 araç grubundan oluşmakta ve 82 ülkeye ihracat yapmaktadır (OSD,2022). Ekonomik kalkınmada büyük rol oynayan otomotiv sektörü, ülkedeki istihdamın büyük bir bölümünü oluşturmakla kalmayıp, tedarikçileri ve yan sanayileri ile birçok farklı sektör yaratmıştır. Tüm komponentleri ve kendi motoru gibi yerli ürünleri geliştirmeyi başaran bu sektör, diğer ülkelere yaptığı ihracatla da etkin bir uluslararası oyuncu olmayı başarmış görünmektedir. 1995 yılında AB ile imzalanan Gümrük Birliği Anlaşması ile Türkiye, coğrafi konumunu stratejik olarak kullanmayı başarmış ve Avrupa'nın en büyük ihracatçısı konumuna gelmiştir. Bugün Türkiye, dünyanın 14'üncü, Avrupa'nın ise 4'üncü büyük otomotiv üretim merkezidir ve küresel otomotiv zincirinin güçlü bir halkasıdır (KPMG, 2023). OSD verilerine göre yıllık yaklaşık 2 milyon adet üretim kapasitesine ulaşan bu sektör, dünyadaki gelişmelere ayak uydurmak için yeni bir dönüşüm sürecindedir (2022). Karbon sıfır hedeflerine katkı sağlamayı amaçlayan Türkiye Cumhuriyeti, hem ülkenin lokomotif sektörlerinden biri olan hem de karbon salımının önemli bir kısmından sorumlu olan otomotiv sektörünün bu dönüşümü güçlü yönlerini kaybetmeden ve kendisine yeni fırsatlar yaratacak şekilde geçirmesine destek olmalıdır.

Pandemi sonrası çip tedarikinde yaşanan kriz nedeniyle birçok ülkede otomotiv sektörünün büyüme oranları düşerken, Türkiye'de baz etkisi nedeniyle 2022 yılında bir önceki yıla göre büyümede artış görülmüştür (KPMG, 2023). Ancak son yıllarda üretimin talebi karşılayamaması nedeniyle fiyatlar kademeli olarak artma eğilimine girmiş ve özellikle yüksek ÖTV oranları fiyatlar üzerinde baskı oluşturmuştur. Örneğin ODMD verilerine göre 2023 yılına kıyasla 160 kW altı elektrikli otomobil satışları yüzde 453,1 artışla yüzde 84,2'ye, 160 kW üstü elektrikli otomobil satışları ise yüzde 34,5 artışla yüzde 15,8'e yükselmiştir (2024, Ocak). Bunun nedeni 160 kW altı elektrikli araçlarda ÖTV oranının yüzde 10, 160 kW üstü elektrikli araçlarda ise yüzde 50-60 olmasıdır. Böylece 2024 verilerine göre elektrikli araçların toplam otomotiv pazarındaki payı %6,2'ye yükselmiştir (ODMD, 2024).

Küresel otomotiv üreticilerinin karbon nötrlüğü hedeflerine uyum sağlamak için dijitalleşme ve sürdürülebilirlik temalarıyla birçok teknolojik gelişme sağlamaya çalıştığı görülmektedir. Tesla'nın ortaya çıkışı ve pazardaki hakimiyeti ile Çin gibi ülkeler kendi yerli markalarını piyasaya sürmeye çalışırken, mevcut markalar da yeni elektrikli modeller üzerinde çalışarak birçok teknolojik yenilik getirmişlerdir. Bu bağlamda Türkiye'nin sadece üretim kapasitesini değil, insan kaynağını ve araştırma-geliştirme faaliyetlerini de geliştirmesi gerekmektedir. Teknolojik yetenek analizi, Türkiye gibi gelişmekte olan ülkeler için üzerinde çalışılması ve düşünülmesi gereken bir konudur. Elektrikli araçlar ve depolama teknolojileri zorluklar teşkil etse de Türkiye için birçok fırsat da sunmaktadır. Bu süreç sadece yeni teknolojileri ithal etme ve adapte etme süreci değil, aynı zamanda teknolojik yeteneklerini kullanarak yenilikler üreten ve geliştiren bir ülke olma sürecidir. Bu çalışma, Türkiye'nin otomotiv endüstrisinin küresel pazardaki konumunu koruması ve geliştirmesi için teknolojik yetenek literatürüne dayanarak Türkiye'nin potansiyelini anlamaya çalışmakta ve bir yol haritası oluşturmak için politika önerileri sunmaktadır.

Bu tez toplam 6 bölüm olarak yapılandırılmıştır. Tezin temel amacı, elektrikli araçlar ve depolama teknolojileri kapsamında Türkiye'nin teknolojik kabiliyetlerini analiz etmektir. Bu kapsamda ilk olarak elektrikli araçların doğuşu, sıfır karbon hedefleri ve Türkiye'nin bu dönüşümdeki yeri anlatılmaktadır. Bölüm 2'de teknolojik kabiliyetlere ilişkin literatür incelenmiş ve teorik çerçeve belirlenmiştir. Teknolojik kabiliyetler konusu literatürden spesifik çalışmalar ile incelenmiştir. Bölüm 3'te elektrikli araçlar ve depolama teknolojileri özelinde batarya hammaddeleri üzerine bir tartışma yürütülmüştür. Bu teknolojilerin gelişmesinde en büyük etken olarak görülen kritik hammaddeler, pazardaki aktörler incelenerek açıklanmıştır. Türkiye'nin bu konudaki durumu özetlenmiştir. Bölüm 4'te tezin araştırma yöntemleri ve tasarımı açıklanmıştır. Bu tezde veri toplanırken nitel araştırma yöntemleri kullanılmıştır. Bu nedenle 10 adet yarı yapılandırılmış görüşme gerçekleştirilmiştir. Görüşülen kişiler arasında Türkiye'deki elektrikli araç ve batarya üreticileri ile bu ağın önemli paydaşlarından biri olan akademisyenler yer almıştır. Veriler MaxQDA kullanılarak analiz edilmiştir ve yapılandırmacı bir bakış açısı hakimdir. Bölüm 5'te verilerin analizi sonucunda elde edilen bulgular sunulacaktır. Bu bulgulara dayanarak tematik analiz yapılmış ve araştırma sorularına yanıt aranmıştır. Son bölümde ise elde edilen sonuçlar tartışılacak ve Türkiye'nin bilim ve teknoloji politikaları gözden geçirilecektir. Araştırma sonuçlarına dayanarak bir dizi politika önerisi sunulmuş ve Türkiye'nin bilim ve teknoloji politikalarına katkı sağlanması hedeflenmiştir.

Otomotiv sektörünün dönüşüm sürecinin yanı sıra karbonsuzlaşma hedefleriyle yeşil dönüşüm sürecine giren Türkiye, birçok farklı zorlukla karşı karşıyadır. Bu bağlamda tezin araştırma soruları, şirketlerin bu dönüşüme nasıl adapte olduklarını, bu süreçte ne gibi zorluklarla karşılaştıklarını ve bu zorlukları aşmak için ne gibi politikalara ihtiyaç duyulduğunu anlamaya yöneliktir. Bu sorulara cevap aranırken, sürecin Türkiye'ye özgü yönlerini ortaya çıkarmak için Togg ve Çin gibi diğer ülkeler gibi spesifik örnekler incelenmiştir. Türkiye örneğine odaklanan bu vaka çalışmasında, elektrikli araç ve batarya teknolojilerinin geliştirilmesi ve yaygınlaştırılması için sahip olunması gereken teknolojik kabiliyetler literatüre dayalı olarak analiz edilmektedir. Bu kapsamda şirketlerin dinamik kabiliyetleri, hızla değişen çevre koşullarına uyum sağlama açısından incelenmiştir. Tamamlayıcı kabiliyetlerin varlığı sorgulanmıştır. Geliştirilmesi gereken kabiliyetler için devletin uygulaması gereken bilim ve teknoloji politikaları UYS (NIS) kapsamında tartışılmıştır. Bu çalışma, Türkiye için yeni ve hızlı bir süreç olan bu ikili dönüşüm sürecini ele alarak, teknolojik kabiliyetleri analiz ederek ve gelecek çalışmalar için mevcut durumu özetleyerek literatüre katkı sağlamayı amaçlamaktadır. Elektrikli araçlar ve depolama teknolojilerindeki darboğazları göstererek Türkiye'nin bu darboğazlardan fırsatlar yaratarak çıkabilmesi için önemli bulguları paylaşmaktadır.

Özetle bu tez, Türkiye'nin hızla dönüşen otomotiv endüstrisinde elektrikli araçlar ve batarya teknolojileri alanındaki teknolojik yeteneklerinin kapsamlı bir analizini sunmayı amaçlamaktadır. Çalışma, mevcut durumu ortaya koyduktan sonra, elektrikli araçların ve depolama teknolojilerinin üretimi, geliştirilmesi ve benimsenmesinin önündeki engellerin aşılması ve fırsatların değerlendirilmesi için bir rehber görevi görecek ve böylece Türkiye'nin küresel otomotiv ve enerji pazarlarında rekabetçi bir oyuncu olarak yer almasına katkıda bulunacaktır.

Küresel İnovasyon Endeksi'ne göre üst orta gelir grubunda yer alan Türkiye, inovasyon performansı açısından dünyadaki 132 ülke arasında 39. sırada, bölgesinde ise İsrail ve BAE'nin ardından 3. sırada yer almaktadır. Türkiye, son 10 yılda inovasyon alanında en fazla ilerleme kaydeden orta gelirli ekonomilerden biri olmasına rağmen, inovasyon performansında halen AB ortalamasının altındadır. İnovasyon performansının en büyük kaynaklarından biri olan teknolojik yetenekler, Türkiye için daha fazla çalışılması gereken bir konudur. Stratejik yönetim yaklaşımıyla teknolojik kabiliyetler literatürünün en popüler teorik çerçevelerinden biri Dinamik Kabiliyetler'dir. Teece, Pisano ve Shuen (1997) dinamik kabiliyetler olarak tanımladıkları teknolojik kabiliyetlerin, firmaların değişen piyasa koşullarına uyum sağlarken rekabet avantajı elde etme yetkinliğini artırdığını iddia etmektedir. Bu kabiliyetler ile inovasyon performansı arasındaki doğrudan ilişki şu şekilde özetlenebilir: Dinamik kabiliyetler, hızla değişen ortamlara uyum sağlamak için firmanın iç ve dış kabiliyetlerini bütünleştiren, inşa eden ve yeniden yapılandıran kabiliyetlerdir ve firmanın yenilikçi rekabet avantajı biçimlerine ulaşma yeteneğini tanımlar. Burada dinamik vurgusu, hızla değişen bir çevrede firmaların esnekliğini vurgulamak için kullanılmaktadır.

Literatüre dayanarak, Türk firmalarının elektrikli araçlar ve batarya teknolojisindeki karbonsuzlaşma dönüşümü bu hızlı değişen ortama bir örnektir.

Teece (2007) temelinde Türkiye'deki elektrikli araç ve batarya firmalarının iç ve dış kabiliyetlerini değerlendirdiğimizde;

1. Özümseme kapasitesinin günümüzde algılama kapasitesine dönüşmüş hali olan fırsat ve tehditleri algılama yeteneği, firmaların gelgitli piyasa koşullarında ortaya çıkabilecek krizlerin farkında olma ve bu krizleri fırsata çevirebilme yeteneği olarak adlandırılabilir. Türkiye'deki elektrikli araç ve batarya şirketlerinin Türkiye ve dünya pazar koşullarına uyum sağlayabilmesi tam da böyle bir kabiliyet gerektirmektedir. Potansiyel tehditlerin farkında olsalar da, bunları ele almak için geliştirdikleri çözümler yenilikçi veya benzersiz değildir. Sürdürülebilirlik hedefleriyle eşgüdüm sağlama ve burada mevcut olmayan sınırlı teknolojileri transfer etme ve uyarlama kapasitesine sahiptirler.
2. Yukarıda da belirtildiği gibi, şirketler bir diğer dinamik kabiliyet olan fırsatları yakalama konusunda bir içgörüye sahip olsalar da girişimci bir tutum sergilememektedirler. Geri dönüşüm ve batarya şarj kapasitesinin önemini ve yarattığı fırsatları algılamış olmalarına rağmen, bu fırsatları değerlendirecek ekonomik bir girişim bulunmamaktadır. Bu konuda devletin teşvik edici tutumuna ihtiyaç duyan firmalar, kısıtlı imkanlar nedeniyle ilk yatırım ve üretim maliyetlerinden çekinmektedir. Akademi tarafı zaten bu durumun farkında ve özellikle malzeme biliminde geleceğe yatırım olarak araştırmalarını sürdürüyor gözükmekte ve bilgi birikimi oluşturmaktadır. Bu noktada devletin malzeme alanında çalışan firma ve akademi paydaşlarını bir araya getirmesi ve Ar-Ge çalışmalarını artırmaları için fonlarla desteklemesi fırsatları yakalayabilmeye katkı sağlayacaktır. Son olarak algılanan ve yakalanan fırsat analitik düşünce ile değerlendirilmelidir. Şirket çalışanlarının bakış açıları ve kurum kültürü bu fırsatların ihtiyaçları doğrultusunda geliştirilmesi gereken becerilere cevap verebilmelidir. Görüşmelerden yaptığım çıkarımlara göre bireyler bu becerilere sahip olsalar da hepsi bunları şirket düzeyine aktarma konusunda başarılı olamamaktadır. Aslında bu durum şirketlerin kendilerine özgü farklılıklarını ortaya koyabilmeleri açısından önemli teknolojik kabiliyetlerden biri olduğunu gözler önüne sermektedir.
3. Tespit ve yakalama aşamasından sonra yeniden yapılandırma aşaması olası tehditleri kapsar. Teece'nin (2007) yeni kaynak ve varlıkların organizasyona entegrasyonunun

altını çizdiği bu dinamik kabiliyet, ilk iki aşamada elde edilen bilgilerin kolektif paylaşımı anlamına gelmektedir. Teece'ye (1982) göre öğrenme ile yaratılan yeni bilgi bireylerin kendilerinde saklı olduğu için bilginin paylaşılması, yani şirket düzeyinde bütünleştirilmesi gerekmektedir. Bu dinamik yetenek sayesinde firmalar kendilerini sürekli güncel tutabilir ve pazardaki hızlı değişimlerden rekabet avantajı elde edebilirler (Teece, 2007).

Bu bağlamda, McKinsey'in Türkiye'nin 2024 yılındaki sürdürülebilirlik dönüşümüne ilişkin çalışması, mülakat verileri ile teorik çerçeveyi birleştirmek için iyi bir temel sağlamaktadır. Net sıfır fırsatı başlıklı çalışma, Türkiye'nin vaat ettiği 2053 hedeflerine ilişkin bir projeksiyon sunmaktadır. Buna göre, Türkiye'nin bu hedefleri gerçekleştirmek için 2053 yılına kadar GSYH'sinin yaklaşık %7'sini, yani 3,1 trilyon doları enerji, malzeme, arazi kullanımı ve altyapı geliştirme için harcaması gerekiyor. Bu kadar büyük bir kaynak gerektiren dönüşüm sürecinin ancak paydaşlar arasında iş birliği ile gerçekleştirilebileceğini savunmaktadır. Bu paydaşlar yeşil fon sağlayacak finans kuruluşlarından yeşil talepleri olan tüketicilere kadar uzanmaktadır. Bu raporun dinamik yetenekler literatürü ile uyumlu olduğu nokta ise bu dönüşüm sürecini hem kriz hem de fırsat perspektifinden ele almasıdır.

Buna göre kriz, 2026 yılında yürürlüğe girecek olan Avrupa Karbon Sınır Ayarlama Mekanizması'nın (CBAM) çelik, çimento, alüminyum, gübre, hidrojen ve elektrik gibi yüksek karbonlu malzemelerin Avrupa Birliği'ne ithalatından vergi alacak olmasıdır. Avrupa Birliği'ne giren karbon yoğun malların üretiminden kaynaklanan emisyonlara bir fiyat koyarak temiz sanayi üretimini teşvik etmeyi amaçlayan bu mekanizma, Avrupa pazarında önemli bir yere sahip olan Türk otomotiv endüstrisini karbon ayak izini azaltmak için çaba göstermeye itecektir. Görüşmeler sırasında benzer ifadeler kullanan firmalardan biri olan Görüşmeci J, batarya pasaportu konusunda yaptıkları çalışmalarla 2026 yılında potansiyel müşterilerine bu konuda çözüm sunan bir ürünle ulaşmayı hedeflediklerini belirtmişti. Elektrikli otobüs üreticisi Görüşmeci C ise misyon ve vizyonları ile ilgili olarak tüm fabrika binalarını güneş panelleri ile donatarak elektrik üretimini temiz hale getirmeye çalıştıklarını belirtmişti. Bu şirketlerin AB Emisyon Ticaret Sistemi'nin kendi bünyelerinde yaratacağı olası krizleri çözmek için yeniden yapılanma sürecine girdiklerini görüyoruz. Bu bağlamda dinamik kabiliyetlere sahip olduklarını söyleyebilsek de krizi fırsata çevirecek bir inisiyatife sahip olduklarını söyleyemeyiz. Bu durum firmaların hem ürün portföyü hem de ihracat kalemleri ile ilgili bir durumdur. Geri dönüşüme devletin el atması gerektiğini ifade etmeleri, bu alanda tamamlayıcı ve yardımcı bir sanayinin oluşması gerektiğine vurgu yapıyor. Buna göre emisyonu yüksek olan sektörlerin mümkün olduğunca öncelikli ve hızlı bir şekilde dönüşüm sürecine girmesi gerektiği ortaya çıkıyor. TÜİK verilerine göre 2021 yılında toplam sera gazı emisyonu 564 Mt Co2 iken bunun 91 Mt Co2'sini ulaştırma sektörü oluşturmaktadır. Bu pay ulaştırmaya öncelik verilmesi için yeterlidir. Bu alanlarda, sürdürülebilir iş modelleri ile yeşil teknolojilere geçiş için teknolojik kabiliyetlerin oluşturulması ve kaynakların stratejik olarak yeniden dağıtılması gerekmektedir. Elektrikli araçların bataryalarının geri dönüşümü, potansiyel fırsatlar açısından Türkiye'nin rekabet gücüne katkıda bulunabilir.

Çalışmanın sonucunda varılan sonuç, Türkiye'nin yıllardır yetkin bir konuma yükseldiği otomotiv endüstrisindeki bu gücünü kaybetmemek için hem karbonsuzlaşma hem de elektrifikasyon dönüşüm süreçlerine aynı anda girmiş olmasının getirdiği zorlukları ancak teknolojik yeteneklerini geliştirerek kompanse edebileceğidir. Bu bağlamda devlete düşen rol hem teknolojik yeteneklerin bir kaynağı olan Ulusal Yenilik Sistemi politikalarına öncelik vermesi hem de bilim ve teknoloji politikaları kapsamında tamamlayıcı yeteneklerden olan alt yapı eksiklikleri ve olgunlaşmamış yan sanayi için acil çözümler üretmesidir. Bu bağlamda tezin sonuç kısmında politika önerileri sunularak kullanılabilecek politika araçları özetlenmiştir. Özellikle kritik hammaddeler konusunda yerel girişimlerin gerektiği aşikardır çünkü hammadde konusunda Çin'in tekeli yalnızca elektrikli araç bataryaları için değil yenilenebilir enerjileri için gereken depolama teknolojilerinin de ilerlemesi önünde bir engeldir. Bu tezin sunduğu katkı hem bu alanda ileride yapılacak çok daha fazla çalışmaya ihtiyaç olduğunu göstermesi hem de BYD yatırımı gibi spesifik gelişmelerin olası etkilerini bundan sonraki çalışmalarda tartışılabilmesi için kapıyı aralaması olarak özetlenebilir.

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<u>**TEZİN ADI /** TITLE OF THE THESIS</u> (**İngilizce /** English): TECHNOLOGICAL CAPABILITIES ANALYSIS WITHIN THE SCOPE OF ELECTRICAL VEHICLE AND ENERGY STORAGE TECHNOLOGIES: THE CASE OF TÜRKİYE

<u>**TEZİN TÜRÜ**</u> **/** <u>DEGREE:</u> **Yüksek Lisans /** Master ☒ **Doktora /** PhD ☐

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