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Battery Production Worldwide and in Turkey

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Özet-In this study, the definition, history, types, and production stages of batteries, as well as a competitive overview of battery production in Turkey and globally, are discussed. According to the research, global battery production has seen significant growth, especially with the rise of electric vehicles and renewable energy systems. Lithium-ion batteries are among the leading technologies in this transformation. These batteries have become popular due to their long lifespan, lightweight design, and high energy capacity. Leading producers include countries like China, the USA, and Japan. China stands out as the largest global battery producer, with large-scale production for both the domestic market and export. Manufacturers in these countries are also continuously conducting R&D to enhance battery performance, demonstrating their potential for further development. Battery production in Turkey is also an important sector, primarily led by major domestic companies. Turkey's battery industry offers a wide range of products for both automotive and industrial applications. While the country has traditionally focused on conventional technologies such as lead-acid batteries, in recent years, it has also begun to venture into lithium-ion battery production. Turkey is increasing its investments to meet domestic demand and expand regional exports in battery production. Additionally, new applications such as energy storage systems and electric vehicles present significant opportunities for innovative approaches and technological advancements in the sector. In conclusion, while battery production is undergoing a significant transformation globally, Turkey is also strengthening its role in the sector by investing in both traditional and innovative technologies as part of this dynamic shift.

Keywords: Battery, Lithium-İon Battery, Liquid Battery Production, Import, Export.

I. INTRODUCTION

1.1. Definition of a Battery

A battery is a device that directly converts chemical energy into electrical energy through an electrochemical oxidation-reduction (redox) reaction. In rechargeable systems, the battery operation is reversed to perform the charging process. This type of reaction involves the transfer of electrons from one material to another through an electrical circuit. In a non-electrochemical redox reaction, electron transfer occurs directly, with heat being the only affected byproduct. Batteries have high energy conversion efficiency [1]. Basic electrochemical devices are commonly referred to as batteries. Batteries consist of cells connected in series, parallel, or both, depending on the desired output voltage and capacity. Cells are simple electrochemical elements that play a role in the direct conversion of chemical energy into electrical energy [1]. These cells consist of three main components [2]:

1. **Anode or Negative Electrode (Reducing or Fuel Electrode):** It undergoes oxidation during the electrochemical reaction by removing electrons from the external circuit [2].
2. **Cathode or Positive Electrode (Oxidizing Electrode):** It accepts electrons from the external circuit and is reduced during the electrochemical reaction [2].
3. **Electrolyte (Ionic Conductor):** It allows the transfer of charge as ions within the cell between the anode and cathode. Electrolytes are typically liquids, such as water or other solvents, containing dissolved salts, acids, or bases to impart ionic conductivity. In some batteries, solid electrolytes are used as ionic conductors at the operating temperature of the cell [2].

In terms of advantages, the combination of the lightest anode and cathode materials, which provide high cell voltage and high capacity, should be preferred. However, such combinations have disadvantages like polarization, handling difficulty, high cost, and reactivity with other cell components [2]. The anode should be an efficient reducing agent, stable, a good conductor, low-cost, and easy to manufacture. While metals are generally suitable as anodes, hydrogen, zinc, and lithium are frequently preferred metals in this regard [2]. The cathode should be an effective oxidizing agent, stable when in contact with the electrolyte, and have a useful operating voltage. Metallic oxides are generally suitable as cathodes, and materials such as oxygen, halogens, oxyhalides, sulfur, and oxides are known to be used as cathode materials [2]. The electrolyte must have good ionic conductivity but should not be electronically conductive, as this would cause internal short-circuiting. Additionally, it should be stable against electrode materials and temperature changes, safe for handling, and low-cost. Aqueous solutions are generally suitable as electrolytes, but significant exceptions include thermal and lithium anode batteries, where molten salts and other non-aqueous electrolytes are used to prevent the anode from reacting with the electrolyte [2]. Physically, the anode and cathode electrodes must be electronically isolated within the cell to prevent internal short circuits, yet they must be surrounded by the electrolyte. Additionally, a separator material that maintains ionic conductivity should be used to mechanically separate the anode and cathode electrodes. When necessary, electrically conductive grids or suitable materials are added to the electrodes to reduce internal resistance [2]. Cells are manufactured in various shapes and configurations, such as cylindrical, button, flat, and prismatic. Cells are sealed in various ways to prevent leakage and drying. Some cells are equipped with ventilation devices or other methods to allow the escape of accumulated gas. Additionally, appropriate cases, terminal connections, and labeling methods are used in cell and battery manufacturing [2].Depending on the properties of the electrolyte used, batteries containing bases or acids are made. In this study, lead-acid batteries are discussed. The components and general appearance of a typical lead-acid battery are shown in Figure 1 [2].

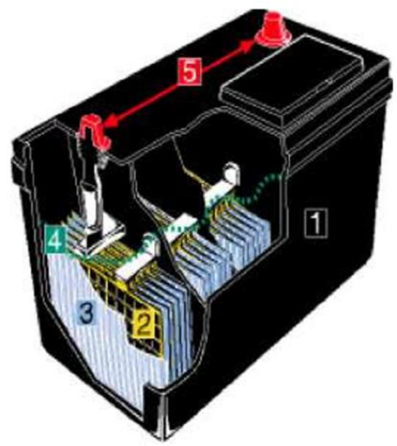

Figure 1. General View of a Lead-Acid Battery [2]

(1) Number indicates the battery case

(2) Number indicates the plates

(3) Number indicates the separator that prevents contact between the positive and negative plates

(4) Number indicates the connection bridge [2].

1.2 History of the Battery

The use of batteries containing sulfuric acid or lead components is quite common. Their usage dates back to 1860, following the invention by Raymond Gaston Plante. Plante cells were designed to increase the amount of stored energy by creating lead dioxide on a lead foil to form the positive active material. This design had an expanded surface area. Primary cells were used as the power source for this formation [3]. The active material is typically coated onto cast or grid structures, which have undergone a cementation process (interlocking crystalline lattice) to enhance structural strength and retention properties. This is generally known as a flat plate design, but studies have shown that the central conductive wire or rod is surrounded by the active material, housed in a porous insulating tube, and the electrode is cylindrical or oval-shaped [3]. It is known that Planté created the first accumulator, consisting of two lead plates separated by rubber strips and immersed in sulfuric acid. One year later, he presented an accumulator battery composed of nine devices, housed in a protective case and connected in parallel, to the French Academy of Sciences (Figure 2) [2]. The improved form of this accumulator, capable of providing large currents, is widely used in automobiles today.

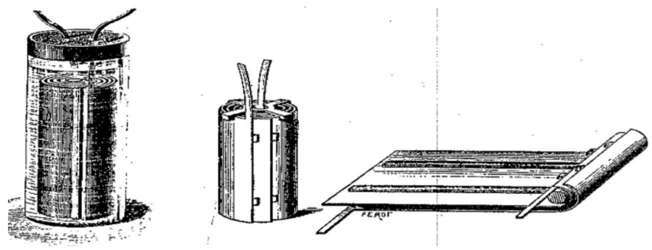

Figure 2. The First Battery [2]

1.3 Applications of Batteries

The general application areas of batteries are as follows:

- In military applications, such as signaling and standby power systems,
- In portable electrical and electronic devices, including lighting, photographic equipment, PDAs (Personal Digital Assistants), communication equipment, hearing aids, watches, toys, memory backup, and various other applications,
- In the automotive sector's lighting and ignition (SLI) systems, as well as in small secondary batteries used in portable systems such as vehicles, toys, lighting, photography, radios, computers, camcorders, and mobile phones,
- In automotive and aircraft systems, uninterruptible power supplies (UPS) that can be used in emergency failure and standby situations, stationary energy storage (SES) systems for balancing electrical service loads, and hybrid electric vehicles,
- In portable consumer electronics, electrical home appliances, and electric vehicles,
- In missiles, torpedoes, and other weapon systems,
- In spacecraft, air-breathing systems, load balancing systems, electric vehicles, and distributed or on-site power generators [4].

1.3 Types of Batteries and Production Technologies

1.4 Operating Principle of a Battery

Batteries that use lead as the electrode and diluted sulfuric acid as the electrolyte are known as lead-acid batteries. When the battery plates are charged, the positive (+) electrode contains lead dioxide (PbO_2) ready to react, while the negative (-) electrode contains spongy lead [4]. During discharge, both electrodes are covered with a layer of lead sulfate ($PbSO_4$).

The reactions occurring at the positive (+) terminal during discharge are as follows (Equations 1-6):

$$PbO_2+4H^++2e^-\rightarrow Pb^{2+}+2H_2O \quad (1)$$

$$Pb^{2+}+SO_4^{2-}\rightarrow PbSO_4 \quad (2)$$

$$PbO_2+4H^++SO_4^{2-}+2e^-\rightarrow PbSO_4+2H_2O(\text{overall reaction}) \quad (3)$$

The reactions occurring at the negative (-) terminal during discharge are:

$$Pb\rightarrow Pb^{2+}+2e^- \quad (4)$$

$$Pb^{2+}+SO_4^{2-}\rightarrow PbSO_4 \quad (5)$$

$$Pb+SO_4^{2-}\rightarrow PbSO_4+2e^- \quad (6)$$

As seen from the reaction results, lead sulfate is produced at both terminals by consuming sulfuric acid. During these reactions, water is formed at the positive (+) terminal [4]. When the reverse of the above reactions occurs, the battery is considered charged. However, for the reactions to reverse direction, a voltage slightly higher than the battery's voltage needs to be applied externally in the reverse direction. When the charging and discharging reactions at both terminals are summed up, the following equations result (Equations 7-8):

Charging:

$$2PbSO_4+2H_2O\rightarrow PbO_2+2H_2SO_4+Pb \quad (7)$$

Discharging:

$$PbO_2+2H_2SO_4+Pb\rightarrow 2PbSO_4+2H_2O \quad (8)$$

As seen in the chemical reactions occurring within the battery cell, the voltage in lead-acid batteries is highly dependent on the concentration of sulfuric acid. The total voltage of a cell is found by subtracting the negative electrode voltage from the positive electrode voltage. The voltage of the positive electrode is (+), and the voltage of the negative electrode is (-). Voltage values vary depending on the type of electrodes and the substance used as the electrolyte. In a lead-acid cell, the theoretical voltage is:

$V=V_p-V_n=1.74-(-0.27)=2$ volts

In a lead-acid cell, which is typically accepted as 2V, the actual voltage ranges between 2.05 and 2.15 volts per cell, depending on the electrolyte density. The voltage per cell is calculated by assuming 2 volts. Batteries used in vehicles are 6-volt or 12-volt batteries, formed by connecting 3 or 6 cells in series [4]. The average cell voltage of a fully discharged lead-acid battery is considered to be 1.75 volts. The limit voltage for discharge varies according to the rate of current drawn. At the end of discharge, not all of the chemical material in the plates is converted. A certain percentage of the total chemical energy inside the cell is converted into electrical energy, which depends on the amount of discharge current and the lower limit voltage [4].

1.3 Types of Batteries

1.4 Starter Batteries

Starter batteries, also known as cranking batteries, starting batteries, or start batteries, are specifically designed for use in vehicles and generators. For example, when starting a car, the electrical energy required to start the engine is provided by this type of battery. Starter batteries are capable of delivering high currents momentarily, but they are not suitable for continuous, steady current draw. They are primarily used in applications where initial movement is critical, such as in the automotive industry. However, they are not suitable for use in Uninterruptible Power Supply (UPS) systems, meaning they should not be used as stationary batteries [5].

1.3.1 Traction Batteries

Batteries used in mobile vehicles are specifically designed to power machines that operate with electrical energy, such as those used in tunnels, mines, electric locomotives, forklifts, and similar electrically-driven vehicles. They continuously supply a medium current to machines and devices. Typically, they consist of 2-volt cells arranged to provide 24 volts and are housed in a case. Their structure is much more robust than automotive batteries, and as a result, they are known for their long lifespan [5].

1.3.2 Stationary Batteries (Standby Batteries)

Stationary batteries are also referred to as "Fixed Facility Batteries." These batteries are designed for use in fixed, stationary locations. Due to their operating principle and plate structure, they have the ability to supply a steady current for extended periods. Rather than delivering high current instantaneously, these batteries are capable of continuously providing low current. They charge and discharge with a small current. They are long-lasting and protect loads from the negative effects of sudden power outages (Figure 3) [5]. They are commonly used in places like telecommunications stations, alarm systems, and security centers. Although suitable for uninterruptible power supply (UPS) systems, they are often not preferred in many applications due to the maintenance they require [5].

Figure 3. Stationary Batteries [5]

1.3.1 Dry Batteries (Completely Maintenance-Free Lead-Acid Batteries)

Maintenance-free (no acid or water addition required) sealed batteries are referred to as "Dry Batteries." These batteries are also known as VRLA (Valve Regulated Lead Acid) or SLA (Sealed Lead Acid) batteries. Due to their maintenance-free nature, they have a wide range of applications. They contain no liquid, and gas emission is minimal. Being completely sealed, they are safe to use. Since they have a high capacity to handle instantaneous high currents, they are widely used in uninterruptible power supplies (UPS) [5].

1.3 Battery Production Process

1.3.1 Oxide Production

Lead pellets (Pb) made of pure lead are subjected to both abrasion and surface oxidation simultaneously in a ball mill, resulting in the production of lead oxide (PbO). The product obtained from the exothermic oxidation reaction is then stored in silos for one day to cool down. The composition of the final product is approximately 25% Pb and 75% PbO. This product is used in the production of both negative and positive plates [6].

1.3.1 Strip-Grid Production

Grids are produced in three different ways depending on the technology used. The production methods of these grids, shown in Figure 4 [6], are as follows:

1. **Cast Grid**: Lead is melted in melting pots and then cast into grids, followed by annealing.
2. **Exmet Grid**: Utilizing more advanced technology, an Exmet machine processes rolled lead through automatic pressing, expanding, and shaping to produce the grid [6].

3. **Punch Grid**: The latest technological method involves production using the Punch method, known for its pressing technique [6].

In grid production, lead-antimony or lead-tin-calcium alloys are commonly used in specific proportions [6]. The effects of positive and negative grid alloys are provided in Table 1.

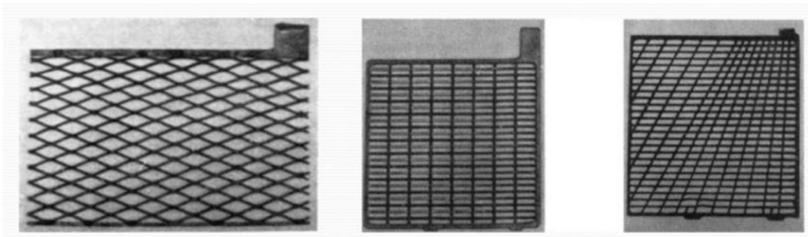

Figure 4. Types of Grids: Exmet-Punch-Casting [6]

Table 1. Effects of Grid Alloys [6]

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
As		+	+	+							+	
Ag	+		+			+						
Cu	+	+	+			+						
Sn	+				+				+			
Se	+					+						
S	+											
Ca						+	+	+				
Al		+				+			+	+	+	+
1.	Ensuring the uniformity of the material's granular structure [6]											
2.	Reducing slag in molten lead [6]											
3.	Hardening of the grid [6]											
4.	Protecting the grid from fractures and cracks [6]											
5.	Facilitating the smooth pouring of lead [6]											
6.	Providing resistance against oxidation [6]											
7.	Reducing the battery's self-discharge [6]											
8.	Increasing electrical conductivity [6]											
9.	Reducing calcium loss [6]											
10.	Facilitating easier welding during assembly [6]											
11.	Ensuring mechanical strength [6]											
12.	Protecting the grid from passivation [6]											

1.3.1 Paste Mixing and Pasting Process

The paste, with the desired density and consistency, is applied to the grids using a hopper. Both sides of the pasted plate are covered with special paper to prevent the plates from sticking to each other. After each plate is cut, it is passed through a tunnel for partial drying and then stacked [7].

Some chemicals added to the active material:

- **Lead Oxide:** Used to prevent shrinkage issues in the negative plate. It also improves the battery's performance at low temperatures, enhances cold cranking ability, and extends the cycle life [7].
- **Vanispers:** Lignosulfonates have lubricating and anti-caking properties. They help create a porous structure in the paste, increasing the plate's surface area [7].
- **BaSO4:** Barium (Ba), Strontium (Sr), and Lead (Pb) sulfates have similar structures. During the reaction of oxide (PbO) and sulfuric acid (H2SO4), positions are created for the formation of the PbSO4 phase. Thus, barium sulfate in the negative active material aids in the formation of lead sulfate during battery discharge. Barium sulfate is electrochemically inactive, allowing it to maintain its unchanged and stable structure even after long cycle durations [7].
- **Carbon Black:** Used to increase the conductivity of the active material during deep discharge when the concentration of lead sulfate with high resistance is high [7].

1.3.2 Curing Process

The independent 3BS (or 4BS) and PbO particles in the plate structure bind to each other and to the grid, which acts as a current collector, forming a continuous framework. The lead remaining in the lead oxide oxidizes to PbO, and the grid undergoes partial corrosion. The 3BS (or 4BS) and PbO particles then recrystallize. After the curing process, the paste is dried. To achieve good adhesion between the grid and the positive active material, a corrosion layer of a certain critical thickness must form during the curing process. The curing and drying processes are carried out in special chambers where temperature, humidity, and time are precisely controlled [7].

1.3.1 Assembly

The cured plate is placed into microporous envelope separators. The negative and positive plates are grouped and welded together to form a single element. The elements are placed into plastic containers with spot-welded holes, and spot welding is performed. The container and lid are joined through thermal bonding. The terminal posts are cast into shape [7].

1.3.1.1 Enveloping Section

The enveloping section is responsible for carrying out the enveloping and grouping processes of the plates. During the enveloping process, the negative and positive plates are combined [7].

1.3.1.1 COS (Cast On Strap) Section

In this line, the battery elements that arrive grouped are brushed, the plates are connected to each other at the lug sections, and the elements are placed into the container [7].

1.3.2 Charging Process

The assembled battery is filled with a water and sulfuric acid mixture as the electrolyte, and the charging process is carried out using rectifiers [7].

1.3.2 Tests and Processes (Finishing Process)

The mechanical and electrical properties of the battery, including high current charge-discharge conditions, sealing, and electrical leakage, are tested. After being washed and cleaned, the terminal posts are brushed, the battery is weighed, and it is labeled and prepared for shipment [7].

II. BATTERY INDUSTRY

2.1 Global Battery Industry

The global battery industry encompasses a wide range of battery technologies used in industrial, commercial, and consumer applications. This sector covers the production and distribution of batteries used in electric vehicles, solar energy storage systems, mobile phones, laptops, portable electronic devices, industrial equipment, and many other areas. Here are some key points about the global battery industry [8]:

1. **Electric Vehicles**: Electric vehicles are a significant factor driving battery demand worldwide. As the popularity of electric vehicles increases, so does the demand for lithium-ion and other advanced battery technologies [8].

2. **Renewable Energy Storage**: The increasing use of solar, wind, and other renewable energy sources has led to a rise in demand for energy storage solutions, further boosting battery usage [8].

3. **Lithium-Ion Technology**: In recent years, the increasing use of lithium-ion batteries has made this technology a defining feature of the battery industry. Lithium-ion batteries offer advantages such as high energy density, long life, and fast charge/discharge capabilities [8].

4. **R&D and Innovation**: Continuous advancements in battery technologies encourage investment in research and development (R&D) and innovation. Developing more efficient, reliable, and environmentally friendly batteries is a key focus in the industry [8].

5. **Global Manufacturing and Trade**: Many countries play a crucial role in battery production and trade globally. Countries like China, the U.S., Japan, South Korea, and European nations are leaders in battery manufacturing and account for a significant portion of global battery trade [8].

Battery usage continues to grow for energy storage, emergency power, and electric and hybrid vehicles (including closed vehicles). Vehicle lighting and engine ignition (SLI) represent a large portion of the market. This segment accounted for approximately 40% to 45% of all battery sales in 1999, with a market value of about $15 billion at the manufacturer level. At the retail level, this value increases by 2 to 3 times. These figures do not include some countries, such as Russia and China, where complete market data is not available. Lead-acid batteries are widely used in telephone systems, power tools, communication devices, emergency lighting systems, and as a power source for mining and material handling equipment. The widespread use of lead-acid batteries can be attributed to their low cost and ease of production. Lead-acid batteries are consistently regarded as the most cost-effective batteries, providing the best performance and lifespan [8]. New applications, designs, and manufacturing processes continue to be introduced in significant proportions. Modern electric vehicles, energy storage, and electronic applications are being integrated into lead-acid battery designs. Several improvements have been made to charging systems to enhance the performance of high-voltage batteries. Electric vehicle batteries typically operate in systems ranging from 100 to 300 V. Lead-acid batteries are appealing for electric vehicle and energy storage applications due to their high electrical conversion efficiency of 75% to 80%. Traditional vertical plate batteries are capable of energy densities above 40 Wh/kg, and horizontal plate designs with higher energy and power densities are being used in traction and stacking applications. Modified lead-acid batteries are being researched for both electric and hybrid vehicles. The world's largest energy storage battery system was completed in late 1988 in Chino, California. This 40 MWh battery uses industrial-sized lead-acid cells connected in series and parallel to create a 10 MW system, delivering power at 2000 V and 8000 A for 4 hours to the grid. This battery operated for over a decade as a demonstration project. There are also small individual lead-acid batteries with quick connections for use in small electric household appliances and electronic applications. The value of the global battery market was estimated at approximately $44.6 billion in 2014. According to market research reports, this value grew to $58.5 billion by 2020, with an annual growth rate of 4.6%. The battery industry, which employs around 120,000 people globally, is expected to provide more job opportunities as its market share continues to grow [8].

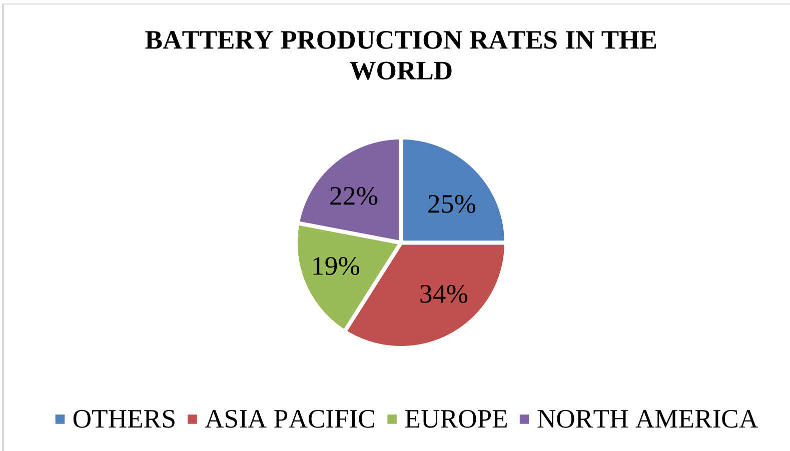

Figure 5. Global Battery Production Distribution [8]

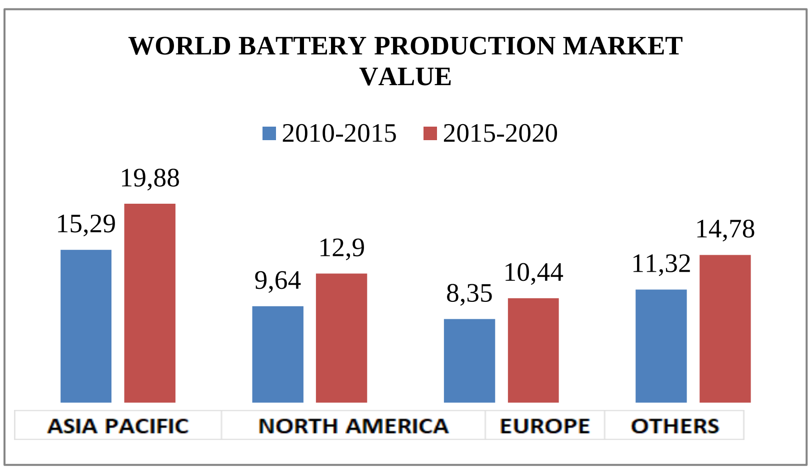

Figure 6. Global Battery Production Market Values

III. GLOBAL IMPORTS

Table 2 below lists the countries that were the largest importers in the battery industry from 2020 to 2022. The largest importing country is the United States, with an import value of 1,570,497 in 2020. According to the data, the United States' import value continues to increase through 2022. The second-largest importer is

France, and similarly, the data shows that France's import values in the battery sector increase from 2020 to 2022 [8].

Table 2. The World's Largest Importing Countries from 2020 to 2022 [8]

Importers	**Imported value in 2020**	**Imported value in 2021**	**Imported value in 2022**
World	9950379	12015011	11976875
United States of America	1570497	1822407	2225918
France	633013	805990	705090
Canada	448863	504695	620230
Germany	536921	681696	523840
United Kingdom	409879	473691	467246
Italy	336021	406696	429924
Spain	283756	368378	378228
Japan	269314	326313	299483
Poland	204683	312227	282763
Australia	241544	249010	281278
Saudi Arabia	172473	203260	265104

Table 3 below shows the value increase in imports by countries from 2019 to 2022. According to the data, the highest increase in battery import values occurred in 2021.

Table 3. The World's Largest Importing Countries from 2019 to 2022 [8]

Importers	**Imported growth in value between 2018-2019, %**	**Imported growth in value between 2019-2020, %**	**Imported growth in value between 2020-2021, %**	**Imported growth in value between 2021-2022, %**	**Imported value in 2022, US Dollar thousand**
World	N/A	N/A	N/A	N/A	11976875
United States of America	6	7	16	22	2225918
France	-10	-12	27	-13	705090
Canada	-10	-9	12	23	620230
Germany	-10	-1	27	-23	523840
United Kingdom	-21	-10	16	-1	467246
Italy	-8	1	21	6	429924
Spain	1	-3	30	3	378228
Japan	3	8	21	-8	299483
Poland	-7	-2	53	-9	282763
Australia	-2	4	3	13	281278

IV. GLOBAL EXPORTS

Information about the countries exporting batteries worldwide between 2020 and 2022 is provided in Table 4.

Table 4. Countries Exporting Batteries [8]

Exporters	**Exported value in 2020**	**Exported value in 2021**	**Exported value in 2022**
World	10577072	12710963	12130246
Korea, Republic of	1719006	1992255	1801939
Germany	1061596	1291587	1284429
China	724045	876508	962653
Mexico	883546	905040	942306
Czech Republic	712382	956002	872743
Spain	713323	910038	860507
United States of America	649969	703773	807636
Türkiye	282823	416895	455647
Poland	388772	507447	446167
Italy	337959	474203	396890
France	459048	403287	326358
India	159883	218592	225086
Thailand	173889	189738	197386
United Arab Emirates	199304	165242	170043
Viet Nam	98790	126455	166746
Colombia	106052	132217	153850
Slovenia	141455	163771	151358
Austria	214992	278051	129165

As seen in Table 4 [8], South Korea is the leading country in global battery exports, followed by Germany in second place. Table 5 [8] below shows the value increase in battery exports by countries.

Table 5. Value Increase in Battery Exports by Countries [8]

Exporters	**Exported growth in value between 2019-2020, %**	**Exported growth in value between 2020-2021, %**	**Exported growth in value between 2021-2022, %**	**Exported value in 2022, US Dollar thousand**
World	N/A	N/A	N/A	12130246
Korea, Republic of	0	16	-10	1801939
Germany	-3	22	-1	1284429
China	23	21	10	962653
Mexico	10	2	4	942306
Czech Republic	26	34	-9	872743
Spain	-2	28	-5	860507
United States of America	-22	8	15	807636
Türkiye	-9	47	9	455647
Poland	0	31	-12	446167

4.1 Global Export Map

The global export map for the years 2021 to 2022 is provided in Figure 7 below [8].

Figure 7. Global Export Map [8]

4.2 Growth Rates in Imports

Table 6 [8] below presents data on the growth rates of countries in battery imports worldwide for the years 2020-2022.

Table 6. Countries Importing Batteries Worldwide from 2020 to 2022 [8]

Importers	**Imported growth in quantity between 2020-2021, %**	**Imported growth in quantity between 2021-2022, %**	**Imported quantity, 2022**	**Unit**
World	N/A	N/A	0	No quantity
Malaysia	5	54	20146954	Units
Spain	N/A	N/A	10281438	Units
Canada	6	12	9880648	Units
Australia	-3	5	5573440	Units
Czech Republic	25	N/A	4762819	Units
South Africa	-13	46	2470488	Units
Thailand	75	-45	2443092	Units
Chile	61	-43	1916873	Units
United States of America	16	17	744950	Tons
Nepal	53	-23	649097	Units

4.3 Global Import Map

Figure 6 presents the world import map [8].

Figure 6. Global Import Map [8]

4.3 Unit Prices

Table 7 [8] shows the numerical import values of countries between 2020 and 2022. In 2020, the unit value for the United States was $2,865, while in 2022, it increased to $744,950. This indicates a significant increase in unit prices for the United States in 2022. Similarly, when looking at other countries in the table, it is observed that import unit prices increased from 2020 to 2022.

Table 7. Unit Prices of Countries Between 2020 and 2022 [8]

Importerts	2020		2021		2022		Imported Value ın 2022, Dollar Thousand	Imported Quantity in 2022	Quantity Unıt in 2022
	Imported Unıt Value	Unıt	Imported Unıt Value	Unıt	Imported Unıt Value	Unıt			
World							11976875	0	No Quntity
USA	2865	Us Dollar/Tons	2864	Us Dollar/Tons	2988	Us Dollar/Tons	2225918	744950	Tons
France	2472	Us Dollar/Tons	2649	Us Dollar/Tons	2648	Us Dollar/Tons	705090	266236	Tons
Canada	54	Us Dollar/Tons	57	Us Dollar/Tons	63	Us Dollar/Tons	620230	9880648	Unıts
Germany	2931	Us Dollar/Tons	2991	Us Dollar/Tons	3165	Us Dollar/Tons	523840	165530	Tons
Kingdom	2891	Us Dollar/Tons	2966	Us Dollar/Tons	3117	Us Dollar/Tons	467246	149902	Tons

V. BATTERY INDUSTRY IN TURKEY

The battery industry in our country has made significant progress in recent years. Large manufacturers have increased both their capacities and qualities through technological investments, making them competitive with foreign companies. The production capacity of large and small established companies, which provide employment for approximately 3,000 people, is around 20 million units annually. However, the domestic market's battery sales, including the automotive industry, are approximately 5 million units (Figure 7) [8]. There are 25 battery manufacturing businesses of various sizes in Turkey. The total production capacity of these 25 businesses is approximately 20 million units. Of this production, 1/3 is sold domestically, while 2/3 is exported. Investments in the sector are also increasing in Turkey. As a result, production capacities are being expanded. Generally, there are more importing companies than battery manufacturers in the domestic market. However, domestic manufacturers hold a market share of around 85%. It has been observed that the leading companies in the sector have reached a level where they can compete with foreign companies in terms of quantity and quality, thanks to technological investments. The product range of companies operating in the battery sector, which contribute to both the domestic and foreign markets in terms of products and raw materials, is quite diverse. Essentially, batteries are classified into two categories: automotive and industrial. Within these two categories, batteries are divided into four groups according to their intended use [8].

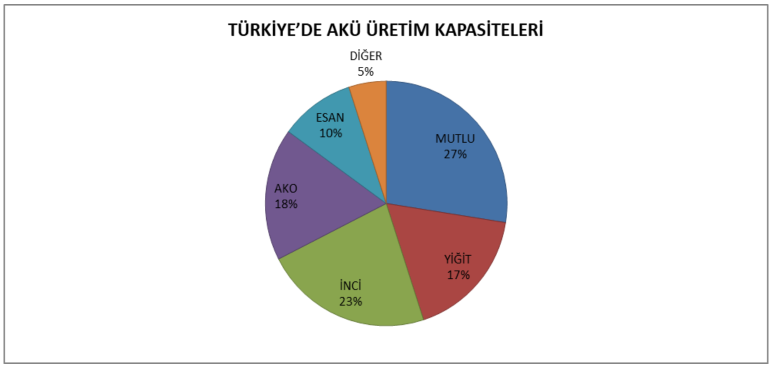

Figure 7. Battery Production Capacity Distribution in Turkey [8]

5.1 Turkey's Exports

Export plays a significant role in a country's economy. When exports increase, there is an improvement in factor productivity, gains from economies of scale and positive externalities increase, and the easing of foreign exchange shortages facilitates the import of intermediate and capital goods. Additionally, production costs in export sectors decrease, and policies aimed at providing new technologies are encouraged. On the other hand, exports increase employment and contribute to the welfare of the country and the world by allowing for a resource allocation that is in line with international division of labor. The export-led growth hypothesis assumes that economic growth is driven by an increase in exports. A country's economic growth is influenced not only by increases in domestic labor and capital but also by the growth in total exports. According to the export-led growth approach, increasing total exports is necessary to raise the economic growth rate [8].

The Structure of Exports in the Turkish Economy: From 1950 to the 1980s, the share of agricultural products in total exports was higher than that of industrial products. However, starting from 1980, the share of industrial product exports in total exports saw significant increases, while the share of agricultural products decreased, causing industrial product exports to surpass agricultural product exports in value. From 1980 to 2013, the share of industrial products in total exports increased by nearly 100%, while the share of agricultural products dropped to between 0% and 10%. When we look at the share of mining in total exports, it was higher by 2-3% between 1950 and 1980 compared to other years, and since 1980, it has remained around 2-2.5% [8]. Below, Table 8 [8] presents Turkey's export data for the years 2020-2022.

Table 8. Turkey's Exports by Year [8]

Importers	**Exported value in 2020**	**Exported value in 2021**	**Exported value in 2022**
World	282823	416895	455647
Russian Federation	16143	22654	49847
United States of America	5020	35898	44701
United Kingdom	20816	37690	29150
Israel	21441	28404	24746
Italy	16237	20459	22086
Iraq	24146	22376	21152
Egypt	18856	24077	17770
France	10622	13917	16662

Table 9. Turkey's Export Volume Growth by Year [8]

Importers	**Exported growth in quantity between 2020-2021, %**	**Exported growth in quantity between 2021-2022, %**	**Exported quantity in 2022, Tons**
World	38	3	199999
Russian Federation	31	97	18423
United States of America	460	18	17918
United Kingdom	65	-25	12813
Italy	18	2	10831
Iraq	-13	-14	10537
Israel	18	-15	10208
Egypt	31	-34	7899
France	23	22	7813

Table 9 [8] shows the export growth of countries between 2021 and 2022. It is observed that Russia is the country to which Turkey exports the most batteries.

5.2 Turkey's Export Map

Figure 8 shows Turkey's export map [8].

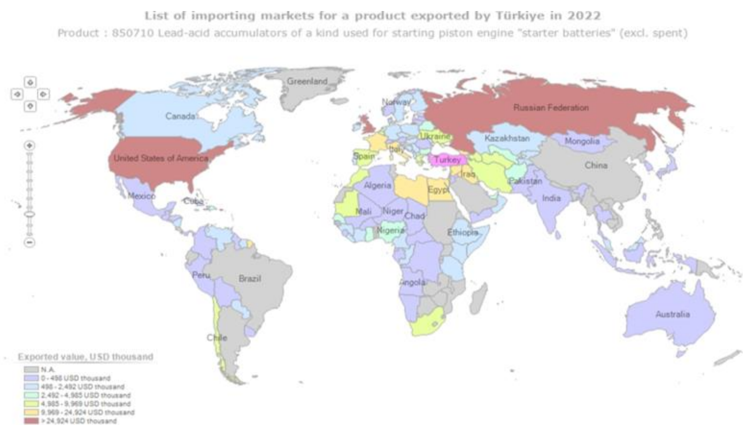

Figure 8. Turkey's Export Map [8]

5.3 Turkey's Competitiveness Bubble

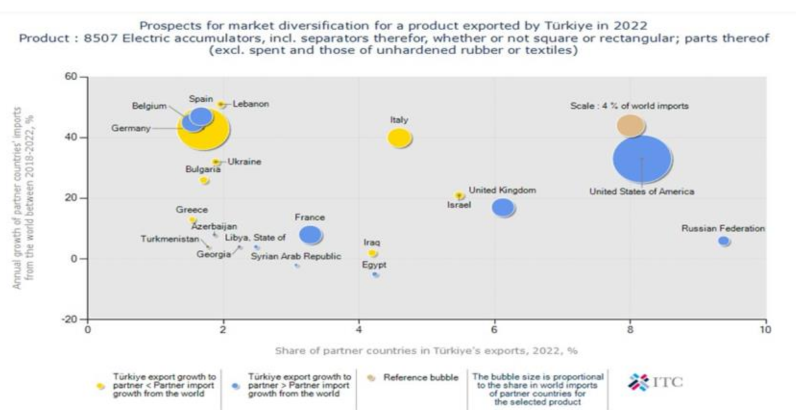

Figure 9. Turkey's Competitiveness Bubble [8]

In Figure 9 [8], the blue balloons indicate that Turkey's growth rate, as a percentage, is greater than that country's proportional imports from the world. The yellow balloons, on the other hand, represent countries where Turkey's export growth, as a percentage, is smaller than the world's growth rate during the same period [8].

VI. CONCLUSION AND EVALUATION

Battery production worldwide and in Turkey is closely related to industrial and technological developments. The importance of batteries in areas such as electric vehicles, renewable energy storage systems, and many other fields is steadily increasing. Therefore, research and development related to battery production and technologies are of great importance for the future of the sector. Globally, the battery industry is closely linked to technological and industrial developments in fields such as electric vehicles, energy storage systems, and portable electronic devices. Thus, advancements in battery technologies can have a significant impact on areas such as environmentally friendly energy storage solutions and the widespread adoption of electrification.

Research has shown that the top three countries in battery exports are South Korea, Germany, and China. The top three countries in battery imports are the United States, France, and Canada. In terms of battery exports, Turkey has seen an increase in volume from 2020 to 2022. Turkish battery manufacturers have contributed to economic growth and stood out in exports by producing and exporting various types of batteries to many countries around the world.

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