DYNAMIC SUSTAINABILITY LAB™
AT SYRACUSE UNIVERSITY

LITHIUM BATTERY MANUFACTURING & THE EV TRANSITION

www.DynamicsLab.org

Researching the Risks and Opportunities of the Global Sustainability Transition

Bulletin No. 20220406

CONTENTS

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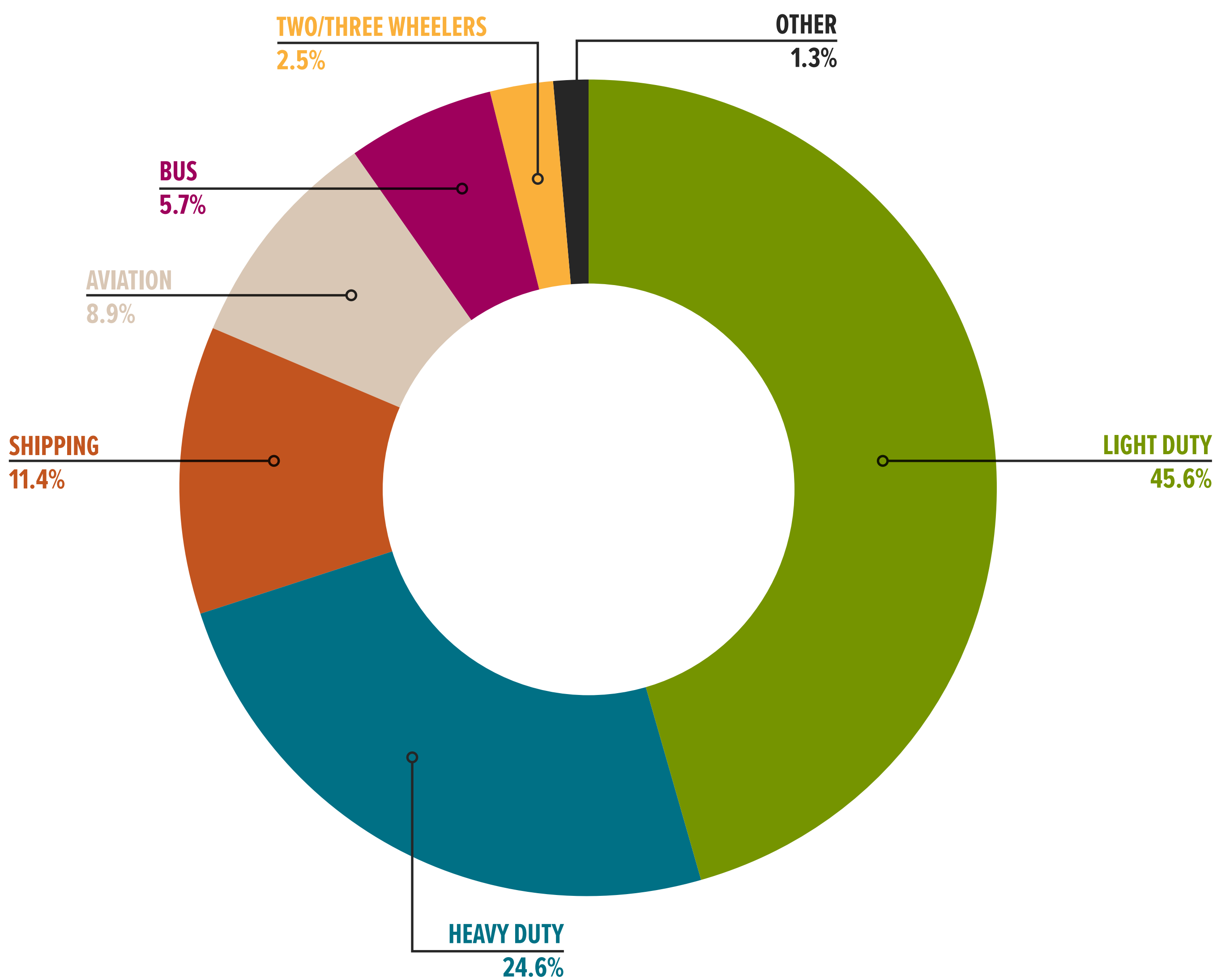
GLOBAL CO_2 EMISSIONS BY TRANSPORT 2020

Figure 1 [ref. 01].



INTRODUCTION

Lithium batteries are essential to global electric vehicle transition by providing energy storage both for vehicles and intermittent renewable energy sources. The pace and scale of manufacturing capabilities determines the transitions feasibility and the rate at which countries are able to fully move to zero emission vehicles, and ultimately reach Net-Zero targets.

In 2019, the transportation sector emitted 29% of the United State's Greenhouse gas emissions [2]. To achieve the targets set by the Paris Agreement and limit global warming to well below 2 degrees Celsius or preferably 1.5 degrees Celsius, transitioning to zero-emission transportation sources is a vital step to ensuring these targets can be achieved. The electric vehicle transition has the ability to significantly mitigate the effects of climate change and decarbonize our economy.

Globally in 2020, light and heavy duty vehicles, two/three-wheeler vehicles and buses were responsible for 78% of the total transportation sectors CO2 [1]. Electric Vehicles (EVs) have become an attractive and attainable solution to transform those vehicle types into fully battery powered, zero–emission vehicles, leading to significant CO2 reductions.

FAST FACTS

The Dynamic Sustainability Lab™

125

China has 125 active gigafactories since 2022, totaling more than every other country combined [74].

12.3%

The lithium-ion battery industry is expected to grow at a CARG of 12.3% from 2021 to 2030 [73].

134

The number of projected EV models available for sale in the United States, a doubling from 2020 with only 48 available [81].

$7B

In 2022, General Motors announced the largest manufacturing investment to date for EV battery production, located in Michigan [80].

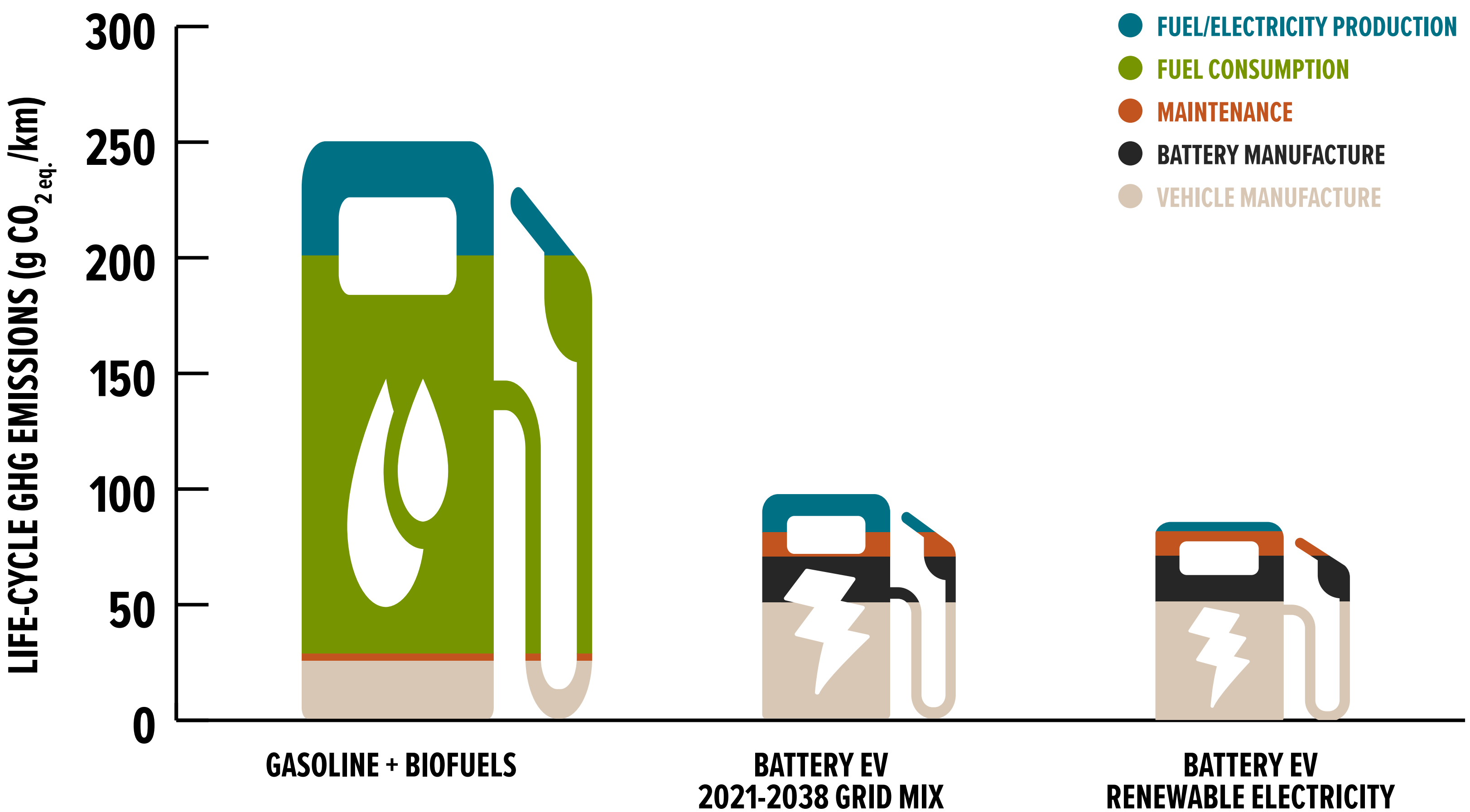
89%

Battery pack prices have decreased by 89% since 2010, dropping from $1,200/kWh to $132/kWh in 2021 [79].

LIFE CYCLE EMISSIONS
ICE VS. EV

Electric Vehicles are powered by electricity and do not combust fuel like typical gasoline or internal combustion engines (ICE). The elimination of fuel significantly reduces greenhouse gas emissions, as a typical ICE vehicle creates 8,887 grams of tailpipe CO2 per gallon, compared to 0 grams of tailpipe CO2 for EVs [3]. With an average lifespan of 18 years for both vehicles, a 2021 EV produces 57%-68% lower GHG emissions than an ICE vehicle, and 61%-76% lower when comparing projected 2030 models [4]. When EV's run on 100% renewable energy they produce 82% less GHG emissions than an ICE vehicle [4].

Figure 2 [ref. 04].



ELECTRICITY AND RENEWABLE ENERGY

increasing electricity demand

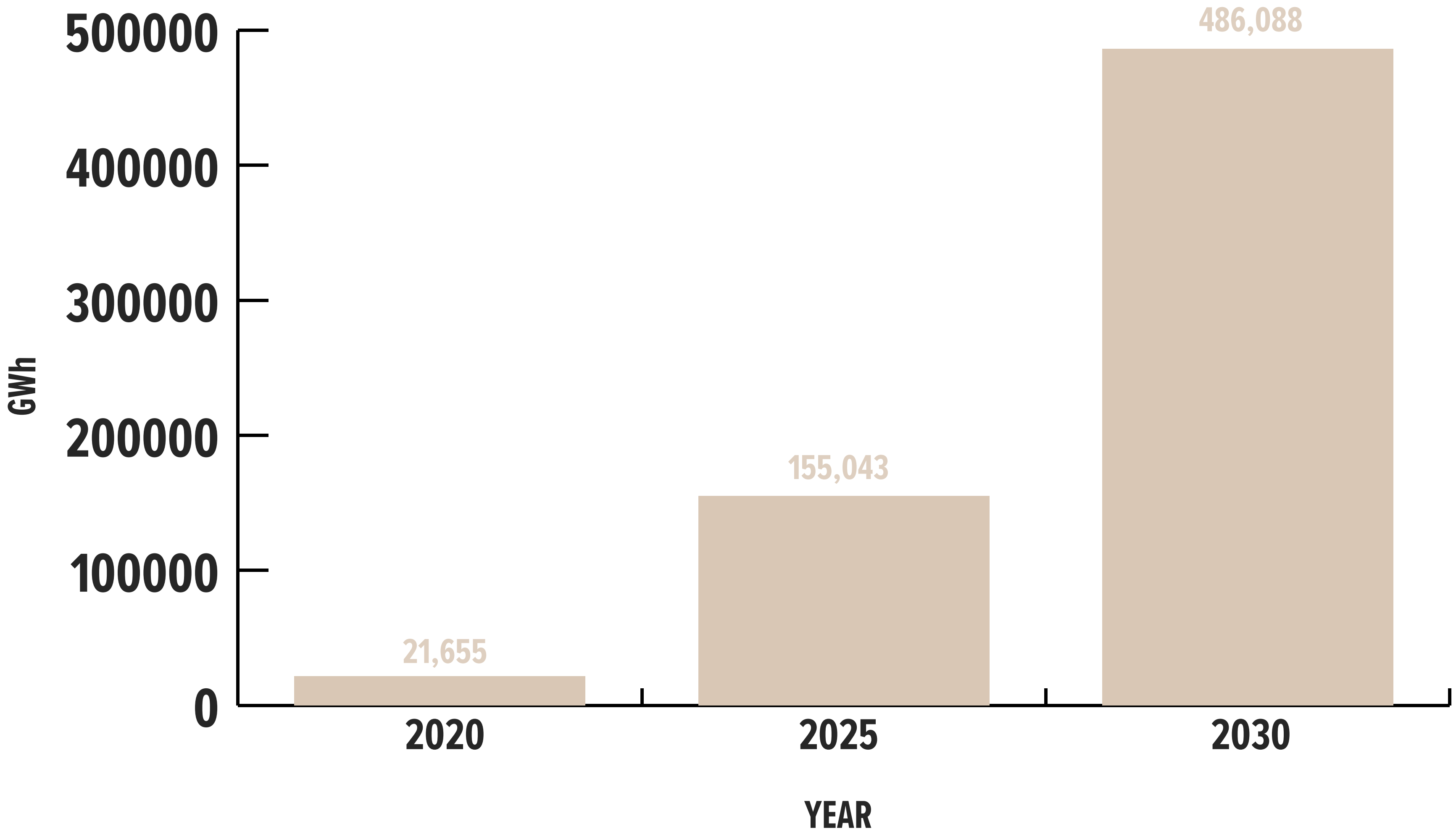
To successfully transition vehicles into EVs, grids across the globe will have to expand their electric capacities to meet the growing electricity demand from EVs [5]. According to the Sustainable Development Scenario (SDS)* by the International Energy Agency (IEA), 230 million cars will be needed on the road in 2030 to meet Paris Agreement targets [6]. This will increase the demand of electricity from cars from 21,000 GWh in 2020 to 480,000 GWh in 2030, a 22x increase [6]. With the current grid already struggling to keep up with global demand, grid expansions are vital.

*SDS is a scenario that outlines the outcomes targeted by the Paris Agreement and limit warming to well below 2 degrees C.

GLOBAL ELECTRICITY DEMAND FROM CARS

GWh, 2020

Figure 3 [ref. 06].

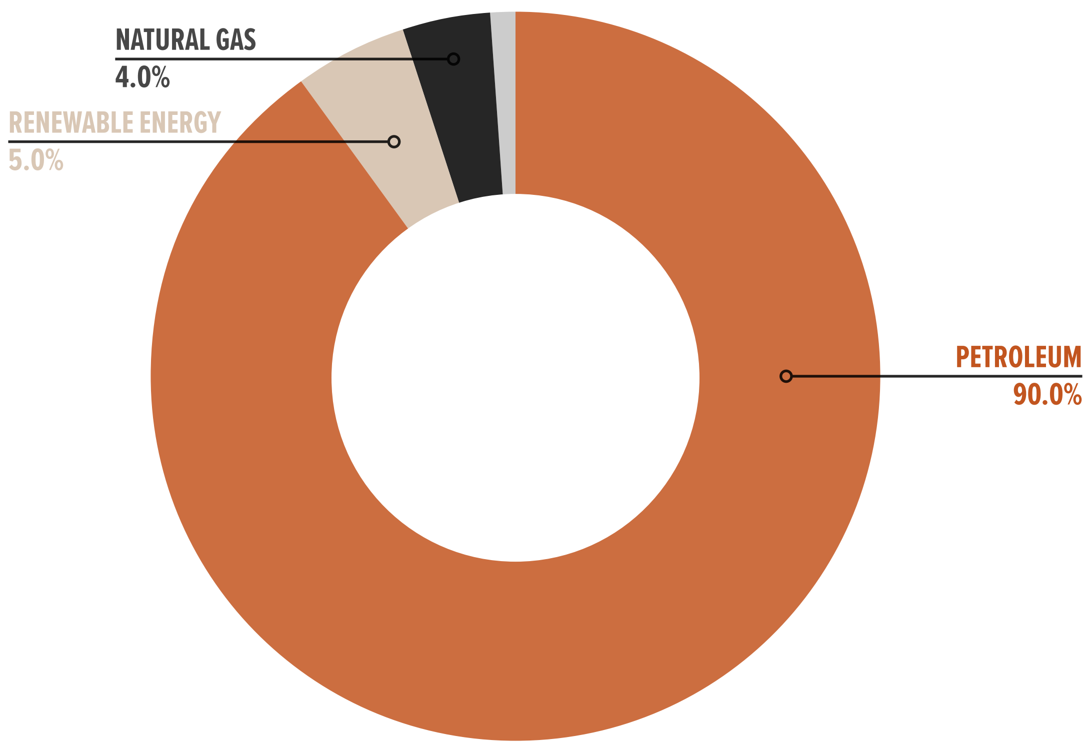


IMPORTANCE OF RENEWABLE ENERGY

In 2020, the U.S transportation sector sourced 90% of it's energy from fossil fuel sources and remained having the smallest share of renewable energy at 5% [7]. According to IEA STEPS* scenario, the United States alone is expected to increase their demand in electricity from cars to 135,000 GWh in 2030, satisfying the demand of 13.7 million EVs [8]. With new demand quickly approaching within the next decade, renewable energy infrastructure must be built to successfully satisfy current and future energy demands to ensure new demand isn't met with fossil fuel sources.

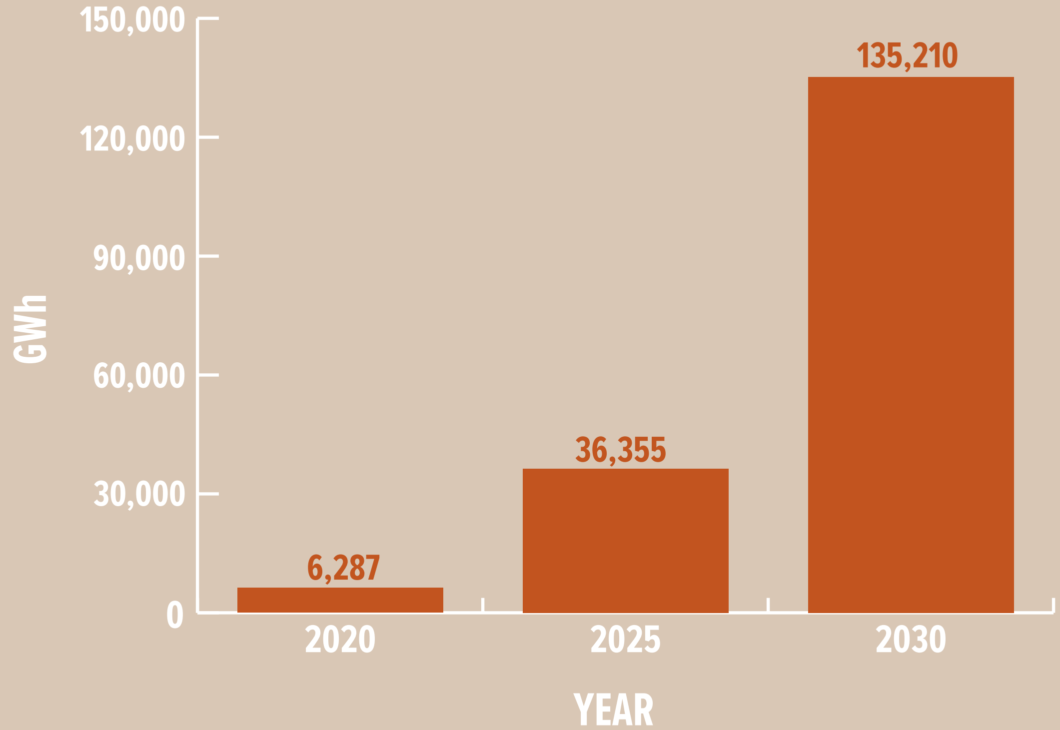
US TRANSPORTATION SECTOR BY ENERGY SOURCE 2020

Figure 4 [ref. 07].



US ELECTRICITY DEMAND FROM CARS GWh

Figure 5 [ref. 08].



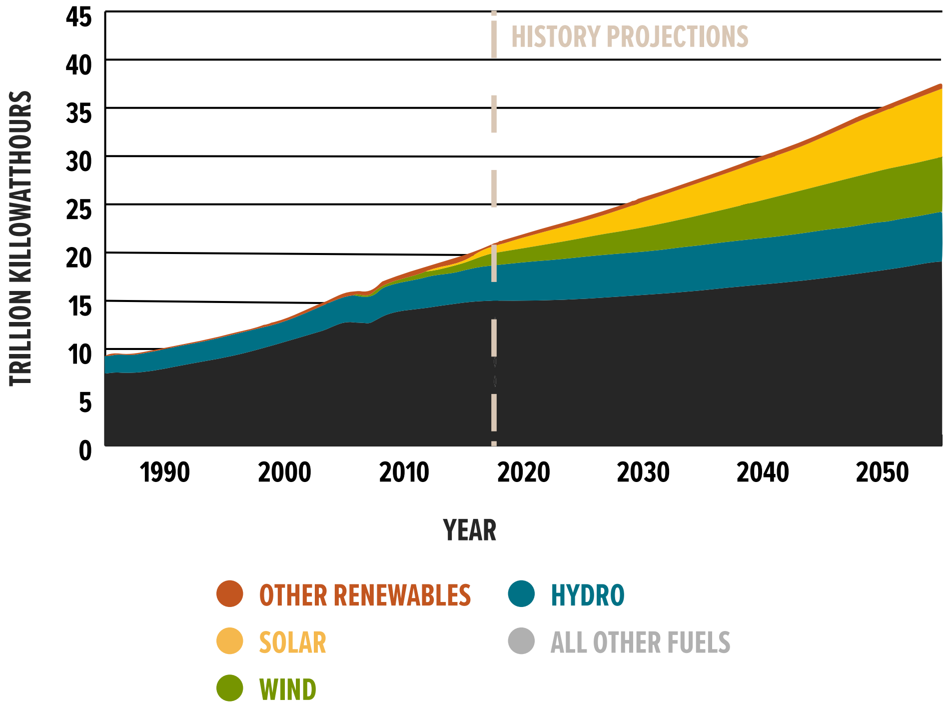
*STEPS scenario is projections based off current and proposed policies

GLOBAL RENEWABLE ENERGY

Global renewable energy grew by 10.3% during 2020 and reached a generating capacity of 2,799 GW [9]. Wind and solar energy combined to account for 91% of new renewable capacity installation in 2020 totaling 238 GW [9], the highest annual increase in renewable generation capacity. Renewable energy will account for 95% of new power capacity growth through 2026 [10] and is projected to provide 49% of the globe's electricity generation in 2050 [11]. Wind and solar generation will continue to be responsible for most of this growth.

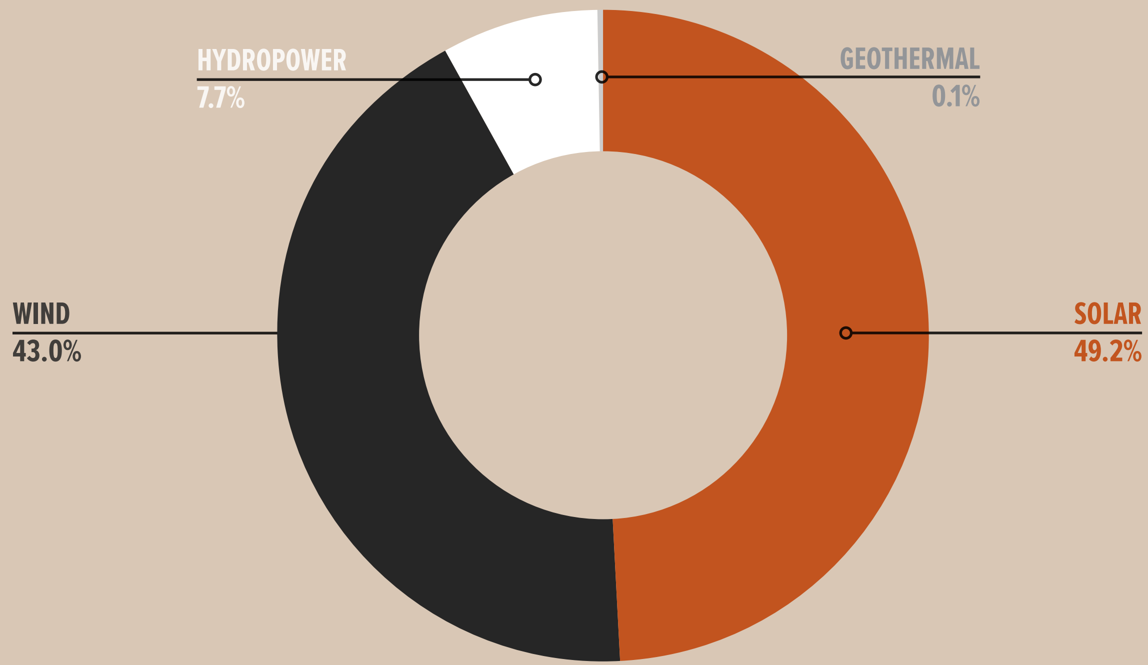
WORLD NET ELECTRICITY GENERATION IEO2019 REFERENCE CASE (1990 - 2050)

Figure 6 [ref. 11].



ADDED RENEWABLE ENERGY CAPACITY 2020

Figure 7 [ref. 09].

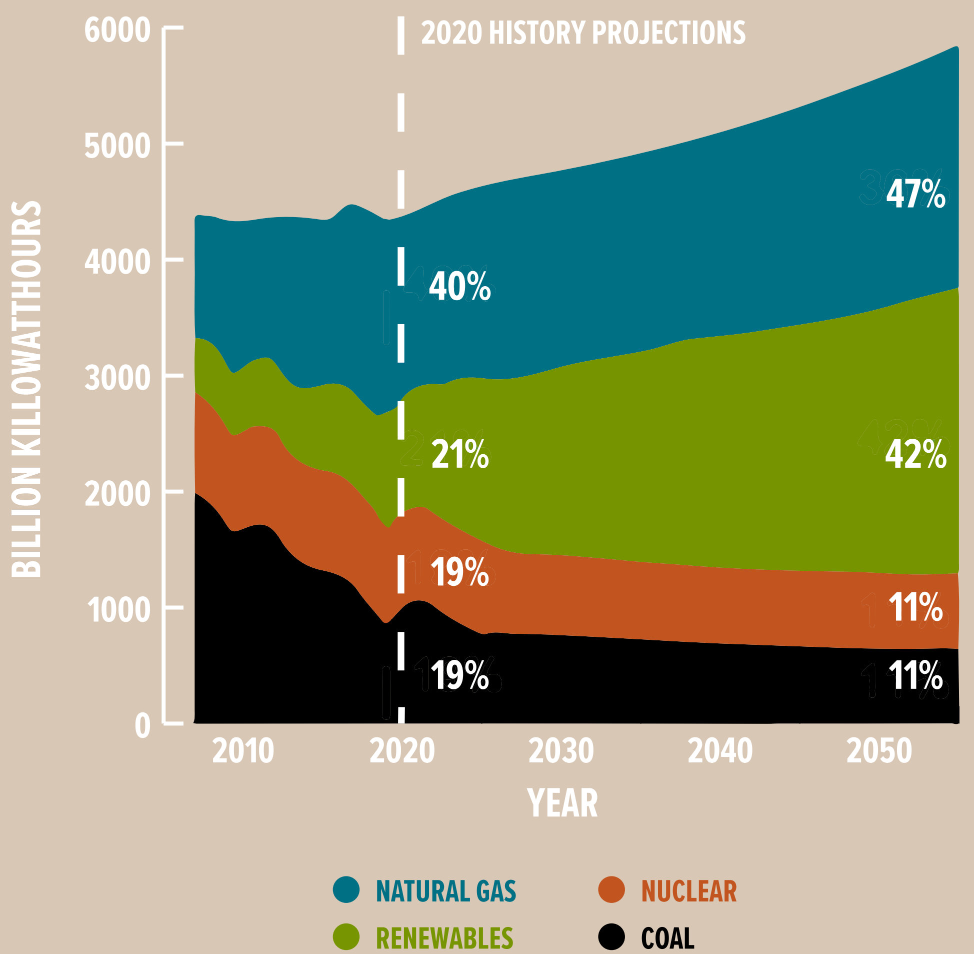


US RENEWABLE ENERGY

The United State's share of renewable energy for electricity generation is expected to increase from 21% in 2020 to 42% in 2050 [12]. Combined, solar and wind energy will be responsible for 81% of the total renewable energy electricity generation in 2050.

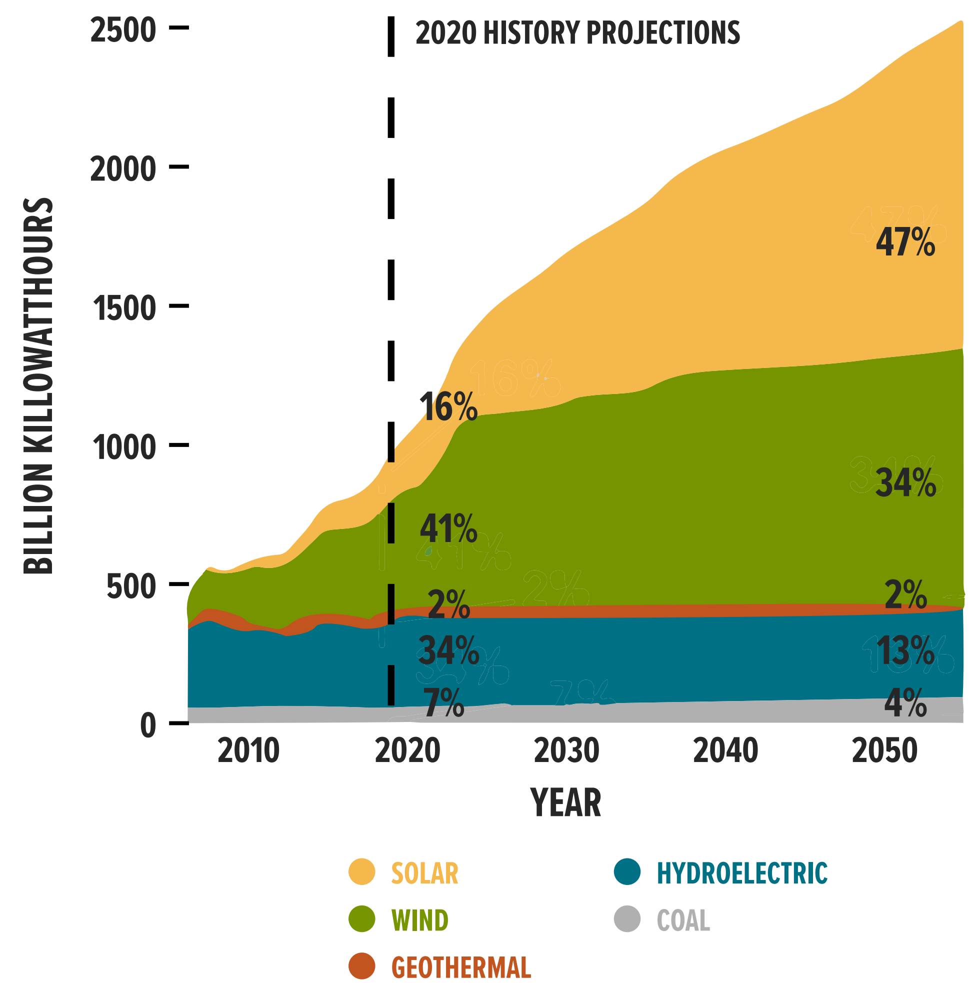
US ELECTRICITY GENERATION FROM SELECTED FUELS AEO2021 REFRENCE CASE

Figure 8 [ref. 12].



US RENEWABLE ELECTRICITY GENERATION AEO2021 REFERENCE CASE

Figure 9 [ref. 12].



OFF-SHORE WIND GROWTH IN THE UNITED STATES

As part of the United States commitment to the Paris Agreement, the Biden Administration's has aimed to reduce greenhouse gas emissions by 50-52% from 2005 levels by 2030 [13]. A critical step to achieve this goal is through scaling offshore wind infrastructure. The Department of Interior (DOI), Energy (DOE), and Commerce (DOC) have announced a shared target of installing 30 gigawatts of offshore wind energy by 2030 in the U.S., the first U.S. national offshore wind energy goal [14]. Achieving this goal will unlock the U.S's potential of 110 GW by 2050 [14], compared to 35,000 MW in 2020 [15]. Jump starting the target, two commercial-scale offshore wind projects have been approved, Vineyard Wind and South Fork Wind, combing to power a total of 470,000 homes [16].

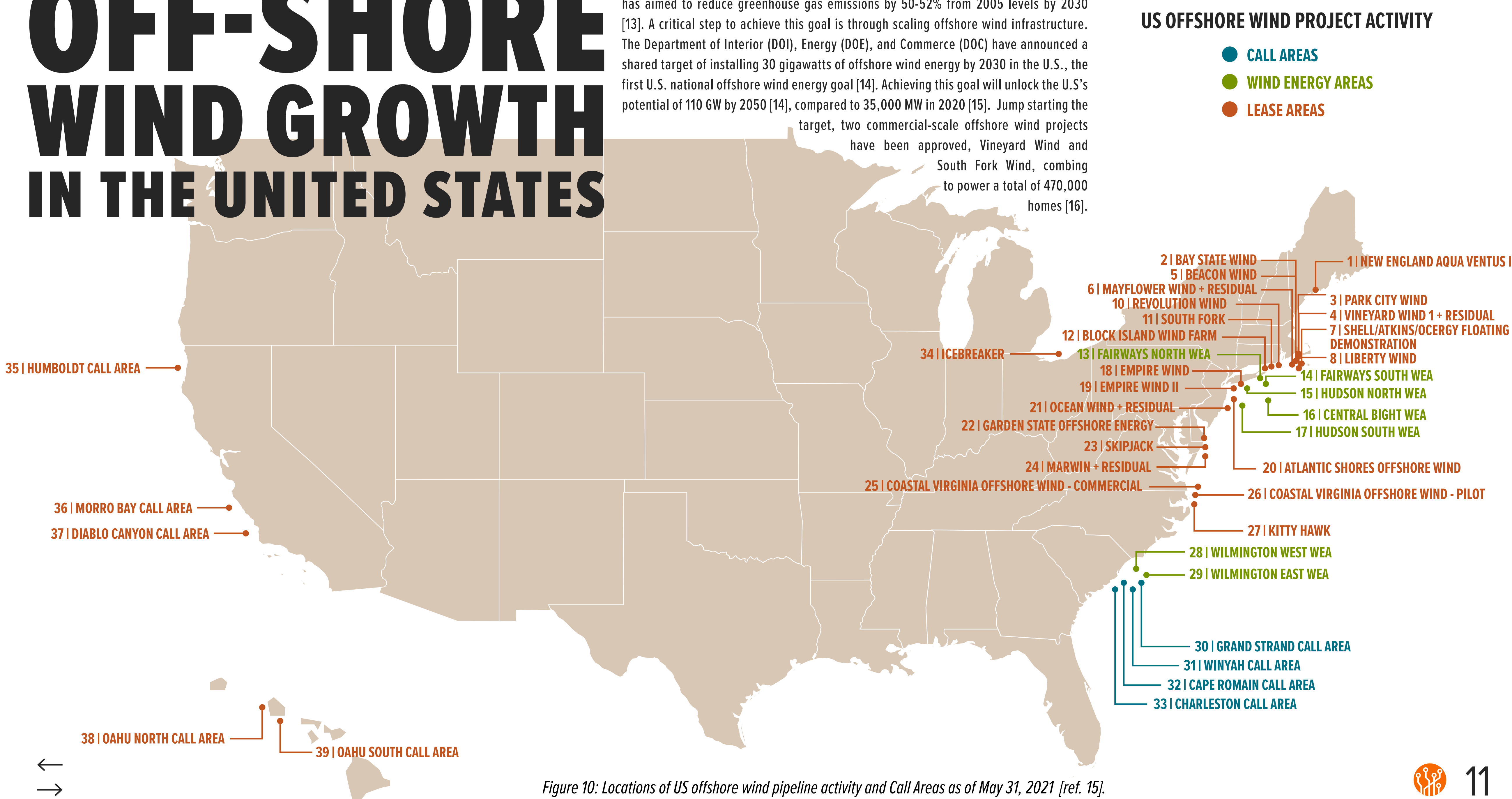


Figure 10: Locations of US offshore wind pipeline activity and Call Areas as of May 31, 2021 [ref. 15].

INTERMITTENT RENEWABLE ENERGY DEMANDING ENERGY STORAGE

Expansions in renewable energy and especially intermittent sources such as wind and solar, are increasing the demand of energy storage devices [17]. Lithium-ion batteries have become a popular battery storage option due having high energy density, 95% efficiency, and much lower weight than traditional lead acid batteries [18]. Lithium-ion batteries create opportunity to leverage intermittent sources and allow generated energy to be stored, creating a surplus when energy demand is low. The surplus of energy would then be exported to the grid when demand is high and effectively power the utility grid through renewable energy. This tactic is called energy shifting. Without energy storage devices, peak demands would be met with fossil fuel sources and most of the renewable energy generated would be unutilized.

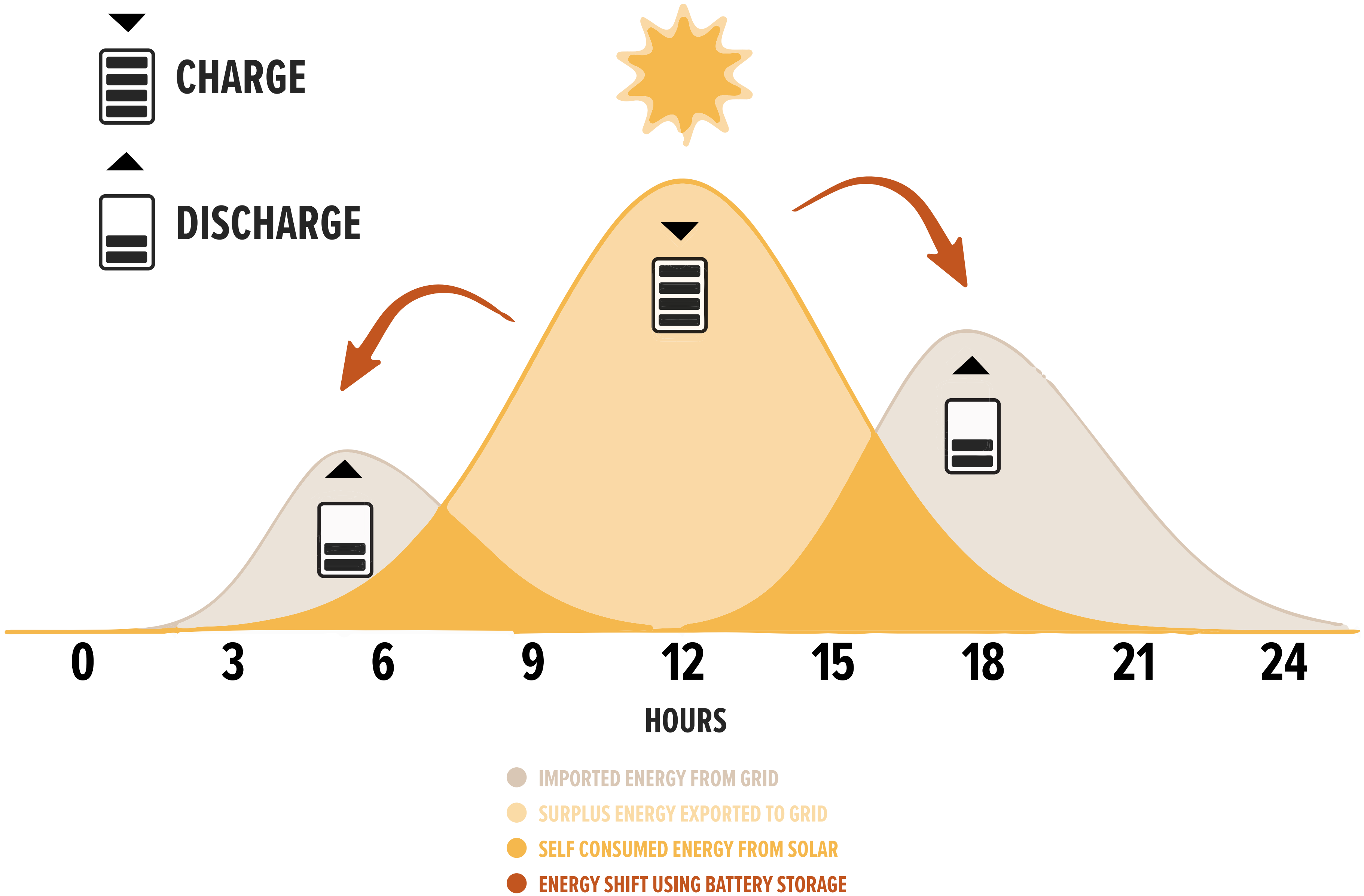


Figure 11 [ref. 17].

GLOBAL ENERGY STORAGE INSTALLATIONS

According to Bloomberg NEF, by the end of 2030, global energy storage installations will reach a cumulative total of 358 GW or 1,028 GWh, compared to 2020 with only 17 GW/34 GWh online. The major expansion will require $262 billion of investments according to estimates [20].

China and the United States are expected to be the two largest markets and represent over 50% in energy storage installations by 2030 [20].

Forecasts created by BNEF suggests that 55% of energy storage built by 2030 will be utilized in energy shifting and 25% be used in homes and businesses [20].

ELECTRIC VEHICLES

ELECTRIC VEHICLE TRENDS

Although EV's progress throughout the past decade has been impressive, it has yet to reach the necessary pace to meet countries Net-Zero Emission by 2050 targets.

By the end of 2020, 3 million electric cars were sold, totaling 10 million electric cars on the road, a 41% increase from 2019 [21]. EV's had a 4.6% sales share in total cars sold during 2020, with 7.2% sales share observed in the first half of 2021 [21].

Although in order to meet Net-Zero Emissions by 2050, the IEA projects that 61% of new car sales must be electric vehicles in 2030, totaling 300 million EVs on the road [21]. Currently, we are only a small fraction of the way there.

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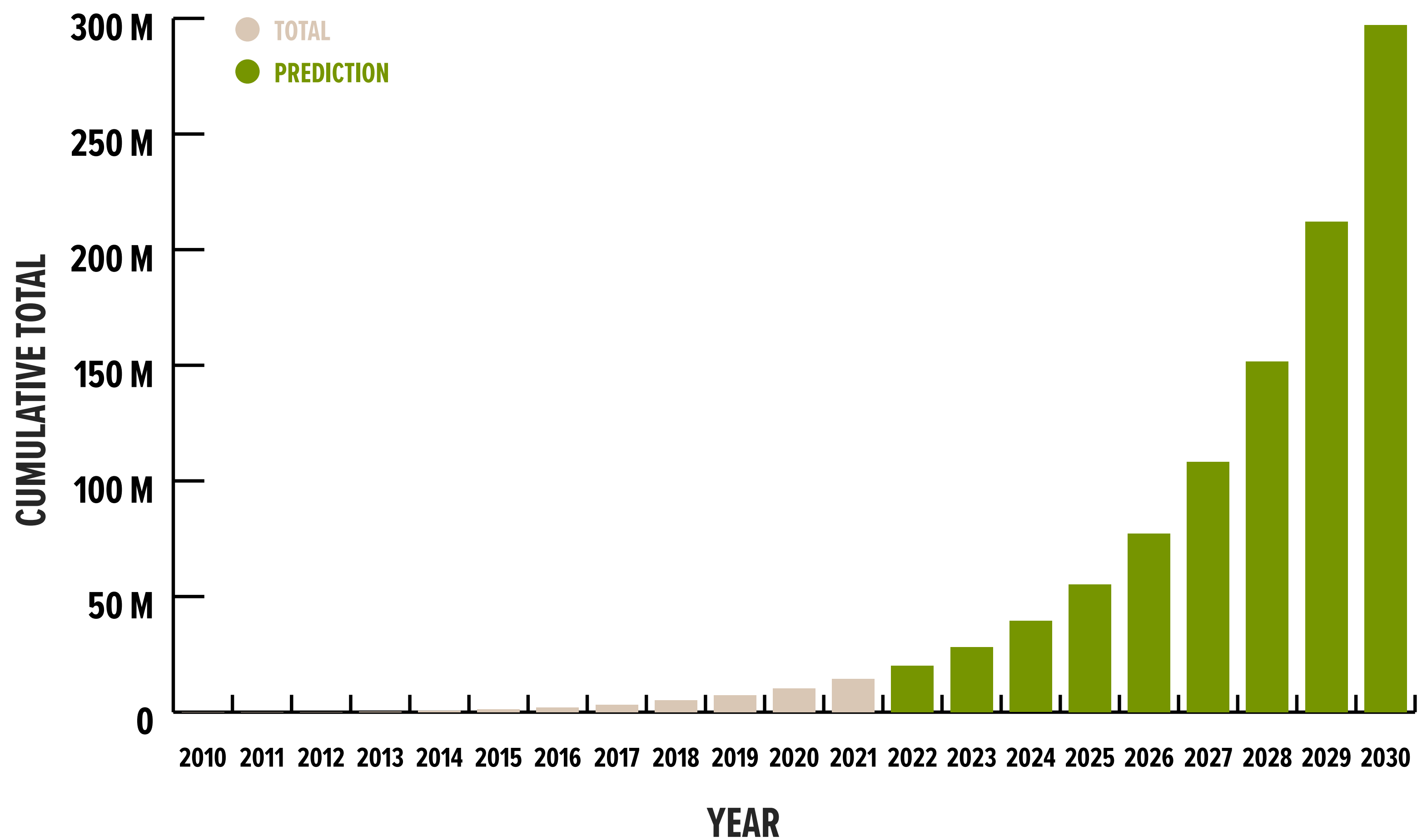
GLOBAL ELECTRIC VEHICLE STOCK

Figure 12 [ref. 21, 22].



COUNTRY & STATE COMMITMENTS

More than 20 countries and US states have announced phase out targets to fully ban the sale of internal combustion engine vehicles (ICE) [23] [24]. Norway has the most aggressive target with a set date of 2025, committing to the sale of 100% zero emission vehicles (ZEV)[24]. These policies help create a more competitive EV market and promote the acceleration of the EV transition.

Figure 13 [ref. 23,24].

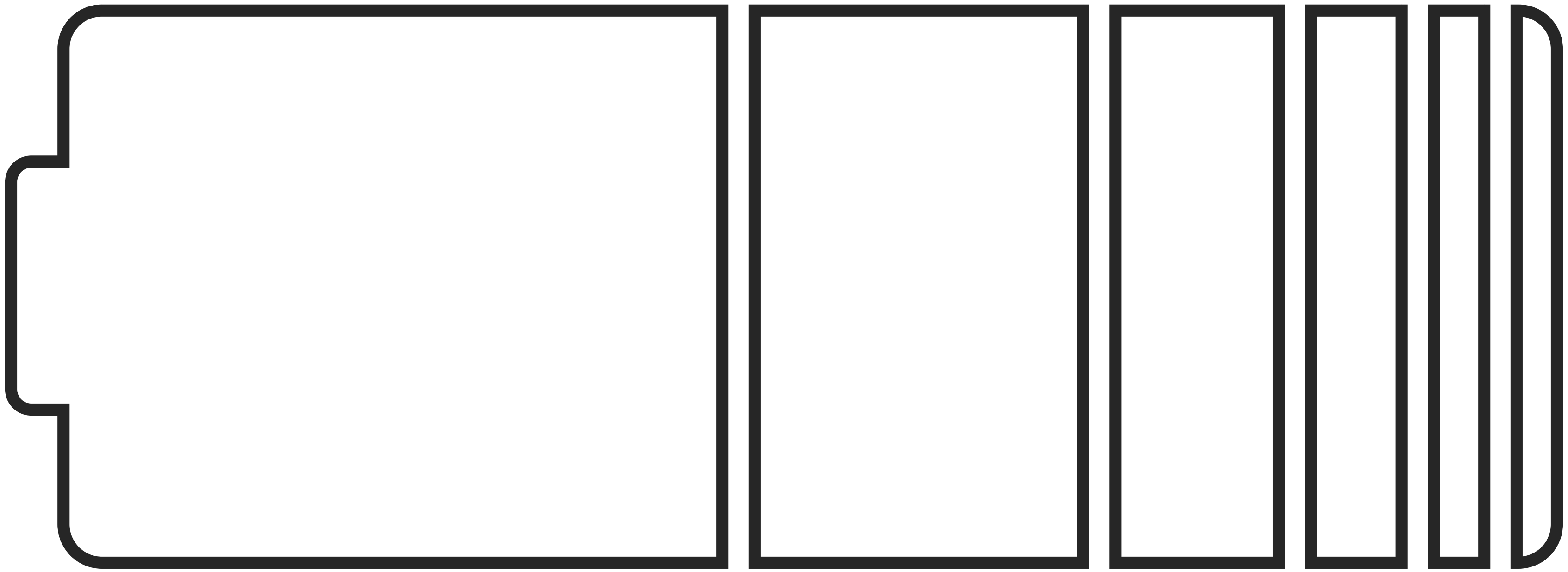
2025
NORWAY

2030
SWEDEN
ISRAEL
SLOVENIA
ICELAND
DENMARK
NETHERLANDS

2035
UNITED KINGDOM
NEW YORK
JAPAN
CHINA
CANADA
COLUMBIA
CALIFORNIA
SCOTLAND

2040
PROTUGAL
SPAIN
FRANCE

2050
COSTA RICA
GERMANY



LITHIUM ION BATTERY

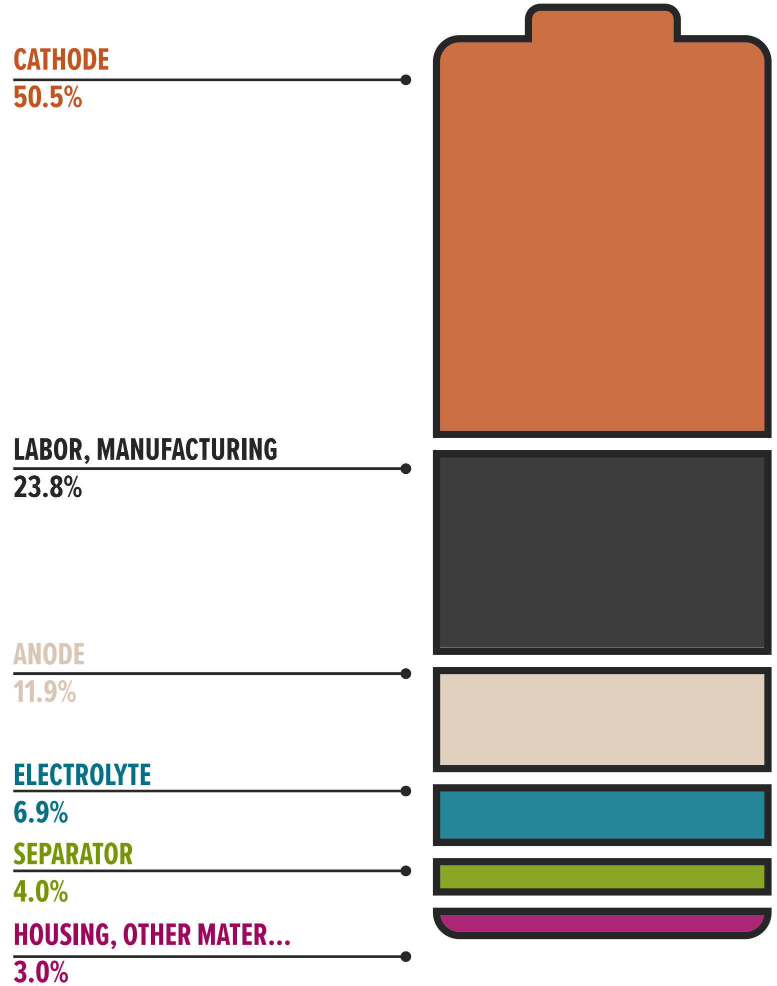
In the 1970s, a British chemist named Stanley Whittingham began exploring creating a rechargeable battery that he hoped would eliminate the dependence on fossil fuel energy. Through several attempts, the battery continued to short circuit due to the use of lithium metals and titanium disulfides [82]. In the early 1980s, John Goodenough, altered this experiment and used lithium cobalt oxide, followed by Akira Yoshino who made several altercations that allowed for commercial production of the battery [83].

Lithium-ion batteries are the currently the leading battery technology being used in electric vehicles, due to their high power to weight ratio, high energy efficiency, high-temperature performance, and low self-discharge [25].

Currently at a market size of $41.4 billion, the global lithium-ion battery market is projected to grow to $116.6 billion by 2030, driven primarily by the deployment of electric vehicles within the next decade [26].

BATTERY PRICE BREAKDOWN

Figure 14 [ref. 29].



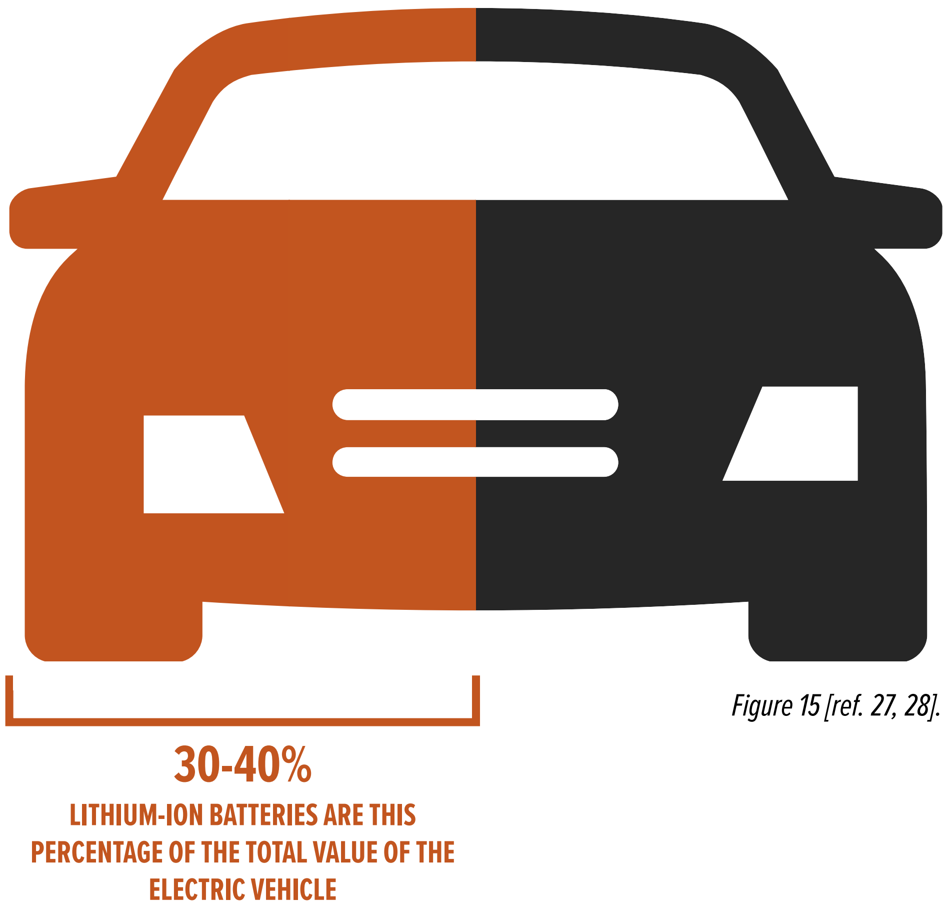


Figure 15 [ref. 27, 28].

Li-ion batteries are 30%-40% of the total value of the electric vehicle, indicating the demand of their manufacturing is essential to successfully electrify vehicles fleets and reduce carbon emissions [27] [28]. 50% of the total battery cost is devoted to the cathode, making it the most valuable piece of technology in the EV [29].

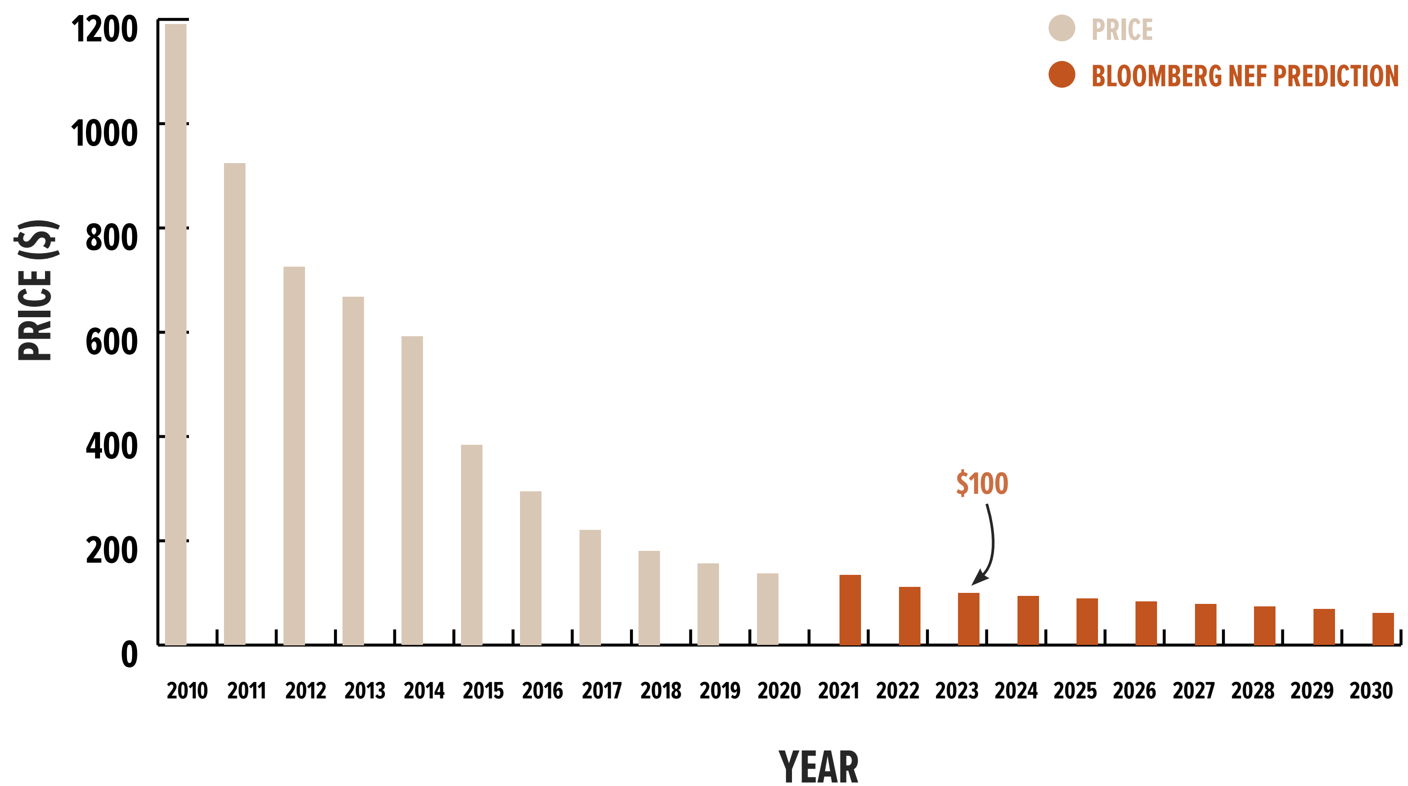
FALLING BATTERY PRICES

One of the main driving factors for the industry is the falling cost of battery packs. Since 2010, there has been at 89% price decrease per kWh from $1,200 to $137kWh in 2020, and this fall is expected to continue. An electric vehicle with a 50kWh battery pack would have a savings of $43,000 [78].

According to BloombergNEF, EV prices will become competitive with gas cars when the price of packs reach $100/kWh. This is projected to happen by 2023 [78].

PRICE OF BATTERY PACKS

Figure 15 [ref. 75].

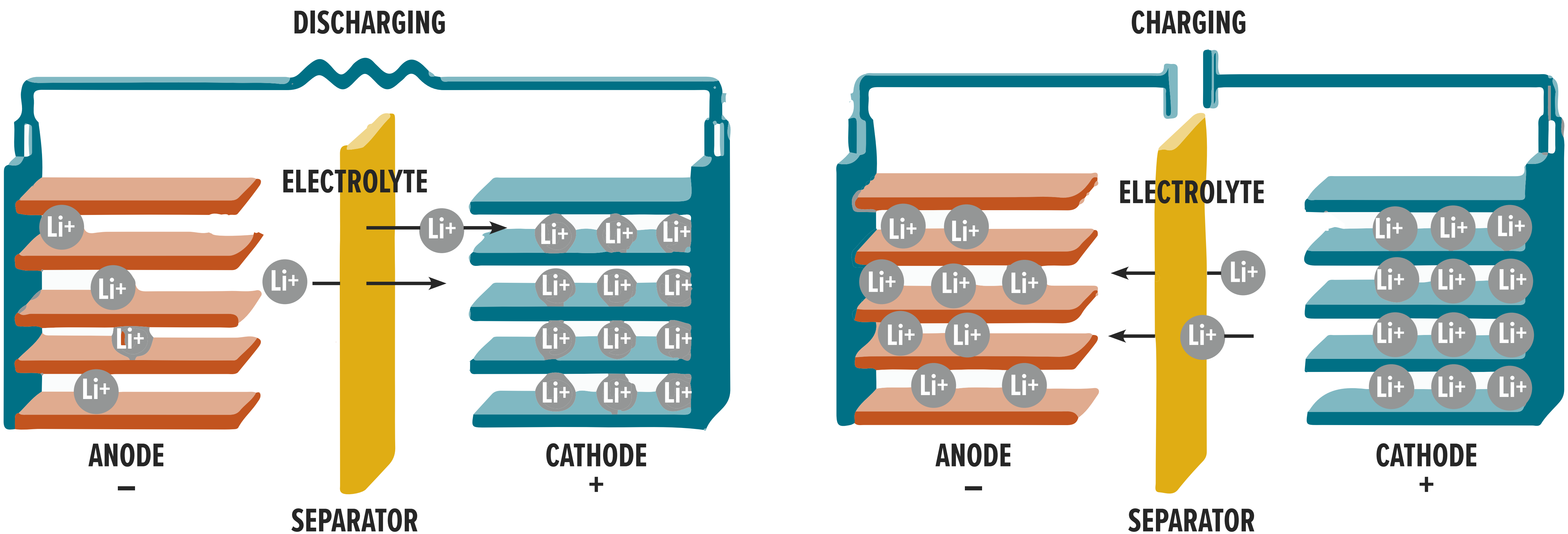


CHEMISTRY

A Li-ion battery has four main components: cathode (positive electrode), anode (negative electrode), electrolyte and a separator.

When the battery is in use it is discharging, meaning lithium ions travel from the anode to the cathode through the electrolyte. This causes the electrons to move from the anode to the cathode externally, powering the vehicle [30].

When the battery is plugged in and charging the opposite occurs. Lithium ions are released by the cathode and received by the anode, causing electrons to move from the cathode to the anode [30].



The separator plays a vital role in ensuring there is a barrier between the cathode and anode and prevents internal movement of electrons, allowing only the ions to pass. Without it, the battery would catch fire on contact [30].

Figure 16 [ref. 30].

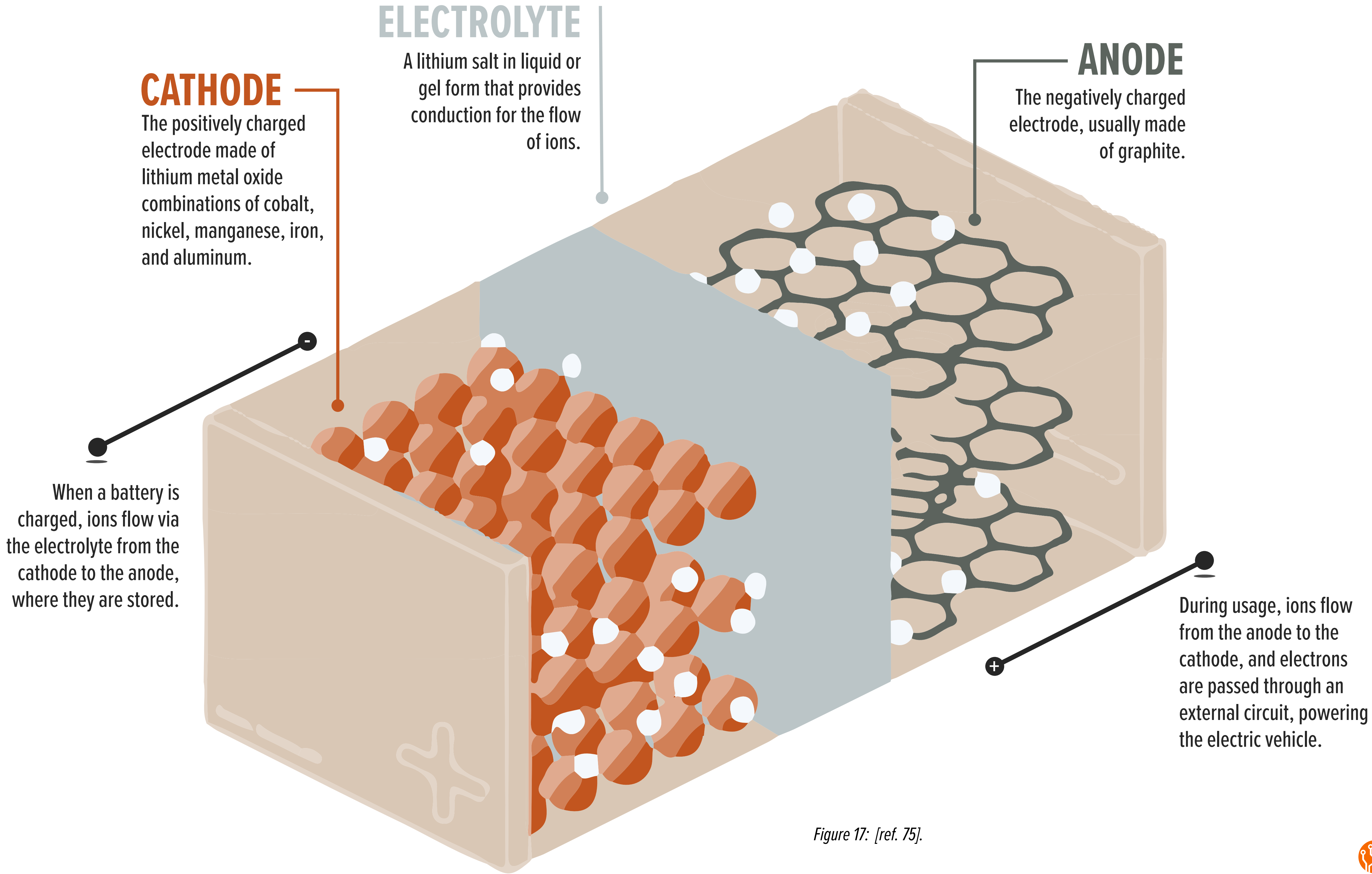


Figure 17: [ref. 75].

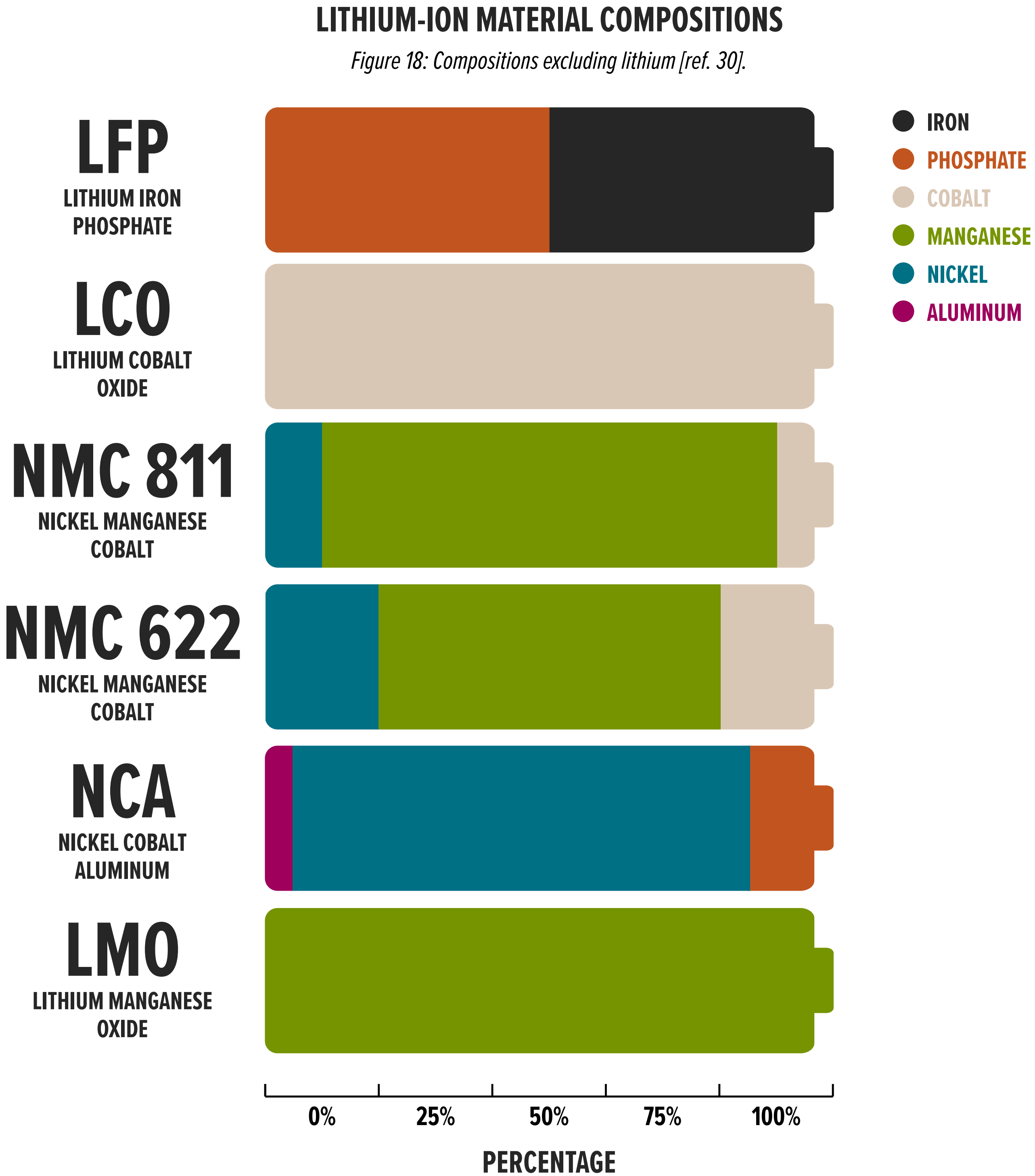


Figure 18: Compositions excluding lithium [ref. 30].

LI-ION CATHODES

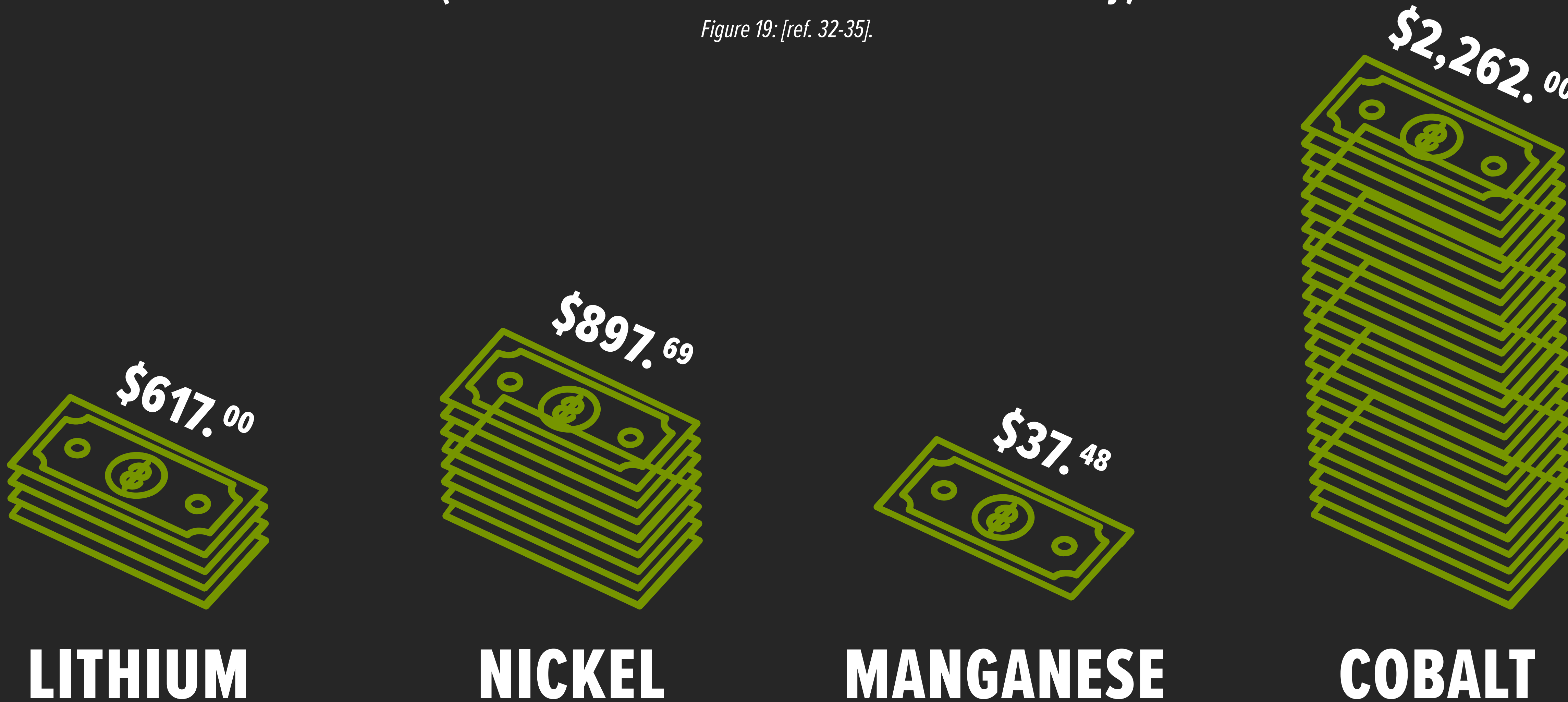
The cathode in the Li-ion battery is the key performance source that determines the batteries capacity and power. Developments of various cathode mineral compositions have looked to increase energy density, decrease cost, and increase lifespan and safety. Mineral availability, cost and environmental and social issues are also key drivers in the development of new Li-ion batteries.

To read about critical minerals and its impact on the EV transition read Bulletin 20220102.

NATURAL RESOURCES & COST$

(estimates based on a NMC 532 battery)

Figure 19: [ref. 32-35].



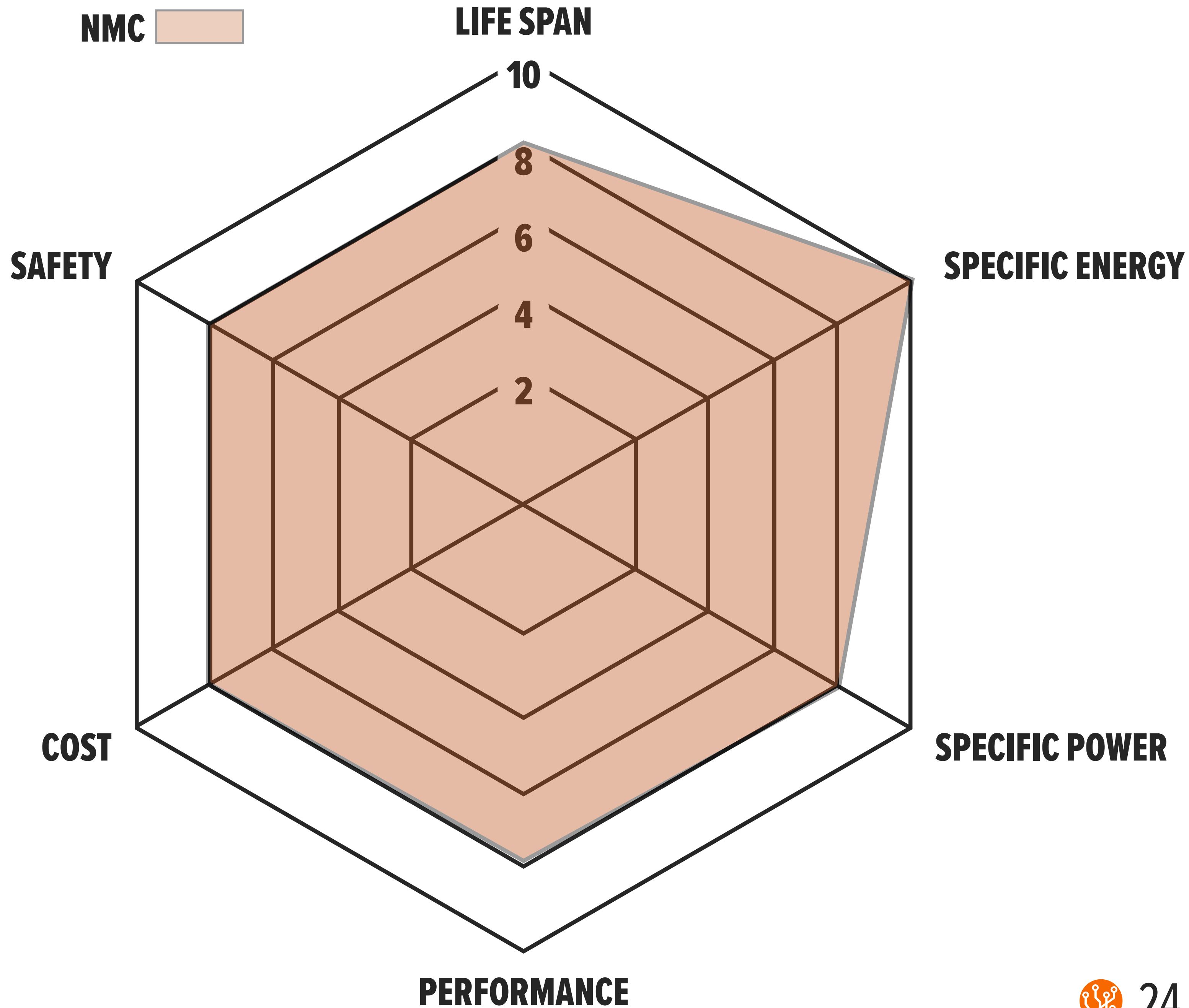
NMC SPECS

Lithium Nickel Manganese Cobalt Oxide (NMC) has historically been the most common cathode in Li-ion batteries, with different compositions including NMC 111, NMC 622, NMC 811 and NMC 532. Its' success has been attributed to delivering a high energy density while remaining light and more compact than other technologies [36].

Although, each NMC battery contains cobalt, a critical mineral that has received pushback due to unethical mining practices and high processing cost. This has pushed the industry to explore cobalt-free batteries.

NMC BATTERY CHARACTERISTICS

Figure 20: [ref. 37].



COBALT & HUMAN RIGHTS

The heavy use of critical minerals and metals have led to serious environmental and social consequences. This is specifically true for one of lithium-ion batteries most valuable raw material, cobalt. Although depending on the battery type and vehicle, a single electric vehicle lithium-ion battery pack could contain 14 kg of cobalt [38].

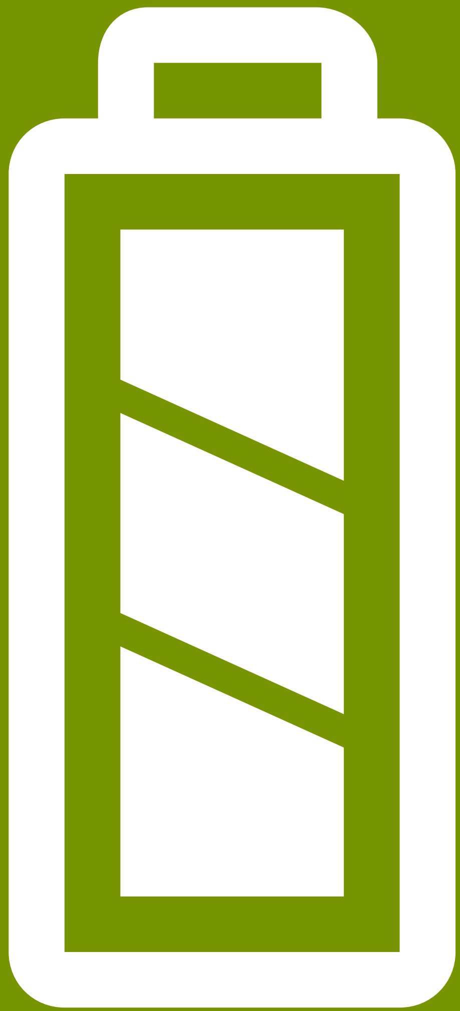
Cobalt is predominately mined in the Democratic Republic of Congo, encompassing about 70% of the global supply [39]. As of 2020, 15 out of the 19 cobalt producing mines in DRC were either owned or financed by Chinese companies [40]. Chinese ownership has led to a substantial decline in the safety of workers with reports made of abusive and neglecting working conditions, increase in severe injuries, as well as forced child labor [40].

Due to the human rights issues associated with Cobalt as well as the projected price increase, many are turning away from using cobalt in their electric vehicles and are looking at alternatives.

TRANSITIONING AWAY FROM COBALT

Research has shown that cobalt can be eliminated from cathodes without compromising the battery's performance [41], and many car manufactures are in favor.

In October of 2021, Tesla announced that they will be adopting the lithium iron phosphate (LFP) battery for their lower-mid range models [42], capitalizing on the lower expense of this battery compared to NMC and NCA chemistry. Toyota and Volkswagen have also showed interest in diversifying into LFP technology [42,43].



LFP & CHINA

Within the past year, LFP batteries have gained traction due to its lower cost from eliminating price volatile metals such as nickel and cobalt [42].

Although, this technology is not new to the market. China has been predominately manufacturing LFP batteries for their EVs for the past 10 years through agreements made with a consortium of universities and research institutions [42]. The agreement stated that Chinese battery manufactures would be excused from a licensing fee provided that the use of LFP battery technology be remained in China [42]. However, these patents are due to expire in 2022, which explains the recent adoption by Tesla, Toyota and Volkswagen [42, 44].

LFP BATTERY CHARACTERISTICS

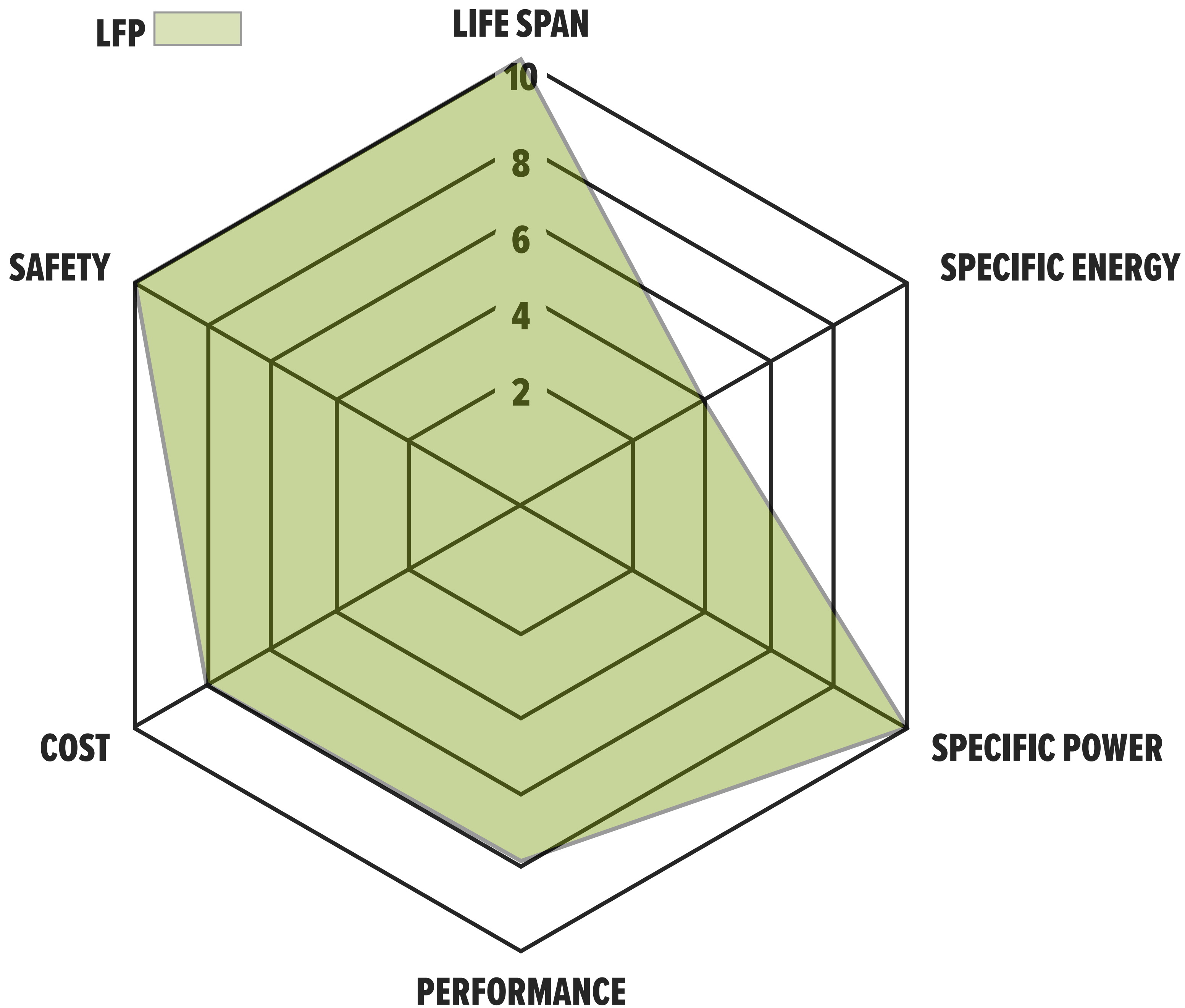


Figure 21: [ref. 37].

LFP SPECS

Lithium Iron Phosphate (LFP) batteries offer benefits beyond its' lower price point, including longer lifespan, increase safety, and high specific power [45].

A LFP battery has shown to be capable of 2,000-3,000 full charge/discharge cycles before reaching 80% of its' original capacity, compared to an NMC battery which usually reaches this from only 500-1,000 cycles [36]. This demonstrates a LFP battery's ability to provide 3x more cycle life than a typical NMC battery.

Additionally, LFP have better thermal and chemical stability, meaning the risk of fires is nearly eliminated compared to NMCs [36].

Even though a typical LFP battery has lower specific energy, meaning less energy storage capacity, it can deliver high amounts of power without overheating [46], making it a safe option for EVs.

BATTERY MARKET SHARE FORECAST

As previously stated, NMC batteries have been the most popular option amongst battery chemistry for energy storage, encompassing 75% of the energy storage market in 2015, while LFP only represented less than 10% [47]. Due to increased interest and ability to manufacture LFP batteries outside of China, it's expected that LFP batteries overtake NMC by 2030 and grow to over 30% of the market [47].

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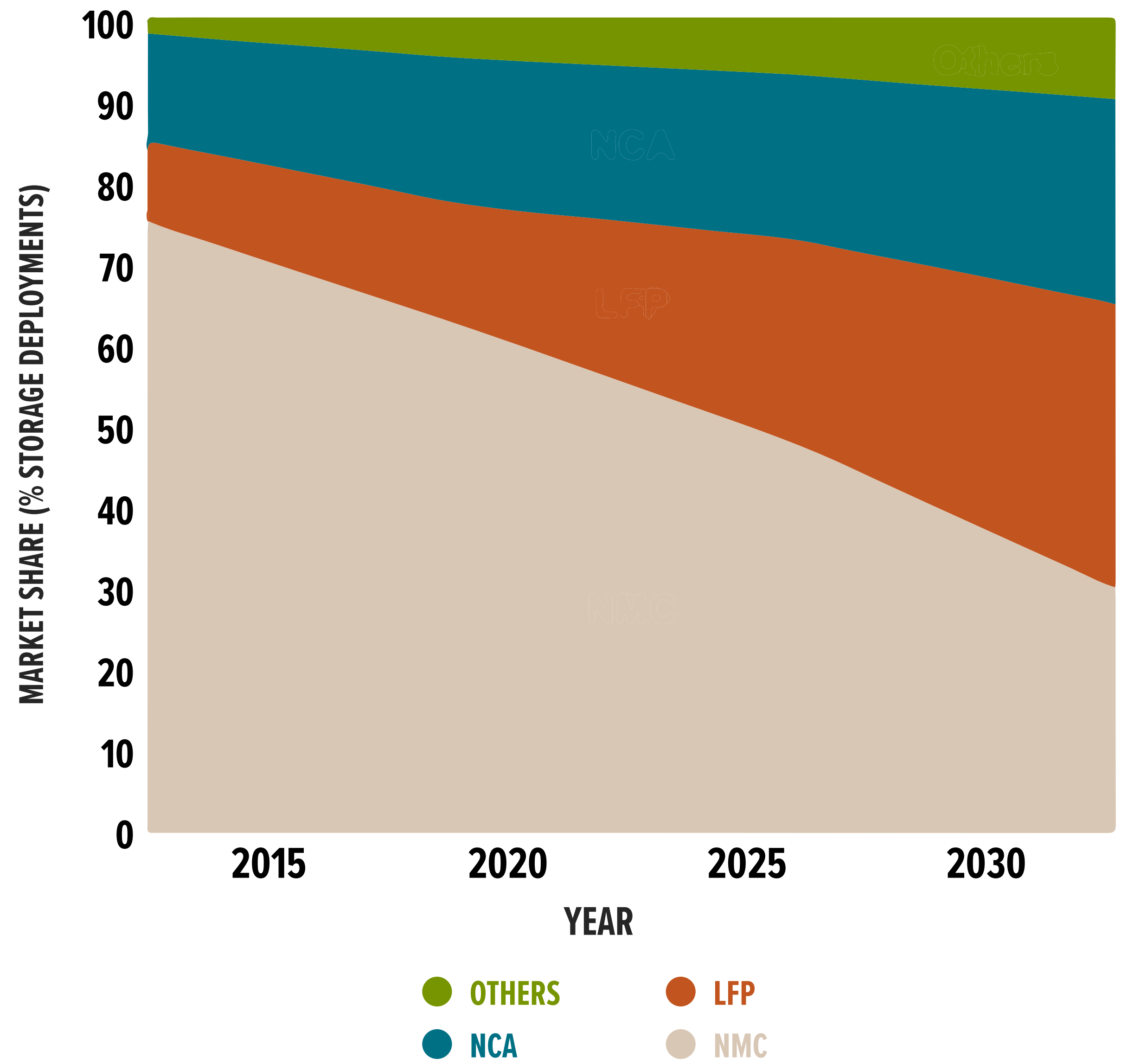
ESS BATTERY CHEMISTRY MARKET SHARE FORECAST

Figure 22 [ref. 47].



BATTERY MANUFACTURING

MANUFACTURING LOCATIONS

The market for lithium-ion battery manufacturing is highly dominated by China, with a manufacturing capacity of 570 GWh in 2020 [48]. This is mainly attributed to China's advanced policy incentives and containing 80% of the globe's chemical processing for critical minerals (Nelson, slide 6). Europe, Japan, South Korea and the United States all fall behind China at much smaller annual capacities.

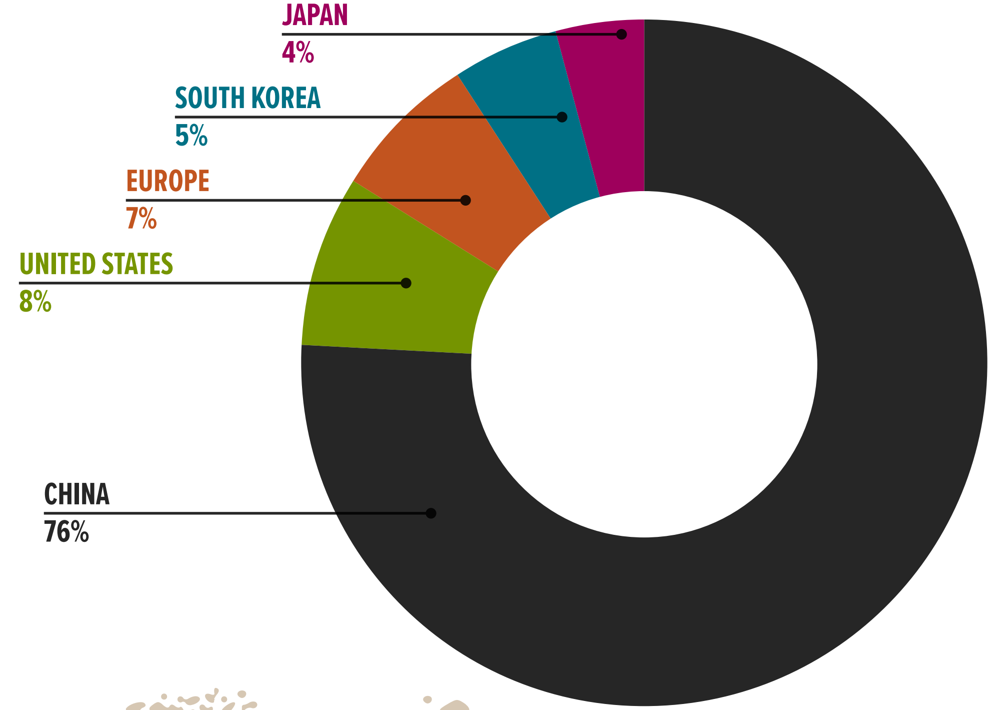


Figure 23: Global Li-Ion Battery Capacity, 2020 [ref. 48].

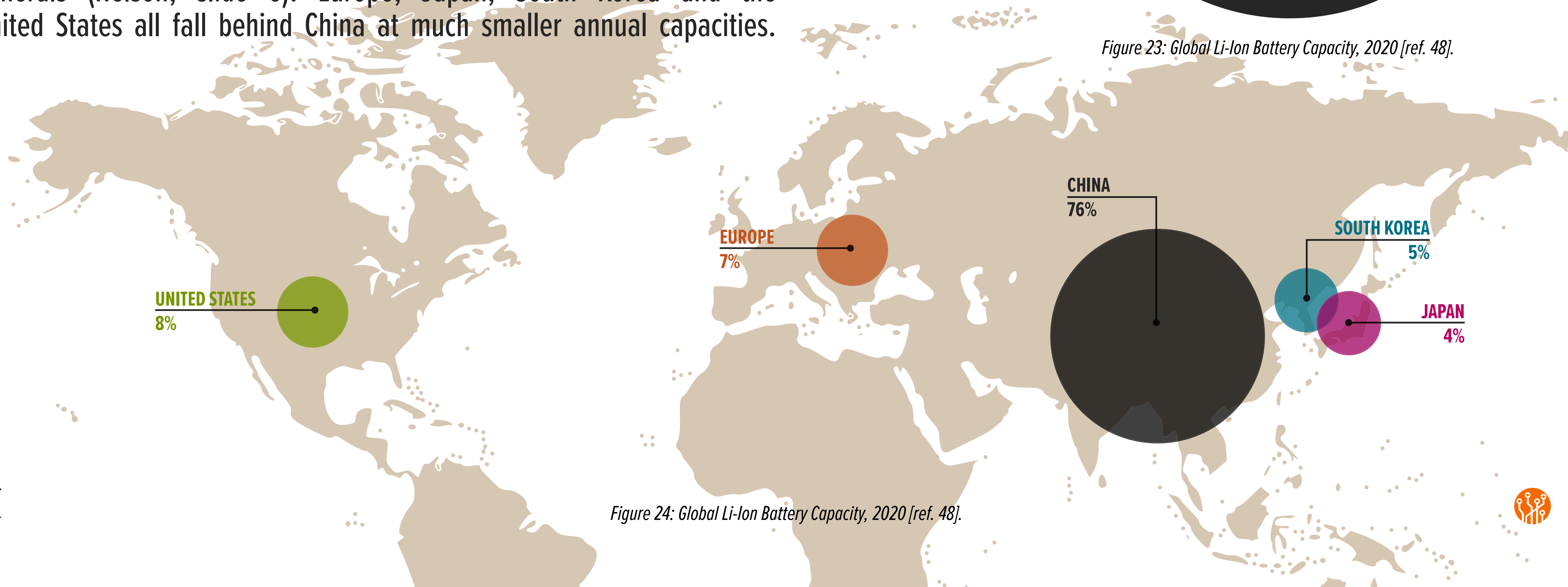
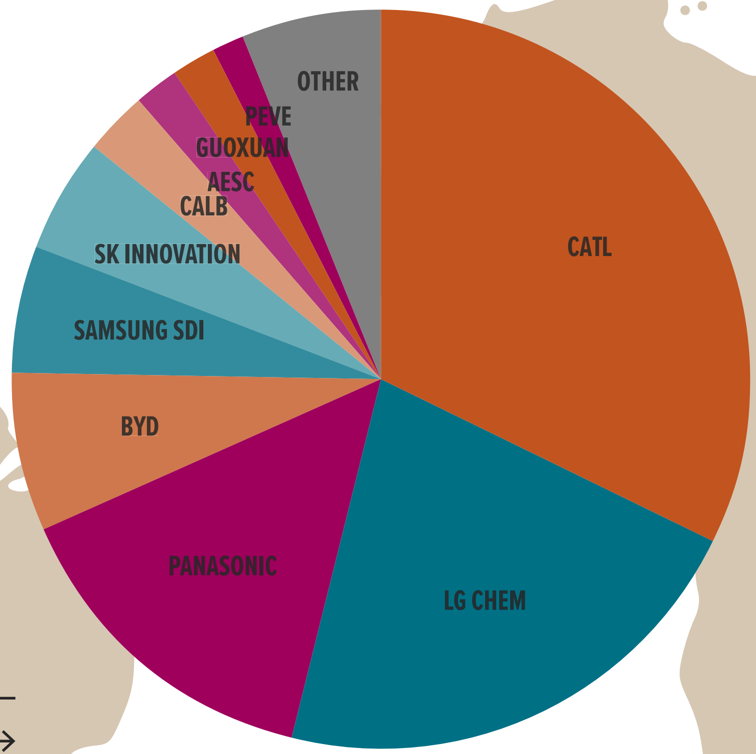


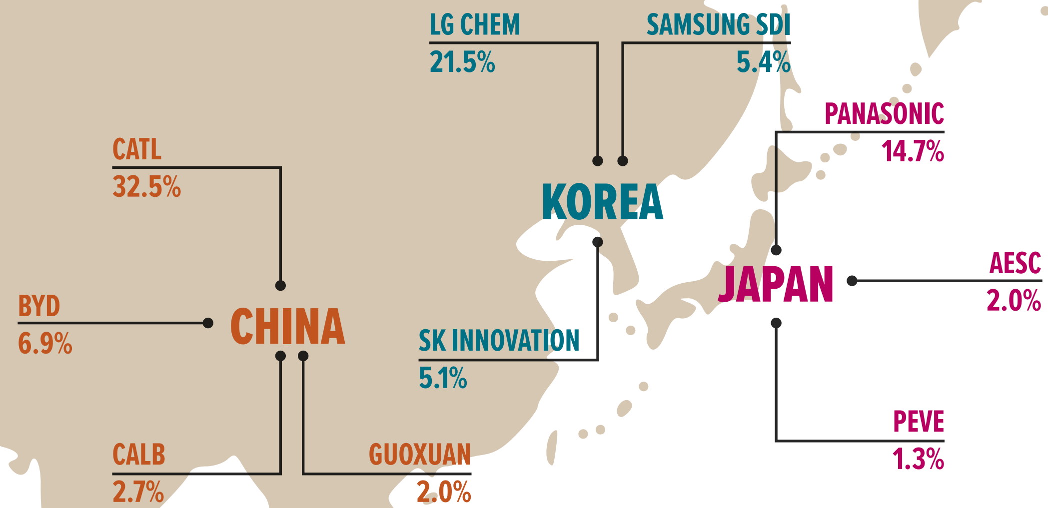
Figure 24: Global Li-Ion Battery Capacity, 2020 [ref. 48].

LEADING MANUFACTURERS

The manufacturing market is primarily driven by three main players, CATL, LG Chem, and Panasonic, who combine to make up 70% of market share [49]. All top 10 manufacturers are headquartered in Asian countries.

Figure 25: Headquarter Locations and Market Shares [ref. 49].





JOINT VENTURES

Original equipment manufacturers (OEM), such as Toyota, Ford, and General Motors, have recognized the importance of a strong lithium-ion battery chain and how critical it is to ensure it's part of their control. Many have announced joint ventures with key li-ion manufacturers with plans of expansion, with the most notable one being Tesla and Panasonic.

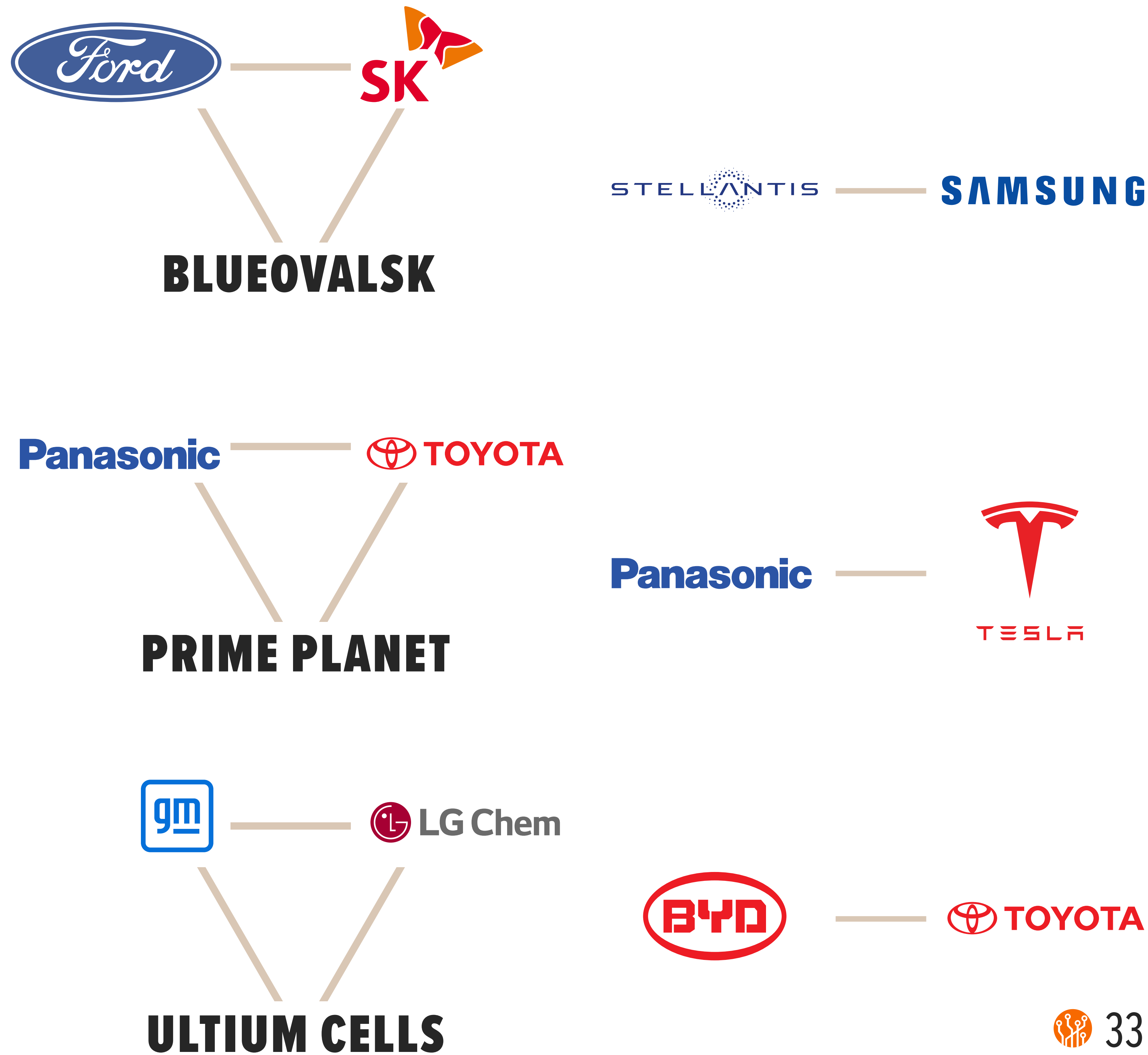


Figure 26: [ref. 77].

← →

DAIMER

- CATL
- SAMSUNG SDI
- SK INNOVATION
- LG CHEM

VOLKSWAGEN

- LG CHEM
- SK INNOVATION
- NORTHVOLT
- SAMSUNG SDI
- PANASONIC

SUPPLIER RELATIONS

In addition to joint ventures, OEM's also source from different suppliers to ensure they are in positions of new technology and competing prices. This creates flexibility advantages and mitigates risk in shortages and price spikes.

Figure 27: [ref. 77].

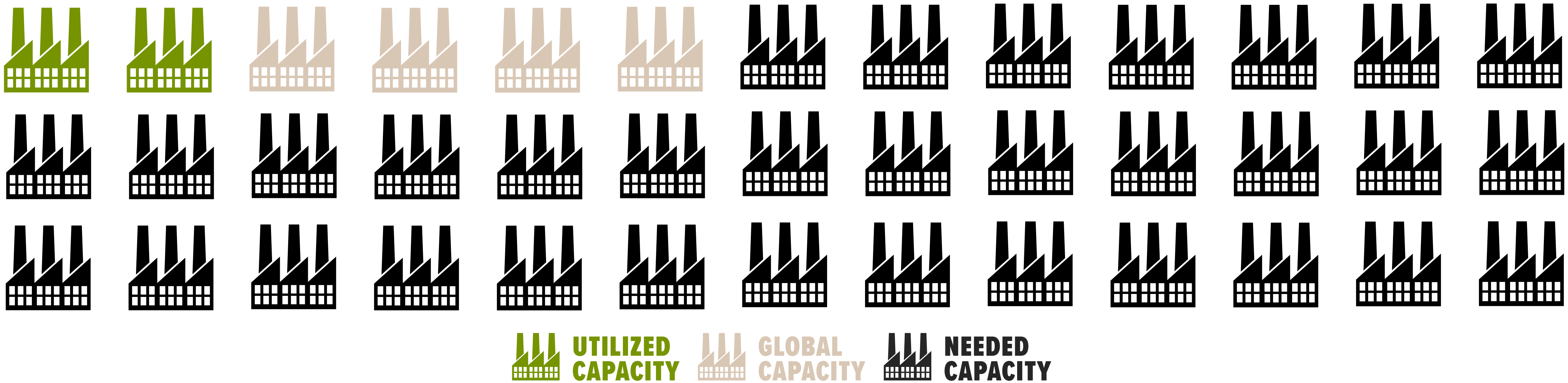
FORD

- BYD
- SK INNOVATION
- LG CHEM
- SAMSUNG SDI
- PANASONIC

TESLA

- SK INNOVATION
- LG CHEM
- PANASONIC

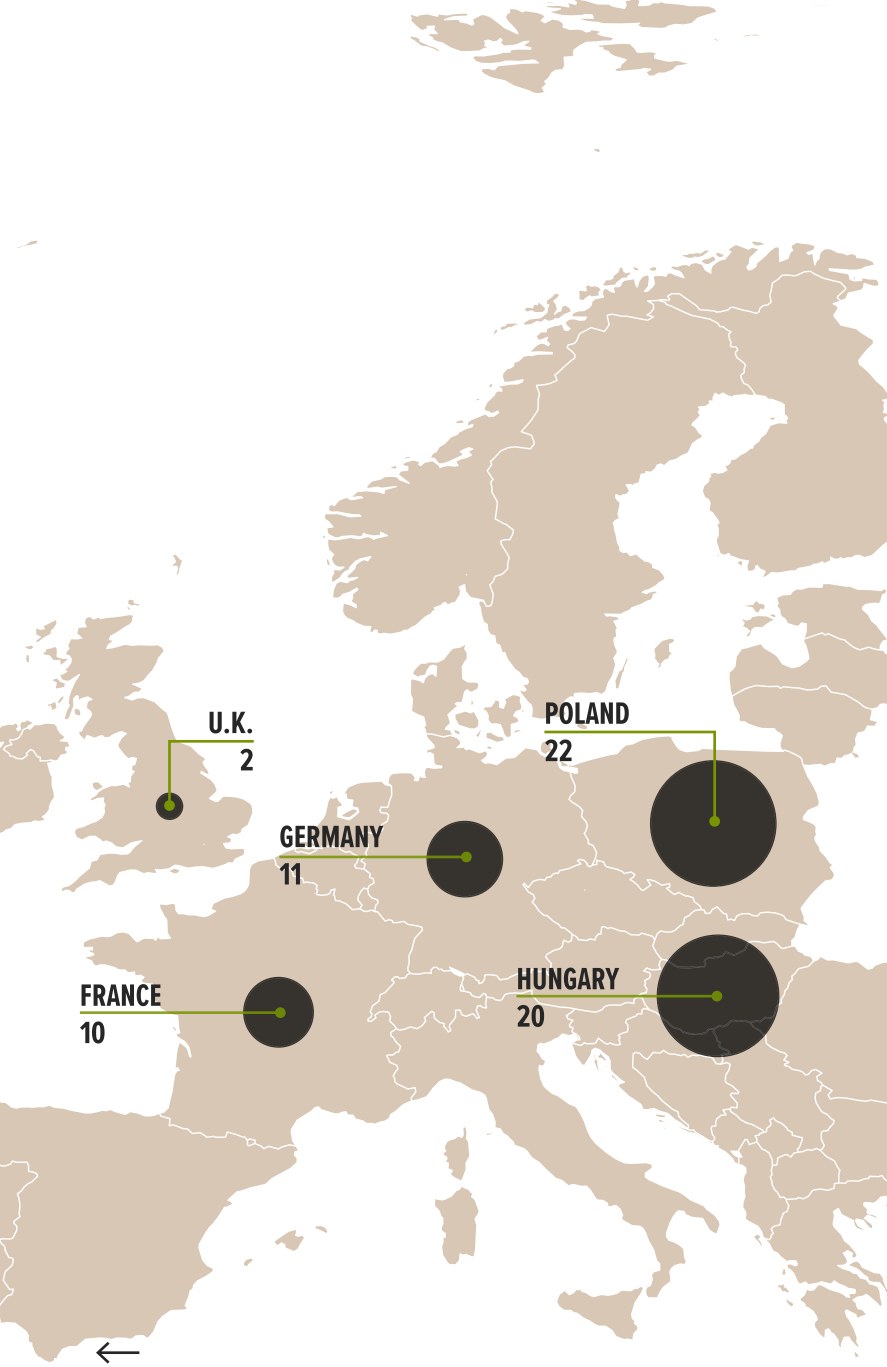
GLOBAL CAPACITY



In 2020, the global annual lithium-ion battery capacity was 300-432GWh, with only 160-228 GWh being utilized in manufacturing actual batteries [56] [57]. Although to adequately satisfy the rapid demand of EV's, annual capacity must be increased to 3,000-3,900 GWh (3 TWh) by 2030 [58] [59]. Lithium-ion battery manufacturers have identified the valuable growth associated with growing EV demand and have been quick to publicize their plans of expansion. Recent announcements have demonstrated an expected global increase to about 2,912 Gwh by 2030, provided by 60 new gigafactories [59]. Despite the fact this total capacity is roughly on target to meet demands in 2030 of 3,000-3,900 GWh, facilities often run on only 50% of their capacity, meaning current announcements would only be able to supply 37-48% of demands in 2030 [56]. Additionally, many gigafactories take 3-6 years until they fully ramp up to their capacity, demonstrating the immediate need to accelerate manufacturing capabilities within the next couple years [59].

Figure 28: [ref. 56-59].

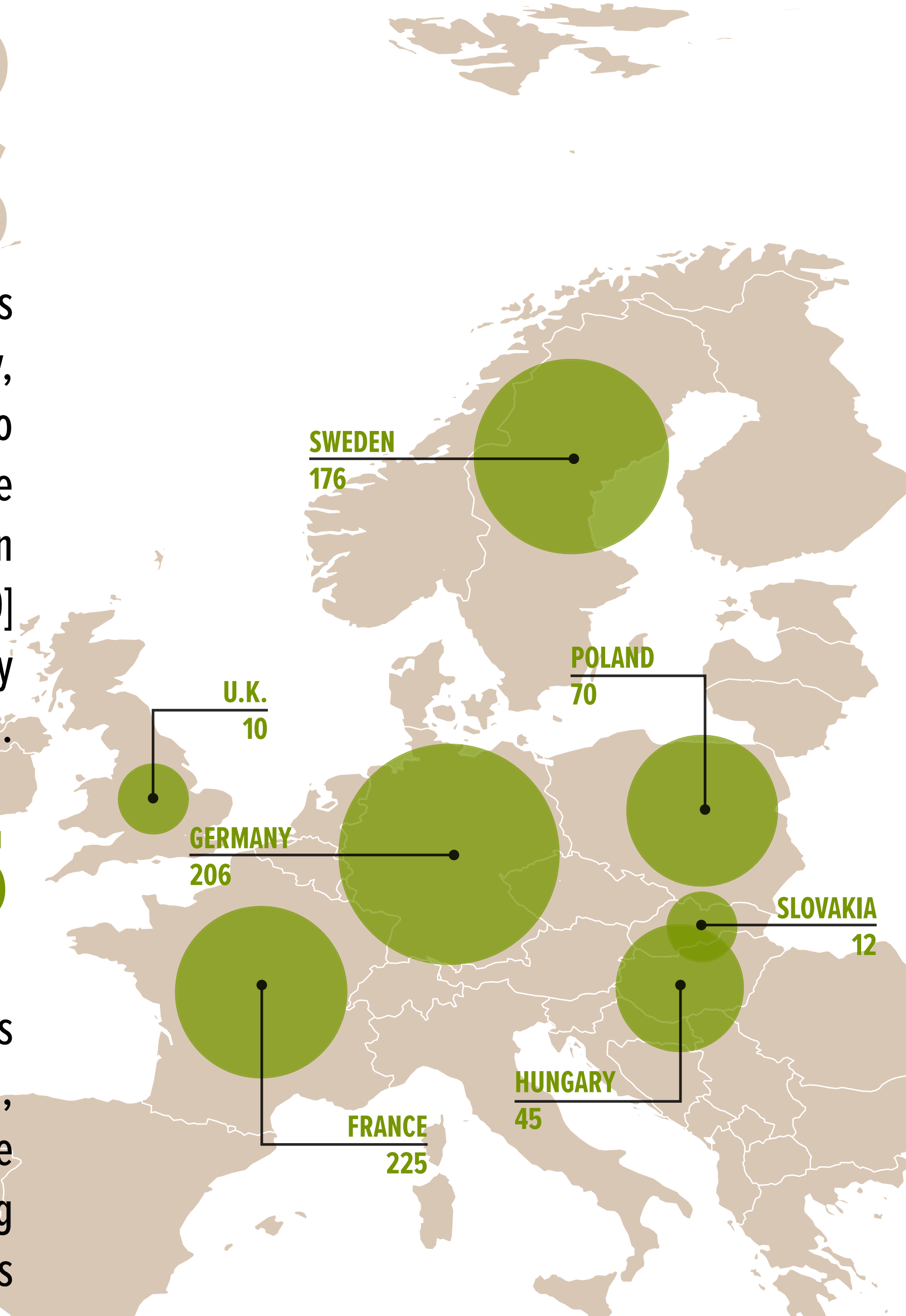
EUROPE'S EXPANSIONS



Europe's production within the EV battery industry is expected to grow up to one third of the global capacity, expanding from 7% in 2020 to 25% in 2025 and up to 31% in 2030 [60] [61]. The two largest facilitates are expected by Tesla and Northvolt in Germany and Sweden respectfully, each at 100 Gwh operating capacities [60] [62]. Europe announced that they expect to no longer rely on EV battery imports and be self sufficient by 2025 [63].

2021 → 2025

Figure 29 [ref. 60,62].



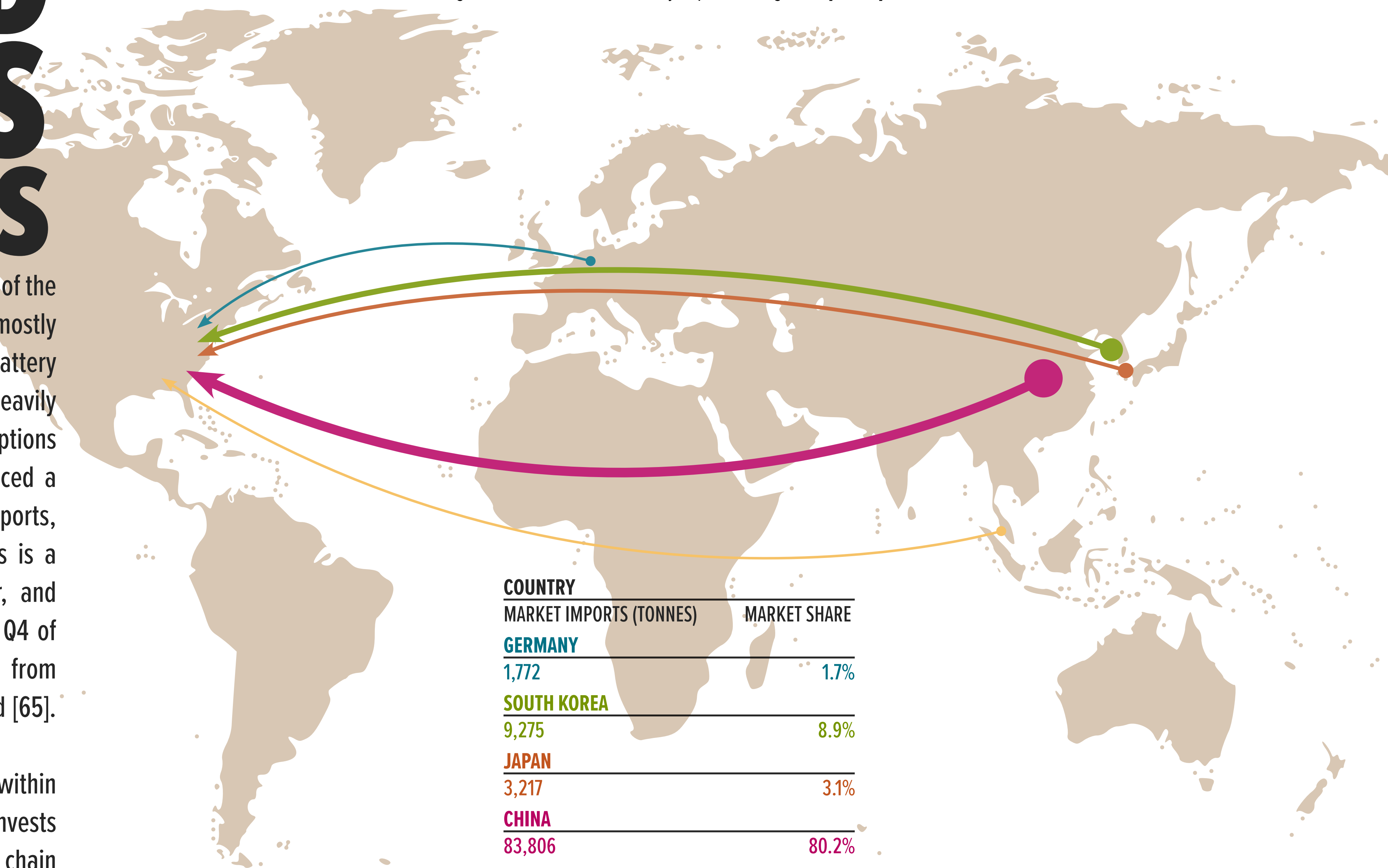
State support of $7.3 billion has propelled the investments of major companies to emerge new growth in Europe, totaling $71 billion [61]. The development of the European Battery Alliance has also contributed to strong coordinated efforts and investments to ensure success and competitiveness in Europe's battery value chain [64].

UNITED STATES IMPORTS

With the United States only producing 8% of the world's lithium-ion batteries and relying mostly on imports to satisfy their demand of EV battery packs, the nation's supply chain is heavily threatened by foreign supply disruptions [48]. The last quarter of 2021 experienced a record high of lithium-ion battery imports, reaching 103,899 metric tons [65]. This is a 137% increase from the previous year, and 24% increase from last quarter [65]. In Q4 of 2020 the United States imported 50% from China, compared to 80% this past period [65].

To ensure the long-term success of EV's within the US, it's vital that the United States invests in a growing and diversified supply chain for EV batteries, without relying on imports.

Figure 30: US Lithium-Ion Battery Imports during Q4'21 [ref. 65].



COUNTRY	MARKET IMPORTS (TONNES)	MARKET SHARE
GERMANY	1,772	1.7%
SOUTH KOREA	9,275	8.9%
JAPAN	3,217	3.1%
CHINA	83,806	80.2%
MALAYSIA	1,745	1.7%

←
→

UNITED STATES MANUFAC-TURING POLICIES

Within the past year, the United States has made progress on prioritizing the U.S's supply chain for large capacity batteries, after having limited framework in place. In February of 2021, President Joe Biden signed Executive Order 14017 to examine America's most critical supply chains, one of which being large capacity batteries [66]. After the 100-day review The Department of Energy (DOE) announced the National Blueprint for Lithium Batteries 2021, outlining crucial steps for next 9 years and guiding investments towards developing a domestic lithium battery manufacturing value chain. One of the main goals is to, "Implement policies and support that enable the expansion of U.S. lithium battery manufacturing, including electrodes, cell and pack production" [48]. On February 11, 2022, the DOE announced an investment intent of $2.91 billion to increase end to end production of batteries for EVs and energy storage [68].

ADDITIONAL PROGRAMS IN PLACE

In 2017 the United States authorized the Advanced Technology Vehicle Manufacturing Loan Program (ATVM), a $17.7 million loan authority that supports the manufacturing of eligible light-duty vehicle [69]. In May of 2021, Congress approved to expand the program to support medium and heavy-duty zero emission vehicles as well as manufacturing advanced batteries [70].

The DOE also established Li-Bridge, a public-private alliance that brings in key stakeholders that will strength the domestic lithium-ion supply chain [71].

UNITED STATES EXPANSION

With framework and investments in place, the United States is experiencing a ramp up on in-house manufacturing. BloombergNEF's global lithium battery supply chain ranking ranked the United State in 2nd for 2021 and 2026 projections, following behind China in 1st place. This showed significant improvement for the US from 6th in 2020 [67]. Capacity is expected to reach 475 GWh by 2025, compared to around 40 GWh in 2020 [72].

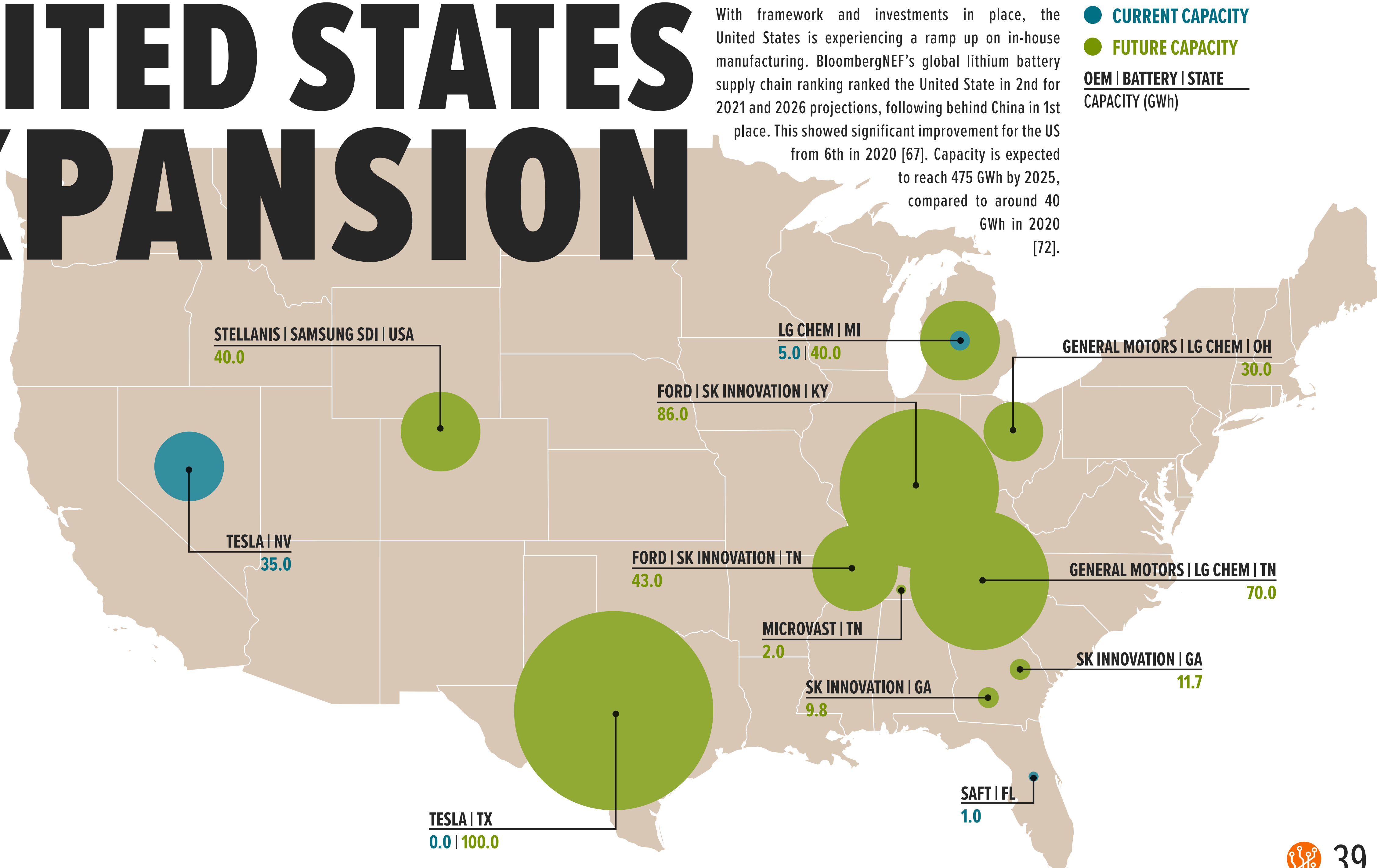


Figure 31: [ref. 72].

POLICY NEEDS

1. Implement smart state and federal ICE phase out frameworks and regulations to achieve GHG emission targets and scale electric vehicles

2. Increase R&D funding for disruptive battery technologies, including solid-state batteries and synthetic graphite anodes

3. Expand the United States Advanced Technology Vehicle Manufacturing program to allow high utilization by private companies

4. Phase out fossil fuel subsidizes to allow competitiveness for electric vehicle purchasing and renewable energy usage

5. Increase state manufacturing incentives within the United States, as well as consumer incentives for EV purchasing

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BULLETIN NO. 20220101

The transition to Sustainable Aviation Fuels (SAF) has the potential to significantly benefit both the domestic economy and environment. SAF can reduce the risks of the Electric Vehicle Transition which is expected to have significant implications for the production and demand of sustainable/renewable fuels such as Ethanol of renewable diesel.

https://www.dynamicslab.org/sustainable-aviation-fuels-technical-bul

CRITICAL MINERALS & THE EV TRANSITION

BULLETIN NO. 20220102

The production of a typical lithium-ion battery requires five minerals dubbed "critical minerals" by the USGS - lithium, cobalt, manganese, nickel, and graphite. These critical minerals each face potentially significant supply chain bottlenecks and disruptions, such as: inadequate supply, dominance by select countries in production and refining, an oligopoly of producers, and more. Additionally, the extraction of critical minerals includes environmental and socio-political impacts that must be addressed for a sustainable and just EV transition.

https://www.dynamicslab.org/critical-minerals-ev

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ABOUT THE LAB

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MISSION STATEMENT

Provide support to public and private organizations on the risks, unintended consequences, and opportunities of the global sustainability transition

PRIMARY TRANSITION AREAS OF FOCUS

Technology Transitions – Energy Transitions – Biobased Transitions Economy

COMPONENTS OF THE TRANSITION

Supply Chains – Green Finance – Critical Minerals – ESG – National Security

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