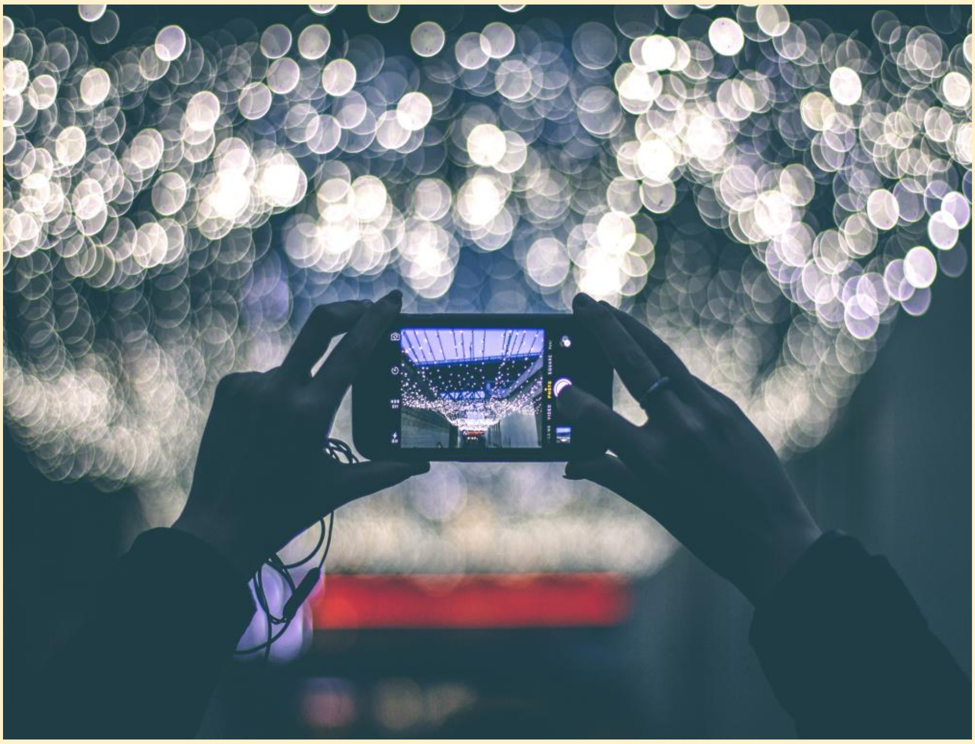
ESK outlook 2017-2025



Forecast of Demand of Battery-Dependent Appliances (BDA) Lithium Batteries (LIB) and Lithium (LCE) - upstream analysis

With black swans scenarios and geopolitics in the unicorns era

Outlook 2017-2025

More than 8 million electric vehicles will be sold in the year 2025, against 1 million sold in 2017. There are 150 GWh of lithium batteries available in the world, but 790 GWh will enter by 2025, enough to provide electricity to a city of 3 million homes for one month. Fifty per cent of the world population will carry a battery in their pocket. Almost 800 thousand tons of Lithium (LCE) will be needed in 2025, about 3.2 times the current demand, the details and reasons in the following report.

Jaime Alée G.

www.eskorpion.com-
Jun 2018

Description of the chapters and their contents

1.- CONTEXT	**Analysis of the context in which this study is conducted, applying technological factors, high-impact disruptive innovations, called "black swans", the increasingly present geopolitical factors that "twist" the inertia of the free competition and market and, lastly, the merging factors of the Internet era with the era of the energy revolution for climate change that cause an exponential economy.**
2.-METHODOLOGY	The methodology explained in the singular terms of this study, mainly based on our own judgments and only using references validated in the baseline of the results from 2016 and 2017.
3.-RESULTS AND INTEGRATED PROJECTIONS	The final results of the year-by-year projections, until 2015 of the annual ton demand of LCE (lithium carbonate equivalent), the demand until 2025, of batteries, expressed in GWh and the demand of each one of the categories that make said demand. All of this separated by subcategory.
4.- ANALYSIS, SCENARIO AND PROJECTIONS PER CATEGORY	Each category and subcategory is analyzed in detail, looking into its technological evolution and market experience, as well as its projection in both senses. The foundation and the projections of the annual demand until 2015 in aggregated and disaggregated terms, as well as the upstream effects, are shown in detail.
4.1 ELECTROMOBILITY	Electromobility is analyzed based on three subcategories, light and semi-light electric vehicles distinguishing the hybrids (PHEV) and the fully electric (BEV), as well as the heavy vehicles, primarily looking into the E-buses.

	4.2 STATIONARYBATTERIES	**The use of energy storage in the electrical grid is analyzed in three categories. On the generation, distribution and demand sides. Their uses and trends, as well as their problems are looked into.**
	4.3 PERSONAL ELECTRONIC DEVICES	The evolution of the personal electronic devices, especially smartphones, laptops and tablets are researched from its past evolution to its possible projection.
	4.4 OTHER DEVICES	Hundreds of other devices that use batteries are appearing. In this section we analyzed in detail the E-bikes, portable electric tools and other devices in emerging stages.
BLACK SWANS AND GEOPOLITICAL CIRCUMSTANCES		Every category presents, in addition to the analysis and projection curves, a list of potential contingencies that might radically change the projections, based on the potential high-impact disruptive innovations and geopolitical factors that might deform the market through the influence of the governments and their struggle for a global supremacy.

Outlook 2017-2025: from mainstream to upstream

CONTENT

¿The era of unicorns?

The Unicorns, from an Innovation point of view, are those companies that are able to invoice more than US$1 billion in some of their capital raise stages. They are disruptive companies that are developing high-impact technologies and with influence on humanity.

Unicorns started appearing in the 1990s, some of them have in fact

changed humanity and we don't have to identify them, because we can see them daily in the press as well as their founders discussing subjects that are more associated with political leaders than with entrepreneurs.

Many unicorns may be born in the next decade and it is hard to predict where or what their objectives will be, but they must be considered as part of the outlook for the next few years.

Glossary

Term	Meaning
LCE	Lithium carbonate equivalent, standard unit to measure the different types of lithium derivatives.
LIB	Lithium Batteries
EV	Electric vehicle in general
ICE	Internal combustion vehicle
BEV	Full electric vehicle
HEV	Hybrid vehicle, with both electric traction and internal combustion.
PHEV-X	Pluggable hybrid vehicle with X autonomy of km (miles) in electric mode
E-BUS	Electric bus, in general. There are several categories of electric buses
GWh	Giga Watt per hour, energy measure used in the electricity world. One million kilowatts per hour.
Energy Density	Energy that can be stored for each mass unit (kg) of battery (or cell)
Cyclability	Useful life measure or number of complete loading and unloading cicles guaranteed by the manufacturer in battery's use window range (usually between 10 and 90%).
Off/on-Grid	Electricity auto-generation solution by a final user completely disconnected from the electricity grid (off) or complementarily connected to the grid optimizing both sources according to the occasion (on).
GHG	Greenhouse gases
BDA	In general "Battery-Dependent Appliances" as EV, Portable electronic devices, notebooks, E-Bike, drones, etc

Main references and their use in the study

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- (International Energy Agency (IEA.org), 2017)WEO used for the underlying analysis and electricity projection criteria in the world.
- (argonne national Lab USA, 2017), BACPAC was used for the determination of the mass parameter (Kg) of LCE to KWh in a lithium battery.
- (ESK consulting, 2017), Development methodology used to connect exponential evolution phenomena in the industries and the market being studies.

Projection Adjustments and their margin of error

The projections shown in this document are responsibility of the author and they are based on the results of the analysis shown in the same document. These projections are trends based on empirical observations, as well as on economic and market criteria, justified in every case. This study was designed as an informed reflection tool. If the criteria are wrong or debatable, the projections obviously will differ. The public scenario is unique, and the optimistic or pessimistic scenarios could come from the changes of diagnoses in terms of unexpected events (see BLACK SWANS and GEOPOLITICAL CONTINGENCIES in every category).

One thing is saying what and how …

Another thing is saying how much

SUMMARY

The present study is based on the holistic research, both technological and market, and on key circumstantial facts of the markets and industries that use lithium batteries.

The expert judgment of 10 years of study in subjects related to said research is applied case by case, using consensus analysis and examples based on internalized experiences on this emerging industry in its first decade.

The methodology is based on the hypothesis that two global processes born separately 20 years ago and originated by very different events, are rapidly converging and, furthermore, merging into a new replenished and growing phenomenon.

These phenomena we have denominated by the Greek letter “**Iota**”, symbolizing “**I**nternet” and the Greek letter “**Epsilon”** for the phenomenon in the **E**nergy industry of the last 20 years, are generating, in a continuous feedback, a series of exponential evolution consequences where the elements of the “mobility or portability” and the electric autonomy of the electronic devices, along with the use of emerging primary sources of energy based mainly on the sun and the wind, essentially variable in their availability, have a common denominator which is the need for

THE AUTOR: With almost 40 years of experience, Electrical Engineer. The first 10 years in the field of engineering he worked as director of large telecommunication projects in Chile. In the second decade he actively participated in Innovation subjects, including the foundation and operation in 1994 of the first “.com” in Chile, Telemultimedia, one of the firsts in the world. In the third decade he worked in the international field as CEO of the Chilean subsidiary of the Japanese NEC Corp., mainly in the industry of information technology. The last 10 years he joined the University of Chile as an expert professor of the energy center and the department of Industries, where he has actively promoted the link between science and the company. He founded in 2010, taking charge of the successful no profit “*think-tank*” “Lithium Innovation Center”, co-financed by the companies SQM, Rockwood and Marubeni, along with the University. Since 2010, he has been studying electro-mobility and lithium batteries, acting as an expert consultant and speaker in different parts of the world, and he has been interviewed in different media interviews. He has been an activist of these technologies and he is recognized for his opinions on a national and international level. Likewise, he advise and cled the foundation and direction of the science-based innovation center Openbeauchef (Science-based Innovation). During this last decade he founded two companies, “ESK Consulting” and “Elibatt Lithium Batteries”. He has been CEO and Board Member several times, consultant and advisor in energy and technology subjects on a local and international level, for a few years he has been the analyst of investment scenarios using his own methodology “Iota+Epsilon” based on expert knowledge methods. He periodically issues his opinions in his own eskorpion.com column and in media mainstream and television. He is currently requested about it by international or local companies and goverments, especially investment funds or related activities. He is part of the Gerson Lehrman Group board, as senior advisor. He is also the senior advisor of the Energy Center of the University of Chile. He is the director of the software company TINET.cl, a company expert in digital transformation. Founding member and “principal” of ESK consulting electricity storage sources, being the lithium battery, which we have called "vector", the winning storage element so far, which we foresee will continue for at least one decade, given the already-committed investments in research and engineering, installation, production and massive and industrial operation. This inertia that quantitatively reflects a relevant industrial decision and huge amounts of committed money, implicitly avoids its sudden replacement.

...the present document uses very few referenced sources, which are chosen because of their independence and global consensus prestige. They are used in the baseline, or data of the recent past (2016 and 2017). The judgments and projections correspond to the author's well-informed opinions and analysis based on his own experience gathered from the basis of the observed and analyzed behavior of the last 20 years with the Iota-Epsilon methodology.

Fig. 1 Downstream from raw material to the demand, going through the batteries

Figure 1 shows, in a dramatic and complex image, how many industries of different areas are developed, namely; mining, chemical, industrial, electronic, software, etc., until reaching the different demand of **BDA**[1]. The present document analyzes and researches the final markets and their vertiginous changes, in order to return upstream to the previously-committed industries and considering the economic phenomenon of the knowledge area where we are now, combined with the innovation potential of each industrial segment.

The result of this analysis directly affects the demand of key raw materials, such as cobalt, nickel, manganese ...and particularly this industry's key material, lithium, which is the only

[1] BDA: Battery-dependent appliances, como por ej.- Electric Vehicles, Smartphones, PV solar installations, etc

element that includes any combination of the chemistry of the cathode's active material of the cells that make the batteries.

While there is an agreement that Lithium is abundant in the entire world and that there isn't a risk of having problems with the reserves and resources or problems with the supply of the processed material in the long term, we mustn't underestimate the fact that the speed of change that is happening is very relevant and that starting the real operation of high-quality grade Lithium batteries require some development years and numerous mining-based investments. Therefore, it is essential being able to predict the demand of Lithium (and other materials), which will affect its price if it is not synchronized with the demand. Since the price is not relevant in the driven final product, the battery, there isn't an excessive pressure on behalf of the requestors of said supplies who are more concerned about the safety and quality of the supply than the circumstantial price.

…The high prices of the LCE in the last few years have to do with the real-time demand, and therefore the growth's gradient. This could not be associated with an irreversible phenomenon, but if the demand continues to be greater than the supply, this price could remain for a long time. The complexity of this material's market, in terms of how the contracts and prices are negotiated, case by case, and the few incumbents in the origin of the material, not in the reserves but in the production operation, complicate the entry of new players. This aggravated by the excessively-complex way, to say the least, in which the countries that own those resourses administrate the material's production, as if they were handling uranium instead of a simple and abundant material[2].

Our methodology focuses on a delicate analysis of the technological and strategic context of the mainstream, symbolically speaking, full of tributaries and isolated conceptualizations with their own merits, because they are from different and diverse worlds and in different levels of development and state of the art.

Generally, the analysis avoids leaning on references from other studies[3], since its intention is to generate its own hypothesis built from its own expert experience and several personally-constructed analysis. The basic foundation is to start with a reasonably-reliable recent baseline, therefore the research has focused on finding consensus data regarding the 2017 already-closed numbers or, eventually, from 2016 if the 2017 data is not available.

Then, the analysis takes the liberty to project these base data based on criteria and claims, which are explained in detail in the same.

[2] This is particularly relevant in the so-called "lithium triangle" in South America where geopolitical factors have taken this material as an example and a struggle flag for a long history of dependence on raw materials. This implies naturally to mix opinions with emotions and many aspects beyond the technical aspects, creating post-truths about lithium by mixing desires with realities. That is only one example "of geopolitical factor in the chain of Iota-Epsilon related industries. Of course there are hundred of this type of factors in Asia, USA, Europa, etc.

[3] This statement is partially true. Strictly speaking, this is not a "blind" study. The analyzed studies represent a context and boundary conditions to be considered, but always as a results comparison reference, not using the referred ones. On the other hand, this study does gather the base data reports which are an initial level of the same, the elapsed years and with recent statistical references. Likewise, the determination of key parameters like lithium's density/KWh in a battery or scientific research and market and geopolitics behavior data are gathered from widely-recognized public sources, properly referenced.

A couple of phenomena, which are more and more present today, are specified in each case as a reflection tool, like the unexpected high-impact innovations (for better or worse) called **black swans**[4], as well as the geopolitical events that are causing today major market deformations due to global strategies coming from the economic and political volatility, and from radical changes of government leadership, along with the lack of precision regarding the political course of some developed nations or regions, in general.

Obviously, the **Iota+Epsilon** effect is additionally considered as the key catalyst that enables the implicit technological changes in this development, as well as the real industrial powers that affect today's political decisions due to the accumulated knowledge in key technologies, like the artificial intelligence combined with "big data", thus the ability to create new markets based on the insight of the potential clients. The phenomenon of creating new markets, foreseeing a social need through delicate studies based on social networks and sophisticated algorithms that process a vast number of data and can determine trends and vice versa influence the same, strengthening what people wish to follow but without expressing it, through artificial intelligence machines that learn individual behavior reinforcing the insights of person's decision.

...A FEW RESULTS

The demand projection of LCE (*Lithium Carbonate Equivalent*) between 2016 and 2025, calculated on the basis of the vectors and drivers foundations, shows a growth from 215,500 tons in the year 2017[5], to 793,000 tons in 2025.

[4] Nassim Nicholas Taleb Black Swan is an event with the following three characteristics. Firstly, it's an atypical case, because it is outside the field of regular expectations, since there is nothing in the past that can aim convincingly to its possibility. Secondly, it leads to an extreme impact. Thirdly, despite its rarity, human nature makes us come up with explanations for its presence after the facts, so it is explicable and predictable

[5] We know that in 2017 the demand for LCE was 230 thousand tons. We prefer to use our reference based on foundations, because that is what we project

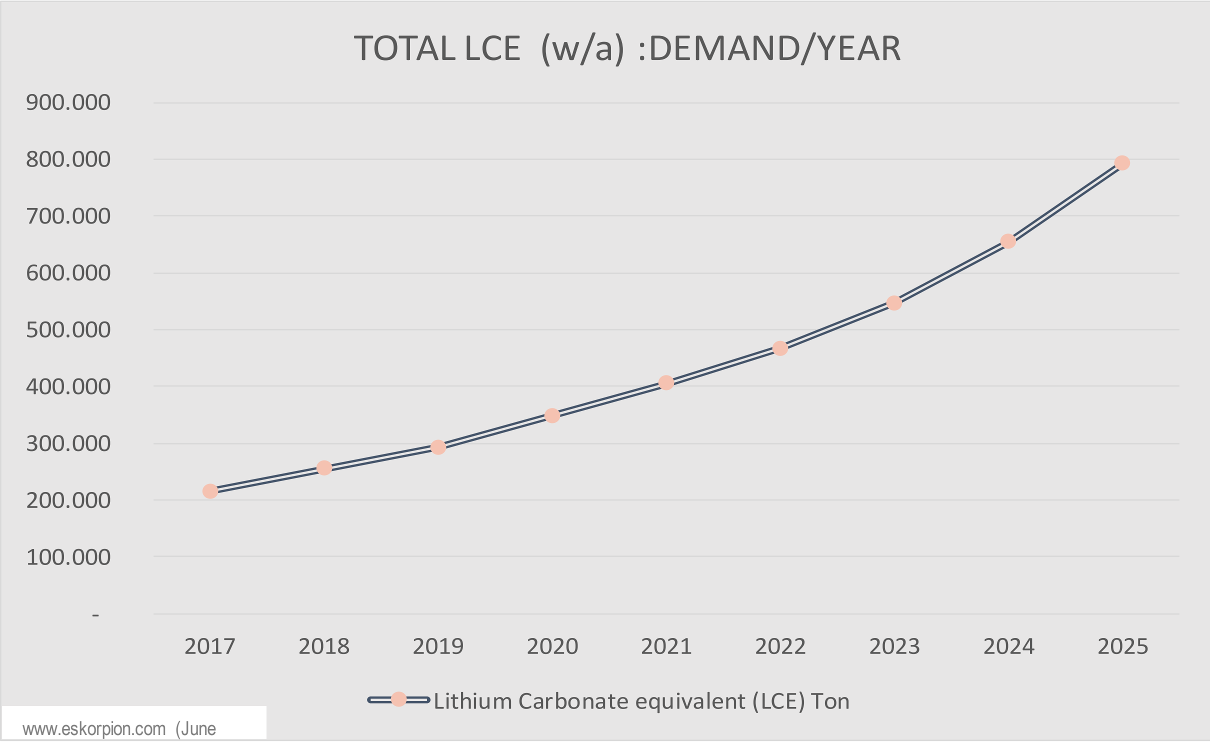


Fig. 2 2016-2025 LCE projection demand with adjustments of market's purchase model[6]

The total demand will be connected to the battery demand (vectors) in different segments, in this case

- **Electromobility (EV),**
- **Stationary batteries for energy storage**
- **Batteries for portable electronic devices**
- **Batteries for other devices**

In Figure 3 we can see that the main "driver" impacting the lithium battery demand is the electromobility market, focused on light and utility vehicles, on one hand, and buses on the other. However, a sustained growth is observed regarding the use of electric storage systems in the energy grid, in the use of temporary compensation of variable energies, like balance of the demand in the distribution and serves (backup) in the generation cases. The case of the projection for the final home or industrial demand seems to be relevant, which is analyzed in detail in the respective chapter.

[6] **There is a demand adjustment due to the inventory purchases and clients' reservations.**

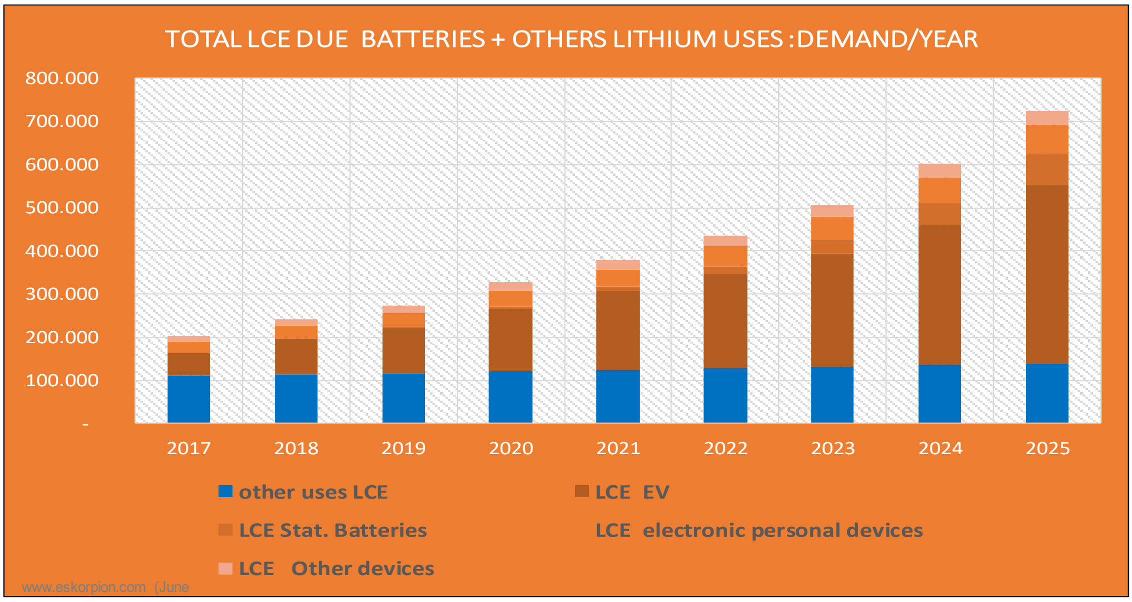


Fig. 3 Annual demand of energy in lithium batteries and others lithium uses.

Likewise, there is a not-so-relevant growth in portable devices, possibly due to the fact that it is a mature market with a great implementation in more than 50% of the world's population.

Indeed, the sustained participation in the other devices will increase as new applications are created and demanded, especially on a people and homes level.

the current participation of the lithium demand for other known and traditional uses like lubricants, glass, ceramics, medications, etc., (about 100 annual thousand tons of LCE) is still relevant in the year 2018, but its participation will be less relevant by the year 2025, although new uses will be foreseen as well as a discreet growth of the demand in this category.

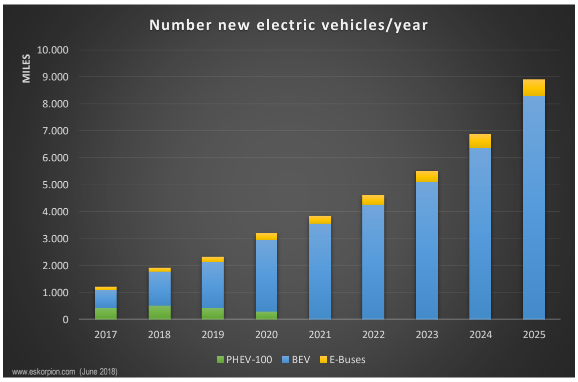
Regarding Electromobility ;the mainstream of the battery use in the future, will continue leading the absolute demand of stored energy.

In this case we can see a very accelerated growth of the demand, even larger than the one seen in several studies of the recent past year, reaching more than 3 million registered units in 2017 (against 2 million "On the road" in 2016). The registered sale of 2017 reaches 1,100,000 units[7]. In 2017, China became the first world player regarding supply and demand of electromobility and a powerful political influencer in this field

...More than 50% of the world's population carry a lithium battery in their pocket, even in poor countries...

[7] IEA, EV Outlook 2018. The relevance and seriousness of EIA studies are considered a must in the studies of electrical engineering and global energy policies. This is why they are used as the basis chosen for the electromobility reference of the year 2017

Fig.5.-Registry number of new electric vehicles (2019-2025 e)



The number of vehicles considered in this study[8] would increase considerably in terms of new registers per year, reaching more than 8.3 million registers in the year 2025, considering the buses. Likewise, it is projected, in the short term, the end of the transition of light hybrid vehicles with range extension (a referential extended range of 100 km is considered for this study, PHEV-100) due to how competitive the pure electric vehicle (BEV) will become, which is estimated to occur very soon based on the recent trends in China and the promises of new electric models from the main brands.

When considering the demand in terms of energy in batteries, we can see that the relative value of the buses is taking great importance, since the use trend of completely-electric large-range buses (> 250 km) implies an energy demand per bus equal to 5 BEV light vehicles. With this, a demand of 560 GWh would be reahced in 2025, against approximately 110 GWh in 2018. The accumulated energy availability in lithium batteries (LIB) during that period would reach almost 3.5 TWh.

The buses

Public transportation is an issue in itself. There is a demand for thousands of bus fleets in every city and those are decisions promoted by transportation authorities, putting pressure on private and public operators in either direction. On the other hand, the electricity distribution companies are acting and strongly influencing this sector, even acting as provider and lessor of electric bus fleets, thus promoting the technology of completely-electric buses, for obvious reasons. These new clients of the distributors consume in one month the electricity of 30 homes. A fleet of 5,000 buses, normal in any big city in the world, is equal to 150,000 new homes in terms of demand.

...The demand of lithium carbonate and lithium hydroxide would grow more than anticipated by the recently-published studies, due to the agents that are accelerating electromobility and the demand of stationary solutions for the auto-generation of NCRE in the demand...

[8]Vehicles were considered with an impact on the size of the battery. For this study, an utility truck is the equivalent of a passengers vehicle and the high-tonnage trucks are not considered because the penetration of the batteries in this category will be slow and with marginal effects.

1.- CONTEXT

		Lithium battery	Lead acid battery	1 vs 2
Net Price		US$ 400-600	US$ 200-300	Doble price
Weight		10 Kgs	32 Kgs	1/3 weight
Operational life		8-10 years	3-4 years	2.5 times
Maintenance		no	annual	OPEX=0
Modularity unit		3.2 V	12 V	Reparation facility
Waste contamination		low	high	-
Vector Appliances	• Personal and portable	Yes	No	-
	• On mobile appliance energy sourse	Yes	No	-
	• Stationary apllication	yes	Yes	-

Prologue: The essential reason of accelerated raise in use of Lithium Batteries (LIB) in many applications is determined by its electric energy potential in terms of energy/weight and energy/volume, also its operating facilities and long operative life. In the specially prepared figure, two equivalent batteries are shown in a common known format, such as the traditional 12-volt battery for "ignition on" in a conventional vehicle. When analyzing differences between LIB with equal energy characteristics than traditional lead-acid battery (LAB) , LIB surpasse LAB in almost all the characteristics- in many of them by far. The only element where LIB still weak is the price.

However, in next 8 years the current price of around US $120/kWh of a lead-acid battery could be much closer to the price of a lithium battery, according to the price projections that would reach about US $180-US $150/kWh at the 2025.

However, despite the fact that price is a very important factor, in our opinion it is overvalued as a decision-making element. In our opinion, the price-elasticity in some appliances is less as designated in much reports. In many BDA the price appreciation is only one of factors to consider, because are very appreciated and valued the design and some performance benefits. We don't think that a price drop of 30% of LIB will Influence in radical way the decision of purchase of an electric vehicle over the performance, design or some superior characteristics in the markets that they participate. The examples of TESLA, in case of BEV or APPLE with its smartphones are evidents.

The TCO is mentioned[9] as a key element in the tendency of penetration of the electric vehicles, but only some potential customers consider the vehicles an

[9] TCO: Total Cost Ownership

investment to need to payback. Mainly the fleets operators really calculate the TCO. Most of users of vehicles consider it as costs and the insight it´s related with how much of design features, status, power, etc they can get for the price.

Also is mentioned in the figure – and it´s very relevant- that LIB is the only industrial solution of electric energy storage that enables the real production of portable devices and mobile applications, where the battery must be part of the weight to be carried. This is why the remarkable success of this technology in this category devices and why we mention the LIB as "vector" . LIB has allowed the design and development of many appliances that we use today such as smartphones, drones or electric cars.

The analysis mechanism of the projections and predictions presented in this document is based on a thorough analysis of the respective references, which have very different projections depending on the assumption used.

The use mainstream of lithium batteries (LIB) clearly shows the "**BDA**[10]" : electromobility as a very relevant parameter. However, being the battery a vector that enables not-yet-mature technologies, it is likely that other applications appear in the medium term.

Particularly, batteries were initially used in the market of personal electronic devices, like laptops, smartphones, tablets, etc. That was the use they initially had and the main reason for the development of multimedia devices that had to be "portable and personal" with growing energy requirements.

Until the arrival of the iPhone-1, in 2007, cell phones, used as mobile telephones, had insignificant energy demands and, therefore, a nickel-cadmium battery gave them many hours of autonomy, even weeks with a battery that surrounded the 600-800 mAh. However, the iPhone had a screen that used the entire front of the device, audio with speakers, video and an incorporated photographic camera. This implied sophisticated electronic requirements with a battery of 1,500 mAh. Barely 10 years later, smartphones come with 3,000 to 4,000 mAh batteries and their autonomy leaves much to be desired, regarding the first iPhones and, even worse,regarding the cell phones with no screen of the 2010s. The battery projections back then were mainly calculated thinking on the amount of smartphone users, never imagining the sophisticated equipments that we have today, which, in practice, are devices of a very different category than the originals, becoming multipurpose equipments of all types of media, which telephone use dropped from 90% in 2007 to less than 20% today, with autonomous applications like photography, videos, reading, entertainment and connectivity tools with contents to create or rescue, much more than the simple verbal or even textual communication with other people.

Nevertheless, the use is essential and more than 5 billion people have them. In terms of battery use, it implies an energy in LIB of about 50 GWh "in the pockets", which was unimaginable 10 years ago. This has created an unexpected situation regarding the lithium

[10] **BDA: Battery-dependent appliances, e.. - Electric Vehicles, Smartphones, PV solar installations, etc**

demand, much higher in tons than expected (**Tons LCE**: Tons of lithium carbonate equivalent), and of course in the price of Tons of LCE.

The numbers and projections found in studies from this period, a decade ago, looking at them with the perspective of what really happened, were usually optimistic regarding the amount of units, but they projected modest numbers regarding energy requirements per device. For example, in 2010 electric cars with a base of 25 KWh were projected for 2017, which is almost double the average of vehicles currently on sale.

…BEWARE OF THE BLACK SWANS.

Likewise, it is necessary to consider how unpredictable, but potentially possible, the so-called **"black swans[11]"** are, as well as the unexpected innovation events that cause a huge exponential change and unexpected impacts. There are a lot of examples, but we can highlight the appearance of unexpected devices like civilian-used drones and the autonomous driving technology massively incorporated in vehicles of our era. These black swans can also be a threat that can lead to the market's ruin, like the analog photographic cameras. These examples in the final market can accelerate or paralyze the demand in "quantum" terms.

…THE GEOPOLITICAL EFFECTS OF THE GIANTS.

Likewise, it is necessary to consider the influence of **geopolitical factors** and acts of voluntarism of a country that decides to enforce the game rules in order to obtain benefits during its leadership, considering China as a clear example, which is a reluctant player in terms of complying with and committing to its own measures about climate change. In only 10 years, and in an unexpected back flip, the country became a relevant player, if not the main one, regarding regulatory measures and political will that have turned it into the main global player in terms of supply and demand. It is a champion of climate change, industrial technology and usage of lithium-battery technology. Its regulatory policies also stir the world market of overseas players that need to be present in this giant country.

…THE IOTA VS EPSILON[12] EFFECT

The current global scenario is due to the convergence and merging of two worlds that have generated a geopolitical and social insight from the traditional perspective of the scenario analysis. **Iota** refers to the era that started in 1994 with the development of the **Internet**, which has created an inorganic global means of communication that monopolizes humanity's information mechanism and the way people communicate and inform "peer to peer". The companies that supply the platforms and their leaders are the ones ruling

[11] Nassim Nicholas Taleb Black Swan is an event with the following three characteristics. Firstly, it's an atypical case, because it is outside the field of regular expectations, since there is nothing in the past that can aim convincingly to its possibility. Secondly, it leads to an extreme impact. Thirdly, despite its rarity, human nature makes us come up with explanations for its presence after the facts, so it is explicable and predictable

[12] Concept developed by the author of this document. More details in https://www.eskorpion.com/single-post/2017/11/30/%CE%B9-%CE%B5-EL-EFECTO-%E2%80%9CIOTA%E2%80%9D-SE-MEZCLA-CON-EL-EFECTO-%E2%80%9C%C3%89PSILON%E2%80%9D-La-explicaci%C3%B3n-de-la-transformaci%C3%B3n-digital--la-tormenta-perfecta

society's economic world and power influences. The political power is incapable of managing or controlling this real power. **Epsilon** refers to the time that formally started in Kyoto in 1997[13]and which started the revolution of the new green and renewable **Energy** threatened by the acknowledgement of climate change. The acknowledgement of the substitution of fossil sources (petroleum, gas and coal) due to their effect of the emission of greenhouse gases has caused an exemplary change that has generated a major economic and political effect, changing paradigms that founded the industrial society. The electromobility that affects the largest industry in the world, the automobile industry, that moves twice Brazil's GDP, is being transformed by this phenomenon. Today, both effects have merged creating a volatile and unpredictable scenario in industrial, political and lines-of-power terms. One of the effects of this phenomenon is the control of the demand by small knowledge groups that have access to the use of technology and practices associated to Iota and epsilon, to influence the creation of non-explicit needs ("insight") and therefore enable said demand in their businesses and interests. Most of the companies that have developed global transformation like "Black Swans" haven't started with a traditional market research, but the market has been created starting from the product/service (Apple, Facebook, Google are examples of this phenomenon). With the evolution of the ability of the customized digital marketing supported by "big data" tools and "learning machines" (IA) it is relatively easy to create a market appealing to the insight of the potential clients.

... The analysis of the why, when and how much? Requires an expert judgment in issues of technological evolution, markets' behavior evolution and geopolitical aspects of our era...

[13]The Kyoto Protocol2 is a protocol from the United Nations Framework Convention on Climate Change (UNFCCC) and an international agreement which purpose is to reduce the emission of six greenhouse gases causing global warming. The protocol was adopted on September 11, 1997 in Kyoto, Japan

These phenomena applied to our methodology allow us to analyze the future of the drivers demand (mainstream) based on potential explosive demands appealing to potential insights of the served markets[14].

For this reason, we have based this analysis on a prospective study of the different applications that use batteries, on their own merits.

That is why we have created four categories of **BDA**[15]:

i. **Electromobility Category (EV)**
   a. Plug-InHybrid Vehicles with 100 km of electric autonomy (PHEV-100).
   b. Fully electric vehicles with 380 km of autonomy (BEV).
ii. **Stationary Batteries Category for industrial or home use**
   a. Support storage solutions in generation to supply/demand cycle variable energies and technical reserves.
   b. Storage solutions for the use of distribution networks (Grid) for costs and backup optimization.
   c. Storage solutions on the demand's side for industries, communities and homes, for backup or support of auto-generation of Off/On Grid Solar or Wind power.
iii. **Mobile electronic devices category** for personal use, like laptops, tablets, smartphones
iv. **Other devices category,** like ebikes (or other small-scale device), drones, home devices (Internet of the IoT things), portable tools, etc.

[14] For example, it is clear that electromobility came from Epsilon as a substitution mechanism for the use of oil in transportation, which is an important emitter of GHG and depended 100% on fossil sources. This implied very generous subsidy policies for the manufacturers and early users. However, the market took a quantum leap, with a black swan coming from Sillicon Valley, TESLA motors, who designed a very radical EV concept and a design and luxury object that impacted the automobile market. Until that moment, the EV were designed as traditional vehicles, but with a very low performance and ugly design for an extremely small niche.

[15] BDA: Battery-dependent appliances, e.. - Electric Vehicles, Smartphones, PV solar installations, etc

2.- METHODOLOGY

2.A Basic Unit, ENERGY

Evidently, the key element to objectively measure a battery is the mean energy it is capable of store (KWh), according to the application and its evolution.

In order to determine the amount of lithium, in Lithium Carbonate equivalent, in a battery a factor of 740 Kg/GWh is used, determined by the design model and modeling of the Argonne battery called BatPac,V 3.1 in its 2017 version for a pack of 57 KWh with 240 cells in a chemistry active material NMC_{333}. . This value is referential and very difficult to estimate so it should be considered a configurable value, according to the methodology that is applied, in a range between 0.55 and 0.78.

In fact, it could be determined that different chemistries use more or less lithium carbonate and it will depend on which active material chemistry wins in the cells to specify the projections. In any case, it is estimated that the variations, while not significant, in later studies a more detailed research should be incorporated regarding the use ratio of one or another chemistry in the different devices. Of course that precision complicates considerably. the estimation.

It is also relevant in this calculation the level of production in KWh of the factory, because in the case of the reference model of Argonne is estimated a plant at full capacity with production volumes of 100,000 packs per year. There are many smaller plants in the world that manufacture in a more inefficient way than model and the material use factor is lower due to this reality. The Yield of production affect the use of the active material (the calculation of Argonne is based on the use of daily mass of active materials by a daily estimated production).

Likewise, it’s not really true that the Lithium ratio is the same in any cell, because it will depend on the its design characteristic. There are cells that are more focused on the energy density and others more focused on the discharge power, thermal stress or cyclability (SOH), depending on the type of use of the final device. That is also true, however, in this case reaching this end of accuracy doesn’t benefit the big numbers or trends, but it is necessary to take that into account that that is an implicit factor in the calculation error.

Finally, using the mentioned parameter of LCE kg/GWh , is calculated the **theoretical demand of lithium**, but the **real demand** in orders of purchase (P/O) of lithium , must be adjusted on our criterion, with two additional factors, such as purchases of Inventory anticipated by cell/battery manufacturers for production orders for the following year and over-volume in stock to cover yield factory factor. In our estimations, we assume that 75% of the actual demand is for the theoretical demand of the year and 25% is for the theoretical demand of the following year plus a 5% extra purchase of the theoretical demand of the year to cover losses of efficiency in the production[16].

In any case, under a growth stage, the amount of LCE calculated as real demand for a year is always greater than the theoretically demanded calculated for same year.

[16] **Dreal_año (i) = 0.75 * Dteo_año (i) + 0.25 * Dteo_año (i + 1) + 0.05 * Dteo_año (i)**

That is why there is an implicit demand error associated at the speed of change and inventory Anxiety , which could lead to an eventual over-purchase, no necessary required, on some large customers.

We leave to the reader's judgement, the percentage of margin of error that could mean these estimations, since finally in a model of multiple variables, the application and use depends on the criteria which the eventual contingencies are pragmatically applied.

Same condition should be used to estimates demand for other very important raw materials demands as: cobalt, nickel, manganese, etc. where different supply scenarios and purchase mechanisms should be added. Many of that materials are critical and offer is much concentrated than lithium.

This situation could affect the estimation in a more dramatic way than lithium forecast, because since more or less lithium maintains its proportion in active material due it is always present, however, in cathode chemicals such as LPF, NMC, NCA and others (whose tendencies and use are different according to the category of the BDA analyzed) the proportion of the other materials varies radically.

2.B The “P”x”Q”

The impact on the energy use is obviously determined by the unit quantity of energy used by the device and by the amount of devices. In the case of smartphones, for example, while the unit energy use is small (≈0,01 KWh), there are almost 5 billion devices in the market, about 1.7 billion are demanded per year (2017), which implies a very relevant demand and probably the primary nowadays. The electric bus uses about 250 KWh per unit, which is the equivalent to 25,000 smartphones. There are thousands of electric buses on the road and their total demand is not meaningful. This combination of unit demand for growth forecast is the key of the methodological calculation, but it also reflects an additional complexity since it is involved in aspects of the evolution of applications (As mentioned before, a smartphone has doubled its energy requirements in 10 years).

2.C The Demand Projection

The methodology is based on three concepts

The baseline or starting point is to verify the real sale numbers or records of the most recent years closed (2016 or 2017)[17].

Subsequently, the projections for each one of these categories by 2025 are analyzed, on the basis of different studies of recognized analysts, including research from highly-reliable independent consensus organizations, like the International Energy Agency (IEA, see

[17]This number is hard to determine because, while there are reports per country, the global consolidated reports are different depending on the sources. That is why a widely-prestigious consolidated reference is used and, if possible, independent from a country in particular.

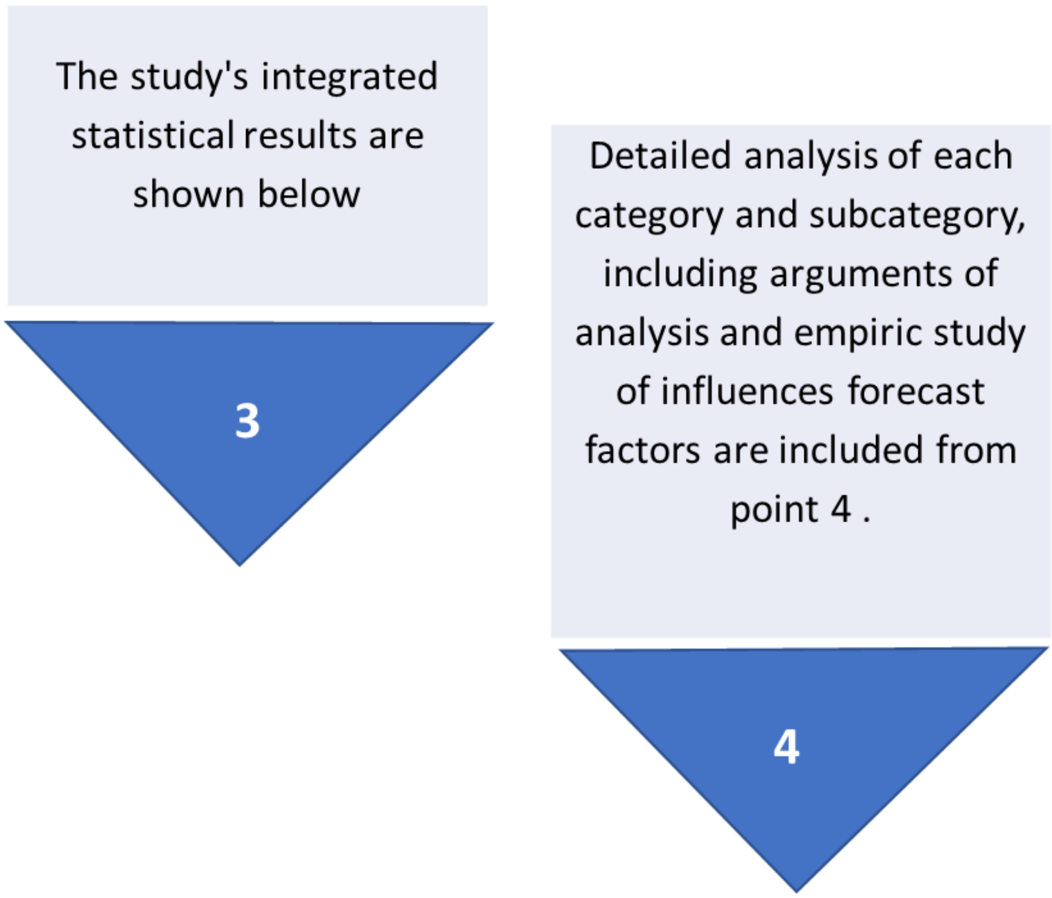
References). The most optimistic and the most pessimistic projections will be set that year, and depending on the "average" of the studies, the most likely will be estimated.

Later, and based on the experience of the experts, based on its own merit, the growth potentials are analyzed, as well as the gradient critical factors of each of the categories.

Each category is assigned a KWh consumption number according to the current state of the art and it is checked in each year's research.

	Mean KW /unit
PHEV-100	20
BEV	50
ESS-Gene	100,000
ESS-Dist	100
ESS-Micr	15

The categories not included in the table have a history and a degree of maturity, so the baseline is explained in due time.

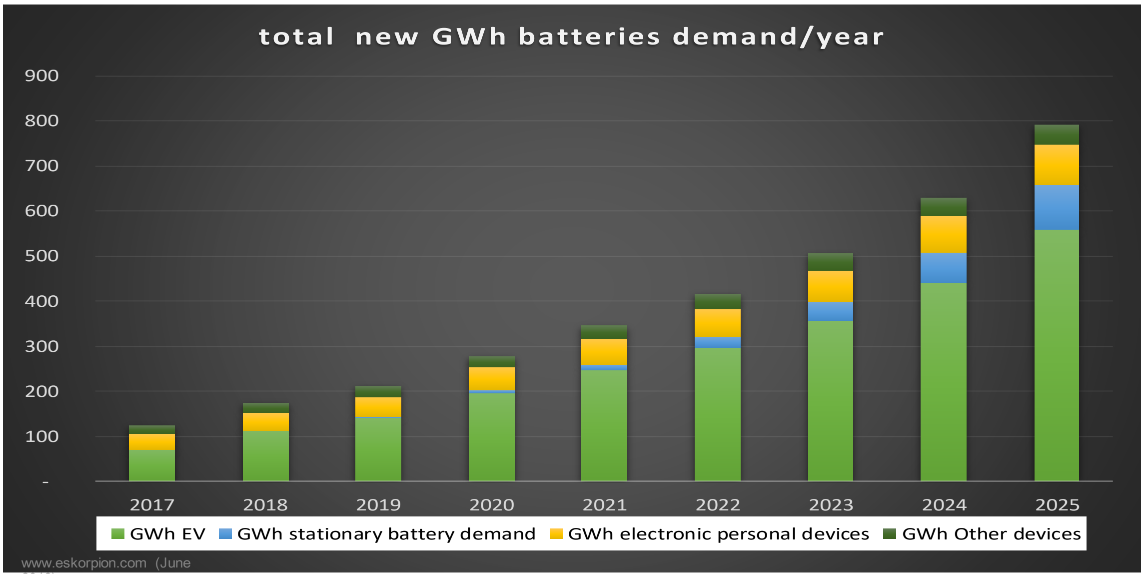


3.- STUDY'S INTEGRATED RESULTS

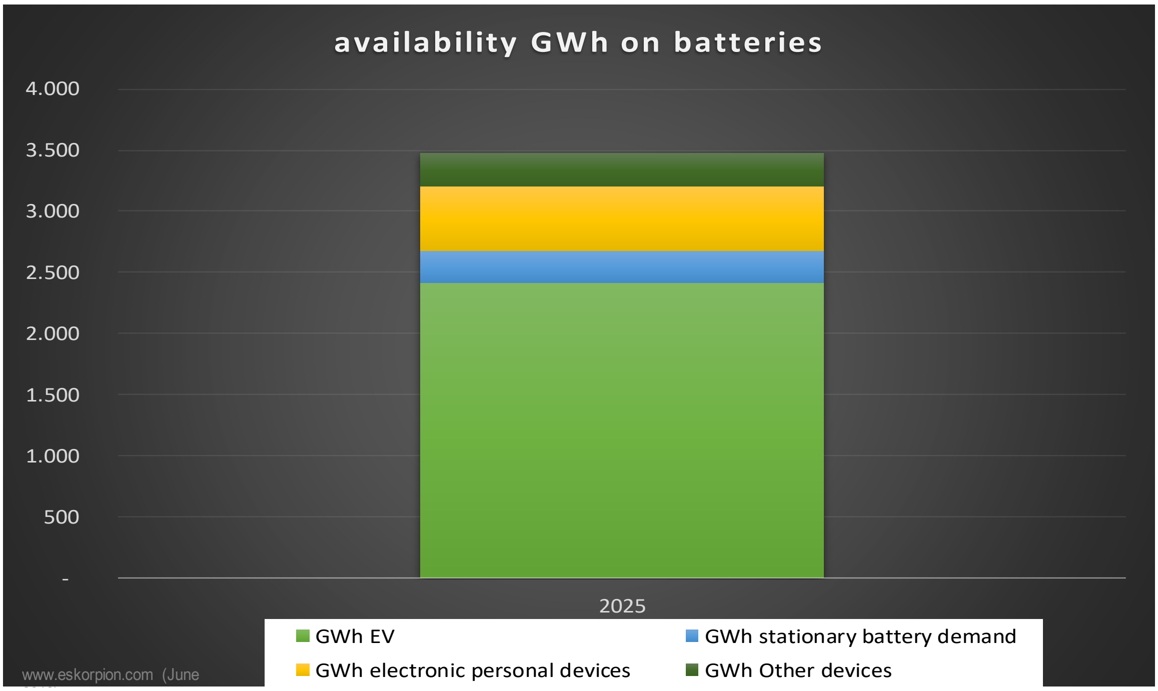
...Growth by the year 2025 is prominent, considering the analyzed period, which implies a GWh demand of 6.4 times that of 2017. Likewise, the LCE demand would increase 3.7 times the demand of 2017.

	register / year (entries)			accumulated
	2017	2025 e	F:2025/2017	
GWH on batteries LIB	**124**	**792**	**6,4**	3.473
Electric Vehicles	71	559	**7,9**	2.419
Stationary Grid sol	1	97	**159,6**	256
Personal Devices	35	91	**2,6**	527
Other applications	18	45	**2,5**	272
LCE demand (ton)	**215.500**	**792.865**	**3,7**	
Electric Vehicles	52.207	413.925	**7,9**	
Stationary Grid sol	450	71.791	**159,6**	
Personal Devices	25.900	67.035	**2,6**	
Other applications	13.290	33.619	**2,5**	
inventory flow adjustments	13.653	67.151	**4,9**	
Other uses of Lithum	110.000	139.345	**1,3**	

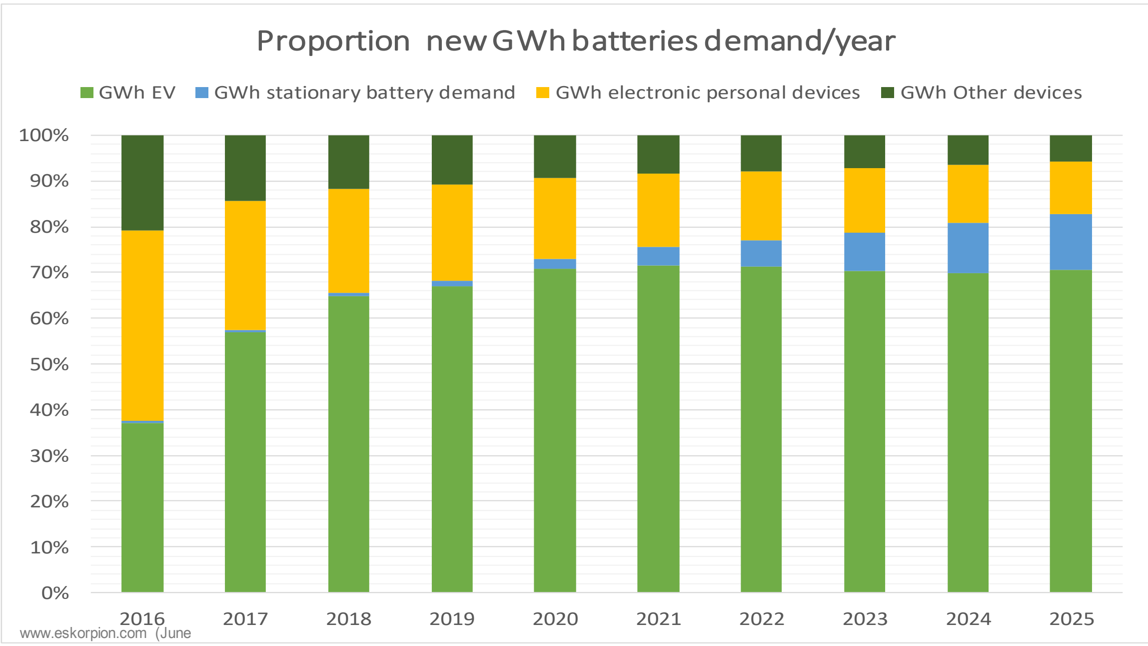
...The batteries demand will be strongly pressed by electromobility, thus surprising the growth of the demand forstationary LIB to be used in the electrical grid.



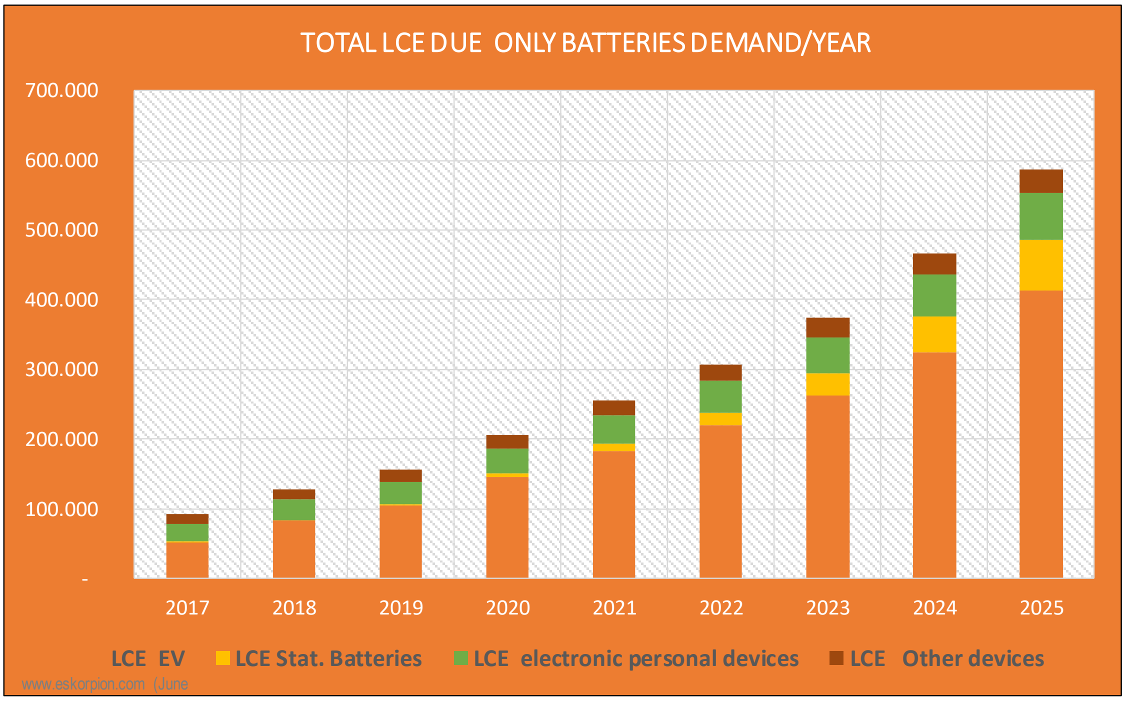
...The accumulated demand for battery GWh in said period would reach almost 3.5 TWh. However, those that will be discharged must be excluded (for example, portable devices) and a strong recycling business is expected.



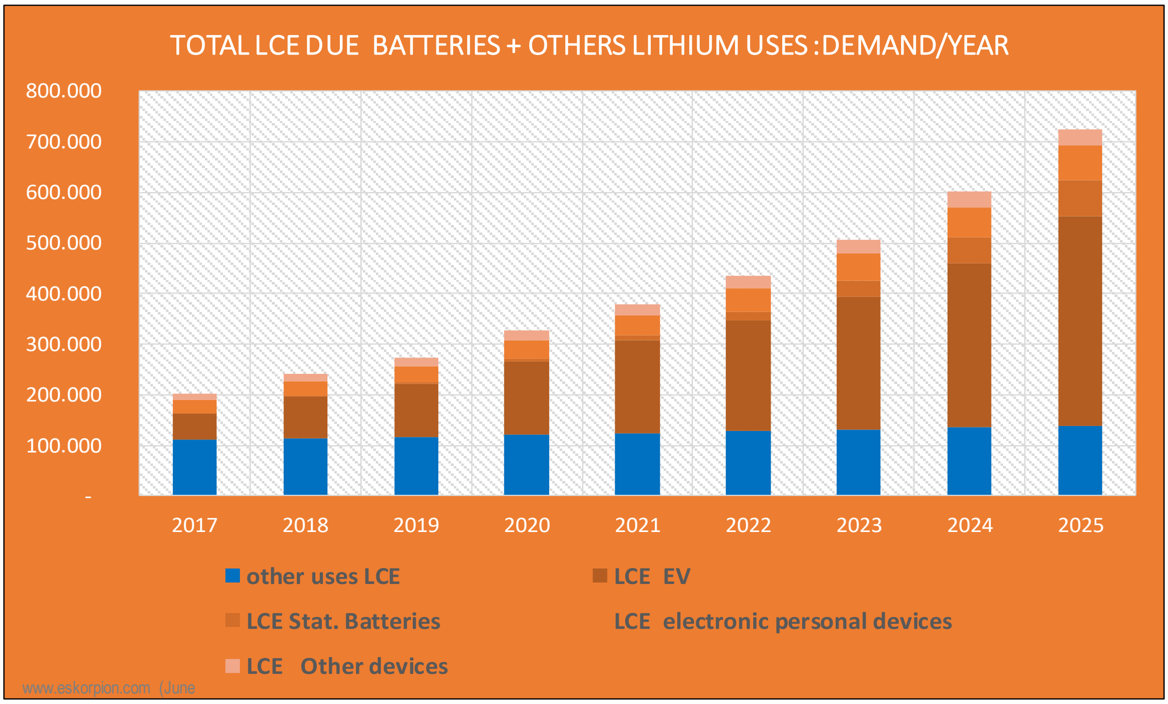
...In 2025, almost 70% of the battery demand will focus on electromobility, against 38% of 2017. This mainly due to the growth of the units sold per year.



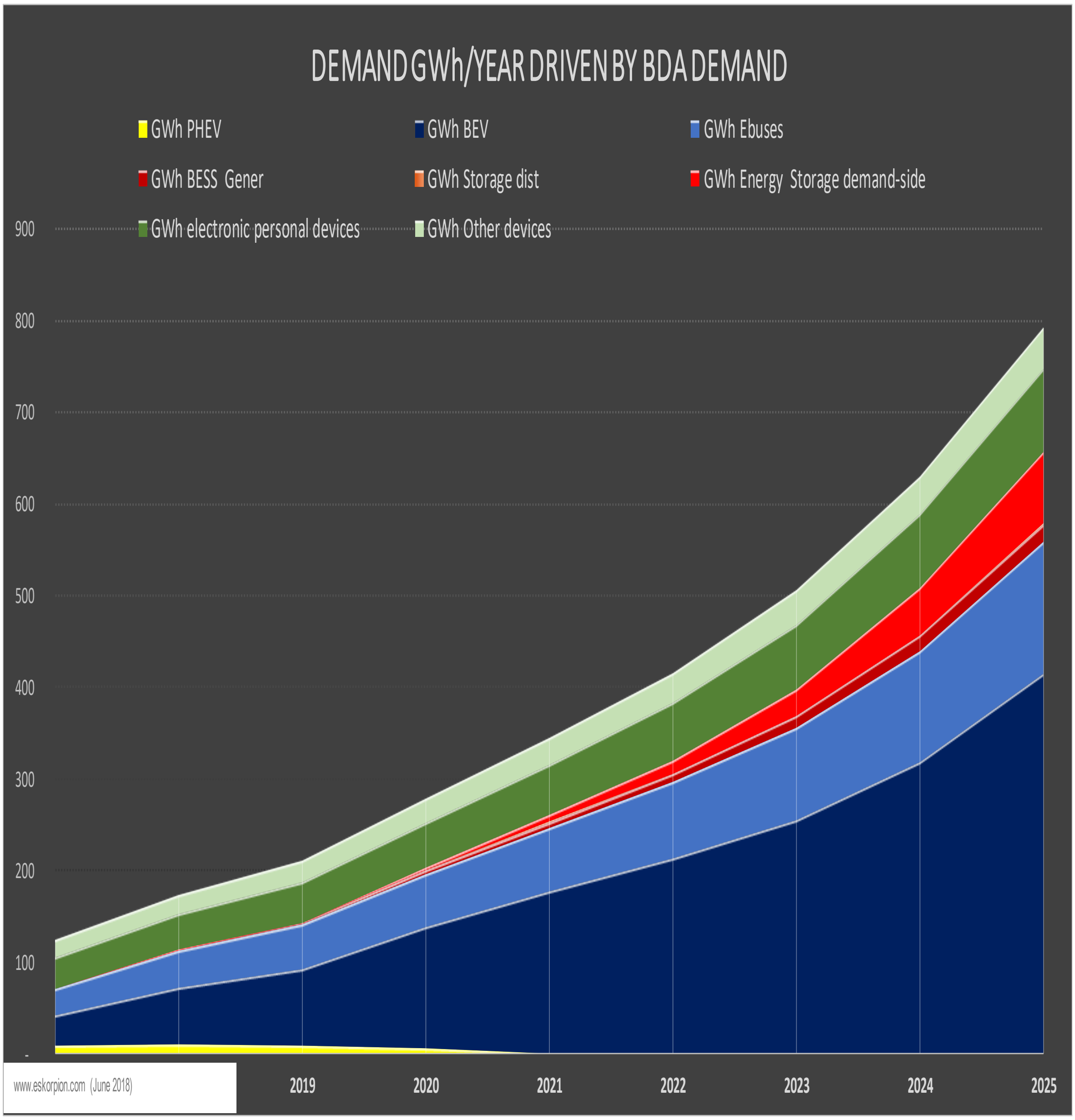
... The LCE demand due to LIB will have a strong growth by the year 2025, easily exceeding the Lithium demand for traditional uses.



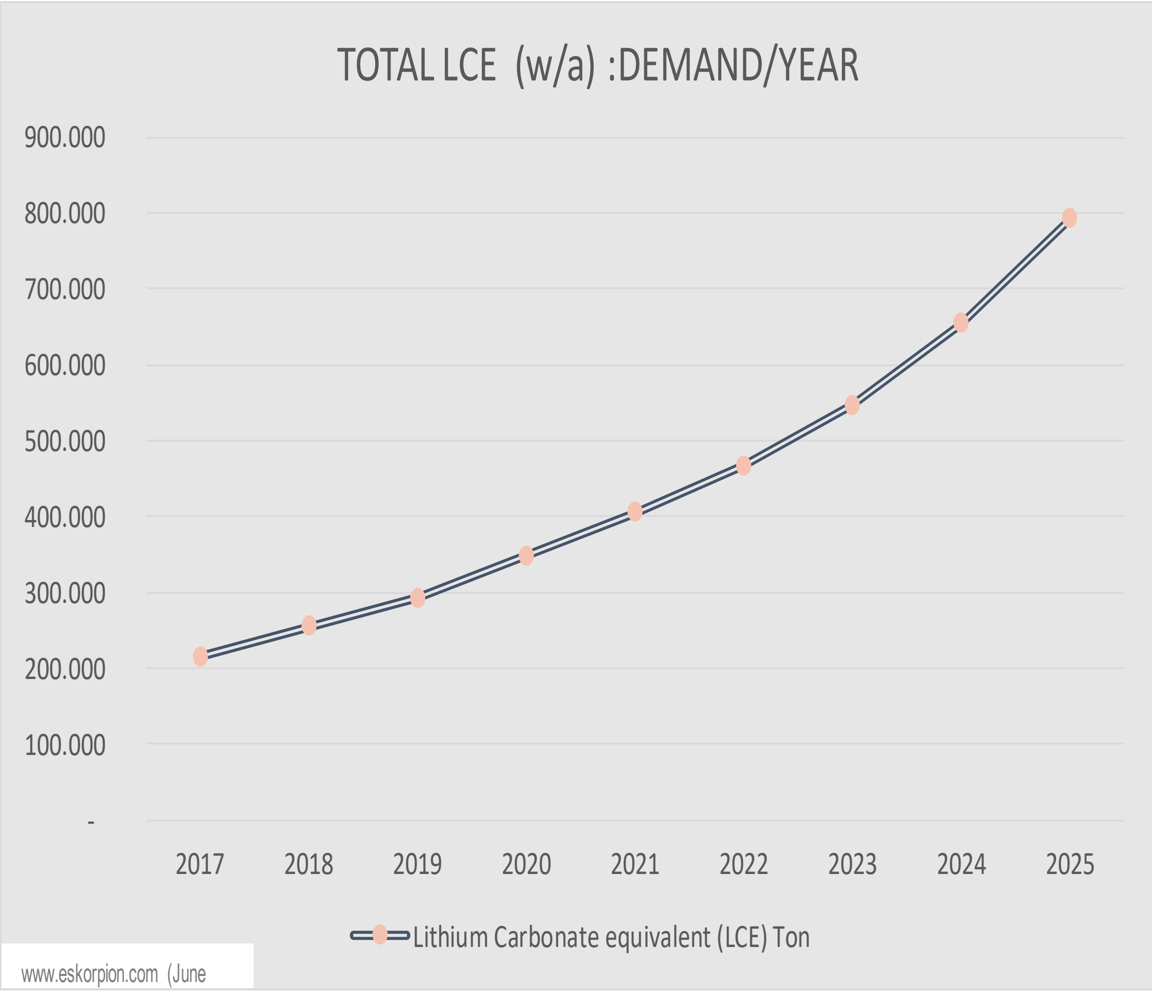
... The LCE demand per year adding the traditional demands plus the battery demand would exceed the 725 thousand tons by the year 2025.



… The energy demand in batteries by BDA drivers reaches about 800GWh per year on 2025. Electromobility (BEV) would share around 50%, but there are several other emerging applications in the market of the BDA which is necessary to take in mind



...The LCE demand per year correcting the inventory adjustment purchases and the factory losses adjustment would reach the 793 thousand tons by 2025. This year, 2018, about 254 tons are estimated.



4.- ANALYSIS PER CATEGORY

…Obtaining numeric data that determines the potential projection requires an analysis of its own and a critical and independent approach. The following chapter does this in full.

ELECTROMOBILITY

4.A.-ELECTROMOBILITY CATEGORY

This is the most important category and the one that will certainly mark the future of the battery demand. Particularly due to the decrease in US$/KWh value. When this technology started, in 2008-10, hybrid vehicles were being developed, which had a very small battery, smaller than 4 KWh, which only purpose was to provide supplementary traction during the a vehicle's maximum inefficiency points, when the vehicle starts from zero or when the driver accelerates abruptly.

This meant an efficiency improvement between 30 to 50%, with an electric engine that works in parallel with the ICE engine[18], usually providing supplementary traction to the axis that is not connected to the internal combustion engine. Subsequently, the battery is charged with regenerative brakes. Historically, the most popular of these types of vehicles is the Toyota Prius. As the battery costs decrease and the density improves, the batteries were enhanced in order to achieve a full electric journey for several km. That is, it goes from a support engine at times to full electric mobility for long stretches combined with conventional mobility in another stretch. In both cases they are hybrid vehicles, however, the first one is going away because its complicated electronics and mechanics does not compensate the light benefit.

4.A.1 Subcategory PHEV-100 (transition category)

The hybrid plug-in vehicles are classified in this category. They are vehicles that are plugged to an external charger (which doesn't happen with the hybrids) and with full electric autonomy. In this case an X number is added, like we use PHEV-100 as a calculation model, with 100 km of electric autonomy (62 miles)[19]. A 20 km battery allows providing this nominal range, so said unit energy value is assimilated to this range. In any case, it is assumed that said vehicles will be gradually replaced by BEV as the cost of the battery decreases and its cost is more or less equal. We have to consider that while the PHEV has a very high money/km performance (2:1) regarding the internal combustion vehicles, ICE. However, the maintenance cost is higher, considering it has both engines with every element, part and pieces of both worlds plus a sophisticated computer that regulates the parallel use. While these vehicles still represent almost 50% of the electric vehicle sales in the world, we predict that they will be practically extinguished by the year 2020 or they will simply be irrelevant.

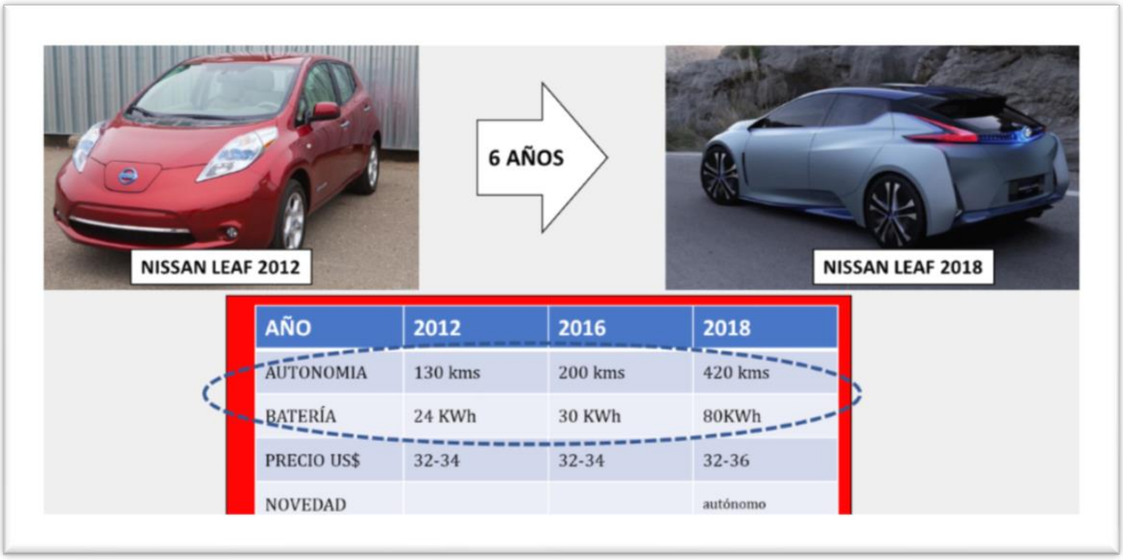
4.A.2 Subcategory BEV

This category classifies the 100% electric cars. They are vehicles that are plugged to an external charger and with full electric autonomy. In this case it is estimated that the energy density increase in the last few years and the cost decrease of the batteries from US$1,000/KWh to almost US$300/KWh (decreasing even more to less than US$150/KWh by 2025).

[18]ICE: Internal Combustion Engine.

[19]An iconic vehicle in this category would be the Chevy Volt, which already has a few production years. There are a lot of ranges available. The use of 100 is a calculation model.

This breakthrough has been used by the manufacturers during the first decade, not to decrease the price of the cars (still 30% higher than ICE), but to increase the range without increasing the price to achieve a minimum standard of customer satisfaction.



AÑO	2012	2016	2018
AUTONOMIA	130 kms	200 kms	420 kms
BATERÍA	24 KWh	30 KWh	80KWh
PRECIO US$	32-34	32-34	32-36
NOVEDAD			autónomo

Fig.4.A.2-1 Evolution of Nissan Leaf 2012-2018

In the example of Nissan Leaf, Fig. 4.A.2-1, we can see than in the multiple versions range has been chosen over price.

However, it is assumed that, in the years to come, it is very feasible that the range higher than 350 km is standardized and the real price-design competition starts[20]. In fact, by reaching a **TCO**[21] equivalent to the ICE, the war of multiple models soon to come to the market possibly attracts new clients where this variety of supply would really be the key of the accelerated growth and substitution of the ICEs.

That is why an average value of 50 KWh is assumed, which is equal to about 330 km of autonomy.

It is true that nowadays the premium electric vehicles exceed the 450 km of autonomy (with batteries higher than 80 KWh), but in this assessment, just as indicated, the PxQ must be considered, as well as the amount of users of cheaper electric vehicles will be much higher (particularly in China, the largest already-consolidated world market).

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[20] Today, vehicles are chosen mostly for the design, power performance and comfort. While the price is an important factor, it shouldn't be overvalued in the consumers' decision

[21] TCO: Total Cost of Ownership, it is the updated operating cost for a period of 3-4 years, added to the investment cost. Just like the BEV, its Capex is higher than that of an ICE, of equal categories; an Opex should be added, where the BEV has major advantages over the ICE.

This definition of the weighted average range parameter of the future middle-term electric vehicles is key, because by defining, for example, a unit value of 70 KWh per battery unit of the BEV would significantly affect the average. That is why the basis of our hypothesis is sustained in this trend. Reaching a consensus status between the manufacturers and then focusing on the designs and princes.

Fig.4.A.2-2Beijing Auto EC180 2017

The EC 180 Model of Fig. 4.A.2-2 is the best-selling vehicle in China, with a range of 180 km. These types of vehicles will probably be the most popular ones in the EV era.

In our model we project an exponential growth in the next two years, since the baseline is still quite low and the trend between 2016 and 2017 consolidates this assessment.

The conclusion of 1,100,000 cars registered in 2017[22] with a ratio close to 40% BEV and 60% PHEV implies a ratio of between 1 and 1.5% of the cars volume sold every year in the world, with an increase in the slope in the year 2020, mainly because in the automobile industry the “year” of the model is very relevant.

Probably, due to commercial and marketing reasons, that will be the year chosen by a lot of important brands to bring new their new models to the market. We predict that the 2020 models will have a non-marginal upgrade and it will be the beginning of the next stage, which is the competition for market participation and to at least maintain the current portion.

[22] IEA EV Outlook 2018

That focuses mainly on those pertaining to the ICE world; the famous brand like Volkswagen, Peugeot, Mercedes, BMW, Volvo, Ford, Toyota, Nissan, Renault, Audi, etc., most of them of European origin.

We must consider that in the world of brands, the EVs that lead the entering brands (outsiders) don't come from the traditional automobile world, but from the technology world, like Tesla, or from the battery world, like BYD.

The same happened in the mobile telephony, where the market incumbents and dominants have practically disappeared in the last 10 years, and today, incumbents that never thought 10 years ago would be selling these devices are the new rulers, much less that they would be the core of their business, like Apple, LG, Samsung, etc.

Traditional brands have a captive market of faithful customers (less and less), but it is clear that the first electric vehicle is not purchased due to loyalty; you have to be re-enchanted.

The trade-off of maintaining the ICE models of the traditional brands vs the manufacturers of full BEV can be the beginning of an epic battle.

The largest industry's market in theworld has been affected by a paradigm shift and nobody can sleep peacefully.

Fig.4.A.2-3 New models (late) to be launched in 2020?

It's logical to think that in the first few years there were internal subsidies from the incumbents to the EVs to sustain their position in the ICE market, especially if they (and the register) can handle it, which will force the newcomers to be more and more competitive and daring[23].

[23]The case of Tesla is a good example of what could happen in the future. The company is not making money, but they have stayed in the fight due to the loyalty of their investors and shareholders. Tesla has developed a series of

Of course, we can predict the winners and losers, who will become subsequent case studies.

In our forecast we estimate that that business war would start in the year 2020, it will probably contribute to a fast-growing marker from 2020 to 2025.

This market will be the largest contributor to the batteries market in the next decade, and probably to the innovation of the ***Iota-Epsilon*** 's merger era.

4.A.3 Special Subcategory of Heavy Vehicles

In this category we are focusing on heavy vehicles, especially electric trucks and electric buses.

Regarding the electric trucks, we distinguish the light trucks that focus mainly on the city-utility market, with a load capacity of up to 2 tons, which can be absorbed in the BEV category, because while they are large, they are designed for a smaller autonomy than the personal-use vehicle since their use is limited to a city with the return to a loading point, therefore, their range is not that demanding. In that sense, they can assimilate, regarding their battery, to the light electric vehicles.

Regarding the larger electric trucks, used for long trunk routes, there is a trend of the use of other energy storage trends, in the case of electromobility, like the hydrogen cells[24], because of their larger range, considering that the recharging points are limited to the trucks' supply replenishment stations. We don't believe there is a significant transformation of these types of electric-engine vehicles with lithium batteries in the next decade, because we are incapable of visualizing comparative advantages.

However, regarding the E-Buses, it is a category we have decided to incorporate separately, because they have had an unexpected performance caused by the "giants' geopolitical effect", mentioned in point 1, CONTEXT. There is also a special note in the "result" of the SUMMARY.

In the 2012 forecast, the prestigious consulting company Frost and Sullivan (https://ww2.frost.com/), estimated 19,000 and 80,000 electric and hybrid buses for 2015 and 2022, respectively. If we consider the information from the EV Outlook 2018 de EIA (Energy International Agency)it is mentioned that 2017 registered 100,000 new E-Bus units in China alone (and an on the road cumulative number of 370,000 units). 85% of the E-Buses sold in China in 2017 were BEV.

This proves that China's effort to lead the demand market and the vehicles supply (most of the electric buses have a Chinese origin), has generated an unexpected quantum jump barely 5 years ago, with an error of an order of magnitude.

extremely innovative mechanisms in the marketing, sales, technology and after-sale models. This is impossible to continue due to the governance of the traditional brands with 50 years of predefined rules in their organizations.

[24] Hydrogen cells as electric storage source are an alternative to LIB because of their get higher energy density. However, its main disadvantage is the distribution, transport and storage (similar gasoline) that increases cost and logistics. The existence of grid give tremendous advantage of the widespread distribution of electricity in the world, including households.

Because a BEV bus consumes a 250 KWh battery, and its numbers are growing in a significant manner, we have created a separate chapter about it.

Fig. 4.A.3-1 BEV-Bus operating in Santiago, Chile.

In our projection, using the records recently delivered by the IEA in March 2018 as a baseline, with the most recent results from 2017, and an exponential growth projection, but at the same time decreasing because the total global market is small and could collapse in less than a decade, but at the same time it could be the market with the greatest electromobility implementation in the world[25].

In the last few years there has been a controversy regarding the feeding characteristic of an E-Bus and its technology. In Europe (with an intense use of buses) advocate for hybrid or fuel-cell vehicles. BEV-Buses were considered excessively expensive (CAPEX) and difficult to maintain the service's requirements. This until 4 years ago when they opened to the possibility to consider partial-load electric buses, this means relatively small batteries (about 30-40 KWh), but with on-the-road ultra-fast inductive load that allows reaching the next loading station. This is all about costs and the maintenance of a semi-captive market. China has promoted the full electric bus with 250 km of autonomy. They seems to be winning this battle, both in China, of course, and in the latest fleet biddings in the world. This has forced the European brands, like Volvo, Mercedes, etc., to quickly align with this trend. The same companies influenced the governments to maintain their local markets based on the hypothesis mentioned earlier. Meanwhile, the Chinese E-Buses rule the world market, and they are even lowering the prices in a very aggressive marketing campaign, including the USA and European markets, and we will probably see European competence arriving in this category to the market in the next few years grudgingly rejecting their own hypotheses.

[25]In general, public transportation depends on the transport authorities of every country and, therefore, the fleet operation is conditioned to tender requirements or political-strategic decisions. There is a trend in terms of NGOs and climate change oriented organizations to gather to force electric and clean electric public transportation in major cities around the world. This trend is accelerated with plausible examples like China and the best prices due to the increase of the sales volume.

4.A.4.- RESULTS OF THE EV CATEGORY

As a result of the projections according to the previously-mentioned criteria, a projection is obtained summarized in the following table:

	register / year (entries)			accumulated Millions on the road >
	2017	2025 e	F:2025/2017	
Númber Light & Medium and Buses EV	1.215.000	8.879.587	**7,3**	37,4
PHEV-100	440.000	-	-	2,8
BEV	660.000	8.302.694	**12,6**	34,4
E-Buses	115.000	576.892	**5,0**	2,8
GWH consumed	71	559	**7,9**	2.480
PHEV	9	-	-	55
BEV	33	415	**12,6**	1.719
E-Buses	29	144	**5,0**	705
LCE used in Batteries (ton)	52.207	413.925	**7,9**	
PHEV	6.512	-	-	
BEV	24.420	307.200	**12,6**	
E-Buses	21.275	106.725	**5,0**	

Fig.4.A.4-1 Comparison of baseline data (2017) with 2025 projection.

The number of electric vehicles projected until 2025 in terms of implementation, would reach about 8% of the industry's total sales, in terms of amount of sold vehicles in the global market. Practically, the entirety of the vehicles would be of the BEV category with autonomy ranges between 200 until 600 km, with an average of 350 km.

Electric vehicles by that time will have incorporated factory standards like the monitored autonomous driving (alert driver, E-CoPilot), and they will probably incorporate improvements to the current versions (since they include maintenance of synchronized automatic speed to en-route vehicles, track adjustment and automatic passing, full automatic parking, and other current improvements). These improvements will be connected to warning communications systems between vehicles, and between vehicles and warning systems with "electronic headlights" in highways and cities.

Regarding the number of vehicles per year, figure 4.A.4-2 shows that in the year 2020 it will exceed the 3 million vehicles per year, which is equal to a little less that 3% of the total annual sales.

Likewise, it is clearly warned that 2020 is the year when the sale of new hybrid vehicles would practically disappear, including those with range extension (PHEV). We can also foresee that, for marketing reasons, the **"2020"** models will be launched with new models and practically all of them will be BEV.

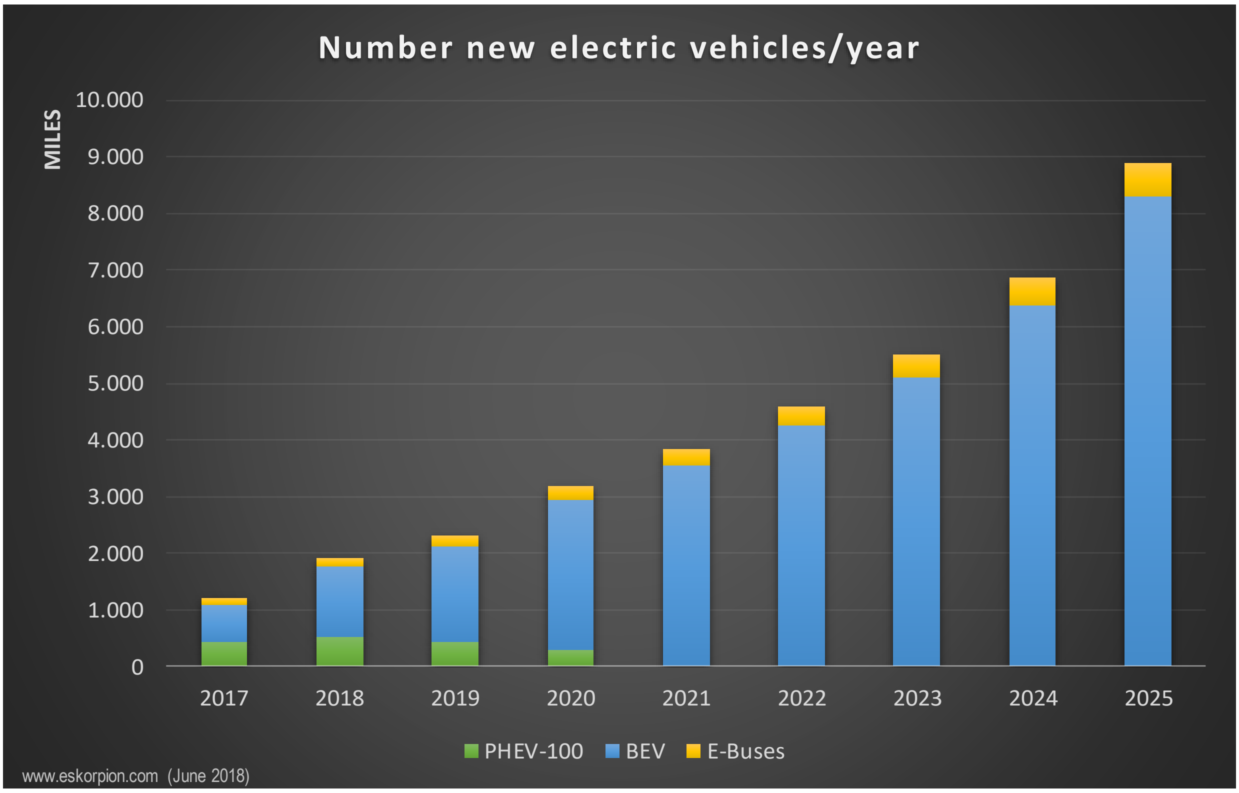


Fig.4.A.4-2 Number of new electric vehicles per year.

In spite of this increase, we have to integrate, in the category considerations, the alleged standards for **20 KWh** (PHEV-100), **50 KWh** (BEV) and **250 KWh** (E-Buses), to determine the size of the batteries and that way project the battery demand expressed in GWh.

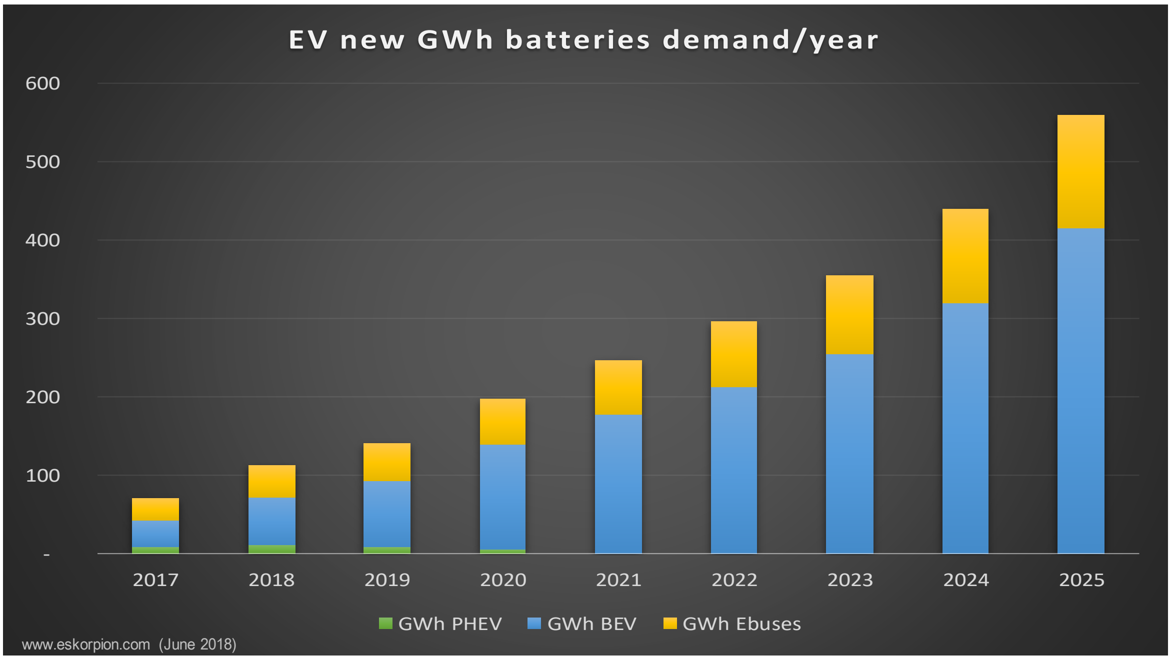


Fig.4.A.4-3 LIB Battery demand (expressed in GWh) per year per electromobility category

The energy demand of the electric buses will be relevant in the years 2018 and 2019, due to the explosive growth of the full electric buses, which, as we mentioned earlier, consume

500% the energy of a conventional light vehicle. By increasing the entry of E-Buses in "quantum" terms, due to the nature of the operation in the cities where the "fleets" of thousands of units are replaced, this growth will be very relevant. However, it would subsequently increase, also considering that its replacement rate is of at least years, being greatly surpassed by the BEV vehicles.

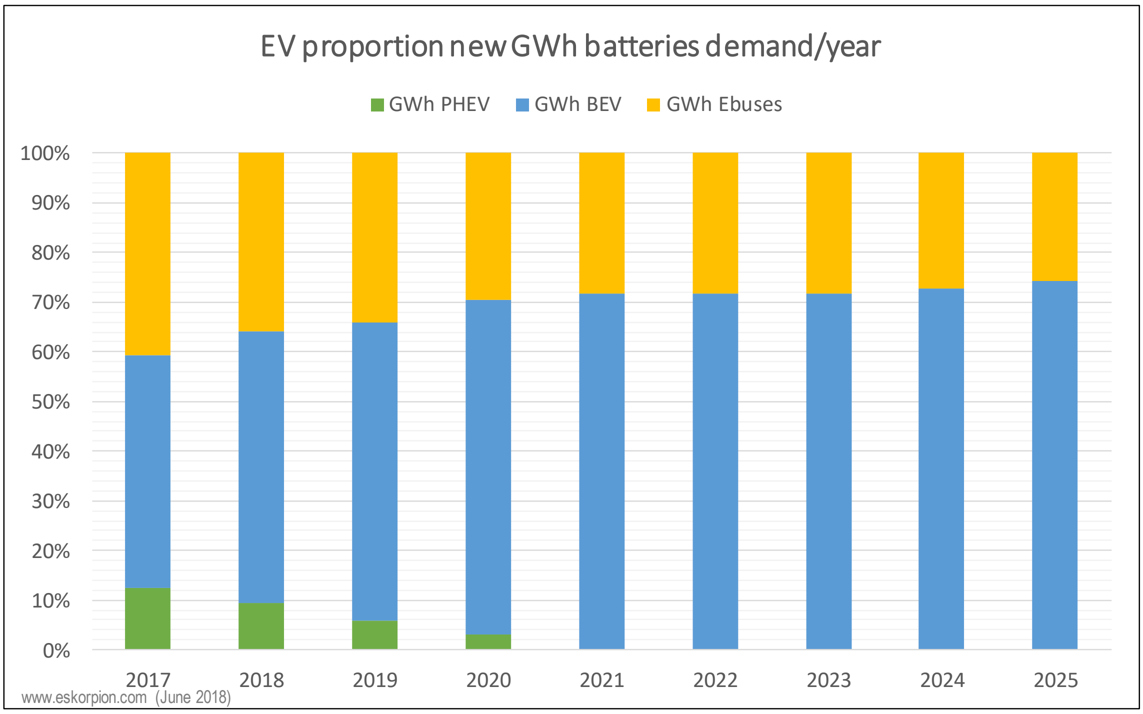


Fig.4.A.4-4 Ratio of battery use per category of new registered electric vehicles per year.

Figure 4.A.4-4 shows this effect very graphically, where in 2016 and 2017 the LIB demand in energy installed in electric buses was very relevant in respect of the other EVs. However, by 2020 their influence would decrease to less than 30%, reaching almost 27% in 2025. This will probably decrease in the following decade.

Note that in 2016, the potential energy in batteries of hybrid vehicles (PHEV) was equivalent to those of the BEVs.

This situation will influence the demand for raw materials and, as shown in figure D-5, electric vehicles will have a larger influence in terms of lithium need.

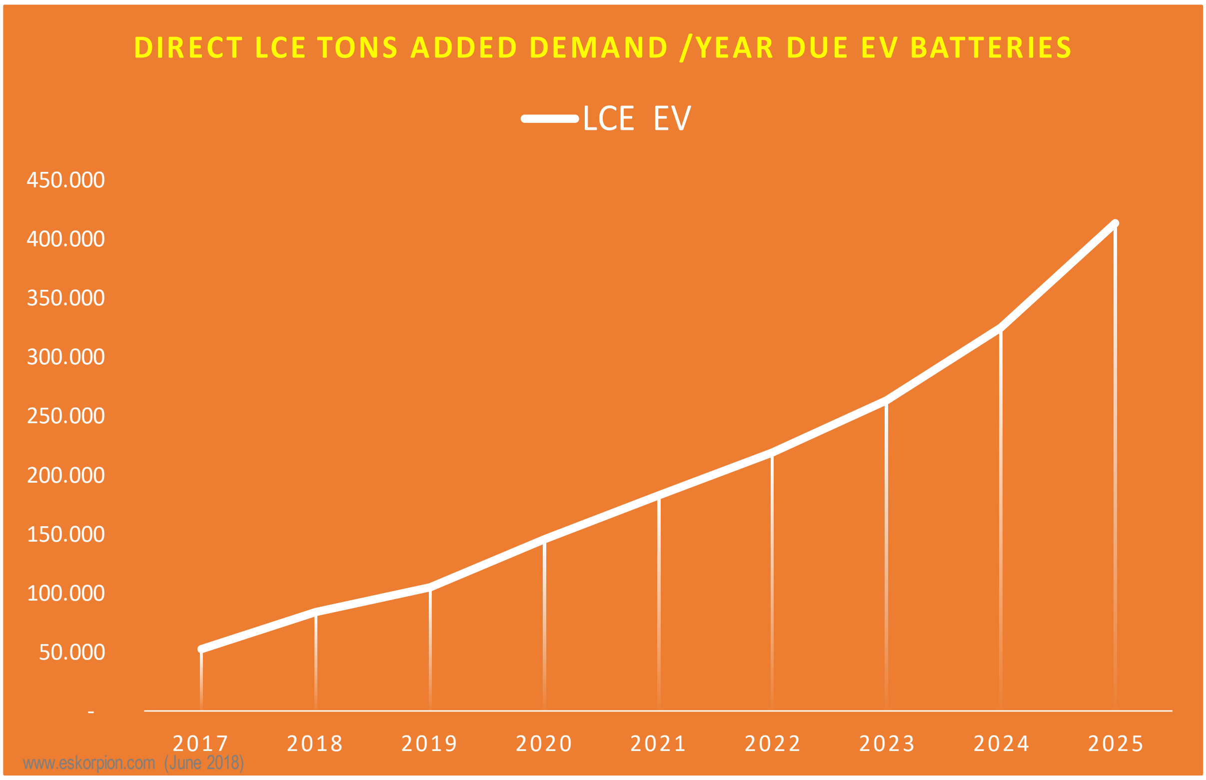


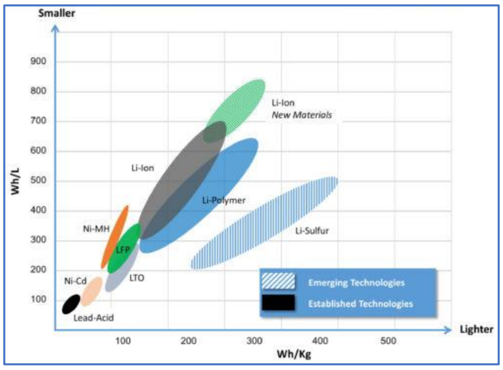
Fig.4.A.4-5 Demanda de Toneladas de LCE (en Toneladas) por efecto de electromovilidad

It is likely that by the year 2023, EVs on their own, will generate a demand equivalent to the global demand projections of the year 2018.

4.A.5.- ELECTROMOBILITY CONCEIVABLE SCENARIOS

BLACK SWANS

❖ **Potential situation of the lithium battery by another disruptive technology**



While there are a lot of permanent announcements about it and although it is very unlikely, a new more cost-effective and heavier source could have a not very significant impact on electric vehicles, although it will impact heavy vehicles (trucks) and flying vehicles (airplanes) as well as maritime transport. In these cases, it's not possible, according to the foreseeable state of the art of the next decade, to develop batteries that feed the electric engines of these vehicles with the desired range and autonomy requirements. Likewise, this would collapse the mining of raw materials and the first layers of value of the battery industry and the not compatible investments in terms of super-factories. In any case, the route map of the evolution of the lithium batteries, showed in the figure, still foresees a significant evolution of this category in the next 10 years, at least doubling its energy density per mass and improving the volumetric density.

❖ **Accelerated evolution of full driverless autonomous vehicles**

This will have a significant impact on the entire automobile industry because transport would evolve to the use of shared vehicles instead of their own investments. This could dramatically lower the demand of new vehicles with a business model like Uber to a worldwide level, and without drivers (dramatically lowering the costs).

❖ **The "2020" Model**

The year 2000, magic number, affected the global economy, particularly the software developers due to the impressive change of the software assets of millions of companies that were scared that the previous versions, limited to two digits for the year's register (90, 95, etc.) would not understand the "00" and this zero division would cause chaos in the financial systems and others. This boosted the development of this industry, and part of the current unicorns was born from this hazardous circumstance. In cars, the "model" does matter, and the "2020" model will definitely give an implicit marketing sense to electromobility. If this contingency happens, a psychological effect could occur that will cause a media resonance that could eventually promote many unicorns, as well as a trend that is unpredictable today.

❖ **The potential replacement of the lead-acid starting batteries**

Technically, the possible substitution of the lead-acid battery for a Lithium battery is perfectly feasible today. The only thing stopping this possibility is the cost and potential lobby of the lead battery industry. If that happens, which could be very close if the lithium battery comes close to the US$120/KW of the lead batteries, eventually an innovation with a chemistry that allows radically lowering the price by lowering the cyclability, but still with performances higher than that of lead in terms of useful life, maintenance costs, carbon footprint legacy and the contamination of materials, could create a huge not-considered demand. In the fuel cars, which will be current for many years, about 300 million batteries are consumed every year[26]. Considering 600 Wh per battery (50Ah-12V), there are 180 GWh of annual potential, about 130,000 tons of LCE per year.

GEOPOLITICAL ACTIONS

❖ **Increase of the oil price**

The increase of the oil price would, without a doubt, benefit a more accelerated growth of electromobility, since the TCO[27] of the electric vehicle would improve regarding the combustion vehicle. The oil price argument was overused between 2008 and 2010, as an incentive to purchase electric vehicles. However, the decrease of the oil prices to less than half in those years, this benefit was declining in importance, to the point where it was thought that that decrease would definitely stop electromobility. Nonetheless, the latter exploded, because the technological improvements, lowering investment costs and environmental regulations have generated sufficient incentives.

❖ **Import taxes as a defense for falling behind**

Some countries could establish obstacles to the import of electric vehicles to protect the local lagging industry. Since producers are currently focused on some countries, it could stop the price decrease and stall the electric vehicle in a niche market.

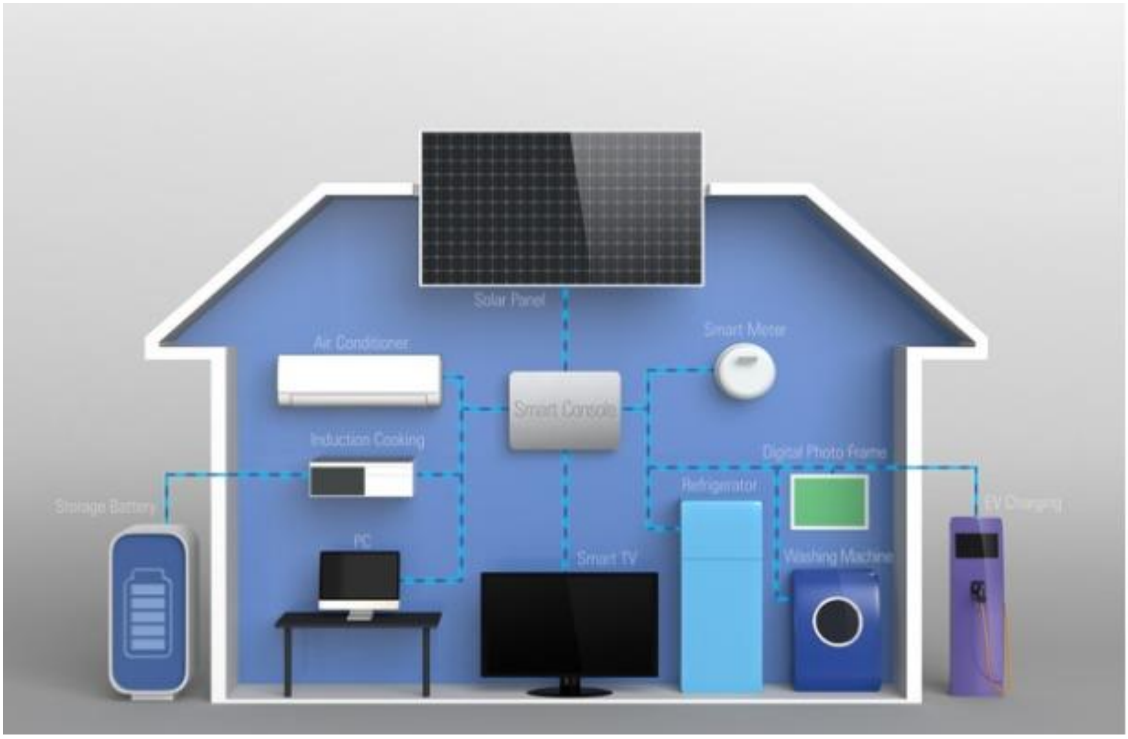
❖ **Failures in the upstream supply market**

Any problems in the supply chain, especially batteries and raw materials due to the actions of a predominant country, would bring back the memories of the oil cartel and it would probably negatively influence this industry's development. This is not a small issue, since according to our projections, the demand is explosive and, therefore, it's not

[26] Around 100 million of batteries are estimated in new sales cars each year, plus a 20% replacement of existing cars, a billion vehicles.
[27] TCO, Total Cost Ownership, Capex+Opex approach.

only an issue of price increase of raw materials but of their plausible provision sources. At this point, there are plenty of movements regarding the control of these origin sources by the industries and countries, strategically speaking. The sales are in the long term and mechanisms like these can be used effectively to attack the competition; leaving them without bullets.

STATIONARY BATTERIES



4.B.-STATIONARY BATTERIES CATEGORY

This category is where every expert foresees as necessary and relevant due to the boom of the variable energies, wind and solar, which require as a logical complement, the energy storage to adjust the supply to the demand.

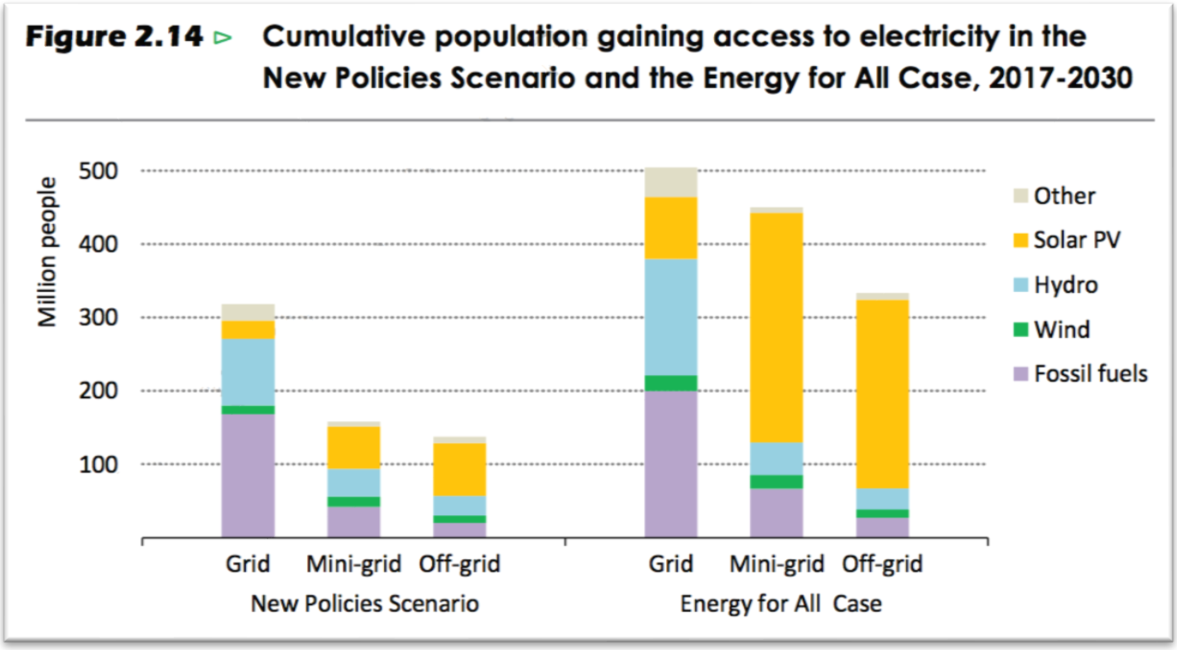


Fig. 4.B-1 Electricity demand from different origins 2017-2030 (IEA WEO 2017)

The use of batteries as an electricity storage element for backup, flatten the peak hours in generation, stabilize distribution, complement the off-grid and on-grid use in the demand purposes, etc, are recurrent issues in the specialized world.

In fact, figure B-2 shows an excellent conceptualization of these uses and potential applications, prepared by the Japanese company NEC.

...Stationary batteries have a great potential as usage complement for variable energies and as storage potential of quick entry reaction before power failure...

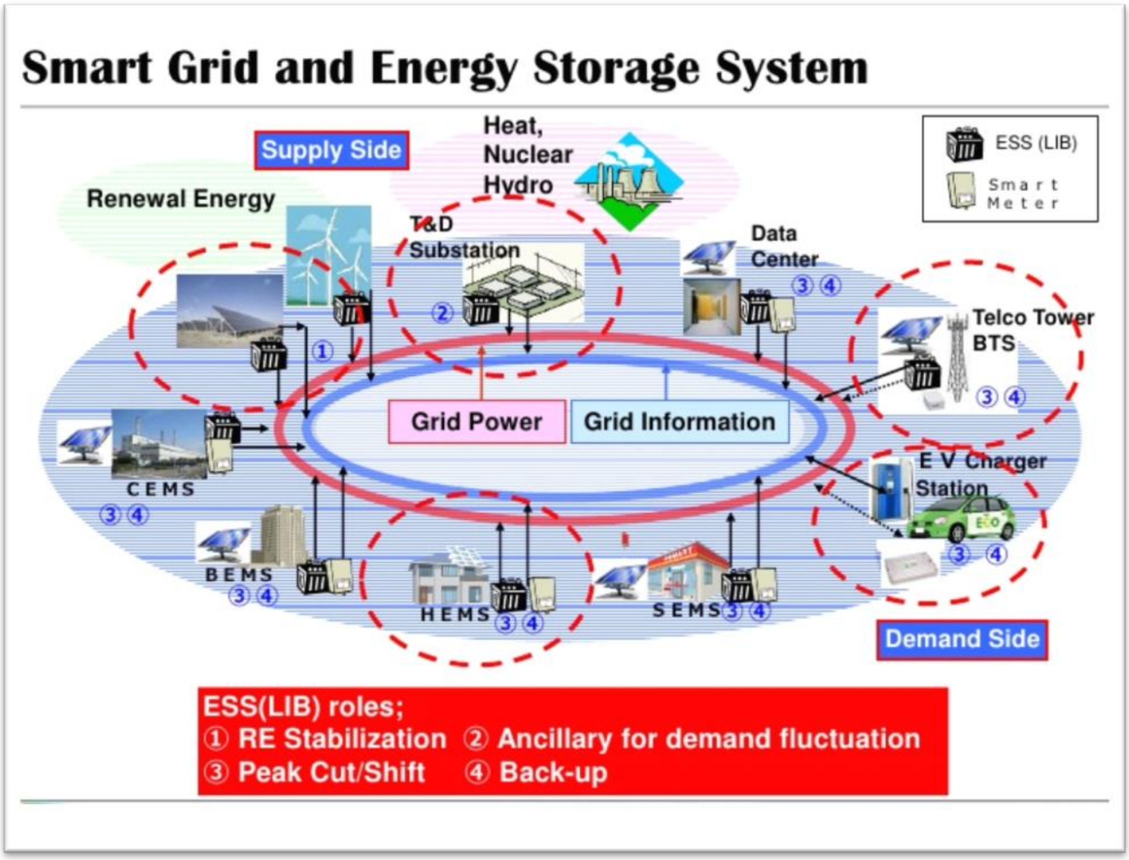


Fig.4.B-2 Usage of stationary batteries in electrical grid (Ref. NEC Corp)

Even this concept that integrates operations in the network and even with the electric cars, which in practice are huge portable batteries, smartly integrate to the network in a concept called Smart-Grid. This is a classic example of the so-called Iota and Epsilon merger effect, previously described in point 1, Context.

It's necessary to recognize that, while this scenario is foreseeable, it is slowly emerging and has entry barriers, for different reasons, mainly linked to the analog legacy of the electricity companies and the regulatory environment they moved around in, many times contrary to innovation.

The restrictions and commitments taken in the Paris[28] Agreement have forced the nations to establish regulatory pressures and to promote the use of renewable sources with the purpose of fulfilling said commitments and the associated KPIs.

[28] The Paris Agreement (French: *Accord de Paris*) is an agreement within the United Nations Framework Convention on Climate Change (UNFCCC) dealing with greenhouse gas emissions mitigation, adaptation, and finance starting in the year 2020.

On the other hand, China's strong and its active commitment to lead in its own country this change as a double hegemonic benefit, which incredibly enough was promoted due to the great environmental pollution in the Chinese cities, were widely exposed in 2015 with the toxic cloud that covered Beijing in December of that year and that represented the tip of the iceberg of an already massive problem in 50 cities of this country.

That time, the first red alert was declared in China, and maybe that was the formal beginning of a change that has had unexpected implications on a humanity level, which, in our opinion, still haven't been accepted.

While the particle and gas pollution of a city is not directly related to the emission of greenhouse gases (GHG), the measures are the same and they are to eliminate the contaminating sources producing the GHG.

This implied in China, as a collateral and regulatory effect, the use of renewable generation sources additional to the water resources, like the use of solar and wind power, which are a relevant part of the so-called NCRE group (Non-Conventional Renewable Energy).

Then there was a radical price decrease of the photovoltaic panels and wind generators produced in that country, at the beginning to be used at large generation farms, but nowadays used more and more for particular uses at a home scale. With this, the need for storage, inherent to these variable energy sources, has grown parallel to the growth of the energy generation of these origins.

While the required storage volumes are enormous, much of the same is possible by providing other cheaper technologies, from thermal or mechanic storage for the generators, to the lead batteries in smaller levels, every time the great energy density advantage (Wh/Kg and WH/L) of the LIBs are not strict requirements for these cases, since, by being stationary, usually it is not a restriction. The storage cost is relevant and other less sophisticated, but cheaper, solutions still maintain by far the leadership over the Lithium batteries.

But this is slowly changing as the LIB costs have decreased and cyclability[29]. It is possible and that is our projection, that this solution in the electrical grid has a significant relevance in the year 2025, the year of our prediction horizon.

4.B.1 Generation subcategory

Generating plants based on variable energies, solar (PV) and wind require the use of storage to amortize the investment. If they only sell energy to the grid in the hours when they have the primary source (sun and wind) it is evident that their plant[30] factor is very low (10% - 20%) against any thermal or hydraulic or nuclear power station (> 60 %). Therefore, storage is an obvious way to adjust the factor to flatten the supply-demand time curve. There is also the technical concept called "power reserve" which is a marginal value to the installed nominal power that must be reserved by regulation for the purpose of stabilizing eventual volatility of demand. This value is established at around 5-10% of the nominal capacity of the generation power. One of the characteristics of this reserve is that it must be delivered, especially primary sources, in very short times to the network (<30 sec). In other words, it is not possible to keep this reserve in slow start systems (e.g., emergency generators or other slow start options) and in general, what is done is to underutilize the generation plant in a percentage that simply remains artificially passive or, to put it another way, oversize the nominal capacity. This is clearly an over-investment in capacity rarely used and with an obvious economic value. In this case, it is possible and economically profitable to use large battery stations (BESS, Battery Energy Storage Systems) that allow having this source of rapid reaction generation and that should be sized to be able to generate said power over a period of determined volatility (in any case a maximum of a few hours).

[29] The breaking point in the decision is the value of the KWh provided by the battery versus its CAPEX or OPEX, in relation to other solutions. A battery is measured by a value of US$/KWh, of investment, but once it is acquired it can be used thousands of times (Charging and discharging cycles in its useful life), so the value of the KWh in the operation is the result of the investment cost divided by the use cycles, to determine the cost of the used stored KWh. To that, we have to add the value of the operating costs.

[30] The plant factor (also called the net capacity factor or load factor) of a power plant is the quotient between the actual energy generated by the power plant during a period (usually annual) and the energy generated if it had been working at full load during the same period

Fig.4. B.1-1 Use of stationary batteries in the electrical network

A very recent example is the BESS of lithium batteries installed by the company Tesla in Australia with a capacity of 100 MWh and which reacted to a network drop in 120 milliseconds. These examples, we believe, will be replicated in the future, gradually growing in a somewhat hostile environment to the technological investment of electricity (vs costs). In any case, only in terms of comparison of the ease of implementation of this subcategory, this mega battery represents about 2,000 vehicles of the BEV category analyzed above. However, 2,000 BEVs are sold in a few hours, but these plants are installed very occasionally and customers are very few, in relative terms.

We have used the parameter 100 MWh per unit as a potential energy factor to determine the energy size of the associated battery demand. We have considered as baseline, 2 units installed in 2017. In any case, a higher level of tolerance can be allowed considering the little impact on the large numbers that are intended to be discovered in the present work.

4.B.2 Distribution Subcategory.

The use of batteries in the distribution network is an incipient area of development, mainly due to the limited incentives of companies that distribute electricity to optimize their networks. In fact, electricity rates are generally regulated and companies that distribute energy are paid for the amount of energy transported to customers. If customers consume a lot, the company wins. If the energy is squandered, the company wins.

This situation is mentioned, as it is evident that there is a lack of optimization in the distribution of energy, due to the heterogeneity of the demand. It is possible to think that a distribution company could buy energy in hours of low demand, at lower prices, and transport it to place it in batteries in stations close to the demand. That means that the batteries distributed on the poles are virtual clients or temporary intermediaries that allow an economic benefit of buying cheap and selling expensive at peak hours.

Also, they would be support centers for eventualities of sectoral fault events.

Nowadays, these business models are in experimental phase in some companies and are studied in academic environments. Implementing them massively requires a key factor that, in general, the distribution networks do not have; computational intelligence in the network and artificial intelligence models to modulate this complex network.

The batteries for these solutions would not be extremely large, but the number of units could be enormous.

In our model, we have considered 100 KWh units, enough to supply about 80 houses during a couple of hours in peak hours. We have started with about 80 units in 2017, estimative figures by the way, because as indicated, they are very experimental solutions and require a sophisticated structural technological development plus an ad-hoc regulation that is not yet implemented massively.

Despite this, we have projected an exponential growth from 2020, once the new smart-grid standards are matured and the corresponding regulations are introduced for the distribution network. In this case we have estimated that this model of battery use could evolve quite fast up to almost 10,000 units by 2025.[31]

4.B.3 Demand Subcategory

With respect to the demand, the potential of the use of batteries in the electric network can be better appreciated. Associated use to optimize the use of a solar panel between generation and demand provided as an indissoluble solution and today speaks of photovoltaic panels + storage as a couple is a single integrated solution. The same applies to solutions based on wind energy or mixed solutions that contain both integrated variable energy sources.

The type of demand solutions associated with this technology are known as micro or mini grid plus on-grid and off-grid. This is the solution of **energy self-sufficiency** of small communities up to an isolated home without connection to the network (island type) or with connection to the network, acting both complementary. These solutions refer to self-generation solutions based on Solar or Wind energy in almost 99% of cases.[32]).

[31]This estimative value is subject to very large errors, since this technology can evolve in an unexpected way, in one or the other sense. In any case, considering that storage units are only twice those of a BEV, any error, even an order of magnitude, will not have a radical influence compared to the millions of BEV estimated per year.

[32]There are solutions associated with water currents, called mini or micro hydro, for self-supply, but with a much higher plant factor, where practically no storage is required and limited to very limited geographical situations.

... The differences between these categories is that they refer to the size of the demand and its geographic concentration, as well as its isolation (off grid) from the regular distribution network. From a home isolated in the middle of nowhere to a small village or community (building) connected to a power grid, but used as a backup at certain peak times, meaning that it generates a base demand and much lower costs of operation (on Grid).

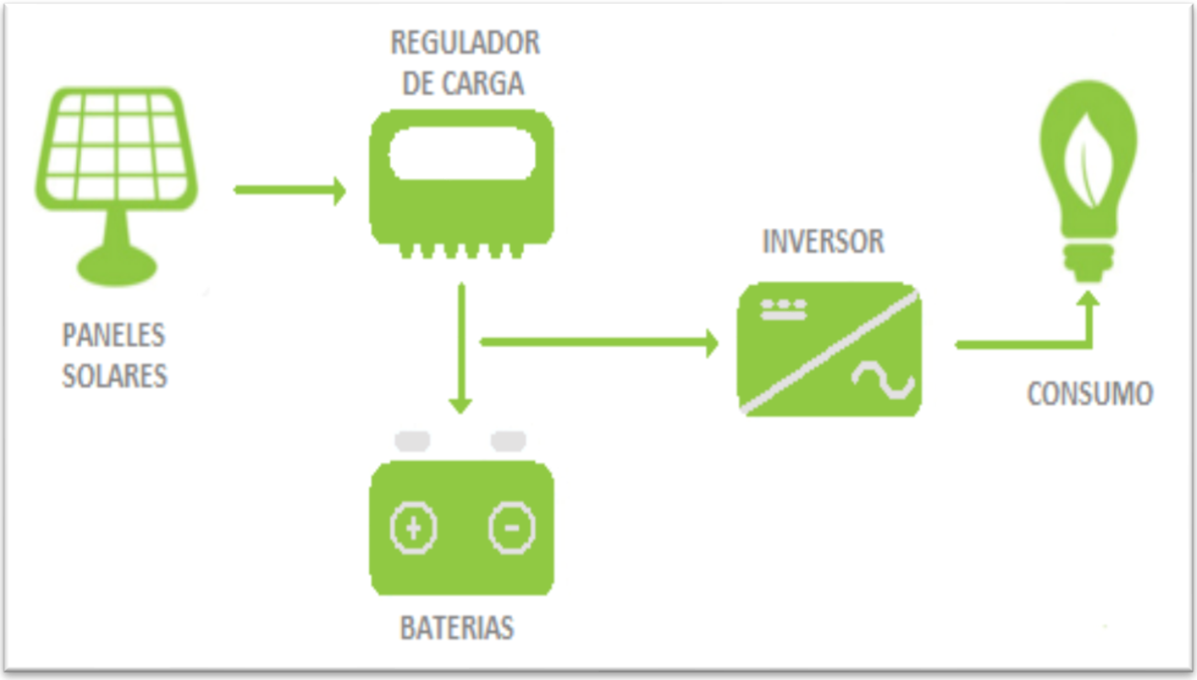


Fig.4. B.3-1 Classic home solution PV + Storage

This solution that integrates a battery is quite standard as shown in Figure 4.B.3-1, and therefore its growth potential is enormous, but linked to the projection of solar panels on roofs in the year 2025.

However, this is a very difficult market to predict at this time because it is an extremely diversified market, with enormous potential in terms of demand, without much data in the baseline regarding our objective and with very dissimilar predictions over time.

... THE BASE SOLUTION

The optimal solution is that each PV Off - Grid solution is the one in Figure 4.B.3-1. However, we must consider that many facilities do not have batteries and, those that have, most do not use lithium batteries for their cost vs the popular and economical deep-cycle lead batteries.

It is also true that Off-Grid solutions are proportionally much smaller than On-Grid since the current integration of the electricity network as a basic public service allows it to reach an important part of the national territories. In the case of these solutions, the battery is virtually supported by the same electricity network, whose cost of supplying the hours without light is less than the cost of storing it. With the regulations for selling surpluses to the network, it may be that the model is generated when there is sun for the network and recover when there is no sun buying to the network.

... NUMBERS

The most integrated Off-Grid solution is developed in the poorest countries of Africa and the Middle East (including India) to provide clean, fast and economical energy to those who had never had it before.

In Figure 4.B.3-2, from IEA WEO (2017) shows figures from 10 million (2017) to 70 (2022) million PV off -Grid units in Sub-Saharan African countries and Asia low-development countries. However, the amount of associated GWh reaches a cumulative 3GWh in 2022. This gives a very small unit figure of less than 0.05 KWh per unit, or 50 Wh per unit [33] . This is funded with subsidy funds and they are very small solutions.

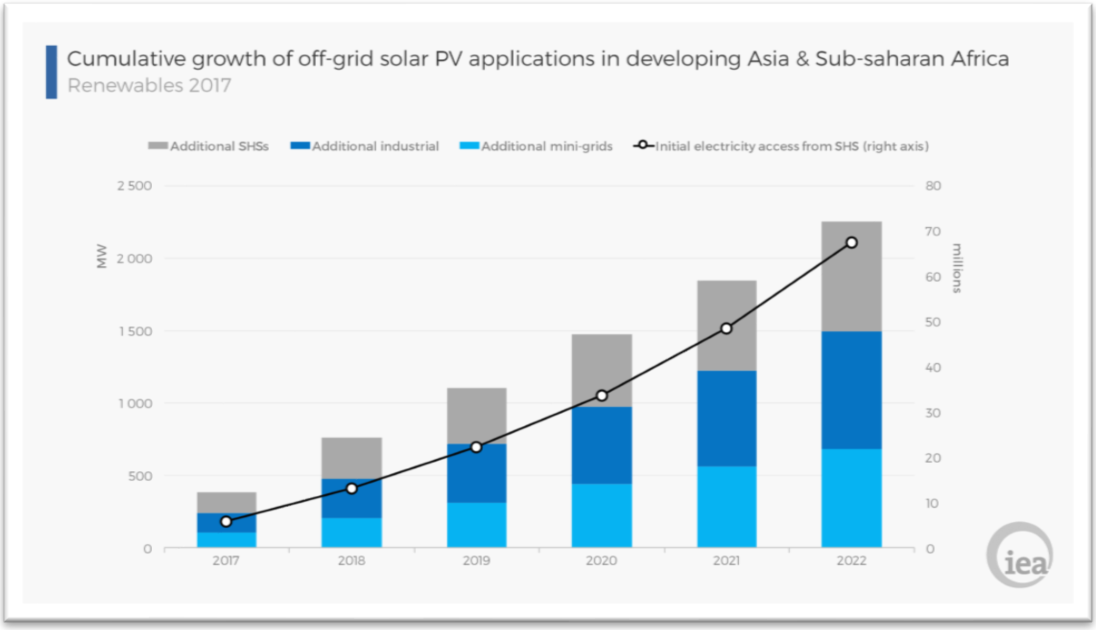


Fig.4. B.3-2 Growth Rise of installation off-grid solutions in Asia and sub- Sahara

33 https://www.iea.org/newsroom/energysnapshots/cumulative-growth-of-off-grid-solar-pv-in-developing-asia-and-sub-saharan-africa.html

It is understandable, since the goal is to democratize access to electricity, although in very small demand stages, but having electric lighting or to charging a cell phone makes the social difference.

Fig. 4.B.3-3 Tesla fix energy blackout in children´s Hospital in Puerto Rico

Interestingly, (fig.4.B.3-3) a similar plan, but in much greater magnitudes, is developed in Puerto Rico, a country that has not been able to recover from the disaster of Hurricane Maria, which impacted the electrical infrastructure of the island last September. The company TESLA is turning the recovery into an opportunity to supply the island with solar panels and batteries as an alternative mechanism to the slow reaction of the devastated electricity company. It is a very important case to follow, because it represents a scale of solution and demand that could have impacts on our projections.

It is important to note that there are popular solutions for sunroofs in industrialized countries such as USA, where 2017 were installed 12 GW[34]. However, how many of these solar roofs have a Lithium battery is another issue. We estimate that, in 2017, less than 1% have Lithium batteries associated with solar roofs.[35]

Finally, there is a market that is not yet sufficiently exploited, which are the batteries used only as backup to homes. It is possible that energy distribution companies may deliver them to households as part of the service (in leases) in exchange for providing the uptime quality levels required by the regulators without investing so much money in the physical distribution networks. This implies units that deliver at least 1-hour autonomy, or about 10 KWh per unit. Climate change is promoting this type of initiatives and several distribution companies are contemplating innovative measures for emergency solutions in the case of increasingly frequent incidents.

[34]https://www.reuters.com/article/us-usa-solar/u-s-solar-installations-to-fall-more-than-expected-in-2017-idUSKBN1E80GZ

[35] TESLA owns SolarCity, the main supplier of solar panels in the USA. The battery unit, optional to the solar roof -Powerwall- adds about US $ 10,000 to the panel cost.

In our opinion, we estimate the typical average value of this unit for backup and temporary storage purposes for photovoltaic panels or wind solutions at 15 KWh/unit.

We have been pessimistic based on the data collected from different sources with respect to the 2017 baseline, which we estimate at just 18,000 equivalent units of this size. The previous case of USA of the year 2017, applying these considerations the calculations indicate that the batteries of Lithium of home for complement of solar roofs would represent hardly 8,000 units in 2017.

However, we are optimistic about the integration of this subcategory since in our opinion we are right at the entry level of this industry. We estimate that a drop in the cost of the battery to less than US $ 150/KWh would bring the cost of the KWh stored to less than US $ 0.15 (considering a operational life of LIB of 1.000 cicles) which is very close to the value of the KWh purchased from the electricity distributor. With this, on-grid solutions become very profitable and are those that we believe have the main option to grow, considering the rate of integration of the electricity network worldwide. The potential market is huge and would reach hundreds of millions of units.

Therefore, we forecast a growth of an order of magnitude to 2020 and an exponential growth very accelerated until 2025, reaching more than 4.5 million units of lithium batteries for stationary solutions in demand side entered in that year.

4.B-4 RESULTS FROM STANDING BATTERIES CATEGORY

As a result of the projection according to the previously mentioned criteria, a summary projection is obtained in the following table:

	register / year (entries)			accumulated Millions on the road >
	2017	2025 e	F:2025/2017	
Number units				aproach
Generation LIB Sol	3	184	61,3	690
Distribution LIB Sol	80	8.761	109,5	23.539
Demand LIB Sol	20.000	5.184.000	259,2	12.308.000
GWH consumed	1	97	159,6	256
Generation LIB Sol	0	18	61,3	69
Distribution LIB Sol	0	1	109,5	2
Demand LIB Sol	0	78	259,2	185
LCE used in Batterie	450	71.791	159,6	
Generation LIB Sol	222	13.600	61,3	
Distribution LIB Sol	6	648	109,5	
Demand LIB Sol	222	57.542	259,2	

Fig.4. B.4-1 Comparison of baseline data (2017) with projection 2025.

The amount of stationary batteries for use in electric power grid applications, from generation to demand would increase from practically zero in 2017 to 97 GWh equivalents that would be installed by the year 2025. This will affect the demand for LCE from just 450

Tons in 2017 to more than 70,000 tons in 2025, concentrated in Off-Grid and On-Grid applications on the demand side of electricity.

In addition, this has much to do with the electrification of homes by the use of electronic devices and, importantly, it would be accelerated by the use of electric vehicles that will entail an "upgrade" of home power standards and with it the possibility to replace some direct demands for gas or other sources by electrical equipment.

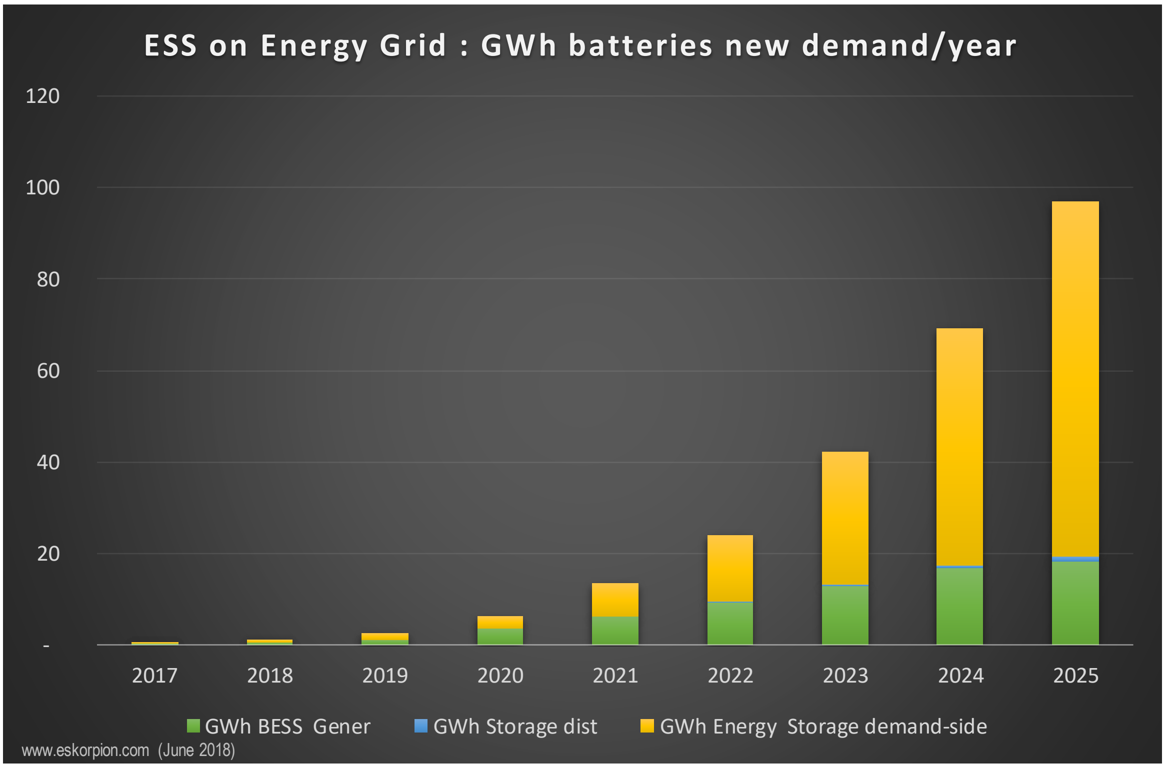


Fig4. B.4-2 Demand for LIB batteries for stationary use in GWh

In the most detailed vision year after year, this demand will be relevant from 2020, where we expect to start an exponential growth caused mainly by new regulations and the overcrowding of applications of variable solar and wind sources at the level of self-generation in industries, homes and small communities.

The use of greater social impact will be the growth of Off-Grid applications in countries with low development and low integration of services, to increase access to electricity in the poorest communities, where the physical network has not yet arrived. This in the cases of India and Africa will have a huge impact on the quality of life for hundreds of millions of people. However, this demand of high social impact will not have the same effect on the demand of batteries, due to the low rate of use of batteries, particularly lithium, in these solutions of primary care level.

However, we estimate that the demand for on-grid self-generation in the most developed countries will have an ever greater integration to the extent that the costs of integrating them are profitable for users. Also, if they are co-financed by the distribution network company to be used as backup. The integration of lithium batteries in on-grid PV solutions in complementary mode will be increased when the cost of a stationary LIB for these purposes is close to US $ 150/KWh.[36].

In relative terms, the relative demand of LIB batteries used in generation, as a reserve of power and improvement of the plant factor of wind or solar farms, will be surpassed by the uses in the energy demand sector.

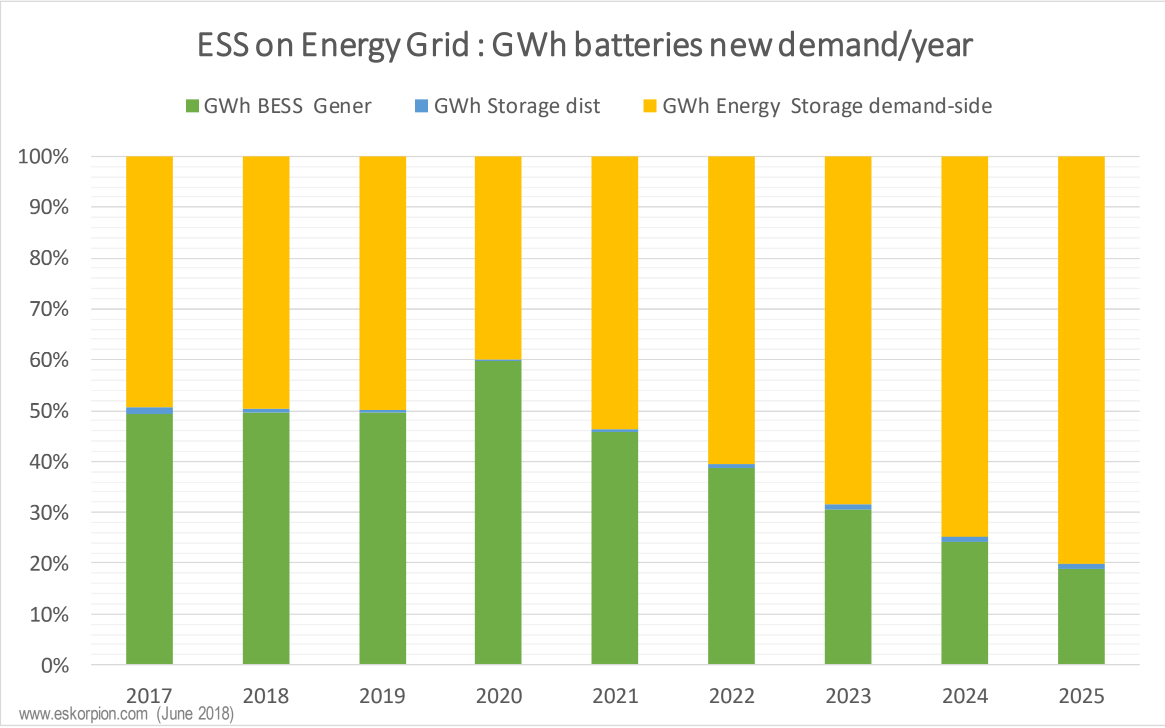


Fig. 4.B.4-3 Proportion of use of batteries for each subcategory of use of stationary batteries

Figure 4.B.4-3 shows that effect graphically. It is important to highlight the potential impact this paradigm shift will have on the business models of the electric companies.

A singular point to highlight and explain is the "anomaly" of the 2020 graph, where there is a jump of energy in LIB associated with generation. The reason is that, in our scenario, a quantum jump in demand was assumed that year of BESS for Generation, which then grows gradually. However, on the demand side, growth is always gradual but sustained, due to the level of scale of the demand weight of the solution, due to its growth units.

[36]Note that in the case of dual use, with the contribution of the distributor for a backup service, a dual-use solution of the LIB could be reached, which could reach the home user very quickly at the mentioned equilibrium cost.

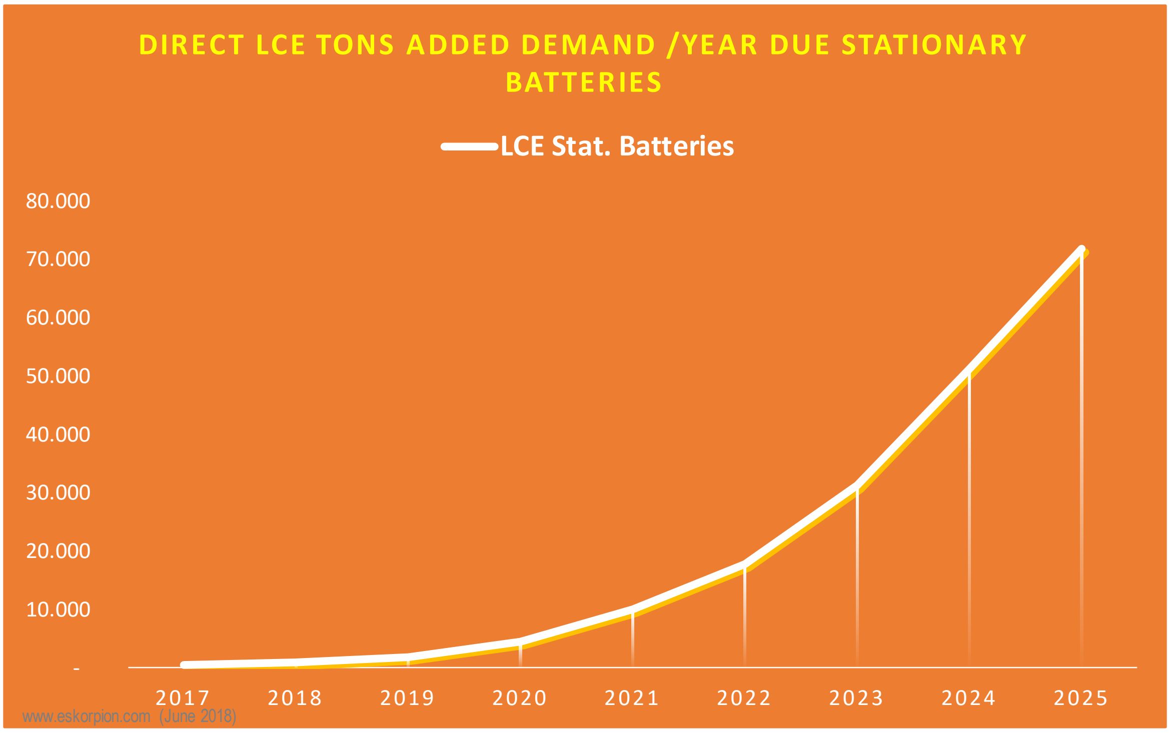


Fig. 4.B.4-4 Demand for Tons of LCE (in Tons) due to demand for stationary batteries

Finally, the effect of exponential growth from 2020 is clearly visible, where the effect on the demand of Lithium will begin to be noticed. In any case, this demand will be a newly emerging demand and therefore, unlike portable devices that are replaced by market reasons in an intense way, this curve maintains a growth of the low starting base and could continue growing up to a decade more because the unmet potential demand is extremely large.

4.B.5 CONTINGENT SCENARIOS, STATIONARY BATTERIES

BLACK SWANS

- **Possible replacement of the Lithium battery by another disruptive technology**

  Already commented previously.

- **Centralized storage services solutions**

  A company that provides the energy storage service at the level of several independent customers of the transmission network, could generate a deformation of the self-generation market. This could possibly be accompanied by the self-generation energy supply of small independent companies, resulting in the possibility of competition in the electricity market at the distribution level. This unthinkable vision occurred in the market of telecommunications monopolies in the 90s where nobody imagined the current scenario 28 years later. Today, the original telecommunications companies offer entertainment using the internet and when fixed telephones disappear, they compete in a hard war to maintain their market share in mobile telephony.

- **Unthinkable use in the generation of electric vehicles**

Electric vehicles could be a source of "unicorns" for generating and transporting energy with the advantage that they have a strong technological base that would allow them to integrate other applications.

GEOPOLITICAL ACTIONS

- **Regulations and climate change**

This category is possibly the most susceptible to be influenced by political decisions of baseline impact. Governments are clear that there is a pending task in the modernization of the way in which electric power is generated and distributed and where they must set tariffs or simply take charge of the service. The possibility that self-generation delivers is enormous in terms of social impact and, therefore, some incentives should be introduced to spread it.

The effect that the transfer of initiative and investment in the transformation of the matrix towards non-conventional renewable energies to the users themselves, including subsidies if necessary, is also relevant.

- **Grid security**

One of the great threats that humanity faces today is the manipulation of software with sophisticated computer viruses to compromise critical systems, even intervening the actuators and generating physical damage.

The need to guarantee energy support at all levels will be more necessary with the rise of electronic systems and information technologies manipulating electricity networks, on which people increasingly depend.

An important challenge of the "Smart-grids" is to guarantee a much more complex security than the fall of trees or physical attacks to the nodes of the old cable networks.

The solution of batteries distributing the support at user level would then be an ideal solution in terms of security and in terms of centralized maintenance services of the physical distribution networks and their multiple components.

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PERSONAL ELECTRONIC DEVICES

4.C.- PERSONAL ELECTRONIC DEVICES CATEGORY

This category mainly analyzes the devices that are massively used and with an implementation that, even if their individual battery consumption is small, their volume is massive and are used by billions of people with a very high renovation rate due to the business model they are in.

We are talking about Smartphones and personal computers, where we have gathered Tablet PC and Laptops.

Of course, there are other categories like cameras, personal backup batteries, Bluetooth devices associated to the main ones, E-watches and, in the future, sensors inserted in clothing (wearables). The latter are not as relevant in terms of implementation or in the use of energy in batteries.

In all of our projections we estimate an annual growth of the unit battery based on the natural increase of the energy density of the cells added to an increase of the energy demanded by the device. That, multiplied by the increase of the device's units, based on demand perceptions determines the increase of the demanded batteries in GWh.

4.C.1 Smartphones Subcategory

The evolution of the smartphones has remained in a very particular business model, where the design and its usability characteristics allow them to be frequently renovated by the users, like fashion items.

This leads to an implementation rate of more than 5 billion units in the world (2017) [37].

Almost 1.7 billion new units were sold in 2017[38].

...Smartphones are the beachhead of humanity's technological evolution, as well as the most revolutionary social change instrument in living memory. Their effects will be part of the history of the coming century and the explanation for how we got there...

[37] https://www.gsma.com/

[38] Many units go to the replacement of the previous model, which is resold, which implies a part of new users, and the oldest ones are discharged

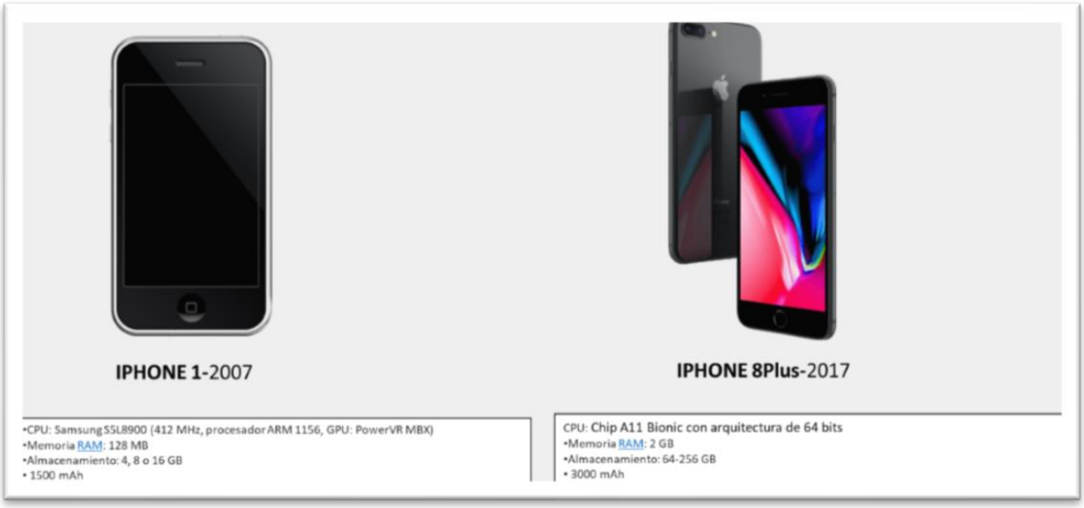

Fig.4. C.1-1Example of the evolution of the key features of Smartphones in 10 years.

En nuestro caso es relevante determinar el elemento clave de este estudio relacionado con la batería de Litio.

While smartphones have evolved spectacularly in the performance and output, increasing in orders of magnitude their process speed, RAM memory and information storage. The battery has only doubled its capacity; from about 4.5 Wh to 10 Wh[39].

This has happened because the manufacturers have invested a lot of money in the energy efficiency of the active electronics, and they have sacrificed the range time for better performance and lower costs, due to the brutal competition in this segment, especially with the arrival of new Chinese models.

In the future, it is possible to think that the unit prices will decrease, as well as the development investment efforts plus performance, that don't add value that might return in profit. It's very possible that there will be a focus on the software and operating systems, with user interaction features, like simultaneous translation, voice recognition, artificial intelligence, interconnection with other devices (IoT), etc.

That is why we believe that while the size of the battery will not increase radically (we hope it reaches 20 Wh by 2025, because of the increase of the energy density of the new chemistry in the cells), we think that the new prices will increase the substitution rate reasonably and the implementation rate marginally.

[39] The tipical nominal voltage is 3,2 V. In other hand there are other devices of upper requirements and use time. Some have 4.500 mAh.

4.C.2 Tablet and Laptops Subcategory

Tablets and laptops have evolved in an unequal manner. On one hand, the first tablets were dedicated to replace books (E-Books) and had a screen that emulated paper.

Later, with the arrival of Apple's IPad, they became a multipurpose device until they fulfill a computer's tasks.

On the other hand, laptops have evolved in terms of their lightness and cost, competing with the tablets' prices.

In fact, the latest models are a combination of both worlds and they are expected to impact the users.

The 2018 model, shown in figure c4.C.2-1, from Microsoft, is a product of relative value of the top layer, but a good example of a trend consolidating quickly.

Tablets and Laptops have a battery, and just like smartphones they haven't increased their capacity. However, the range of the devices has increased a lot, from a couple of hours in 2010 to more than 8 hours today.

This has to do with the energy efficiency achieved mainly in the use of solid-state drive (SSD) instead of a hard drive, which included an engine and a slow data transfer, more efficient processors and screens with a better efficiency than the original technologies. While these SSDs were quite expensive at the beginning, it is possible to predict that they will replace the hard drives in the short-term with similar costs[40].

...Portable computers and tablets will have to change categories due to the accelerated merger seen in these devices, which users really appreciate...

[40]The use of the cloud and off-computer storage services allow having memories with smaller capacity. It is no longer necessary to download 1-2 Gbyte movies; you can watch them online.

Pic 4.C.2-1 Laptop (tablet?) Surface book 2 from Microsoft with 512 G SSD plus 15`

The substitution market of tablets and laptops, which we will analyze together due to their possible technological merger, will reach 300 million units in 2017, only information we will allude of the IDC frame inserted in this paragraph.

Personal Computing Device Forecast, 2017-2022 (shipments in millions)

Product Category	2017 Shipments	2017 Share	2022 Shipments*	2022 Share*	2017-2022 CAGR*
Desktop + DT & Datacenter Workstation	97.8	23.1%	86.0	22.3%	-2.5%
Notebook + Mobile Workstation	161.6	38.2%	162.2	42.1%	0.1%
Detachable Tablet	21.9	5.2%	34.6	9.0%	9.6%
Slate Tablet	141.8	33.5%	102.9	26.7%	-6.2%
Grand Total	**423.2**	**100.0%**	**385.7**	**100.0%**	**-1.8%**
Traditional PC	259.4	61.3%	248.3	64.4%	-0.9%
Traditional PC + Detachable	281.3	66.5%	282.9	73.3%	0.1%
Total Tablet (Slate + Detachable)	163.8	38.7%	137.5	35.6%	-3.4%

Source: IDC Worldwide Quarterly Personal Computing Device Tracker, February 28, 2018

* Forecast data

Since we are considering a 60 Wh battery, oversize for tablets, we lowered this amount to 250 million to compensate the excess of average carried energy.

The additional support is that we understand that tablets, as such, will disappear and will be replaced by the big-screen cell phones categories, which are more and more popular, or by 2x1 laptops, like in figure 4.C.2-1.

We project a marginal growth of units of 3% per year, since the market is quite mature.

4.C.3 Others portable devices subcategory (Gadgets)

Fig. 4.C.3-1 Other portable electronic devices

Indeed, a number of personal-use devices are arriving, from the traditional digital machines to a number of devices defined as Wearables.

Their involvement in society could be very significant, especially in long distance and customized medicine, but from our standpoint, it wouldn't be significant in terms of use of unit battery, although its market potential and low costs allow predicting a very relevant global implementation. In any case, we estimate an impact of 3 GWh from these devices in 2017, reaching 4 GWh in 2025.

4.C-4 RESULTS OF THE PORTABLE ELECTRONIC DEVICES CATEGORY

As a result of the projection according to the previously-mentioned criteria, a baseline criterion is obtained (2017), projection summarized in the following frame:

	Others Portable Devices (base 2017)		
	SPhones	Notes*Table	Others
P(Wh/u)	10	60	
Q (u) Mills	1700	250	
P*Q (GWh)	17	15	3
TOT:GWh	35		

	register / year (entries)			accumulated Millions on the road >
	2017	2025 e	F:2025/2017	
Number units				aproach
Smartphones (mills)	1.700	2.710	1,6	690
Notes&Tablets (mills)	250	317	1,3	23.559
Others				
GWH consumed	35	91	2,6	256
Smartphones (mills)	17	58	3,4	69
Notes&Tablets (mills)	15	28	1,9	2
Others	3	4	1,5	185
LCE used in Batteries (tc	25.900	67.035	2,6	
Generation LIB Sol	12.580	42.980	3,4	
Distribution LIB Sol	11.100	20.775	1,9	
Demand LIB Sol	2.220	3.280	1,5	

Fig.4.C.4-1 Comparison of baseline data (2017) with 2025 projection.

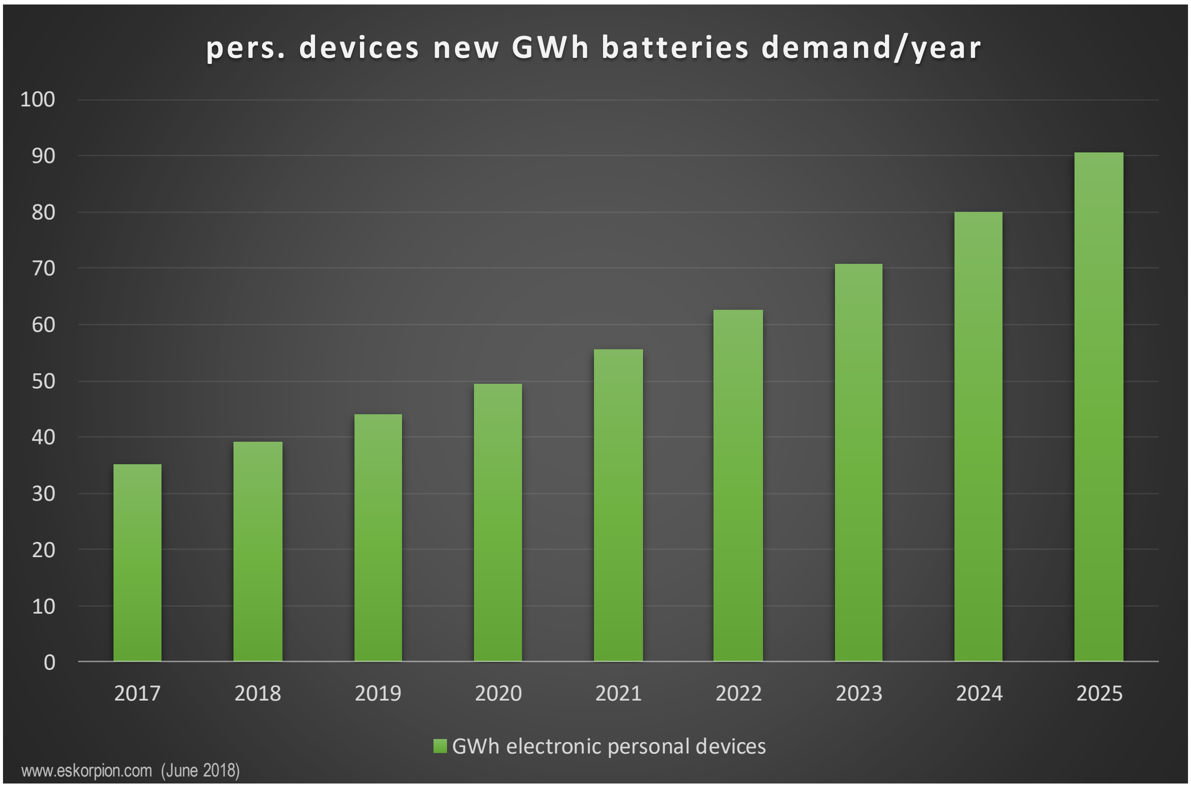

Fig. 4.C.4-2 Demand of LIB Batteries to be used in "personal electronic devices" in GWh

It's clear that the growth of the GWh demand for this subcategory increases practically linearly, which corresponds to a mature market. The growth is due mainly to the higher density of the batteries more than a growth in the amount of devices sold each year.

...The so-called "*personal electronic devices*", that today represent an important component of the LCE demand, would represent a less relevant share because while in full maturity, its potential is smaller, and the market doesn't grow exponentially...

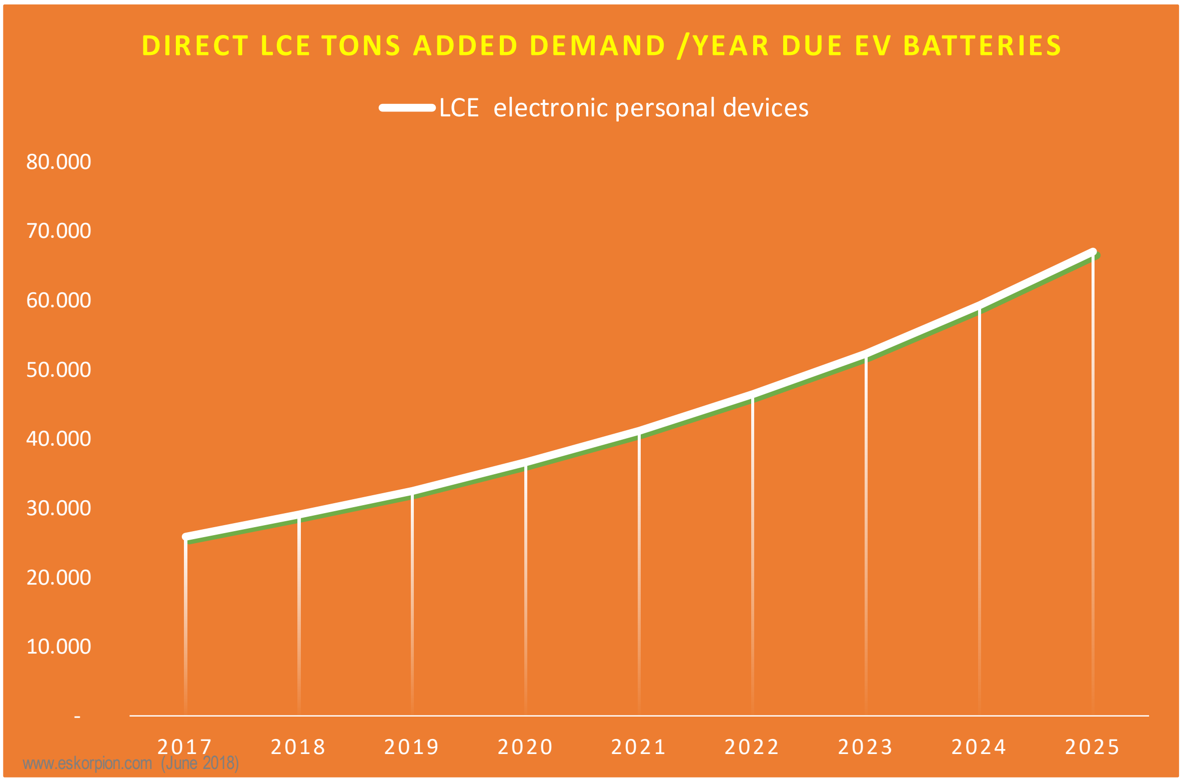

Fig. 4.C.4-3 Demand of LCE tons as a result of the demand of batteries in personal electronic devices.

The effect of the "***personal electronic devices***" in the demand of LCE will represent an 11% of the demand versus 16% of the present.

4.C.5 PERSONAL ELECTRONIC DEVICES INCIDENTAL SCENARIOS

BLACK SWANS

GEOPOLITICAL ACTIONS

From the start, these are markets full of black swans, which is why it's not possible to predict a surprising effect regarding the use of batteries. Likewise, the manufacture market of these equipments is focused in China and we can't see any concern coming from geopolitical pressures of a market deformation. This doesn't rule out any of these phenomena, but the author can't see them.

OTHER APPLICATIONS

4.D.-OTHER APPLICATIONS CATEGORY

The "portability" effect is a growing global phenomenon. Nobody wants to be physically connected to something fix, and while the technology coming from "IOTA", Internet, has already make this concept accessible in the communications field, the same is still trapped in the "EPSILON" networks, Energy.

Lithium batteries have provided this opportunity, so there is a primitive trend, almost essential to the insight of the "homo sapiens", to break free from the chains. That is why it's not absurd to think that the "unplugged" solutions will be part of humanity's future. This chapter shows this trend, still emerging, but we believe that almost philosophically, it will grow stronger. That is why our real question is not whether this will happen, but when and what will be the magnitude of this evolution.

The other applications category comprises the rest of the lithium battery uses that have not been previously classified, but that add up a significant and growing demand. Particularly, the market of electric bikes, electric tools and others such as electric motorcycles, drones, extremely light two and three-wheel vehicles, emergency lightning, batteries for medical systems, military systems, etc.

Many of these products are new and there isn't a lot of information of their markets, not even of a baseline, so we took over their estimation, just like in other similar cases.

4.D.1 E-Bikes Subcategory

E-bikes were born as a precedent of the electric vehicle. The solution was technically excellent, because it was a small engine embedded in a wheel, a small lithium battery, a small inverter and an acceleration control, integrated to the pedaling.

The solution was born in China, where transportation in light vehicles is done by hundreds of millions of people.

In 2017, 33 million E-bikes were sold, where 90% of the market is in China.

Fig.4.D.1-1Ebike

The E-bike has had a low implementation in the rest of the world, despite the fact that the bikes market, which is obviously the market to be replaced, is huge.

In European countries, with a 21 million demand of bikes per year[41], barely 5% of the market is made of electric bikes.

The main apparent reason is that cyclists see the e-bike as a different-category vehicle and because it has an engine, it loses its charm of exercising while moving, a sense that implicitly moves the cyclist.

That is why we don’t believe e-bikes will have an exponential growth, although they will continue to conquer the distant Chinese market, which still has a very small penetration.

An E-bike has a 0.36 KWh battery and it gives it a hybrid-type of autonomy with assisted pedaling (pedelec) of about 20-30 km. This is equal to the energy stored in about 36 smartphones.

[41] www.conebi.eu/

Since the range is still considered limited, which in a bicycle is key, considering the range anxiety is causes, it is possible to foresee in the short term an increase of the autonomy which implies a battery increase, although the number of sales doesn't increase that much.

This leads to the fact that the energy stored in the E-bike sales increases beyond the unit sale, thus projecting an increase between 2017 and 2025 of 1.6 times the amount of units, and 2.4 times the energy incorporated in the battery.

It is also possible to foretell that E-bikes will evolve into another type of light vehicle, which is already happening, but using the same principle and design elements of an E-bike.

4.D.2 Portable electric LIB tools

This subcategory is relative emergent, and it only made sense with the use of the lithium battery. While about 200 million electric tools are sold every year, the huge energy and power demand left portability in the minor league of amateur tools. That is why, professional electric tools were doomed to have wires and be connected to the electrical grid to function.

In construction sites in general, portability generates a great benefit, due to the obvious precariousness of the infrastructure to "plug in" the tools, and to the difficulty of the workers to adapt their use due to the limitations of the plugged-in connecting cable. This in sites with hundreds or thousands of workers, implies a problem that has lasted for many years, since we went from the manual to the electric tools.

The nickel-cadmium batteries used by (and still used massively today) portable tools have limitations because of their memory effect and the power they could allow, and the charging times were quite long (industrial tools discharge all the time). This forces them to have a niche market in the amateur or home use.

That is why, while it is a favorable market for LIBs, the implementation of these batteries has grown a lot, and we estimate that about 6 million units were sold in 2017, mainly in substitution of current wireless tools lines NI-CA Bats[42].

[42]This very conservative estimation was based on the fact that they are still very expensive and only a small percentage of pluggable tools become electric. There isn't a lot of information about it and in any case it is secondary to this study's main problem, which admits these errors.

Fig.4. D.2-1 New model of shared use of LIBs in portable tools (Thanks to Bosh)

The battery unit for these features, according to the specifications, is about 180 Wh, half of an E-bike.

The marketing model has been perfected, separating the battery from the tool in a multipurpose mode, creating the possibility of a parallel market of battery manufacturers for tolls beyond the brand, which is just starting.

We estimate an exponential growth of the demand, both in the increase of new units sold, which is 4 times the baseline of 2025, like the density per battery we estimate will grow 50% in that same period. The market potential is still very important, and we foretell a growing trend of substitution of wired electric tools for portable electric tools.

4.D.3 Other Applications Subcategory

There is a variety of devices being developed and that are flooding the market.

Fig. 4.D.3-1 Other applications with LIB

The combination of an electric engine and a light and strongly dense battery allow the development of different unexpected designs in a conventional engine.

We believe that this world of uses of lithium batteries is just getting started and many things could change for the business models that have these applications.

We believe that this “others” section will have a minimum demand of 5 GWh in 2017, half of the E-bikes, and a conservative growth of 10% per year.

4.D-4 RESULTS OF THE OTHER APPLICATIONS CATEGORY

As a result of the projection according to the previously-mentioned criteria, a baseline criterion is obtained (2017), projection summarized in the following frame:

	Others Devices (base 2017)		
	Ebikes	PT LIB	Others
P(Wh/u)	360	180	
Q (u) Mills	33	6	
P*Q (GWh)	12	1	5
TOT:GWh	18,0		

The following frame summarizes the projections of units, energy and tons of LCE:

	register / year (entries)		
	2017	2025 e	F:2025/2017
Number units			
Ebikes (millions)	33	53	1,6
LIB Portable Power Tools (millions)	6	25	4,2
Others			
GWH consumed	18	45	2,5
Ebikes	12	28	2,4
LIB Portable Power Tools	1	7	6,2
Others	5	11	2,1
LCE used in Batteries (ton)	13.290	33.619	2,5
Ebikes	8.791	20.702	2,4
LIB Portable Power Tools	799	4.986	6,2
Others	3.700	7.931	2,1

Fig.4.D.4-1 Comparison od baseline data (2017) with 2025 projection.

...The applications of the lithium batteries in uses we don't know are unimagined. In the last 5 years a great amount of uses have appeared, mainly in new transportation systems and they've been given traditional uses, like portable tools.

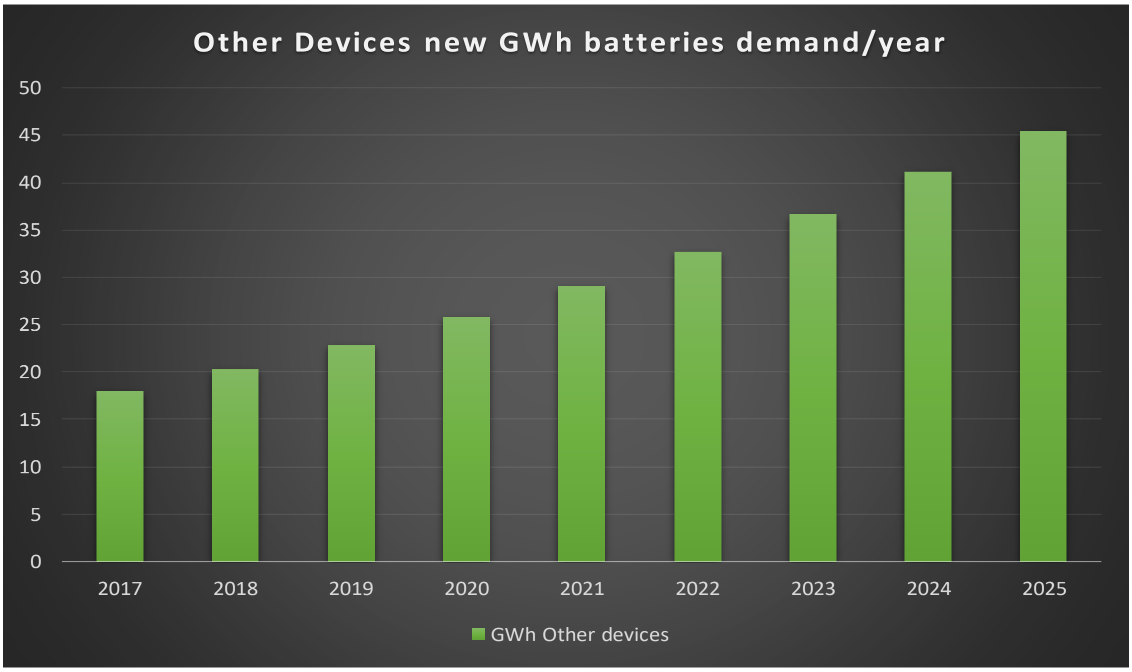

Fig. 4.D.4-2 Demand of LIBs to be used in other devices in GWh

We can see that the growth of the GWh demand in this subcategory increases exponentially with a marginal factor. In our estimation is due to our conservative estimations for not having enough basic information.

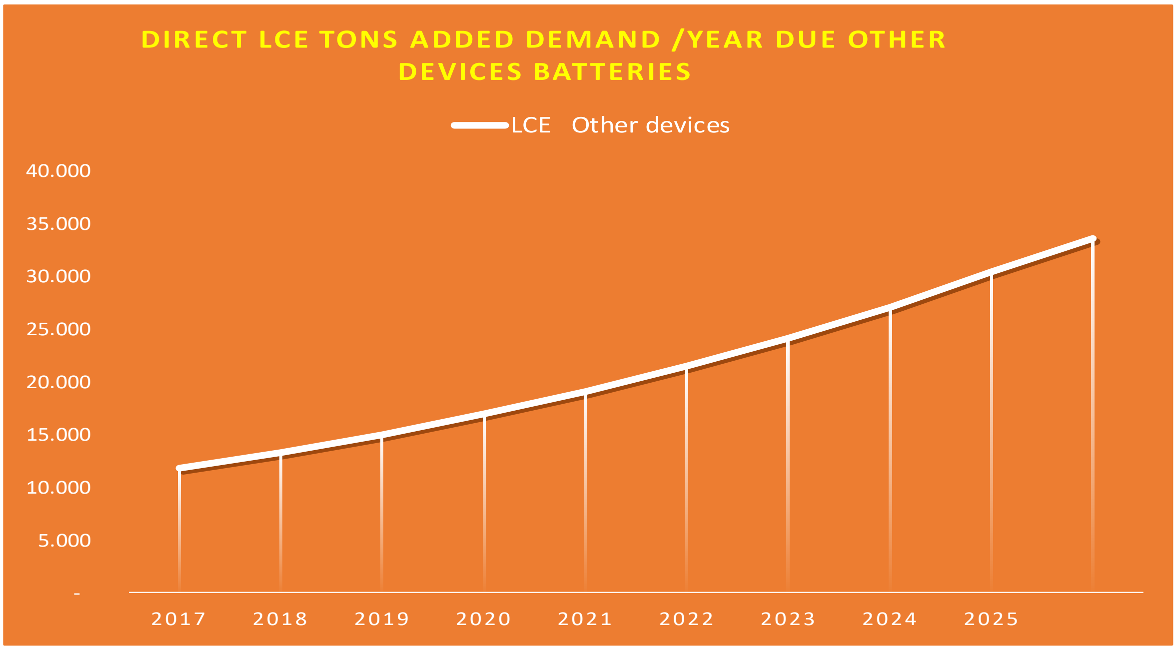

Fig. 4.D.4-3 Demand of Tons of LCEs (in Tons) as a result of the demand of batteries in other devices.

4.D.5OTHER APPLICATIONS INCIDENTAL SCENARIOS

BLACK SWANS

- **Development of an unusual means of transportation in a global business model**

  There are several examples of black swans in shared transportation systems. The arrival of a system that satisfies the city's transportation needs, comfortable and green, can be a significant vector for an unexpected growth of this subcategory, which without a doubt has a lot of surprises.

GEOPOLITICAL ACTIONS

- **Transportation networks and municipal emergency systems are promoting these applications**

  Traffic created by transportation and the need to provide green solutions for this problem generates an opportunity for these solutions that are easy to implement is shared-use systems. Likewise, city lightning, emergency backup for catastrophes allow foreseeing the intervention of local governments in the massive use of these applications or the generation of markets on the basis of large tenders.

5.- COMPOUND ANNUAL GROWTH RATE (GAGR)

$$CAGR = \left(\frac{\text{Ending Value}}{\text{Beginning Value}}\right)^{\left(\frac{1}{\#\text{ of years}}\right)} - 1$$

In all cases a variable and parametric annual growth rate was applied over the base and all subsequent years. Not fix rate was used for period, but year to year special scenarios were assumed (for example the 2020 was assumed a 40% of growth in the sale of EV with respect to 2019 due to the effect "2020" explained) . We estimate it´s a finer prognosis and includes the temporary circumstances of the BDA's stage of evolution[43] . Obviously depends on the detailed analyses and opinions regarded in each one of the chapters and subchapters.

Our methodology was based in the prognosis year to year supported in expert opinion. It was considered a criterion for the growth of P (units) and Q (energy density) supported on baselines (empirical 2016-2017), reference of 5 years ago behavior and expert judgments. We **don´t** expect to adjust a target in 2025 and after re-adjust the annual rate incidentally.

As reference in the table below, we calculate the average annual compound growth rates (GAGR 2017-2025) ex-post the results.

It is clear that our methodology implies that GAGR rates can vary in a relevant way depending on some subperiod and trends to be analyzed.

Most market is based in emerging BDA. It´s possible that rates may appear high as first view, but should be considered the market potential and penetration level, as well the collateral environment. Finally, there is an implicit evolution in battery energy density by industrial and technology development of this industry.

			2017-2025	2017-2020
		Diferents items	**GARG 1**	**GARG 3**
units	Tot	Nro EV (ref a base bev)	29%	39%
	sc	PHEV-100	-100%	
	sc	BEV	37%	
	sc	E-Buses	22%	
GWh	sc	GWh PHEV	-100%	
	sc	GWh BEV	37%	
	sc	GWh Ebuses	22%	
	Tot	GWh EV	30%	41%
units	sc	BESS Gener	67%	
	sc	Storage dist	80%	
	sc	Energy Storage demand-side	100%	
GWh	sc	GWh BESS Gener	67%	
	sc	GWh Storage dist	80%	
	sc	GWh Energy Storage demand-side	100%	
	Tot	GWh stationary battery demand	89%	115%
GWh	sc	GWh electronic personal devices	13%	
	sc	GWh Other devices	12%	
	Tot	GWh totales	26%	31%
LCE Ton	sc	LCE EV	30%	
	sc	LCE Stat. Batteries	89%	
	sc	LCE electronic personal devices	13%	
	sc	LCE Other devices	12%	
	Tot	Lithium Carbonate equivalent (LCE) Ton	18%	17%

Table 5.0 GAGR 2107-2025 y 2020-2025

[43] **BDA: Battery-dependent appliances, como por ej. - Electric Vehicles, Smartphones, PV solar installations, etc**