

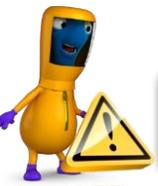


Future Lithium Battery demand and impact on cathode raw materials

Jaime Alée G.
ESK consulting
June 2019

How black swans[☆] will affect the future outlook and how the evidence turns into speculation

conference will be given in Spanish,
but English is used in pages



[☆]**Black Swan concept** it's based in the book of Nassim Nicholas Taleb to nominate 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



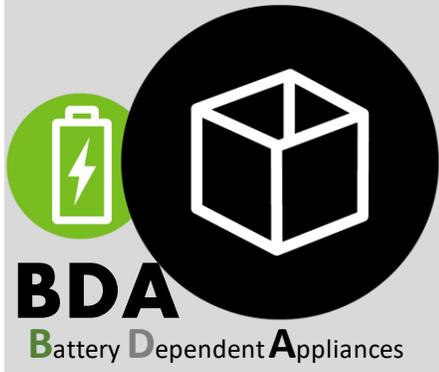
black swan metaphor: Innovation with huge impact but no predicted

- **Incumbents** only predict evolutive innovations based in his domain paradigm.
- **Black swan coming from other domain** (out the box) and other paradigm rules
- **When Black swan appear:** incumbents can not repel the attack, many die.

E.g. Internet (1994), smartphones by Apple (2008), Uber (2017) , etc.



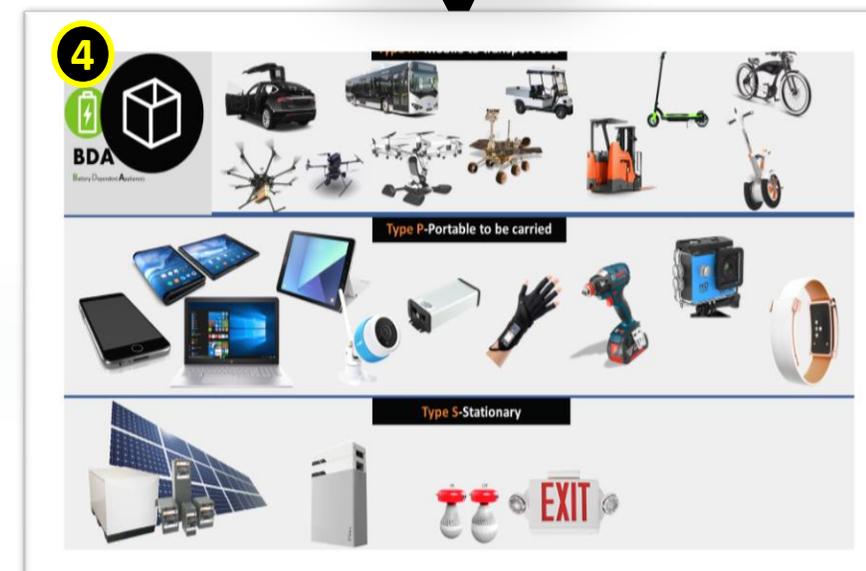
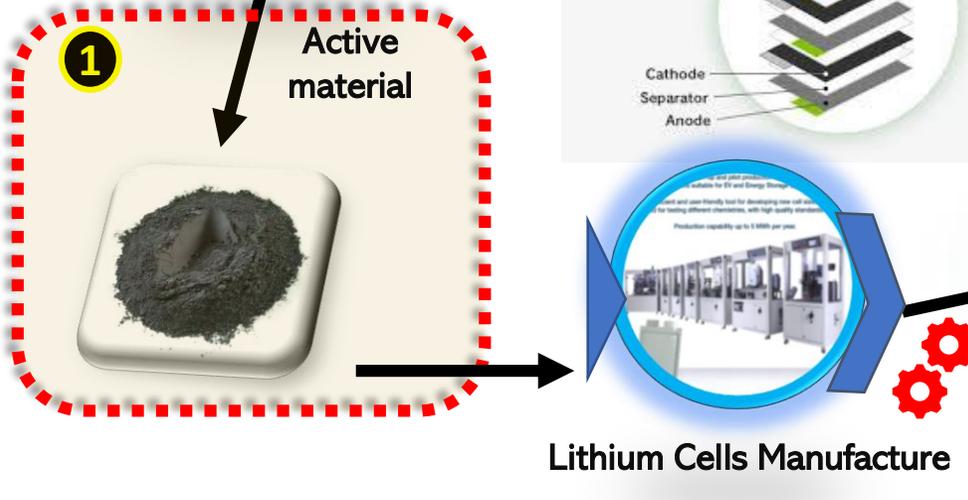
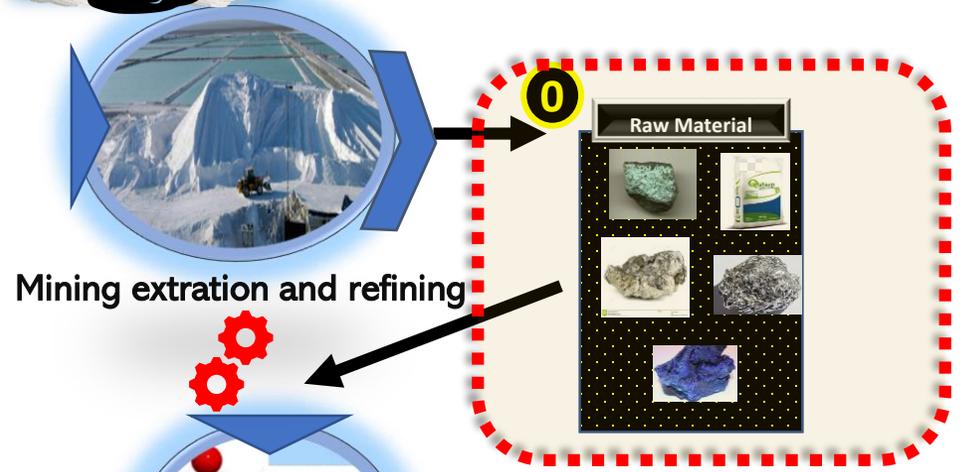
THE STAGE OF LITHIUM BATTERIES ON MAIN STREAM MARKET





BSI
Black swan intelligence

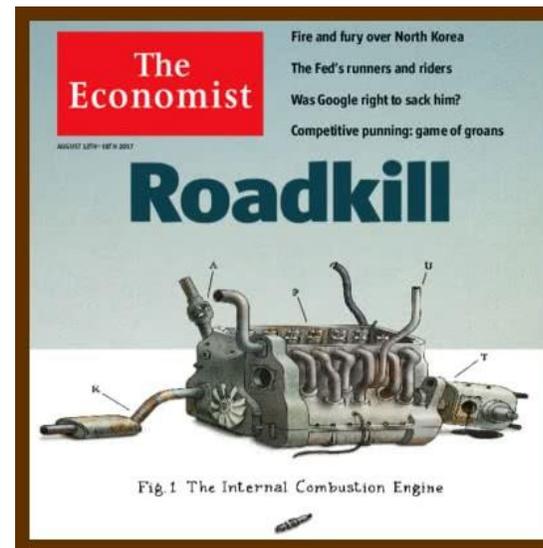
THE LITHIUM BATTERIES VALUE CHAIN-from Upstream to Mainstream





MAINSTREAM MARKET REPRESENT THE MERGE BETWEEN:

- **I**NTERNET (INFORMATION AND TECHNOLOGY AGE •1994→)
- **E**NERGY (CHANGE OF THE PARADIGM AFTER KYOTO CLIMATE CHANGE RECOGNITION •1997→)





MAINSTREAM MARKET REPRESENT THE MERGE BETWEEN:

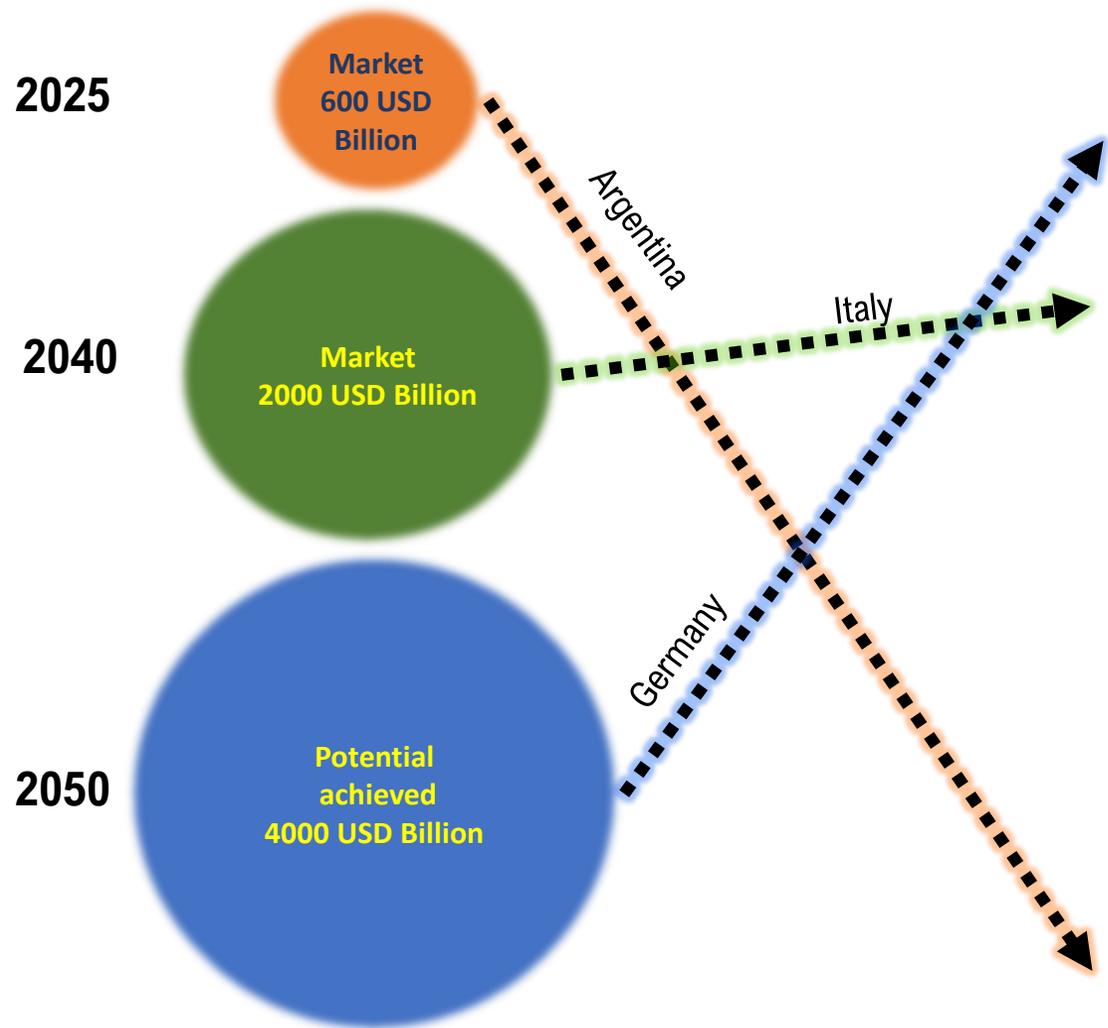
- **I**NTERNET (INFORMATION AND TECHNOLOGY AGE •1994→)
- **E**NERGY (CHANGE OF THE PARADIGM AFTER KYOTO CLIMATE CHANGE RECOGNITION •1997→)

AND WILL IMPACT DEEPLY TWO HUGE&TRADITIONAL INDUSTRIAL SECTORS OF THE WORLD:

- **AUTOMOTIVE INDUSTRY** TOTAL CHANGE OF CHAIN SUPPLY AND OEM ASSOCIATED INDUSTRY
- **ELECTRICITY UTILITY INDUSTRY** NEW AGE BASED IN NON CONVENTIONAL RENEWABLE AND VARIABLE ENERGY



MARKET SIZE CONTEXT IMPACTED BY LITHIUM BATTERIES



GDP in Current Prices World Bank 2018
Billion USD

1	United States	20,494
2	China	13,407
3	Japan	4,972
4	Germany	4,000
5	United Kingdom	2,829
6	France	2,775
7	India	2,717
8	Italy	2,072
9	Brazil	1,868
10	Canada	1,711
11	Russia	1,631
12	Korea	1,619
13	Spain	1,426
14	Australia	1,418
15	Mexico	1,223
16	Indonesia	1,022
17	Netherlands	913
18	Saudi Arabia	782
19	Turkey	766
20	Switzerland	704
21	Taiwan Province of China	589
22	Poland	586
23	Sweden	551
24	Belgium	533
25	Argentina	518
26	Thailand	487

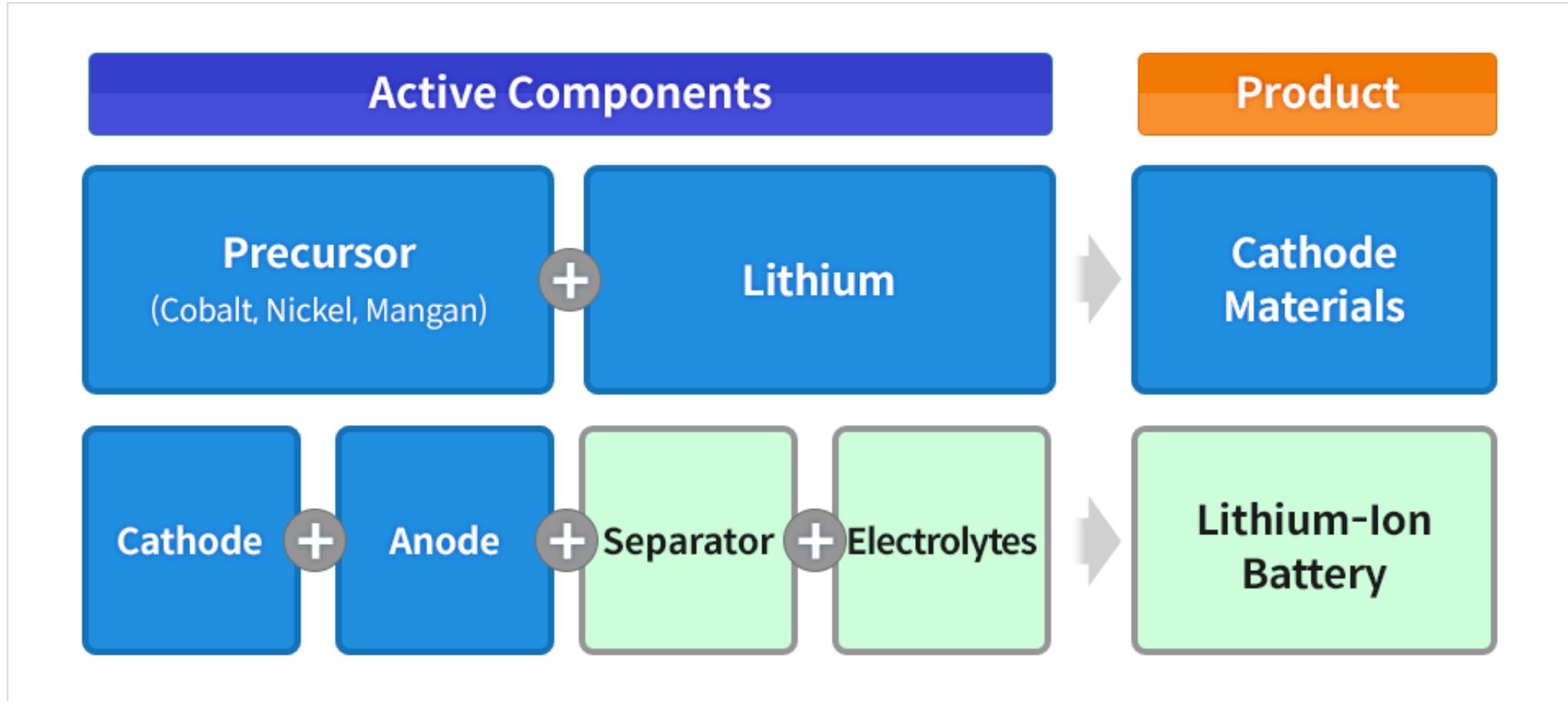
Size of market place disrupted is so large and gradient of adoption so fast that it is foreseeable a huge industrial and geopolitical impact higher of the internet impact on the society



Own preparation based in estimation of base line of automotive market industry and Renewable Energy industry (IEA WEI 2018)



LITHIUM CELL COMPONENTS





TRADE-OFF BETWEEN :

+Energy

+Power

 Charge-discharge rate

-Cost

∞ Cycle life

+ Safety

↓ Environmental impact



THE CURRENT CHALLENGES IN LITHIUM CELLS I+D+i

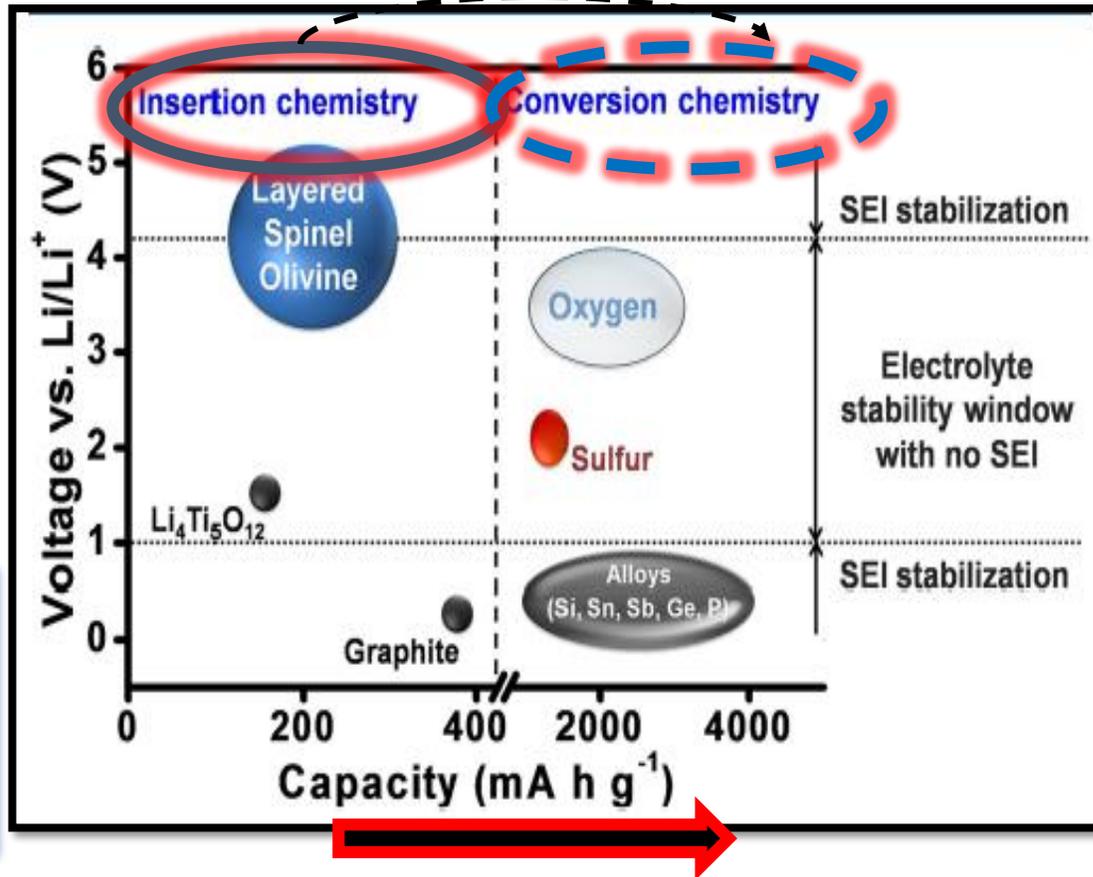
TRADE OFF COMPLICATIONS ON PHYSICALS LIMITS

Optimization of engineering design cell
volumen and save cost in production performance are given an additional push to US\$/KWh and KWh/Kg challenge

Increasing the Cell Voltage.
(it's close to limit Li/Li⁺ electrodes potential)

Increasing the Charge-Storage Capacity in electrodes

FUTURE



The current lithium ion technology based on **insertion-reaction cathodes and anodes** will continue for the foreseeable future, despite their limited energy density dictated by the number of crystallographic sites available as well as the structural and chemical instabilities at deep charge.

Much effort has been made toward **conversion-reaction anodes and cathodes** as they offer up to an **order of magnitude higher capacities** than insertion-reaction electrodes, but their practical viability is met with challenges.

Renewed interest in employing **lithium metal as an anode and replacing liquid electrolytes with a solid electrolyte** has emerged recently as they can offer safer cells with **higher operating voltages and charge-storage capacity**, but only time will reveal their practical viability.

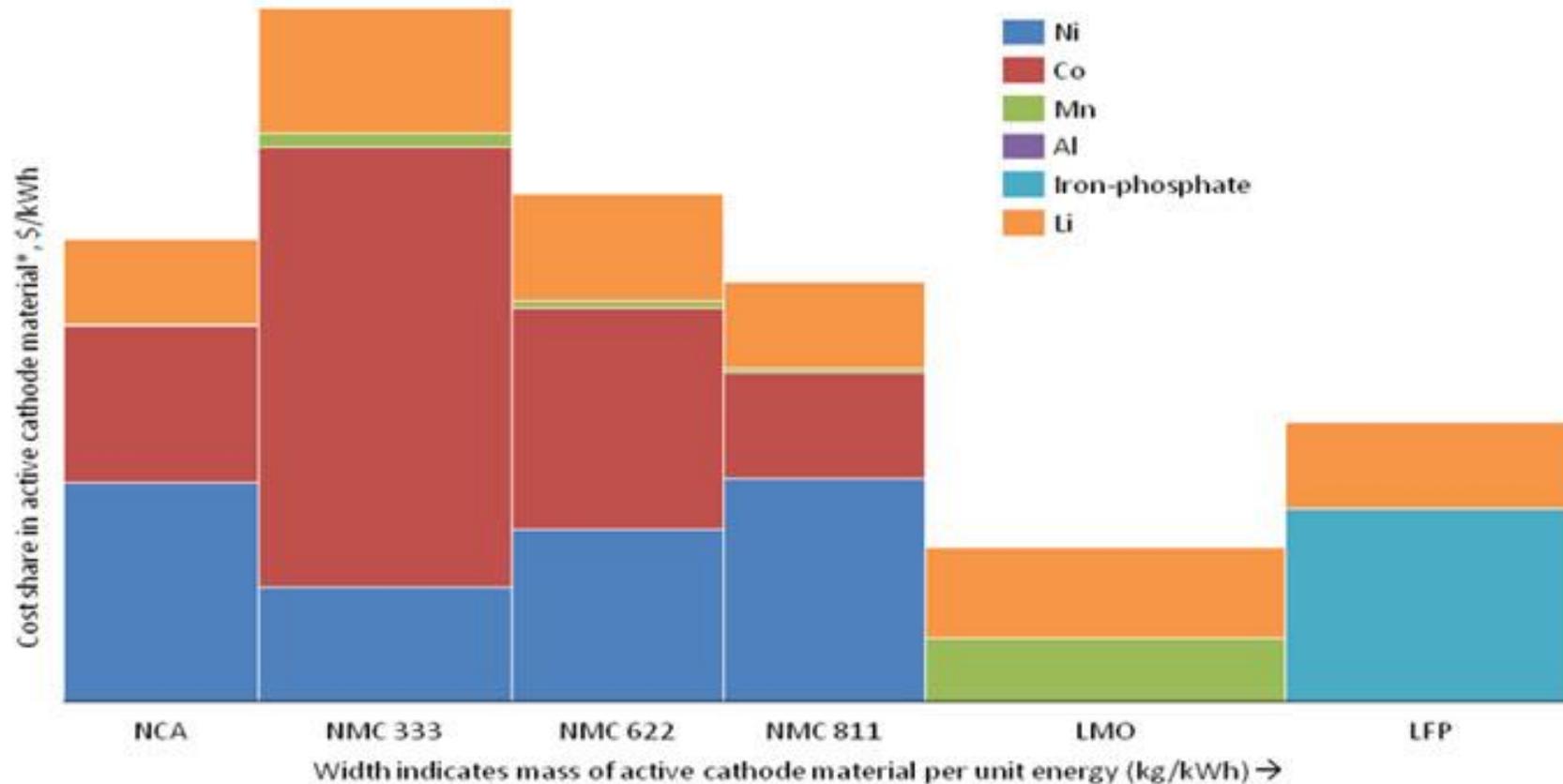
With the challenges encountered with the alternatives (conversion-reaction electrodes, lithium metal, and solid electrolytes), a feasible near-term strategy is to focus on **high-nickel layered oxide cathodes**, liquid electrolytes compatible with and forming stable SEI on both graphite anode and **high-Ni cathodes**, innovations in cell engineering to fabricate thicker electrodes and reduce inactive components, and novel system integration to realize safer, longlife, affordable systems. (see ref)



THE BILL OF MATERIALS (BoM) IN ACTIVE MATERIAL CHEMICALS

Figur

Relative mass (width) Kg/KWh →



↑
Relative cost
US\$/KWh

It's clear that Cobalt and Niquel are the most affected in NMC evolution chemistry and Lithium not be affected in any scenary

*does not include manufacturing cost of active cathode materials but only cost share of precursors

CRU **includes cost of lithium in the electrolyte

<https://www.crugroup.com/knowledge-and-insights/spotlights/new-energy-vehicles-in-india/>



TRENDS OUTLOOK

- **Around 50% of LiB battery market use LFP cathode chemical (Mainly Chinese electromobility industry)**
- **Cobalt clearly are going to reduce the participation because good tendency of NMC811 results, but Nickel will increase the participation.**
- **Precursor materials has alternatives. Lithium it's present in any productive project today**
- **Main customers privilege long term secure supply and quality over prices.**
- **Next generation of Solid State Lithium Batteries could affect some material as metallic lithium in anode and eventual cheaper and simple chemical in Cathode.**
- **About mentioned concern of copper production for EV industry. Context of current production in the world it's around 25 Millions ton (share of EV copper demand in 2040 could demand 3 Million ton, irrelevant)**



Batteries and Lithium reviewed outlook 2018-2026

by ESK

Nasa confirms Mars rover Opportunity is dead

Robot the size of a golf buggy has sent data to Earth for 15 years but fell silent eight months ago and Nasa says mission is complete



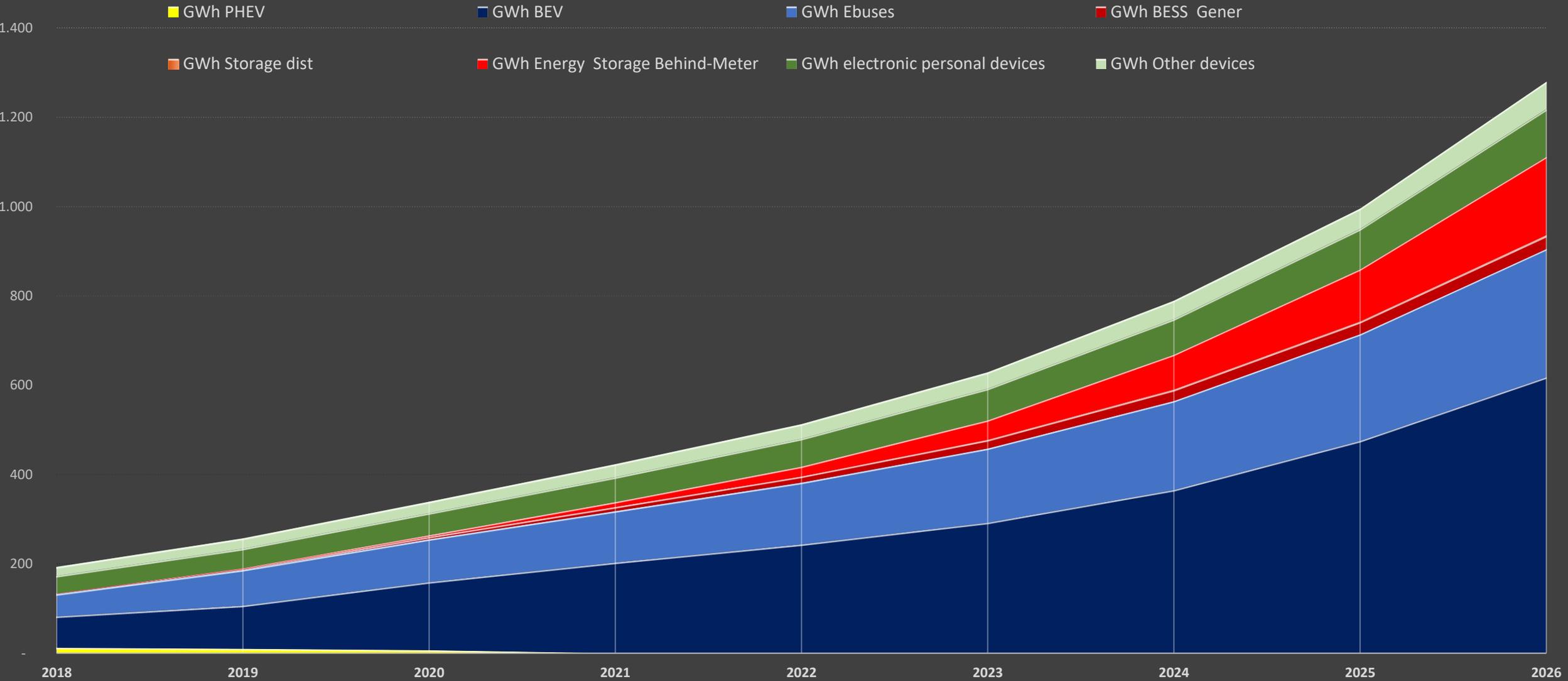
And it's last words were "My batter is low and it's getting dark"



UPDATED OUTLOOK 2018-2026 BATTERY DEMAND (by ESK)

www.eskorpion.com (June 2019)

DEMAND GWh/YEAR DRIVEN BY BDA DEMAND





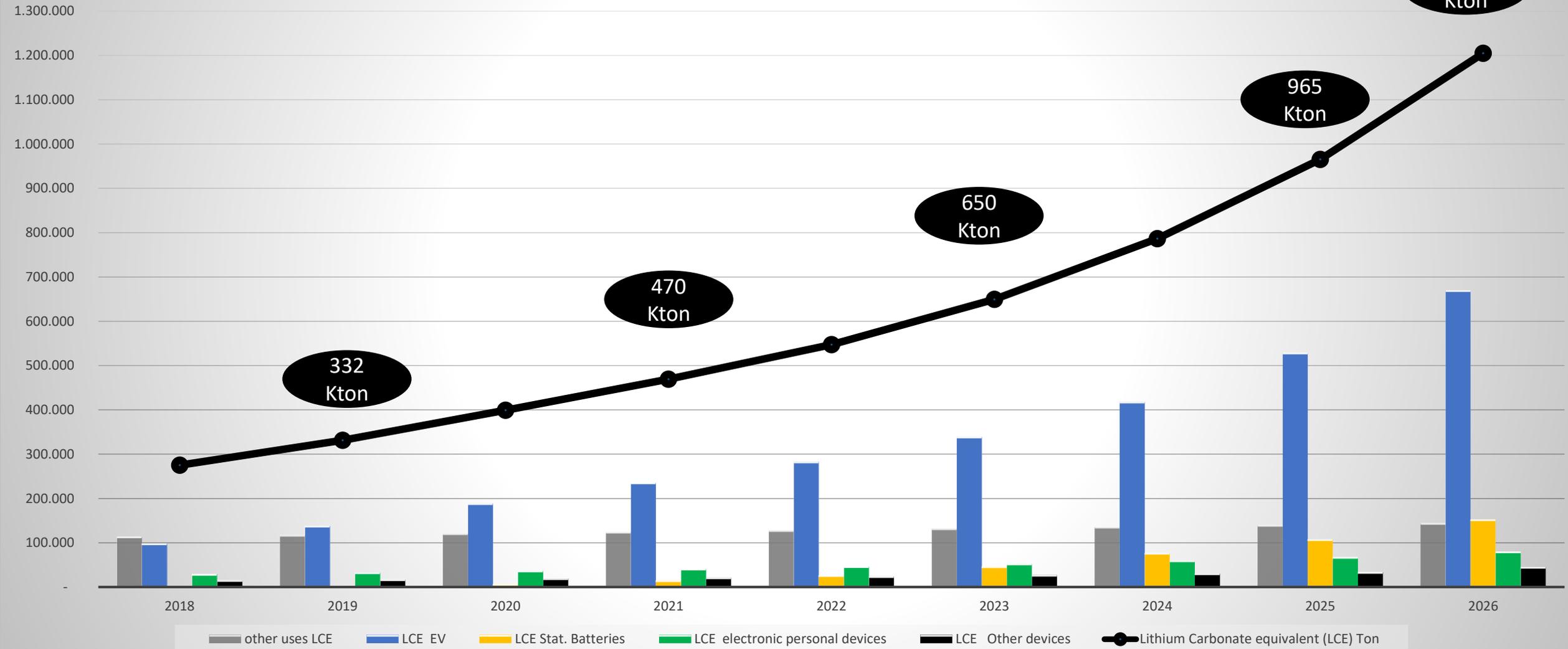
UPDATED OUTLOOK 2018-2026 Lithium LCE Tons (by ESK)

www.eskorpion.com (2019)

TOTAL LCE Tons Outlook 2018-2026

adjusted by inventory stocks

batteries and other use demands





BUT...





GRAY CLOUDS ANNOUNCE A STORM ON THE HORIZON



Global Scale

- Profit after Market Penetration EV (armies are preparing)
- Tech obsolescence and accelerated depreciation of batteries
- Electric utilities companies face the breakdown of paradigms
- Business sustainability of batteries without state subsidies
- Games of Thrones between kingdom of Silicon Valley, kingdom of vertical climbers in utilities and kingdom of incumbents of automotive industry
- Review of traditional business model on a different age
- Merge between tech platforms and transport new platforms

VOLATILITY



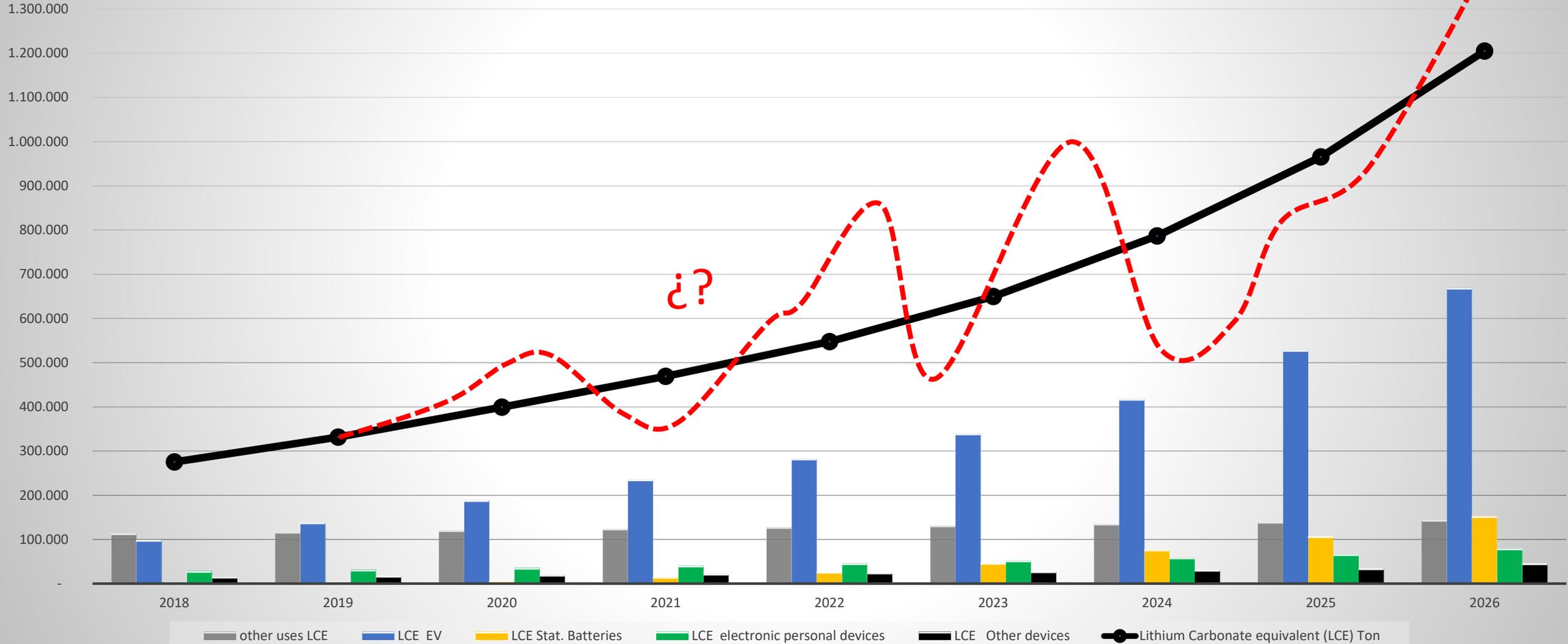


www.eskorpion.com (2019)

TOTAL LCE Tons Outlook 2018-2026

adjusted by inventory stocks

batteries and other use demands



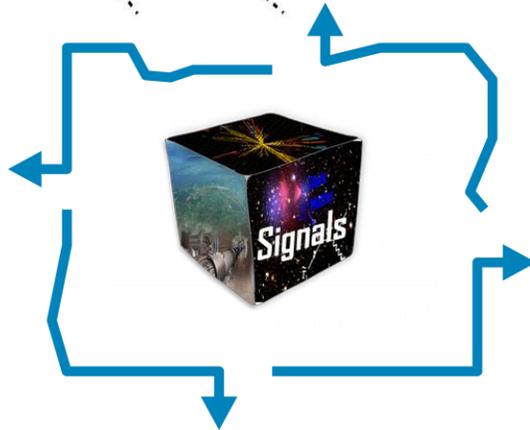


¿IT'S POSSIBLE QUANTIFY THE VOLATILITY?



Forecast based in the fundamentals it's correct

...but try to find rupture innovations need to seek outside the box and go-deep in next level

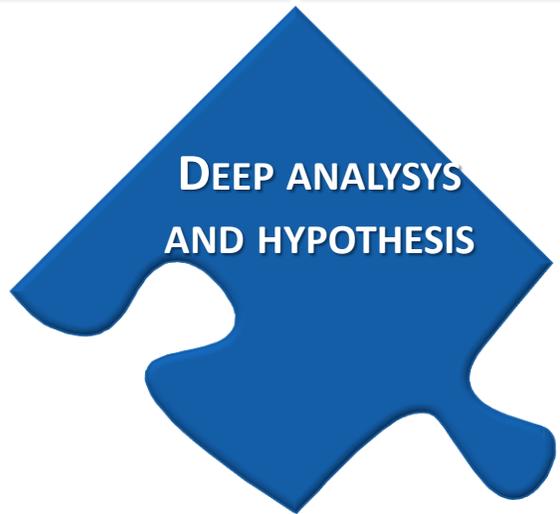




¿IT'S POSSIBLE QUANTIFY THE VOLATILITY?



Evidences
(triple link analysis)
Following the correct
signal on at least
three different
complementary
references

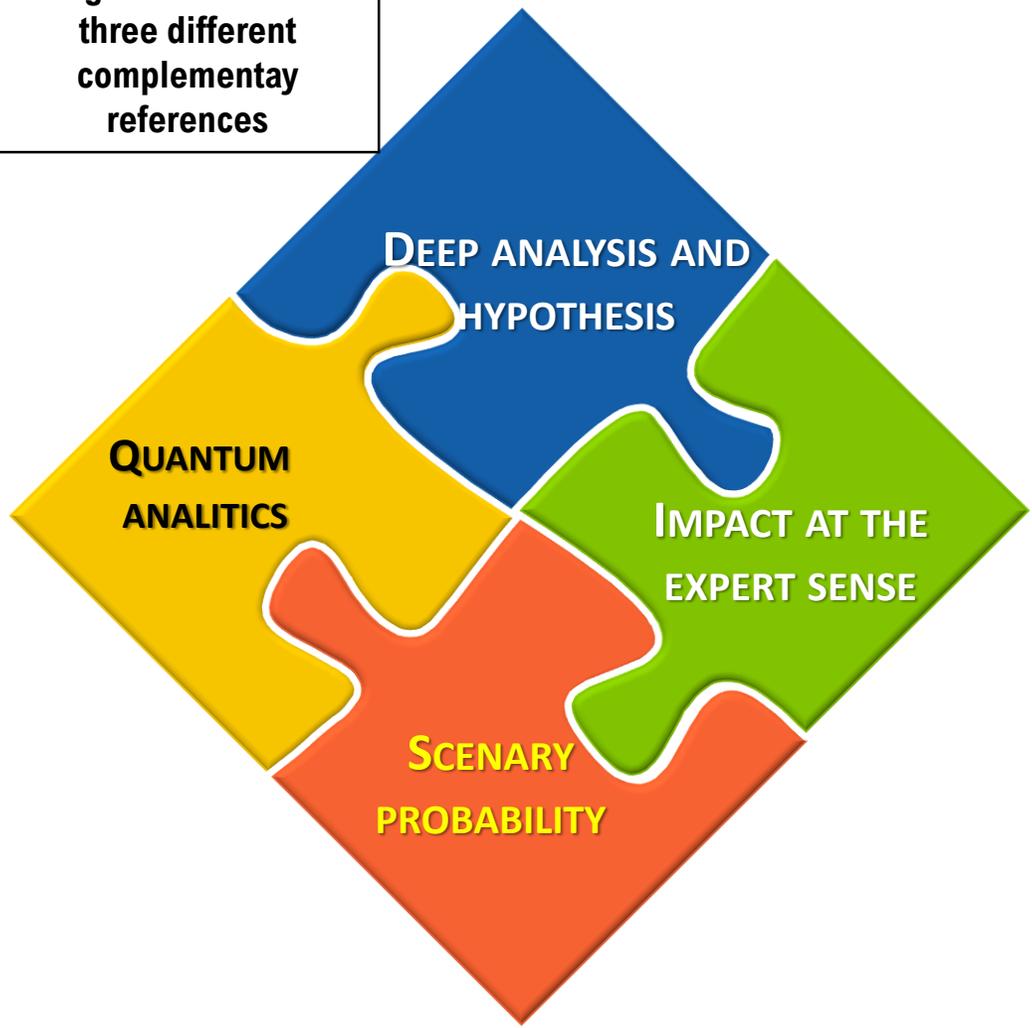




¿IT'S POSSIBLE QUANTIFY THE VOLATILITY?



Evidences
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¿IT'S POSSIBLE QUANTIFY THE VOLATILITY?



Evidences

(triple link analysis)

Following the correct signal on at least three different complementary references



Signals

- **Signal:** India will be **second economy in the world in 10 years** with solid growth over 7% last 10 years and 1 Billion inhabitants.
- **Signal :** **Educational, industrial and technology capabilities** has huge potential
- **Signal:** **Infraestructure is bad** and need huge investment to update to new economy status

Signals análisis, Hypothesis and relevance of Impact

- **Analysis** **India need to provide access to basic services** to the population, including electric services (Only 77% of rural people has electricity services Access, BAD. About 230 Millions people don't have electric services)
- **Hypothesis:** **India will get advantage of solar distributed energy** to quick update of electricity access and will deploy in next years a plan of PV+Battery off grid solutions
- **Impact:** This plan could have a huge impact at global level of **battery chain supply**

Scenary, quantification and prob. approach

Scenary: 50% of rural gap will be cover with solar PV BTM services in next 5 years. That mean around 50 Millions sites customers. If 50% of new solutions will have battery storage of 1KWh. That mean 25 GWh of **non predictable batteries demand in 2025.**

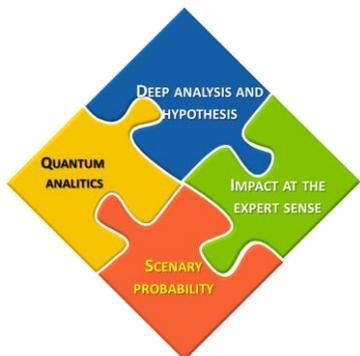
Prob: Over 45%

Case

Geopolitical Black Sawn

Where: **India**

Why: **Something big it's happening**





SOME EXAMPLES OF DEEP ANALYSIS OF ANALYTIC BUSINESS INTELLIGENCE BASED ON UNCERTAIN EVIDENCE





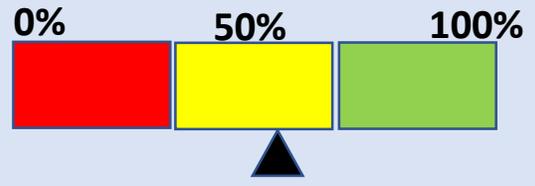
BSI
Black swan intelligence

CANIBALIZATION OF LEAD-ACID BATTERIES

LiB REPLACE THE STANDARD OF STARTED-LIGHT -IGNITION LEAD-ACID BATTERY

Sector Impacted:
WHOLE VEHICLES MARKET
Accumulate park spares
and new vehicles

probability estimation



Y.-Because It's possible and huge market
N.-Too early to fulfill mature production process

;; New sheaper and entry level LiB cells oriented to killing market 12V Lead-acid ignition batteries with prices less than US\$ 80/KWh appear in next three years!!

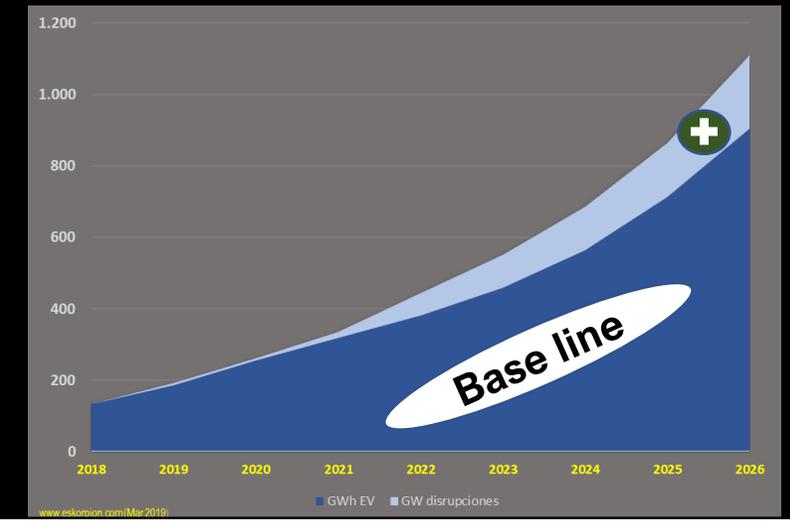
The consequences at 2026

+206 GWh of LiB demand on Electromobility market

Lithium: +174 Kton of LCE demand on the year (567 Kton period accumulated)



TOTAL MARKET EFFECT		
	2025	2026
GWh base	995	1.279
GWh disrupt	151	206
GWh Total	1.146	1.485
LCE Ton base	965.164	1.204.814
LCE Ton Disrupt	127.338	174.319
LCE Ton Total	1.092.502	1.379.133
LCE Ton acum only disrupt effect (2018->)		567.476



GWH demand on electromobility Market



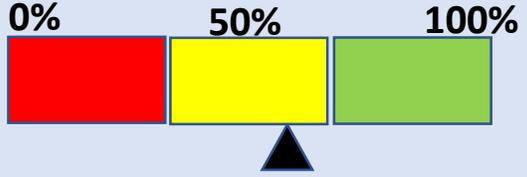
BSI
Black swan intelligence

SUCCESSFUL WAY TO RECYCLE-> 2nd Life

RECYCLING OF USED EV'S BATTERIES COULD BE A SUCCESSFUL PATH OF CIRCULAR ECONOMY DUE TO ACCELERATED TECHNICAL OBSOLESCENCE OF BATTERIES

Sector Impacted:
STATIONARY GRID BATTERIES DEMAND
¿New or used LiB Batteries?

probability estimation



Y.-Accelerated replacement for commercial depreciation by technological evolution gradient
N.-Difficult trade-off between falling prices new versions and potential discount batteries used before end of life

;; Use of reconditioned LiB from electromobility to liquidation prices with less than 4 years of use in order to avoid the accelerated depreciation of the EV as the effect of a new version with a disruptive battery inside !!

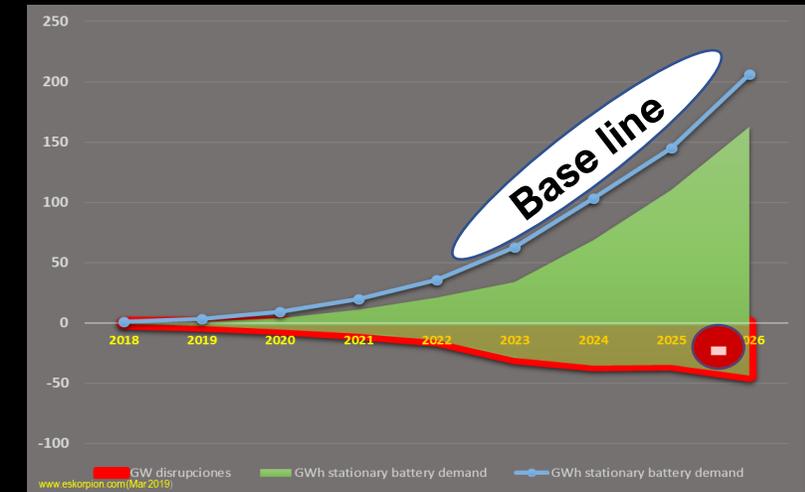
The consequences at 2026

-44 GWh of LiB demand on storage grid market

Lithium: -36 Kton of LCE demand on the year (145 Kton period accumulated)



TOTAL MARKET EFFECT		
	2025	2026
GWh base	995	1.279
GWh disrupt	-35	-44
GWh Total	961	1.235
LCE Ton base	965.164	1.204.814
LCE Ton Disrupt	-28.647	-36.004
LCE Ton Total	936.517	1.168.810
LCE Ton acum only disrupt effect (2018->)		-145.203



GWH demand on Storage Grid Market



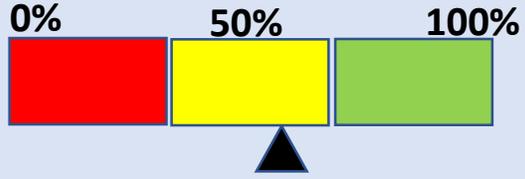
BSI
Black swan intelligence

Integration PV+LiB storage as standard

VERTICAL INTEGRATION ON FACTORY OF SOLAR AND STORAGE AS INTEGRATED SOLUTION ON GRID (BM)

Sector Impacted:
STATIONARY GRID BATTERIES
DEMAND

probability estimation



Y.-new regulations generate incentives in complementary storage businesses
 N.-Difficulty of compensating the investment in batteries with falling energy prices in the grid

!! Scale of vertical integration PV+Storage in Behind the Meter (BTM) solutions !!

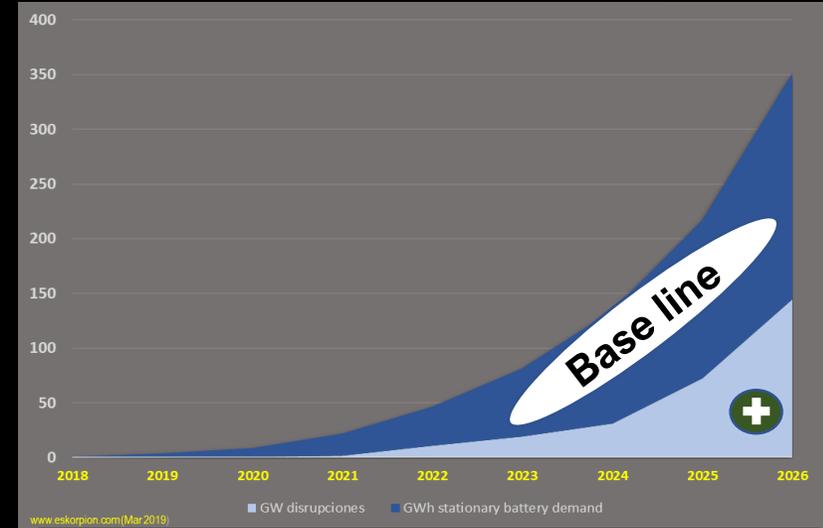
The consequences at 2026

+144 GWh of LiB demand on storage grid market

Lithium +139 Kton of LCE demand on the year (270 Kton period accumulated)



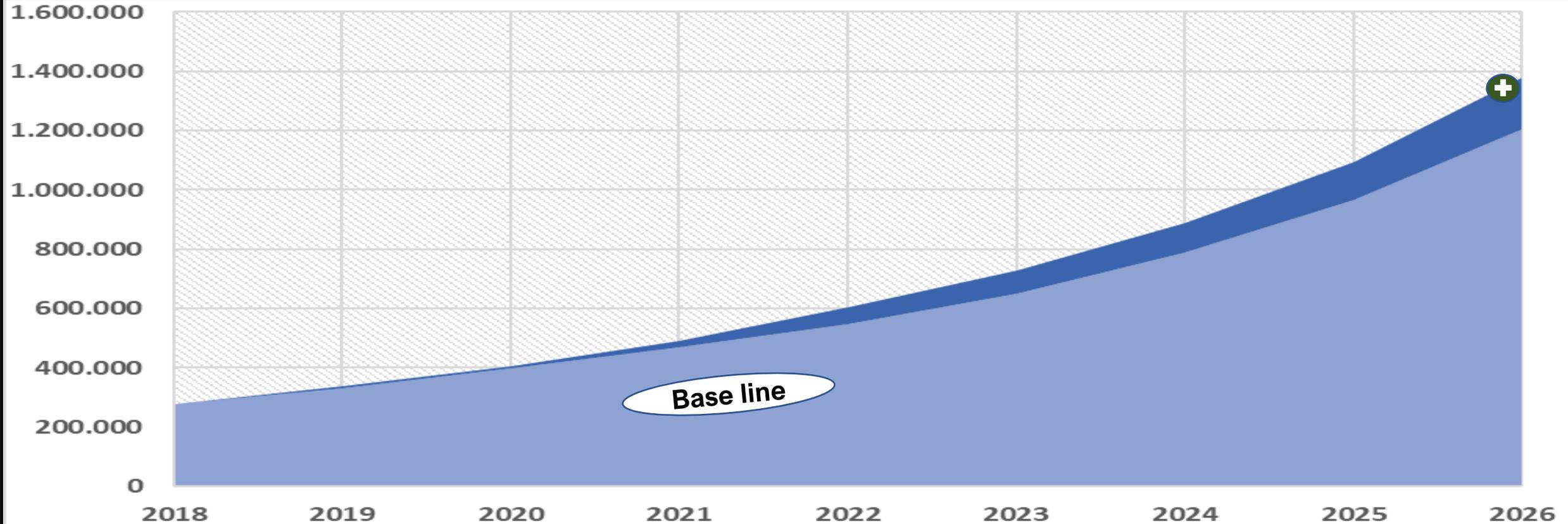
TOTAL MARKET EFFECT		
	2025	2026
GWh base	995	1.279
GWh disrupt	73	144
GWh Total	1.068	1.424
LCE Ton base	965.164	1.204.814
LCE Ton Disrupt	69.677	138.788
LCE Ton Total	1.034.841	1.343.602
LCE Ton acum only disrupt effect (2018->)		270.533



GWh demand on Storage Grid Market



COMBINATED EFFECT OVER LITHIUM MKT



Global Lithium Market effect

■ Lithium Carbonate equivalent (LCE) Ton

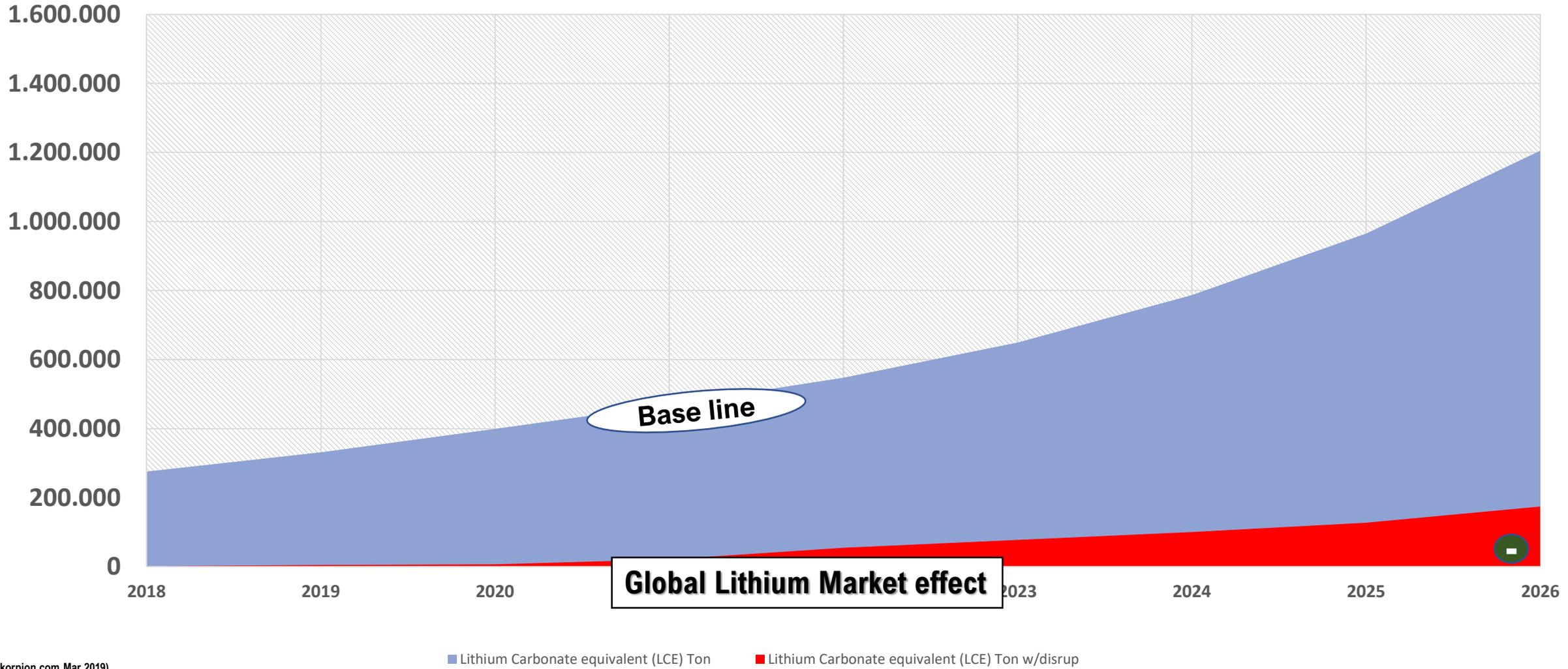
■ Lithium Carbonate equivalent (LCE) Ton w/disrup

www.eskorpion.com Mar 2019)

black swan 1



COMBINATED EFFECT OVER LITHIUM MKT



www.eskorpion.com Mar 2019)

■ Lithium Carbonate equivalent (LCE) Ton

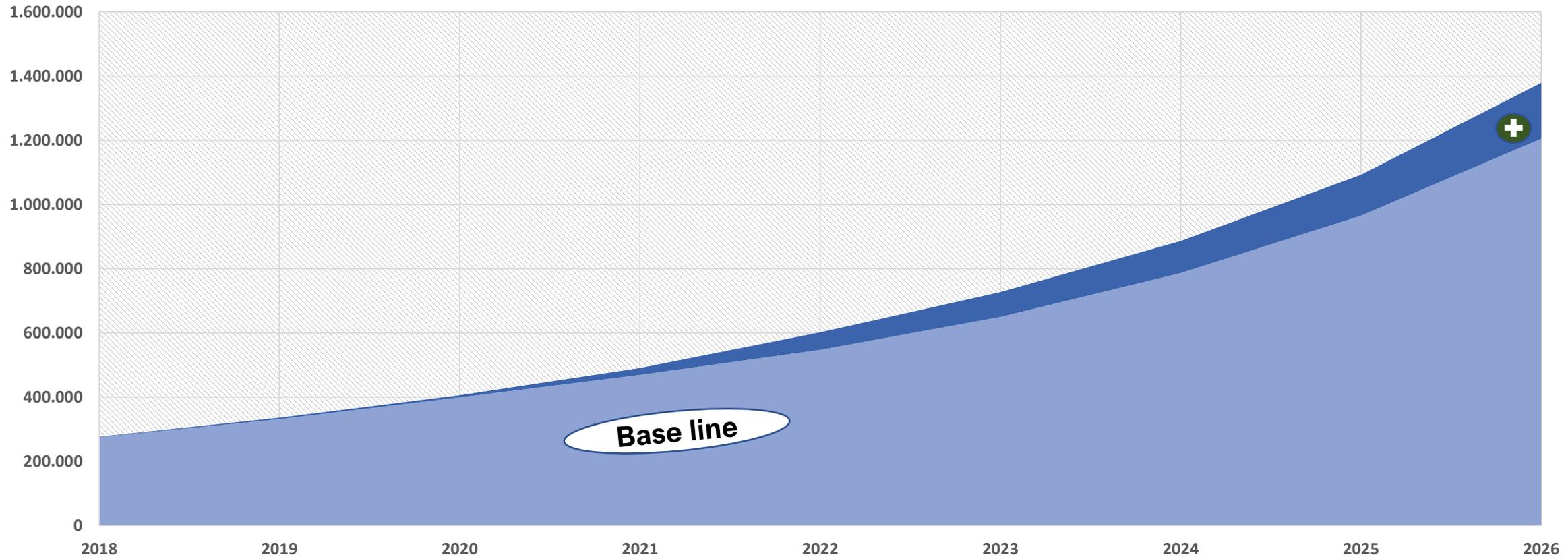
■ Lithium Carbonate equivalent (LCE) Ton w/disrup

black swan 2



COMBINATED EFFECT OVER LITHIUM MKT

ALL EFFECTS HAPPENED AS WAS EVENTUAL PREDICTED



Global Lithium Market effect

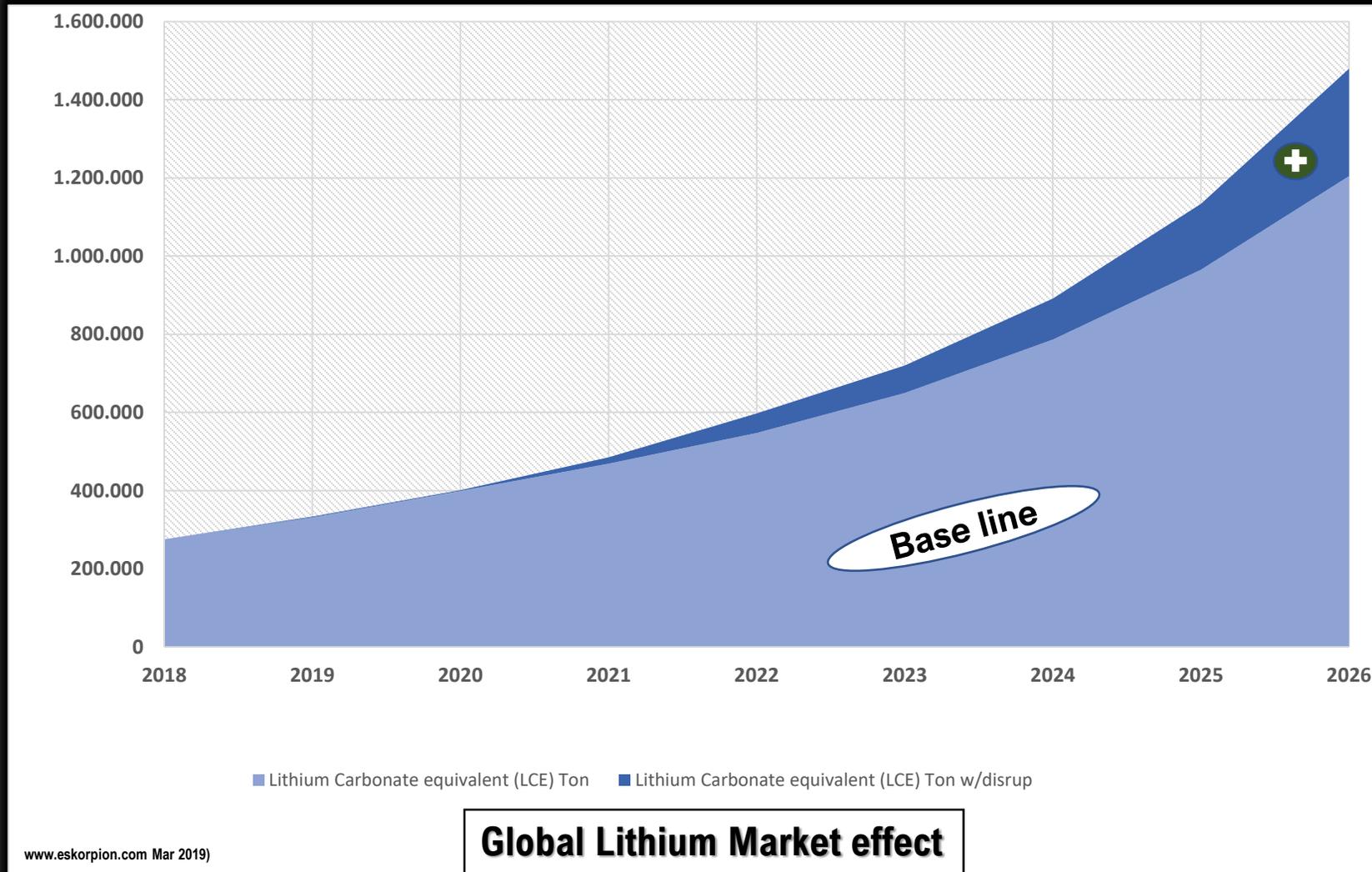
■ Lithium Carbonate equivalent (LCE) Ton ■ Lithium Carbonate equivalent (LCE) Ton w/disrup

www.eskorpion.com Mar 2019)

black swan 3



COMBINATED EFFECT OVER LITHIUM MKT (eventual black swan effect)



TOTAL MARKET EFFECT		
	2025	2026
GWh base	995	1.279
GWh disrupt	188	307
GWh Total	1.184	1.586
LCE Ton base	965.164	1.204.814
LCE Ton Disrupt	168.367	274.342
LCE Ton Total	1.133.532	1.479.156
LCE Ton acum only disrupt effect (2018->)		690.046

**2026 -> + 274 Kton LCE
Over base line**

**+ 700 Kton LCE acumm period 2018-2026
underestimated in forecast**



6 CONCLUSIONS

- 1. METHODOLOGIES OF BUSINESS INTELLIGENCE, MUST BE IMPROVED DUE TO MULTIPLE MARKET ABNORMALITIES.**
- 2. THE IMPACT OF THE BLACK SWAN WILL BE MUCH GREATER AND MORE ACCELERATED.**
- 3. SOME PEOPLE WITH TOO MUCH POLITICAL OR BUSINESS ASSETS AND SOCIAL NETWORKS ADDICTS , CAN BE HIGHER DANGEROUS THAN CORPORATIVE COMPANY BIG MISTAKES.**
- 4. TYPE "TITANIC" COMPANIES WILL FACE ICEBERGS, INEVITABLY.**
- 5. QUESTION: ¿COULD THE LITHIUM COMPANIES PROMOTE SOME BLACK SWANS?**

And ...

- 6. IT IS NECESSARY TO IMPROVE THE FILTERS AT ANY COST, ONLY THUS IT WILL BE POSSIBLE TO DISTINGUISH THE BLACK HOLE, (... AND BLACK HOLES EXIST)**



64 ANTENNAS AT 5,500 MTS OF ALTITUD, US\$ 2 BILLIONS INVESTMENT OF GLOBAL CONSORSIUM OF COUNTRIES AGENCIES. ...THAT WAS NECESSARY TO DEVELOP “ALMA”, THE LARGEST RADIO TELESCOPE IN THE WORLD



ALMA, WAS THE KEY INSTRUMENT IN THE GLOBAL ARRAY TO “SEE” THE FIRST BLACKHOLE IN HUMANITY STORY just one month ago **-TO LOOK BEHIND THE SIGNALS-**



**ALMA[☆] RADIO TELESCOPE IT'S LOCATED VERY CLOSE OF LITHIUM MINES
WHERE YOU WILL GO IN NORTH OF CHILE THIS WEEK ..**

**... ENJOY THE TRIP
Its a signal..**

([☆]) Atacama Large Millimeter/submillimeter Array