NEW LITHIUM PRODUCTION IN EUROPE

A report covering the need for lithium for use in lithium-ion batteries in Europe & how this can be achieved

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1. THE NEED FOR LITHIUM

1.1 Critical Li Ion Battery Materials

A typical lithium-ion battery for an EV car weighs 450 Kg and contains 8 Kg lithium, 40 kg nickel, 14 kg cobalt and 20 kg manganese for the cathode (these are often referred to as 'NCM' batteries) and 60 kg graphite for the anode. Lithium iron phosphate batteries (referred to as LFP) are a cheaper alternative which do not contain cobalt or nickel but have lower energy density and a shorter driving range.

Copper is used in Li ion batteries to conduct the current. Aluminium foil provides a high surface area for lithium & cobalt to work, giving a higher charge density (more power in a smaller size).

Lithium for NCM batteries is supplied as the hydroxide whilst that for LFP batteries is supplied as the carbonate. The key material in each case is lithium due to its high charge density.

1.2 The Move to EV's

Europe's has committed to net zero greenhouse gas emissions by 2050. Currently fuel combustion across the road transport sector accounts for 20% of EU total greenhouse gas emissions, hence the move from internal combustion engines (ICEs) to electric vehicles (EVs)

Transport and Environment lifecycle assessments show that the average fully electric (BEV) vehicle is more than 3 X cleaner than an equivalent petrol car, with 69% less emissions

The European Parliament is pushing to ban the sale of new internal combustion engine cars by 2035, meaning the demand for battery materials will dramatically increase.

The IEA reports that lithium demand for EVs accounted for 85% of the total in 2023

1.3 Lithium Requirement

The European Geothermal Energy Council has forecast that 200,000 tonnes per annum LCE (lithium carbonate equivalent, 99.5%) will be needed in the EU for electric vehicles by 2025 and 400,000 tpa by 2028.

According to Benchmark Mineral Intelligence, by 2030 Europe will be the second largest consumer accounting for 25% of global consumption, with China the highest at 40%.

The British Geological Society (BGS) estimate the UK will have an annual requirement by 2030 for 15,000mt of LCE (considerably less than estimated new production from Cornwall over the next few years) and the Faraday Institution have calculated this will be 80,000mt by 2035 and 135,000mt by 2040.

Global LCE in 2020 was 400,000mt and may reach 2.0 million mt by 2030 (Bloomberg New Energy Finance).

1.4 Current Supply

Currently all supplies of battery grade lithium used in Europe are imported, mostly from Chile. The only commercial lithium in Europe is mined by MOTA Ceramic Solutions in Portugal and sold entirely into ceramics.

According to Reuters, China accounts for nearly two thirds of global lithium processing, 75% of cobalt processing, 95% of manganese capacity and nearly 100% of graphite. Europe is desperate to reduce this dependency.

Whilst there is no LCE lithium manufacture in Europe, there is a healthy and growing industry for EV battery manufacture, with 38 giga factories operating in the EU, including 12 in Germany and 5 in France.

The UK has a few smaller producers such as Ultramax and PMBL and plans are underway to build 3 giga factories: Tata will build near to Bridgewater in Somerset to supply their Jaguar Landrover plants; Envision (in which Nissan has a 20% stake) will build in Sunderland and EVE Energy (Chinese) at Coventry.

Mobility Portal estimate that Europe will open 250 new factories by 2033

2. LITHIUM MANUFACTURE AND GLOBAL RESERVES

2.1 Production

Lithium can be produced by mining lithium bearing minerals in hard rock, salar brines and geothermal brines and by recycling end of life batteries.

Very approximate costs per tonne (USD) for LCE are as follows: Geothermal $4000 (Vulcan, Germany); Spodumene $5,500; Brines $6,400; Lepidolite $10,000 (Chinese mines)

2.2 Reserves and Global Mining

USGS calculates that there are 88 million tonnes of lithium globally, of which 22 million is economically viable to mine, which is enough to manufacture batteries for 2.8 billion EVs (there are 1.47 billion vehicles globally as of 2023)

In 2022 most lithium was extracted by 3 countries: Australia accounting for 47% by hard rock mining of spodumene, Chile 26% by evaporation from salar brines and China 17% from spodumene, lepidolite & salar brines

3. HARD ROCK MINING

Source rock includes spodumene and petalite in pegmatite, lepidolite & zinnwaldite mica in pegmatites and granites and Jadarite

Whilst not hard rock as such, another source worth mentioning is hectorite, a clay mineral which under investigation in the US, Peru and elsewhere.

The lithium content and chemical formula for some major lithium bearing minerals is shown in Table 1. These minerals occur in natural rock deposits associated with other minerals, for example spodumene and micas are often present in pegmatites and granites which contain larger percentages of quartz & feldspar.

Spodumene contains the highest lithium content and represents the lion’s share of global hard rock mining, supplying more than half of the world’s lithium. Australia is the biggest supplier, much of which is refined to 5 - 6% Li and shipped to China for further refining to LCE. Two lithium carbonate / lithium hydroxide plants have been built in Australia with a third under construction.

Table 1: Some of the Main Lithium Bearing Minerals

Mineral	% Li_2O	% Li	Chemical Formula
Spodumene	8.0	3.7	$Li\,Al\,Si_2\,O_6$
Amblygonite	7.4	3.4	$(Li, Na)\,Al\,(PO_4)\,(F, OH)$
Petalite	4.9	2.3	$Li\,Al\,Si_4\,O_{10}$
Lepidolite Mica	7.7	3.6	$K\,(Li, Al)_3\,(Al, Si, Rb)_4\,O_{10}\,(F, OH)_2$
Zinnwaldite Mica	2 - 4	0.9 – 1.8	$K\,Li\,Al\,(Al, Si_3)_{10}\,(OH, F)_2$
Jadarite	7.3	3.4	$Li\,Na\,Si\,B_3\,O_7\,(OH)$

Lepidolite is mined in China with ~ 85,000 tonnes produced in 2022, accounting for 12% of global production (Zihao Li, Fastmarkets, May 2023). However, CATL have recently announced the closure of their Jiangxi mine which will negatively impact Chinese lithium carbonate production by some 8%

To date there is no evidence of commercial production from zinnwaldite

Lithium chemicals are produced from hard rock sources in two stages:

i. Beneficiation of spodumene to a 5 – 6% Li_2O concentrate or petalite to a 3 – 4% is achieved by flotation and/or dense media separation. Lepidolite is beneficiated by flotation and zinnwaldite by magnetic separation.

ii. In the next hydrometallurgical steps concentrates are calcined at ~ 1000 – 1100 deg C to produce a more reactive crystal form which is followed by leaching with conc. sulphuric acid at high temperature, to yield lithium sulphate. This can be converted to the carbonate by adding soda ash (which removes magnesium impurities) and then to the hydroxide, normally the preferred option, by adding lime.

Lepidolite and zinnwaldite contain fluorine which is driven off during calcining, hence scrubbers are required to collect this and prevent escape to the atmosphere.

Lepidico, an Australian company with lithium mining prospects in Namibia, have developed a procedure to refine Li micas which includes froth flotation & magnetic separation but does not require a calcining stage.

Extracting lithium from Jadarite follows similar procedures, requiring very high volumes of acid for leaching.

CO_2 emissions for hard rock mining are higher than all the other processes with calcining and heating & neutralising of leach solutions the biggest problems.

% Yield for all hard rock projects is low with 80 - 90% of the raw ore designated as “waste”. In some cases commercial by products can be generated. Brownfield sites such as those in Cornwall, Cinovec and Zinnwald have the advantage of old disused mines for waste disposal. The largest source of waste material is mine overburden which ranges from 2 – 20 times the mass of ore extracted and suitable disposal sites need to be identified in the early project development phase.

4. SOLAR EVAPORATION OF BRINES

Brine found beneath salt flats is pumped into evaporation ponds, occupying vast areas, where it undergoes a minimum year-long process to achieve sufficient lithium concentration.

The ‘Lithium Triangle’, covering parts of Argentina, Bolivia and Chile, hosts ~ 50% of global lithium resources

Huge volumes of water are required at @ 2 million liters per tonne, 90% of which is lost in evaporation

Lithium carbonate is manufactured rather than the hydroxide.

This traditional approach is being challenged by new Direct Lithium Extraction (DLE) procedures which use resins to specifically capture Li ions using ion exchange technology. Production time is much shorter but water requirement is still high. There are now 4 commercial sites in operation, 1 in Argentina and 3 in China.

Evaporation Ponds in the Atacama Desert

5. GEOTHERMAL

There are many examples of geothermal energy projects where high temperature brine is pumped to the surface and converted into electricity &/or used for low-cost heating, helping with the transition from fossil fuels. In cases where the brine contains elevated lithium-ion concentrations (typically 100–400 mg/L), lithium can be extracted by Direct Lithium Extraction (DLE) techniques. These processes do not pollute hence geothermal lithium is zero carbon. It also requires much smaller land space.

6. RECYCLING

End of Life (EOL) lithium-ion batteries can be processed to recover lithium, cobalt, manganese, and nickel.

6.1 Why Recycle

Placing used Li ion batteries into landfill is not a safe option as some constituents are highly toxic, particularly the electrolyte and binders, both of which are fluorinated and can react to form hydrogen fluoride. Cobalt and nickel compounds are also mutagens and respiratory sensitisers.

Recycling isn't just a sustainable option providing circularity, it is also a profitable way to recover precious metals, hence the surge in recycling capacity across the world with approx. 200 businesses recycling 1 million tpa of End-of-Life batteries (EOL)

Recycling facilities can now recover nearly all of the cobalt and nickel and over 80% of the lithium from used batteries and manufacturing scrap left over from battery production. Recyclers plan to resell those metals for a price nearly competitive with that of mined materials. Aluminium, copper, and graphite can also be recovered.

6.2 Legislation

The European Commission for energy, climate change and environment introduced new legislation for batteries in August 2023 as described below, which will require new circular partnerships between battery manufacturers and recycling companies. The UK is likely to mirror these regulations

i. From 2026 recycling must achieve 65% by weight, increasing to 70% by 2031

ii. Minimum recycling of specific critical minerals will come into effect from 2028 and increase from 2031:

Table 3: EU Minimum Recycling of Battery Metals

Date	Lithium	Cobalt	Nickel	Copper
2028	50%	90%	90%	90%
2031	80%	95%	95%	95%

iii. From 2030 batteries will need to contain a minimum recycled content of critical minerals

Table 4: Minimum Content Recycled Metals in New Batteries

Date	Lithium	Cobalt	Nickel
2030	4%	12%	4%
2035	10%	20%	12%

According to Fraunhofer Institute, in 2040 as much as 40% of the cobalt and more than 15% of the lithium, nickel and copper required for battery production in Europe could be from recycled sources.

6.3 Commercial Recycling Procedures

Simplified recycling procedures can vary as shown below:

1. Pyrometallurgical

   i. Initial heating at 140 -500 C to drive off volatile electrolytes and solvents is followed by high temperature pyrolysis at ~ 1500 C in a furnace. Lithium is separated in a lightweight slag and cobalt, copper and nickel are separated in an alloy.

   ii. Cobalt, copper and nickel are recovered by chemical processing. In some cases lithium is also recovered.

2. Hydrometallurgical

   i. EOL batteries are discharged to prevent risk of toxic gases or explosion

   ii. Mechanical pre -treatment using hammer mills, granulators and blade crushers etc to separate plastic, polymers, aluminum and copper from the cathode & anode. The cathode and anode component is a shiny black metallic mixture, known as "Black Mass" (the black colour is due to graphite from the anode)

   iii. Solvent extraction and precipitation, often at high temperatures. Research is underway to minimize CO_2 footprint and omit the high temperature procedures

Black mass is often sold into China as it is cheaper to export, process and re-import rather than refine domestically.

Pyrometallurgical is energy intensive with a high CO_2 footprint hence most R & D is focused on hydrometallurgical or new techniques. As an example, Kyburz Switzerland have developed direct technology that doesn't shred the cells or produce black mass but carefully strips materials from intact electrodes so that they retain the exact composition needed for a new battery

Huge corporations such as BASF, Johnson Mathey and Eramet are planning new recycling ventures in Europe

6.4 Feed Source for Recycling

The main source of feed material for recycling companies is currently from battery manufacturing scrap (giga factories typically produce 8 – 10% scrap). As the use of EVs increases and vehicles are retired, this will become the dominant source. The Advanced Propulsion Centre estimates that there will be 28,000 tonnes of used battery cells by 2030 and 235,000 t by 2040, in the UK alone

7. OTHER PRODUCTION ROUTES FOR LITHIUM

Other processes are possible, for example recovery from clay minerals such as hectorite or smectites and from seawater but not yet proven to be economically viable.

Lithium Americas are investigating lithium recovery from smectites in Nevada and a new venture between King Abdullah University of Science and Technology (KAUST) & Saudi mining company Ma'aden will use seawater, sourced from the Red Sea.

8. LCE PRICING

Predictions for an increase in demand and high prices throughout 2022 prompted a huge effort in Europe and the rest of the world to produce more lithium. Prices peaked at over $79,637/t in December 2022, driven by high demand for EVs.

In 2023, the rush of investment in lithium production resulted in a global surge in supply and at the same time EV sales dropped, causing lithium prices to fall by > 80%: lithium carbonate averaged $72,000/t in 2022 but by late October 2024 is just $10,036/t.

The recent level of mergers and acquisitions in the lithium space (Pilbara Minerals $600m purchase of Latin Resources assets in Brazil and the $10bn takeover of Arcadium Lithium by Rio Tinto) suggests lithium demand will increase strongly with a corresponding increase in lithium prices.

Shanghai Metals Market stated in May 2024 "experts anticipate a recovery in lithium prices, averaging around $30,000/t to 2030". No one expects a return to the highs of 2022.

9. NEW LITHIUM PROJECTS IN EUROPE

Projects include hard rock, geothermal and recycling. There are no solar evaporation projects.

Output at the commencement of new projects is not likely to reach the expected annual output for a period of time whilst commissioning is completed and gremlins are sorted out.

Most companies involved have received both public and private funding

Many companies already have offtake agreements in place. There is a general trend for car makers such as VW (PowerCo), Stellantis, Tesla, Jaguar-Land Rover to vertically integrate through buying directly from the mines to secure affordable raw materials supply. As they sell directly to end-consumers, they are very ESG-conscious and impose this onto the mining companies.

Whilst efforts were made to include all the projects under development, the list is not guaranteed exhaustive

10 HARD ROCK PROJECTS

Most of the lithium granites currently being investigated were formed during the Hercynian (also known as Variscan) orogeny in Devonian to Carboniferous times. Those in Cornwall, Zinnwald and Cinovec are chemically similar with enrichment in Li, F, Rb, Cs, Nb, Ta, Sn, W, Sc and U

Commercial by products such as quartz & feldspar and rubidium and caesium will be manufactured by companies fortunate enough to have the right geology and chemistry. Feldspar is a by-product from pegmatites and over the next few years, as spodumene projects are brought into production, there could be as much as 1mtpa new production available within Europe, for which the major markets are ceramics and glass

Some projects have been fiercely protested by local people concerned about changes to the landscape and pollution. The jadarite projects in Serbia and Bosnia Herzegovia and the Savannah spodumene project in Portugal are good examples. The mining companies countered this by preparing plans to conserve the environment, communicated by on-site meetings. The Cornish, German and Czech projects are situated on brown field sites and have not been subjected to the same problems.

The Imerys project at Beauvoir in France is a good example of how steps were taken at the beginning to minimise impact on the eco system with a capex of ~ 1 bn euros to include underground mining, disposal of most tailings underground, an electric fleet and the use of the French low-carbon electricity. CO_2 emissions are expected to be less than 50% of typical hard rock operations.

The projects below are listed according to location and roughly in date order for expected commercial production.

10.1 Finland

Sibanye – Stillwater
SS intend to produce 15,000 tpa lithium hydroxide over 16 years, from 5 spodumene pegmatite mines in the Keliber region of W. Finland. Analcime (Na zeolite) and fine-grained quartz & feldspar are potential commercial by products

Construction is well underway and production will commence 2025

An Australia company, Resource Mining Corporation have a similar deposit at Kolar along strike from Keliber, at an early exploration stage

10.2 Portugal

In November 2023 the Portuguese Prime Minister resigned following allegations of "corruption and influence peddling in lithium mining concessions in northern Portugal".

Savannah Resources
Savannah are developing the Barosso Lithium project, near Boticas in northern Portugal and intend to produce 191,000 tpa of 5.5% spodumene (equ.25,000tpa LCE) over 14 years from 4 open pit mines, commencing late 2027.

They have extensive reserves of quartz & feldspar by product, successfully evaluated in ceramics and glass.

Lusorecursos Portugal Lithium
LPL are planning to produce lithium hydroxide from petalite and spodumene found in aplite pegmatite dykes at the Romano mine (formerly mined for tin, tantalum & niobium) near Montalegre in the Alto Barroso region, just a few Km from Savannah Resources. An intention to separate quartz, potash feldspars (microcline & orthoclase) and soda feldspar (plagioclase) for use in ceramics and glass is stated on their website. First production is anticipated in 2027.

Mota Ceramic Solutions (MCS)

MCS is not new to lithium and has in fact been operating numerous mines and quarries for many years including the Alvarrões Lepidolite Mine, from which it produces 20,000 tpa of lithium minerals. Lepidolite is concentrated using optical sorting to a grading of ~ 2.5% Li_2O, mainly for use in the ceramics industry. The potential for a large-scale operation geared towards the production of lithium chemicals for the battery market has *not* been evaluated.

10.3 Austria

European Lithium.
The Wolfsberg project is expected to produce 8,800 tpa lithium hydroxide over 14.6 years by mining pegmatite veins located near Corinthia. Their website states "By products of feldspar and quartz were also produced which are suitable for ceramics and glass". Start-up is anticipated for late 2026.

10.4 UK

Cornish Lithium
CL are located in Cornwall, at Trelavour Downs near to St Dennis, where they will mine a granite containing zinnwaldite and lepidolite. Their proposal is to produce 7,800 tpa lithium hydroxide over 20 years starting late 2026 or early 2027, using the Lepidico process described above. Gypsum, potassium sulphate, caesium sulphate and rubidium sulphate are by-products.

Lithium was mined in the Trelavour Downs area during WW2 and used to control CO_2 levels in submarines.

Imerys British Lithium
BL plan to produce 21,000 tpa lithium carbonate from Gunheath in Cornwall over 30 years, processed from zinnwaldite mica found in granite. Commercial by products are not discussed. Anticipated start up is "before 2030".

10.5 France

Imerys

Imerys plan to produce lithium hydroxide from its Beauvoir site in the Allier district of central France, from 2028. The project is known as EMILI and is situated beneath a small kaolin mine where an extensive granite contains lepidolite. Each year 2.1mt of granite ore will be processed over at least 25 years to produce 34,000 tpa lithium hydroxide and 420,000 tpa commercial feldspar for use ceramics. There is also potential for tin, tantalum and niobium recovery.

10.6 Spain

Lithium Iberia

LI plan to mine 1.2mtpa ore from pegmatite veins at Canaveral on the Iberian Massif, processing lepidolite mica to produce 30,000 tpa lithium hydroxide. The pegmatites are also rich in caesium, rubidium and tin which might provide further revenue. Anticipated start-up date is not known.

Infinity Lithium

At the San Jose Lithium project Infinity plan to produce 19,500 tpa lithium hydroxide from zinnwaldite mica in Hercynian slates, over 26 years. Location is near to Caceras in the Extremedura region. By products / waste from their froth flotation process will include quartz and tourmaline. Anticipated start-up date is not known

10.7 Czech Republic

European Metals

Cinovec is a lithium-tin-tungsten deposit near the surface of a granite pluton of late Hercynian age. Lithium occurs mainly in zinnwaldite mica while tin and tungsten occur in cassiterite and wolframite. EM intend to mine 2.25 mtpa of ore over 25 years to produce 29,386 tpa of lithium hydroxide. Much smaller tonnages of tin and tungsten will also be produced. Anticipated start-up date is not known

10.8 Germany

Zinnwald Lithium

ZL will produce ~ 17,000 tpa battery grade lithium in the form of hydroxide, carbonate or fluoride over a period of 35 years. The source is zinnwaldite mica contained in granite and the location is Erzgebirge in eastern Germany, not far from the Cinovec deposit on the Czech border. Potassium sulphate, precipitated calcium carbonate and quartz are the forecasted by products, the latter for use in construction. Anticipated start-up date is not known

10.9 Serbia

Rio Tinto

Rio Tinto aim to produce 58,000 tpa lithium carbonate from Jadarite deposits (a lithium boron mineral), found near Loznica in the Jadar Valley, 160 km from Belgrade. By products include boric acid and sodium sulphate.

The Jadar mine has reserves amounting to 118 million tonnes of ore grading 1.8% lithium oxide which is sufficient to cover most of Europe's needs.

According to Dordevic et al (Nature, July 2024) the extraction process involves digesting raw ore at low pH using conc. sulfuric acid at temperatures of 80 - 95 °C. The digestate is further treated to produce $B(OH)_3$, Li_2CO_3, and Na_2SO_4. The proposed processing of ore (853,333 t/year) would require 320,000 t/year of concentrated H_2SO_4, various fuels & other materials and suitable disposal of waste tailings, which will include associated arsenic.

Anticipated start-up date is not known

10.10 Bosnia & Herzegovina

Arcore AG
Arcore have identified similar deposits to those in the Jadar valley at Mount Majevica near to Lopare. The company estimates that the deposit contains 1.5 million tons of lithium (LCE), 14 mt of boron, 35 mt of potassium and 94 mt of magnesium sulphate. They expect to start lithium production by the end of 2026, aiming to produce 10,000 tpa LCE by 2032 through surface mining over a period of 50 years.

10.11 Ireland

Global Battery Metals / Int Lithium + Ganfeng Lithium / Arkle Resources
The above three companies are exploring spodumene pegmatites in or near to the Leinster granite in Co Wicklow. They are at an early stage but likely to progress to feasibility studies soon.

10.12 Ukraine

Ukr Lithium Mining LLC
ULM have produced a feasibility study on the Polokhiveske petalite project which hosts a deposit of 50 mt grading of 1 to 2% Li_2O in central Ukraine but progress is hampered by the ongoing conflict between Ukraine and Russia.

11. GEOTHERMAL BRINE PROJECTS

11.1 Discussion

This is a relatively new process distinct from the procedures used to extract lithium from brine reservoirs located beneath salt flats, such as those in Chile, Argentina and Bolivia, where brine which is pumped to the surface and directed to evaporation ponds.

Geothermal brines are obtained at much greater depths from high temperature circulating ground waters, which might reach as much as 140 C at 5 Km depth.

Currently there is no industrial scale production of lithium from geothermal brine but a number of large-scale projects are under development. A small tonnage is made through demonstration plants.

11.2 Germany

The geothermal brines of the Upper Rhine Valley are characterized by high lithium concentrations of up to 200 mg/L

Vulcan Energy Resources
Vulcan's "Zero-Carbon Lithium Project" is Europe's leading geothermal project with resources of more than 16 million tonnes LCE identified, located in the upper Rhine valley. Vulcan aim to produce 40,000 tpa LCE with production scheduled to start in Q4 2025. Vulcan Energie France has been established to evaluate brines in Alsace

LevertonHELM and EnBW
EnBW extracted a lithium chloride solution from the thermal water of the geothermal power plant in Bruchsal, Baden-Württemberg (Upper Rhine Valley, 50 Km from the Vulcan project) using direct lithium extraction (DLE).

LevertonHELM converted and refined this solution at its facilities in Basingstoke, UK. The two companies will work together to provide a business plan for future commercial production

11.3 Italy

Vulcan and Enel Green Power
A JV is under development at Cesano near Rome

Altamin
Altamin are also researching geothermal brines in the Cesano district and at Viterbo

11.4 France

Eramet in conjunction with Electricite de Strasbourg
Eramet is developing the Ageli project at the Soultz-sous Forets geothermal plant in the upper Rhine Valley near Alsace in northeastern France. Eramet intend to produce both geothermal energy and battery grade lithium via a patented DLE process already in use at their 24,000 tpa plant in Argentina. Production is expected to be 10,000 tpa lithium carbonate, scheduled to commence before 2030.

Lithium de France
Lithium de France are also working in the upper Rhine Valley, with plans to extract hot brines from depths of up to 3 km to provide geothermal heat for industrial use and to operate a DLE process for lithium extraction, producing 32,000 tpa by 2030.

11.5 UK

There are 2 granite intrusions in the UK where geothermal brines can be extracted, Cornwall and Weardale in Co Durham. Both are high heat producing (HHP) granites with slightly raised levels of radioactive potassium, uranium and thorium whose decay produces heat at depth

Cornish Lithium
CL are investigating the potential for the co-production of lithium and renewable heat in west Cornwall at a number of sites near to Redruth. At United Downs and Blackwater, boreholes have been drilled down to 1 to 2 Km to produce brine enriched in lithium which has been used for DLE testing.

CL are also investigating potential to extract other metals required for lithium-ion batteries. No decisions on annual output or start up dates as yet

Geothermal Engineering Ltd
GEL are also active at United Downs in Cornwall having drilled two wells, a production well at 5.275 Km (the deepest in the UK ever drilled) and a reinjection well at 2.393 Km. High Li - ion levels at 340 ppm were measured.

A pilot plant is expected to be installed by March 2025 to produce 100 tpa, ramping up to at least 1,000 tonnes per annum by 2026, using zero carbon DLE technology. The company already has planning permission for two other geothermal projects in Cornwall and aims to expand production to over 12,000 tpa by 2030

Northern Lithium.
NL aim to produce 5,000 to 10,000 tpa LCE from brines within the Weardale granite in Co Durham, using DLE technology. Commercial production is expected to commence in 2027, scaling up to 10,000 tpa within 10 years.

Weardale Lithium
WL plan to process LCE at Eastgate using DLE to achieve commercial production of 10,000 tpa in 4 years' time.

12 RECYCLING PROJECTS

12.1 Discussion

The list below is non exhaustive.

Some companies are integrated ie they make batteries and recycle critical minerals and some have sales agreements with major car manufacturers

Substantial government grants have been provided in many cases

12.2 Norway

In 2022 an impressive 79% of cars sold in Norway were EV's, due to generous tax incentives & a high number of public charging stations. A supply of used batteries prompted a surge in research for recovery of lithium etc

Hydrovolt
The largest operation in Europe, Hydrovolt is a jv between Hydro in Norway and Swedish battery manufacturer Northvolt with a capacity of 12 000 tpa and recovery of up to 95% of battery metals, including the "black mass" containing lithium, manganese and cobalt**.** The company is in financial difficulty and likely to declare bankruptcy

12.3 Finland

Fortum
Fortum claim to recover 95% of critical metals from the black mass using hydrometallurgical procedures. They are aiming to expand to a capacity of 200,000 tpa across Europe

12.4 Belgium

Umicore
A 7000 tpa pyro plant operating since 2011 is claimed to recover 95% cobalt, nickel & copper plus 70% lithium, extracted from slag and flue dust. A new 150,000 tpa plant is planned, to commence operating in 2026

12.5 Germany

Cylib
A consortium of European backers which includes Porsche and Bosch will begin operating a 30,000 tpa plant in Dormagen in 2026, using a water-based process to recover lithium, cobalt, nickel and graphite.

12.6 France

ReLieVe Project
The ReLieVe project (Recycling of Li-ion Batteries for electric Vehicles) is a collaboration between Suez and Eramet who intend to build 2 plants in Dunkirk capable of processing 50,000 tpa with start up in 2027

12.7 UK

Veolia have predicted that 350,000 tpa EOL batteries will be available in the UK by 2040

Recyclus Group
Situated at Wolverhampton, this is the first industrial scale plant in the UK with a capacity of 22,000tpa

Veolia
This is a smaller operation processing a few thousand tpa, based at Minworth, near Birmingham

Cellcycle
Based at Manchester, Cellcycle run two plants with a combined capacity of 80,000tpa, the largest in the UK

13. SUMMARY

13.1 Meeting Demand for 2030

If the expectations from companies in Europe planning new hard rock projects reach full potential, there will be almost 300,000tpa LCE available by 2030. Geothermal projects would bring in another 114,000tpa, giving a total of approximately 414,000tpa. Allowing for new production from recycling, based on 1.77% by weight LCE per battery and 75% recovery rate, we can add another 6000t, bringing the total to 420,000t

Transport & Environment estimated in May 2024 that Europe will need 490,000 tonnes by 2030 so even if everything goes to plan with new production, there will be shortfall of ~ 70,000t. A few start-ups haven't announced their expected annual output and there may be projects not accounted for, so the shortfall may be lower.

The big question however, is will all the projects make it into commercial production and, if so, will this happen by 2030? According to McKinsey, 80% of mining projects are completed late and are over budget by an average of 43%

13.2 What Will Help Projects Succeed

i. Investment by battery or vehicle manufacturers with long term offtake agreements

ii. Government investment. As an example, in March 2024 the European Investment Bank confirmed a loan of up to $830m to Vulcan Energy Resources for their geothermal project in Germany

iii. Production of lithium carbonate or hydroxide rather than partly refined concentrate

iv. Brownfield site rather than greenfield

v. Spodumene rather than lepidolite or zinnwaldite due to established technology and higher Li content

vi. High output, economy of scale

vii. Projects with commercial by products

viii. Geothermal brines have the advantage of lower production costs vs hard rock with additional revenue from heat and electricity generation but are unproven.

ix. An increase in price for LCE will help all projects get off the ground. Global production exceeding demand is likely to keep prices down for the next few years as output from existing operations is increased and new projects start production. Increasing sales of EVs and energy storage units should eventually take up the slack and see prices rising.

13.3 EV Sales

European governments have decreed that all new car sales must be electric by 2035, aiming for 80% by 2030. The EU also has a target to cut CO_2 emissions from cars and vans by 55% by 2030.

According to the IEA new electric car registrations reached nearly 3.2 million in Europe in 2023, increasing by almost 20% relative to 2022. In 2023 around 25% of all cars sold in Germany, France and the United Kingdom were electric, 30% in the Netherlands, 60% in Sweden and almost 95% in Norway.

This year, however, there has been a slowdown in sales, particularly in France and Germany, caused by several factors, not least Germany phasing out subsidies in 2023 and high prices. Only two days ago Volkswagen announced plans to close at least three plants in Germany and downsize all remaining factories which will result in the loss of tens of thousands of jobs. German car manufacturers were slow to invest in EV's and have not kept up with the likes of Tesla in the US and BYD in China. This is a challenge for all European car manufacturers.

On a more positive note, most experts expect sales to pick up from 2025 and keep rising to 2030 and beyond, albeit at a slower pace than earlier predictions.

According to New AutoMotive, electric car registrations (includes hybrids) in the UK recorded their best month on record in September (2024) with over 50,000 new registrations.

From the Financial Times Oct 13th: 'European carmakers are planning dozens of affordable electric models next year'.

In conclusion there is little doubt that EV sales will substantially increase, as will the demand for lithium.