GM 28572

LITHIUM, WORLD SURVEY OF PRODUCTION AND CONSUMPTION WITH SPECIAL REFERENCE TO FUTURE DEMAND AND PRICES

GROUPE MINIER/**SULLIVAN**/MINING GROUP LTÉE LTD.

Montréal, le 11 janvier 1972.

Ministère des Richesses Naturelles, Québec
SERVICE DE LA
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Date: 24 AVR 1973
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Honorable J. Gilles Massé, Ministre
Département des Richesses Naturelles,
Hotel du Gouvernement,
Québec, P.Q.

Monsieur le Ministre,

Nous vous remercions de l'intérêt que vous portez à l'industrie minière et particulièrement à la possibilité de la réouverture de notre propriété de lithium, située à Barraute, en Abitibi.

Le retard à répondre à votre lettre du 9 décembre 1971 est dû à un assez long travail nécessité pour l'étude des coûts qui a été faite.

Vous trouverez ci-joint, l'étude comparative des coûts de production du carbonate de lithium de 1963 qui vous ont été présentés avec ceux que nous prévoyons pour 1972. Il est à remarquer que les coûts de 1963 sont basés sur une production annuelle de 2,000,000 lbs de carbonate et ceux de 1972 le sont sur une production possible de 7,000,000 lbs. De plus, nous vous envoyons, sous même pli, les détails des coûts de 1972.

Dans votre lettre, il est mentionné "si les alumineries peuvent fort bien, utiliser le lithium dans leur production, l'aluminium produit avec ce procédé est d'utilisation difficile par les clients des alumineries mêmes, au stade de la transformation des lingots d'aluminium en produits finis". D'après les informations que nous avons, l'Alcan n'utilise pas encore sur une base industrielle le lithium dans son procédé. Cependant nous savons que Reynolds de Baie Comeau achète annuellement de la Russie 1,000,000 lbs de carbonate de lithium. De plus, Kaiser, une des plus importantes alumineries américaines emploie le carbonate de lithium dans sa fabrication d'aluminium.

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Au début de votre lettre, il est dit que "le Dr. Olivier aimerait, avant de faire les recherches demandées par Québec Lithium, sur la corrosion résultant de l'utilisation d'un nouveau procédé, qu'une étude de bénéfice - coût de ce procédé lui-même soit fournie. En effet la technique déjà utilisée par la compagnie Québec Lithium a fait ses preuves et parait demeurer compétitive". Nous sommes d'accord avec le Dr. Olivier sur la valeur compétitive du procédé au carbonate de sodium. D'ailleurs notre intention serait si nous pouvions recommencer nos opérations, utiliser à la raffinerie le même procédé, à savoir celui au carbonate de sodium développé par votre ministère. Cependant nous pensons, après des tests de laboratoire que nos chimistes ont fait en 1965, que le procédé au chlorure de sodium pourrait avoir des avantages. Mais tel que mentionné par le Dr. Olivier, nous avons des craintes en ce qui concerne la corrosion. De toute façon, ce procédé pourrait être davantage expérimenté durant les opérations futures. D'ailleurs un procédé ou l'autre ne changerait pratiquement rien dans l'équipement de la raffinerie. Donc si des tests confirmaient nos espérances, nous pourrions passer d'un procédé à l'autre en arrêtant la production que pendant quelques jours.

Nous avons lu avec intérêt les quatre études de marchés qui accompagnaient votre lettre.

Pour le moment, si vous nous le permettez, nous commenterons seulement l'étude sur le marché du lithium. Car nos ventes de lithium seraient sûrement le revenu principal de nos opérations. Cependant nous ne voulons pas dire par là que nous négligerions les profits possibles faits sur des ventes de feldspath et de silice. D'ailleurs nous avions, dans le passé, vendu du feldspath dont notre client était des plus satisfait.

Mais, pour le moment, il nous faut considérer la propriété de lithium au simple point de vue des ventes de carbonate de lithium. Des ventes de feldspath et de quartz ne viendraient qu'ajouter à la rentabilité du projet.

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Dans l'étude du marché du lithium, que vous nous avez fait parvenir et qui a été faite par Monsieur Claude Garon, il est indiqué que, dans le monde libre, la production de 1970 était entre 25 et 27 millions de livres. Cependant dans une étude de "O.W. Roskill & Co. (Reports) Ltd" (que vous trouverez sous même pli), vous remarquerez à la page 7 que la consommation mondiale de lithium en équivalent de Li_2O est 13.5 millions, ce qui équivaut en carbonate à 33.5 millions de livres.

Durant nos dernières années d'opération, nous avions environ 20% du marché du monde libre. Si en quelques années, nous pouvions prendre la même proportion du marché actuel, nous vendrions un volume d'à-peu-près 6,000,000 lbs de carbonate. Il ne faut pas oublier l'augmentation annuelle qui est de 10 à 15%. Avec un tel volume de vente, nous considérons que notre propriété de lithium pourrait opérer de façon compétitive.

500,000

Dans votre étude du marché de lithium à la page 5, il est indiqué que les prix du carbonate de lithium varient de $0.49 à $0.54 la livre (dépendant du volume de la commande): ces prix sont ceux de septembre 1971.

Nos ingénieurs (dont l'un est l'ancien gérant de Québec Lithium) ont préparé des coûts de production, dont vous trouverez les détails: pour une production annuelle d'environ 7,000,000 lbs le coût d'opération à la mine serait $0.3825 par lb.

Le montant nécessaire requis pour le redémarrage de notre propriété de lithium est, après une étude faite par notre directeur de projet, de l'ordre de $1,250,000.00 à $1,500,000.00.

Le financement des stocks de carbonate de lithium, des inventaires de matériel, des comptes recevables, du fonds de roulement serait de l'ordre de $4,000,000.00 pour la première année et ce montant diminuerait sensiblement dans les années subséquentes. Ce prêt de la part du gouvernement aurait comme garantie collatérale les inventaires des seuls de lithium et du matériel de magasin.

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Le coût d'électricité au taux régulier est de l'ordre de $0.03 à $0.04 la livre de carbonate (évidemment ce coût unitaire couvre la charge faite aux travaux souterrains, à la concentration, à la décrépitation et à la raffinerie).

Les informations qui vous sont données dans cette lettre pourront être complétées et explicitées, si vous le désirez, à Messieurs Garon, Olivier, Maurice et Kelly.

Bien à vous,

L C Béliveau

Lucien C. Béliveau,
Vice-président (Mines)

LCB/TO

Steel [illegible] [illegible]

L I T H I U M

WORLD SURVEY OF PRODUCTION AND CONSUMPTION WITH SPECIAL REFERENCE TO FUTURE DEMAND AND PRICES

O.W. ROSKILL & CO. (REPORTS) LTD.,
14 Great College Street,
London, S.W.1

Lithium: World Survey of Production and Consumption with special reference to future demand and prices.

O. W. ROSKILL

7th May, 1971.

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Lithium

1. Historical.

The first commercial use for lithium was in 1900 as an additive to the electrolyte in nickel iron batteries and there has been a steady consumption for this purpose ever since. In 1918 a lead-lithium bearing alloy later known as Bahnmetall was developed in Germany but its use was discontinued in the 1930's. During World Was 2 lithium was used as an alloying element in aluminium and lithium hydride as a source of hydrogen for balloons but after the war there was considerable excess capacity for the production of lithium compounds. The latter were made available for research and a number of new uses developed in lubricating greases, ceramics, glass and vitreous enamels, welding and brazing fluxes, air conditioning and pharmaceuticals.

By 1955 the division of consumption of lithium in all forms for industrial uses in the U.S.A. was estimated as follows:-

	000 lbs. $L_{12}0$	Per cent
Lubricating greases	1,340	39
Ceramics	650	19
Welding and brazing	450	13
Air conditioning	450	13
Alkaline storage batteries	250	7
Pharmaceuticals	10	...
Other uses	300	9
	3,450	100

Since 1955 little information has been published regarding division of consumption by uses but by 1969 the consumption in greases in the U.S.A. was probably about 3.0 mill. lbs . (40 per cent of total consumption), in ceramics and vitrous enamels and in aluminium pot lines 2.0 mill. lbs (27 per cent), in air conditioning and refrigeration 0.8 mill. lbs (11 per cent), welding and brazing fluxes 0.4 mill. lbs (5 per cent), storage batteries 0.4 mill. lbs (5 per cent), catalysts 0.1 mill. lbs (1 per cent) and all other uses 0.7 mill. lbs (9 per cent).

During the 1950's the U.S. Atomic Energy Commission entered into contracts for the purchase of lithium hydroxide from 3 U.S. producers. The quantities involved were substantial and gave rise to active exploration for lithium ores throughout the world with the result that world production reached a peak about 1959. The A.E.C. however was interested only in the Li_6 isotope as an intermediate in the production of the hydrogen bomb. This accounts for only 7.5 per cent of the lithium atom and for the great majority of commercial uses the residual Li_7 is quite satisfactory. Fulfilling the A.E.C.'s requirement for the Li_6 isotope therefore resulted in building up substantial stocks of lithium hydroxide. The A.E.C. contracts provided that these stocks should not be sold for 10 years, except to the original producers. At the end of 1958 the A.E.C. announced that it did not intend to renew the contracts for lithium hydroxide when they expired on 1st May 1959.

This brought about considerable world overproduction, a sharp fall in output and a fall in prices. Since 1959, however, consumption has expanded for most of the applications listed above and new uses have been developed e.g. as a catalyst in the production of polyisoprene and polybutadiene rubber. Estimated U.S. consumption had recovered by 1969 to 7.4 mill. lbs and world consumption to 11.6 mill. lbs. Li_2O. During the past few years supplies of lithium minerals from Rhodesia, the major source outside the U.S.A., have been cut off owing to the sanctions imposed against that country and a considerable part of the consumption of lithium compounds in non-Communist countries other than the U.S.A. has been supplied by the U.S.S.R. in the form of lithium hydroxide from which the lithium 6 isotope has been removed. Indigenous production in the U.S.A. has been expanded and the U.S.A. now supplies some lithium minerals to West Germany and lithium chemicals to Japan and Europe.

While some of the newer applications for lithium have not entirely fulfilled their early promise, consumption is now much more widely based than was the case 20 years ago and total demand for lithium in all forms may well expand by 10 to 15 per cent per annum.

The Foote Mineral Co. (1), the largest U.S. producer, recently expressed the opinion that rising costs and declining reserves of coal, petroleum, natural gas and uranium and increasing concern about the environment may lead to the development of two big new markets for lithium chemicals. The first is the non-polluting generation of electric power using Li_6 isotope in a nuclear fusion reaction and the other the propulsion of motor vehicles by high-energy lightweight storage batteries using lithium metal electrodes and lithium-containing electrolytes. In both cases further development work is required by if either application is adopted it would result in a change of dimension in lithium consumption.

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(1) Newmont Mining Corp. holds a 19.8 per cent interest.

On the supply side a substantial increase in recovery of lithium compounds from salt brines promises a reduction in production costs which should further stimulate consumption. Since the imposition of sanctions against exports from Rhodesia in 1965 one of the main problems has been a shortage of low iron lithium minerals suitable for use in the glass and ceramic industries. While lithium carbonate and other compounds can be used instead they are more expensive. A good deal of work has therefore been undertaken into the removal of iron from lithium minerals and additional supplies of low iron minerals are now being made available in Canada and the U.S.A.

2. Lithium minerals.

2.1. Principal sources of lithium.

The main sources of lithium are pegmatites and certain brines from which it is recovered by solar evaporation as a by-product of the production of potash, sodium sulphate, borax and salt. In the U.S.A. the cost of production of lithium metal and lithium chemicals from brines is substantially below that from pegmatites and increasing quantities are being produced by evaporation. The pegmatites are increasingly being used as direct additions in the production of special glass compositions and vitreous enamels as a low-cost method of adding lithium oxide.

The main lithium minerals are:-

(1) Spodumene, a lithium aluminium silicate with a theoretical Li_2O content of 8.03 per cent. This is the main lithium ore and large deposits exist in North Carolina, in the U.S.A., Quebec, Ontario, Manitoba and the Northwest Territories in Canada, Brazil, Argentina, Spain, Congo (kinshasa) and the U.S.S.R. The natural ore usually contains 1 to 2 per cent Li_2O and this is concentrated by froth flotation to 5 to 6 per cent before extraction of lithium.

(2) Petalite, also a lithium aluminium silicate with a theoretical Li_2O content of 4.88 per cent. The main deposits are at Bikita in Rhodesia, in South West Africa and the U.S.S.R.

(3) Lepidolite, a complex lithium mica with a Li_2O content of 3 to 4 per cent, which often also contains moderate amounts of rubidium and cesium. The main deposits are at Bikita in Rhodesia, South West Africa, Manitoba, Canada and Mozambique.

(4) Amblygonite, a complex phosphate with a Li_2O content of 7.5 to 9 per cent. Minor deposits are widely distributed but no major deposits are known.

The low percentages by weight of Li_2O in the minerals make the latter appear low grade, but are largely a reflection of the low atomic weight of lithium.

Spodumene is the main lithium ore available in North America and processes for the extraction of lithium from spodumene have been developed by Foote Mineral Co., which produces crystalline lithium hydroxide monohydrate; Lithium Corporation of America which recovers lithium sulphate, subsequently precipitated with soda ash to lithium carbonate and Quebec Lithium Corporation (subsidiary of Sullivan Mining Group Ltd.) which produces lithium bicarbonate solution from which lithium carbonate is precipitated by heating. American Lithium Chemicals Inc. formerly operated a process at San Antonio, Texas to produce from Rhodesian lepidolite lithium hydroxide monohydrate and a mixed carbonate by-product containing potassium, rubidium, cesium, sodium and lithium carbonates. American Potash and Chemical Co. recover lithium-sodium-phosphate containing about 20 per cent Li_2O from the brine of Searles Lake California. After roasting the product is heated with sulphuric acid, phosphoric acid is recovered, the alkali sulphates dissolved and lithium carbonate precipitated by the addition of soda ash.

Until the imposition of sanctions Rhodesian minerals were formerly processed in the U.K. by Associated Lead Manufacturers Ltd. Lithium minerals are also processed by Hans Heinrich Hütte GmbH., (a subsidiary of Metallgesellschaft A.G.) using mainly U.S. ores in West Germany, by Ste. des Usines Chimiques Rhône Poulenc in France and by Montecatini-Edison S.p.A. in Italy.

2.2. World production and consumption of lithium minerals.

The following table shows world production of lithium minerals insofar as statistics are available.

Table 1 : World production of lithium minerals (long tons).

	1965	1966	1967	1968	1969
Argentina					
Lithium minerals	612	266	243	...	...
Australia					
Petalite	310	933)	667	738	710
Spodumene	-	-)			
Brazil (1)					
Amblygonite	25	-	6,022 (2)	-	...
Spodumene	6,707	98	49	-	...
Canada					
Lithium minerals (Li_2O content)	452	113	195	-	-
Mozambique					
Lepidolite	75	...	246	591	385
Rhodesia					
Amblygonite	- (3)	...	...	...	...
Eucryptite	476 (3)	...	...	...	...
Lepodilite	11,867 (3)	...	...	...	...
Petalite	20,034 (3)	...	...	...	...
Spodumene	10,278 (3)	...	...	...	...
South Africa					
Spodumene	855	301	-	36	35
South West Africa					
Amblygomite	35	27	...	...	...
Lepidolite	266	326	...	...	...
Petalite	1,189	1,200	...	...	...
Uganda					
Amblygonite	75	-	50 (1)	44	6

Production statistics have not been available for Rhodesia since September 1965. Prior to the imposition of sanctions Rhodesia supplied lithium minerals to the U.S.A., Belgium, U.K., Netherlands, Italy, Japan and West Germany. The U.S.A. is the largest producer of lithium minerals but production statistics have not been published since 1954, when production amounted to 75.7 mill. lbs (34,000 tons) containing 5 mill. lbs Li_2O. By 1968 the latter figure had probably risen to 8.5 mill lbs., by 1969 to about 10.7 mill. lbs. and by 1970 to 12.5 mill lbs.

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(1) Exports,

(2) Lithium minerals other than spodumene.

(3) January to September only.

World exports and imports of lithium minerals, so far as separately recorded, are shown in Tables 2 and 3.

Table 2 : Exports of lithium minerals (long tons).

	1965	1966	1967	1968	1969
Australia	-	345	-	-	...
Brazil					
Amblygonite	25	-	6,022	-	...
Spodumene	6,707	98	49	-	...
Germany, Western	606	243	148	126	79
Mozambique					
Lepidolite	75	...	99	547	502
Rhodesia	49,932	...	...	...	...
South Africa	409	486	-	-	-
South West Africa					
Amblygonite	597	12	...	...	...
Lepidolite	152	534	...	...	...
Petalite	991	1,185	...	...	...
Uganda					
Amblygonite	-	-	50	-	50

Table 3 : Imports of lithium minerals (long tons).

	1965	1966	1967	1968	1969
Belgium/Luxembourg	227	311	635	753	1,307
France	...	4,602	2,498	2,559	2,989
Germany, Western	10,766	9,667	6,207	10,621	7,554
Italy	3,551	12,796	992	4,851	5,105
Japan (1)	3,500	...	...	...	...
Netherlands (1)	6,500	...	...	...	...
Spain	130	241	360	419	347
United Kingdom (1)	7,000	...	...	...	...
U.S.A.	10,040	8,268	23,154	10,172	1,239 (2)

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(1) Figures represent exports to these countries from Rhodesia and are not necessarily complete.

(2) From U.S. Bureau of Mines preprint.

World consumption of lithium as Li_2O has been estimated by W.F. Luckenbach, Vice-President, marketing, of Foote Mineral Co. as shown in Table 4.

Table 4 : Estimated world consumption of lithium (Li_2O basis) (mill. lbs.)

	1966	1967	1968	1969	1970 (1)
U.S.A.	5.9	6.6	6.7	7.4	8.5
Europe	1.8	1.9	2.1	2.5	2.8
Japan	0.4	0.5	0.7	0.7	0.9
Other non-Communist	0.4	0.4	0.4	0.6	0.7
Communist	-	-	-	0.4	0.6
Total	8.5	9.4	9.9	11.6	13.5

These figures include the quantities of minerals used as such:- e.g. in glasses and enamels, as well as those processed to lithium metal and compounds. The estimated consumption in communist countries would seem to omit the consumption of the 6-isotope in hydrogen bombs.

2.2.1. Australia.

Australia is a minor lithium producer with an output of 300 to 400 tons of lithium minerals, mostly petalite with smaller quantities of amblygonite and spodumene. From 1951 until September 1967 exports of lithium minerals, metal and alloys were controlled by the Australian Government. In the case of ores and concentrates an export permit was required from the Australian National Development Committee and for metals and alloys one from the Australian Atomic Energy Commission. In September 1967 controls were removed for ores and concentrates but remained in force for metal and alloys.

The Western Mining Corporation (in which Broken Hill South, North Broken Hill and Selection Trust are shareholders) revealed in 1968 that in conjunction with Broken Hill South it had established large reserves of lithium at Mount Marion, 22 miles South of Kalgoorlie. The company said it was only awaiting the development of an overseas market to establish a lithium industry in Australia. It was hoped to export to West Germany, Eastern Europe and Japan but the market had weakened and no sales could be arranged. International Nickel Southern Exploration also put in a number of claims in the same area but Western Mining claimed that some of these encroached on their own holdings.

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(1) Estimates by O. W. Roskill.

2.2.2. Brazil.

Orquima S.A., San Paulo, from time to time produces substantial quantities of lithium minerals, most of which are exported to the U.S.A. Amblygonite ore is produced mainly in Minas Gerais and in the north-eastern States of Ceara and Rio Grande do Norte. Petalite is also mined in Minas Gerais but substantially the whole output is used by the Brazilian glass industry.

2.2.3. Canada.

In Canada Quebec Lithium Corporation announced in December 1966 that it would cease production of spodumene concentrate in the Val d'Or area of Quebec and of lithium carbonate and hydroxide monohydrate for export. The reasons given were a strike which had lasted two months, growing over-capacity and price competition in the industry and the development of new and cheaper sources of lithium such as Lake brines.

The Canadian industry developed in the mid-1950's and production by Quebec Lithium Corporation (the only producer) reached a peak of 5.1 mill. lbs. Li_2O content in 1957. Thereafter it declined sharply partly owing to cancellation by Lithium Corporation of America of a long term contract for the purchase of spodumene concentrates from Quebec Lithium Corporation. Production recovered temporarily to 1.1 mill. lbs. in 1964 and 1965. After the closure of the mines in 1966 shipments continued from stock in 1967 but ceased in 1968.

Some production of low-iron spodumene and lepidolite for the glass and ceramics industries is expected during 1971 or 1972 by the Tentalum Mining Corporation at Bermic Lake, a subsidiary of Northern Goldfield Investment Ltd. and Chemalloy Minerals Ltd. Besides spodumene and lepidolite the pegmatite ore body contains the cesium mineral, pollucite, and bays as well as tantallon. Tantalum Mining Corp., started production of tantalite in 1969 and announced plans to instal a mill of capacity 350 tons per day to produce low-iron spodumene concentrates. The company is owned by the Goldfield Corporation (60 per cent) and Chemalloy Materials Ltd. (40 per cent). The Bernic Lake deposits are said to amount to about 5 mill. tons of lithium minerals assaying about 3 per cent Li_2O. It is reported that the Fe content is not in the crystal lattice and can therefore be reduced to levels suitable for the ceramic industry by flotation, whereas the Foote Mineral Co. in the U.S.A. has to use chemical means to reduce the iron content.

2.2.4. <u>Chile.</u>

In June 1970 the Chilean State Mines Service said that surveys made by themselves and the Geological Research Institute had shown some substantial deposits of potassium and lithium salts in the Salar de Apacama in northern Chile. Preliminary calculations suggested that the reserves of lithium might amount to 1.2 mill. tons containing 0.2 per cent Li_2O.

2.2.5. <u>Rhodesia.</u>

Bikita Minerals (Pvt.) Ltd. was formed in 1953 as a subsidiary of Selection Trust Ltd. to take over deposits of lithium-bearing pegmatites in 1953. When the U.S. Atomic Energy Commission started to buy lithium hydroxide, American Potash and Chemical Corp. and American Metal Climax took an interest in Bikita. American Potash and Chemical Corp. formed a U.S. subsidiary, American Lithium Chemicals Inc., to convert lepidolite to lithium hydroxide at a plant erected at San Antonio, Texas in 1956. This plant continued to operate until the AEC contracts expired, when it closed. This forced Bikita to close its mine for a few months but the company had purchased a neighbouring deposit of petalite in 1959 and began to supply lump petalite to the glass industry in the U.S.A., Europe and Japan.

Rhodesian production in the years immediately preceding the imposition of sanctions in 1965 is shown in Table 5.

Table 5 : Rhodesia: output of lithium minerals (long tons).

	1962	1963	1964	1965 (1)
Petalite	19,379	26,738	32,544	20,034
Lepidolite	18,967	14,426	20,485	11,867
Spodumene	1,136	1,996	6,219	10,278
Encryptite	773	1,039	720	476
Amblygonite	31	46	-	-
Total	40,286	44,245	59,968	42,655

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(1) January to September only.

Reserves of pickable ore have been estimated at 5 mill. tons averaging 2.8 per cent Li_2O and there is a small flotation mill which produces lepidolite of 4 per cent Li_2O from low grade materials.

For the last year for which statistics are available Rhodesian exports of lithium ores were as follows:-

Table 6 : Rhodesia: Exports of lithium ores 1965.

	Long tons
Belgium/Luxembourg	14,700
Germany, Western	400
Italy	4,100
Japan	3,100
Netherlands	5,900
South Africa	300
United Kingdom	6,400
United States	15,100
	49,900

The U.S.A. continued to buy lithium minerals in 1967 and 1968 (see Section 2.2.7.) and initially the effect of sanctions was not very great, production in 1966 being only about 12 per cent lower than in 1965. No production or export statistics are available for later years.

2.2.6. South Africa and South-West Africa.

Production of lithium minerals in South-West Africa was stimulated by the imposition of sanctions against Rhodesia. In 1968 Klockner & Co. A.G., West Germany acquired a controlling interest in S.W.A. Lithium Mines (Pty) Ltd., which produces lepidolite, petalite and small quantities of amblygonite from two mines named Helicon and Rubicon, south-east of Karibib, South-West Africa. The Klockner subsidiary Klockner-Humboldt-Deutz installed a new flotation plant for S.W.A. Lithium designed to produce about 10,000 tons per annum of lepidolite concentrates. Reserves suitable for hand cobbing had been reduced to 1,700 tons but a further 1 mill. tons was available suitable for concentration by flotation.

There is also some production of lithium minerals in South Africa, but on a smaller scale than in either Rhodesia or South-West Africa. The principal producer is Otavi Mining Company (Pty.) Ltd., which produces low-iron petalite (4 per cent Li_2O and 0.05 per cent Fe_2O_3) spodumene (4.5 per cent Li_2O) and two grades of lepidolite at Mica, Transvaal.

2.2.7. U.S.A.

The main producer of lithium minerals in the U.S.A. is Foote Minerals Co., Exton. Pa. The company produces spodumene at King's Mountain, North Carolina where reserves are equivalent to over 500 mill. lbs of lithium metal. Reserves in the State of North Carolina as a whole are estimated at over 200 mill. tons of ore containing 1,500 mill. lbs of lithium metal. Foote also obtains lithium salts by solar evaporation of brines at Silver Peak, Nevada where reserves of recoverable lithium are said to be between 5,000 and 10,000 mill. lbs. The brine contains 0.04 per cent lithium compared with only 0.006 per cent in the Great Salt Lake and Searles Lake brines (see below). The capacity of the concentration plant has been reported as 10 mill. lbs. lithium carbonate per annum (say - 4 mill. lbs Li_2O) but is believed to have been increased recently.

The company stated in 1968 that with the growth in output by evaporation new outlets would have to be developed for the spodumene concentrates produced at Kings Mountain. A semi-commercial plant was erected later in the year to produce low-iron spodumene for the ceramic industry. Hitherto petalite from Rhodesia has been the main lithium ore to be used directly in the ceramic industry. The U.S.A. continued to import from Rhodesia until 1968, but early in 1970 it was stated that in spite of the availability of small supplies from South West Africa, stocks of petalite were getting low. This has provided an additional impetus to the production of low-iron spodumene.

American Potash and Chemical Corporation produces crude dilithium-sodium phosphate from Searles Lake brines at Trona, California and processes them to lithium carbonate.

The Lithium Corporation of America which for some years treated imported spodumene from Canada and later bought from Foote Mineral Co. started production of spodumene near Bessemer City, North Carolina towards the end of 1968. It was stated that production was expected to rise to 1,200 tons a day and to yield 20 mill. lbs of lithium carbonate per annum. The company is a subsidiary of Gulf Resources and Chemical Corporation and has a 51 per cent interest in Great Salt Lake Minerals and Chemical Corporation, of which the remaining 49 per cent is held by Chemsalt Corporation a subsidiary of Salzdetfurth A.G., West Germany.

In 1967 Great Salt Lake Minerals and Chemical Corporation started to establish evaporation facilities in the Bear River Basin of Great Salt Lake, Utah, estimated to cost $24 mill. Initially these were to produce potash, sodium sulphate, magnesium chloride and salt but in 1968 it was announced that they would produce about 10 mill. lbs. a year of lithium products in the early 1970's. National Lead Co. has also announced its intention to produce lithium compounds (10 mill. lbs. p.a. lithium chloride equivalent) from Great Salt Lake brines by late 1971.

In 1971 Belco Petroleum Corporation, New York expressed interest in the Great Salt Lake deposits and said it proposed to make a thorough investigation of the possibilities.

There is a small production of lepidolite and amblygonite by Keystone Chemical Corporation at Keystone, South Dakota.

No Statistics have been published for U.S. production of lithium in minerals since 1954 when output amounted to 75.7 mill. lbs. valued at $3.1 mill. and containing 5 mill. lbs Li_2O. The U.S. Bureau of Mines stated in 1968 that record production occurred in 1959 and was followed by a very sharp decline. In 1963 and 1964 however an upward trend was resumed. This rise has apparently continued since Table 4 shows that U.S. consumption of lithium in all forms has risen from 5.9 mill. lbs Li_2O in 1966 to 6.7 mill. lbs in 1968 and 7.4 mill. lbs in 1969. The import statistics do not state the Li_2O content but if this is assumed to be 4 per cent they amounted to about 0.9 mill. lbs. Li_2O in 1968 but were probably very small in 1969. Exports are calculated in Section 4.1 as at least 2.7 mill. lbs in 1968, 3.3. mill. lbs in 1969 and 3.9 mill. lbs in 1970, and production may be estimated at 8.5 mill. lbs in 1968, 10.7 mill. lbs in 1969 and about 12.5 mill. lbs in 1970.

U.S. imports for consumption of lithium ores by country of origin and U.S. customs district are shown in Table 7.

Table 7: U.S.A.: Imports of lithium ore.

Country and customs district	1967		1968	
	Sh. tons	$000	Sh. tons	$000
Brazil: Baltimore	45	35	-	-
Canada: St. Albans	2,333	44	-	-
Rhodesia: Baltimore	22,424	669	11,016	360
Charleston	1,131	48	-	-
South Africa: Baltimore	-	-	377	22
Total	25,933	766	11.398	382

In later years imports have been small.

2.2.8. Other countries.

The major lithium deposit in Mozambique is owned by Empresa Mineira do Alto Ligorha in the nortern part of the country. Production is intermittent but has been rising since 1967.

2.3. Prices.

Up to 1966 quoted prices of lithium ores in Europe were based on the prices of Rhodesian mineral f.o.b. Beira. In 1968 prices were quoted c.i.f. European port irrespective of country of origin. Since the imposition of sanctions against Rhodesia the quantities of lithium mineral available on the free market have been small and part of the supplies to Europe, particularly to Germany, have been obtained on long term contract from the U.S.A. Between 1968 and 1970 the published prices have shown little change except in the case of Amblygonite for which the mean price rose by 14 per cent.

Table 8: End of year price of lithium ores in Europe.
(\$. per long ton unit of Li_2O)

	Petalite 4 per cent Li_2O	Lepidolite 3½ per cent Li_2O	Spodumene 3.8 per cent Li_2O	Amblygonite 6 to 8 per cent Li_2O (basis 8 per cent)
1965 (f.o.b. Beira)	70	80	75	...
1966 (f.o.b. Beira)	70	none	75	...
1967 (f.o.b. Beira)	none	none	none	...
1968 (c.i.f.)	140 to 150	110 to 125	115 to 125	125 to 130
1969 (c.i.f.)	140 to 145	110 to 125	115 to 120	135 to 155
1970 (c.i.f.)	140 to 145	110 to 125	115 to 120	135 to 155

3. Applications of Lithium metal and compounds.

3.1. Lithium metal.

No statistics are available for production of lithium metal. Although first used as an alloying element in Germany at the end of World War I its commercial importance dates from about 1930. It is used mainly in the metallurgical field but also as the starting material in the manufacture of lithium compounds such as the amide, hydride and nitride and a number of organo-lithium compounds. It is produced by electrolysis from a lithium chloride-potassium chloride mixture giving a purity of 99.8 per cent or better.

The metal is available commercially as quarter -, half-, one- and two-pound ingots; special shapes including ribbon, wire and rod; shot and dispersions. It is also available in hermetically sealed copper cartridges and in sealed copper tubes for use in treating molten copper and copper-base alloy. Dispersions, usually in mineral oil but also in other solvents, are used for organic chemical reactions.

The main metallurgical applications for lithium metal are in magnesium-lithium alloys which are used as armour plate in U.S. military vehicles and in aerospace applications. The most widely used alloy contains 85 per cent magnesium, 14 per cent lithium and 1 per cent aluminium. The weight of these alloys is only about 1.35 g. per c.c. compared with 1.74 g. per c.c. for pure magnesium

Other metallurgical applications include the addition of up to 5 per cent lithium to copper-nickel brazing alloys and to silver-copper-zinc solder and brazing alloys. The addition of up to 1 per cent of lithium improves the high-temperature strength and modulus of elasticity of aluminium. The addition of small amounts of lithium (0.05 per cent by weight) improves the toughness, tensile strength and hardness of lead castings, without affecting the ductility. Lithium is also used as a scavenger for oxygen and sulphur in molten steel and copper e.g. in the production of high conductivity copper castings. It is also a good grain refiner of copper. Lithium copper castings are available in a range of standard sizes suitable for direct addition to the melt. The Lithium Corporation of America for example make a range of sizes with nominal lithium content of 2.25g. suitable for a melt of 50 lbs., to 108 g., suitable for 2,400 lbs. The amount of lithium required is thus of the order of 0.01 per cent of the weight of the melt.

Lithium metal is also used as an intermediate in the synthesis of vitamins.

3.2. Lithium compounds.

The main lithium compounds and their applications are as follows:

Compound	Formula	Percent Li	Applications
Lithium acetate	$CH_3COOLi2H_2O$	6.8	Organic synthesis, medicines catalyst for alkyd resin manufacture.
Lithium amide	$LiNH_2$	30.3	Synthesis of anti histamines Claissen condensations, synthesis of ethynyl compounds and acetylenic alcohols, alkylation of nitriles and ketones.
Lithium borate	$LiBO_2 2H_2O$	8.1)	Glasses and enamels
Lithium tetraborate	$Li_2B_4O_7$	8.3)	
Lithium bromide	LiBr	8.0	Hypnotics and sedatives; laboratory catalyst; dehydrohalogenating agent.

Compounds	Formula	Percent Li	Applications
Lithium carbonate	Li_2CO_3	18.8	Enamels, glasses and glazes aluminium potliners (U.S. consumption is several mill. lbs. p.a.).
Lithium chloride	LiCe	16.4	Raw material for lithium metal; brazing fluxes, additive to electrolytes of low-temperature dry-cell batteries; dehumidifier in air conditioning (U.S. consumption exceeded only by that of carbonate and hydroxide).
Lithium formate	$HCOOLiH_2O$	9.9	Catalyst for alkyd resin manufacture.
Lithium fluoride	LiF	26.6	Flux in enamels, glasses and glazes; in brazing and welding fluxes; additive to bath in aluminium manufacture; heat-silk material in space vehicles for storing thermal energy from solar radiation.
Lithium hydride	LiH	87.4	Raw material for lithium aluminium hydride (a strong reducing agent; used also in the purification of silicon for transistors), and lithium borohydride; shielding material for thermal neutrons; heat sink, fuel cells, hydrogen source.
Lithium hydroxide	LiOH	29.0	Production of lithium stearate and other lithium soaps for addition to lubricating greases to maintain viscosity at low and high temperatures; ingredient in the aqueous electrolyte of alkaline storage batteries.
Lithium hypochlorite	LiOCe	11.9	Laundry bleach and bactericide for swimming pools.
Lithium iodide	LiI	5.2	Catalyst in manufacture of aromatic hydrocarbons.
Lithium nitrate	$LiNO_3$	10.1	Heat-transfer medium; flame-colourant in flares and fireworks; glass etching.
Lithium oxide	Li_2O	46.5	CO_2 absorbant.
Lithium perchlorate	$LiCEO_4$	6.5	Source of pure oxygen; rocket fuel oxidiser.

Compounds	Formula	Percent Li	Applications
Lithium peroxide	Li_2O_2	30.3	Regeneration of breathing atmospheres.
Lithium silicate	Li_2SiO_3	15.4	Enamels and glazes, base for inorganic zinc coatings.
Lithium sulphate	Li_2SO_4	12.6	High strength glass.
N-Butyllithium	$CH_3CH_3CH_2CH_2Li$	10.9	Catalyst with stereospecific action in polymerization of butadiene, isoprene and styrene to yield synthetic rubbers with special properties. (U.S. consumption several hundred thousand lbs. per annum).
Sec-Butyl lithium	$CH_3CH_2CH(Li)$ CH_3	10.9	As for n-Butyl lithium but the quantities used are smaller.
Tert-Butyl lithium	$(CH_3)_3CLi$	10.9	Experimental catalyst in polymerisation of isoprene.
Methyl lithium	CH_3Li	31.7	Synthesis of vitamins A & D and various analgesics (experimental).
Vinyl lithium	$CH_2{=}CHLi$	20.4	Experimental.
Lithium acetylide - ethylenediamine complex	$LiC{=}CH.H_2NCH_2$ CH_2NH_2	7.5	Ketosteroids and ketones to yield ethymyl alcohols (pharmaceutical).
Phenyl lithium	C_6H_5Li	8.3	Preparation of vitamins and hormones, amalgesics and other chemo therapentic agents; phenyl-substituted silicon and tin organics; alkyl lithium compounds.

The main commercial applications which have been responsible for the bulk of the growth in world consumption of lithium in the last few years are therefore the use of lithium carbonate in aluminium potlines and in glass and ceramics; of lithium hydroxide in multi-purpose lubricant greases; of lithium bromide in absorption refrigeration and air conditioning and of organo lithium compounds as catalysts in the production of polyisoprene and polybutadiene synthetic rubbers. All these uses are expected to continue to expand though the rate of expansion in the use of lithium hydroxide in lubricant greases is tending to fall off because lithium has largely replaced sodium, calcium and aluminium in this application and the total market for greases is not expanding to any great extent.

A new use, which is expected to grow, is that of lithium carbonate in the treatment of mental disturbances. The largest potential use, however, is in batteries if the electric car becomes widely adopted, though a number of problems remain to be overcome associated with the storage and handling of molten lithium and of chlorine in a vehicle which may be involved in a road accident.

3.2.1. Atomic energy.

According to Professor Rotblat the use of lithium in the hydrogen bomb is based on the fact that the Li_6 isotope has a high neutron cross-section and is the isotope from which the hydrogen isotopes employed in thermo-nuclear fusion are derived. He deduced that the hydrogen bomb is composed of a fusion core, probably containing plutonium, surrounded by a mass of lithium deuteride, which in turn is surrounded by a shell of ordinary uranium acting at the same time as a tamper.

The Li_6 isotope is also a potentially important constituent of the moderating blanket surrounding the plasma tube in certain types of fusion generator. The blanket serves a number of purposes: it absorbs the neutrons emitted by the fusion reactions so that the neutron energy, which would otherwise be wasted, can be turned into useful heat, and protects the surroundings from the flux of high energy neutrons. It may also serve another important function. Conditions for sustaining a thermo-nuclear reaction are more favourable if the fuel is a mixture of deuterium and tritium than if it comprises deuterium alone. The chief method of producing tritium is by irradiating Li_6 with neutrons. Lithium combines good moderating ability, i.e. it slows fast neutrons down to thermal speeds very efficiently, and has a high cross section for the production of tritium. If a lithium blanket is used the tritium required to fuel the reactor can be generated by the neutrons produced in the reactor.

Lithium is in fact a better moderator than graphite which is used in fission reactors but cannot be used in place of graphite because the small fraction of Li_6 present has such a high neutron capture cross section. If, however, the lithium is used in a fusion generator for the production of tritium the Li_6 content is depleted and the remaining Li_7 might then be used in fission reactors such as those used for propulsion.

Hitherto both in the U.S.A. and the U.S.S.R. most of the residual lithium hydroxide after the extraction of the Li_6 isotope has been stockpiled or made available for purchase by the suppliers or by end users of lithium hydroxide. In 1963, however, the U.S. Atomic Energy Commission awarded a contract for the construction of a high-termpature lithium-cooled reactor in Idaho and the project became known as the Lithium Cooled Reactor Experiment (LCRE).

3.2.2. Aluminium production.

The addition of lithium carbonate to aluminium reduction cells has been one of the most rapidly growing applications during the last four or five years. Kaiser Aluminium was one of the pioneers in the field but work has also been done by Montecatini and other aluminium producers. Kaiser has claimed that it is possible to raise aluminium production by 8 per cent through the addition of between 2 and 8 per cent of lithium to the molten electrolyte. The lithium improves the conductivity of the bath and allows more current to be passed through the cell without the normal disadvantages of higher temperatures, loss of efficiency and formation of aluminium fog caused by reoxidation of aluminium. The effect has been known for many years but the increased capacity attainable must be weighed against the cost of the lithium. The consumption of lithium carbonate is therefore likely to be high when there is a shortage of aluminium production capacity but will decline if pressure on capacity eases.

3.2.3. Glasses, ceramics and vitreous enamels.

Lithium may be introduced into glass, ceramics and vitrerous enamels as lithium carbonate and other compounds or as the minerals amblygonite, lepidolite and petalite. Spodumene can also be used if the iron content is low enough or can be reduced to an acceptable level. In the glass industry lithium is used mainly in the manufacture of cathode ray tubes which, in the U.K. may account for about 180 tons per annum of Li_2O mainly in the form of petalite. It is also used in sealed beam head lamps and in special glasses such as toughened and heat-resisting glass. Lithium compounds in ceramics act primarily as a flux, permit the use of lower firing temperatures, improve the quality of the product by reducing thermal expansion and increase chemical durability and the refractive index.

Lithium is added to vitreous enamels primarily to reduce the fusion temperature of the frit but is also said to improve the resistance of the enamel to alkalies and acids. It is used particularly in the formulation of enamels for aluminium where a low melting point is required.

Of the manufactured compounds lithium carbonate is most widely used but the fluoride, manganite, cobaltite, titanate and zirconate are also used. In 1968 it was estimated that 80 per cent of the U.S. consumption of lithium carbonate (other than that used to produce other lithium chemicals) went into glasses and enamels. The proportion is probably now lower owing to increasing use in aluminium potlines.

The use of the natural minerals is usually cheaper, particularly where they also supply other useful additives e.g. alumina and phosphate. In other instances the impurities in the minerals cannot be tolerated and the use of a suitable lithium compound permits much closer control of the quantity added.

Lithium carbonate has been substituted for lead oxide in glazes for vitreous and semi-vitreous ceramic products since it eliminates the health hazards associated with the use of lead and provides a superior glaze.

3.2.4. Greases.

The majority of all-purpose or multi-purpose greases now contain lithium stearate or other lithium soap. Such greases retain their lubricating properties over a very wide temperature range, from sub-zero to over 300°F. They have good water resistance, resist oxidation and, if liquified, reform a stable grease on cooling. Many military specifications for grease can only be met through the incorporation of lithium soaps and in industrial, automotive, aircraft and marine applications a single lithium grease can be used for a multiplicity of applications which formerly required several different types. This has resulted in a more or less complete substitution of lithium greases for sodium and calcium greases, though at very high temperatures barium and strontium greases may be superior to those containing lithium.

The lithium is generally introduced as lithium hydroxide monohydrate and saponifies in situ. It is claimed that this is both the cheapest and the most effective method, though commercially prepared lithium stearates including lithium 12-hydroxystearate are sometimes used. The lithium soap content varies from 6.5 per cent to about 12 per cent in the highest grades of grease but the average is about 8 per cent. It has been estimated that about 4 mill. lbs. of lithium hydroxide monohydrate was used in greases in the U.S.A. in 1964. According to another source lithium greases at that time accounted for 40 per cent of the total production of lubricating greases and the potential consumption of lithium hydroxide monohydrate in greases was therefore about 10 mill. lbs. and may have since risen to about 12 mill. lbs. This is equivalent to about 4.3 mill. lbs. Li_2O. Actual consumption of lithium hydroxide monohydrate in greases in the U.S.A. may be about 3 mill. lbs. Li_2O or 40 per cent of total consumption of lithium in all forms.

3.2.5. Refrigeration and air conditioning.

Lithium bromide, chloride or nitrate are used in absorption refrigeration systems because they have a high absorption value for ammonia and a number of chlorinated organic refrigerants, a low vapour pressure and low freezing point.

Lithium chloride is used as a dehumidifier in air conditioning systems particularly in hospitals since it is claimed to result in a considerable measure of air sterilization. In the U.K. W.C. Holmes & Co. Ltd. held a license from the International Engineering and Trading Society N.V. to market the Kathabar system, developed by the Surface Combustion Corporation, Ohio, U.S.A. which was claimed to remove 97 per cent of airborne bacteria.

3.2.6. Catalysts.

Organolithium compounds are extensively used as catalysts in polymer production. In particular n-Butyl lithium is used in the manufacture of polyisoprene rubbers and a few years ago was one of the most effective catalysts in directing polymerization towards the cis-1, 4 structure which confers properties most closely resembling natural rubber. The highest Cis 1-4 contents are, however, obtained using Ziegler type catalysts based on aluminium and titanium which, until recently, received more attention than lithium-based materials largely owing to the greater availability and lower cost of aluminium. The Butyl lithiums also catalyse the stereospecific polymerization of butadiene and of its copolymers with styrene and x-methylstyrene. While they are the most effective catalysts for this purpose, Grignard reagents, dialkylmagnesiu compounds and sodium and potassium alkyls are also used. Lithium aluminium organic compounds are used in the low-pressure polymerization of ethylene to polymers ranging from butenes to waxy solids. Lithium formate, oxalate, acetate, naphthenate and ricinoleate as well as lithium hydroxide and lithium hydride are used as catalysts in the production of alkyd resins and related condensation polymers.

It is very difficult to estimate the quantity of organolithium compounds used as catalysts, though the value of butyllithium catalysts produced in the U.S.A. in 1963 has been estimated at $1 mill. The total U.S. capacity for n-butyllithium in 1961 was said to be about 325,000 lbs. per annum made up as follows:-

	000 lbs. per annum
Lithium Corporation of America	150
Foote Mineral Co.	100
American Potash & Chemical Co.	75

The total capacity is equivalent to about 76,000 lbs Li_2O. Rate of usage is about 0.1 per cent of total raw material consumption in the polymerisation plant and the residues remain in the end product i.e. there is no recovery of catalyst. Although polyisoprene rubber most closely resembles natural rubber and should therefore have a high growth potential it is an expensive polymer to produce. So far as is known the only two plants in Europe are those operated by Shell Nederland in the Netherlands with a capacity of 70,000 tons per annum and by Dunlop-Chemical Products Division with a capacity of about 10,000 tons in the U.K. in Italy ANIC is erecting a plant with a capacity of 30,000 tons per annum, which is due to start operations during 1971. In West Germany Hüls Bunawerke is due to start up a plant in 1971 with a capacity of 30,000 tons, which in France the Cie. du Polyisoprene Synthetique, a joint subsidiary of Goodyear Tire & Rubber and Michelin, is erecting a plant at Le Havre of 60,000 tons per annum which will use isoprene supplied from West Germany by Bayer. A plant with a capacity of 30,000 tons per annum is also being erected in Japan by a new company Japan Polyisoprene Rubber Co. formed jointly by Goodyear Tyre and Rubber Co. (50 per cent) Japan Synthetic Rubber Co. (35 per cent) and Bridgestone Tire Co. (15 per cent). Asahi Chemical Co. have plans to build a plant of capacity 20,000 tons per annum for completion in 1973; the Kuraroy Co. propose to produce 20,000 tons per annum from the autumn of 1971 and Japanese Geon propose to erect a plant with a capacity of 25,000 tons per annum.

A high rate of growth in output of polyisoprene rubber is also expected in the U.S.A. and the U.S.S.R. The U.S. production of isoprene monomer was about 100,000 tons per annum in 1970 and is expected to rise to 260,000 tons in 1973. In the U.S.S.R. the output of polyisoprene rubber is expected to double by 1973 to 120,000 tons per annum. In the world as a whole polyisoprene rubbers are estimated to have accounted for about 2.5 per cent of synthetic rubber consumption in 1965 and 7.3 per cent in 1970. By 1975 they are expected to account for nearly 10 per cent and to be the third most important type after SBR and polybutadiene. If all the plants listed were to use lithium based catalysts the consumption of n-Butyllithium might be as high as 1.35 mill. lbs. per annum equivalent to 315,000 lbs. Li_2O. In practice it seems that consumption will be only a small fraction of this figure, since most plants seem likely to use catalysts other than lithium. The Goodyear process to be used in France employs an aluminium isopropylate catalyst and this probably also applies to their U.S. plant and the proposed plant in Japan.

During the last 15 years a considerable amount of work has been done on the organo-lithium catalysts and the following advantages are claimed for them:-

(1) reactions have a fast initiation and a relatively slow propagation step. This means that the reaction proceeds until stopped, following only one injection of catalyst.

(2) efficiencies are very high and products do not contain harmful transition metal residues. Work-up techniques are therefore simpler than those required to rid Ziegler polymer of its residues, which tend to accelerate oxidation of the product if not fully extracted.

(3) only a one- or at most two-component catalyst is required against two to four components in the Ziegler catalysts.

(4) greater versatility is possible even than when using Ziegler mixed catalysts since the polymer chain structure can be changed easily at any time during the reaction.

The polyisoprene rubber produced with lithium catalysts is often blended with styrene-butadiene co-polymer or with polybutadiene. Two types of styrene-butadiene copolymer are produced with lithium catalysts: one has a random arrangement of monomer units while the other has short blocks of polystyrene in the chain. The latter is used in footwear and for extrusion and injection mouldings. The Firestone process for the production of polybutadiene uses a catalyst based on Butyllithium but is apparently the only such process to do so.

Organo lithium compounds are also used as catalysts in the production of Lithene liquid butadiene telomers, which were developed by the Lithium Corporation of American and are to be produced by Revertex Ltd. in the U.K. It was stated in January 1971 that production was then 1,200 tons a year and was planned to reach 10,000 tons within two years. The catalyst can, however, be regenerated and the consumption of lithium is not expected to be large.

3.2.7. Batteries.

Probably the oldest application for lithium hydroxide was as an additive in the electrolyte of nickel iron-alkaline storage batteries. The electrolyte comprises a solution of potassium hydroxide in water to which a small quantity of lithium hydroxide is added to increase the capacity and life of the cell.

Interest has been expressed from time to time in the use of lithium in high energy batteries since its electrochemical equivalent (3.86 Ah/g.) is second only to that of beryllium. Its standard oxidation potential of 3.045V is the highest of any element and it is therefore the most concentrated energy potentially available. Owing to its reaction with an aqueous electrolytic medium, however, it must be used in the form of a dry cell.

In a study prepared for the U.S. Department of Health Education and Welfare, Arthur D. Little concluded that while a metal-air battery would provide a completely adequate solution to the problems posed by an electric commuter or run-about car, a family car with high speeds and long range would have to be based on battery systems operating at 600°C. on lithium or sodium with sulphur or chlorine. They thought that at least 10 years development work would be necessary into means of handling molten metal and poisonous materials such as chlorine. Shielding and crash-proofing would be major areas of work. Although such systems would give the requisite high power density it may be doubted whether they would in fact be acceptable as a solution to the problem of atmospheric pollution.

A prototype car with lithium batteries has been developed in the U.S.A. by General Motors Corporation in conjunction with Gulton Industries Company, Metuchen, New Jersey. It is claimed that the car has a range of 150 miles without recharging and a cruising speed of up to 50 m.p.h. A feature of the design is a regenerated-braking system which can add up to 25 per cent to the range. G.M. have been working on a lithium chlorine cell since 1964. It operates at 600°C. and the main problems are concerned with handling molten lithium at this temperature and keeping the batteries hot for a quick start in the morning. Gulton have also been working since 1964 on a lithium-nickel halide cell primarily for the U.S. Air Force. This is said to have a low rate of discharge but it was proposed to link an auxiliary fast-discharge nickel-cadmium battery to provide quick burst of power for acceleration after which the auxiliary would be recharged from the main unit.

If a lithium battery can be developed for large scale use in motor vehicles this could well become the biggest outlet for lithium but it is of course possible that some type of fuel cell will be adopted before this stage is reached.

Argonne National Laboratory, Argonne, Ill. have been working on a lithium-sulphur cell using as electrolyte the molten ternary eutectic of lithium fluoride - lithium chloride - lithium iodide. The operating temperature is 350 to 400°C.

3.2.8. Miscellaneous uses.

Lithium hydride is used as a portable source of hydrogen: 4 lb. reacted with water will yield 200 cu.ft. of hydrogen. In the U.S.A. the Lithium Corporation has developed a gas generator float, which uses lithium hydride to provide hydrogen for buoyancy. It is also used by Olin-Mathieson Chemical Corporation in the production of di-borane, a high energy rocket fuel with a heat value of 32,000 B.Th.U's per lb. The diborane may be pyrolysed to pentaborane or decaborane which are then alkydated to give the final high-energy fuels.

Lithium aluminium hydride, derived from lithium hydride is used in organic reductions such as reduction of esters, carboxylic acids, and anhydrides and acid chlorides to primary alcohols. It is also used in the purification of silicon for use in transistors.

Lithium hypochlorite is sold as a bleach and is widely used in the U.S.A. for the treatment of swimming pools. Although more expensive than sodium or calcium hypochlorite its advantages are high active-chlorine content, stability in storage and rapid and complete solubility in water. The most widely used chemical, however, is probably still calcium hypochlorite of which consumption in swimming pools in the U.S.A. was about 33,000 tons in 1967 and was probably approaching 40,000 tons in 1970. Other products used include sodium hypochlorite, chloroisocyanurates and chlorine gas in cylinders.

Lithium carbonate has been proposed by Chas. Pfizer and Rowell Laboratories as a treatment for certain mental disorders. An earlier use of lithium compounds for this purpose was banned in the U.S.A. in 1950 as a result of fatalities which occurred when lithium chloride was used as a salt substitute for cardiac patients, while lithium carbonate was also discredited because of misuse in treatment of gout and rheumatism. It is now claimed however, that lithium carbonate can be used in high-purity form. Its use was approved during 1970 by the U.S. Food and Drug Administration for the control of the manic phase of manic depressives. It is said to be 70 to 80 per cent effective within 5 to 10 days and may largely replace electric shock therapy within the next 10 years.

Lithium chloride and lithium fluoride are used as oxide scavengers and metal cleaners in welding and brazing fluxes, particularly in the welding of aluminium where they have the ability to remove the film of aluminium oxide from the metal surface. Lithium chloride is also used in fluxes in brazing magnesium, titanium and zirconium. This application, however, has not grown to any great extent owing to the development of argon arc welding. Lithium chloride is a constituent of the electrolyte in a process developed by the U.S. Bureau of Mines for the recovery of nickel and cobalt from nickel-cobalt alloys.

Anhydrous lithium hydroxide has been used to absorb carbon dioxide in submarines, the Apollo space vehicles and other confined spaces. It can absorb up to three-quarters of its own weight of carbon dioxide and has the advantage over alternatives such as caustic soda of remaining solid without caking until it is entirely converted to carbonate.

Small quantities of lithium chloride are used as an addition to the electrolyte in dry cells intended for operation at low temperatures, particularly in the range 0 to -60°F.

4. Consumption and main producers of lithium chemicals.

4.1. World consumption and trade.

The U.S.A. is by far the largest producer of lithium chemicals and in addition to supplying the U.S. market exports to Japan and Europe. The U.S.S.R. is also a major supplier to Europe of surplus lithium hydroxide accumulated during the development of fusion weapons, since all the samples examined are said to show a marked depletion of the 6-isotope. In Europe lithium chemicals are produced in Italy where estimated production in 1969 was 400,000 lbs. Li_2O content, in West Germany and probably in small quantities in France. Production in the U.K. appears to have ceased after the imposition of sanctions against exports of lithium minerals from Rhodesia. The fact that a country records imports of lithium minerals does not necessarily imply that it produces lithium metal or lithium chemicals since the mineral may be used directly in the production of glass or vitreous enamels.

Details of imports of lithium metal and lithium chemicals into the main European countries and Japan are shown in the individual country sections below and are summarised in Table 9.

Table 9 : Imports of lithium metal and chemicals into main using countries. (m. tons).

	1968	1969	1970(1)
1. Lithium metal			
France	1.0	-	(1.0)
Germany, Western	5.9	5.4	7.7
Italy	0.3	2.1	1.1
Japan	4.1	6.5	8.8
Total	11.3	14.0	18.6
2. Lithium carbonate			
Belgium/Luxembourg	142.8	228.9	44.4
France	215.0	242.0	(270.0)
Germany, Western	1,224.9	1,434.1	1,620.1
Japan	486.7	774.9	1,298.5
Netherlands	88.0	126.0	139.0
United Kingdom	(160.0)	(180.0)	(200.0)
Total of above	2,317.4	2,985.9	3,572.0
3. Lithium chloride			
Germany, Western	21.7	32.5	35.8
Japan	...	30.2	72.4
U.K.	...	38.0	84.0
Total of above	...	100.7	192.2
4. Lithium oxide and hydroxide			
Belgium/Luxembourg	49.7	66.2	81.4
France	357.0	588.0	(650.0)
Germany, Western	910.9	1,192.9	965.3
Italy	130.8	63.9	155.0
Japan	248.2	332.4	428.0
Netherlands	55.0	92.0	269.0
U.K.	(200.0)	(250.0)	(350.0)
Total of above	1,951.6	2,585.4	2,898.7

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(1) Partly estimated.

Some of these imports are supplied from other European countries (there are no recorded exports from Japan) but as stated above the main sources are the U.S.A. and U.S.S.R. and the following table attempts to build up a picture of the exports from these two countries:-

Table 10: Estimated exports of lithium metal and chemicals from the U.S.A. and the U.S.S.R. (m. tons)

	1968	1969	1970
Lithium metal			
Germany, Western	1.3	1.7	3.6
Japan	4.1	6.5	8.8
Total	5.4	8.2	12.4
Li_2O equivalent	12	18	27
1. U.S.A.			
Lithium carbonate			
Belgium/Luxembourg	-	-	25.7
Germany, Western	403.2	352.7	845.6
Japan	474.7	526.6	543.0
Netherlands	31.0	6.0	14.0
U.K.(1)	....	(35.0)	...
Total	908.9	920.3	1,428.3
Li_2O equivalent	367	372	576
Lithium chloride			
Germany, Western	7.3	12.4	-
Japan	...	30.1	72.4
U.K.(1)	...	(68.0)	...
Total	...	110.5	...
Li_2O equivalent	(30)	39	(50)
Lithium oxide and hydroxide			
Belgium/Luxembourg	22.2	29.5	24.0
France	291.0	370.0	(400.0)
Italy	38.2	...	106.8
Germany, Western	691.6	806.3	681.7
Japan	248.2	332.4	428.0
Netherlands	33.0	30.0	228.0
U.K.(1)	...	(79.0)	(14.0)
Total	1,294.2	1,727.4	1,882.5
Li_2O equivalent (assumed to be mainly hydroxide)	808	1,078	1,180
Total Li_2O equivalent	1,217	1,807	1,833

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(1) Incomplete.

Table 10: Estimated exports of lithium metal and chemicals from the U.S.A. and the U.S.S.R. (m. tons)

Table 10 (cont.)...	1968	1969	1970
2. U.S.S.R.			
Lithium metal			
Germany, Western	4.6	3.7	4.1
Italy	0.3	...	...
Li_2O equivalent	11	8	9
Lithium carbonate			
Belgium/Luxembourg	100.3	181.2	-
France	21.0	80.0	(100.0)
Germany, Western	684.2	691.3	646.6
Japan	12.0	248.2	755.5
Netherlands	26.0	7.0	38.0
Total	843.5	1,207.7	1,540.1
Li_2O equivalent	342	488	624
Lithium chloride			
Germany, Western	12.9	18.0	30.0
Li_2O equivalent	5	6	11
Lithium oxide and hydroxide			
Belgium/Luxembourg	-	20.5	28.8
France	50.0	66.0	(70.0)
Germany, Western	184.6	297.4	226.1
Total	234.6	383.9	324.9
Li_2O equivalent (assumed to be mainly hydroxide)	147	240	203
Total Li_2O equivalent	505	742	847

4.2. Belgium/Luxembourg.

Belgian imports and exports of lithium compounds are shown in Tables 11 and 12.

Table 11 : Belgium: Imports of lithium compounds.
(m. tons).

Countries of origin	1966	1967	1968	1969	1970[1]
1. Lithium carbonate					
Germany, Western	...	...	28.1	25.2	6.7
U.S.A.	...	...	-	-	25.7
U.S.S.R.	...	...	100.3	181.2	-
Others	...	...	14.4	22.5	12.0
Total	17.6	43.4	142.8	228.9	44.4
2. Lithium oxide and hydroxide					
Germany, Western	37.8	...	20.4	13.7	14.2
Netherlands	-	...	-	-	12.0
U.K.	0.5	...	-	-	-
U.S.A.	26.2	...	22.2	29.5	24.0
U.S.S.R.	-	...	-	20.5	28.8
Others	1.7	...	7.1	2.5	2.4
Total	66.2	70.2	49.7	66.2	81.4

Table 12 : Belgium: Exports of lithium compounds.

	1966	1967	1968	1969	1970[1]
1. Lithium carbonate					
Total	0.4	0.3	101.7	181.6	1.0
2. Lithium oxide and hydroxide					
Total	0.2	1.0	2.7	-	-

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(1) Based on 1st 7 months.

4.3. Brazil.

In Brazil Orquima S.A. has been producing up to 300 tons per annum of lithium carbonate since 1956. Part of the output is sold to lubricant manufacturers in Brazil and part is exported to the U.S.A.

4.4. France.

The main producers of lithium compounds in France is the Sté. des Usines Chimiques Rhone-Poulenc, 22 Av. Montaigne, 75 Paris 8^{e}. This company produces lithium benzoate, carbonate, citrate, fluoride, hydroxide, nitrate, salicylate and succinate. Two other companies listed as producers of lithium salts are Dia-Prosim S.A., 107 rue Edith Cavell, Vitry and Tiscco S.A., 145 ruede Paris, Bobigny.

French imports and exports are shown in Tables 13 and 14.

Table 13 : France: Imports of lithium metal and compounds. (m. tons)

Country of origin	1966	1967	1968	1969
1. Lithium metal				
Total	1	1	1	-
2. Lithium carbonate				
Germany, Western	59	40	193	134
Italy	13	-	-	20
U.S.A.	-	24	-	-
U.S.S.R.	-	-	21	80
Other	1	7	1	-
Total	73	71	215	242
3. Lithium oxides and hydroxides				
Germany, Western	11	-	16	152
U.S.A.	282	430	291	370
U.S.S.R.	14	21	50	66
Total	307	451	357	588

Table 14: France: Exports of Lithium metal and compounds. (m. tons)

Country of destination	1966	1967	1968	1969
1. Lithium metal				
Total	...	...	...	4
2. Lithium carbonate				
E.E.C.	2	-	1	21
Other	1	2	3	60
Total	3	2	4	81
3. Lithium oxides and hydroxides				
Germany, Western	...	27	20	86
Other	...	-	6	1
Total	...	27	26	87

4.5. West Germany.

In West Germany lithium metal and compounds are produced by:-

Chemische Fabrik Budenheim Rudolf A. Oetker, 6501 Budenheim, Postf. 45-47.
Mono-,di-and tri-lithium ortho phosphate, lithium polyphosphate.

Chemische Fabrik Hoesch K.G., 5160 Düren (Rhld.) Postf. 175.
Lithium stearate.

Chemische Fabrik Lehrte Dr. Andreas Kossel GmbH., 3160 Lehrte (Hann.), Postf. 147.
Lithium acetate, benzoate, citrate, formate, hydroxide, lactate, oxalate, salicylate, tartrate.

Chemische Fabrik Dr. Herbert Wolff & Co., (subsidiary of Th. Goldschmidt A.G., Essen), 2000 Hamburg-Eidelstedt 1, Postf. 14947.
Lithium palmitate, stearate.

Degussa, Deutsche Gold- und Silber-Scheideanstalt vormals
Roessler, 600 Frankfurt/M, 1., Postf. 3993.
Lithium dispersions in oil or wax, lithium bromide.

Heyl & Co., Chemische-pharmazeutische Fabrik, 1000 Berlin 37,
(Zehlendorff), Goerzallee 253.
Lithium borohydride, cyanoborohydride.

Kepec Chemische Fabrik GmbH., 5200 Siegburg (Rhld.), Postf.90,
Barbarastr. 34.
Lithium salicylate.

Dr. Paul Lohmann Chemische Fabrik, 3,254 Emmerthal-Kirchohsen,
Postf. 48, Hauptstr. 2.
Lithium acetate, citrate, formate, phosphate.

E. Merck A.G., 6100 Darmstadt, FrankfurterStr. 250.
Lithium metal, aluminium hydride, benzoate, Butyl lithium, lithium carbonate, chloride, citrate, hydroxide, iodide, sulphate.

Metallgesellschaft A.G., Abt. T.A. Lithium, 6000 Frankfurt/M,
Postf. 2609.
Lithium metal, dispersions, aluminium hydride, amide, borohydride, bromide, butyl lithium, lithium carbonate, chloride, fluoride, hydride, hydroxide, molybdate, nitrate, phenyllithium, trilithium orthophosphate, silicate, sulphate.

Riedel-de Haën A.G., 3016 Seelze-Hannover, Wunstorfer Str.40.
Lithium benzoate, chloride, fluoride, nitrate, salicylate, sulphate.

Dr. Theodor Schuchardt GmbH. & Co., 8000 München 13, Postf.320.
Lithium acetate, metaborate, hippurate, lactate.

Serva-Entwicklungslabor von Grothe & Co., 6000 Heidelberg 1,
Postf. 1505.
Lithium perchlorate.

Germany is the second largest importer of lithium minerals. Hans Heinrich Hütte GmbH., a subsidiary of Metallgesellschaft A.G., which was the first company in Germany to produce lithium metal and compounds, in 1964 made an agreement to import spodumene from the Foote Mineral Co. in the U.S.A. Hans Heinrich Hütte was, in fact, the world's first producer of lithium metal and salts in a plant erected in 1923 to treat micaceous sands occurring at Zinnwald in the Erzgebirge. The lithium produced was used mainly in the production of lead-based bearing alloys which though used for railway rolling stock for several years were discontinued in the 1930's. The original raw material was exhausted about 1942 and since then lithium ores have been purchased from a number of countries. However no figures are available for imports of lithium ores.

German imports and exports of lithium metal, lithium carbonate, lithium chloride, lithium oxide and hydroxide are shown in Tables 15 and 16.

Table 15: West Germany: Imports of lithium metal and compounds. (m. tons).

Country of origin	1966	1967	1968	1969	1970(1)
1. Lithium metal					
U.S.A.	...	0.7	1.3	1.7	3.6
U.S.S.R.	...	-	4.6	3.7	4.1
Other	...	0.1	-	-	-
Total	...	0.8	5.9	5.4	7.7
2. Lithium carbonate					
Canada	...	24.4	-	-	-
Italy	...	169.6	137.4	380.0	101.9
Netherlands	...	-	-	10.1	26.8
U.S.A.	...	133.2	403.2	352.7	845.6
U.S.S.R.	...	220.3	684.2	691.3	646.0
Total	...	547.5	1,224.9	1,434.1	1,620.7
3. Lithium chloride					
U.S.A.	...	13.3	7.3	12.4	-
U.S.S.R.	...	-	12.9	18.0	30.0
Other	...	-	1.5	2.1	5.8
Total	...	13.3	21.7	32.5	35.8
4. Lithium oxide and hydroxide					
France	...	11.9	34.7	89.1	51.6
U.S.A.	...	841.3	691.6	806.3	681.7
U.S.S.R.	...	15.3	184.6	297.4	226.1
Total	...	868.5	910.9	1,192.9	965.3

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(1) Estimated on basis of 1st 10 months.

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Table 16: West Germany: Exports of lithium metal and compounds
(m. tons)

Country of destination	1966	1967	1968	1969	1970(1
1. Lithium metal					
France	...	0.7	0.3	-	-
India	...	0.3	0.7	-	-
Italy	...	-	-	0.3	-
Switzerland	...	-	12.1	18.1	15.5
Other	...	0.1	0.1	0.1	1.0
Total	...	1.1	13.2	18.1	16.5
2. Lithium carbonate					
Austria	...	5.0	-	5.6	-
Belgium/Luxembourg	...	10.2	22.6	47.9	36.7
Czechoslovakia	...	-	33.0	17.0	-
France	...	68.1	200.4	125.5	43.2
Italy	...	4.3	-	-	-
Netherlands	...	16.2	25.7	-	11.2
Norway	...	-	-	-	25.7
Poland	...	-	-	20.0	-
Switzerland	...	-	17.4	148.2	78.2
Yugoslavia	...	-	-	5.2	-
Other	...	6.5	8.8	55.2	45.1
Total	...	110.3	307.9	424.6	240.1
3. Lithium chloride					
Australia	...	3.8	3.9	-	-
France	...	15.3	15.1	50.1	60.5
Italy	...	32.1	-	14.6	-
Netherlands	...	34.2	44.8	63.6	67.3
Norway	...	3.1	-	-	-
Sweden	...	3.2	5.3	4.6	-
Switzerland	...	2.3	-	-	-
Other	...	8.7	7.1	9.9	39.8
Total	...	99.5	76.2	142.8	167.6

/Table contd...

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(1) Based on 1st 10 months.

/table continued...

Table 16: West Germany: Exports of lithium metal and compounds. (m. tons)

Country of destination	1966	1967	1968	1969	1970(1)
4. Lithium oxide and hydroxide					
Argentina	...	7.0	10.0	-	-
Austria	...	18.0	35.3	47.5	56.3
Belgium/Luxembourg	...	34.0	23.0	11.0	12.0
Chile	...	-	4.8	-	-
Denmark	...	15.1	18.0	18.0	18.1
Finland	...	3.5	6.5	-	-
France	...	10.0	35.0	150.8	25.2
Italy	...	70.1	84.1	80.4	96.1
Netherlands	...	45.2	30.2	30.8	-
South Africa	...	14.9	34.5	-	-
Spain	...	21.0	29.0	8.0	22.8
Sweden	...	22.2	8.1	22.9	27.6
Switzerland	...	8.2	13.9	7.1	-
United Arab Rep.	...	-	15.0	13.2	-
U.K.	...	49.6	28.0	60.5	46.8
Other	...	53.1	34.1	72.9	-
Total	...	349.7	399.5	523.1	304.9

4.6. Italy.

Lithium metal and lithium compounds are said to be produced in Italy by Montecatini-Edison S.p.A. and compounds are also produced by Carlo Erba S.p.A. both of Milan. Italy also imports both lithium metal and lithium oxide and hydroxide as shown in Tables 17 and 18.

Table 17: Italy: Imports of Lithium metal. (m. tons) (kgs.)

	1966	1967	1968	1969	1970 (Jan.-Sept.)
Germany, West		0.2	...	...	...
Switzerland		...	-	...	...
U.K.		...	-	...	...
U.S.A.		...	...	...	...
U.S.S.R.		-	0.3	...	...
Total		0.3	0.3	2.1	1.1

No exports of Lithium metal are recorded.

Table 18: Italy: Imports of Lithium oxide and hydroxide. (m. tons).

	1966	1967	1968	1969	1970(Jan.-Sept.)
Germany, West	35.3	36.2	38.2	...	80.1
U.S.A.	26.8	67.6	92.7	...	-
Other	-	-	-	...	36.4
Total	62.1	103.7	130.8	63.9	116.5

4.7. Japan.

The following are the principal Japanese manufacturers of lithium metal and lithium compounds.

Nippon Chemical Industrial Co. Ltd., 200-9-chome, Kameido-machi., Koto-ku, Tokyo.
Lithium metal, Lithium carbonate, Lithium hydroxide.

Byron Industries Ltd., Kinsan Bldg, 5 Nihombashi Muro machi, 4-chome, Chuo-ku, Tokyo.
Lithium metal, Lithium isotopes.

Wako Bussan Co. Ltd., 8th Nippon Bldg, 6-2 Ohtemachi 2-chome, Chiyoda-ku, Tokyo.
Lithium metal.

Kanto Chemical Co. Inc., 7, Honcho 3-chome, Nihombashi, Chuo-ku, Tokyo.
Lithium carbonate, Lithium citrate, Lithium hydroxide.

Ohara & Co. Ltd., 7-4, Nihombashi Kobuna-cho 2-chome, Chuo-ku, Tokyo.
Lithium carbonate, Lithium hydroxide, Lithium oxide.

United Resources Industry Co. Ltd., 9, Kyobashi-2-chome, Chuo-ku, Tokyo.
Lithium iodide.

Honjo Zinc Co. Ltd., Kawakami Bldg., 1 to 30 Ebienaka, Fukushima-ku, Osaka.
Lithium metal and compounds.

There are no recorded exports of lithium metal or lithium compounds from Japan. Imports are shown in Table 19.

Table 19 : Japan: Imports of lithium metal and lithium compounds. (m. tons).

Countries of origin	1966	1967	1968	1969	1970(1)
1. Lithium metal					
Canada	-	3.0	-	-	-
Germany, Western	-	-	(2)	(2)	(2)
U.S.A.	20.3	15.6	4.1	6.5	8.8
Total	20.3	18.6	4.1	6.5	8.8
2. Lithium carbonate					
Germany, Western	-	-	-	0.1	-
U.K.	-	-	-	-	(2)
U.S.A.	222.5	419.0	474.7	526.6	543.0
U.S.S.R.	1.0	13.1	12.0	248.2	755.5
Total	223.5	432.1	486.7	774.9	1,298.5
3. Lithium chloride					
Germany, Western	...	1.0	...	0.1	(2)
U.S.A.	...	-	...	30.1	72.4
Total	...	1.0	...	30.2	72.4
4. Lithium hydroxide					
Germany, Western	0.1	-	-	-	-
Netherlands	4.0	-	-	-	-
U.S.A.	165.6	236.6	248.2	332.4	428.0
Total	169.7	236.6	248.2	332.4	428.0

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(1) Estimated on 1st 10 months.
(2) Less than 50 kg.

4.8. Netherlands.

Associatie Voor Chemische Produkten Lithos N.V., Postbus 234, Vlaardingen produce lithium metal and a range of chemicals including Butyllithium, lithium carbonate, bromide, chloride, fluoride, iodide, hydroxide, nitrate, silicate and sulphate.

The Netherlands imports some lithium carbonate and lithium hydroxide. Exports are small.

Table 20 : Netherlands: Imports of lithium compounds.
(m. tons)

Country of origin	1966	1967	1968	1969	1970(1)
1. Lithium carbonate					
Belgium/ Luxembourg	-	-	2	2	1
Germany, Western	22	17	27	110	85
U.S.A.	15	19	31	6	14
U.S.S.R.	18	22	26	7	38
Other	3	2	2	1	-
Total	58	60	88	126	139
2. Lithium oxide and hydroxide					
Belgium/ Luxembourg	-	-	12	20	29
Germany, Western	66	45	10	40	-
U.S.A.	36	12	33	30	228
Other	1	-	-	2	12
Total	103	57	55	92	269

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(1) Estimated on 1st 10 months.

Table 21 : Netherlands: Exports of lithium compounds.
(m. tons)

Countries of destination	1966	1967	1968	1969	1970
1. Lithium carbonate					
France	...	3	5	-	-
Germany, Western	...	-	-	10	-
Other	...	-	-	-	22
Total	...	3	5	10	22
2. Lithium oxide and hydroxide					
Belgium/Luxembourg	-	-	-	-	1
France	-	-	-	-	-
Germany, Western	-	-	-	-	192
U.S.A.	-	-	-	-	-
Other	-	1	-	-	12
Total	-	1	-	-	205

4.9 United Kingdom.

The U.K. trade returns do not show imports of lithium minerals. Before the imposition of sanctions against Rhodesia the bulk of the imports were obtained from that country and in 1965 the last year for which statistics of Rhodesian exports are available shipments to the U.K. totalled 6,900 tons of which it is estimated that about half was used as such in glass and vitreous enamels and half as a source of lithium metal and compounds. Of the consumption of compounds, i.e. home-produced and imported, about 45 per cent is estimated to have been used in glass and enamels which thus accounted for about two-thirds of the total available supplies of lithium. Demand in these industries, however, is probably not increasing to any great extent. The only other major use was in greases which probably accounted for between 20 and 25 per cent of consumption. Relatively small quantities were used in alkaline batteries, refrigerants and miscellaneous salts and compounds.

Consumption of lithium hydroxide or lithium stearate in greases is believed to be still increasing but relatively slowly because lithium based greases already account for about 50 per cent of the total consumption of greases and have virtually replaced sodium and calcium greases. The consumption of lithium hydroxide and lithium stearate in greases is likely in future to expand at about the same rate as that of the consumption of grease as a whole.

For high temperature application in the aircraft industry organic based greases are being used in place of lithium greases but there appears to have been no general adoption of such greases for automotive and industrial uses.

Imported lithium minerals are available in the U.K. from:-

Abrafract Ltd., Sheffield.
Beralt Tin and Wolfram Ltd., London, E.C.1.
British Metal Corporation Ltd., London, E.C.2.
Derby & Co. Ltd., London, E.C.2.
Ralph Lawton Ltd., Newcastle-under-Lyme, Staffs.
Leopold Lazarus Ltd., London, E.C.4.
Leigh and Sullivan Ltd., Macclesfield, Cheshire.
Metal Traders Strauss Ltd., London, E.C.4.
Colin Stewart Minerals Ltd., London, W.C.1.

U.K. producers of lithium metal and lithium compounds are:-

A.B.M. Industrial Products Ltd., Woodley, Stockport, Cheshire.
Lithium naphthenate.

Albright & Wilson Ltd., Oldbury Div., 1 Knightsbridge Green, London, S.W.1.
Lithium 12- hydroxystearate, phosphate, stearate (commercial).

Associated Lead Manufacturers Ltd., Clements House, 14, Gresham Street, London, E.C.2.
Lithium metal, acetate, bromide, carbonate, chloride, fluoride, hydroxide, nitrate, sulphate.

Blackwell's Metallurgical Works Ltd., Lytham St. Annes, Lancs.
Lithium metal and alloys.

The British Drug Houses Ltd., Broom Road, Poole, Dorset.
Lithium acetate, dilithium acetyl-phosphate, lithium benzoate, bromide, carbonate, chloride, dilithium ethylenediamine-NNN'N'-tetra-acetate, lithium fluoride, iodide, lactate, nitrate, oxalate, perchlorate, pyruvate, sulphate, dilithium tetraborate, lithium thiocyanate.

Durham Chemicals Ltd., Birtley, Co. Durham.
Lithium 12-hydroxystearate, octanoate, palmitate, stearate.

Evans Medical Ltd., Speke, Liverpool 24.
Lithium citrate.

Fisons Scientific Apparatus Ltd., Bishop Meadow Road, Loughborough, Leics.
Dilithium ethylenediamine-NNN'N'-tetra-acetate.

Gerhardt-Penick Ltd.
Lithium benzoate.

Hardman & Holden Ltd., Manox House, Coleshill Street, Miles Platting, Manchester, 10.
Lithium naphthenate.

Harrington Brothers Ltd., 12A Weir Road, Balham, London, S.W.12.
Lithium bromate, bromide, chloride, dichromate, formate, iodate, iodide, nitrate, oxalate.

Hopkin & Williams Ltd., Freshwater Road, Chadwick Heath, Essex.
Lithium acetate, bromate, chloride, dilithium and disodium ethylenediamine-NNN'N'-tetra-acetate, dilithium ethylenadiamine-NNN'N'-tetra-acetate, lithium fluoride, formate, hydroxide, iodide, lactate, nitrate, trilithium orthophosphate, lithium perchlorate,sulphate, dilithium tetraborate, lithium thiocyanate.

Johnson Matthey Chemicals Ltd., 74 Hatton Garden, London,E.C.1.
Lithium metal, acetate, bromide solution, carbonate, chloride, fluoride, nitrate, silicate, dilithium tetraborate.

Koch-Light Laboratories Ltd., Poyle Trading Estate, Colnbrook, Bucks.
Lithium metal, borohydride, carbamylphosphate, pyruvate.

Laporte Industries Ltd., General Chemicals Div., Moorfield Road, Widnes, Lancs.
Lithium fluoride.

Lunevale Products Ltd., Low Mill, Halton, Lancaster.
Lithium ricinoleate.

May & Baker Ltd., Dagenham, Essex.
hexalithium antimonytri (mercapto succinate), lithium bromide.

Metal Alloys (S. Wales) Ltd., Treforest Estate, Pontypridd,
Wales.
Lithium alloys.

Nuodex Ltd., Birtley, Co. Durham.
Lithium naphthenate.

Associated Lead Manufacturers began the production of lithium carbonate in June 1956 in a new plant erected at Liverpool and later started to produce lithium hydroxide and other chemicals. British imports of lithium compounds are not available in full since details for a number of months are reserved from separate publication and in other cases information regarding countries of origin is withheld.

In the case of lithium carbonate for 1969 no details are available for the months March, April and September except that in each month the value of imports exceeded £10,000. For July and October together total imports were 1,443 cwt. valued at £28,957 but no details are available regarding countries of origin. For the remaining seven months of the year imports totalled 714 cwt. valued at £14,328 of which 712 cwt. valued at £14,078 came from the U.S.A. Total imports for the year must therefore have been at least 3,600 cwt. valued at £73,300 and may have been considerably higher. Insufficient information is available to draw any useful conclusions regarding total imports in other recent years.

Imports of lithium chloride in 1969 totalled 750 cwt. valued at £22,250 of which 31 cwt. valued at £1,171 came from the Netherlands and 719 cwt. valued at £21,079 from the U.S.A. In 1970 no details are available for the month of September except that imports were less than £10,000. For the ten months January to August, October and November imports totalled 1,379 cwt. valued at £39,544 of which 1,376 cwt. valued at £38,974 came from the U.S.A. Total imports in 1970 may be estimated at about 1,650 cwt. valued at £47,000.

Details of imports of lithium hydroxide are suppressed for the months of February, March, July and December 1969 except that they exceeded £10,000 per month in February and December and were less than £10,000 in the other two months. For the remaining 8 months of the year imports were:-

Country of Origin	cwt.	£
West Germany	860	23,171
Switzerland	1,063	21,985
U.S.A.	1,589	37,131
Total	3,512	82,287

Total imports cannot be estimated with any accuracy but may have been about 5,000 cwt. valued at £120,000.

In 1970 total imports in the 10 months January to July and September to November were 5,741 cwt. valued at £126,654. In August imports exceeded £10,000 and at the time this report was prepared no figure was available for December. Total imports therefore may have amounted to about 6,750 cwt. valued at £150,000. Details of country of origin are available only for March, May, July and November:-

	cwt.	£
West Germany	303	7,804
Switzerland	461	10,498
U.S.A.	280	6,904
Total	1,044	25,206

4.10. U.S.A.

Lithium metal and a full range of lithium compounds are produced by Foote Mineral Company and Lithium Corporation of America. The third primary producer mentioned in Section 2.2.6., American Potash and Chemical Corporation sells lithium carbonate and lithium tetraborate.

Other U.S. producers of lithium chemicals include:

Allied Chemical Corp., Industrial Chemical Div.,
Dept. TR, P. O. Box 353, Morristown, N.J.,
(chromate and dichromate).

Alloys Unlimited Inc., 320 L.I. Expressway S.,
Melville, N.Y.

American Fluoride Corp., 855 Av. of the Americas,
New York City, N.Y.
(fluoride).

Atomergic Chemicals Co., Div. of Gallard-Schlesinger
Chemical Mfg. Corp.,584 Mineola Ave, Carle Place,
L.I., New York.
(high purity metal and chemicals).

Baker Castor Oil Co., 40 Av. A., Bayonne, N.J.
(ricinoleate).

Belmont Smelting & Refining Works, 320 Belmont Avenue,
Brooklyn, N.Y.
(metal).

Bergstrom Trading Co. Inc., 4306 Woolworth Bldg.,
New York City, N.Y.
(metal,hydroxide).

BraunMetallurgical Chemical Co., 245 W. Chelten Avenue,
Philadelphia, Pa.

Carus Chemical Co., 1375 Eighth, La Salle, Ill.
(permanganate).

Cerac Inc., P. O. Box 597, Butler, Wis.

City Chemical Corp., 130 W. 22nd, New York City, N.Y.,
(Acetate, arsenate, bromate, iodate, lactate,
molybdate, silico-fluoride, tungstate).

Electronic Space Products Inc., 854 S. Robertson Boulevard,
Los Angeles, Calif.

The Harshaw Chemical Co., Div. of Kewanee Oil Co.,
1933 E 97th, New York City, N.Y.
(fluoride, optical crystals).

The O Hommel Co., P. O. Box 475, Pittsburgh, Pa.
(lithium carbonate).

Hyperrefiners Inc., P. O. Box 80.T, Clifton, N.J.
(ultra high purity metal 99.999 per cent).

Isomet Corp., 431 Commercial Avenue, Palisades Park, N.J.
(lithium fluoride and tantalate).

Kawecki Berylco Industries Inc., 220 E. 42nd.,
New York City, N.Y.
(metal and compounds).

Kraft Chemical Co., 917 W. 18th Street, Chicago, Ill.

Lesco Industries Inc., Fisa Bldg., 250 W. 57th., New York
City, N.Y.
(high purity metal, oxides and compounds).

Mallinckrodt Chemical Works, 2nd and Mallinckrodt, St. Louis,
Mo.
(carbonate, chloride, nitrate, iodide, phosphate, salts,
sulphate).

Mathe Chemical Co., 169 Kennedy Drive, Lodi, N.J.
(stearate).

McKerson Chemical Co., 708 Third Avenue, New York City, N.Y.
(carbonate, chloride, hydroxide, stearate).

Mooney Chemicals Inc., 2269 Scranton Road, Cleveland, Ohio.
(naphthenate, stearate and neoclecanoate).

Nuclear Elements Corp., 422 S. McKean, Butler,Pa.
(single crystal compounds).

Pancoast International Corp., 120-22 Liberty, New York City,
N.Y.
(metal and compounds).

Semi-Alloys Inc., 22 North MacQuesten Parkway, Mount Vernon,
N.Y.

Stauffer Chemical Co., Anderson Chemical Div., Deters Drive,
Weston, Mich.
(n- Butyl and phenyllithium and lithium chemicals).

Synthetic Products Co., 1629 Wayside Road, Cleveland, Ohio.
(stearate).

United Mineral & Chemical Corp., Hudson & Beach Streets,
New York City, N.Y.
(high purity metal and compounds).

Witco Chemical Corp., 77 Park Avenue, New York City, N.Y.
(hydroxy stearate).

Ventron Corp., Metal Hydrides Div., 2400 Congress, Beverly,
Mass.
(lithium aluminium hydride).

During 1969 the General Services Administration of the U.S. Government offered for sale two lots of by-product lithium hydroxide. The prices bid were for the most part considered inadequate and only a small quantity was sold. It was stated that this was the first offer of by-product material since the completion of the A.E.C. contracts in 1959.

5. Prices of metal and compounds.

Table 22: U.S.: Price of Lithium Metal and Compounds. (end of year). (cents per lb.).

Year	Lithium metal (1,000 lb. lots d/d)	Lithium carbonate (drums, d/d)	Lithium chloride (anhydrous d/d)	Lithium hydroxide monohydrate (drums d/d)
1958(1)	n.a.	0.67	n.a.	0.55-0.72
1959(1)	n.a.	0.67	n.a.	0.72
1960	n.a.	1.30	1,235	0.72
1961	n.a.	0.58	1,235	0.54
1962	n.a.	0.58	1,235	0.54
1963	n.a.	0.55	1,235	0.54
1964	n.a.	0.58	1,235	0.54
1965	7.50	0.46	1,235	0.54
1966	7.50	0.50	1.27	0.575
1967	7.50	0.425-0.445	0.825-0.850	0.535
1968	7.50	0.445	0.850	0.535
1969	7.75	0.460	0.850	0.550
1970	8.18	0.52	0.87	0.59

6. Customs Tariffs.

Table 23: E.E.C. Customs Tariff April 1971.

1. Belgium, France, West Germany, Luxembourg, Netherlands.

Duty applicable to all countries outside the E.E.C.

	per cent
Lithium metal	5.6
Lithium oxide and hydroxide	8.0
Lithium chloride	9.6
Lithium carbonate	10.2
Lithium ores and concentrates	Free

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(1) Average annual price.

Value Added Tax applicable to all products

	per cent
Germany	11
France	23
Belgium	18
Netherlands	14
Luxembourg	10

2. Italy(1)

	per cent
Lithium metal	3.6
Lithium oxide	3.0
Lithium chloride	3.6
Lithium carbonate	2.4

Table 24: Japan: Customs Tariff April 1971

	per cent ad valorem
Lithium metal	15
Lithium salts	6
Lithium compounds	6
Lithium stearate	0.9 cents per lb. plus 6
Lithium ores and concentrates	Free

Table 25: U.K.: Customs Tariff April 1971

	per cent ad valorem
Lithium metal and compounds other than sulphate	23
Lithium sulphate in the form of a stable isotope of atomic weight 6 or 7 valued at £1 per g. or more	temporarily exempt.

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(1) Italy does not yet have an Added Value Tax and the above duty rates are composed of various taxes such as Administrative tax and general turnover tax.

O. W. ROSKILL

JRGL/RM/JRGL/C.

7th May, 1971.