Ministère des
Ressources naturelles
et des Forêts
Québec

Bureau de la sous-ministre et du secrétariat général

PAR COURRIEL

Le 29 mai 2024

DEMANDEUR

N/Réf. : 202404-73

Objet : Demande d'accès à l'information

Monsieur,

Nous donnons suite à votre demande d'accès à l'information reçue le 30 avril 2024 et précisée le 6 mai 2024.

La recherche a permis de repérer des documents concernant votre demande qui vous sont accessibles. Vous les trouverez ci-joints.

Sur réception de ces documents, vous remarquerez que nous avons soustrait certains renseignements, comme le permet l'article 14 de la Loi sur l'accès aux documents des organismes publics et sur la protection des renseignements personnels (RLRQ, chapitre A-2.1), ci-après Loi sur l'accès. En effet, nous avons retranché les renseignements confidentiels au sens des articles 22, 23, 24, 53 et 54 de la Loi sur l'accès.

Par ailleurs, il est pertinent de mentionner que certains documents s'apparentent à des versions de travail, et qu'ils n'ont pas fait l'objet de révision linguistique, que la mise en page et les bibliographies sont incomplètes. Ceci étant, l'information qui y est contenue est fiable.

En terminant, il faut savoir que l'objectif de la création des documents n'est pas l'analyse des besoins futurs de la substance. Quelques passages font mention des besoins futurs au Québec, mais de manière générale et visent des secteurs d'activités spécifiques.

Nous vous indiquons que vous pouvez demander à la Commission d'accès à l'information de réviser cette décision. Vous trouverez ci-joint une note explicative concernant l'exercice de ce recours.

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Veuillez agréer, Monsieur, l'expression de nos sentiments les meilleurs.

La responsable de l’accès à l’information,

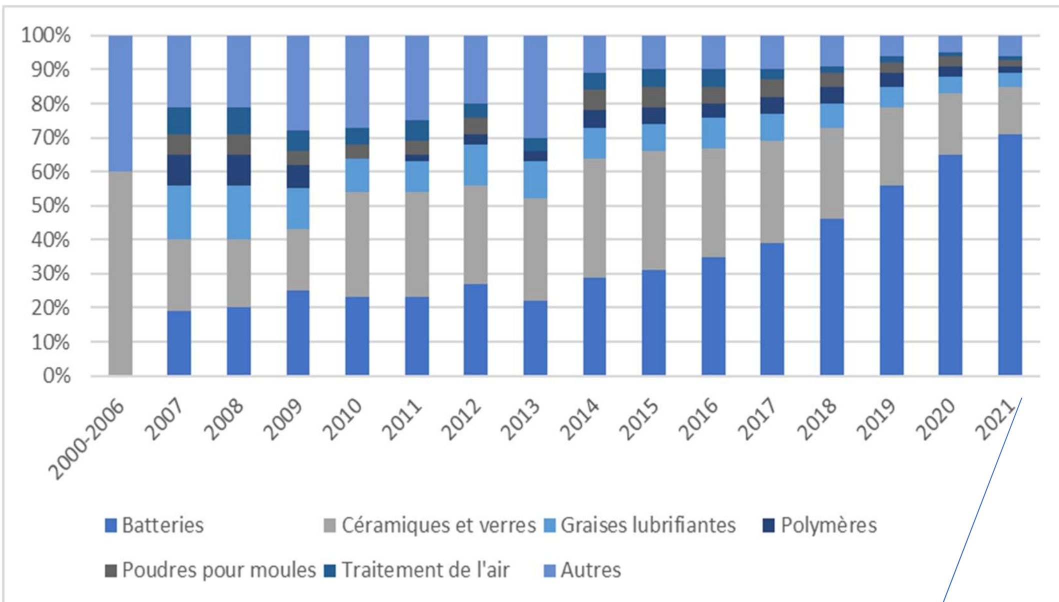
Original signé par

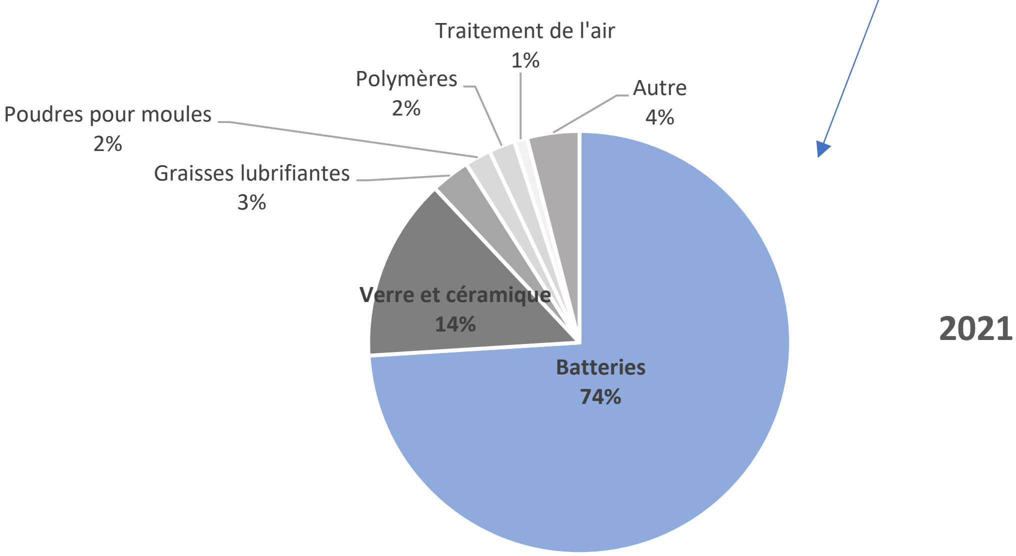
Matilde Théroux-Lemay

p. j. : 2

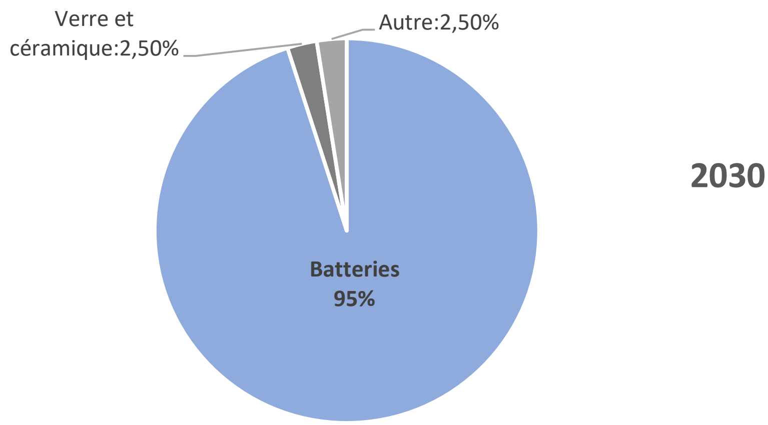
Principales utilisations du lithium

Depuis les 20 dernières années, les batteries représentent un pourcentage croissant de l’utilisation du lithium à travers le monde. Selon le USGS, voici l’évolution des principales utilisations du lithium:





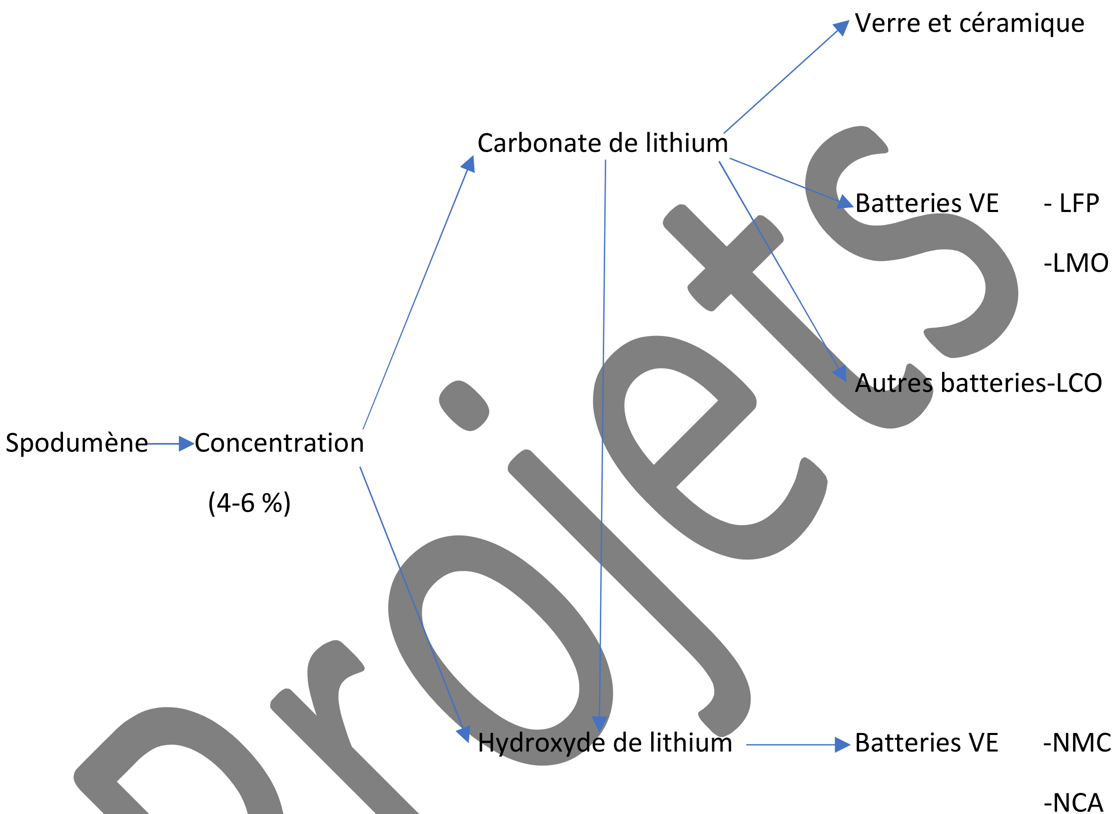
Plusieurs études estiment que les batteries pourraient représenter plus de 90 % de l’utilisation du lithium en d’ici 8 à 10 ans**.** Selon la firme McKinsey[1], les principales utilisations du lithium en **2030** seront :



[1] [How lithium mining is fueling the EV revolution | McKinsey]

<u>Chaîne de valeur du lithium (résumé)</u>

Le lithium produit (ou qui sera produit) au Québec est extrait de spodumène. Voici un résumé de la chaîne de valeur du lithium à partir du spodumène :



Il existe différents grades dans le concentré produit en fonction du niveau d'impureté contenu. La production de verre, céramique et autres produits de spécialité nécessite généralement un concentré de grade technique, contenant un faible niveau d'impureté. Ce type de concentré se vend généralement à prime par rapport au concentré de grade chimique (qui peut contenir plus d'impuretés). Le concentré de grade chimique, lorsqu'il répond aux spécifications des acheteurs, est utilisé dans la fabrication de batteries pour véhicules électriques (VE).

À noter que d'autres pays produisent du lithium à partir de saumures. Bien que le procédé soit différent et nécessite une étape de plus de raffinage pour la production d'hydroxyde, la chaine de valeur demeure similaire.

Note : LFP = lithium-fer-phosphate; LMO=lithium-oxide de manganèse; LCO=lithium-oxide de cobalt; NMC=lithium-nickel-manganèse-cobalt; NCA=lithium-nickel-cobalt-aluminium

<u>Facteurs d'équivalence des sous-produits du lithium</u>

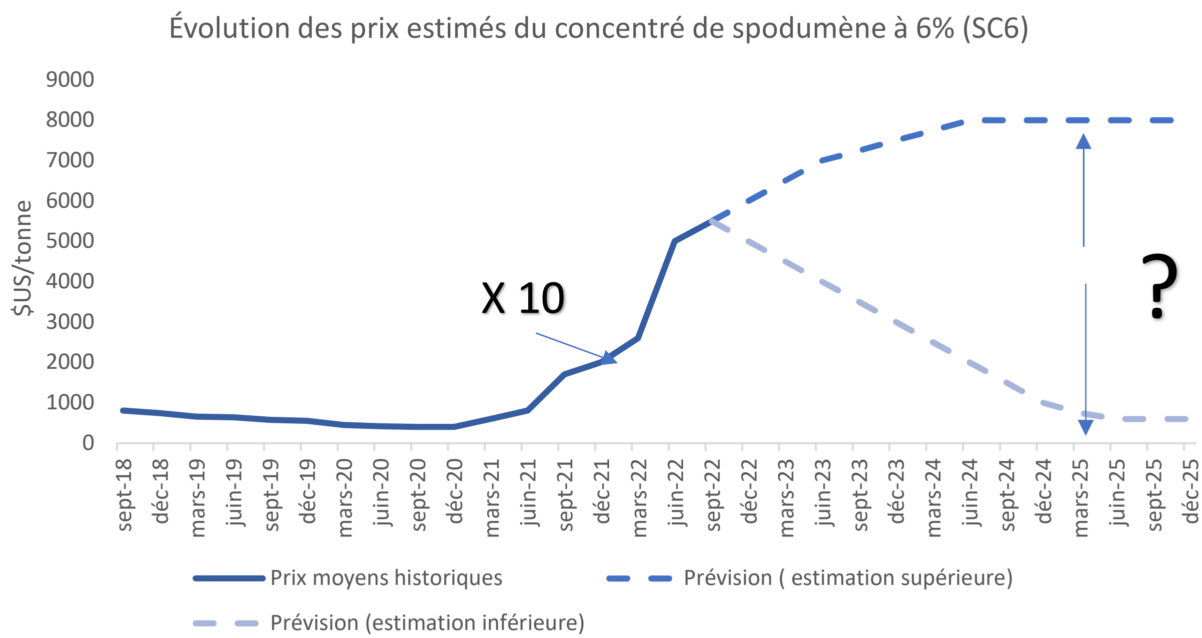
Afin de permettre des comparaisons entre les différents sous-produits du lithium, les quantités produites et vendues sont souvent exprimées sous forme d'équivalent de carbonate de lithium (*lithium carbonate equivalent* ou **LCE**). Les facteurs de conversion en LCE généralement utilisés pour les principaux sous-produits sont les suivants :

	Facteur de conversion en LCE
Lithium (Li)	X 5,323
Oxide de lithium (Li_2O)	X 2,473
Carbonate de lithium (Li_2CO_3)	X 1
Hydroxyde de lithium ($LiOH.H_2O$)	X 0,88

Marché global du lithium

Prix du concentré de spodumène

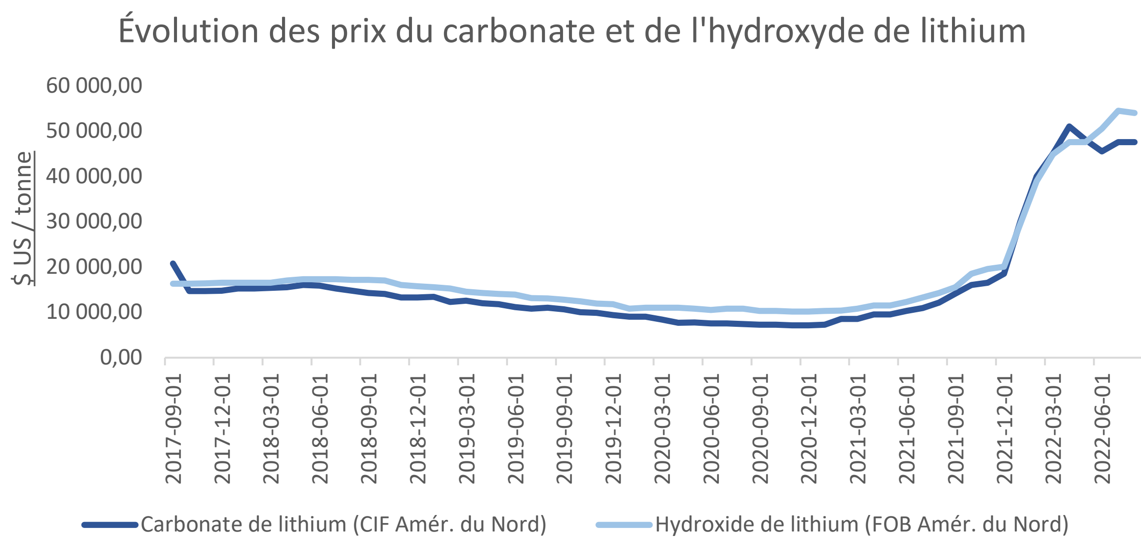
Le marché du concentré de spodumène ne fonctionne pas encore comme un marché de commodité. Il n'est actuellement pas possible d'obtenir un prix de référence international pour chaque type de concentré. Les prix sont déterminés sur les bases de négociations contractuelles privées entre producteurs et acheteurs et le producteur se doit de s'assurer que son produit répond aux exigences de l'acheteur. Le degré de concentration ainsi que les propriétés du concentré ont des impacts sur les prix. Les prix ont également tendances à varier légèrement en fonction de la situation géographique des acheteurs et producteurs. De façon général, plus le % de concentration est élevé et plus le prix sera élevé. Également, un concentré de grade technique (qui contient moins d'impureté) commande généralement un prix plus élevé qu'un concentré de grade chimique (celui utilisé pour les batteries), bien que cette prime semble avoir diminuée au cours des 2 dernières années. Les prix ont connu une hausse fulgurante en 2022 sur la base d'une demande en expansion et d'une offre qui peine à suivre. Les prévisions pour les années suivantes sont toutefois variables d'une source à l'autre et contiennent un niveau d'incertitude très élevé.



Sources : rapports d'entreprises, S&P Global, Benchmark minerals, Fastmarket

Prix de l'hydroxyde et du carbonate

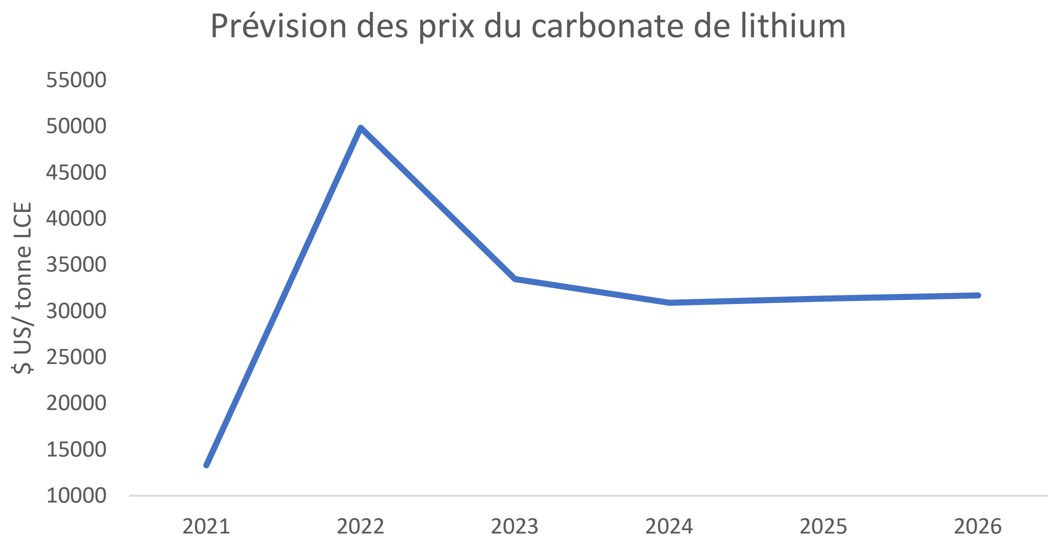
Les deux principaux dérivés chimiques du lithium sont l'hydroxyde ($LiOH.H_2O$) et le carbonate (Li_2CO_3). Les prix de l'hydroxyde et du carbonate ont suivi une tendance similaire à ceux du concentré de spodumène au cours des dernières années. Les prix sont également établis via négociations contractuelles mais une proportion de plus en plus importante de contrats sont établis en se basant sur des index de prix (tel que ceux compilés par BMI) avec des clauses d'ajustements selon l'évolution des prix:



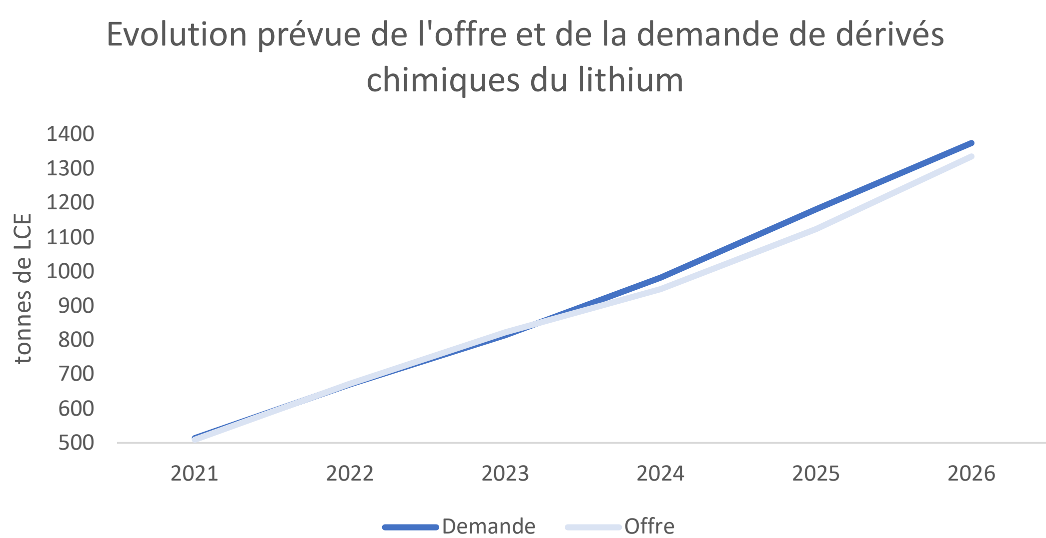
Source : S&P Global

Qui contrôle production hydroxyde dans le monde ?

Les prévisions de prix des différents organismes et entreprises sont encore une fois très variables, bien qu'une majorité voie les prix se replier graduellement tout en demeurant au-dessus de 30 000 $ US/ tonne à long terme. S&P Global et BMI entrevoit tous deux un déficit entre l'offre et la demande de dérivés chimiques de lithium qui devrait s'accentuer avec les années et contribuer à soutenir les prix.



Source : SP Global – Carbonate de lithium CIF Asie



Source : SP Global

- S&P Global prévoit que la demande de lithium pourrait excéder l'offre de près de 40 000 tonnes en 2026.
- BMI[2] ont des chiffres similaires et extrapole même un déficit pouvant atteindre plus de 1 M tonnes en 2035 selon certains scénarios.

[2] What is driving lithium prices in 2022 and beyond? | Benchmark (benchmarkminerals.com)

Pour d'autres, comme Mckinsey[3], l'offre de lithium pourrait éventuellement rattraper et égaler la demande au cours des prochaines années.

Ces scénarios se basent toutefois sur certaines hypothèses affectant l'offre et la demande

Demande globale pour le lithium

La demande pour le lithium au cours des prochaine années sera intimement liée à la transition énergétique et plus spécifiquement à l'électrification des transports (batteries pour véhicules électriques).

La plupart des scénarios d'augmentation de la demande utilisent comme point de départ deux scénarios de l'Agence internationale de l'Énergie sur l'adoption des technologies propres :

- Un scénario de base où les gouvernements se contentent de mettre en œuvre les différentes politiques déjà annoncées et touchant les technologies propres et la décarbonisation de l'économie (STEPS) (demande vs 2020 X13 d'ici 2040)
- Un scénario plus optimiste où les économies plus industrialisées deviendraient carbo-neutre d'ici 2050 (SDS) (demande vs 2020 x 42 d'ici 2040)

Bien que le scénario STEPS soit plus conservateur que le scénario SDS, les deux scénarios nous apparaissent optimistes. Plusieurs facteurs affectant la demande seront à surveiller et pourraient avoir un impact important sur la demande de lithium future :

Technologies :

Vitesse de développement et d'adoption de nouvelles technologies de batteries.

- Quels seront les éléments composant les prochaines générations de batteries?
  - batteries à électrolyte solide (pouvant demander plus ou moins de lithium que les batteries à lithium-ion actuelles selon le type);
  - batteries à métal liquide (n'utilisent pas de lithium);
  - batteries sodium-ion

Macroéconomie :

L'économie mondiale est en territoire complètement inconnu actuellement : taux historiquement bas sur une longue période (2008-2021), niveaux d'endettement records, inflation élevée et maintenant, hausse de taux hyper agressive de la plupart des banques centrales.

Les résultats sont et seront certainement un ralentissement de l'économie mondiale (et donc diminution de la demande) au cours des prochains mois. Toutefois, l'impact à long terme

[3] How lithium mining is fueling the EV revolution | McKinsey

demeure la grande inconnue et rien ne garantit un retour à une croissance soutenue dans les prochaines années.

On compte actuellement plus d'une centaine de projets de méga-usines de batteries qui ont été annoncés et pourraient voir le jour au cours des 6-7 prochaines années. En fonction de l'environnement économique, combien de ces usines verront réellement le jour ?

<u>Habitude des consommateurs</u>

- Est-ce que les consommateurs voudront toujours posséder un véhicule ou assisteront nous à une plus grande adoption du transport en commun ?
- Est-ce que les consommateurs pourront retrouver le pouvoir d'achat perdu avec l'inflation? Est-ce que l'achat de véhicules sera impacté par la perte de pouvoir d'achat à long terme?

<u>Géopolitique</u>

- Est-ce que les gouvernements seront en mesure de continuer à subventionner l'acquisition de véhicule électrique malgré une situation budgétaire qui se détériore surtout en Europe) ?
- On assiste à une augmentation des manifestations de la population face à la hausse du coût de la vie et aux politiques énergétiques de certains gouvernement. Est-ce que la pression populaire pourrait faire reculer les gouvernements sur leurs agendas verts ?
- Est-ce qu'on pourrait assister à l'élection de gouvernements plus favorables aux énergies fossiles dans les prochaines années ?

Offre globale pour le lithium

L'augmentation de l'offre de lithium au cours des prochaines années proviendra de la mise en production de nouveaux gisements ainsi que de l'augmentation de la capacité de raffinage. Le recyclage pourrait également jouer un rôle important bien que peu de données soient disponibles à ce sujet à ce jour. À court terme, l'augmentation de l'offre proviendra principalement de l'augmentation de la production par des producteurs déjà établis.

Vitesse de développement des nouveaux projets miniers et des usines de raffinage

- Accélération de la mise en production de nouvelles mines (positif)
- Difficulté de démarrer de nouvelles mines en raison de l'acceptabilité sociale et de l'impact environnementale des mines (négatif)
- Intérêt des investisseurs
- Augmentation de la capacité de raffinage. Un survol non exhaustif des projets avancés démontrent que la capacité de production d'hydroxyde pourrait potentiellement augmenter de plus de 500 000 tonnes annuellement d'ici 5 ans.

Développement de nouvelles technologies d'extraction et de nouveaux types de gisement

- Extraction directe du lithium (DLE)
- *Direct lithium to product* (DLP)
- Lithium à partir d'eaux géothermales
- Lithium à partir des saumures de champs pétroliers

Recyclage

- Les données sont encore difficiles à obtenir mais le développement de nouvelles technologies et la mise en place d'usines de recyclage pourrait être un apport non négligeable de matière première.

Géopolitique

- Élection de gouvernement à tendances plus socialistes (ex : Amérique du Sud) qui veulent augmenter les redevances, voir nationaliser le lithium, donc diminution de l'offre.
- Protectionnisme et nationalisme économique (protectionnisme, quota d'exportation, mise en place d'initiatives étatiques pour assurer un approvisionnement, etc)
- Concentration de la capacité de raffinage dans un nombre restreint de pays

Situation au Québec

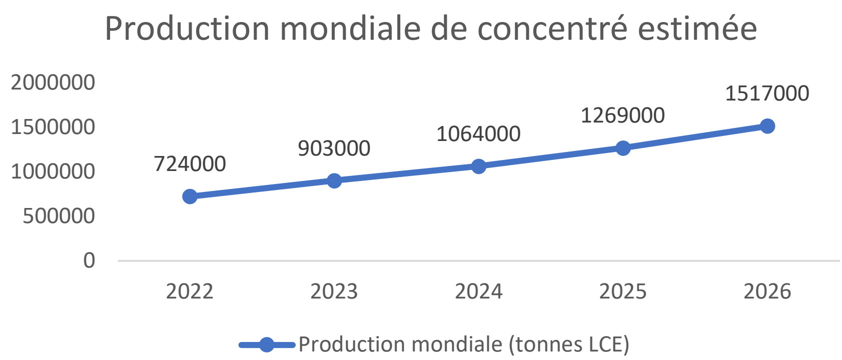
Réserves québécoises vs mondiales (août 2022)

Réserves québécoises : 1 604 000 tonnes (source : SP Global)

Réserves mondiales : +/- 22 000 000 tonnes (source : USGS)

23-24

Pour la même période S&P Global Market Intelligence prévoit que la production mondiale de concentré pourrait être la suivante :



En fonction du nombre de projets qui entreront en production, la production québécoise pourrait donc potentiellement atteindre environ 10 % de la production mondiale en 2026.

23-24

23-24

Utilisation du lithium au Québec-filière batterie

23-24

D'autres usines pourraient éventuellement voir le jour, comme par exemple Nano One qui cherche à compléter l'acquisition de l'usine pilote de Johnson Matthey près de Montréal (batteries de type LFP). Sans compter Bolloré qui exploite actuellement une usine de fabrication de batterie à électrolyte solide au Québec qui pourrait prendre de l'expansion d'ici 2026.

Au risque de citer l'évidence, on peut conclure, que si l'ensemble des projets miniers, de raffinage et de production de batteries et matériaux de batteries annoncés au Québec venaient à voir le jour au cours des 5-6 prochaines années :

- La production de dérivés chimiques de lithium (carbonate et hydroxyde) au Québec ne sera pas suffisante pour répondre à la demande des usines de la filière batteries qui devront sécuriser des approvisionnements à l'étranger.
- Pour les producteurs de concentrés québécois, la capacité de raffinage québécoise ne sera pas suffisante pour traiter l'ensemble du concentré produit et le concentré devra être vendu à des raffineurs hors Québec. (à titre d'exemple, NAL a déjà une entente pour vendre près de 50 % de sa production à Piedmont Lithium aux États-Unis)

Zoom sur le marché du cobalt

ANALYSE DE MARCHÉ

Effectuée dans le cadre de la mesure

2.1.3 Analyser les tendances du marché des filières de MCS du

Plan québécois pour la valorisation des minéraux critiques et stratégiques 2020-2025 (PQVMCS)

Document de travail

VERSION JUIN 2023

Table des matières (à revoir)

1. Mise en contexte

1.1 Mise en contexte de la démarche

Comme plusieurs autres gouvernements, le Québec s'est doté, en 2020, de plans pour assurer un approvisionnement et un développement des minéraux critique et stratégique (MCS). En effet, le Plan québécois pour la valorisation des minéraux critiques et stratégiques (PQVMCS), s'inscrivant dans une vision gouvernementale globale, s'assure, par le biais de plusieurs actions, de l'accès et de la disponibilité des ressources minérales importantes pour l'économie du Québec.

Ainsi, dans le cadre de la mesure 2.1.3 analyses des tendances de marché des MCS, il est prévu que pour « maximiser les retombées économiques liées à la mise en valeur des MCS au Québec, le MERN développera ses connaissances et son expertise en matière de prévisions économiques afin d'être en mesure d'anticiper les demandes futures tant pour les minéraux actuellement reconnus comme critiques ou stratégiques que pour ceux qui le deviendront. » (MERN, 2020) Le document suivant répond à cette mesure en faisant le recensement des connaissances et des expertises sur le marché d'un métal critique ou stratégique. Les études permettent alors de dresser un portrait du marché de certains des MCS (taille, production, consommation) et de la position des acteurs québécois sur le marché mondial, comparée à celle des autres acteurs mondiaux.

1.2 Liste des MCS identifiés pour la veille économique

Dans le Plan québécois de valorisation des minéraux critiques et stratégiques (PQVMCS), les minéraux critiques ou stratégiques sont définis « comme [les minéraux] qui revêtent aujourd'hui une importance économique significative pour des secteurs clés de notre économie, qui présentent un risque d'approvisionnement élevé et qui n'ont pas de substituts disponibles commercialement [ou] sont des substances minérales nécessaires à la mise en œuvre de différentes politiques du Québec. » (MERN, 2020) Les 22 minéraux critiques ou stratégiques identifiés par le gouvernement du Québec se divisent en 3 catégories :

- Les minéraux critiques pour l'approvisionnement des usines québécoises de transformation.
- Les minéraux stratégiques nécessaires pour la mise en œuvre des politiques québécoises : Parmi ces politiques, mentionnons la stratégie gouvernementale de développement durable, la Politique énergétique 2030, la Politique de mobilité durable 2030 et le Plan pour une économie verte 2030.
- Les minéraux critiques ou stratégiques pour les états avec qui le Québec a développé (ou peut développer) des accords commerciaux pour la mise en valeur de nos minéraux critiques ou stratégiques.

Le présent document fera l'analyse du marché du cobalt qui se trouve dans la deuxième catégorie des minéraux critique ou stratégique.

2. Applications industrielles et chaîne de valeur

2.1 Applications industrielles

La demande de cobalt était de 178 634 t en 2022, la demande est distribuée selon deux grandes catégories. La première est la demande chimique qui représente environ 78 % en 2022, elle est en constante augmentation depuis les dernières années puisqu'on y retrouve les batteries pour les véhicules électriques, les batteries électroniques (téléphone cellulaire, outils, etc.) qui sont des secteurs en plein essor. La deuxième partie est la demande métallurgique plus traditionnelle qui représentait 22% de la demande en 2022, dans cette catégorie on retrouve les alliages-superalliages, les carbures cémentés principalement utilisés dans différents outils comme les scies, les fraises et les mèches et autres. Cette partie de la demande demeure relativement stable avec le temps.

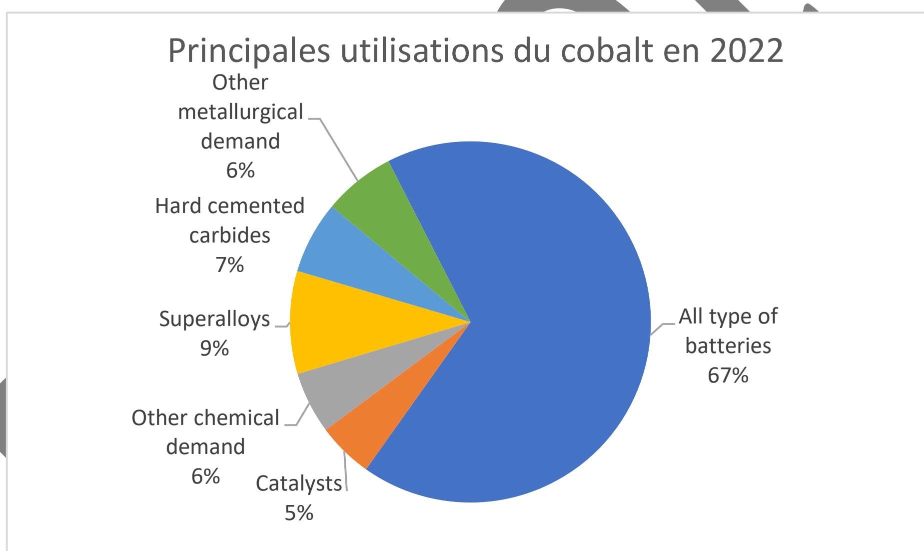


Figure 1 – Utilisations du cobalt en 2022

2.2 Chaîne de valeur de l’industrie du cobalt **et portrait mondial**

La chaine de valeur du cobalt est complexe, mais elle mène essentiellement à la production de deux produits différents. La première catégorie est le sulfate de cobalt qui est principalement utilisé dans la fabrication de batteries. La deuxième catégorie est le cobalt métal utilisé dans le domaine métallurgique.

Résumé de la chaine de valeur du Cobalt

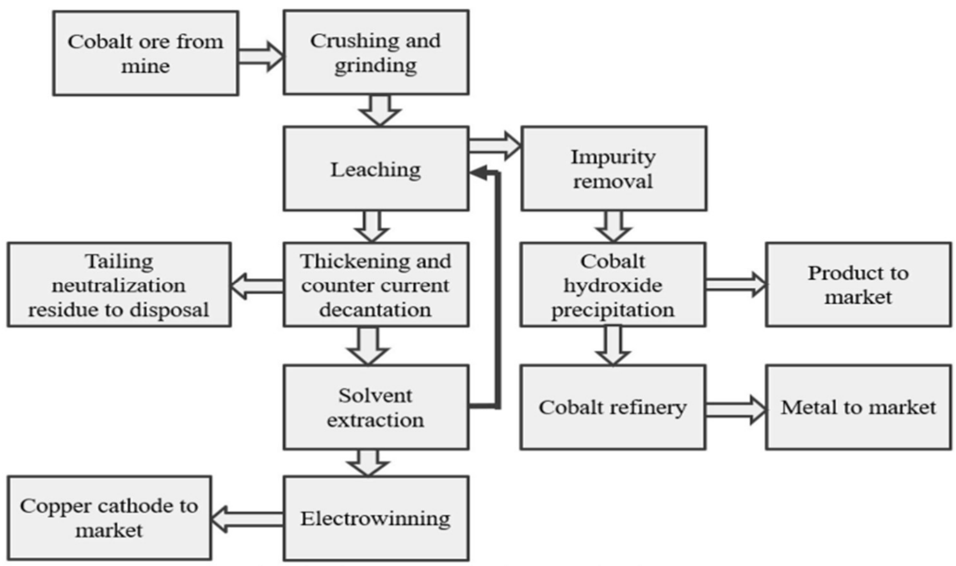


Figure 2 – Chaîne de valeur

Trouver la proportion de sulfate de cobalt produit vs cobalt metal (proche de la même chose que la demande ?)

Selon SP global en 2024 l'extraction totale mondiale de cobalt en 2024 sera de 300 000 tonnes, réparties entre les pays de la manière suivante :

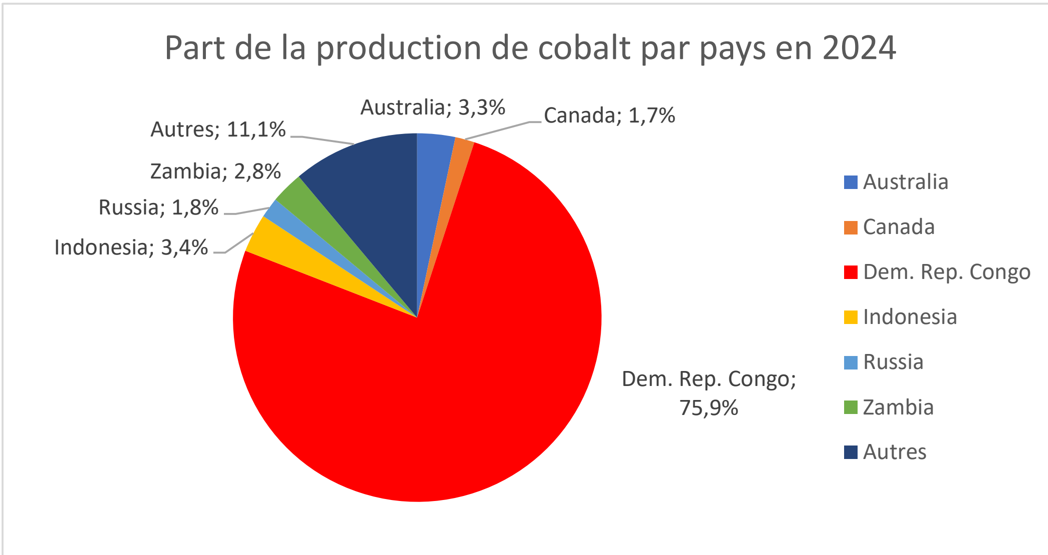


Figure 3 – Extractions mondiales de cobalt

En regardant, le marché mondial, on observe que la production est très centralisée en République Démocratique du Congo. Elle produit plus de 75 % du cobalt mondial. Cependant, le Congo ne possède pas les infrastructures nécessaires pour raffiner son cobalt, elle doit donc l'exporter vers d'autres pays. Les mines officielles de cobalt au Congo sont pratiquement toutes possédées par des entreprises chinoises, en 2020 les intérêts chinois possédaient 15 des 19 mines en activité. Cela fait en sorte que les exportations de cobalt se dirigent vers la Chine. Le graphique suivant montre la capacité de raffinage selon les pays en 2019.

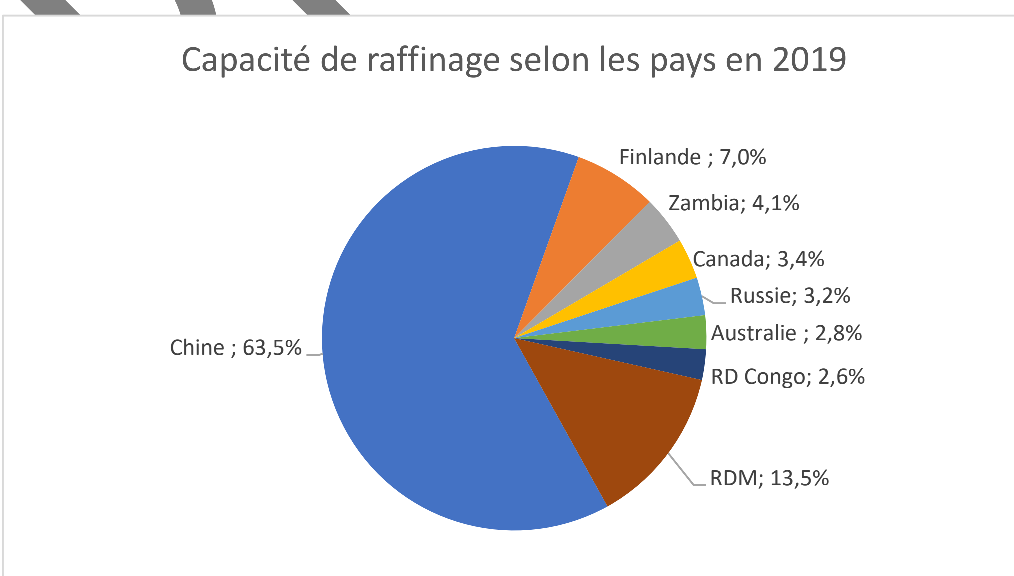


Figure 4 -Proportion de la capacité de raffinage

Avec la majorité des exportations de cobalt vers la Chine, il est évident qu'elle possède une capacité de raffinage très élevé et qu'elle domine le marché. En 2022, la Chine a continué à augmenter sa capacité de raffinage et par le fait même ça quantité raffinée atteignant 66 % du raffinage mondial de cobalt. Aucun autre pays ne possède une capacité de raffinage semblable à la Chine, donc il y a un risque dans la chaine de valeur autant à l'étape de l'extraction qu'à l'étape de raffinage.

De 2018 à aujourd'hui, l'extraction était principalement concentrée en RDC. La production de cobalt croît/croîtra à un rythme très rapide à partir de 2020. Le graphique suivant donnera un aperçu de l'extraction de cobalt dans les différents pays.

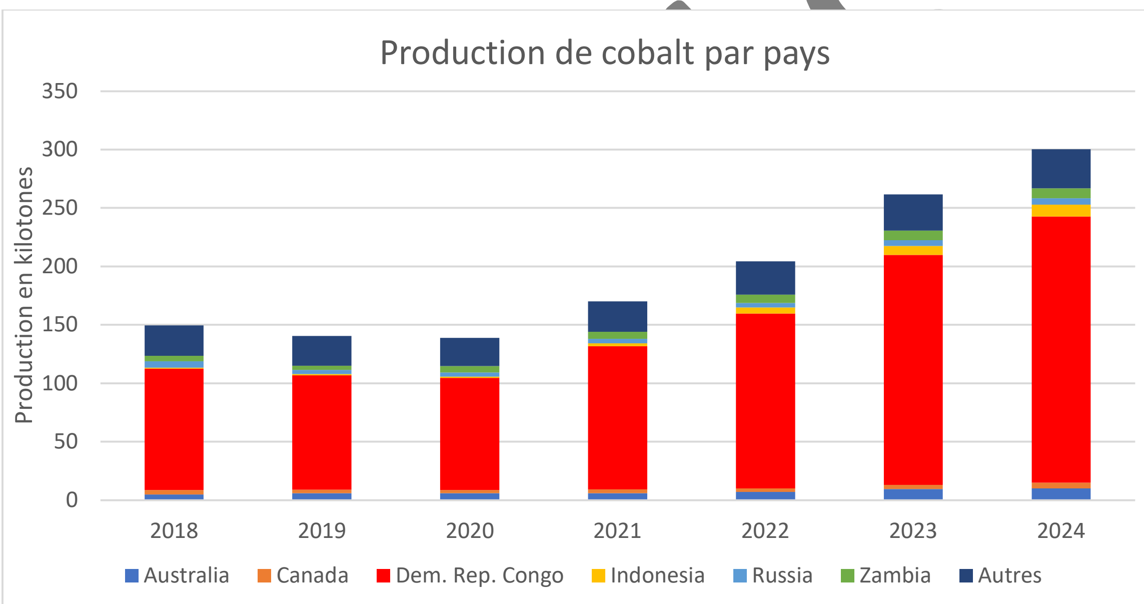


Figure 5 - évaluation de la part de marché des principaux pays producteurs

Ensuite, les principaux extracteurs de cobalt anticipés dans les prochaines années sont les suivants :

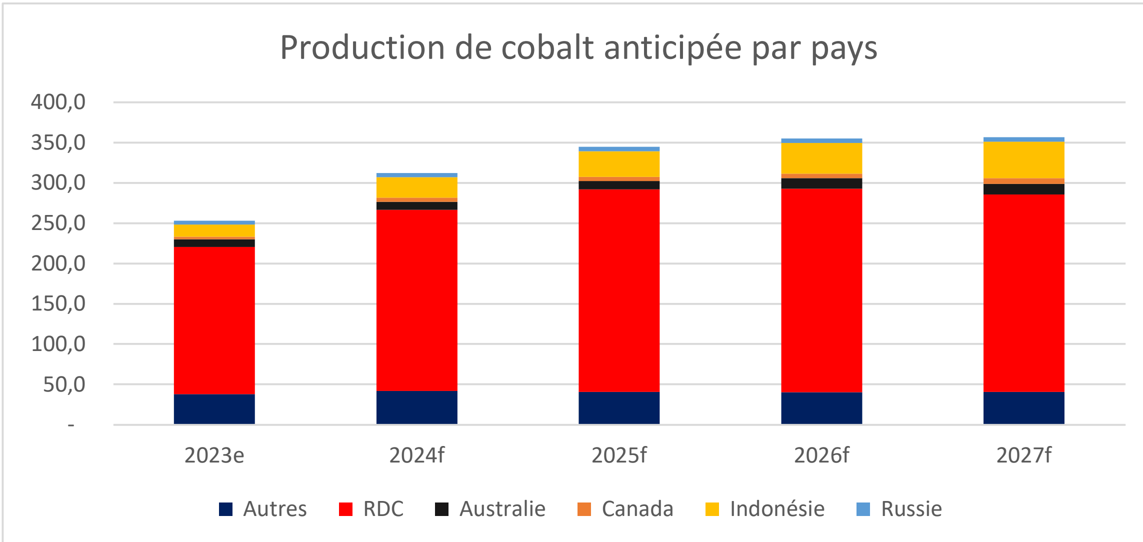


Figure 6 - Évolution anticipée des principaux pays extracteurs de cobalt

La RDC reste encore un producteur majeur pour le cobalt en 2023, elle produira 72 % et en 2027 encore près de 70 % de la part mondiale de cobalt. L'Indonésie deviendra un joueur plus important dans les années à venir. En 2027, ça part de marché sera d'environ 13 %. Elle deviendra donc le deuxième producteur à l'échelle mondiale. Son ascension devrait continuer dans les années subséquentes Par contre, le Congo restera de loin le plus grand producteur de cobalt. La part du Canada augmentera légèrement. En 2023 elle serait à 1,4 % et en 2027 à 2 % de la production mondiale de cobalt.

Par conséquent, la chaine de valeur du cobalt est contrôlée majoritairement par un seul pays pour chaque étape de celle-ci, autant présentement que dans les huit prochaines années. Cela peut devenir un enjeu important puisque l'approvisionnement, en minerai ou en sulfate, peut être contrôlé par un seul pays. Il y a donc un très grand risque d'approvisionnement pour les pays qui ont besoin du cobalt dans leurs chaines de valeurs comme l'assemblage de batteries pour les voitures électriques.

2.3 Prévisions et prix

Le marché du cobalt a toujours été en surplus jusqu'à maintenant à l'exception de 2021. On devrait avoir une situation de surplus de cobalt sur le marché jusqu'en 2025. À partir de l'année 2026, la demande surpassera l'offre, ce qui engendrera un déficit. On anticipe que ce déficit restera pour les années futur en raison d'une demande future croissante principalement alimentée par les véhicules électriques. Ce déficit entrainera une augmentation des prix dans les années à venir. L'augmentation rapide de la demande provient d'un nouvel usage du cobalt ce qui causera une restructuration du marché et causera des variations de prix à court terme.

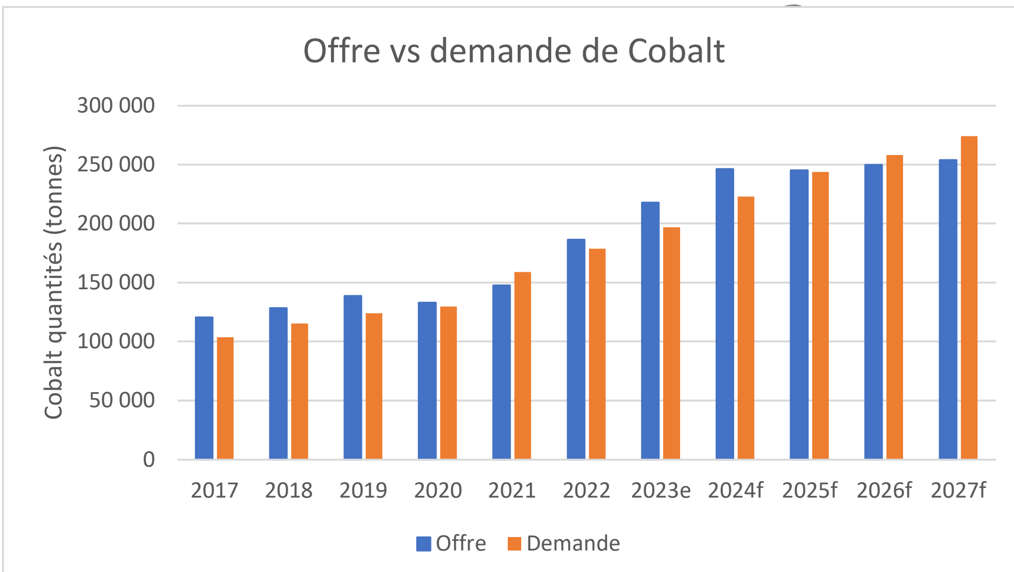


Figure 7 - Évolution de l'offre et la demande de cobalt

Maintenant, pour les prix, on observe une très grande volatilité depuis 2016. Par exemple, de 2016 à 2017 le prix a augmenté de 119 %, de 2017 à 2018 il a augmenté de 31 % et en 2019 il a diminué de 54 %. Le prix du cobalt demeure assez volatil encore aujourd'hui. Les variations de prix importantes du cobalt peuvent être attribuées à la concentration de la production et du raffinage dans un seul pays (Congo et Chine), ainsi qu'à l'impact de la pandémie de COVID-19 sur la demande du secteur des voitures électriques.

En revanche, les prévisions de prix à partir de 2025 sont beaucoup moins volatiles, on s'attend à des variations de prix avoisinant les 10 %. Les prévisions selon Focus Economics et SP global sont semblables, ils s'attendent à une baisse de prix de majeure en 2023 (37 % pour focus et 47 % pour SP) et à une remontée graduelle des prix d'environ 10 % par année.

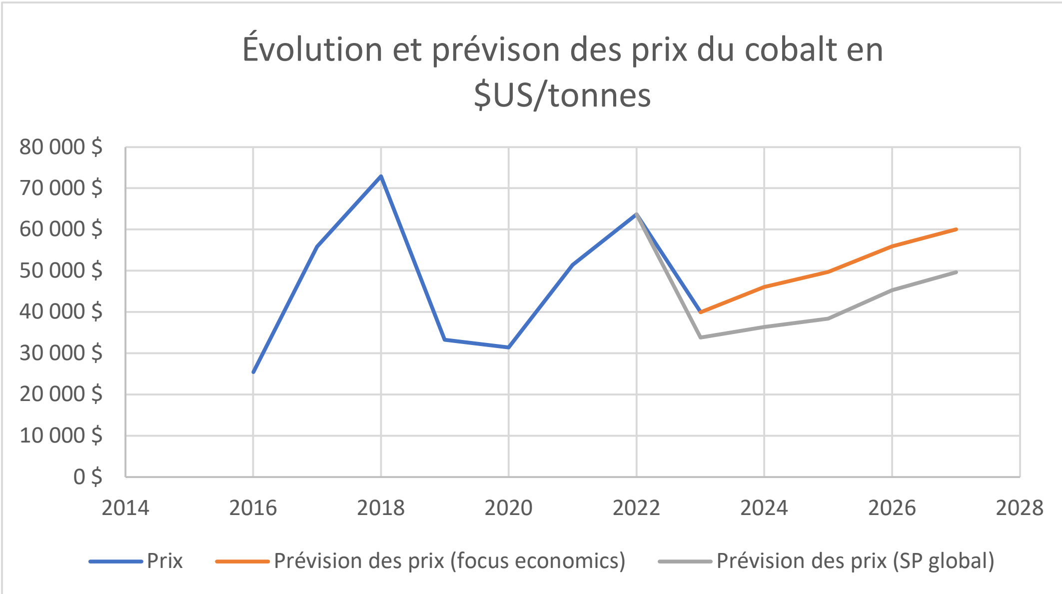


Figure 8 - Évolution et prévision des prix

2.4 Perspectives

Principales Tendances

<u>Demande de cobalt</u>

1) Conjoncture économique

Le cobalt est un élément essentiel pour la transition énergétique et la transition énergétique est la principale raison de l'augmentation de la demande. Si certains gouvernements sont moins enclins à promouvoir la transition énergétique, on pourrait avoir une baisse de la demande et une baisse du prix. Par contre, une grande majorité des pays industrialisés ont adopté des lois pour favoriser la transition énergétique et par le fait même augmenter la demande de MCS dont le cobalt. Par exemple aux États-Unis il y a eu le « inflation Reduction Act » favorisant l'utilisation des MCS provenant de pays où ils ont une entente de libre-échange.

2) Électrification des transports

La hausse de la demande pour les véhicules électriques à des effets positifs sur la demande de cobalt. Selon SP global la demande de cobalt pour les batteries de voitures électriques devrait augmenter d'environ 19 % une année à l'autre de 2022 à 2027. En 2022 le nombre de tonnes de cobalt utilisé pour la production de ces batteries était d'environ 61 000 tonnes et en 2027 d'environ 135 935 tonnes. En 2027, il est estimé que 50 % de la demande de cobalt provienne de ces batteries. Cela est une des principales raisons de la hausse de la demande attendue dans les prochaines années.

Par contre, le marché du cobalt n'est pas à l'abri de certains risques. Par exemple, certaines batteries ne contiennent pas ou très peu de cobalt donc si ces batteries viennent à prendre une part importante du marché automobile, la demande de cobalt pourrait diminuer fortement à long terme. Les batteries ne contenant pas de cobalt sont :

LMFP: Lithium-Manganese-Iron-Phosphate

LFP: Lithium-Iron-Phosphate

LNMO: Lithium-Nickel-Manganese Oxide

LMO: Lithium-ion Manganese Oxide

LMR: Lithium-Manganese Rich

3) Le marché technologique

Le cobalt est aussi très présent dans la fabrication des batteries électroniques, ce qui inclut les téléphones portables, les ordinateurs portables et tout ce qui utilise des batteries lithium-ion. Cette demande est légèrement croissante au rythme de 4%/année et elle atteindra 21 % de la demande totale de cobalt, ce qui représente environ 56 000 tonnes de cobalt en 2027.

Offre de cobalt

1) Nouvelles mines

Le développement de nouvelles mines de cobalt est assez ardu. Une des raisons est que l'extraction du cobalt est souvent complémentaire à l'extraction de nickel. Les mines ayant le cobalt comme ressource principale sont très rares et se situent pour la majorité en Afrique. Il existe seulement deux projets en Amérique du Nord qui sont Idaho Cobalt Operations(É-U) et Nico (Canada), aucune de ces 2 mines n'est rendue au stade de production, tous les autres sont des mines qui exploitent le cobalt comme sous-produit du nickel. De plus, le processus pour ouvrir une mine est très long et avec un marché aussi incertain que celui du cobalt, le nombre de projets qui sont rendus à un stade avancé est très peu nombreux.

2) Contexte géopolitique

Le principal enjeu géopolitique associé au cobalt réside dans son extraction en République démocratique du Congo, caractérisée par des pratiques non éthiques. L'extraction au Congo est en grande majorité contrôlée par les Chinois. Les conditions de travail sont atroces, il y a plusieurs enfants qui travaillent dans les mines et les travailleurs sont exploités. Selon plusieurs témoignages de Congolais travaillant dans les mines, ils sont traités comme des esclaves. Ils reçoivent à peine 3,5 $ par jour en travaillant un nombre d'heures inhumain. Dans le contexte actuel mondial, les grosses compagnies comme Apple, Samsung et Tesla tentent de mieux contrôler leur chaine d'approvisionnement et d'éviter le Cobalt du Congo. Avec la forte demande de cobalt actuelle, il est difficile pour ces compagnies d'ignorer complètement cette source. L'inflation Reduction Act entraînera aussi des conséquences sur la demande de cobalt du secteur américain. Le Québec serait avantagé par cette loi et pourrait vendre son cobalt aux américains à un meilleur prix puisqu'il serait éthique et proviendrait d'un pays ayant un accord de libre-échange avec les États-Unis. La traçabilité sera un moyen de prouver aux compagnies américaines que le cobalt produit au Canada provient de source éthique et respecte les demandes de l'IRA tout au long de la chaine de valeur. De plus, avec la situation géopolitique actuelle et l'émergence de différents blocs économiques géographique, il peut être risqué de seulement s'approvisionner l'autre côté du globe.

3) Recyclage

Le recyclage des batteries fabriquées avec du Cobalt apparait comme une bonne solution à long terme pour diminuer la quantité de cobalt provenant des mines. Par contre, selon SP Global, le recyclage représente environ 12 % de l'offre en 2022 et il représentera 16 % en 2027. L'extraction minière sera encore très importante et le Congo dominera encore fortement le marché d'extraction du cobalt.

3.1 Investissements privés et publics

Je crois avoir besoin de données de l'ISQ pour compléter cette section

4. Conclusion

Le marché du cobalt est en constante croissance depuis les dernières années, il devrait continuer d'augmenter en raison de la demande croissante des véhicules électriques.

Bien qu'un surplus soit anticipé sur le marché mondial dans les années à venir, de nouveaux approvisionnements régionaux devront arriver sur le marché, surtout s'il y a création de blocs économiques distincts à travers le monde. Présentement, nous sommes fortement dépendants du Congo et par le fait même de la Chine, si ses pays décident de mettre un frein à leurs exportations, il sera difficile de combler la demande de cobalt.

Le Québec n'est pas actuellement très bien positionné dans la chaine de valeur du cobalt. Bien que plusieurs projets au stade d'exploration et de mise en valeur de gisements de cobalt soient en cours au Québec, on ne retrouve qu'un seul site en activité, la mine Raglan. De plus, il existe seulement deux entreprises au Québec qui transforment et utilisent le cobalt pour créer un produit. Avec le projet de filière batterie à Bécancour, le Québec aura besoin de cobalt et de projets de transformations/utilisation pour avoir une filière batterie bien développée.

5. BIBLIOGRAPHIE (à compléter)

Conclusion

Les perspectives à court terme pour le lithium demeurent très positives comme en fait foi l'augmentation vertigineuse des prix depuis environ 18 mois.

À long terme, il demeure très difficile à prévoir de prévoir l'évolution de ce marché, d'où l'importance d'effectuer une veille constante sur les principaux facteurs pouvant influencer l'offre et la demande

Un scénario qui nous apparait plus réaliste serait une augmentation de la demande moindre qu'anticipée dans les principaux scénarios. Quant à l'offre, le rythme et la quantité d'augmentation demeure les grands inconnus.

Compte tenu des incertitudes importantes, le gouvernement peut certainement avoir un rôle à jouer à l'ensemble des étapes de la chaine de valeur du lithium pour assurer un développement harmonieux de la filiale.

Zoom sur le marché du Manganèse

ANALYSE DE MARCHÉ

Effectuée dans le cadre de la mesure

2.1.3 Analyser les tendances du marché des filières de MCS du

Plan québécois pour la valorisation des minéraux critiques et stratégiques 2020-2025 (PQVMCS)

Document de travail

VERSION JUILLET 2023

Table des matières (à revoir)

1. Mise en contexte

1.1 Mise en contexte de la démarche

Comme plusieurs autres gouvernements, le Québec s'est doté, en 2020, de plans pour assurer un approvisionnement et un développement des minéraux critique et stratégique (MCS). En effet, le Plan québécois pour la valorisation des minéraux critiques et stratégiques (PQVMCS), s'inscrivant dans une vision gouvernementale globale, s'assure, par le biais de plusieurs actions, de l'accès et de la disponibilité des ressources minérales importantes pour l'économie du Québec.

Ainsi, dans le cadre de la mesure 2.1.3 analyse des tendances de marché des MCS, il est prévu que pour « maximiser les retombées économiques liées à la mise en valeur des MCS au Québec, le MERN développera ses connaissances et son expertise en matière de prévisions économiques afin d'être en mesure d'anticiper les demandes futures tant pour les minéraux actuellement reconnus comme critiques ou stratégiques que pour ceux qui le deviendront. » (MERN, 2020) Le document suivant répond à cette mesure en faisant le recensement des connaissances et des expertises sur le marché d'un métal critique ou stratégique. Les études permettent alors de dresser un portrait du marché de certains des MCS (taille, production, consommation) et de la position des acteurs québécois sur le marché mondial, comparée à celle des autres acteurs mondiaux.

1.2 Liste des MCS identifiés pour la veille économique

Dans le Plan québécois de valorisation des minéraux critiques et stratégiques (PQVMCS), les minéraux critiques ou stratégiques sont définis « comme [les minéraux] qui revêtent aujourd'hui une importance économique significative pour des secteurs clés de notre économie, qui présentent un risque d'approvisionnement élevé et qui n'ont pas de substituts disponibles commercialement [ou] sont des substances minérales nécessaires à la mise en œuvre de différentes politiques du Québec. » (MERN, 2020) Les 22 minéraux critiques ou stratégiques identifiés par le gouvernement du Québec se divisent en 3 catégories :

- Les minéraux critiques pour l'approvisionnement des usines québécoises de transformation.
- Les minéraux stratégiques nécessaires pour la mise en œuvre des politiques québécoises : Parmi ces politiques, mentionnons la stratégie gouvernementale de développement durable, la Politique énergétique 2030, la Politique de mobilité durable 2030 et le Plan pour une économie verte 2030.
- Les minéraux critiques ou stratégiques pour les états avec qui le Québec a développé (ou peut développer) des accords commerciaux pour la mise en valeur de nos minéraux critiques ou stratégiques.

Le présent document fera l'analyse du marché du manganèse qui pourrait intégrer la liste des MCS en 2023, en raison de son potentiel dans l'utilisation des batteries de véhicules électriques

2. Applications industrielles et chaîne de valeur

2.1 Applications industrielles

La demande de manganèse est distribuée selon 2 grandes catégories qui sont les ferroalliages et le manganèse de haute pureté. La grande majorité du manganèse, 91% en 2021, était utilisé pour la fabrication d'acier. Pour le 9% restant, il s'agit d'application niche comme on peut voir sur le graphique. Ce qui est intéressant d'observer est que moins de 1% du manganèse extrait va dans la production de batteries.

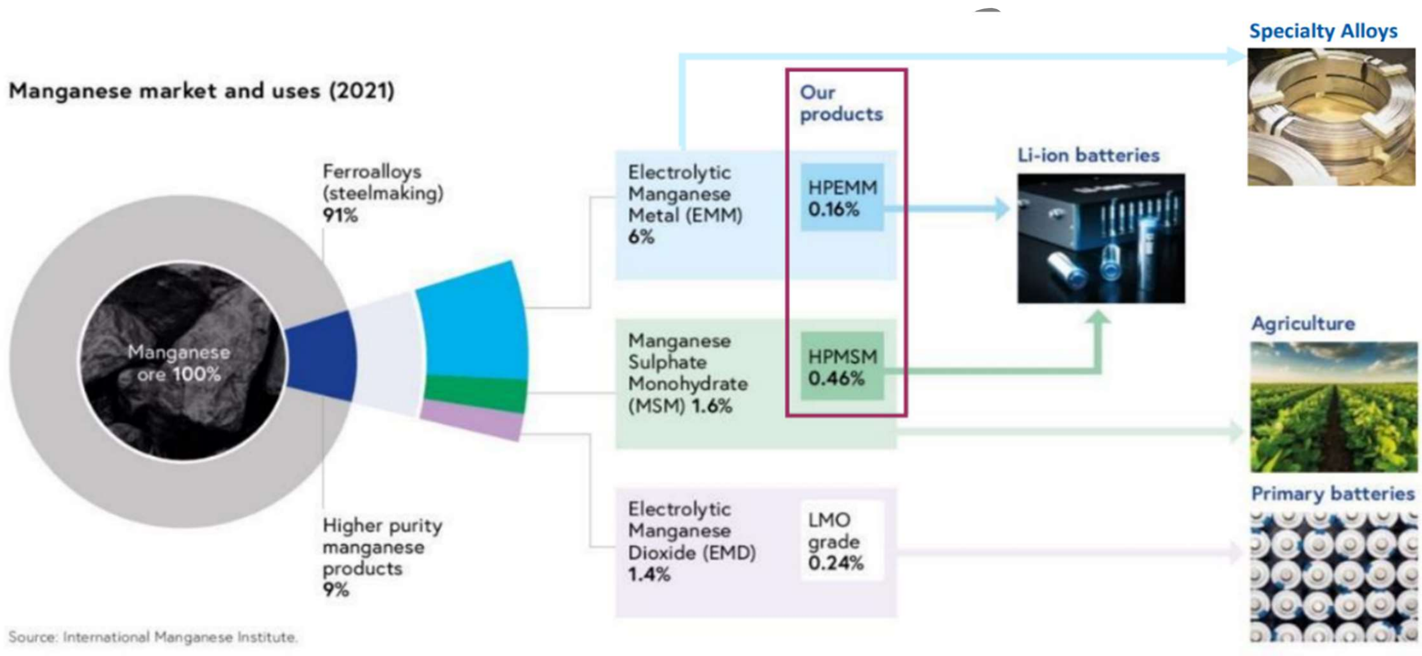


Figure 1 — Applications pour le manganèse en 2021

2.2 Chaîne de valeur de l'industrie du manganèse

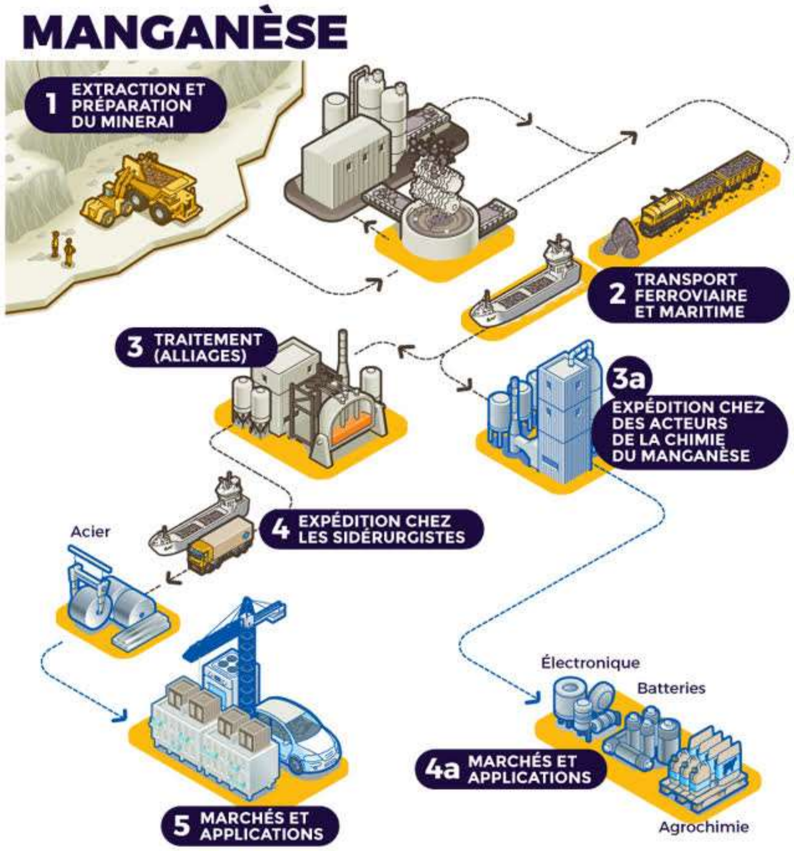


Figure 2 — Chaîne de valeur

Les deux premières étapes de la chaîne de valeur du manganèse sont les mêmes, ce qui implique que le minerai de manganèse peut être utilisé dans les deux types de raffinage. Par contre pour l'étape 3A le manganèse doit avoir une certaine pureté pour répondre aux standards. À l'étape suivante, le minerai de manganèse est raffiné pour deux applications finales distinctes. La majeure partie est traitée pour être utilisée dans l'industrie de l'acier, tandis qu'une fraction restante est transformée en manganèse d'une très haute pureté qui trouve des applications dans l'électronique, les batteries et l'agrochimie. Plus en détails comment on produit le sulfate pour les batteries :

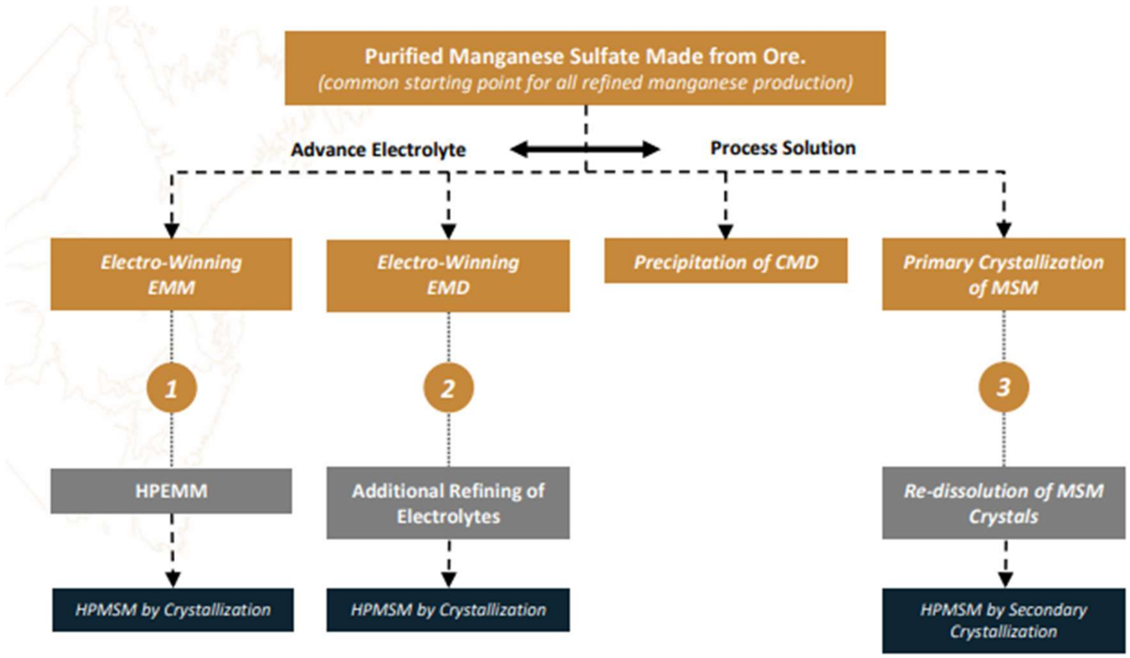


Figure 3 – Production du sulfate de manganèse

En 2022, l'USGS estime l'extraction mondiale de minerai de manganèse à 20 090 000 tonnes, réparties entre les pays de la manière suivante :

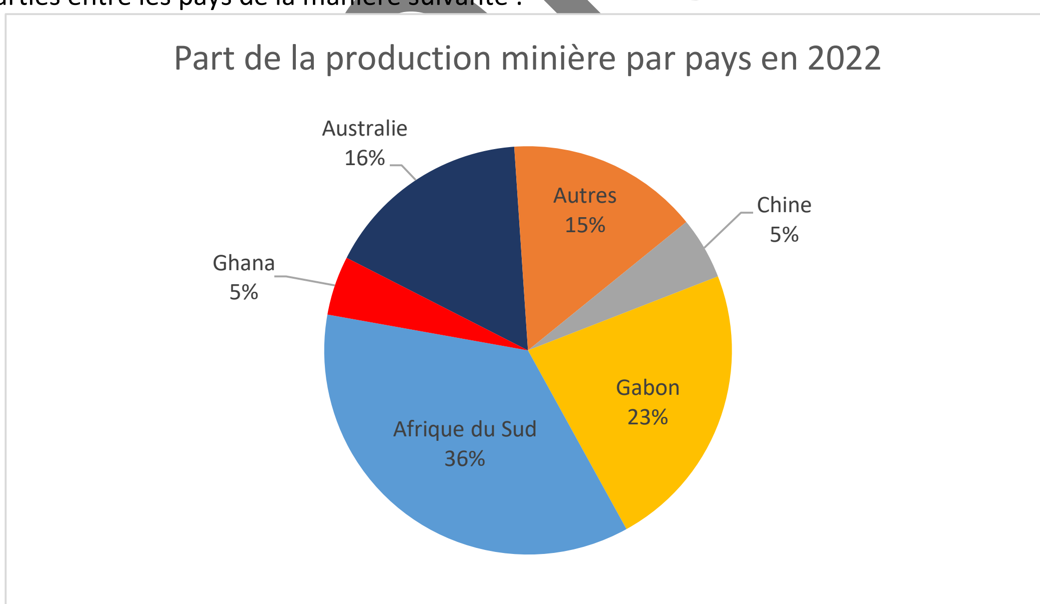


Figure 4 – Production minière par pays 2022

En observant ce graphique, on constate que la production de manganèse est concentrée principalement en Afrique du Sud, au Gabon et en Australie. En effet, ces trois pays dominent le marché. L'Afrique contribue à plus de 60% de la production mondiale de manganèse, ce qui lui confère un rôle majeur dans ce secteur. En revanche, de nombreux autres pays ne produisent que des quantités marginales de manganèse, ce qui indique que l'extraction de ce minerai n'est pas diversifiée sur le plan géographique.

Il est pertinent d'examiner les réserves de manganèse par pays afin d'identifier ceux qui pourraient se démarquer à l'avenir et ceux qui possèdent des réserves suffisamment vastes pour potentiellement dominer le marché. En 2022, les réserves mondiales totales de manganèse étaient estimées à 1,7 milliard de tonnes, avec une répartition comme suit :

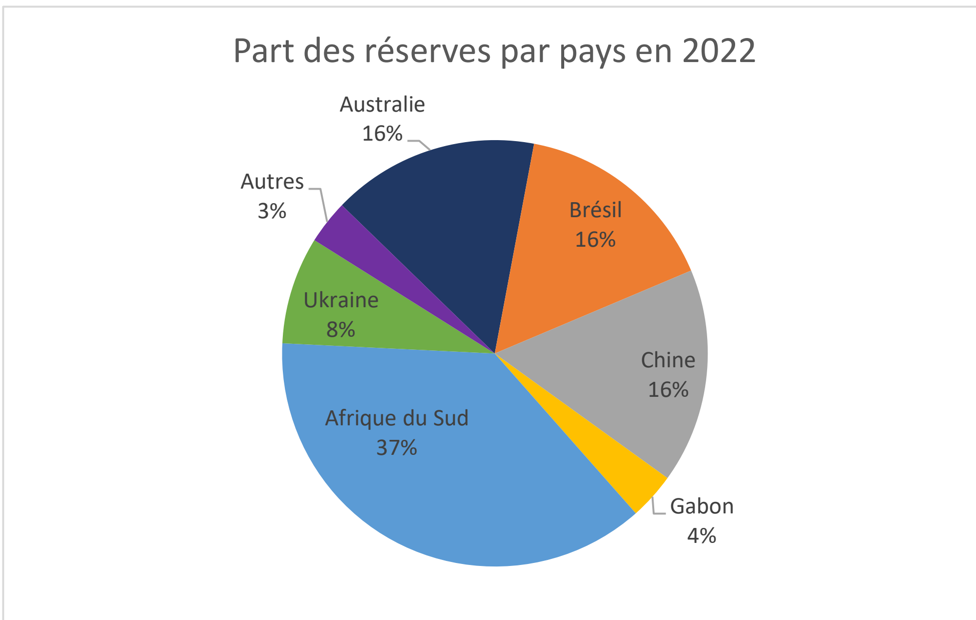


Figure 5 – Part des réserves par pays

On observe que l'Afrique du Sud détient une part considérable des réserves minières. En plus de cela, il existe trois autres pays qui ont ou pourraient avoir une position dominante. L'Australie est déjà un acteur majeur sur le marché minier, tandis que la Chine et le Brésil sont des pays qui pourraient augmenter leur présence sur le marché en raison de l'ampleur de leurs réserves.

De plus, il convient de se pencher sur le raffinage du manganèse à haute pureté, qui représente environ 10 % du raffinage total. La Chine est responsable de 97 % du raffinage du manganèse utilisé dans les batteries des véhicules électriques, ce qui présente un risque élevé d'approvisionnement pour ce type spécifique de manganèse.

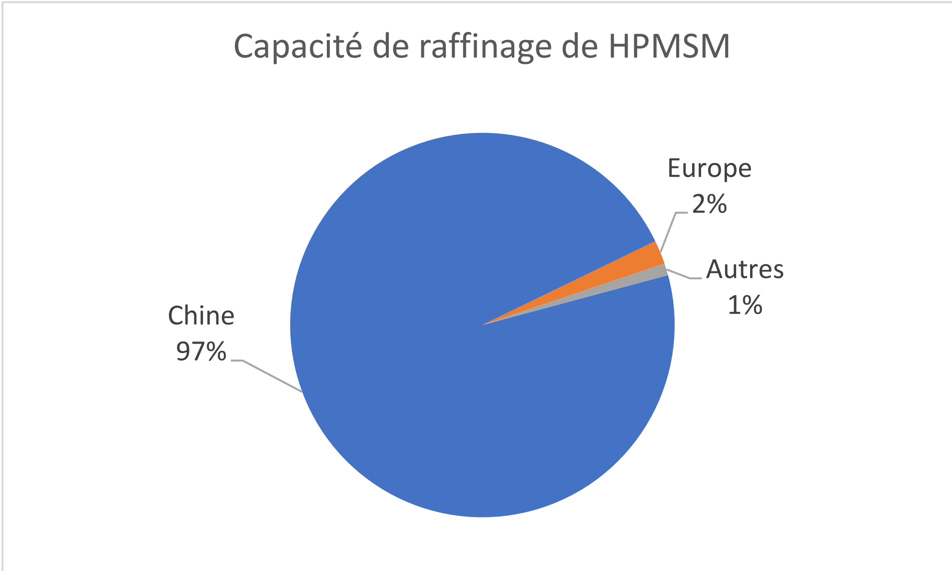


Figure 6 – Capacité de raffinage du manganèse de type HPMSM

Les principaux utilisateurs de manganèse sont les pays qui produisent la plus grande quantité d'acier, car 90% de la demande de manganèse provient de ce secteur. Obtenir des données précises sur la consommation de manganèse à haute pureté est difficile, mais compte tenu de la demande croissante pour les batteries des véhicules électriques, il serait intéressant de surveiller cette consommation à l'avenir. Étant donné que les données directes sont très difficiles à obtenir, une estimation peut être faite en se basant sur la production d'acier. En 2022, la production mondiale d'acier était d'environ 1,6 milliard de tonnes, répartie de la manière suivante :

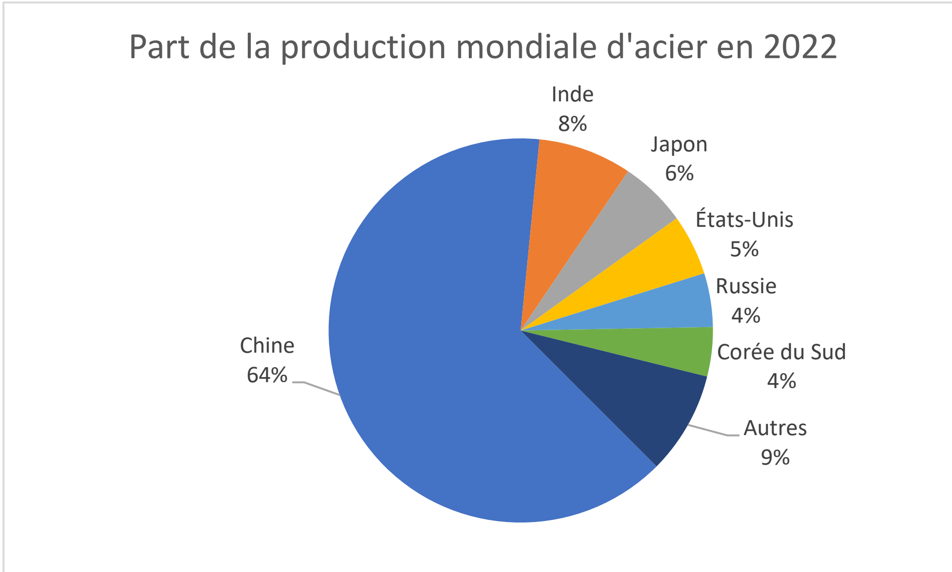


Figure 7 – Part de la production d'acier par pays

Il est évident que la Chine occupe une position dominante sur le marché de l'acier. Par conséquent, la Chine est actuellement le plus grand consommateur de manganèse. Toutefois, à l'avenir, avec l'émergence du manganèse de haute pureté dans les batteries, il pourrait y avoir un changement dans les principaux consommateurs de manganèse. Il est fort probable que la Chine reste le principal consommateur, étant donné sa domination actuelle sur le marché des batteries pour voitures électriques. Cependant, il pourrait y avoir des changements parmi les plus petits consommateurs.

2.3 Prévisions et prix

Les prévisions pour l'offre et la demande de sulfate de manganèse sont très déficitaires à long terme. Même en incluant les projets incertains et possibles, un grand déficit persiste. À court terme, un léger surplus entraîne des prix plus bas actuellement. À l'avenir, les prix devraient augmenter en raison de la forte demande par rapport à l'offre. Certains projets non rentables pourraient devenir viables. L'offre et la demande futures sont représentées ci-dessous :

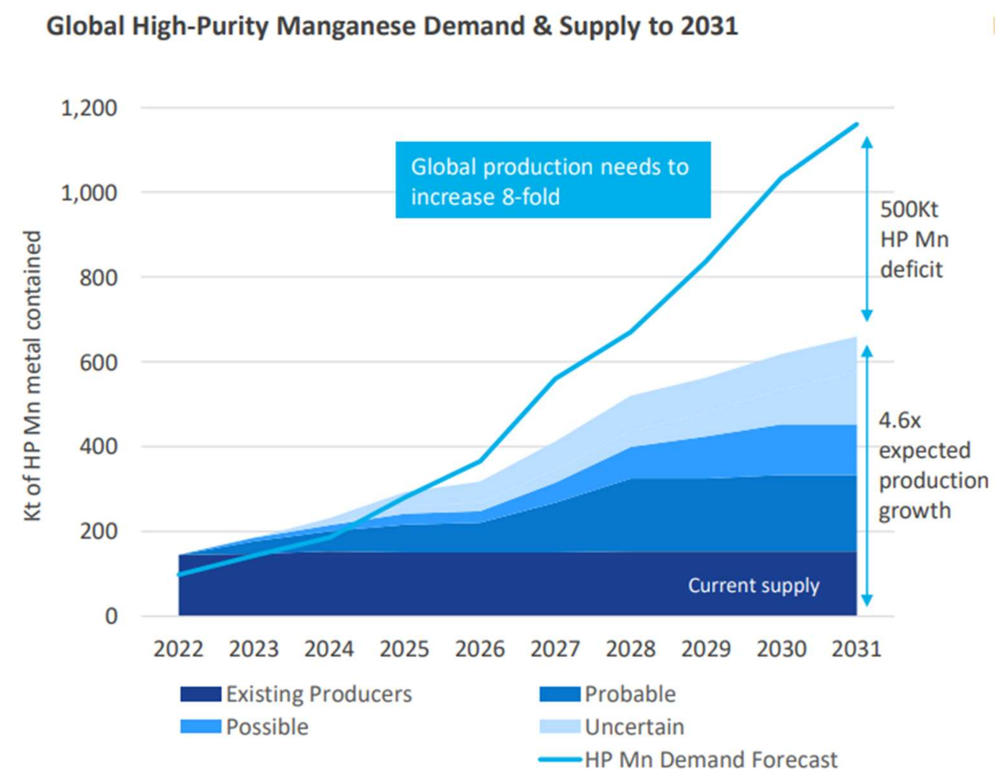


Figure 8 – Offre et demande de sulfate

Quant aux prix, ils ont maintenu une certaine stabilité au cours des dernières années. En examinant le manganèse 44%, on constate que son prix a connu des variations en fonction de l'activité économique. Par exemple, lors de la crise de la Covid, le prix a atteint son niveau le plus bas des cinq dernières années. Pour le futur, on s'attend à une croissance modérée des prix dans les années à venir. De plus, le prix du sulfate de manganèse suit le prix du minerai de manganèse mais se transige avec une prime très élevé le prix pour 1 tonne de sulfate est d'environ 750$ US.

Le graphique ci-dessous présente l’évolution des prix ainsi que les prévisions.

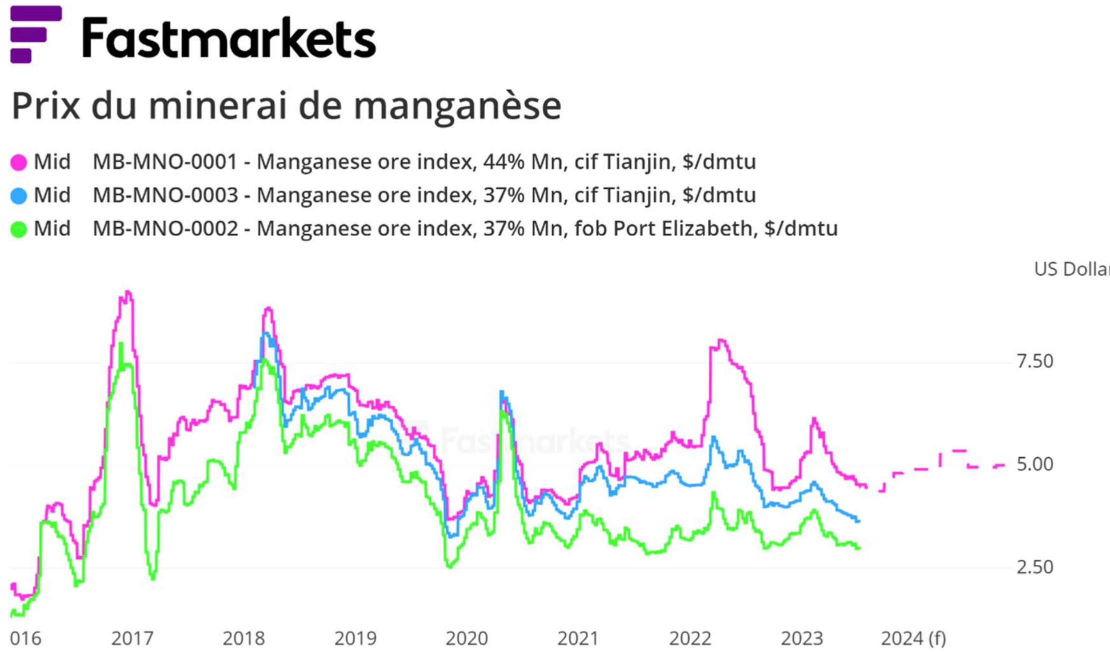


Figure 9 – Prix du manganèse

2.4 Perspectives

Principales tendances

<u>Demande de manganèse</u>

1) Conjoncture économique

Le marché du manganèse est normalement lié à la conjoncture économique mondiale, principalement en raison de la demande d'acier, dont l'acier inoxydable et les alliages d’acier contenant du manganèse. La demande d'acier est souvent considérée comme un indicateur fiable de l'état global de l'activité économique. Par conséquent, le ralentissement économique actuel, qui est susceptible de persister dans les mois ou les années à venir, exerce une pression à la baisse sur la demande de manganèse et par le fait même le prix.

2) Électrification des transports

Par contre, la hausse de la demande pour les véhicules électriques (VÉ), dont l'ampleur future reste à voir, pourrait constituer une hausse importante de la demande pour le manganèse de haute pureté. L'ampleur de cette hausse reste difficile à déterminer puisque les batteries de VÉ ne contiennent pas tous du manganèse et il est difficile de prévoir quelle technologie dominera le marché.

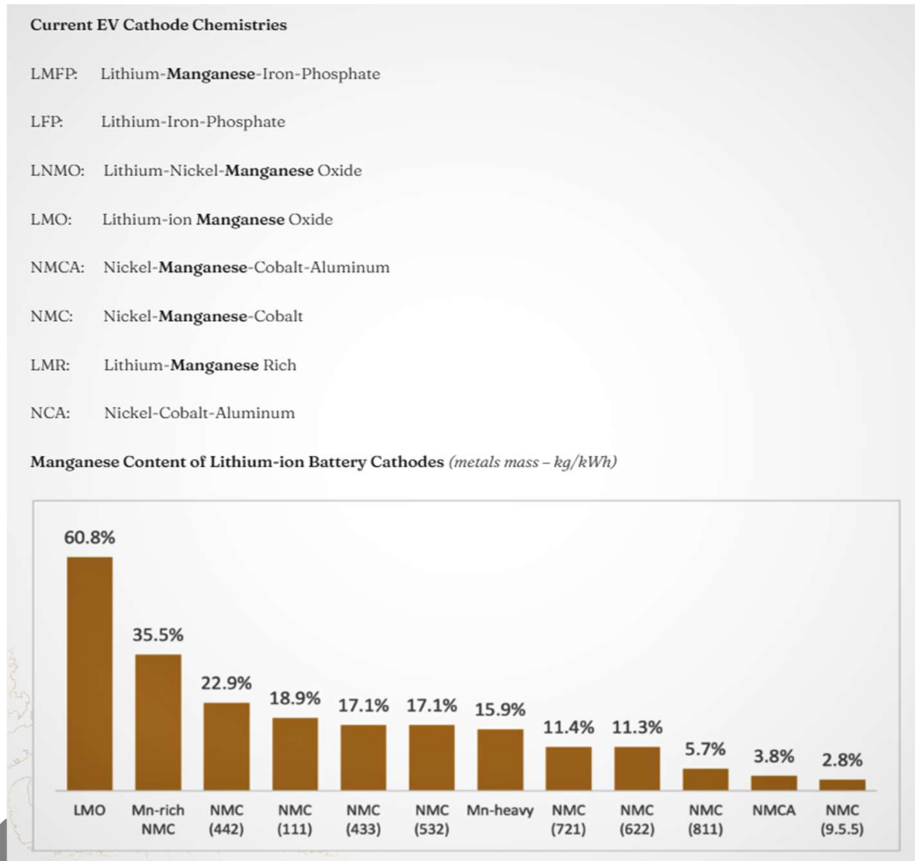


Figure 10 – Quantité de manganèse dans les différents types de batteries

Globalement, on peut penser qu'avec l'ajout de la demande provenant des VÉ, la demande pour le manganèse de haute pureté sera à la hausse. Les fabricants de VÉ tentent d'éliminer le plus possible le cobalt de leur batterie en raison des problèmes éthique au Congo, ce qui fait en sorte qu'on augmente la proportion de manganèse dans les batteries contenant du Cobalt. Cela permet de diminuer le cout global de la batterie en perdant peu d'efficacité. Voici une idée de la répartition des couts pour une batterie NMC 622 :

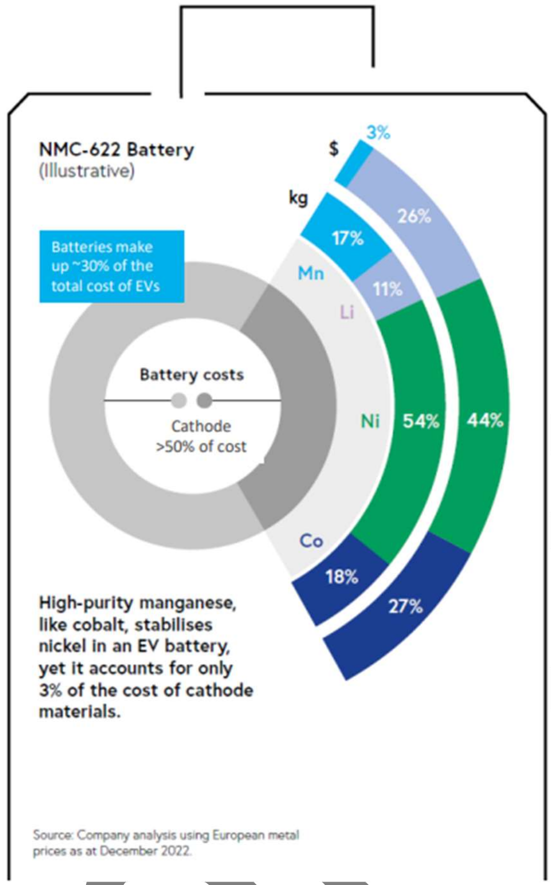


Figure 11 – Représentation du coût d'une batterie selon les minéraux

Offre de manganèse

De son côté, l'offre de manganèse demeure croissante d'année en année. La croissance de l'économie mondiale et l'utilisation du manganèse dans les batteries de VE auront un impact sur l'offre puisqu'ils moduleront les investissements en exploration minière. L'Afrique peut aussi influencer l'offre en modifiant son extraction. Cela aura pour conséquence de faire varier les prix autant à la hausse qu'à la baisse.

1) Nouvelles mines

L'établissement de nouvelles mines connaît une difficulté croissante. Depuis le début des années 2000, moins de 20 % des projets d'exploration, toutes substances confondues, parviennent à leur aboutissement. La mise en place d'une mine requiert généralement une période de 10 à 20 ans, accompagnée d'investissements réguliers dépassant le milliard de dollars. Par ailleurs, les mines de manganèse se font plutôt rares, avec seulement 28 mines actives recensées à l'échelle mondiale. La mise en œuvre d'une mine de manganèse exige le respect de plusieurs conditions préalables, notamment la présence d'un important gisement avec une teneur en minerai significative et des coûts d'extraction faible.

Actuellement, certains projets nord-américains liés au manganèse se trouvent aux stades d'exploration ou de développement, tandis qu'il n'existe qu'une seule mine en activité en Amérique du Nord, localisée au Mexique.

2) Géopolitique

En plus des enjeux techniques relatifs à la découverte d'un gisement, il faut aussi tenir compte des enjeux géopolitiques. On assiste depuis plusieurs années à une montée du nationalisme des ressources naturelles. À ce titre, plusieurs épisodes se sont manifestés au cours des dernières années.

Un enjeu important avec le manganèse est que la grande majorité est extrait loin de l'Amérique du Nord et qu'il est raffiné en grande majorité en Asie. L'Amérique du Nord est donc très vulnérable à des enjeux géopolitiques et par conséquent exposé à un risque dans la chaine d'approvisionnement du manganèse.

De plus, un rapport de l'OCDE montre que le nombre de mesures protectionnistes visant les ressources naturelles a augmenté de façon exponentielle depuis 2010. Il y a donc un certain risque que notre approvisionnement en manganèse soit perturbé d'ici les prochaines années si on ne s'approvisionne pas plus près de chez soi.

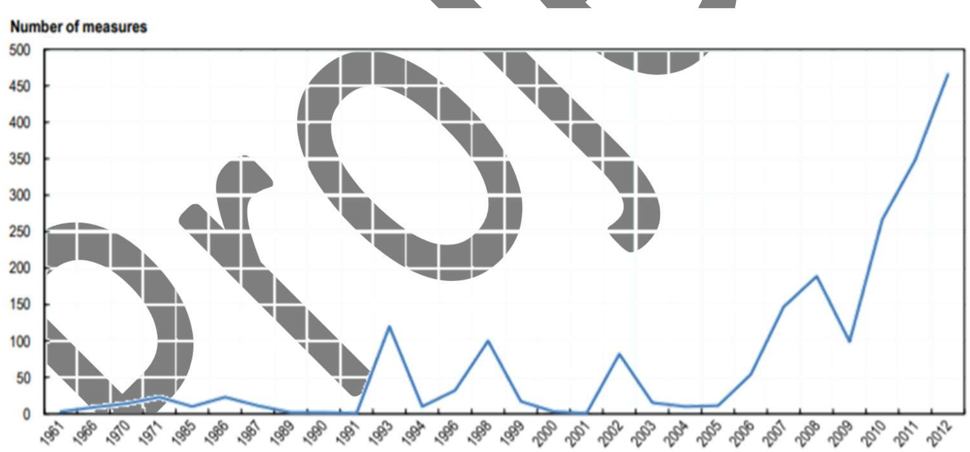


Figure 12 — Nombre de mesures protectionnistes visant les ressources naturelles

Source: OCDE. Trade and Agriculture directorate

3) Recyclage

Le recyclage des batteries est considéré comme une solution importante pour faire face aux défis d'approvisionnement à long terme. Les fabricants pourraient rencontrer des difficultés à répondre à la demande croissante de sulfate de manganèse à l'avenir, et le recyclage des batteries pourrait donc jouer un rôle complémentaire en répondant à cette demande accrue.

3. Portrait de la situation actuelle du Québec

Au Québec, la production de manganèse est actuellement limitée, et il n'y a pas de mines de manganèse en exploitation dans la province. De plus, il n’existe aucun projet répertorié qui soit au stade d’exploration ou de mise en valeur, s’il existe des projets ils sont à leur tout début.

En termes de réserves de manganèse, les données précises spécifiques au Québec ne sont pas facilement accessibles. Cependant, le Canada est généralement considéré comme possédant d'importantes réserves de manganèse. Les provinces voisines du Nouveau-Brunswick et de Terre-Neuve-et-Labrador possèdent des gisements de manganèse, mais aucune mine n’est encore en production au Québec.

Le Québec pourrait envisager de se tourner vers la transformation du manganèse, en profitant notamment de certains projets en cours au Nouveau-Brunswick. Il serait intéressant d'envisager la possibilité de transformer ce manganèse directement dans la province. Par ailleurs, la société Euro Manganèse a exprimé son intention de construire une usine de transformation à Bécancour, située dans le parc à batteries. Il serait donc important de suivre attentivement l'évolution de ces initiatives et leurs développements potentiels.

Utilisation du manganèse au Québec

3.1 Investissements privés et publics

Aucune idée voir avec Steve mais je ne crois pas qu'il n'y ait aucun projet actif. Aller voir base de données de Jonathan avant de pousser plus loin l'information.

4. Conclusion

Le marché du manganèse a connu une croissance au cours des dernières années et cette croissance devrait se poursuivre au cours des prochaines années, portée par la demande en VÉ.

Malgré les anticipations d'un surplus à court terme sur le marché mondial, il est crucial d'envisager l'arrivée de nouvelles sources d'approvisionnement. Cela deviendra d'autant plus important si les marchés se régionalisent davantage et si les batteries de véhicules électriques à base de manganèse continuent de gagner une part de marché significative.

Le Québec n'est pas dans une position optimale pour l'extraction de manganèse, il n'existe aucun projet actif pour ce minerai au Québec. Le Québec pourrait se positionner comme transformateur de manganèse pour fournir le sulfate de manganèse aux usines de batteries qui s'établiront à Bécancour et peut être pour transformer le manganèse provenant des probables futurs mines de manganèse aux Nouveau-Brunswick. Porter une attention particulière au projet de l'usine de transformation d'euro Manganèse.

On devra garder un œil sur quelle technologie de batterie émergera comme la plus dominante dans les prochaines années pour déterminer si le manganèse demeura un élément important des batteries produites à Bécancour. Si oui, il faudra s'assurer de diminuer les risques d'approvisionnements pour le manganèse. Sinon le manganèse demeura encore un joueur important du marché de l'acier mais il deviendra moins intéressant pour le Québec.

Potentiel Géologique au Québec ?

Euro manganèse s'approvisionne où ?

5. BIBLIOGRAPHIE (à compléter)

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Zoom sur le marché du nickel

ANALYSE DE MARCHÉ

effectuée dans le cadre de la mesure

2.1.3 Analyser les tendances du marché des filières de MCS du

Plan québécois pour la valorisation des minéraux critiques et stratégiques 2020-2025 (PQVMCS)

Document de travail

VERSION FÉVRIER 2023

Table des matières (à revoir)

1. Mise en contexte

1.1 Mise en contexte de la démarche

Comme plusieurs autres gouvernements, le Québec s'est doté, en 2020, de plans pour assurer un approvisionnement et un développement des minéraux critique et stratégique (MCS). En effet, le Plan québécois pour la valorisation des minéraux critiques et stratégiques (PQVMCS), s'inscrivant dans une vision gouvernementale globale, s'assure, par le biais de plusieurs actions, de l'accès et de la disponibilité des ressources minérales importantes pour l'économie du Québec.

Ainsi, dans le cadre de la mesure 2.1.3 analyse des tendances de marché des MCS, il est prévu que pour « maximiser les retombées économiques liées à la mise en valeur des MCS au Québec, le MERN développera ses connaissances et son expertise en matière de prévisions économiques afin d'être en mesure d'anticiper les demandes futures tant pour les minéraux actuellement reconnus comme critiques ou stratégiques que pour ceux qui le deviendront. » (MERN, 2020) Le document suivant répond à cette mesure en faisant le recensement des connaissances et des expertises sur le marché d'un métal critique ou stratégique. Les études permettent alors de dresser un portrait du marché de certains des MCS (taille, production, consommation) et de la position des acteurs québécois sur le marché mondial, comparée à celle des autres acteurs mondiaux.

1.2 Liste des MCS identifiés pour la veille économique

Dans le Plan québécois de valorisation des minéraux critiques et stratégiques (PQVMCS), les minéraux critiques ou stratégiques sont définis « comme [les minéraux] qui revêtent aujourd'hui une importance économique significative pour des secteurs clés de notre économie, qui présentent un risque d'approvisionnement élevé et qui n'ont pas de substituts disponibles commercialement [ou] sont des substances minérales nécessaires à la mise en œuvre de différentes politiques du Québec. » (MERN, 2020) Les 22 minéraux critiques ou stratégiques identifiés par le gouvernement du Québec se divisent en 3 catégories :

- Les minéraux critiques pour l'approvisionnement des usines québécoises de transformation.
- Les minéraux stratégiques nécessaires pour la mise en œuvre des politiques québécoises : Parmi ces politiques, mentionnons la stratégie gouvernementale de développement durable, la Politique énergétique 2030, la Politique de mobilité durable 2030 et le Plan pour une économie verte 2030.
- Les minéraux critiques ou stratégiques pour les états avec qui le Québec a développé (ou peut développer) des accords commerciaux pour la mise en valeur de nos minéraux critiques ou stratégiques.

Le présent document fera l'analyse du marché du nickel qui se trouve dans la deuxième catégorie des minéraux critique ou stratégique.

2. Applications industrielles et chaîne de valeur

2.1 Applications industrielles

La demande de nickel est distribuée selon certaines applications dont l'acier inoxydable était l'application la plus importante, représentant 69 % de la consommation en 2021 (77 % en 2020). Depuis quelques années, la part associée à la fabrication de batterie à augmenter, se situant à 13 % en 2021 (10 % en 2020).

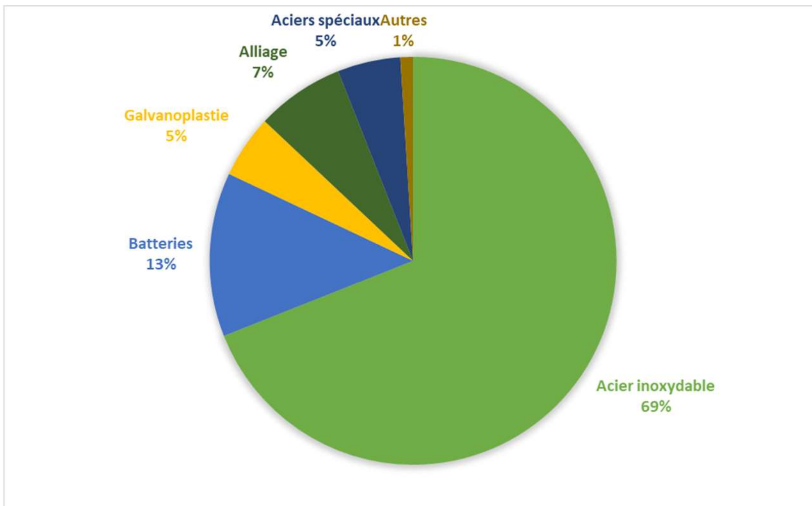


Figure 1 — Applications en 2021

2.2 Chaîne de valeur de l'industrie du nickel

La chaîne de valeur du nickel est complexe mais mène essentiellement à la production de 2 classes de nickel se distinguant par leur niveau de pureté. Le nickel de classe 1 (habituellement plus de 99 % de pureté) est le plus pur disponible sur le marché tandis que le nickel de classe 2 possède un niveau de pureté moins élevé (moins de 99 % de pureté) ainsi que, généralement, un contenu en fer plus élevé. Chaque classe de nickel mène à la fabrication de produits spécifiques, bien que toutes 2 servent à la fabrication d'acier inoxydable.

Résumé de la chaîne de valeur du nickel

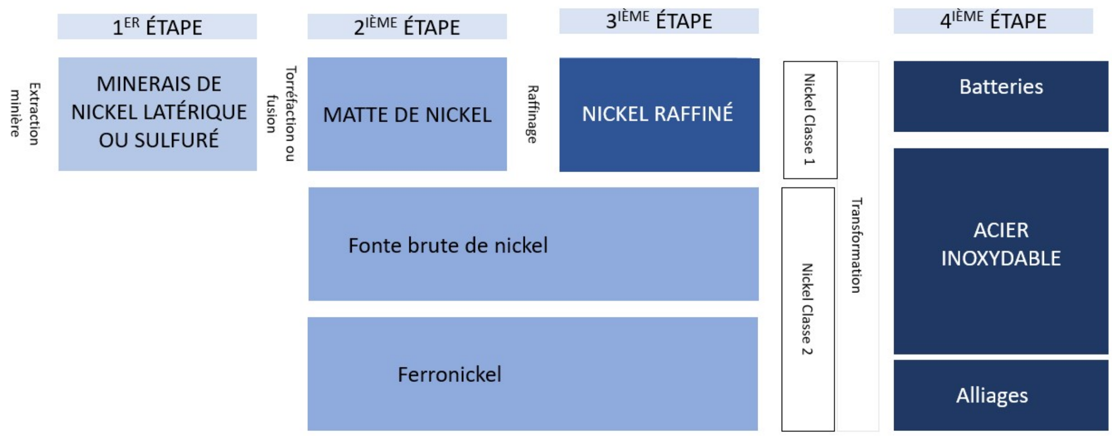
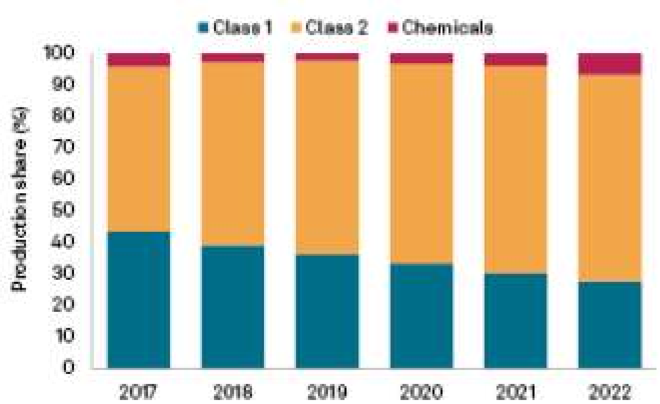


Figure 2 — Chaîne de valeur

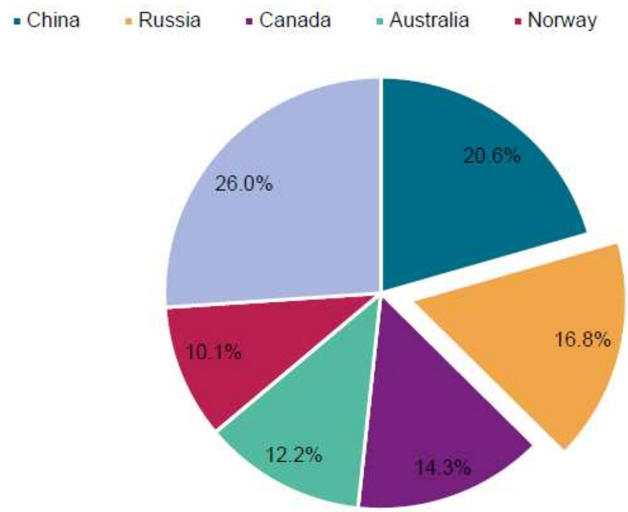
On remarque de plus que la proportion de nickel de classe 1 dans l'ensemble de la production mondiale de nickel tend à diminuer au cours des années.

Proportion de nickel classe 1 par rapport à la production globale de nickel primaire

(S&P Global, janvier 2023)



En 2022, S&P Global estime la production totale mondiale de nickel de classe 1 à environ 846 000 tonnes, réparties entre les pays de la façon suivante :



En étudiant la chaîne de valeur du marché du nickel, il est possible de remarquer qu'elle est géographiquement très étendue. En effet, historiquement, la production du nickel à chaque étape de la chaîne de valeur n'a pas été contrôlée par un seul pays. Toutefois, on remarque que l'Indonésie est dans les principaux producteurs à toutes les étapes de production de nickel et prend de plus en plus d'importance dans cette chaîne de valeur.

En 2022, S&P Global estime que l'Indonésie contribuait à 48 % de la production de minerai de nickel mondiale (la première étape de la chaîne de valeur). Tous les autres producteurs ne contribuent chacun qu'à moins de 10 % de la production mondiale.

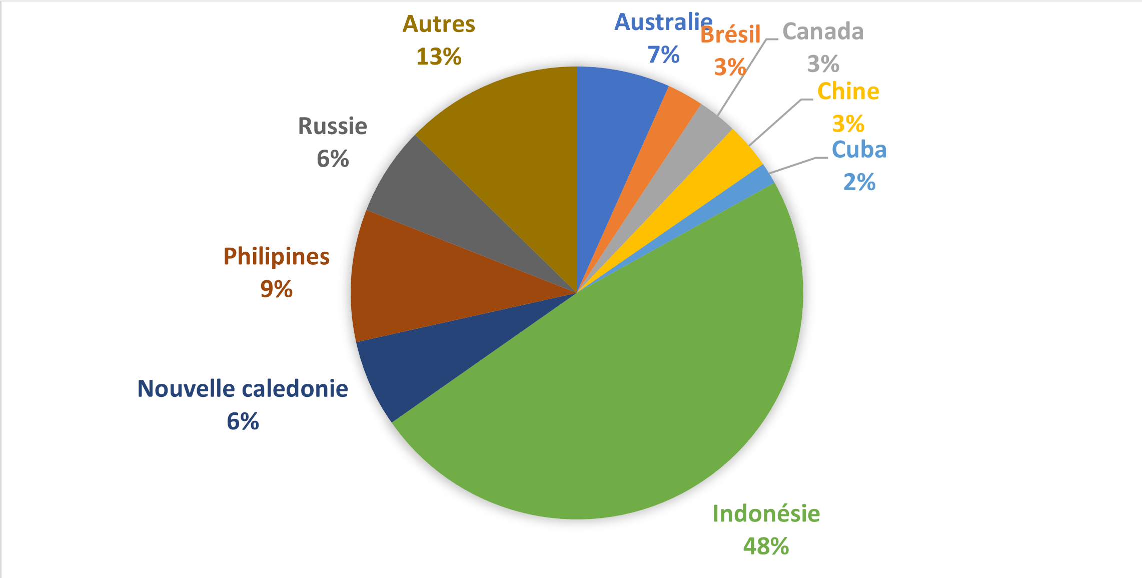


Figure 3 — Principaux pays producteurs en 2022

Historiquement, dans les douze dernières années, la production était répartie entre plusieurs pays. Mais les dernières années ont vu s'accroître la domination de l'Indonésie comme principal pays producteur de minerai de nickel.

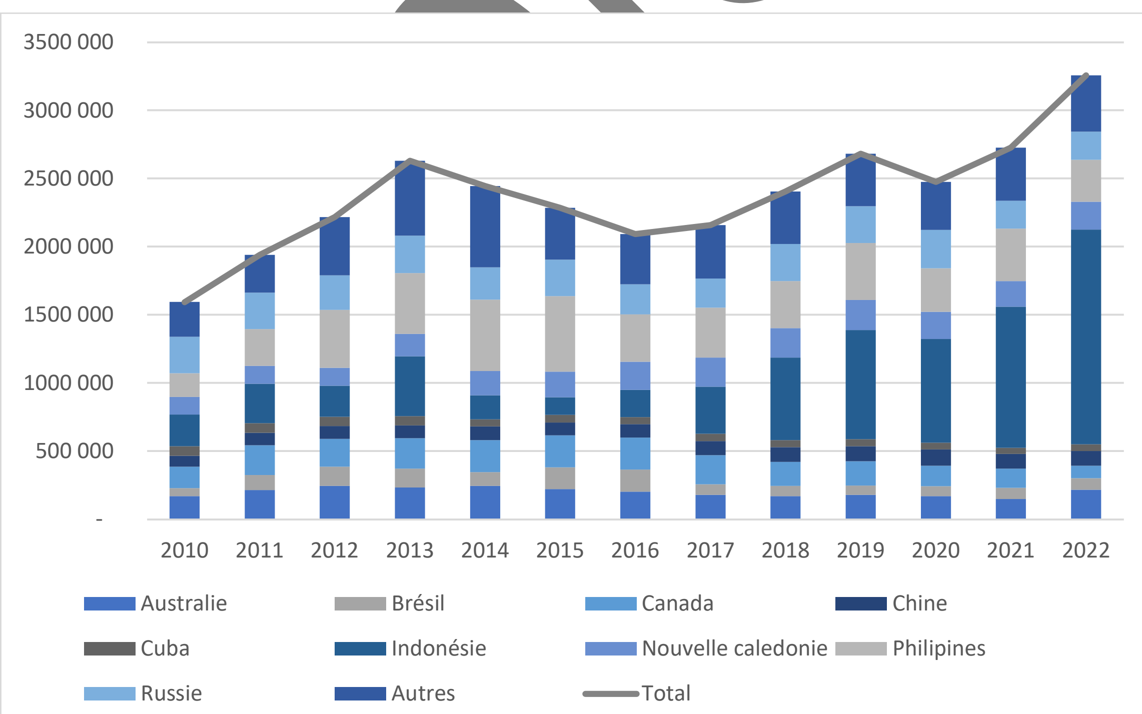
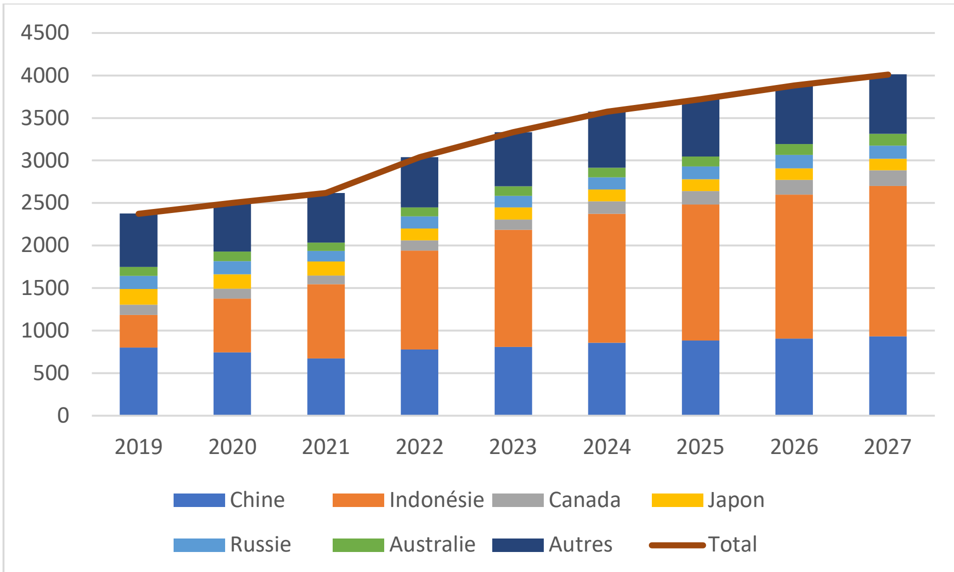


Figure 4 — Évaluation de la part de marché des principaux pays producteurs

Les principaux producteurs mondiaux de nickel primaire actuels et anticipés (étapes 2 et 3 de la chaîne de valeur du nickel) sont les suivants :

Évolution de la production des principaux producteurs mondiaux de nickel primaire

(S&P Global, janvier 2023, en milliers de tonnes)



Ainsi, en plus d'être le leader dans la production de minerai, l'Indonésie est maintenant le leader mondial dans la production de nickel primaire et cette position devrait se consolider dans les prochaines années, puisque l'Indonésie pourrait représenter plus de 43 % de la production de nickel primaire au cours des prochaines années. La décision de l'Indonésie de bannir les exportations de minerai pour augmenter la transformation locale semble donc porter ses fruits. La part du Canada a légèrement diminué au cours des dernières années mais devrait demeurer stable entre 4 % et 5 % de la production mondiale au cours des prochaines années.

Finalement, la Chine est le principal consommateur de nickel et devrait le demeurer au cours des prochaines années tandis que l'Indonésie est maintenant le deuxième consommateur mondial de nickel, devant les Américains, l'Europe et le Japon. En 2014, sa consommation équivalait à 50 % de la demande mondiale de nickel. Cette proportion a diminué à 46 % en 2017.

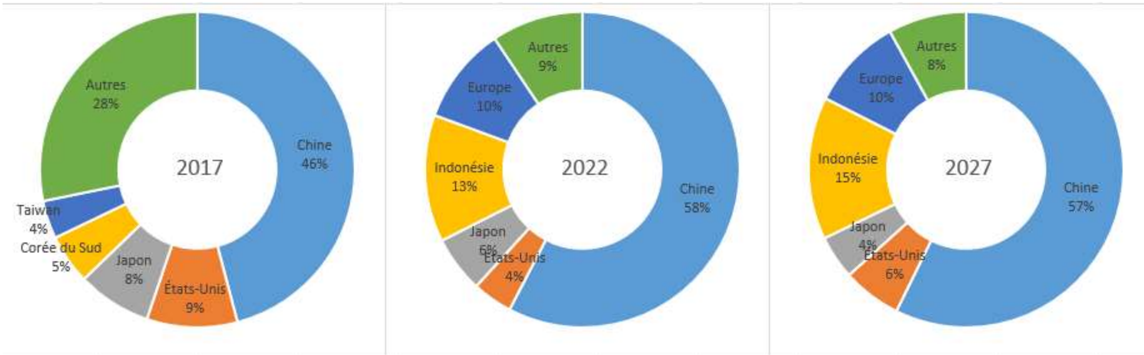


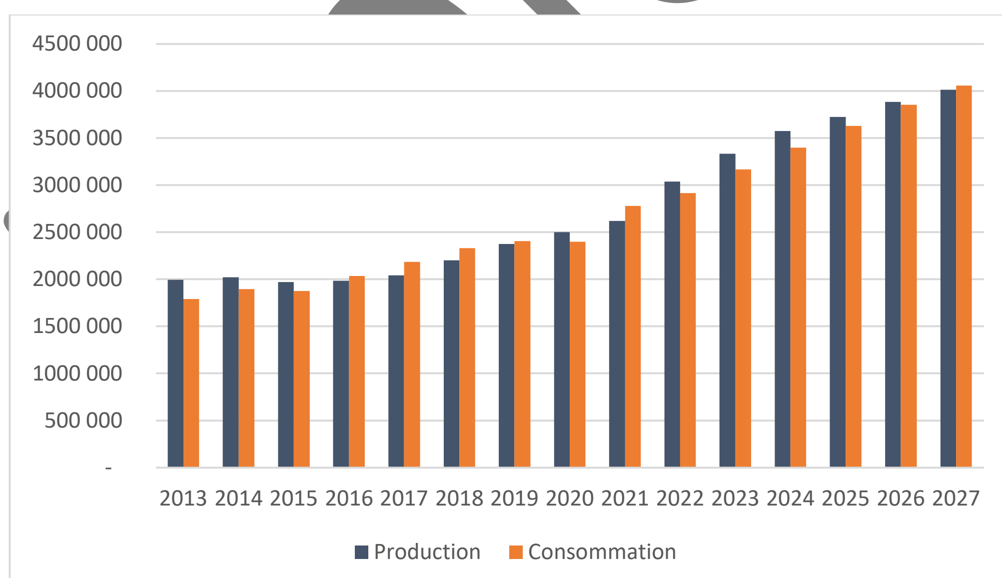
Figure 5 — Principaux consommateurs de nickel en 2017, 2022 et 2027 (source Statista et S&P Global)

2.3 Prévisions et prix

Le marché du nickel primaire était en déficit en 2021 mais devrait revenir à l'équilibre en 2022 et même afficher un léger surplus au cours des prochaines années, malgré une hausse anticipée de la demande provenant du secteur des batteries pour véhicules électriques.

Évolution de l'offre et de la demande de nickel primaire (en tonnes)

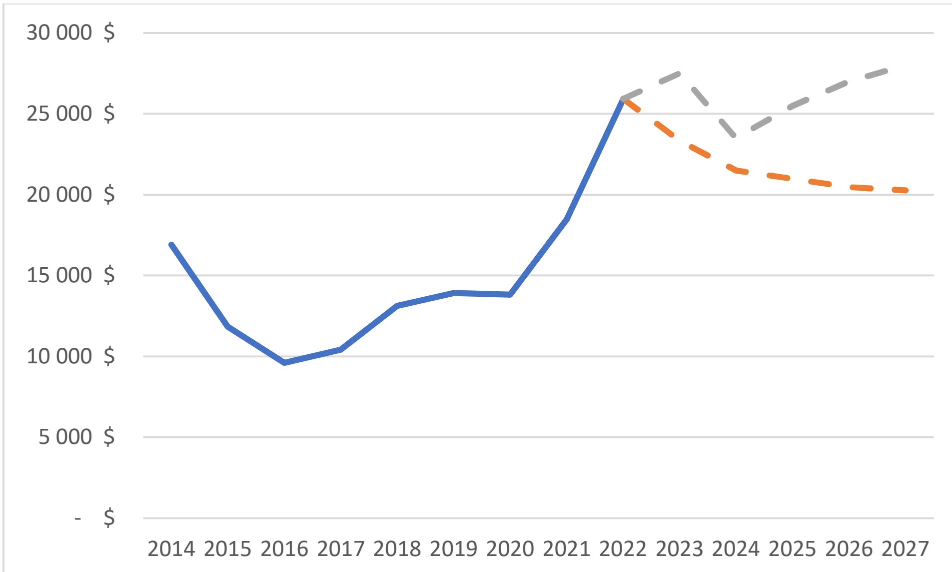
(S&P Global, janvier 2023)



Quant aux prix, ceux-ci ont connu une forte volatilité en 2022, causée notamment par les problématiques vécues sur le LME. Ils poursuivent toutefois une tendance à la hausse depuis les dernières années. Le graphique suivant présente l'évolution et les prévisions de prix (optimistes et pessimistes) selon différentes sources.

Évolution et prévision des prix du nickel (LME, $US/tonne)

(sources : Focus economics, S&P Global – Janvier 2023)



2.4 Perspectives

Principales tendances

<u>Demande de nickel</u>

1) Conjoncture économique

Le marché du nickel suit généralement la conjoncture économique mondiale puisque la demande en acier inoxydable, qui demeure l'une des principales utilisations du nickel, est un bon indicateur de l'état de l'activité économique mondiale. Ainsi, le ralentissement économique actuel, qui pourrait se poursuivre dans les prochains mois/années demeure un frein à la demande de nickel.

2) Électrification des transports

Par contre, la hausse de la demande pour les véhicules électriques (VÉ), dont l'ampleur future reste à voir, a des effets positifs pour la demande de nickel, surtout de classe 1.

Globalement, on peut penser qu'avec l'ajout de la demande provenant des VÉ, la demande pour le nickel sera à la hausse pour les prochaines années.

<u>Offre de nickel</u>

De son côté, l'offre du nickel est restée plutôt stable dans les dernières années. La croissance de l'économie mondiale et la force du dollar américain pourraient également avoir un effet sur l'offre future de nickel comme ils moduleront les investissements en exploration minière. Le niveau des stocks de nickel influencera également l'offre de nickel puisqu'inonder le marché de nickel aura tendance à diminuer les prix. Les producteurs auront donc intérêt à garder le marché sous-approvisionné pour maintenir les prix du nickel haut.

1) Nouvelles mines

De plus, le développement de nouvelles mines est de plus en plus ardu. Depuis le début des années 2000, c'est moins de 20 % des projets d'exploration, toutes substances confondues, qui voient le jour. Il faut compter entre 10 et 20 années pour mettre en places une mine et les sommes à investir dépassent régulièrement le milliard de dollars.

2) Géopolitique

En plus des enjeux techniques relatifs à la découverte d'un gisement, il faut aussi tenir compte des enjeux géopolitiques. On assiste depuis plusieurs années à une montée du nationalisme des ressources naturelles. À ce titre, plusieurs épisodes se sont manifestés au cours des dernières années.

La décision de l'Indonésie d'interdire les exportations de minerai de nickel non transformé semble porter ses fruits pour le développement économique de ce pays (plusieurs annonces récentes d'usine dans la chaîne de valeur de la batterie). Toutefois, cette décision met de la pression sur le marché du nickel en réduisant l'offre pour les autres pays.

De plus, les Philippines annonçaient en janvier 2023 qu'ils étudiaient la possibilité d'imiter l'Indonésie en interdisant les exportations de minerai.

De plus, un rapport de l'OCDE montre que le nombre de mesures protectionnistes visant les ressources naturelles a augmenté de façon exponentielle depuis 2010.

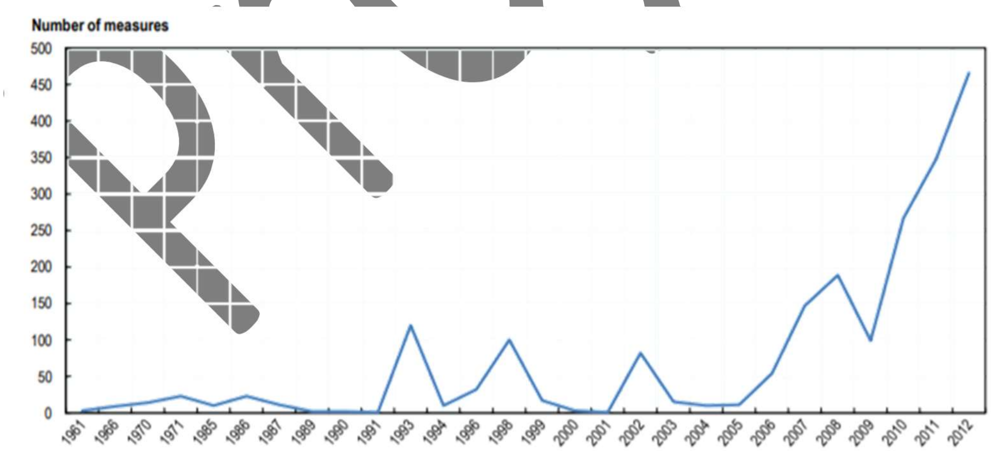


Figure 6 — Nombre de mesures protectionnistes visant les ressources naturelles

Source : OCDE. Trade and Agriculture directorate

3) Reconversion d'usines

D'ailleurs, la Chine annonçait récemment son intention de convertir certaines usines de raffinage de cuivre pour produire du nickel de classe 1 à partir de fonte de nickel, ce qui pourrait contribuer à réduire la pression sur le marché du nickel de classe 1.

4) Recyclage

De plus, le recyclage des batteries apparaît comme une partie de la solution aux enjeux d'approvisionnement mais à plus long terme.

Malgré certains obstacles, les producteurs semblent en mesure de répondre à la demande et la plupart des prévisions entrevoient même un surplus sur le marché du nickel pour les prochaines années.

Ceci n'empêche pas que la production minière devra se renouveler, surtout avec la possible émergence de différents blocs économiques géographiques.

3. Portrait de la situation actuelle du Québec

Production :

22

Réserves :

Selon le USGS, les réserves mondiales de nickel sont estimées à plus de 100 Mt. Bien qu'il soit difficile d'obtenir les données exactes, on peut estimer les réserves québécoises autour de 3 Mt, ce qui représenterait moins de 3 % des réserves mondiales et plus de 50% des réserves canadiennes.

Utilisation du nickel au Québec

Plusieurs entreprises au Québec utilisent du nickel. Les quantités totales utilisées sont donc difficiles à estimer. Le tableau suivant, tiré de l'analyse des chaînes de valeurs des MCS au Québec de PWC, donne un aperçu des principaux utilisateurs de nickel au Québec et l'utilisation qui en est faite :

Secteur d'activité visé	Compagnie	Description des applications
Alliages spéciaux	5N Plus	Divers
	Rio Tinto Fer et Titane	Alliages
	AP&C Revêtements & Poudres Avancées	Poudre de métal
	Tekna	Poudre de métal
Batteries	Blue Solutions (Bolloré)	Production de cellules de batteries
Placage	Service Chrome et Zinc	Galvanoplastie et placage de pièces

Sources : Questionnaires, sites Web des entreprises. Analyse PwC.

22

3.1 Investissements privés et publics

En 2021, selon l'étude préliminaire de l'institut de la statistique du Québec (ISQ), les investissements privés totaux dans des projets miniers de nickel s'élevaient à 326 M$, dont 2 M$ était investi dans la mise en valeur hors site minier, 41 M$ en exploration hors site minier et 200 M$ en aménagement des complexes miniers.

4. Conclusion

Le marché du nickel a connu une croissance au cours des dernières années et cette croissance devrait se poursuivre au cours des prochaines années, portée par la demande en VÉ.

Bien qu'un surplus soit anticipé sur le marché mondial, de nouveaux approvisionnements devront arriver sur le marché, surtout si les marchés se régionalisent davantage.

Le Québec est actuellement bien positionné dans la chaîne de valeur du nickel et la transition énergétique, jumelée aux renforcements des chaînes d'approvisionnement nord-américaines sont une bonne opportunité pour :

Favoriser la mise en production de nouveaux gisements sur son territoire

Favoriser une transformation locale pour répondre aux besoins locaux, notamment dans la filière batterie

L’annonce récente de Vale d’implanter une usine de sulfate de nickel à Bécancourt (d’une capacité de traitement de 25 kt) est une bonne nouvelle et la demande additionnelle anticipée provenant des fabricants potentiels de matériaux avancés de cathodes pourraient justifier l’implantation de d’autres usines similaires.

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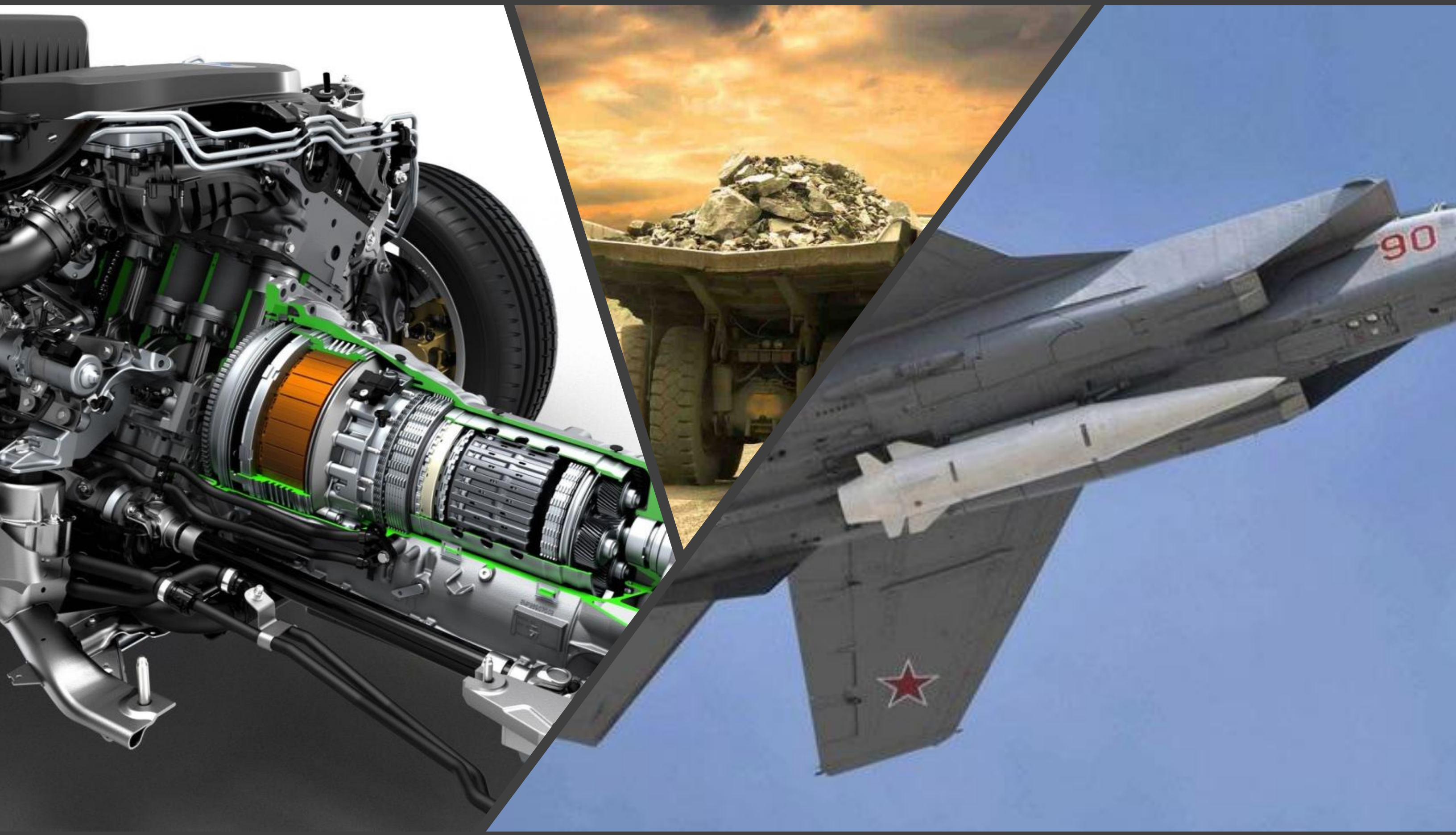

Rare Earth Elements Sector Review

January 2021

TAHUTI GLOBAL

Énergie et Ressources naturelles
Québec

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January 22nd, 2021

Attn: Project Managers
Christiane Morin, Directrice générale du développement de l'industrie minière
François Belle-Isle, ing., M.Sc., Ingénieur minier
Direction générale du développement de l'industrie minière
Ministère de l'Énergie et des Ressources naturelles

MERN – Rare Earth Elements Sector Review 2020

RE: Final Draft Report

Dear Madam Christiane Morin,

Please find the final report of the rare earth sector review attached to this letter. The report presents a detailed analysis of the current rare earth market, including global production and demand, and price trends. Canada imports a variety of rare earth products that are used by local manufacturers; the size of the import market is reported and the list of Québec and other Canadian end-users presented.

The report also includes a review of rare earth projects around the world, and the Québec projects are compared to other projects in Canada and abroad. The rare earth demand and supply analysis shows a dramatic increase in demand for rare earths in the next 10 years, presenting a timely opportunity for Québec rare earth projects to become an ethical and clean source of rare earths to the global markets.

Specific recommendations are proposed concerning the development of the rare earth supply chain in Québec, with an emphasis on magnets, which are the largest rare earth market segment.

We trust that the report will be helpful to your team as you consider strategies and policies to support the development of the rare earth sector in Québec.

Thank you for entrusting Tahuti Global with this important project. Please do not hesitate to contact us if you have any questions.

Sincerely,

53-54

Tahuti Global Inc.
+1 647 462 6039

Table of contents

Exhibits

Acronyms and Abbreviations

ASM	Australia Strategic Minerals
CC	Catalytic Converter
Ce	Cerium
CNSC	Canadian Nuclear Safety Commission
DFS	Definitive Feasibility Study
Dy	Dysprosium
Er	Erbium
Eu	Europium
EU	European Union
EV	Electric Vehicle
FCC	Fluid Cracking Catalyst
FS	Feasibility Study
Gd	Gadolinium
GDP	Gross Domestic Product
Ho	Holmium
HREE	Heavy Rare Earth Element
HREO	Heavy Rare Earth Oxide
La	Lanthanum
LED	Light Emitting Diodes
LREE	Light Rare Earth Element
LREO	Light Rare Earth Oxide
Lu	Lutetium
MP	Mountain Pass
Nd	Neodymium
NdFeB	Neodymium iron Boron
NdPr	Neodymium and Praseodymium
NWT	North West Territories
PEA	Preliminary Economic Assessment
PFS	Pre-feasibility Study
Pm	Promethium
PMM	Permanent Magnet Motors
Pr	Praseodymium
REO	Rare Earth Oxide
Sc	Scandium
SEG	Samarium, Europium, Gadolinium
Sm	Samarium
SRC	Saskatchewan Research Council
SX	Solvent Extraction
Tb	Terbium
Tm	Thulium
TREO	Total Rare Earth Oxide

UK	United Kingdom
UN	United Nations
WTO	World Trading Organization
Y	Yttrium
Yb	Ytterbium
ZEV	Zero Emissions Vehicles

Key Messages

China is still the largest producer and consumer of rare earths. Mine production outside of China increased from 4,000 tonnes in 2009 to about 80,000 tonnes in 2019, and although China currently only accounts for 62% of the world mine production (compared to 97% in 2009), it represents 85% of refined production. China is also the largest importer of rare earth feedstock, estimated at about 50,000 tonnes per year, and controls the supply chain of many rare earth products.

Demand for rare earths to be driven by the global green agenda. Countries around the world have set up targets to phase out internal combustion engine vehicles, aiming at 100% sales of zero-emission vehicles in the next 10 to 20 years. Assuming that at least 30.0% of all vehicles sold globally will be electric by 2030, and that 87.5% of all electric vehicles (EVs) will have a permanent magnet motor that uses rare earths, an additional 150,000 tonnes of rare earths would have to come online to fulfill demand in the EV sector alone. This will open an opportunity for 5 to 10 new rare earth mines to come into production in the next 10 years.

Québec rare earth projects are relatively less developed and have a complex mineralogy but could bring a much-needed supply of rare earths to the market. Some of the most developed rare earth projects are found in Australia and Africa. In comparison, the currently active Québec projects are less developed, having completed only a preliminary economic assessment (PEA). The Québec projects also have a more complex mineralogy and flowsheet, thus carrying higher technical/processing risk. However, most of the advanced rare earth projects around the world are also facing some degree of processing risk with many not able to produce a high-grade mineral concentrate (>30% TREO) that is usually common in commercial mines[1], and are still optimizing their flowsheets. Some also have high capital requirements and none have been able to attract construction funding after completing a bankable feasibility study. With sufficient funding and technical support, at least one of the projects in Québec could potentially advance to production in the next 7 to 12 years and become a much-needed supplier to the global fast-growing rare-earth magnet market.

Québec has the potential to develop a mine to market rare earth strategy. Rare earths are used in many forms and many applications, with different supply chains. The largest market for rare earths is the magnet market. To build a mine-to-magnet supply chain, Québec should adopt key strategies, which includes investing in the rare earth sector, and lobbying foreign governments to co-develop rare earths mining and supply chain. The province must also acquire know-how for rare earth metal making, alloy fabrication, and magnet manufacturing to build a fully integrated supply chain, as such, it must attract foreign rare earths companies and professionals and invest in R&D. Québec could become a rare earth magnet producer with or without rare earth mining (by importing rare earth oxides and metals). However, rare earth mine production in Québec would be a good incentive to attract rare earth metal, alloy and magnet manufacturing expertise, and the related multi-billion downstream industries to the province.

[1] Except ionic clay mines

Overview

This report was prepared by Tahuti Global Inc. for the Ministry of Energy and Natural Resources (Ministère de l'Énergie et des Ressources Naturelles (MERN)) of Québec. The report was commissioned by MERN and includes a review of the rare earth market, and an assessment of Québec's rare earth projects, particularly their technical challenges, financial requirements, and stage of development relative to other projects around the world. This report will also support MERN in determining the potential for the development of a rare earth supply chain in Québec.

This report starts with an introduction to rare earth elements and a review of events in the sector. Chapter 2 presents the most recent data on production per country compared to 10 years earlier. Mine and refining production are presented separately, and the output per element is estimated. The leading producing companies are also listed.

Global rare earth demand is discussed in Chapter 3, where demand per country is presented by tonnage and value, in addition to demand per application estimates.

In Chapter 4, an analysis of the current status of the global supply chain for the production of rare earth oxides is discussed. The historical prices and recent price trends for a select number of rare earth elements are presented in Chapter 5.

Canada is not a major consumer of rare earth oxides but as a major industrial nation, it imports industrial components and devices that are used in the manufacturing sector, as such, Chapter 6 presents a general review of the import market of rare earth products in Canada and Québec.

Chapters 7 and 8 introduce and compare the most advanced projects in Québec with those elsewhere in Canada and abroad.

The Conclusions and Recommendations section highlights the main findings of the report and lists several recommendations related to the development of rare earth projects and the supply chain in Québec.

1. Introduction

Rare earths are the family of lanthanides (Exhibit 1.1) that are found at the bottom of the periodic table. The rare earths are usually sub-divided into two groups: light rare earth elements (LREE) and heavy rare earth elements (HREE). In this report, LREE includes the elements from lanthanum to samarium and HREE comprise the remaining elements from europium to lutetium and yttrium. Scandium's properties are not similar enough to group as either LREE or HREE.

Exhibit 1.1: Rare earth elements

Name	Atomic Number	Symbol
Lanthanum	57	La
Cerium	58	Ce
Praseodymium	59	Pr
Neodymium	60	Nd
Promethium	61	Pm
Samarium	62	Sm
Europium	63	Eu
Gadolinium	64	Gd
Terbium	65	Tb
Dysprosium	66	Dy
Holmium	67	Ho
Erbium	68	Er
Thulium	69	Tm
Ytterbium	70	Yb
Lutetium	71	Lu
Yttrium	39	Y
Scandium	21	Sc

Source: Periodictable.com

Rare earths are essential elements for many of the technologies that we depend on today, e.g., they are used to make glass, magnets for electric motors, speakers, generators, alloys, refinery and emissions control catalysts, light emitting diodes (LEDs), ceramics, and in military applications, such as missile guidance systems and night vision goggles.

China controls about 85% of the global supply of refined rare earths. The country is fortunate to have the largest (34%) reserves in the world and owns some of the most economically extractable resources currently known. Other countries like the United States, South Africa, and Brazil were significant producers of rare earths in the past; however, increasing regulations, environmental concerns, and pressures from China's low-cost producers changed the supply landscape of rare earths, positioning China as the largest producer. Over the years as rare earth production in China continued to increase, overcapacity caused prices to collapse, making it difficult for companies outside of China to compete.

Claiming environmental concerns and the need to control domestic rare earth output, China first implemented export quotas in 1999. However, the export quotas were discontinued in 2015 as recommended by the World Trade Organization (WTO) after complaints from Europe, Japan, and the United States over China's unfair rare earth trading practices. In turn, China used domestic production quotas to control the market supply. China's policy actions are not only meant to protect the environment but they are also aimed at controlling the rare earth sector given its importance to China's economy and jobs. The global REO (rare earth oxide) production industry is relatively small, estimated at about US$1.6 to US$1.9 billion; however, the industries relying on these materials (e.g., automotive, mobile devices, medical devices) are much larger, worth hundreds of billions of dollars.

In 2010, the dispute between China and Japan over the Senkaku Islands raised concerns that China was going to stop exports of rare earths to Japan, which generated a huge panic causing prices to skyrocket to unsustainable levels. More recently, conflicts between China and the United States again brought the risk that China could use rare earths to leverage its trading relationship with the United States.

Given the importance of rare earths to many industries and defense, Japan, Europe and the United States have implemented incentives, policies and programs to support the production of rare earths outside of China. The proposed green agenda by the world's leading economies will bring additional demand for rare earths, particularly the adoption of EVs. This new demand will put a strain on China's capacity to supply rare earths to the world and open opportunities for existing rare earth projects to reach production. Québec has several advanced rare earth projects that with support could potentially become important sources of rare earths to regional and global markets.

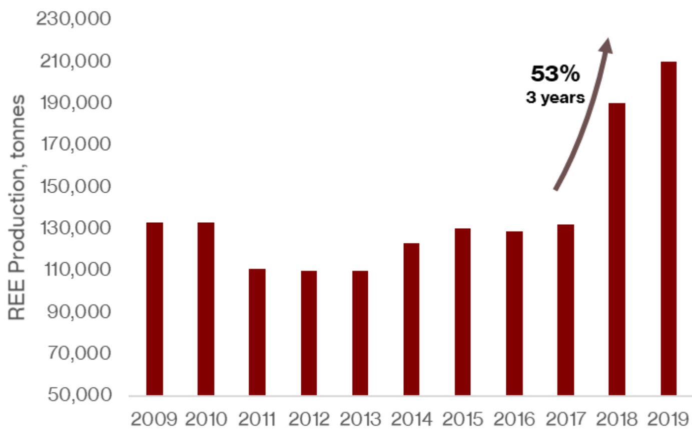
2. Global Production

2.1 Top Producing Countries

Mining Production

Rare earth mining production at the beginning of this decade was completely controlled by China. Global production in 2009 was estimated at around 120,000 to 125,000 tonnes, and China accounted for about 97% of all production. Rare earth production has steadily increased in the last six years, spurred by demand for rare earths in various sectors of the global economy, e.g., automotive, mobile devices, etc.

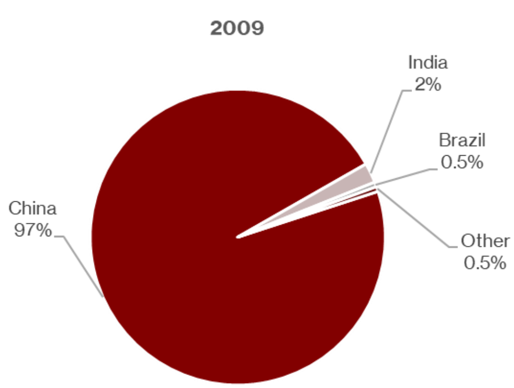
Exhibit 2.1: Rare earth production per year



Source: USGS

Production outside of China has also increased in the last 10 years, motivated in part by fears that China may use its control of rare earth production for political gain.

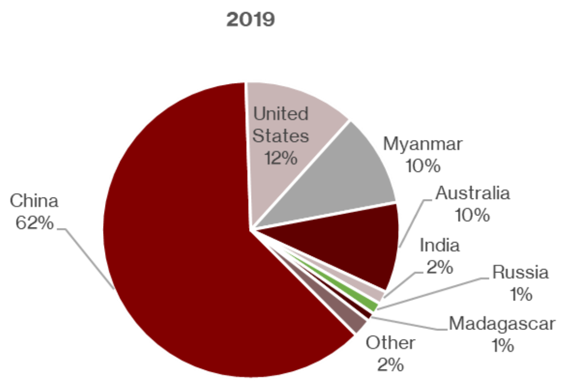
Exhibit 2.2: Global rare earth mine production, 2009



Source: USGS; Tahuti Global

The incident in 2010 between China and Japan over the Senkaku Islands that led to rumours that China was going to cut supplies of rare earths to Japan, was taken seriously by Japan and the Western countries. There are over 400 rare earth concessions around the world and following the Senkaku Islands incident, dozens of companies were able to raise funds in the stock market to develop rare earth exploration projects. As a result, Lynas Corporation, Ltd., mainly supported by Japanese companies, was able to reach commercial mine production. Lynas' Mount Weld mine in Australia has a capacity of 20,000 tonnes TREO (Total Rare Earth Oxides) per year. The Mountain Pass mine in California (United States), which had been a small producer of rare earths (3,000 tonnes), was taken over by Molycorp Inc. and expanded to 20,000 tonnes. Unfortunately, Molycorp, which filed for bankruptcy[2] in 2015, had failed to bring the newly expanded separation facility into production. Myanmar has also emerged as a major producer of rare earths in the last five years, reporting 22,000 tonnes of total rare earth production in 2019. Several ion adsorption clay-type deposits have been discovered in the Kachin State in northern Myanmar near the Chinese border, and are reportedly operated by Chinese companies[3]. The estimated global mine production is currently 210,000 tonnes, with the illegal unreported production of rare earths in China and Myanmar estimated at around 20,000 to 30,000 tonnes a year.

Exhibit 2.3: Global rare earth mine production, 2019



Source: USGS; Tahuti Global

The major rare earth companies in the world are in China and include Inner Mongolia Baotou Steel Rare Earth HiTech, Xiamen Tungsten Co. Ltd., China Minmetals Corp., Aluminum Corp. of China, Ganzhou Rare Earth Group Co. Ltd., China National Nonferrous Metals Industry, and Guangzhou Corp. Outside of China, the largest miners of rare earths include Mountain Pass Materials, Myanmar Ye Huang Mining, and Lynas Corporation.

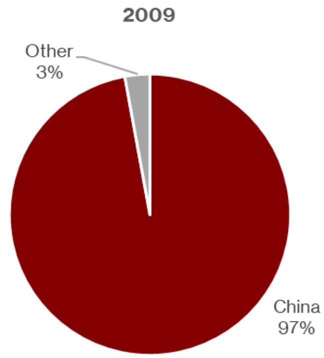
Refinery Production

In 2009, China accounted for at least 97% of the global refinery production, with the remaining production coming from Estonia where the Silmet plant has a capacity of 3,000 tonnes total rare earths, as well as from small operations and recycling, mostly in Asia and Europe.

[2] https://www.wsj.com/articles/this-article-also-appears-in-daily-bankruptcy-review-a-publication-from-dow-jones-co-1435219007

[3] https://elevenmyanmar.com/news/rare-earth-illegally-dug-in-panwar-kachin-mining-department

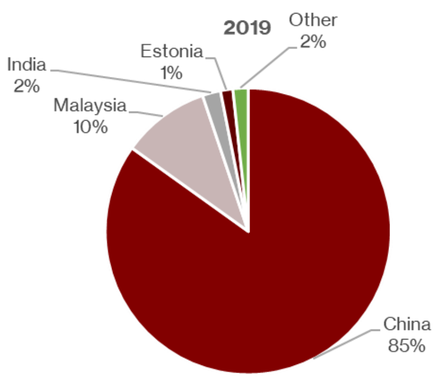
Exhibit 2.4: Global rare earth refining production, 2009



Source: Tahuti Global

Processing of rare earths has increased outside China, but the country still accounts for most of the production, which is estimated at 85% of global output. The only other nations to have sizeable processing operations are Malaysia (from Lynas), India (from IREL (India) Limited (formerly Indian Rare Earths Limited) and Toyota Tsusho Corporation), and Estonia (from Neo Performance Materials (NPM) Silmet). China currently mines over 130,000 tonnes of rare earths but imports more than 50,000 from other nations, such as the United States, Myanmar, Vietnam and Laos, with small amounts from Malaysia, specifically the SEG[4] stream from the separation facility that contains samarium, europium and gadolinium, and the heavy rare earths.

Exhibit 2.5: Global rare earth refining production, 2019



Source: Tahuti Global

The import of unprocessed rare earths is an ideal situation for China because it is able to preserve the domestic mineral resources, while still utilizing the country's rare earth processing capacity. Thus, guaranteeing sufficient domestic supply for dependent industries, and keeping jobs in the sector.

[4] SEG = samarium, europium and gadolinium

Metal Making

The production of rare earth metals is mostly performed in China, and it is estimated that over 88% of all metal production is controlled by China, with the remaining amounts from other operations in Asia (e.g., Vietnam, Thailand and India), and from recycling.

Chapter 4 presents a discussion on the supply chain, highlighting the participation of China and other nations along the supply chain.

2.2 Market Analysis per Element

Most of the rare earth mines currently in operation produce mostly LREE (i.e., La, Ce, Pr, Nd). These mines also have the highest annual production, as such, the global volume of rare earths is skewed towards LREE.

The rare earth distribution (from La to Y, excluding Sc) of the main global producing mines was used to estimate the share of the market for each element (Exhibit 2.6).

The additional production from Myanmar has brought more HREE to the market. The HREE with the highest demand and natural ore concentration are yttrium, dysprosium and terbium; most of the other HREE are only refined in small amounts, often to less than 1,000 tonnes per year, and although their prices are usually high their share of the market value is small. It is estimated that they account for about 5% of the total market value. The average 2019 prices were used to estimate the market value per element (Exhibit 5.1).

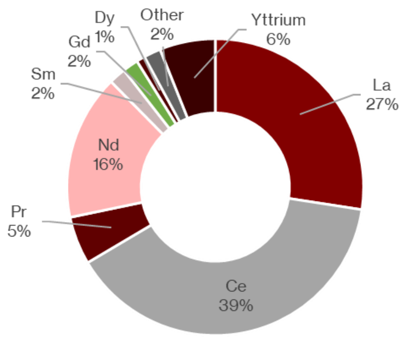
Exhibit 2.6: Select REE deposits and their production

Deposit Location	Production	Distribution
Bayan Obo	50,000	Light
Sichuan	30,000	Light
Shandong	1,500	Light
Guangxi	2,500	Light
Hunan	2,000	Light
Mount Weld	20,000	Light
Manavalakurichi	4,000	Light
Lovozero	3,600	Light
Ganzhou	9,000	Heavy
Fujian	2,000	Heavy
Guangdong	2,200	Heavy
Mountain Pass	26,000	Light
Panwar, Kachin State	22,000	Heavy

Source: Tahuti Global

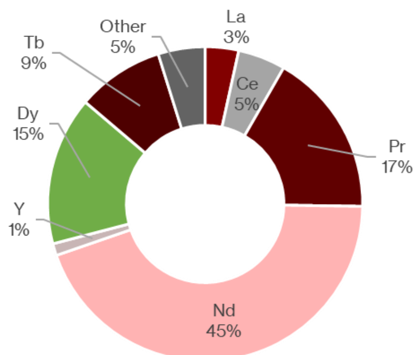
The results of the market analysis indicate that the elements used in magnets (Nd, Pr, Dy, and Tb) represent 86% of the market value. In contrast, lanthanum and cerium, which represent more than 60% of total output, only account for about 8% of the market value. As the rare earths used in magnets account for most of the market value, junior mining companies tend to focus on these elements for the economic assessment of their mineral assets. Moreover, in light deposits, Nd and Pr usually account for 12% to 25%, the highest percentage after La and Ce, and are less costly to extract compared to heavy elements. In deposits with a high percentage of heavy rare earths, yttrium occurs at higher concentrations of all the elements but has a lower price (see Chapter 5).

Exhibit 2.7: Share of market volume per element, 2019



Source: Tahuti Global

Exhibit 2.8: Share of market value per element, 2019

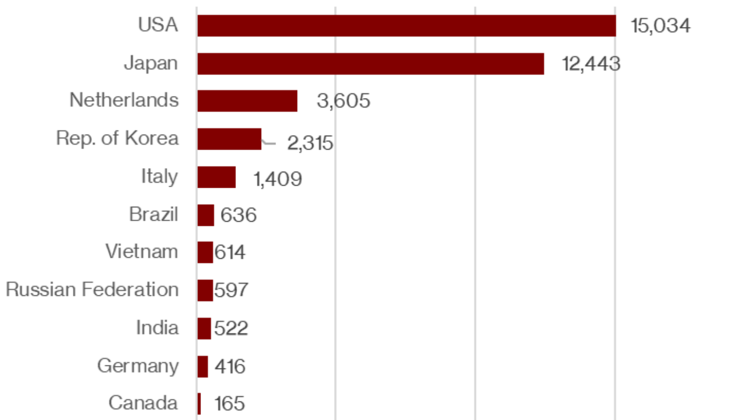


Source: Tahuti Global, 2019 average prices were used

3. Global Demand

Total demand for rare earths in 2019 is estimated at around 200,000 to 235,000 tonnes (US$1.6 to US$1.9 billion). China produces about 85% of total volume of processed/refined rare earths and consumes about 77%. China is also the largest exporter, and in 2019 exported 40,000 tonnes (excluding illegal amounts) of rare earth compounds worth US$324 million; most of the volume went to the United States, Japan and Europe (Exhibit 3.1), the top three consumers of rare earths, after China.

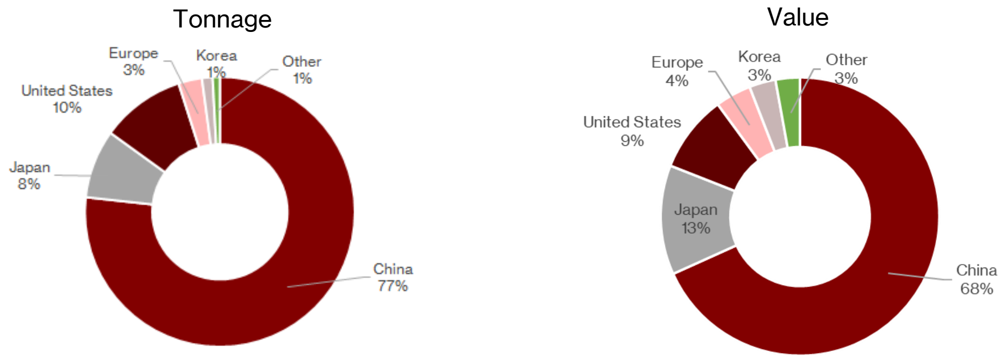
Exhibit 3.1: Top Chinese rare earth export destinations in 2019, in tonnes



Source: Tahuti Global; UN Comtrade HS 2846

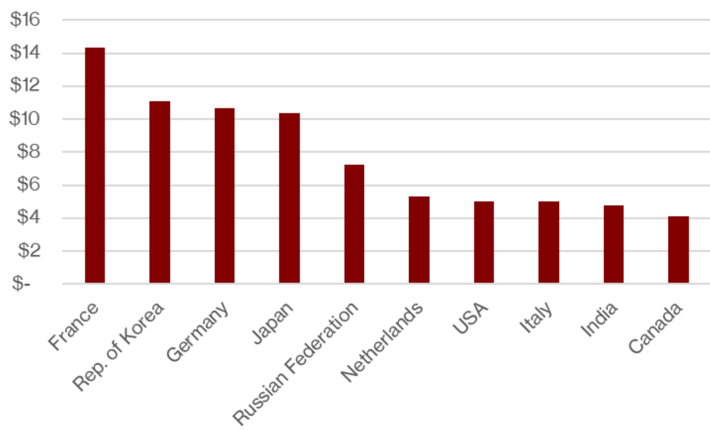
Exhibit 3.2 shows rare earths demand per country. The United States is the second-largest consumer of rare earths accounting for 10% of the total demand volume, followed by Japan (8%) and Europe (3%). In terms of market demand in value, Japan is the second-largest market as it imports higher-value elements compared to the United States, as suggested by the analysis of trade values per tonne (Exhibit 3.3).

Exhibit 3.2: Rare earth share of demand per country, 2019



Source: Tahuti Global

Exhibit 3.3: Unit value of rare earth imports per country



Source: Tahuti Global

3.1 Demand per Application

Exhibit 3.4 shows the main applications for rare earths, which can be segmented as: magnets, phosphors, fluid cracking catalysts (FCC), polishing powders, auto catalysts, glass additives, and fibre optics.

Exhibit 3.4: Rare earth applications

Segment	Elements	Application
Magnets	Nd, Pr, Sm, Tb, Dy	Used to make permanent magnets that are used in motors for EVs, cell phones, cameras, portable music players, cordless powertools, wind turbines, medical devices, fin actuators used to guide missiles in mid-air, and for the detection and detonation of mines, etc.
Phosphors	Eu, Y, Tb, La, Dy, Ce, Pr, Gd	Used in LCDs, PDPs, LEDs, energy efficient lights/lamps/bulbs
Fluid Cracking Catalysts	La, Ce, Pr, Nd	Rare earth oxides enhance catalyst activity and prevent the loss of acid during the FCC unit operation
Polishing Powders	Ce, La, Nd	Used in TVs, monitors, mirrors and silicon chips
Auto Catalysts	Ce, La, Nd	Used in catalytic converters for emissions control
Glass Additive	Ce, La, Nd, Er	Used for digital camera lenses; e.g. cerium reduces UV light
Fibre Optics	Er, Y, Tb, Eu	Used to increase the signal

Source: Tahuti Global

To estimate the volume of rare earths per application, assumptions were made as to the proportion of elements used per application (Exhibit 3.5), which was used together with the estimated volume production of each element (Exhibit 2.8). The results show that the magnet segment attracts the highest volume of rare earth elements (22%), principally neodymium and praseodymium, but also most of the dysprosium, terbium, and samarium produced.

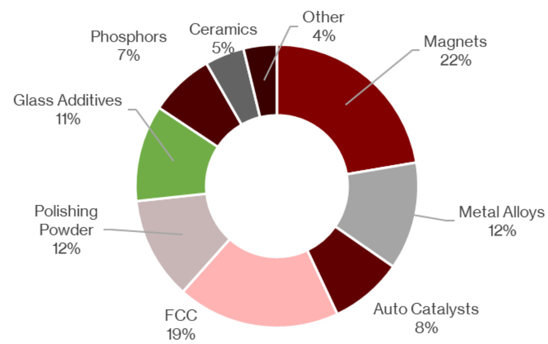
Exhibit 3.5: Element usage per application assumptions

	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Y
Magnets	1%	1%	88%	80%	93%		90%	90%	99%	
Metal Alloys	12%	20%	1%	7%	2%					
Auto Catalysts	2%	19%	1%	2%						
FCC	65%	2%								
Polishing Powder		30%								
Glass Additives	15%	15%	5%	5%						
Phosphors		3%		5%		99%	10%	7%		80%
Ceramics	5%	5%	5%							15%
Other		5%		1%	5%	1%		3%	1%	5%

Source: Tahuti Global

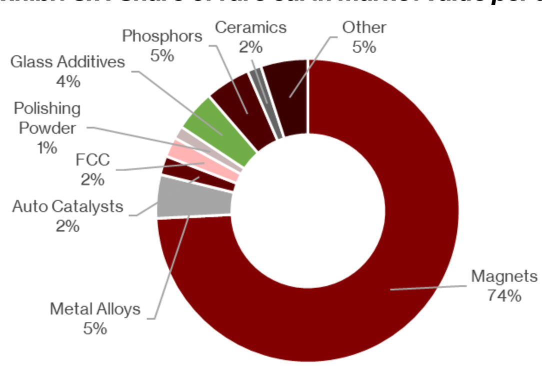
The FCC application where most of the lanthanum is used, is the second-largest segment by tonnage, accounting for 19% of all rare earth annual production. Cerium, the most common element, is used in a variety of applications but mostly in polishing, auto catalysts and alloys, which combined account for 35% of total tonnage.

Exhibit 3.6: Share of rare earth tonnage per application, 2019



Source: Tahuti Global

Exhibit 3.7: Share of rare earth market value per application, 2019



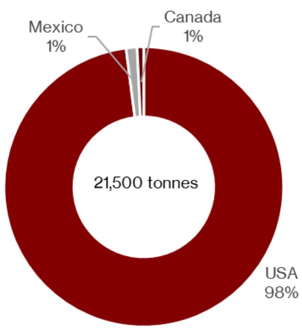
Source: Tahuti Global

In terms of market value, the magnet segment represents 75% of the rare earth market. The FCC and auto catalysts segments, which use mostly lanthanum and cerium, each represent only 2% of the market value. The phosphors and polishing powder have a higher share of the market value at 5% and 4%, respectively, as higher price elements are also used in those applications.

3.2 North American Demand

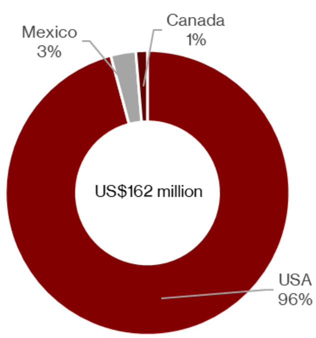
The United States is the largest consumer of rare earths in North America with over 95% of the market value for the region. As the United States no longer has the ability to produce separated rare earth compounds, all of the processed rare earths consumed in the region have to be imported. In 2019, the United States imported about 21,000 tonnes of rare earths valued at circa US$155 million. Canada and Mexico combined imported about 500 tonnes. Approximately 30% to 40% of the rare earths imported by Canada and Mexico come directly from China, with the remaining coming indirectly from the United States and Europe.

Exhibit 3.8: Share of rare earth tonnage demand in North America, 2019



Source: UN Comtrade, Tahuti Global

Exhibit 3.9: North American share of demand value per country, 2019

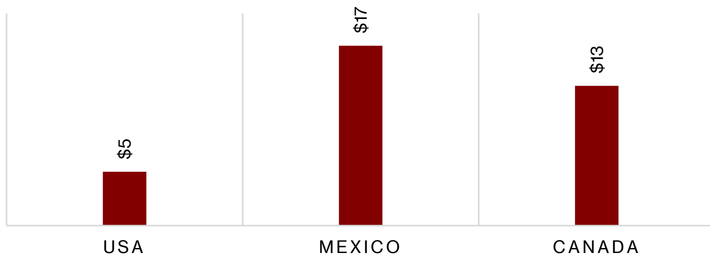


Source: UN Comtrade

The rare earth materials exported from the United States to neighbouring countries carry higher unit prices when compared to the materials received from China. It is possible that the rare earth compounds exported from the United States to neighbouring countries may have been further processed/modified for specific applications[5] (e.g., import lanthanum oxide and process it into lanthanum chloride for use in FCCs and water treatment).

[5] http://finoric.com/LanthanumChloride.htm

Exhibit 3.10: Average rare earth import value per tonne in North America



Source: Tahuti Global, 2019

4. Supply Chain

The production stages for rare earths include mining, beneficiation or mineral upgrade, cracking, separation, and in some cases further refining, metal making and alloying. After mining, the ore is usually beneficiated or upgraded using physical separation techniques, such as magnetic separation, ore sorting, and/or floatation to produce a mineral concentrate, which usually needs to be at least 30% total rare earths to make a project economic. The exception is ion adsorption clays that are mined and cracked on site, and no mineral concentrate is produced. Cracking refers to the process of extracting the rare earths from the rock to produce a mixed chemical compound with all the rare earths. This chemical compound is then further processed to separate the rare earth elements into subgroups or individual oxides.

Exhibit 4.1 depicts the current status of the rare earth supply chain, which suggests that most operations that are able to mine and successfully produce a mineral concentrate can also produce a mineral chemical concentrate within country; the exception is the Mountain Pass operations in the United States where the operator MP Materials Corporation exports the mineral concentrate to China for processing. The company has recently listed its shares on the New York stock market and will be looking for funding to restart its hydrometallurgy plant.

Exhibit 4.1: Countries' participation along the supply chain, 2019

Supply Chain →

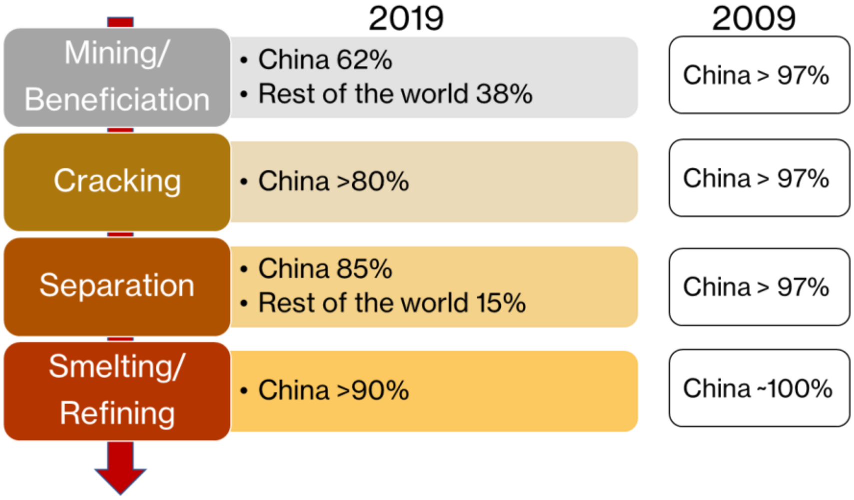
		Stages	**Mining and Mineral Upgrade**	**Cracking**	**Separation**
Production	Country	Product	*Ore Concentrate*	*Mixed Chemical Con.*	*Separate Oxides*
132,000	China		China	China	China
26,000	United States		United States	China	China
22,000	Myanmar		Myanmar	Myanmar, China	China
21,000	Australia		Australia	Malaysia	Malaysia, China
3,000	India		India	India	India
2,700	Russia		Russia	Estonia	Estonia
2,000	Madagascar		Madagascar	China	China
1,800	Thailand		Thailand	Thailand	Thailand
1,000	Brazil		Brazil	Brazil	Brazil
900	Vietnam		Vietnam	Vietnam	Vietnam
600	Burundi		Burundi	China	China

Source: Tahuti Global, USGS

China has been the main supplier of rare earths to the global markets for over three decades, but some progress has been made in the last 10 years to decrease the world's dependency on China's supply, particularly in mining output. Ten years ago, more than 97% of the rare earth mining operations were in China; today this number has fallen to about 62%, with new mining operations in Australia, the United States, India, and other Asian countries like Myanmar, Vietnam, etc. However, China still accounts for 85% of the production of the finished products. One major rare earth separation plant outside of China is the one owned by Lynas in Malaysia, although it should be noted that the heavy rare earth stream from Lynas' operation is sold to Chinese processors for separation.

Metal making capacity also resides mostly in China, although both Japanese and Chinese companies have invested in metal making capacity in Vietnam and Thailand, and there are also metal making capabilities in Japan and India. The alloy company Less Common Metals Ltd. in Europe has received government support to develop metal making capabilities. The European Union (EU) is also funding several universities and research centres. In the United States, Infinium Metals has received federal government support towards its efforts to produce rare earth metals.

Exhibit 4.2: China's share of the supply chain in 2019 compared to 2009

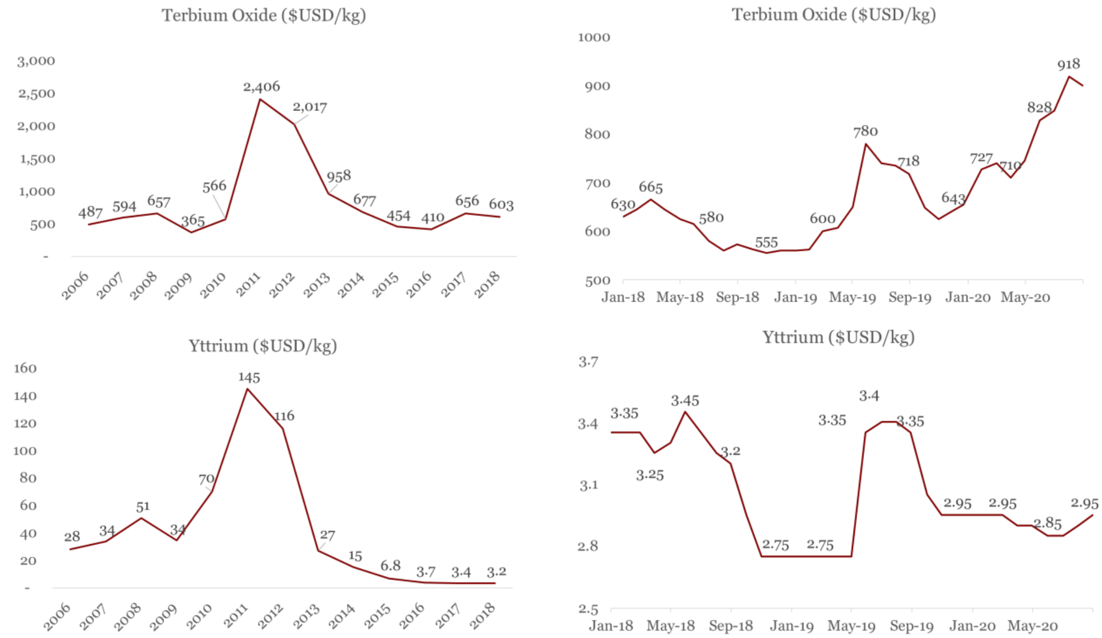


Source: Tahuti Global, USGS

5. Price Trends

The following exhibits show the prices of several rare earth elements over a period of 14 years. The figures on the right highlight price trends between January 2018 and September 2020.

Exhibit 5.1: Rare earth prices



Source: Asian Metals

The 14-year historical data shows that the prices of all rare earths have fallen after the bubble period of panic over potential Chinese production and export restrictions. Although China did implement changes to restrict illegal production and exports, prices still fell as new mining operations outside China led to increased rare earth supply.

Some elements, like lanthanum and cerium that occur at high concentrations in light deposits, reverted to their historical prices. Neodymium, praseodymium and dysprosium, which are used in magnets, appear to be trending somewhat above their pre-bubble historical prices. In contrast, yttrium, which is used in phosphors applications, has been trading between US$2 and US$5 per kilogram, which is significantly below its pre-bubble price (~US$30/kg), likely because of substitution (because of the 2011 bubble prices) and an increase in supply from yttrium-rich mines in Myanmar.

The coronavirus crisis that is affecting the world economy has disrupted mining and processing operations in many locations, including China. Many of the industries that use rare earths have also halted operations, thus reducing demand for rare earths. As such, rare earth prices of many of the elements have fallen in 2020. It should be noted, however, that for some elements, prices were already in a downward trend from 2018, due to weakening demand.

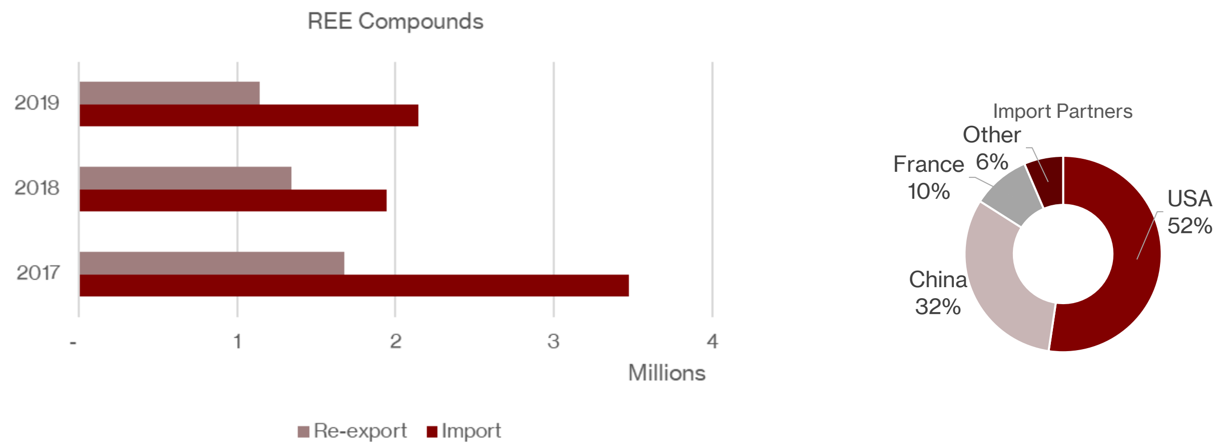
Going forward, if demand for EVs and wind turbine installations continues to increase the demand for permanent magnet materials is likely to stay strong as well, which should keep prices of neodymium, praseodymium, dysprosium and terbium at current levels, or higher if supplies fall short.

Prices of lanthanum and cerium are likely to stay at current levels (US$1.5/kg to US$2.5/kg) in the foreseeable future, particularly if demand for magnet elements grows faster than demand for other elements, leading to an oversupply of elements that occur at high concentrations like cerium and yttrium.

6. REE Market in Canada and Québec

Canada is a relatively small consumer of rare earth oxides, with less than 200 tonnes of rare earth compounds imported in 2019, valued at US$2.1 million, and US$1.4 million worth of rare earth metals. In 2019, most of the rare earth materials were imported from the United States, followed by China and Europe. When the Mountain Pass rare earth mine and processing facilities were in operation, most of the rare earth compounds were sourced from the United States. However, as there is currently no production of rare earth compounds in the United States, the imports from the United States are likely re-exports, i.e., rare earth materials that were imported into the United States and then exported to Canada. Likewise, Canada's exports of rare earth materials are re-exports, as there is no production of rare earths in Canada. The United States is the main destination for the re-exported rare earths from Canada.

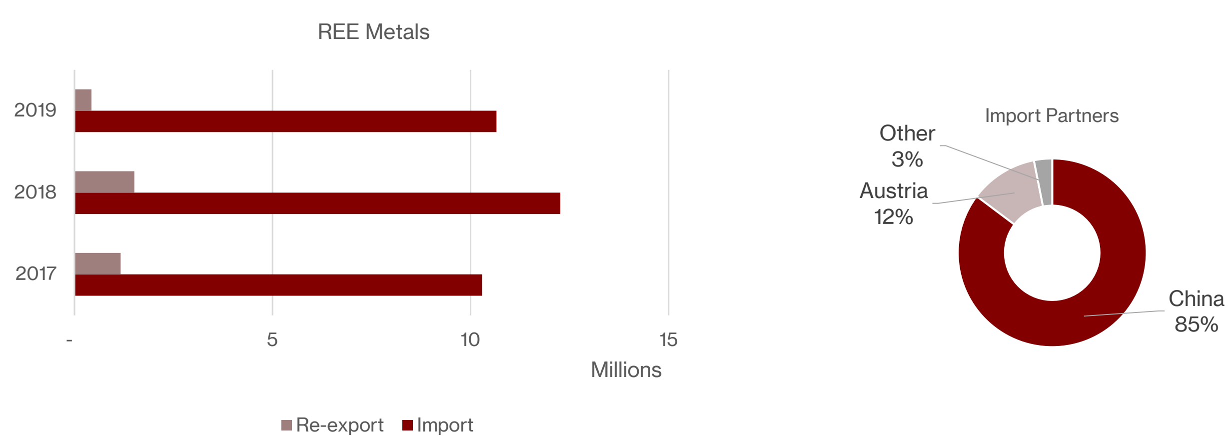
Exhibit 6.1: Canada's re-exports and imports of REE compounds, and import partners



Source: UN Comtrade HS 2805

Almost all of the rare earth metals imported into Canada come from China, and those coming from Europe are likely re-exports as there is no significant metal production outside of Asia.

Exhibit 6.2: Canada's re-exports and imports of REE metals, and import partners



Source: UN Comtrade HS 2805.30

Exhibit 6.3 highlights the companies in Canada that imported rare earth compounds in 2019. Collectively they account for about 80% of all imports. The list includes trading companies that are not the end-users of the products but may be the largest importers. It is likely that Québec's end-users were not included in the table but may purchase rare earth compounds indirectly from trading houses.

Exhibit 6.3: Canada's top importers of rare earth compounds and metals, 2019

Company Name	Province
BTG International Canada Inc.	Ontario
HEFA Rare Earth Canada Co. Ltd.	British Columbia
Indexable Cutting Tools of Canada Limited	Ontario
Kinectrics Inc.	Ontario
Ledvance Ltd.	Ontario
Nordion Canada Inc.	Ontario
Raytheon Canada Limited	Ontario

Source: CID; Note: The importer is not necessarily the end-user of the product.

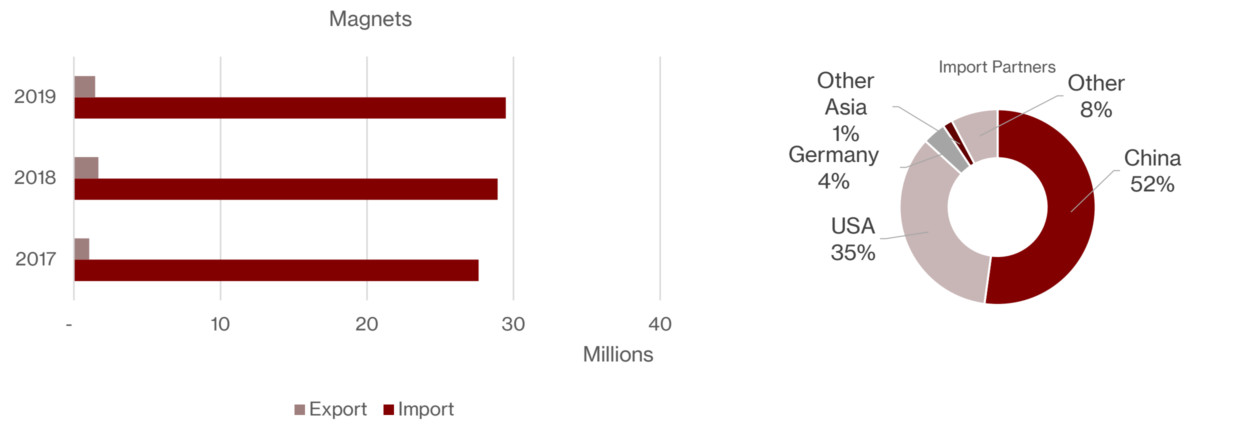
As a major industrial nation, Canada is the world's fifth-largest oil producer and has the world's third-largest proven oil reserves[6], is ranked 12th in passenger vehicle production, and has a vibrant aerospace manufacturing sector. As such, Canada consumes tonnes of rare earths imbedded in various imported products, including LED lights, catalysts, automotive parts, alloys, and magnets, among others. The potential production of rare earth materials in Québec could support the development of supply chains for many of these components and devices that rely on rare earths, to reduce Canada's reliance on imports of some of these products and/or for exports. A closer look at the trading trends of key products that use rare earths (e.g., permanent magnets, LEDs and catalysts) shows the market potential for rare earths in Canada.

Permanent Magnets

There are different types of magnets (i.e., temporary, permanent, and electromagnetic), and rare earths are used to make permanent magnets. The neodymium iron boron (NdFeB) permanent magnets, are the strongest type of permanent magnets commercially available. Canada produces various types of magnets but has to import those containing rare earths. Permanent magnets are used in motors for EVs, televisions, mobile devices, computers, audio systems, etc. In 2019, Canada imported US$29.5 million in permanent magnets (including non-rare earth magnets) and exported US$1.4 million.

[6] https://www.nrcan.gc.ca/our-natural-resources/energy-sources-distribution/clean-fossil-fuels/crude-oil-industry-overview/18078

Exhibit 6.4: Canada's imports/exports of permanent magnets



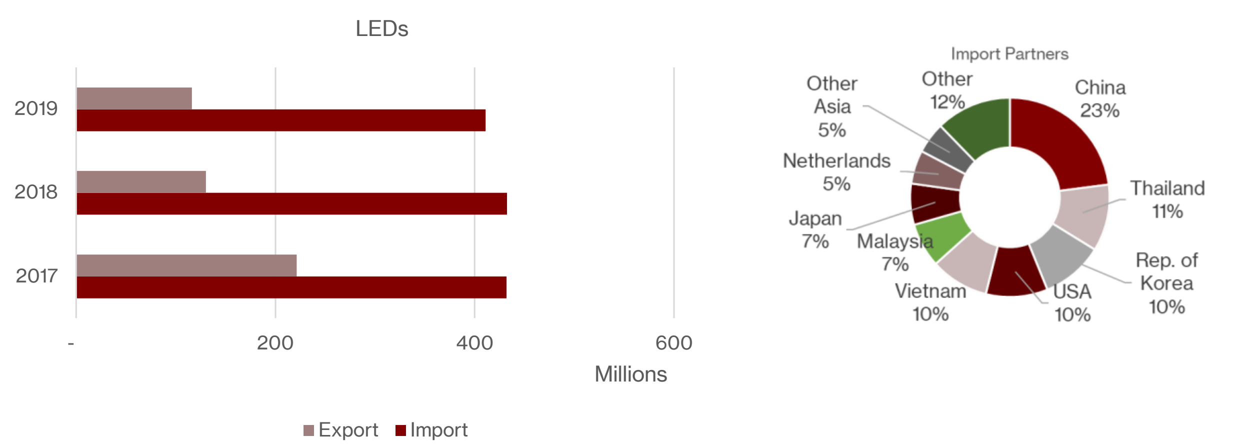
Source: UN Comtrade HS 8505.11

In 2019, nearly 300 companies reported importing permanent magnets into Canada, with 68 located in Québec (see Appendix). To determine the main applications for rare earth magnets in Canada and Québec a survey will have to be conducted. Imports from China accounted for 52% of the total import value of permanent magnets. As China is the largest producer of rare earth metals and derived products, and there is no rare earth metal or rare earth magnet production in the United States, it is likely that most of the permanent magnets that contain rare earths come directly from China, or indirectly via the United States.

Light Emitting Diode (LED)

An LED is a semiconductor device that emits light by electroluminescence. LEDs can be found in mobile devices, home and industrial lighting, all types of vehicles, streetlights, etc. The advantages of LEDs over traditional incandescent and fluorescent lamps include low power consumption, small size, and long life. Nearly 70 companies located in Canada reported importing LEDs, with 28 located in Québec (see Appendix). Canada is a net importer of LEDs and in 2019 imported $411 million worth of LEDs, mainly from Asian countries. China was again the largest import partner (23%), followed by Thailand (11%) and South Korea (10%). Export value in 2019 was $116 million, with most going to the United States (60% of total export value).

Exhibit 6.5: Canada's imports/exports of LEDs

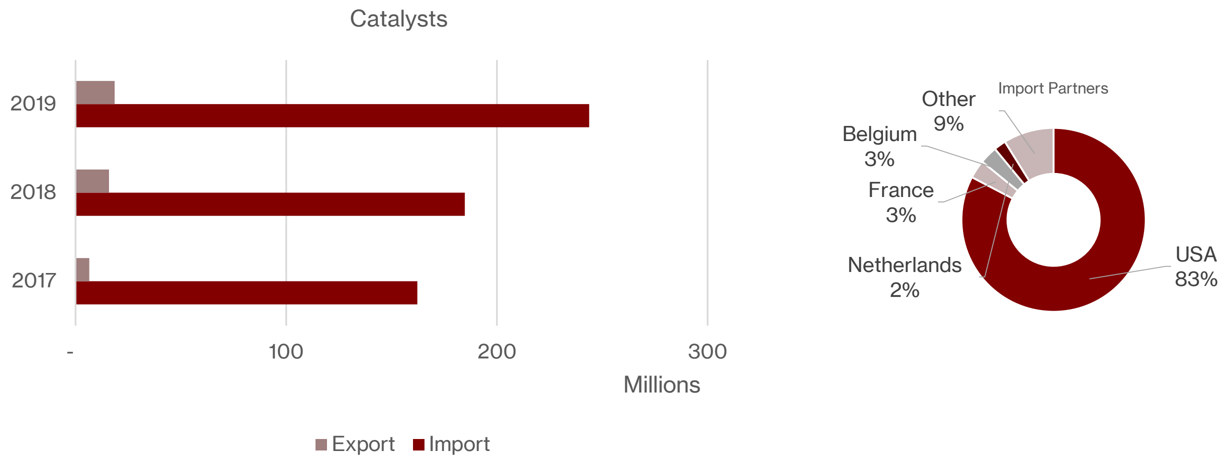


Source: UN Comtrade HS 8541.40

Catalysts

Catalysts are materials that speed up chemical reactions that would otherwise take longer (reactions could happen in seconds instead of months or years). Rare earths are used in different types of catalytic products, including fluid catalytic cracking (FCC) catalysts for petroleum refining and in catalytic converters (CC) for emissions control. Exhibit 6.6 shows imports and exports of catalysts without nickel or precious metals (HS 3815.19), which include FCCs. In 2019, Canada's imports amounted to US$244 million with most coming from the United States (83%). The companies importing these catalysts include oil and gas companies Esso Chemical Canada, Shell Catalysts & Technologies Canada Inc., and Suncor Energy Oil Sands Limited Partnership. Canada exported only US$19 million worth of catalysts with most going to the United States (75% of export value).

Exhibit 6.6: Canada's exports/imports of catalysts



Source: UN Comtrade HS 3815.19

The list of Québec importers of permanent magnets, LEDs and catalysts is presented in the Appendix.

Target Markets

Canada's main trading partner is the United States, which was the destination of 75% of Canada's exports and the origin of 52% of all imports in 2019. The United States is the largest importer of rare earths from China (in tonnage) and it is likely a producer of some rare earth products like catalysts. Given Canada's relatively small population and economy compared to the United States, it makes economic sense for Canadian companies to venture south of the border to access the larger United States market. For instance, while Canada imported US$28 million worth of permanent magnets in 2019, the US import value of permanent magnets was US$393 million (Exhibit 6.7), more than ten times that of Canada. Canada also enjoys good trading relations with the UK and the European community, which are highly dependent on imports of rare earths.

If rare earth compounds were to be produced in Québec it would offer the province and Canada the opportunity to develop the supply chain of various products that depend on rare earths and have access to global downstream markets worth billions of dollars.

Exhibit 6.7: United States' import value of select products that contain rare earths

Source: Google images; Tahuti Global

7. Rare Earth Projects in Québec and Outside Québec

7.1 Projects in Québec and Canada

There are several areas in Québec where rare earths have been identified, but only six locations have been explored in detail. These locations include the Ashram deposit owned by Commerce Resources, the Strange Lake deposit currently owned by Torngat Metals, the Kipawa deposit owned by Québec Precious Metals, the Niobec REE deposit owned by Magris Resources, the Kwyjibo deposit owned by the Québec government and operated by SOQUEM, and the Montviel project owned by Geomega Resources.

Exhibit 7.1: Projects in Québec

Project Name	Stage	Resource	Capital Requirements Next Phase ($M)
Québec Projects			
Ashram, QC, Canada Commerce Resources www.commerceresources.com	PFS ongoing	M+I = 29.3 Mt at 1.89% TREO Inf = 219.8 Mt at 1.88% TREO	25-36
Montviel, QC (Canada) Geomega Resources Inc. www.geomega.ca	-	I = 82.4 Mt @ 1.51% TREO, 766 ppm Pr_2O_3, 2452 ppm Nd_2O_3, 52 ppm Eu_2O_3, 1,715 ppm Nb_2O_5 Inf = 184.2 Mt @ 1.43% TREO, 746 ppm, Pr_2O_3, 2,433 ppm Nd_2O_3, 47 ppm Eu_2O_3, 1,315 ppm Nb_2O_5	-
Strange Lake, QC (Canada) Torngat Metals Ltd. www.torngatmetals.com	New PEA Completed	I = 278.13 Mt @ 0.93% TREO Inf = 214.35 Mt @ 0.85% TREO	36-41
Kwyjibo, QC (Canada) SOQUEM www.soquem.qc.ca	PEA Completed	M = 2.41 Mt @ 2.84% TREO, 54.51% Fe_2O_3, 4.43% P_2O_5 I = 4.51 Mt @ 2.67% TREO, 52.38% Fe_2O_3, 4.44% P_2O_5	30-45
Niobec, QC (Canada) Magris Resources Inc. www.magrisresources.ca	-	Inf =467 Mt @ 1.65% TREO	-
Kipawa, QC Canada Québec Precious Metals (68%) Investment Québec Inc. (32%) www.qpmcorp.ca	-	Historical Resource M+I = 52.6 Mt @ 2.33% TREO Inf = 17.2 Mt @ 0.131% TREO	-

Source: Tahuti Global; DFS = definitive feasibility study; PEA = preliminary economic assessment; M = measured, I = indicated, inf = inferred; Mt = million of tonnes

Ashram

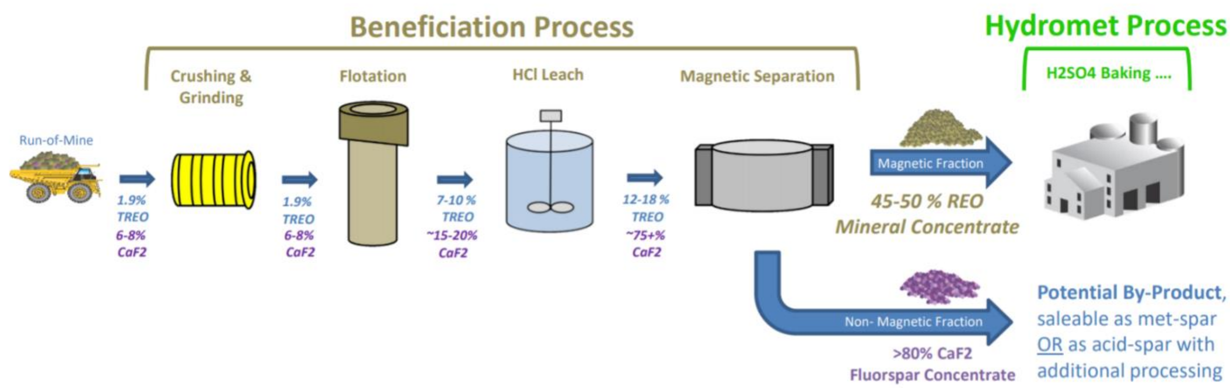
Project Status: **Advanced Exploration**

The Ashram deposit is located in the Nunavik Region of the Province of Québec, approximately 130 km south of the community of Kuujjuaq, and can only be accessed by float or ski-equipped airplane, helicopter, or snowmobile during the winter months. Ashram is owned by Commerce Resources and is being developed for the extraction of rare earth elements and fluorspar. Fluorspar has been included in the list of critical materials by the European Community and the United States; it is used in the production of steel, aluminum, hydrofluorocarbons, Teflon, among other uses, and China is the largest producer. The sale of fluorspar could potentially improve the economics of the Ashram project.

Commerce Resources completed the PEA for the Ashram deposit in 2015 and is currently working on the pre-feasibility study (PFS) that is expected to include fluorspar by-product. Current mineral resources amount to 1.59 million tonnes of measured resources averaging 1.77% TREO, 27.67 million tonnes of indicated resources averaging 1.90% TREO. and 219.8 million tonnes of inferred resources averaging 1.88% TREO.

An important aspect of the project is that a 45% TREO mineral concentrate has been successfully produced. However, as shown in Exhibit 7.2 the flowsheet a hydrometallurgical step is included to bring the mineral concentrate from 7-10% TREO to 45% TREO. The leaching stage is an added cost that puts the Ashram deposit at a disadvantage relative to other monazite deposits already in operation.

Exhibit 7.2: Ashram flowsheet



Source: Commerce Resources

High mineral concentrate using floatation only (with no pre-leach) has been achieved[7], but the recovery rates were relatively low (between 50% and 60%). More tests will be required to produce a high-grade mineral concentrate for Ashram using floatation only.

The Ashram deposit with monazite may be perceived as having the least processing risk in Québec; however, the project is located in a remote area in northern Québec. The ongoing PFS estimates that the project will require a 180 km road with estimated capital costs in the range of $155 to $195 million.

Strange Lake

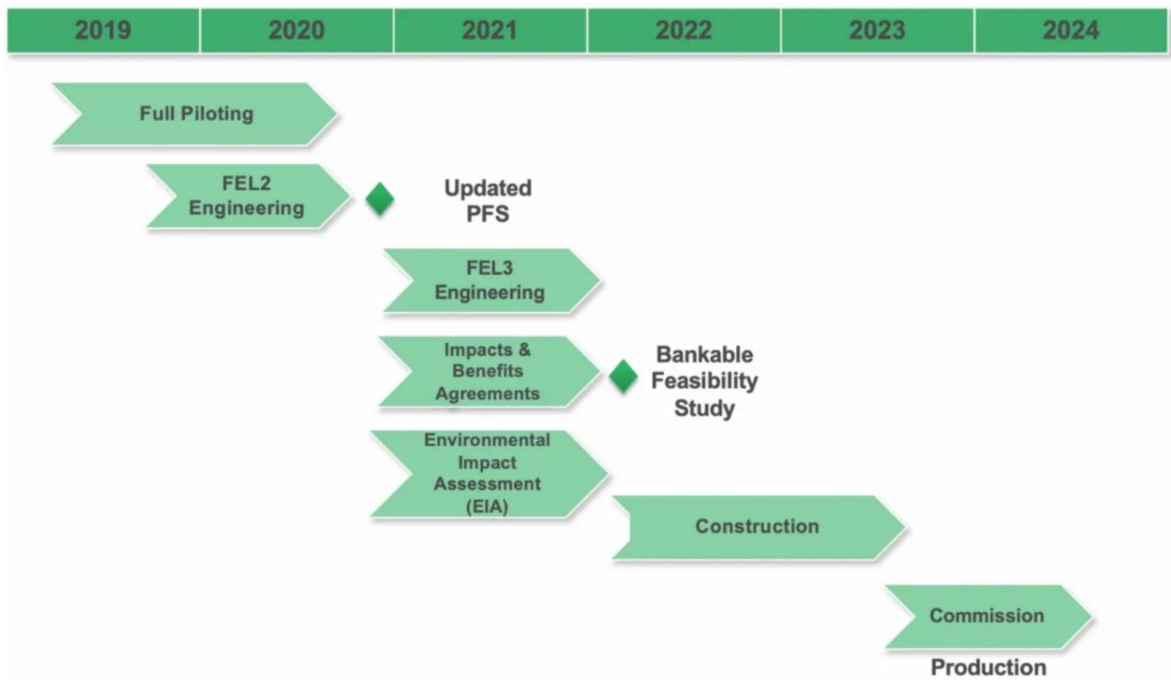
Project Status: **Ongoing**

The Strange Lake deposit is located in northern Québec; the closest town to the site is Naian, about 125 km to the east, on the coast of Labrador. The town has a port and is the trade centre for the nickel-copper mine of Vale SA at Voisey's Bay. The project is currently owned by Torngat Metals Ltd., a private company. The previous owner, Quest Rare Minerals Ltd., advanced the project to the pre-feasibility stage but it was not able to secure financing to scale up metallurgical testwork and complete a feasibility study; it filed for bankruptcy in July 2017.

[7] https://www.commerceresources.com/en/news/commerce-resources-corp-produces-40-treo-mineral-concentrate-from-the-ashram-rare-earth-element-deposit-northern-quebec

Torngat Metals claims to be taking a different approach to the development of Strange Lake. The company completed a new PEA in December 2019 and is working on a new PFS for Strange Lake that is expected to be completed in 2021. The company claims to have developed and patented a cost-competitive process for the production of separated rare earth oxides using currently available technologies. Full-scale piloting of the entire process is apparently underway to support engineering and to have a bankable feasibility study completed by 2022. The company claims that the test work is being conducted by world-leading technology and engineering companies (in Finland/Germany, France and Canada), that after piloting, will "guarantee" the commercial plant's operating performance.

Exhibit 7.3: Strange Lake development schedule



Source: Torngat Metals

Torngat expects the project to reach production in 2024 with 11,150 tonnes of separated rare earth oxides.

One of the major challenges of the Strange Lake project is the remoteness of the deposit, with access available only by foot or air. The estimated initial capital costs for the construction of a port and a 170 km road connecting the mine and concentrated facility to the port has been estimated at almost $300 million. Torngat is strongly considering using Lockheed Martin's Hybrid Airships that are designed to facilitate low-cost air access to locations with limited infrastructure. The hybrid airships would be used to transport ore concentrate from Strange Lake to a railway hub in Schefferville and then by train to Sept-Îles and then by boat or truck to the future processing plant at Bécancour Industrial park near the waterfront of the St. Lawrence River. It should be noted however that the airships are still in the prototype stage and it is not clear when (if ever) they will be available.

The mineral concentrate is expected to be 15% TREO, which is relatively low when compared to the mineral concentrate from rare earth deposits currently in production. The bankable feasibility study will estimate the costs of transporting the relatively low-grade mineral concentrate from Strange Lake to Bécancour and the cost of hydrometallurgy to produce the mixed carbonate product for the separation plant, to determine whether the airships are a viable option for the project.

Kipawa

Project Status: **Inactive**

The Kipawa deposit is located 50 km east of the town of Témiscamingue in the Province of Québec and is owned by Québec Precious Metals (68%) and Investissement Québec (32%). Toyota Tsusho Corp. holds a 10% royalty on net profit in the Kipawa deposit.

As reported in the 2013 feasibility study, total rare earth reserves at Kipawa amounted to 10.2 million tonnes at 0.44% TREO proven and 9.6 million tonnes at 0.38% TREO probable. Heavy rare earths (including yttrium) make up 63% of total rare earths, with yttrium comprising 37% of the heavy elements and 23% of the total rare earths.

Previous exploration work by Matamec Exploration Inc. estimated that 90% of the total rare earth elements occur in two minerals: eudialyte and mosandrite, with the eudialyte zone containing 70% of the deposit's TREO. The eudialyte and mosandrite minerals usually have good percentages of the less common heavy rare earths, particularly the eudialyte which is characterized by a distinctive pinkish colour. However, these minerals have never been processed commercially for the production of rare earths.

The project is currently inactive, no work has been performed in recent years, and the owners are open to selling the property.

Kwyjibo

Project Status: **Ongoing**

The Kwyjibo rare earth deposit is located in the Canadian Shield, in the Lac Magpie Massif of the Basse-Côte-Nord Plateau in Québec; the project is fairly remote and will require the construction of a 70 to 100 km road. Kwyjibo is owned by the Québec government (50% Investissement Québec, 50% SOQUEM) and operated by SOQUEM.

Rare earth elements at Kwyjibo are concentrated in three minerals: apatite, britholite and allanite. The deposit contains 4 million measured and indicated tonnes grading 3.43% TREO, plus 1.1 million inferred tonnes grading 4.04% TREO. A 2018 PEA on Kwyjibo modelled an underground operation with a mine life of 10 years and a separation facility, with a total capital cost investment of $723.6 million.

An underground mine for rare earth mining is unusual, however, it is the best option for the Kwyjibo project due to the high environmental impact an open-pit mine would have; for instance, there is a water stream in the resource area that would have to be redirected. There is also community resistance towards the project, and as such, an underground mine currently seems to be the less invasive option.

According to the PEA report, the hydromet plant will process roughly 174,150 tonnes of concentrate per year from the concentrator and produce 10,000 tonnes of TREO per year. The concentrator plant is expected to produce a non-sellable concentrate product with 7% TREO. The low mineral concentrate will make the transportation and front-end processing costs relatively high, compared to existing producing mines and projects that can make higher REE mineral concentrate (see Chapter 9).

Niobec

Project Status: **Inactive**

The Niobec deposit is a niobium mine located in the Municipality of St. Honoré in the Saguenay-Lac-Saint-Jean region, 200 km north of Québec City. The mine is currently owned by Magris Resources. In 2011, the previous owners, IAMGOLD Corporation, conducted an exploration program in a zone adjacent to the mine (~1 km) and estimated rare earth inferred resources of 466.8 million tonnes at a grade of 1.65% TREO. The rare earth zone had been known for decades and was last explored in 1985. The REE zone was evaluated with a total of 13,798 metres of diamond drilling in 29 holes including an underground drill hole from the Niobec mine.

The St. Honoré carbonatite complex, which contains the niobium mine and the REE zone, is a 25 km^2 alkaline intrusive complex comprising a carbonatite core that is surrounded by nepheline syenite, feldspathoid syenite, and other mafic intrusive phases. The rare mineralization is mainly in the form of REE fluorocarbonates (principally bastnaesite) and monazite. The deposit is a light rare earth deposit, with the light elements comprising 98% of the weight of the total rare earths.

The 2011 drill program aimed at establishing the three-dimensional mineralization zone provides both a preliminary REE grade estimate and samples for preliminary metallurgical test work. However, the project economics became less attractive as rare earth prices declined, thus the previous owners discontinued the program. The Niobec mine was subsequently sold to Magris Resources, which has not reported any rare earth exploration program.

Montviel

Project Status: **Inactive**

The Montviel property is located in the Abitibi region of the Province of Québec. It is 500 km northwest of Montréal and 215 km NNE of the town of Val-d'Or. The property is accessible via a network of secondary logging roads that links to the 1018 logging road, which is connected to Highway 113 leading to the town of Lebel-sur-Quévillon. The property is owned by Geomega Resources.

Montviel is a carbonatite deposit comprised of the following minerals: ankerite, dolomite, siderite, calcite, barytocalcite, strontianite, amphibole, biotite, apatite, Fe oxides, ilmenite, and other silicate minerals, totalling 90.3% of the mineral composition. The niobium and rare earth-bearing minerals also present are pyrochlore and monazite.

In June 2015, Geomega published an updated mineral resource estimate for Montviel, which amounted to 82.4 million tonnes of indicated resources at 1.5% TREO and 184.2 million tonnes of inferred resources at 1.4% TREO. The company also performed some preliminary flowsheet development work for the deposit in 2015.

Currently, Geomega has no plans to progress the deposit and is instead focused on the development of its recycling technology.

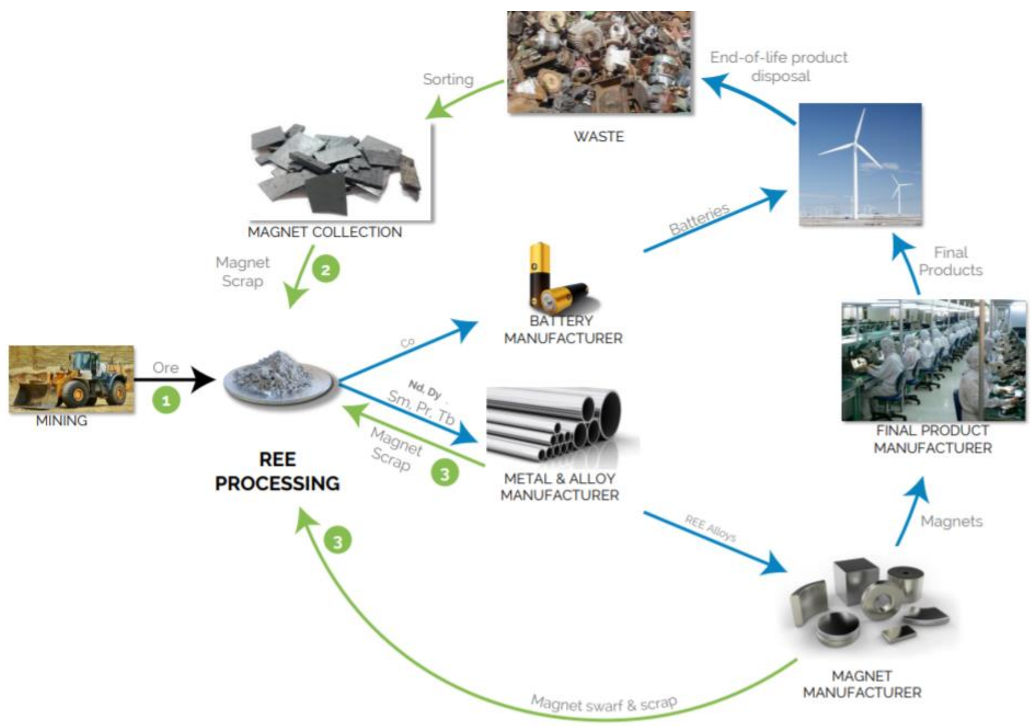
Geomega-Innord REE Recycling Project

Innord is a subsidiary of Geomega that was founded in 2015 with the primary goal of developing the company's proprietary REE separation process. The company is planning to produce rare earth oxides that are used in permanent magnets (i.e., Nd, Pr, Sm, Dy, Tb) by employing industrial waste sources.

Geomega is currently evaluating the economic potential to extract and refine rare earths and other critical metals from a broader range of feeds, including mining ore, tailings, and various industrial waste streams. For instance, the company entered into an agreement with USA Rare Earth, LLC, in July 2020, to treat the waste stream from USA Rare Earth's future expected production of sintered neodymium iron boron (NdFeB) permanent magnets to be built in the United States. It has also engaged companies that are actively producing rare earth alloys and magnets to secure scarf and scrap feedstock for processing.

In addition to rare earths, the company is also planning to use its recycling technology to recover critical battery materials (e.g., cobalt, nickel, vanadium and lithium), as well as niobium, titanium, tantalum, and chromium. Geomega is open to licencing its technology to receive royalties as an additional revenue source.

Exhibit 7.4: Potential feedstock sources



Source: Geomega

Geomega is planning to build a demonstration plant to test its technology and has engaged the firm Hatch for project engineering. The company is using its pilot facility in Boucherville (Québec) to test run the process technology and collect data to support the demo plant engineering. The demonstration plant is expected to have an initial capacity of 1.5 tonnes per day (tpd) and run 8 hours per day, using a 30% TREO (Nd, Pr, Dy, Tb) feedstock. Sales are forecasted to reach $10 million per year, and with an operating cost of $3/kg of TREO the estimated profit margin is 20% (i.e., $2 million profit per year). Capital costs including working capital are estimated at $4.8 million. The company expects to increase capacity to 4.5 tpd and become a 24-hour operation for an additional cost of $1 to $2 million, which should increase sales to about $30 million per year.

The company has received $3.8 million in debt financing from the Government of Québec and will need additional funds to complete the demonstration plant. If funding is successful, the demonstration plant construction is expected to start in the first quarter of 2021, with production in the last quarter of 2021.

To achieve its 2021 production target, the ongoing pilot plant studies have to be successful and completed this year, the company must raise sufficient funds for general operations, demonstration plant capital costs and working capital, secure sufficient feedstock with the appropriate economic concentration, and successfully commission the plant according to the set schedule. If any of these factors are not met the plant schedule could be significantly delayed.

Radioactivity in Québec Rare Earth Deposits

The three projects in Québec that are active all have thorium and uranium levels that will require their respective companies to take measures to manage the radioactive materials.

The Ashram deposit has 350 ppm of thorium and relatively low uranium levels at 2 ppm in their resource. When the mineral concentration is upgraded the thorium also increases, and Commerce Resources has estimated that the thorium grade in the mineral concentrate (>40% REO) ranges between 6,000 to 10,000 ppm (0.6% and 1% Th), and the uranium is less than 4 ppm (about half of what is in a typical granite countertop).

For Ashram, the thorium and uranium goes into a solution with the sulphuric acid bath and is extracted on the solvent extraction circuit (see example in Exhibit 8.3) on the hydromet facility to be located on the South Shore of Québec. The plan is to recover thorium as a hydroxide compound. The company is considering two options: 1) It can either produce the high-grade thorium waste material and store it temporarily at the hydromet facility and then ship it for long-term storage at one of the designated nuclear facility storage sites in central-eastern Canada; or 2) Mix the thorium compound with the tailings and then store it near the facility according to the Canadian Nuclear Safety Commission (CNSC) standards. Commerce Resources has yet to determine the most economic route.

For Strange Lake, the estimated uranium concentration in mine feed is 70 ppm and thorium is about 400 ppm. The concentration of thorium and uranium increases after beneficiation, but Torngat Metals has not disclosed the data. However, rough estimates indicate that after beneficiation the levels of uranium and thorium in the mineral concentrate will be 300 ppm U and 1,500 to 2,000 ppm (or 0.15% to 0.20%) Th. About 50% of the uranium and thorium will stay in the waste rock and flotation tailing at the mine site. At the processing site in Bécancour all the uranium and thorium will remain in the process residue and go into the tailings. The company will likely dilute radioactivity in the tailings, as recommended by the CNSC, by adding soil for example, and then storing it on site.

The Kwyjibo project also has uranium and thorium levels comparable to the other projects because of the type of minerals present (likely, 300-400 ppm Th, less than 50 ppm U). SOQUEM did not include details in its PEA regarding the treatment of radioactive waste. However, the process will likely be similar to that described for the projects above. In the case of Kwyjibo, the radioactive elements are found in the rare earth minerals britholite and apatite and their concentrations increase when the ore is upgraded. During the process, the radioactive elements will likely be recovered in the solvent extraction (SX) circuit and then diluted and stored according to CNSC guidelines.

Other Projects in Canada

There are only three additional mineral projects in Canada (excluding those in Québec) that are active: the Nechalacho deposit in the Northwest Territories (NWT), now run by the Australian company Vital Metals; the Foxtrot deposit in Newfoundland, owned by Search Minerals; and the Wicheeda deposit in British Columbia run by Defense Metals Corp.

Exhibit 7.5: Projects in the rest of Canada

Project Name	Stage	Resource	Capital Requirements Next Phase (C$M)
Rest of Canada			
Nechalacho, NT, Canada Vital Metals www.vitalmetals.com.au	DFS	M+I + Inf = 94.7Mt at 1.46% TREO T Zone M+I = 105,000 @ 8.9% LREO, at 0.3% Nd_2O_3 cut-off	20
Foxtrot, NL, Canada Search Minerals www.searchminerals.ca	Completed PEA	M+I = 7.4 Mt at 1.09% TREO Inf = 2.0 Mt at 1.17% TREO	5 - 10
Wicheeda, BC, Canada Defense Metals Corp. www.defensemetals.com	Resource	Ind. = 4.9 Mt at 3.02 % LREO Inf = 12.1 Mt at 2.90 % LREO, at 1.5% LREE	5 - 10

Source: Tahuti Global; DFS = definitive feasibility study; PEA = preliminary economic assessment; M = measured, I = indicated, inf = inferred; Mt = million of tonnes

Nechalacho

The Nechalacho project is located in the NWT, and was managed by the Canadian company Avalon Advanced Materials Inc., which spent over $120 million to complete site permitting and a feasibility study that included a comprehensive metallurgical test program. However, Avalon was not able to secure financing to build the mine and processing plant estimated at $1.6 billion. In 2019, Avalon sold a portion of the Nechalacho resource, specifically the near-surface resource (Tardiff (T)-Zone) for $5 million to Cheetah Resources Pty Ltd., which was acquired by Vital Metals.

The Nechalacho deposit contains an estimated resource (measured, indicated and inferred) of 94.7 million tonnes at 1.46% REO, and Vital Metals is targeting the North Zone of the deposit that hosts a high-grade resource of 105,000 tonnes at 8.9% light rare earth oxide (LREO) (2.1% NdPr).

One of the key determinants for the development of an economic rare earth mine is the production of a rare earth concentrate of at least 30% total rare earths. Beneficiation tests of the T-Zone showed that a 36% TREO mineral concentrate could be produced from feed containing 10.5% TREO at an REO recovery of 70%; multiple tests showed that up to 41% TREO mineral concentrate can be produced with recoveries up to 87% and upgrade factors up to 5 times[8]. These results increase the potential for commercial development of the T-Zone.

Vital Metals is targeting initial small-scale production of rare earth oxide in 2021. The company has completed detailed engineering for the ore sorting plant, and defined capital and operating costs. Nechalacho is fully permitted to commence mining and sorting operations at the site, and Vital aims to commercially produce a minimum of 5,000 tonnes of contained REO by 2025. The company estimates

[8] Vital Metals Website

that initial construction costs to produce rare earth carbonate at Nechalacho is A$20 million. Instead of going for a large full-scale mine to oxides processing plant, the company's strategy is to start small by selling a carbonate product and then move to separation.

Vital Metals recently signed an agreement with the Saskatchewan Research Council (SRC) for the construction and operation of a rare earth extraction plant to produce a mixed rare earth carbonate product. Vital Metals is planning to build its plant adjacent to SRC's rare earth separation plant in Saskatchewan, and if successful, is planning to provide the rare earth carbonate as feedstock to the SRC's separation plant to produce rare earth oxides.

Foxtrot

The Foxtrot project is located in Labrador and is owned by Search Minerals. In addition to Foxtrot, the company has several other mineral prospects on its 100%-owned Red Wine and Henley Harbour properties that have similar characteristics to Foxtrot, namely the Deep Fox project, as well as the Fox Meadow, Silver Fox and Awesome Fox prospects.

The company's main focus has been the Foxtrot project that according to a PEA has a life of mine (LOM) resource with 4.9 million tonnes at an average grade of 0.98% total rare earth elements (TREE), which could be mined in the first 14 years, including open-pit mining for the first eight years and underground mining thereafter.

Search Minerals developed and patented a metallurgical process for Foxtrot, called the Search Direct Extraction Process. The pilot plant optimization program was completed in March 2020. The program produced both a 58% REO mixed rare earth carbonate concentrate and a 99% pure mixed REO concentrate at apparently good recovery rates, which according to the company can be produced from both the Foxtrot and Deep Fox material. However, it should be noted that Search Minerals does not produce a mineral concentrate from beneficiation (e.g., floatation), which makes the flowsheet less attractive and the project economics less competitive; in fact, estimated operating costs per tonne are currently higher than the basket rare earth prices granting the project uneconomic. However, Search Minerals is moving the project forward in order to optimize the flowsheet.

Wicheeda

The Wicheeda property is located approximately 80 km northeast of the city of Prince George in British Columbia, and is owned by Defense Metals Corporation. The property is positioned alongside a major forestry service road connected to a Highway.

The deposit has estimated indicated resources of 4.9 million tonnes averaging 3.02% LREO and inferred resources of 12.1 million tonnes averaging 2.90% LREO.

The deposit mineralogy consists of monazite and synchysite/parasite-bastnaesite in approximately equal proportions. According to the company, floatation metallurgy returned 48.7% LREO high-grade concentrate of cerium, lanthanum, neodymium, and praseodymium oxides, at 85.7% recovery in locked cycle tests, 10.1 times upgrade from a head grade of 4.81% LREO.

Initial hydrometallurgical studies suggest that high REE extractions can also be achieved through acid leaching and caustic conversion techniques.

The Wicheeda project seems to have good potential for commercialization due to the apparent simple mineralogy and production of the high-grade mineral concentrate, and proximity to roads and power.

Saskatchewan Rare Earth Separation Plant

The Saskatchewan Research Council (SRC) has built a separation pilot plant that can be configured with different separation processes for either group separation or individual REE separation. The SRC adapted that technology to address specific REE separation challenges in processing secondary rare earth resources, such as uranium raffinate.

The SRC's technology is also applicable to separating concentrates from primary rare earth mineral resources, such as monazite and bastnaesite. In addition, the SRC has developed both acidic and alkaline processes to treat rare earth ores from different areas around the world.

The SRC is collaborating with several rare earth exploration companies, including Vital Metals and Search Minerals.

7.2 Global REE Projects

There are over 400 rare earth concessions and deposits around the world, with several of them being developed since 2010 when rare earth prices started to rise on fears of a Chinese supply shortage. However, only a few of these projects are currently still in development.

Africa

In Africa, several active projects have received new interest and funding, including the Ngualla project in Tanzania, owned by Peak Resources Ltd., which received interest from the United States government agency, Overseas Private Investment Corp. that helps American businesses invest in emerging markets[9].

Pensana Metals Ltd. owns the Longonjo project in Angola, and the company is planning to complete a bankable feasibility study this year. It has secured an agreement with the Chinese state company China Great Wall Industry Corp.[10], and as the contractor for the engineering and construction work, it is also committed to helping the company with financing from China.

The Gakara project in Burundi, with one of the highest rare earth grades in the world, is owned by Rainbow Rare Earths and has been producing bastnaesite concentrate since 2017; there is ongoing exploration work to increase resources and production of mineral concentrate[11]. Rainbow is hoping to find 20 to 80,000 tonnes of resource and invest up to US$50 million to build a beneficiation and processing facility to produce 10,000 tonnes of mixed rare earth carbonate. Currently, production is performed manually in an artisanal fashion, with less than 1,000 tonnes of concentrate per year. To achieve higher production, the company will have to mechanize the mine for bulk mining.

The rare earth Makuutu deposit in Uganda is currently being managed by Ionic Rare Earths Ltd. The deposit is considered an ionic clay with a high percentage of LREE, including neodymium and

[9] http://www.shippipedia.com/peak-resources-receives-u-s-funding-interest-for-rare-earth-project/
[10] https://www.macaubusiness.com/angola-chinese-company-to-build-longonjo-rare-earths-mine-in-huambo-province/
[11] https://www.nsenergybusiness.com/projects/gakara-rare-earth-project/

praseodymium. The project does not have a compliant resource and no economic studies have been completed.

There are several rare earth deposits in South Africa, such as the Glenover deposit, run by Galileo Resources, and the Steenkampskraal rare earth deposit, however, there has been little progress to commercialization.

Exhibit 7.6: Select international rare earth projects

Project Name	Stage	Resource	Capital Requirements for Project (US$M)
Longonjo, Angola Pensana Metals Ltd www.pensana.co.uk	PFS	M+I = 313 Mt @ 1.43% REO, 0.32% NdPr	200
Browns Range, Australia Northern Minerals Ltd www.northernminerals.com.au	Demonstration plant, and exploration	I = 4.48 Mt @ 0.71% TREO Inf = 4.48 Mt @ 0.64% TREO	-
Charley Creek, Australia Enova Mining Ltd. www.crosslandstrategic.com	Scoping study	I = 386.9 Mt @ 295 ppm TREO Inf = 418.4 Mt @ 289 ppm TREO	-
Dubbo, Australia ASM Inc. www.asm-au.com	Financing	M = 42.81 Mt @ 0.74% TREO Inf = 32.37 Mt @ 0.74% TREO Total = 75.18 Mt @ 0.74% TREO	1,100
Nolans Bore, Australia Arafura Resources Ltd www.arultd.com	Financing	M = 4.9 Mt @ 3.2% TREO, 13% P_2O_5, 26.1% NdPr I = 30 Mt @ 2.7% TREO, 12% P_2O_5, 26.4% NdPr Inf = 21 Mt @ 2.6% TREO, 11% P_2O_5, 11% NdPr Total = 56 Mt @ 2.6% TREO, 11% P_2O_5, 26.4% NdPr	1,006
Yangibana, Australia Hastings Technology Metals Ltd www.hastingstechmetals.com	Financing	M = 4.6 Mt @ 1.17% TREO, 0.42% Nd_2O_3+Pr_6O_{11} I = 8.7 Mt @ 1.24% TREO, 0.41% Nd_2O_3+Pr_6O_{11} Inf = 8.3 Mt @ 1.09% TREO, 0.36% Nd_2O_3+Pr_6O_{11}	335
Araxá, Brazil CBMM www.cbmm.com	-	M+I = 6.34 Mt at 5.01% TREO Inf = 21.94 Mt at 3.99% TREO	-
Serra Verde, Brazil Mineração Serra Verde www.svpm.com.br	DFS	M = 22 Mt @ 0.21% TREO I = 368 Mt @ 0.15% TREO Inf = 521 Mt @ 0.10% TREO Total = 911 Mt @ 0.12% TREO	-
Gakara, Burundi Rainbow Rare Earths rainbowrareearths.com	Production and Resource Estimation	Total = 20,000 t @ 47% TREO to 80,000 t @ 67% TREO (Historical, non-compliant)	25
Penco, Chile Hochschild Mining Plc www.hochschildmining.com	DFS	-	1,032
Kvanefjeld, Greenland Greenland Minerals and Energy Ltd www.ggg.gl	DFS	M = 143 Mt @ 12,100 ppm, 303 ppm U_3O_8, 10,700 ppm LREO, 432 ppm HERO, 11,100 ppm REO, 978 ppm Y_2O_3, 2,370 ppm Zn I = 308 Mt @ 11,100 ppm, 253 ppm U_3O_8, 9,800 ppm LREO, 411 ppm HERO, 10,200 ppm REO, 899 ppm Y_2O_3, 2,290 ppm Zn Inf = 222 Mt @ 10,000 ppm, 205 ppm U_3O_8, 8,800 ppm LREO, 365 ppm HERO, 9,200 ppm REO, 793 ppm Y_2O_3, 2,180 ppm Zn	1,361

Project Name	Stage	Resource	Capital Requirements for Project (US$M)
Sarfartoq, Greenland Hudson Resources Inc www.hudsonresourcesinc.com	-.	I = 5.8 Mt @ 1.77% TREO, 3,855 ppm La_2O_3, 8,844 ppm Ce_2O_3, 1,012 ppm Pr_2O_3, 3,296 ppm Nd_2O_3, 321 ppm Sm_2O_3, 71 ppm Eu_2O_3, 181 ppm Gd_2O_3, 14 ppm Tb_2O_3, 34 ppm Dy_2O_3, 68 ppm Y_2O_3 Inf = 2.5 Mt @ 1.59% TREO	-
Songwe Hill, Malawi Mkango Resources Ltd www.mkango.ca	DFS	M = 8.81 Mt @ 1.50% TREO I = 12.22 Mt @1.35% TREO Inf = 27.54 Mt @ 1.33% TREO Total = 48.57 Mt @ 1.37% TREO	216
Lofdal, Namibia Namibia Critical Metals Inc. www.namibiacriticalmetals.com	PFS	I = 2.88 Mt @ 0.32% TREO Inf = 3.28 Mt @ 0.27% TREO	163
Tomtor, Russia ThreeArc Mining Ltd	PFS	Total = 30 Mt @ 4% Nb_2O_5, 10.6% REO	-
Glenover, South Africa Galileo Resources www.ressourcesgeomega.ca	Resource	I = 16.7 Mt @ 1.45% TREO, 9.71% P_2O_5, 3,073 ppm Nb2O5, 114.9 ppm Sc_2O_3 Inf = 12.1 Mt @ 0.98% TREO, 9.25% P_2O_5	-
Norra Kärr, Sweden Leading Edge Materials Corp www.leadingedgematerials.com	-	I = 36 Mt @ 0.55% TREO	-
Ngualla, Tanzania Peak Resources Ltd www.peakresources.com.au	BFS	M = 86.1 Mt @ 2.61% REO, 20.2% $BaSO_4$ I = 112.6 Mt @ 1.81% REO, 13.8% $BaSO_4$ Inf = 15.7 Mt @ 2.15% REO, 16.6% $BaSO_4$	356
Makuutui, Uganda Ionic Rare Earths Ltd	Resource	I = 9.5 Mt @ 750 ppm TREO Inf - 69.1 Mt @ 860 ppm TREO Total = 78.6 Mt @ 840 ppm TREO	-
Bokan Mountain, United States Ucore Rare Metals Inc www.ucore.com	-	I = 4.8 Mt @ 0.602% TREO, 460 ppm Nb, 1,880 ppm Zr, 48 ppm Be, 37 ppm Hf, 0.370% TiO_2, 97 ppm V Inf = 1.1 Mt @ 0.603% TREO, 470 ppm Nb, 1,897 ppm Zr, 46 ppm Be, 35 ppm Hf, 0.443% TiO_2, 112 ppm V	-

Source: Tahuti Global; DFS = definitive feasibility study; PEA = preliminary economic assessment; M = measured, I = indicated, inf = inferred; Mt = million of tonnes

Australia

Australia has rare earth production at Lynas Corp.'s Mount Weld mine and the Iluka Resource Ltd.'s Eneabba project is expected to reach production of monazite mineral concentrate this year. Australia also has several rare earth projects.

The Nolans Bore project from Arafura Resources Ltd. is one of the most advanced. An updated feasibility study was completed in February 2019 and Arafura is actively looking for project financing.

Enova Mining Ltd. (previously Crossland Strategic Metals Ltd.) owns the Charley Creek project. The company is reportedly rethinking the project, has performed a new drilling program in 2019, and is currently performing new metallurgical tests.

Hastings Technology Metals Ltd. owns the Yangibana project. The company completed a definitive feasibility study in 2017 but is still working on optimizing the metallurgical process. Hastings has three offtake agreements with Qiandong Rare Earths, China Rare Earth Holdings, and Baotou Sky Rock Rare Earth. The Heavy Browns Range deposit is owned by Northern Minerals Ltd. The company has built a demonstration plant for the production of HREE and is looking to scale-up output at the plant while also focusing on exploration.

The Dubbo project is owned by ASM Inc. The deposit is polymetallic and contains zirconium, rare earths, niobium, hafnium, tantalum and yttrium, all major approvals and licences are in place, and the process flowsheet has been established. The company has completed a feasibility study, is ready for construction, and is pursuing project financing. The export finance Australia (EFA) has shown interest in participating in a financing consortium for the project.

North America

In North America, in addition to the Canadian projects, there are several deposits in the United States. The most developed deposit is the Mountain Pass in California that has been in production for decades. Unfortunately, under the management of Molycorp Inc., the expansion of the processing plant from 3,000 tonnes to 20,000 tonnes of separated oxides was not successful and the company filed for bankruptcy in 2015[12].

The Mountain Pass deposit is now owned by MP Materials Corporation, which is producing mineral concentrate (with ~26,000 contained rare earths) and shipping it to China for processing. MP Materials recently started trading[13] on the New York Stock Exchange and is currently seeking financing to restart the processing plant.

Another project in the United States is the Bokan Mountain deposit owned by Ucore Rare Metals Inc., however, the company has been mostly focused on the development of rare earth processing technologies than the deposit.

There are a number of companies, institutions, and research groups looking at the recovery of rare earths from mineral sands, targeting monazite, or from uranium, coal and phosphate tailings. Energy Fuels, a junior uranium producer in the United States, is currently developing a process to extract uranium and rare earths from monazite.

Medallion Resources, a Canadian-based company, is also looking at developing an economic process to extract rare earths from monazite-rich sands.

South America

There are also several rare earth projects in South America, with the Araxá REE project, run by Companhia Brasileira de Metalurgia e Mineração (CBMM) in Brazil, being the most developed. CBMM is the world's largest producer of niobium (~65%) and has built a demonstration plant to recover rare earths from its tailings. The company is also working on making rare earth metals and alloys. Other ongoing projects include the Serra Verde project, owned by Mineração Serra Verde, which has been funded by Denham Capital Management (an $8.4 billion resource fund), and the HREE-rich ionic clay Penco deposit in Chile, which is owned by Hochschild Mining Plc[14].

Other Regions

In Greenland, Greenland Minerals and Energy Ltd. continues to advance the Kvanefjeld project in partnership with the Chinese firm Shenghe Resources Holding Co Ltd. Greenland Minerals'

[12] https://www.wsj.com/articles/this-article-also-appears-in-daily-bankruptcy-review-a-publication-from-dow-jones-co-1435219007#:~:text=According%20to%20bankruptcy%20court%20documents,its%20books%20at%20%242.5%20billion.
[13] https://www.businesswire.com/news/home/20201117006236/en/MP-Materials-Completes-Business-Combination-and-Will-Begin-Trading-on-the-NYSE-under-%E2%80%9CMP%E2%80%9D
[14] http://www.hochschildmining.com/en/exploration/greenfield_exploration/biolantanidos

collaboration with Shenghe includes technical support, with processing test work conducted both in China and Australia. Another project in Greenland is the Sarfartoq, run by Hudson Resources Inc., which is advancing at a slower pace.

In Russia, ThreeArc Mining Ltd. is advancing the Tomtor project. The most recent resources were estimated in 2018 but are not (NI 43-101 or JORC) compliant. Polymetal International PLC, Russia's second-largest gold company announced that it will invest US$20 million in Tomtor[15] in return for a 9.1% stake in the project. The funds will be used to finance a compliant mineral resource, ore reserve estimation, and a PFS.

It should be noted that some of the reported resources in Exhibit 7.6 were performed over four years ago and under different market conditions; as such, some projects may not be economic at current prices. This list of projects is by no means comprehensive, as several rare earth projects are being developed by private companies around the world and some public companies may have rare earth projects as secondary. However, these are some of the most developed REE projects at the moment.

Among the projects listed in this section, those that may reach commercial production in less than five years are the Araxá project in Brazil and the Northern Mineral's project. Both projects have good financial backing and are in the demonstration plant stage. Unfortunately, completing a positive feasibility study with a high net asset value (NAV) is not synonymous with success and project readiness for construction. Many of the projects discussed here have completed feasibility studies but are too risky for investors.

[15] https://www.spglobal.com/marketintelligence/en/news-insights/latest-news-headlines/polymetal-closes-deal-for-9-1-stake-in-russia-s-tomtor-rare-earths-project-57974181

8. Comparative Analysis

Rare earth exploration projects should be assessed based on a combination of key parameters. The size of the resource and grade is important, but a large resource and high grade are not sufficient to determine project success. In fact, the high-grade Steenkampskraal (14.4% TREE) deposit in South Africa is still facing challenges to reach production, whereas deposits like the ion adsorption clays that usually have low concentration of rare earths (less than 0.1%) have been economically exploited in China and Myanmar. Also, large deposits like the Kvanefjeld in Greenland with an estimated resource of one billion tonnes continue to face challenges to commercialization.

One aspect that is somewhat unique to rare earths is that the 17 rare earth elements usually occur together, but the concentration of individual elements in a deposit may vary significantly depending on the type of minerals in the deposit. For instance, bastnaesite usually has high percentages of light elements, particularly lanthanum and cerium (combined >78%), with only trace amounts of yttrium and the other heavier elements. On the other hand, the xenotime minerals usually have relatively higher concentrations of yttrium and heavier elements, with smaller amounts of lanthanum and cerium.

Rare earth deposits with a simple mineralogy that allow for the production of a high-grade mineral concentrate and have an elemental distribution with relatively high percentages of the most valuable elements, have a higher probability of reaching economic production.

Production of a Mineral Concentrate

In active rare earth mines around the world, the mined ore is usually beneficiated by flotation or gravity, or magnetic processes to produce a mineral concentrate (typically >30% TREO).

Exhibit 8.1: Select rare earth mines, mineralogy and mineral concentrate grades

Deposit	Country	Ligh/Heavy	Grade	Main Mineral	Mineral Concentrate
Bayan Obo	China	Light	6%	Bastnaesite & Monazite	60% REO and 30%REO
Sichuan	China	Light	3.70%	Bastnaesite	50-60% REO
Shandong	China	Light	3.13%	Bastnaesite & Parisite	>30% REO
Mount Weld	Australia	Light	8%	Apatite & Monazite	40% REO
Manavalakurichi	India	Light	<1.5%	Monazite	>30% REO
Lovozero	Russia	Light	<0.5%	Loparite	>30% REO
Ganzhou	China	Heavy	0.03%-0.15%	Ion adsorption clays	n.a.
Mountain Pass	United States	Light	8%	Bastnaesite & Monazite	60% REO

Source: Tahuti Global

The mineral concentrate is subsequently leached with aqueous inorganic acids, such as hydrochloric acid (HCl), sulphuric acid (H2SO4), or nitric acid (HNO3). After filtration or counter current decantation, the result is an REE-rich pregnant solution. Solvent extraction is then usually used to separate individual rare earths or produce mixed rare earth compounds.

The production of a high-grade mineral concentrate makes it more economic to process as fewer reagents are required. Moreover, the size of the front-end equipment could be smaller thus reducing initial capital costs. Also, in the case of deposits located in remote locations, the production of a high-grade mineral concentrate reduces transportation and thus operating costs.

Currently, rare earth projects with a flowsheet that does not include the production of a high mineral concentrate by beneficiation prior to leaching face higher processing risk[16].

Mineralogy

The minerals that have been successfully processed for the recovery of rare earths are monazite, bastnaesite, xenotime, loparite, and ion adsorption clays. The processing of these minerals is extensively documented in scientific papers, books, etc. Attempts to develop an economic flowsheet for rare earth deposits with other minerals have not been successful to date.

Rare earth projects with commercially unproven minerals have higher processing risk.

Among the most developed rare earth projects in Québec (see Section 7.1), the Ashram deposit is the only one with a high percentage of a commercially proven rare earth mineral, i.e., monazite. However, new developments in process technology could lead to successful flowsheets of other rare earth mineral deposit types.

Elemental Distribution and Saleable Products

Exhibit 8.2 shows the typical distribution of rare earth elements in the main minerals. In the so-called light deposits, where bastnaesite and monazite are the dominant minerals, the elements with the highest concentration are cerium, lanthanum, neodymium and praseodymium, making up 97% to 98% of the total concentration. Lanthanum and cerium are low price elements ($1.5-3.0/kg), and neodymium and praseodymium currently sell for $40-50/kg.

Exhibit 8.2: Typical rare earth concentration of principal minerals

Deposit	Sichuan (China)	Manavalakurichi (India)	Guangdong (China)
Mineral	Bastnaesite	Monazite	Xenotime
La	**35.60%**	**22.00%**	1.20%
Ce	**43.80%**	**46.00%**	3.00%
Pr	4.73%	5.50%	0.60%
Nd	**13.10%**	**20.00%**	3.50%
Sm	1.22%	2.50%	2.20%
Eu	0.23%	0.02%	0.20%
Gd	0.52%	1.20%	5.00%
Tb	0.06%	0.06%	1.20%
Dy	0.09%	0.18%	**9.10%**
Ho	0.05%	0.02%	2.60%
Er	0.04%	0.01%	5.60%
Tm	0.01%	0.0008%	1.30%
Yb	0.055%	0.004%	**6.00%**
Lu	0.00%	0.001%	1.80%
Y	0.40%	0.45%	**59.30%**

Source: USGS; Note: bolded are the top three element concentrations

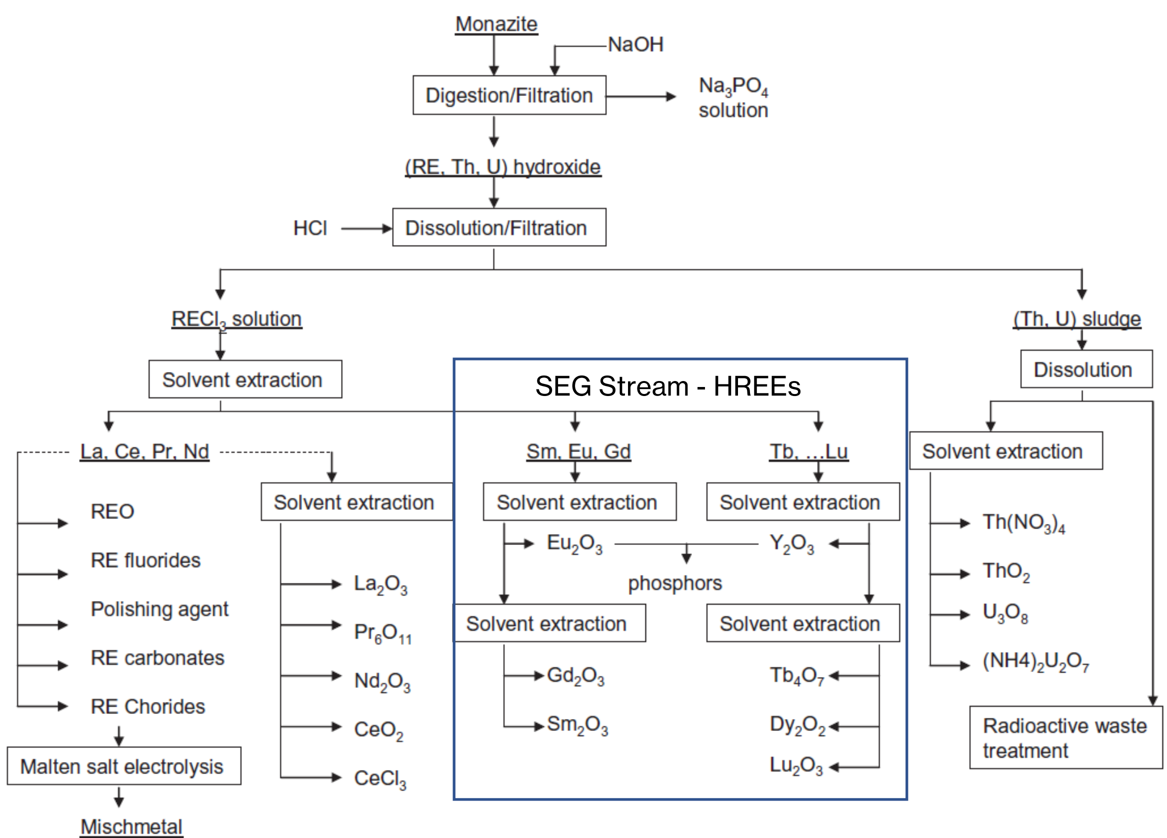
[16] The exception may be ion adsorption projects that are easier to leach and are processed on site.

In 2010 to 2011, when rare earth prices were high, most of the junior mining companies that were able to work on a flowsheet planned to refine and sell all of the rare earth elements. However, as prices reverted to their lower historical levels, it became evident that the separation and refining of all of the elements may not be economic. The capital and operating costs for the separation and refining of the remaining elements, which accounted for only 2% to 3% of the projected output (for light deposits), were too high relative to their market price.

For projects with light deposits, neodymium and praseodymium are the most important elements, first due to their higher price and second because they have a high projected demand (associated with the EV adoption policies).

Exhibit 8.3 shows the example of a flowsheet for monazite feedstock. During processing, the lighter elements (La, Ce, Pr and Nd) are separated from the heavier elements (sometimes referred to as SEG stream). Currently, most junior mining companies have excluded the refining of SEG stream elements from their flowsheets. Lynas Corp., which is now in operation, refines the light elements (La, Ce, Pr and Nd) into different products, but stockpiles and sells the SEG stream to external refiners. In the case of monazite, the radioactive elements (thorium and uranium) have to be treated.

Exhibit 8.3: Example of flowsheet for processing of monazite



Source: Zhang et al.[17]

Deposits with xenotime or with a combination of minerals that have a high percentage of heavier elements usually have high amounts of yttrium and dysprosium (important in high-performance magnets). However, yttrium, which has a low price ($3-5/kg), usually makes up more than 50% of total

[17] Zhang, Z., Li, H., Guo, F., Meng, S., Li, D., 2008. Synergistic extraction and recovery of Cerium(IV) and Fluorin from sulfuric solutions with Cyanex 923 and di-2-ethylhexyl phosphoric acid. Separation and Purification Technology 63, 348–352.

rare earths. In these deposits, dysprosium is usually the most valuable element accounting for most of the basket value; terbium is also of interest as it is used in magnets and has a high price.

Rare earth projects where neodymium and praseodymium, and/or dysprosium and terbium are present at relatively high percentages and can be economically recovered, contribute to stronger project economics.

Projects that include the separation and refining of both light and heavy elements have relatively higher capital cost estimates, and higher financing and process technology risk.

8.1 Comparing Projects Within Canada

Canada has many rare earth occurrences, but currently, there are only six advanced rare earth projects, with three of them in Québec. The main challenges facing these projects are the development of an economic metallurgical process and project financing.

Exhibit 8.4: Comparative table of Canadian projects

	QUEBEC			NWT	BC	NL
Deposit	**Ashram**	**Kwyjibo**	**Strange Lake**	**Nechalacho (T-Zone)**	**Wicheeda**	**Foxtrot**
Company name	Commerce Resources	SOQUEM	Torngat Metals Ltd.	Vital Metals Pty Ltd.	Defense Metals Corp.	Search Minerals
Dominant REE Minerals	Monazite and Bastnäsite	Apatite, britholite, allanite, kainosite	Allanite and Gerenite/Gado-linite/Kainosite	Allanite, Monazite, Bastnaesite and Synchysite	Bastnäsite and Monazite	Allanite and Fergusonite
Metallurgy Complexity	Average	High	High	High	Average	High
Mineral concentrate from beneficiation	7%-10%	7%	15%	>35%	>30%	n.a
Grade (TREO%)	1.9%	2.7%	0.9%	8.90%	1.9%	1.0%
NdPr (% of TREO)	22.3%	20.2%	14.2%	23.6%	12.0%	19.4%
HREO (% of TREO)	2.8%	11.7%	14.2%	n.a	0.0%	13.2%
Y-HREO (% of TREO)	4.8%	32.7%	42.3%	n.a	0.0%	24.1%
Mining & Concentrator Capex	$407	$423	n.a.	n.a.	n.a.	$152
Separation Facility Capex	n.a.	$325	n.a.	n.a.	n.a.	n.a.
Other Capex	$356	n.a.	n.a.	n.a.	n.a.	$80
Total CapEx (US$M)	$763.0	$749	$615	$20	n.a.	$232
Capex/tonne (US$/tonne)	$102	$79	$51	n.a	n.a.	$70
LOM Annual OpEx ($/kg final product)	$7.9	$14.48	16.0	n.a	n.a.	$26.2
Undiscounted Basket Price (US$/kg TREO)	$15.9	$25.3	$24.1	$13.8	$8.0	$21.3
Target Production Rate (tonnes TREO)	7,500	9,483	12,000	5,000	n.a.	3,300
Development Stage	Completed PEA	Completed PEA	Completed New PEA	Metallurgical Studies	Resource Estimate	Completed PEA

Source: Tahuti Global

Among the six deposits, only two (Ashram and Wicheeda) have predominantly monazite and bastnaesite, two minerals that have been processed commercially. All the other projects have a combination of many rare earth minerals that have not been economically processed. That said, not all monazite and bastnaesite deposits have successful flowsheets. In the case of the Ashram deposit, which is predominantly a monazite deposit (~60%), under the current flowsheet the first mineral concentrate product after floatation is relatively low grade; the ore is pre-leached to produce the high-grade concentrate (45% TREO) at reasonable recovery rates. In the current flowsheet, the rare earth mineral concentrate after flotation has less than 10% TREO. It worth noting that a higher-grade mineral concentrate has been obtained for the Ashram project, however, because the recovery rates were low (50% to 60%), Commerce Resources decided to pursue the pre-leach approach which allows for higher recovery of rare earths. The existing flowsheet also offers the potential to commercialize the fluorspar as a by-product.

The only projects in Canada with a flowsheet that includes a high-grade mineral concentrate before any leaching are the Wicheeda project in British Columbia and the Nechalacho project in the NWT.

Vital Metals, in its new approach to the Nechalacho project, is focusing on a high-grade area (the T-Zone) of the deposit and employing X-Ray Transmission (XRT) ore sorting to produce a high-grade concentrate. With this approach, the company expects to become first a producer and seller of market-ready mineral concentrate and then introduce separation capability afterwards. The company is also planning to transport the ore to Saskatchewan for trial separation at the new SRI processing facility. The high-grade mineral concentrate makes long-distance transportation more economically feasible.

In terms of rare earth distribution, the Nechalacho deposit shows the highest NdPr concentration (23.6%) but no heavy elements are reported, likely because the company is not expecting to separate those elements, which reduces processing risk and lowers project capital costs. The Ashram deposit shows the second-highest concentration of NdPr (22.3%). The Kwyjibo deposit shows good levels of both NdPr and HREE and SOQUEM is envisioning a hydromet plant that can separate both LREE and HREE.

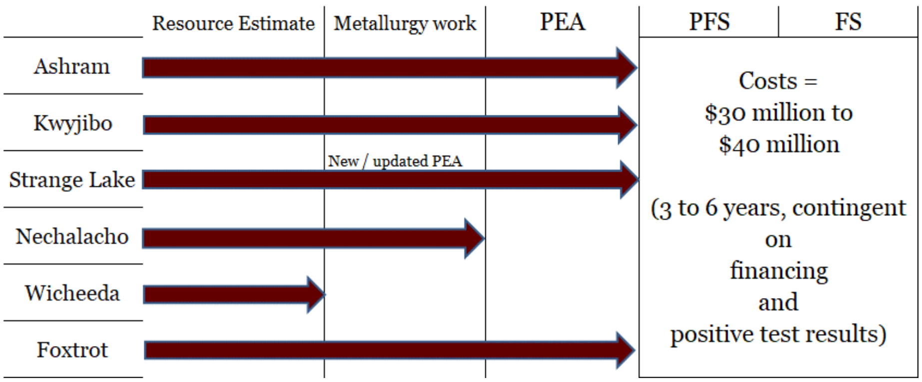
The Strange Lake deposit, which has been characterized as a heavy rare earth deposit, has good but relatively low percentages of NdPr and a high percentage of heavy elements that the company is planning to separate.

The Foxtrot deposit has the highest percentage of NdPr+HREE grade among the six Canadian projects, however, Search Minerals has not been able to produce a mineral concentrate from beneficiation, which means transportation of the ore to an industrial area for processing will be relatively expensive given the project's remote location. Moreover, capital costs for the front-end of the plant will also be high. Another unfortunate aspect for Foxtrot is that operating cost estimates are currently higher than the undiscounted basket price. Hence, based on the last PEA Foxtrot is not economically feasible at current rare earth prices. However, Search Minerals is continuing to receive provincial support (e.g., grants) for metallurgical studies and the company is working on improving the project economics.

It has been suggested, but not yet tested, that the metallurgical process for Strange Lake may also work for the Kwyjibo deposit, which has a grade three times higher than Strange Lake. Kwyjibo also has a higher combined percentage of magnet elements (Nd, Pr, Dy, Tb), but Strange Lake has a much larger resource. If Torngat's flowsheet could be successfully used to process Kwyjibo ore, it could save SOQUEM millions in development costs. However, the consolidation of the two projects would only make sense if overall development costs could be reduced.

Each of the six projects has strengths and weaknesses, but the projects that may be closer to production are the Nechalacho and Wicheeda projects. High-grade mineral concentrates have been successfully produced from both deposits (at laboratory scale) and if the projects are proven feasible, the companies could produce mineral concentrate and export it, similar to the Mountain Pass mineral concentrate product in the United States that is exported to China for processing.

Exhibit 8.5: Stage of development of Canadian projects



Source: Tahuti Global; PEA= preliminary economic assessment, PFS= pre-feasibility study, FS= feasibility study

Among the Québec projects, the Strange Lake deposit was the most advanced, as a PFS was completed (2013), with over $40 million spent in development costs that included advanced pilot scale metallurgical studies. Torngat's adjustments to mining and flowsheet have resulted in a higher mineral concentrate product and significantly lower capital cost ($615 million compared to $2.6 billion previously) for the Strange Lake deposit. The company estimates that it will need about $6 million to complete a new PFS and $30 to $35 million to complete a bankable feasibility study for Strange Lake.

Commerce Resources estimates that it will need up to $6 million to first complete a PFS that would last 12 months and then an additional $20 to $25 million for the feasibility study that should take 12 to 18 months to complete. The Kwyjibo project is the least developed of the three Québec projects analysed in this section and will likely also need $30 – $40 million (or more) to reach the definitive feasibility stage.

8.2 International Landscape

There is renewed interest in rare earth projects since prices collapsed from their bubble levels in 2011, which is in part due to the expected increased demand for rare earth magnets used in permanent magnet motors for EVs. As discussed in Section 7.2, some of the most advanced rare earth projects are found in Australia and Africa. Exhibit 8.6 shows a comparative table for the Australian projects.

Relative to the Canadian projects, the Australian rare earth projects are more advanced. All of the projects in Exhibit 8.6, with the exception of the Charley Creek project, have a feasibility study. It should also be noted that the main minerals in the Australian deposits are those that have been commercially processed, i.e., monazite, bastnaesite and xenotime. As such, at the surface, the metallurgical flowsheet for these projects may be considered less risky than the Canadian projects. However, as none of the project flowsheets for these companies include high-grade mineral concentrates (>30%) from physical beneficiation only, there is probably no obvious flowsheet advantage.

The Australian companies with the highest capital costs are those that are planning to produce separated oxides and have a light rare earth deposit, specifically, Arafura Resources with the Nolan project and ASM with the Dubbo project that has estimated operating costs higher than the current undiscounted basket price.

Exhibit 8.6: Advanced rare earth projects in Australia

	Deposit	**Nolan**	**Yangibana**	**Dubbo**	**Charley Creek**	**Browns Range**
	Company name	Arafura Resources	Hastings Technology Metals	Australian Strategic Materials	Enova Mining	Northern Minerlas
	Country	**Australia**	**Australia**	**Australia**	**Australia**	**Australia**
	Dominant REE Minerals	Apatite	Monazite	Zircon silicates and bastnäsite	Monazite and xenotime	Xenotime
Company Estimates	**Grade (TREO%)**	**2.6%**	**1.2%**	**0.7%**	**0.03%**	**0.6%**
	NdPr (% of TREO)	27.0%	4.4%	18.2%	19.2%	3.9%
	HREO (% of TREO)	2.0%	32.5%	7.4%	8.4%	29.1%
	Y-HREO (% of TREO)	3.3%	85.8%	23.3%	21.3%	87.3%
	Total CapEx (US$M)	$734	$335	$1,100	$114	$329
	Capex/tonne	$46	$39	$220	$31	$108
	LOM Annual OpEx (US$/kg final product)	$9.6	$17.6	$43.5	$4.6	A$37.6
	Undiscounted Basket Price (US$/kg TREO)	$17.3	$36.8	$18.7	$20.2	$36.1
	Target Production (tonnes contained TREO)	16,125	8,500	5,000	3,645	3,060
	Rare Earth Product	Separated Oxides	Mixed Carbonate	Separated Oxides	Mixed Carbonate	Separated Oxides

Source: Tahuti Global

Exhibit 8.7 shows a comparative table of rare earth projects in Africa, and like the Australian projects, most African project's dominant minerals are those that have been commercially processed. Africa is also home to the highest-grade deposits in the world; one such example is the Gakara deposit in Burundi.

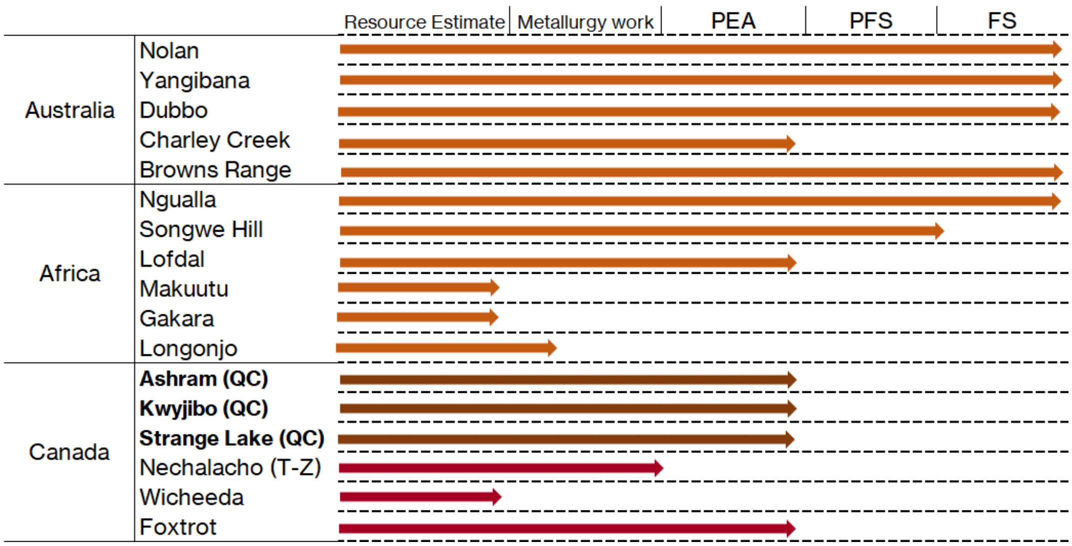
Exhibit 8.7: Advanced rare earth projects in Africa

	Deposit	**Ngualla**	**Songwe Hill**	**Lofdal**	**Makuutu**	**Gakara**	**Longonjo**
	Company name	Peak Resources	Mkango Resources	Namibia Critical Metals	Ionic Rare earths	Rainbow rare Earths	Pesana Metals
	Country	**Tanzania**	**Malawi**	**Namibia**	**Uganda**	**Burundi**	**Angola**
	Dominant REE Minerals	Bastnäsite	Synchysite and apatite	Xenotime	Ionic clays	Bastnäsite	Bastnäsite and monazite
Company Estimates	**Grade (TREO%)**	**4.2%**	**1.4%**	**0.3%**	**0.08%**	**47.0%**	**1.4%**
	NdPr (% of TREO)	21.3%	21.3%	1.3%	n.a.	19.0%	21.9%
	HREO (% of TREO)	1.1%	3.7%	31.7%	n.a	n.a	3.0%
	Y-HREO (% of TREO)	1.3%	7.3%	94.5%	100.0%	2.0%	5.5%
	Total CapEx (US$M)	$365	$216	$163	n.a	$25	$200
	Capex/tonne	$39	$76	$109	n.a	$3	$11
	LOM Annual OpEx (US$/kg final product)	$11.7	$26.4	$50.5	n.a	$1.7	n.a
	Undiscounted Basket Price (US$/kg TREO)	$13.5	$16.5	$37.4	n.a	$12.2	$15.8
	Target Production (tonnes contained TREO)	9,290	2,841	1,500	n.a	10,000	18,273
	Rare Earth Product	Separated Oxides	Mixed Carbonate	Separated Oxides	n.a	Mixed Carbonate	Mixed Carbonate

Source: Tahuti Global

Exhibit 8.8 demonstrates the development stage of a number of international projects, with several at the feasibility stage. However, none of these projects have been able to secure financing to advance to production, likely because some of their assumptions such as rare earth prices are outdated. In this situation, studies have to be repeated and, in some cases, revert to the scoping study level if major adjustments to ore reserves, mining design, and flowsheet are required. It is likely accurate to conclude that most projects are at the same level of development, in the sense that they are looking for strategies to adapt to lower prices and may need to restart projects with new preliminary economic studies.

Exhibit 8.8: Stage of development of Canadian and select international projects



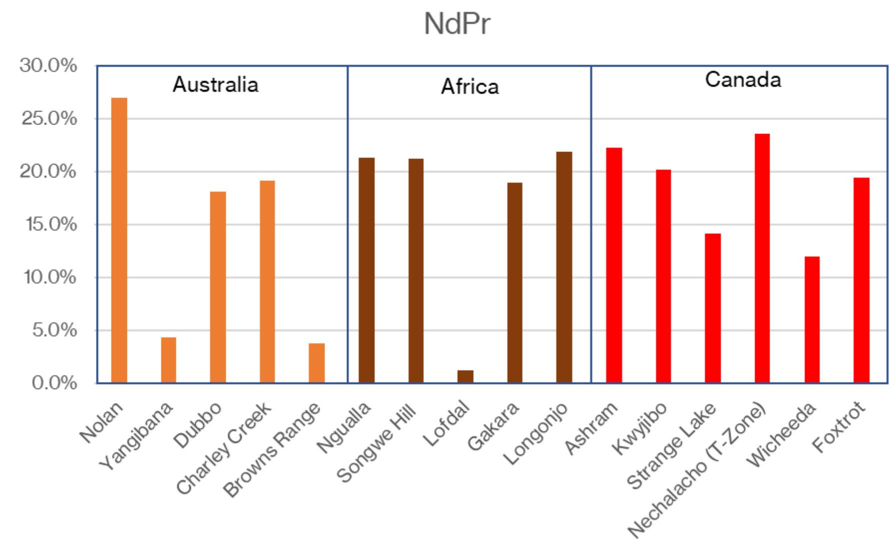
Source: Tahuti Global

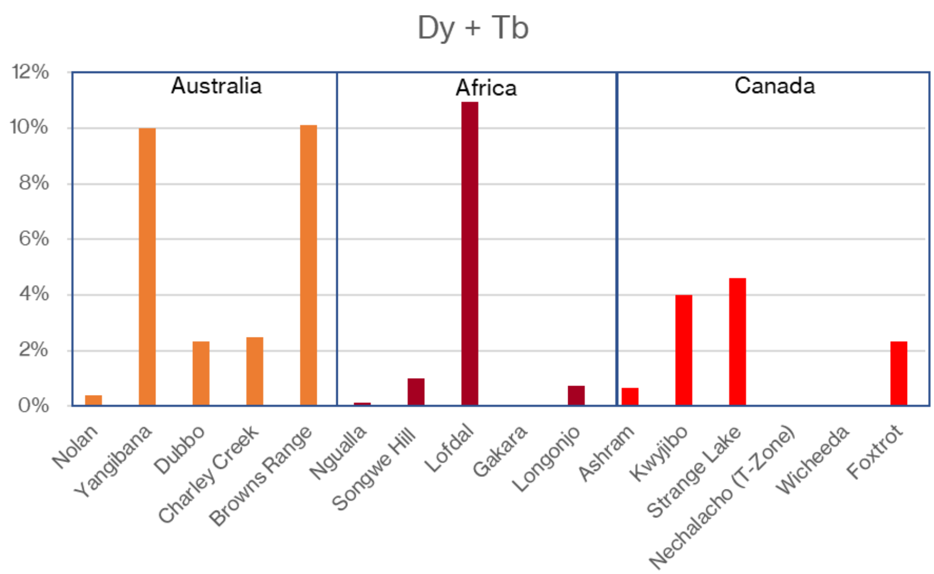
The Québec projects are less developed than many of the projects in Australia and Africa, and with the exception of the Ashram deposit, the Québec deposits have complex mineralogy with minerals that have not been commercially processed. The capital costs of the Québec projects are also some of the highest.

8.3. Analysis of Rare Earth Distribution

The analysis of the rare earth distribution shows that Québec and other Canadian projects have comparable levels of NdPr grade. As expected, the Canadian light deposits, including Ashram, have low levels of heavy rare earths. Kwyjibo and Strange Lake are both considered heavy deposits and they have good levels of dysprosium and terbium.

Exhibit 8.9: Distribution of NdPr, Dy, and Tb in select deposits





Source: Tahuti Global

9. Demand and Supply Forecast

9.1 Demand Forecast

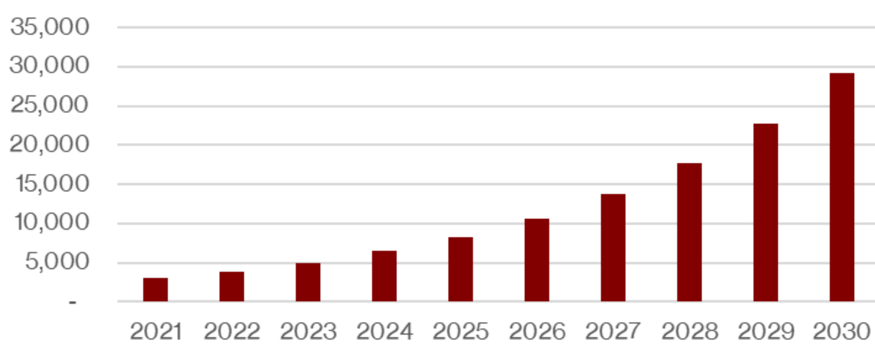
Rare earths are used in all major industries, from automotive, technology and communications to medicine and construction materials. Demand growth for most rare earths is linked to the general performance of the economy and global GDP growth is generally a good forecast rate for the demand growth of most rare earth elements. However, the anticipated increase in the adoption of electric passenger vehicles is expected to cause a dramatic rise in demand for rare earth elements used in EVs. China, India, and several European countries are planning to phase out combustion engine vehicles in the next 15 to 20 years. This aggressive plan will lead to a dramatic increase in demand for many strategic materials including rare earths.

Electric vehicles use electric motors, and the two most commonly used are the induction motor and the permanent magnet motor (PMM), which uses rare earths and tends to offer better performance but is more expensive. It has been estimated that approximately 87.5%[18] of all electric passenger vehicles used PMM in 2019, meaning that of the 2.1 million passenger vehicles sold, 1.9 million had PMMs. The motors have on average 3 kg of NdFeB magnets, and the rare earths account for 31% of the magnets' weight. The total production of neodymium (Nd) and Praseodymium (Pr) in 2019 is estimated at about 40,000 tonnes; with 2.1 million vehicles sold in 2019, the estimated amount of NdPr used in EV passenger vehicles is about 2,400 tonnes. The remaining amounts of Nd and Pr were likely used to make magnets for many other industrial applications, as well as PPM used in non-EV applications, among other applications.

To estimate the long-term demand for additional NdPr for EVs, the following assumptions were made:

- Average annual increase in total passenger vehicles, to 2030 = 2%;
- Average annual increase in EV sales, to 2030 = 25% (would lead to a 30% share of total vehicles sold by 2030). (Similar to some countries in the EU, Canada is targeting 30% zero emission vehicle (ZEV) sales in 2030[19], 100% ZEV sales by 2040);
- NdPr weight per vehicle = 1 kg.

Exhibit 9.1: Demand forecast for additional NdPr for use in PMM for electric vehicles



Source: Tahuti Global

[18] https://copperalliance.org/wp-content/uploads/2020/03/EV-Motors.pdf
[19] https://www.nrcan.gc.ca/energy-efficiency/energy-efficiency-transportation/zero-emission-vehicle-infrastructure-program/21876

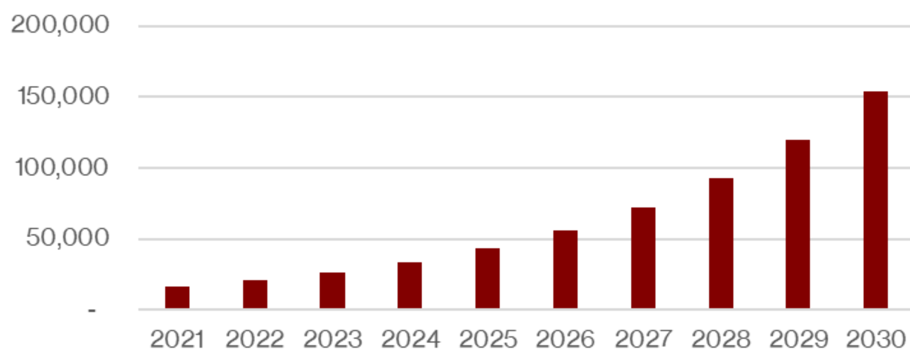
Our forecast assumes that only about 30% of the total passenger vehicles would be electric by 2030 and does not include the use of PMM in any other types of vehicles (e.g., trucks and buses) or devices (e.g., wind turbines, drones, etc.).

The model forecasts that 3,000 tonnes of NdPr would be required in 2021 and that demand would rise to about 30,000 tonnes by 2030.

9.2 Supply Forecast

Rare earth supply increased by 53% from 132,000 tonnes in 2017 to 210,000 tonnes in 2019, with about 80,000 tonnes of new mine production mainly coming from Myanmar, the United States, and China. Given the natural concentrations of Nd and Pr, to supply NdPr for the production of permanent magnets for EV motors alone, the world would have to increase current mine production by 70% in the next 10 years in order to add an additional 150,000 tonnes of total rare earths.

Exhibit 9.2: Estimated supply of total rare earths to fulfill demand for NdPr magnets for electric vehicles



Source: Tahuti Global

Demand for rare earth magnets for other applications, like wind turbines and drones, will drive demand for rare earths even further. For instance, the EU wants to increase its offshore wind capacity, and is planning to build 60 gigawatts (GW) of offshore wind by 2030 and 300GW by 2050[20], from the current capacity of 12GW. On average, an offshore wind turbine requires up to 232 kg of NdPr/MW, which means by 2030, the EU (excluding the UK) would require about 13,920 tonnes of NdPr and by 2050, 69,600 tonnes of NdPr. This equates to an additional 70,000 tonnes of total rare earths by 2030 to fulfil EU demand for NdPr magnets for wind turbines alone. Permanent magnets are also used in drones, and the market value is expected to increase from US$14.1 billion in 2018 to US$43.1 billion by 2024, a 20.5% compounded annual growth rate[21].

9.2.1 New Supply Sources

China is believed to have over 250,000 tonnes of refining capacity, however, the government has closed several operations due to environmental concerns. The Chinese government has also introduced domestic production quotas[22] in an attempt to control the domestic exploitation of rare

[20] https://ieefa.org/europe-plans-massive-expansion-in-offshore-wind-60gw-by-2030-300gw-by-2050/
[21] DRONEII.com
[22] https://ca.reuters.com/article/idUSKCN24H1J8

earth resources. China will likely play an important role in increasing rare earth supply, but additional mines and particularly refining capacity outside China will be required to meet future demand.

The Mountain Pass mine in California (USA) could increase production capacity to 40,000 tonnes of rare earths, but the current processing facility (currently inactive) is designed for a 20,000-tonne capacity. Lynas mine production at Mount Weld in Australia could also increase production to 40,000 tonnes a year at a relatively small capital cost, but it would have to build capacity at a separation facility in Malaysia.

The Myanmar mines have been described as ion adsorption clays with high percentages of yttrium and heavy rare earths, which means their contribution to NdPr production may not be as significant even if mining production doubles. They would however be able to supply the high-priced dysprosium and terbium that are used in high-performance magnets.

With most projects at a similar development stage and facing similar technical and financing challenges, it is difficult to predict which ones will ultimately receive the risky financing from investors and/or government and achieve commercial production. Exhibit 9.3 presents potential sources for new rare earth supply.

Exhibit 9.3: Potential new REE supply sources

Within the next 6 years
Mountain Pass - Start processing facility with capacity of 20,000 t TREO
Mount Weld - Increase production to 40,000 t TREO
Araxá- Start production of separated oxides 5,000 to 10,000 t TREO
Nechalacho WT, (Canada) - Production of mineral concentrate 5,000 t TREO
Wicheeda (BC, Canada) - Production of mineral concentrate 3,000 tTREO
Other - Asia: expansion or new production 5,000 to 20,000 t TREO

Between 7 and 12 years
Mountain Pass - Increase processing capacity to 40,000 t TREO
One or two Australian projects - 5,000 to 20,000 tonnes TREO
One of the Quebec Projects - 7,500 to 15,000 t TREO
Projects in Africa - 5,000 to 20,000 tonnes TREO (separation in Europe/China)
Other - S. America: new mine 5,000 t TREO; Asia: expansion or new production

Source: Tahuti Global

In Canada, the projects that are targeting the production of mineral concentrate and require low capital cost have a good chance of reaching production in less than six years. The most advanced Québec projects all need to complete feasibility studies, which under good financing conditions (and assuming no processing challenges) would take at least two to three years to complete. Project engineering, commissioning, and construction would require another four to six years. However, that is assuming good financing markets and straightforward flowsheet optimization.

Australia has several projects that have completed feasibility studies, but because they are capital intensive, only one or two are likely to reach production. In South America, the Araxá project owned by CBMM could reach production within six years if the company stays committed to the project. CBMM has built a pilot plant and has the funding capacity to bring the project to fruition. In Africa, Rainbow Rare Earths is already producing small amounts of rare earth concentrate and is looking to increase production if additional resources are found.

Some projects in Québec have large resources (e.g. Ashram and Strange Lake) and good levels of NdPr (Exhibits 8.4 and 8.9). One large REE mine in Canada producing 30,000 to 50,000 tonnes of rare earths in the long term could become a major supplier of NdPr for the global markets. This level of output was unthinkable 10 years ago when total production was about 124,000 tonnes and there were no clear demand drivers. With economies of scale, it is possible that the demand for large volumes of rare earths could make some Canadian projects economic at current prices, despite the costly infrastructure requirements.

An aggressive increase in supply will likely lead to excess availability of some rare earth elements, particularly lanthanum and cerium, which usually account for more than 70% of total rare earths in light deposits, and yttrium which usually represents 30% to 65% of the total rare earth concentration in heavy deposits.

9.2.2 Recycling

There are efforts to build recycling capacity to support the production of critical materials for EVs. The battery for EVs today is expected to last at least 10 years, as such, by 2030 the number of EVs available for recycling (the battery, motor and other parts) should not exceed the 2020 sales of EVs (~2 million). If all of the vehicles sold in 2020 had permanent magnet motors and all of them had the motors recycled to recover NdPr, that would add only 2,000 tonnes of NdPr to the market, a fraction of what is required. Recycling of EV parts for the recovery of critical materials will have a more significant contribution in 20 to 30 years as more vehicles become available for recycling; until then, these materials will have to be obtained from primary sources.

10. Conclusions and Recommendations

The supply and consumption of rare earths are still dominated by China. Although China now accounts for much less of the global world production, with 62% of total mine production currently compared to 97% in 2009, the country still controls the production of refined rare earths (85%) and the supply chain of the end products.

Rare earth production has dramatically increased in the last three years (53%) and is expected to continue to grow spurred by future demand for rare earth magnets used in electric motors for EVs. An additional 150,000 tonnes of rare earths will be needed by 2030 to fulfill demand for magnets for the electric market alone. This opens an opportunity for current rare earth projects, like those in Québec, to bring additional rare earth supply to the market.

For Québec to develop a mine to market rare earth strategy, the following recommendations should be considered:

- **Invest in the rare earth sector.** The Québec government should consider supporting the research and development in the rare earth sector and eventually foster the development of rare earth mines in the province through direct equity investment, favourable loans, grants, and other financial and fiscal programs. Rare earth projects are risky and expensive, each requiring nearly one billion dollars to reach production (as per the company's economic studies). Therefore, R&D is essential to ensure solid grounds for the development of rare earth projects. Selecting the projects to support will not be easy, but one of the key requirements for the success of rare earth projects is favourable mineralogy and metallurgy. Projects with a high percentage of multiple and unusual minerals carry higher technical risk. The management team is also key for the success of a company/project; as such, if Québec decides to make any investments towards the development of a project, it should furnish the board and management team of the company/project with competent and experienced personnel.

- **Lobby foreign governments.** The United States and Europe have several initiatives (e.g., ERMA (European Raw Materials Alliance)) to secure critical materials and have allocated billions of dollars. Québec has more and further advanced rare earth projects than those in Europe and the United States, with relatively better potential for commercialization; as such, Québec should approach the European and United States governments with proposals to jointly support the development of a Québec rare earth mine and refinery, as well as the supply chain of various rare earth products in different locations and across borders. Québec mines are a source for ethical, clean (e.g., hydro power) and sustainable minerals.

- **Conduct broad supply-chain study.** Companies in Québec, Canada, and the United States (Canada's largest trading partner) that are importing rare earth products should be engaged to determine what products they are importing, for what end-uses, and the size of those markets. The study will help determine the potential of developing different supply chains for the various rare earth applications to support the North American and export markets.

- **Attract foreign companies and professionals to bring expertise.** The expertise in rare earth metal making, and alloy and magnet production is concentrated in Asia. To complete the supply chain, Québec will need to develop metal and alloy production capabilities.

- **Invest in rare earth-related research and development (R&D).** Rare earths are used in multiple applications due to their unique electric, optical, magnetic, and chemical properties. R&D is key to supporting new products and improving current technologies to make local companies competitive.

Québec does not have to develop a rare earth mine in order to build a rare earth supply chain. However, a local rare earth mine and refinery, as well as metal making and alloy fabrication are more likely to attract downstream businesses.

Appendix

Companies in Québec importing catalysts, LEDs and permanent magnets.

381519 Supported Catalysts - With Other Compound Nes As The Active Substance

Company name

W. R. GRACE CANADA CORP.

854140 Photosensitive Semiconductor Devices, Photovoltaic Cells and Light Emitting Diodes

Company name

9311-6028 QUEBEC INC.

ABB ELECTRIFICATION CANADA

ARANI SYSTEMS CORP.

AXIS LIGHTING INC./ ECLAIRAGELIGHTING INC.

CMC ELECTRONICS INC. CMC ELECTRONIQUE INC.

EXCELITAS CANADA INC.

EXFO INC.

FUTURE ELECTRONICS INC.

GMA SOLAR INC.

GROUPE VARITRON INC.

GUILLEVIN INTERNATIONAL CO

Company name

IAPI-SAINT LAURENTSPARES&SERVICE

LASER COMPONENTS, CANADA INC.

MPB COMMUNICATIONS INC

ON SEMICONDUCTOR CANADA TRADING CORPORATION

SACO TECHNOLOGIES INC.

SIGNALISATION VER-MAC INC.

STACE SOLAR SOLUTIONS INC.

TASK MICRO-ELECTRONICS INC

TELOPS INC.

THALES CANADA, DEFENSE & SECURITY, OPTRONICS

TTI MONTREAL

850511 Permanent Magnets - Metal

Company name

ABB ELECTRIFICATION CANADA ULC/ABB ELECTRIFICATION CANADA SR

AIM RECYCLAGE MONTREAL

AMF AUTOMATION TECHNOLOGIES COMPANY OF CANADA

AROME ET SANTE INC

AXSUB INC.

BARRY CALLEBAUT CANADA INC.

BEACON ROOFING SUPPLY CANADA COMPANY

BITZER CANADA INC

C.D.M.V. INC.

CANADAIR

CANADIAN NATIONAL RAILWAY COMPANY / COMPAGNIE DES CHEMINS DE

CANAROPA 1954 INC

CON-V-AIR INC

CONCASSES DE LA RIVE SUD INC

CONTINENTAL CONVEYOR & MACHINE LTD/CONVOYEUR CONTINENTAL & U

CYCLES DEVINCI INC

DALIMAR INSTRUMENTS ULC

DANESCO INC.

DISTRIBUTION LAURENT LEBLANC INC

DOLLARAMA S.E.C./DOLLARAMA L.P.

ELBY GIFTS INC. LES CADEAUX ELBY INC.

EOCYCLE TECHNOLOGIES INC.

FIVES LINE MACHINES INC.

ROTOBEC INC

SOLUTIONS SERAFIN INC.

SOUVENIR AVANTI INC.

SPECTOR & CO. INC.

SUGATSUNE CANADA INC.

SYSTEMES DE SECURITE PARADOX LTEE

FUJI SEMEC INC.

G2S EQUIPEMENT DE FABRICATIONET D'ENTRETIEN INC.

GASTON RICHARD INC

GROUPE R.Y. BEAUDOIN INC.

HUMAN RESOURCES AND SOCIAL DEVELOPMENT CANADA

HUSSMANN CANADA INC.

ILOT 307 INC.

KEURIG CANADA INC.

LES INDUSTRIES LAM-E INC

LES MOUSTIQUAIRES VISION SCREENS DIV OF NOVAVISION INC.

LES PRODUCTIONS DIAMANT LTEE

LIBRAIRIE RENAUD-BRAY INC

LUMENPULSE GROUP INC. / GROUPE LUMENPULSE INC.

MAAX BATH INC.

OR INTEGRA QUEBEC INC. INTEGRA GOLD QUEBEC INC.

PATRICK MORIN INC.

PRODUITS A+ CANADA INC./A+ PRODUCTS CANADA INC.

PT SYSTEMS AND AUTOMATION

QUINCAILLERIE RICHELIEU LTEE RICHELIEU HARDWARE LTD

RADIO-ONDE INC.

RICHELIEU HARDWARE CANADA LTD.

RIDEAU RECOGNITION SOLUTIONS INC. SOLUTIONS DE RECONNAISSANC

ROLF C. HAGEN INC.

TAG REPERAGE INC.

TECHNOLOGIES LANKA INC.

TELEFLEX MEGATECH INC.

TENAQUIP LIMITEE/

TM4 INC.

TOTEM ACOUSTIQUE INC

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