

Annexes : glossaire, méthodologie et ressources scientifiques

**Vers une utilisation responsable des terres rares
tout au long de leur cycle de vie**

Rapport de l'expertise scientifique collective

Annexes

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Glossaire

Aimant permanent : matériau qui produit un champ magnétique permanent sans consommer d'énergie. Le mouvement relatif d'un aimant par rapport à une bobine de cuivre (ou d'un autre métal conducteur) induit dans celle-ci un courant électrique. À l'inverse, l'injection d'un courant variable dans la bobine produit un effort qui déplace l'aimant. Ce principe est mis en œuvre, par exemple, dans les moteurs de véhicule électrique. Ceux-ci peuvent produire l'effort pour déplacer le véhicule et produire de l'énergie électrique au freinage pour recharger la batterie.

Bauxite : roche formée par accumulation de sédiments et caractérisée par sa forte concentration en aluminium. L'exploitation des mines de bauxite constitue ainsi la principale source de production mondiale d'aluminium. Les résidus de bauxite, également appelés « boues rouges » lorsqu'ils sont hydratés, contiennent des concentrations en ETR pouvant atteindre 0,2% en masse.

Exploitation: organisation des activités visant à extraire et valoriser des métaux.

Extraction : action physique de retirer le minerai du sous-sol (sens géologique) ou l'action physico-chimique de séparer des composés métalliques d'autres composés (sens de l'ingénierie des procédés).

Gisement : gîte pour lequel les conditions du marché satisfont des conditions d'exploitation économiquement viable.

Gîte : une occurrence dans la croûte terrestre de concentrations de substances utiles (comme les métaux) anormalement élevées.

Lixiviation : traitement par dissolution d'une substance par un liquide pour en extraire les constituants solubles. La biolixiviation repose sur des micro-organismes capables d'opérer cette solubilisation.

Métaux stratégiques : métaux associés à certains secteurs stratégiques comme la défense ou ceux des politiques de transition (énergétique, mobilité...). Certains ETR appartiennent à ce groupe qui inclut aussi d'autres métaux (lithium, cobalt...).

Métaux critiques : métaux qui possèdent un rôle économique important, qui sont difficilement substituables et qui présentent des risques d'approvisionnement. Les ETR appartiennent à ce groupe qui inclut aussi d'autres métaux.

Mine urbaine : masse de déchets provenant du milieu urbain (objets en fin de vie) et pouvant représenter une réserve, notamment métalliques, en vue d'être réutilisées ou recyclées.

Performance des matériaux : capacité des propriétés du matériau à répondre efficacement aux exigences d'une application donnée. Par exemple, la performance d'un aimant est l'énergie maximale qu'il est capable de stocker (et donc de livrer) selon son volume, ainsi que le seuil maximal de température à partir duquel il perd son aimantation.

Phosphogypses : déchet minier généré lors de la production d'engrais à partir de roches issues de l'extraction des phosphates destinés à la production d'engrais ou d'acide phosphorique. Le stockage de ce déchet pose certains risques environnementaux et sanitaires, en raison de sa toxicité. Ce déchet contient des ETR.

Raffinage : processus physico-chimique qui permet d'obtenir un métal ou un composé de haute pureté, en éliminant les dernières impuretés présentes dans le produit issu du traitement. Cette étape finale est nécessaire à une majorité d'applications, mais pas à toutes selon les performances souhaitées.

Recyclage court (ou boucle courte) : processus de recyclage visant à réduire les étapes de récupération et de traitements de déchets, en ne revenant pas au composant initial.

Recyclage long (ou boucle longue) : processus de recyclage qui fait intervenir des transformations complexes permettant un usage du matériau recyclé hors de ses applications d'origine.

Réemploi : toute opération par laquelle des produits ou composants qui ne sont pas des déchets sont réutilisés dans le même but que celui pour lequel ils ont été conçus. (Code de l'Environnement français art. L541-1-1)

REP : principe de Responsabilité Élargie des Producteurs, reconnu dans la directive-cadre européenne sur les déchets, selon lequel les producteurs, c'est-à-dire les personnes qui mettent sur le marché certains produits, peuvent être rendus responsables du financement ou de l'organisation de la prévention et de la gestion des déchets issus de ces produits en fin de vie.

Réserve : partie d'une ressource qui peut être extraite de manière économiquement rentable avec les techniques disponibles et selon les conditions légales et environnementales actuelles.

Ressource : quantité totale d'un minerai ou d'un matériau présent dans le sous-sol, qu'il soit exploitable ou non à un moment donné.

Réutilisation : toute opération par laquelle des produits ou composants qui sont des déchets sont réutilisés. (Code de l'Environnement français art. L541-1-1)

Séparation : processus mécanique et/ou physique destinés à concentrer les métaux d'intérêt dans la matière (minerais ou matériau) en les isolant des autres composants.

Sobriété : elle « consiste à nous questionner sur nos besoins et à les satisfaire en limitant leurs impacts sur l'environnement » (ADEME). Dans le cadre de cette expertise, la sobriété a été abordée de trois manières différentes : (i) une approche visant à réduire la consommation d'ETR par une utilisation plus efficace des matériaux et des technologies qui en dépendent ; (ii) le développement de technologies alternatives qui nécessitent moins ou aucune de ces ressources ; (iii) une réflexion sur les usages des objets contenant des ETR et les leviers de réduction de ces usages.

Source secondaire : sources d'ETR autres que la production primaire tirée de l'exploitation des mines d'ETR. Ces sources incluent les déchets d'autres mines (ex. : résidus de bauxite, phosphogypses), les déchets industriels (ex. : cendres de charbon, rebuts de fabrication d'aimants permanents) et les produits en fin de vie contenant des ETR, aussi connus sous le nom de mine urbaine (ex. : smartphones, voitures électriques, éoliennes, solutions d'agents de contraste, etc.)

Traitement : ensemble des opérations physico-chimiques ou métallurgiques destinées à transformer la matière triée (minerais ou matériau) en un concentré métallique plus ou moins pur.

Méthodologie

Cadrage de l'ESCo

En 2023, le CNRS établit la nécessité et l'opportunité d'une expertise scientifique collective sur les terres rares. Les objectifs politiques de transition numérique et énergétique, la rupture des chaînes d'approvisionnement internationales pendant et à la suite de la pandémie, l'aggravation de tensions géopolitiques ont conduit à l'émergence de politiques en Europe, aux États-Unis et ailleurs visant à sécuriser l'approvisionnement en matières critiques et stratégiques des filières industrielles. Une approche par la sécurisation des stocks et des réserves en métaux critiques et stratégiques est abordée par différents acteurs. Aussi, la littérature scientifique portant sur les usages des terres rares est conséquente. Pour autant, il apparaît que ces connaissances demeurent marquées par une relative dispersion, une hétérogénéité selon les disciplines de recherche scientifique. Le 5 janvier 2024, le Président-Directeur général du CNRS saisit la Mission Pour l'Expertise Scientifique afin de synthétiser les acquis de la recherche, mettre en évidence les incertitudes, les controverses et les lacunes, et diffuser publiquement ces résultats en vue d'éclairer la décision et le débat publics.

En 2023, en amont du projet d'ESCo, une phase de préfiguration impliquant notamment quatre chercheur.e.s et des directeurs adjoints scientifiques du CNRS avait fait émerger une dizaine de problématiques disciplinaires relatives aux ETR, mettant en évidence les compétences nécessaires. Les trois pilotes scientifiques ont alors été sélectionné.e.s en raison de leurs compétences et sur la base de leur production scientifique. Les pilotes et la MPES ont fait émerger le choix d'une entrée par les usages responsables des ETR dans une approche d'économie circulaire pour répondre de manière systémique et pluridisciplinaire aux défis géopolitiques et de souveraineté l'approvisionnement de la France et l'Europe. Il est le fruit d'un constat général selon lequel l'approvisionnement actuel en ETR n'est pas soutenable, et cela pour plusieurs raisons :

- les taux de croissance annuels très importants de la demande — y compris en ETR — entraînent une dépendance vis-à-vis des gisements primaires et à un épuisement de ces derniers ;
- l'impact environnemental de l'extraction est très élevé : les gisements sont souvent faiblement concentrés, et les ETR complexes à séparer les unes des autres ;
- les externalités négatives liées à l'extraction et à la transformation des ETR ne sont à l'heure actuelle pas maîtrisées ;
- les risques géopolitiques actuels sont élevés et la dépendance à la Chine pour l'approvisionnement en ETR demeure problématique.

Ces constats avaient déjà fait — pour la plupart — l'objet de travaux détaillés. Ils sont documentés par certains acteurs publics (le BRGM par exemple). Un travail de cadrage en 2023 a permis d'inscrire l'ESCo en complémentarité de l'existant, en interrogeant l'insertion des ETR dans l'économie circulaire : dans quelle mesure une utilisation plus responsable des ETR est-elle envisageable ? L'originalité de l'approche résidait dans le fait de questionner les usages en ETR plutôt que d'interroger les réserves. En questionnant la soutenabilité de l'utilisation des ETR, l'expertise s'est donné l'objectif d'explorer les relations entre la demande et le besoin réel minimum, plutôt que d'établir les conditions d'une augmentation « aveugle » de l'offre des ETR. Ainsi ont émergé les trois axes : Réduire, Recycler et Extraire Autrement.

Constitution du groupe d'expert.e.s

Le collectif d'experts s'est composé de scientifiques appartenant à l'enseignement supérieur et la recherche publics français, affiliés ou non au CNRS. Ce collectif devait représenter la variété des disciplines impliquées. Conformément au principe de compétence de la charte de l'expertise scientifique du CNRS, les expert.e.s ont été identifié.e.s sur la base de leurs champs de compétences et de leurs productions scientifiques, avec les pilotes scientifiques de l'ESCo et avec l'appui du comité de suivi du

CNRS. Ils ont été retrouvés parmi les publiants français.e.s des premières listes de publications réunies sur la base de mots clés. Ils ont été nommés par le CNRS après avis du comité d'orientation de l'expertise scientifique du CNRS. **Un groupe principal de 17 expert.e.s a ainsi été constitué.**

Conformément au principe d'indépendance de la charte, chacun.e a déclaré les liens d'intérêts qu'il entretient au regard du sujet. Ces déclarations ont été analysées par une commission présidée par le Déontologue du CNRS pour établir l'absence de conflits d'intérêts les concernant. Le CNRS n'a pas communiqué leur identité jusqu'à la restitution des résultats afin de les préserver de stratégies d'influence et de toutes formes de pression dont ils pourraient faire l'objet sur les sujets sensibles de l'expertise. Inversement, les expert.e.s n'ont pas communiqué sur leur participation à cette ESCo en dehors de leurs hiérarchies.

L'ESCo a fait appel à un second cercle de **13 expert.e.s contributeurs.trices** pour apporter un éclairage sur un volume restreint de publications et sur des domaines sur lesquels le premier cercle était en limite d'expertise. Leur contribution a pu prendre différentes formes : des lectures des publications et/ou une rédaction de notes intégrées aux livrables et/ou une relecture au sein du rapport ou de la synthèse.

Constitution de la base de ressources scientifiques

La constitution du corpus de publications scientifiques sur laquelle l'ESCo s'est fondée sur l'objectif de restituer l'état de l'art selon les articles publiés dans des revues scientifiques nationales et internationales ayant un processus de relecture par les pairs. D'autres sources ont pu être mobilisées (notamment des ouvrages, importants dans certaines disciplines, comme le droit et la philosophie). La sélection et la certification de ces sources a été placées sous la responsabilité du collectif d'experts et des pilotes scientifiques qui ont procédé à une évaluation de la robustesse de la méthodologie et de la genericité des résultats selon des critères définis collectivement et décrits dans cette partie, de manière à respecter le principe d'impartialité de la charte de l'expertise scientifique du CNRS.

La MPES a fait appel à l'Institut de l'Information Scientifique et Technique (INIST) pour constituer la base de ressources *via* une méthode dite « par entonnoir », d'un corpus élargi au corpus final. Cet assemblage d'une base documentaire constituée exclusivement de publications scientifiques est réalisé de manière « bottom-up » selon trois axes : 1. Réduire, 2. Recycler, 3. Extraire autrement. Chaque axe étant composé d'un corpus dit de « sciences dures » (SD) et un de sciences humaines et sociales (SHS), selon une méthode dite « par entonnoir », basée sur l'interrogation de bases de données documentaires avec des équations de mots-clés relatifs au sujet, puis au tri par le groupe d'expert.e.s sur la base de guides de tri collectivement établis. Ainsi, le corpus n'est pas constitué à partir d'un plan pré-établi pour aller requêter ce qui y serait pertinent mais à l'inverse constitué pour couvrir sans a priori l'étendue de ce qui est publié pour alimenter un plan.

Corpus élargi

Bases de données

Les requêtes ont été réalisées dans plusieurs bases de données, en anglais et en français. Ont été interrogées les bases suivantes :

- Web of Science Core Collection (Clarivate), bases accessibles par abonnement sur la plateforme Web of Science (WoS) :
 - o Science Citation Index Expanded (SCI EXPANDED) ;
 - o Social Sciences Citation Index (SSCI) ;

- Arts & Humanities Citation Index (A&HCI) ;
- Emerging Sources Citation Index (ESCI) ;
- Book Citation Index (BKCI) :
 - Science (BKCI-S)
 - Social Science & Humanities (BKCI-SSH)
- Conference Proceedings Citation Index (CPCI) :
 - Science (CPCI-S)
 - Social Science & Humanities (CPCI-SSH)
- Current Chemical Reactions (CCR-EXPANDED) ;
- Index Chemicus (IC)
- Scopus (Elsevier)
- CorHAL/Conditor (base des publications scientifiques françaises s'appuyant sur HAL, PubMed, CrossRef et les thèses du Sudoc)
- Istex (réservoir d'archives scientifiques multidisciplinaires proposant du texte intégral)
- OpenAlex (base en accès ouvert)

CorHAL/Conditor, Istex et OpenAlex sont des bases gratuites. Le Web of Sciences et Scopus sont des bases payantes dont les accès sont négociés par le CNRS via le portail bib.cnrs. Il est à noter que les accès à Scopus ont été stoppés à la fin de l'année 2023. Les publications des quatre bases ont été fusionnées puis dédoublonnées.

Critères de recherche des bases

Des critères d'exclusion et d'inclusion ont été définis collectivement, d'abord pour l'ensemble des trois axes :

- Des critères d'exclusions pour les deux champs SD et SHS :
 - limitation aux années postérieures à 1990
 - limitation aux langues anglaise et française
 - exclusion des documents de type « *editorial* » ou « *meeting abstract* »
 - exclusion du scandium
- Des critères d'exclusion en SD seulement :
 - travaux spécifiques à un territoire hors UE (sauf si transposable)
 - publications non évaluées par un comité de lecture (exception de livres, par exemple : *Handbook of Rare Earth Elements*)
 - brevets et *proceedings*
 - publications publiées dans des journaux Q3/Q4¹
- Des critères d'inclusion en SHS seulement :
 - les publications peuvent être des papiers de recherche, mais aussi des papiers de revue ou des articles introductifs à des numéros spéciaux
 - les publications doivent :
 - porter sur des objets qui contiennent des terres rares ou qui contiennent des matériaux qui sont similaires dans leurs propriétés sociales (métaux rares ou matières premières critiques par exemple)
 - faire usage de concepts qui sont pertinents pour le sujet (par exemple, sur la chaîne de valeur, la gouvernance, l'écoconception)
 - appartenir disciplinairement au champ des SHS

La façon dont le groupe d'expert.e.s a usé de *transpositions* est décrit [plus loin dans le document](#).

¹ Q, l'abréviation de quartile, est utilisé pour classer les revues scientifiques en fonction de leur impact et de leur qualité dans leur domaine de spécialisation (Impact Factor ou le CiteScore). Les revues Q3 et Q4 font partie de la seconde moitié du classement.

Mots-clés et équations booléennes

Les mots-clés utilisés pour interroger les bases documentaires ont été déterminés collectivement par les pilotes de l'ESCO, les expert.e.s du groupe principal et les documentalistes de l'INIST. Les termes de recherche ont été enrichis avec des synonymes et des variantes orthographiques. Des traductions françaises ou anglaises ont été ajoutées.

Pour chacun des trois axes, les requêtes ont été réalisées en combinant des blocs de mots-clés avec des opérateurs booléens. Chacun des trois axes a été décliné selon les deux orientations SD/SHS avant d'être fusionnées. Les blocs de mots-clés et les équations de recherche sont décrits dans l'annexe de ce document.

Pertinence des corpus

Pour chaque axe et orientation des échantillons de corpus ont été évalués par les pilotes et les expert.e.s en fonction de leur domaine scientifique. Des modifications ont pu être apportées aux requêtes par mots clés en testant la capacité de récupérer les publications d'une liste témoin :

- Pour chacun des trois axes, les expert.e.s ont envoyé environ dix publications faisant référence dans leurs domaines scientifiques respectifs (SD et SHS).
- Les corpus issus des bases de données ont été comparés avec les corpus témoins correspondants.
- Le taux de recouvrement entre les corpus témoins et les corpus issus des bases permettaient d'évaluer le silence. Notamment, il était nécessaire que les publications définies comme « importantes » par les expert.e.s soient présentes dans les corpus.

Les requêtes par mots-clés ont été affinées jusqu'à obtenir un taux de recouvrement supérieur à 98% avec les listes témoins. Cette procédure a permis de garantir la complétude de la couverture des publications pertinentes (absence de silence).

Cette première étape a finalement abouti à un corpus élargi de 13 953 publications scientifiques.

Corpus intermédiaire

Suite à la livraison des corpus documentaires constitués sur la base de mots-clés par l'INIST, le groupe d'expert.e.s a ensuite opéré un tri sur la base des titres, résumés et mots clés pour éliminer les publications non-pertinentes (bruit). Le tri a été réalisé indifféremment par n'importe quel expert.e.s au sein dans chacune des deux orientations (SD et SHS). Pour cette étape, l'outil de revue de littérature Rayyan a été utilisé.

Des critères d'exclusion ont été déterminés collectivement pour chaque axe :

- Axe 1 - SD²

² Devant la taille du corpus, et le nombre de publications redondantes et similaires, il a été recommandé de ne garder que les papiers où la notion de comparaison avec un composé/matériaux/process contenant soit moins (soit plus) d'ETR est explicite et/ou chiffrée. En effet, le "rare-earth free" semble être une très forte tendance de recherche, facile

- de nouveaux composés/matériaux/process "rare earth free", qui ne sont pas comparés avec des composés contenant des ETR
- de nouveaux composés/matériaux/process plus performants à base d'ETR qui ne sont pas comparés avec l'existant
- de nouveaux composés/matériaux/process "rare earth free" dont des performances sont chiffrées dans l'absolu (quantum yield, quantum efficiency, T2 relaxation time,...) mais non comparés
- de nouveaux composés/matériaux/process dont l'amélioration de la propriété visée n'est qu'évoquée sans être réellement mesurée.
- Axe 1 - SHS
 - No REE
 - Wrong location
 - No transposition
 - Wrong publication type
 - Wrong empirical focus
 - Wrong scope
 - No sobriety
 - Wrong outcome
 - Background article
- Axe 2 - SD
 - Out of scope
 - Proceeding
 - Background article
 - Foreign language
 - Wrong study design
 - Wrong drug
 - Wrong publication type
 - Wrong outcome
- Axe 2 - SHS
 - No REE
 - wrong empirical focus
 - Wrong location
 - No transposition
 - Too general
 - Out of scope
 - No abstract
 - Wrong publication type
 - No recycling
 - Background article
- Axe 3 - SD
 - Out of scope
 - Caractérisation de gisements hors Europe (exceptés fonds océaniques), sauf si la caractérisation est originale
 - Extraction à partir d'un minerai hors Europe, sauf si le procédé est original et plus "responsable"
- Axe 3 - SHS
 - No REE
 - no extraction
 - Wrong location
 - Wrong empirical focus
 - No transposition
 - Wrong publication type

à valoriser. Or il semble trop complexe d'évaluer la pertinence d'un nouveau composé/matériaux/process usage par usage pour la seule raison qu'il ne contient pas de terres rares.

À la fin de ce tri, le corpus était constitué de **4 598 publications scientifiques**.

Corpus final

Les références de ce corpus intermédiaire ont été versées dans une bibliothèque numérique collective (Zotero). Le tri opéré par Rayyan avait permis de « tagger » chacune des publications avec des mots-clés tels que (en SD) « magnets », « hydrometallurgy », « sedimentary », (en SHS) « design », « waste management », « controversial project », etc. Cela a permis de répartir les références par expert.e.s au sein de chaque axe. Ensuite, les expert.e.s ont pu classer les références dans des dossiers thématiques correspondant aux futures sections du rapport. Un dossier de « réattribution » a permis de transférer une référence d'un.e expert.e à un.e autre quand la répartition par « tags » n'avait pas été pertinente.

Les textes complets des publications ont été importés pour chacune des références. Un dernier tri a été réalisé sur la base de leur lecture. Les expert.e.s ont classé les publications en trois catégories, celles de premier rang, de second rang et celles à exclure. Ce classement a été réalisé selon la pertinence scientifique du contenu des articles. En particulier, ont été exclues les publications qui présentaient des résultats jugés :

- non robustes : une représentativité de l'échantillon inadaptée, une méthodologie fragile du protocole... ;
- incrémentaux : la reproduction de résultats déjà très documentés, avec par exemple une variation de protocole peu impactante, en particulier pour les études avec un niveau de TRL (*Technology Readiness Level*) faible ;
- en dehors au périmètre de l'ESCo ou non transposable selon le guide de *Mise en œuvre de la transposition* exposé dans la section suivante.

Un peu plus de 1 000 articles ont ainsi été exclus à la lecture. Ces articles sont listés dans la catégorie « Publications exclues » du document *Base de ressources scientifiques (Bibliographie)* joint au rapport.

À l'inverse, des publications ont été ajoutées par le groupe d'expert.e.s. pour les raisons suivantes:

- restent incontournables dans le domaine (très citées) et connues des expert.e.s,
- sont citées par les publications lues et demandent de compléter le sujet,
- ont été publiées après la constitution du corpus (2023-2024),
- ont été signalées comme des manques essentiels par des contributeurs extérieurs,
- sont pertinentes pour contextualiser l'état de l'art dans une perspective historique.

Cas particulier de la littérature juridique : elle n'apparaissait que très peu dans les bases de données (ces publications n'y sont en effet pas toujours référencées) et, par ailleurs, le Critical Raw Materials Act n'ayant pu être traité que très récemment par cette littérature, cela a nécessité des ajouts post-constitution du corpus.

Cas particuliers de la chimie des procédés : la constitution du corpus n'avait pas permis de répertorier correctement les références concernant le démantèlement et le désassemblage dans le recyclage (chapitre 3) et la fin procédé d'extraction (chapitre 4).

Ainsi 923 publications ont été ajoutées.

La base de ressources scientifiques finale sur laquelle se fonde le travail d'expertise contient 4375 publications (listées dans le document « Base de ressources scientifiques (Bibliographie) »). Durant la rédaction, les expert.e.s n'ont pas été amenés à citer une partie de ces publications dans les textes (notamment par soucis de redondance et de cohérence rédactionnelle). **La liste des publications citées est disponible en fin de chaque chapitre. X XXX références ont été citées au total.**

Ce processus de constitution d'un corpus de publications traçable répond au principe de **transparence** de la charte de l'expertise scientifique CNRS et permet de relier les résultats de l'état de l'art à son périmètre et à la **base de ressources scientifiques** réunies.

Mise en œuvre de la transposition

Dès la phase de constitution du corpus initial, il est apparu au groupe SHS que peu d'articles intéressaient directement la problématique de l'ESCo, c'est-à-dire abordaient explicitement l'objet « terres rares », et qui plus est sous l'angle de la question de la sobriété dans les usages : la plupart du temps, la sobriété n'est pas explorée, le grand récit reste celui de la croissance. Il a donc été nécessaire, au moment de réaliser le tri, d'opérer une première sélection des articles en introduisant la notion de « transposition ».

Par transposition, on entend **la possibilité d'appliquer au cas des terres rares des analyses qui portent sur des objets ou des matières qui n'en contiennent pas**. Par exemple, de nombreux articles portent sur l'organisation du recyclage des déchets électriques et électroniques (DEEE). Parfois, ces articles ne mentionnent pas explicitement les ETR et certains DEEE n'en contiennent pas. En revanche, le groupe a considéré que ces articles étaient pertinents (transposables) car ils renseignent sur une source potentielle d'ETR. La transposition a donc servi deux objectifs : 1. elle permettait d'accroître le nombre d'articles afin de limiter les silences et 2. elle permettait d'opérer une sélection raisonnée des articles. La question de la transposition se posait avec moins d'acuité pour le corpus de sciences de la nature : elle n'a donc généralement pas été mobilisée par les expert.e.s SD dans la phase de tri sur titres et abstracts.

La transposition s'est déclinée selon trois dimensions :

- **en termes d'objets/matières** : les caractéristiques d'un objet ou d'une matière les rapprochent des ETR — par exemple, leur caractère de métaux critiques, ou la co-présence fréquente dans un objet de la matière et d'ETR;
- **en termes de notions/concepts** : un concept à valeur générale est employé à propos de situations qui peuvent évoquer le cas des ETR, par exemple la sobriété ou les démarches d'économie de la fonctionnalité appliquées à des objets technologiques;
- **en termes géographiques** : les cas présentés dans les articles concernent des lieux en dehors de la France et de l'Europe, mais ils permettent une montée en généralité.

Pour les expert.e.s de SHS, le concept a permis de trier les articles avec efficacité. Mais à l'étape de la lecture complète, il est apparu nécessaire de préciser davantage la manière dont la transposition peut être utilisée (1) comme critère de hiérarchisation des articles et (2) comme outil dans l'écriture du rapport.

Un exemple d'application proposé par les pilotes et sur lequel le groupe s'est basé pour la transposition est celui de la refabrication des batteries (*rechapage/repurposing*). Pour les publications en SD, il n'y a pas de transposition à opérer : les batteries NiMH contiennent des ETR et rentrent dans le périmètre, tandis que les batteries Li-ion n'en contiennent pas et restent en dehors du périmètre. Les publications en SHS peuvent l'objet d'une transposition à travers la question suivante : le cas des batteries Li-ion permet-il de dire quelque chose des systèmes de collectes et de valorisation de batteries usagées? Même si les batteries Li-ion ne contiennent pas d'ETR, elles peuvent être susceptibles d'éclairer les chaînes de valeur dans lesquelles sont pris les déchets qui peuvent en contenir. La transposition peut alors être justifiée.

La transposition comme outil de catégorisation

Le groupe d'expert.e.s SHS s'est accordé sur la hiérarchisation des articles qui font l'objet d'une lecture complète. Les articles de rang 1 sont des articles de qualité qui sont en plein dans le périmètre de l'ESCo.

Ils portent sur les ETR et abordent la question de leur usage sobre et responsable. Les articles de rang 2 sont des articles de qualité mais qui supposent une transposition :

- du point de vue de l'objet : l'article concerne un autre métal critique, ou des objets ne contenant pas nécessairement d'ETR;
- du point de vue des notions mobilisées : par exemple, les ETR apparaissent sous un angle non lié à leur usage sobre (par exemple, la performance pure);
- du point de vue de la localisation : cela se passe aux USA ou en Inde, par ex., mais cela reste pertinent.

Le groupe a considéré que si un article appelle plus d'une dimension de transposition (par exemple, il concerne un objet contenant des ETR, mais pas du point de vue de leur usage sobre, et en Asie), il tombait dans la catégorie "exclus". Les articles exclus sont les articles du corpus qui ne présentent pas d'information ou d'analyse pertinente pour le propos. Ils étaient donc considérés comme hors périmètre.

La transposition comme outil d'écriture

Pour déterminer la pertinence et le rang d'un article transposé, il fut nécessaire de se projeter dans l'écriture du rapport. De ce fait, le plan initial du rapport était un outil important pour déterminer si un article devait être exclu ou conservé : comment prendrait-il place dans l'architecture générale ?

Pour la transposition en termes d'objets, il fallait pouvoir montrer que ces objets qui n'en contiennent pas permettaient d'éclairer des aspects de la vie sociale des ETR. Pour la transposition en termes de notions, les articles devaient pouvoir illustrer des familles de préoccupations — et montrer comment la sobriété s'illustre dans d'autres configurations que celles impliquant les ETR. Enfin, pour la transposition géographique, il fallait nécessairement que les cas possèdent une forte composante de montée en généralité — par exemple, en étant fondé sur de la comparaison, ou en permettant des formes de *benchmarking*.

Pour autant, il était nécessaire de ne pas trop figer la notion de transposabilité car il existe des formes de transposabilité différentes selon les axes.

Critères d'inclusion de la littérature grise

Certaines études de la littérature grise (textes juridiques ou études quantitatives produites par l'USGS, l'IEA etc.) ont été intégrées, notamment comme données de contexte, par des notes de bas de page dans les textes du rapport.

Définition

La littérature grise désigne un large éventail de documents produits en dehors des canaux traditionnels de publication et de distribution, et sans respecter tous les critères des productions scientifiques (indépendance, affiliations, peer review, etc.) et qui sont donc souvent mal représentés dans les bases de données d'indexation.

Une définition communément admise est : “*information produced on all levels of government, academia, business and industry in electronic and print formats not controlled by commercial publishing, ie. where publishing is not the primary activity of the producing body*”.³

Concrètement, il s’agit ici de rapports parlementaires, d’institutions de recherche ayant aussi des fonctions administratives ou politiques nationales (ADEM, BRGM, etc.) ou internationales (IETI, OCDE, PNU environnement, etc.), de publications d’instituts de recherche liés à l’industrie, tel le Columbia center on Sustainable Investment ou d’ONG (SystExt, Amis de la Terre, etc.) ou d’organisation de l’industrie extractive telle l’ICMM (International Council on Mining and Metals).

Intérêt

Inclure ces productions dans l’expertise sous le terme de littérature grise permet:

- En premier lieu, de faire connaître un document mal référencé, mais que seuls l’industrie, des entreprises, des États ou des activistes ont pu produire, en raison des difficultés d’accès à l’information pour les chercheurs (brevet, procédés, contrats privés, domaine régalien, etc.), ou du manque de recherches scientifiques indépendantes en ces matières extractives.
- En second lieu, de rendre compte explicitement de la nature duale de ces documents, à la fois descriptive et prescriptive (tels les « *best practices* » extractives), à la fois comme descriptions objectivant des pratiques existantes, et comme normes ayant vocation à s’imposer dans l’industrie.
- En troisième lieu, de mettre en garde contre ces productions qui peuvent parfois présenter des risques de « corporate capture » ou de « state capture », ou d’agnotologie, production volontaire de l’ignorance.

Critère d’inclusion

Le critère d’inclusion est à la fois l’importance dans le champ de l’institution public ou privé à la source du document (ex. ICMM), et les présences de marqueurs de « scientificité » (affiliations, indépendance, peer review, etc.).

Exemple

Un exemple d’institution privée : Toledano, P., Brauch, M. D., & Arnold, J. (2023). *Circularity in mineral and renewable energy value chains: Overview of technology, policy, and finance aspects*. Executive Summary, Columbia Center on Sustainable Investment (CCSI), a joint center of Columbia law school and Columbia climate school, research project of the CCSI with ICMM - International Council on Mining and Metals - and the Enel Foundation as acting as knowledge partners.

Le critère de l’indépendance (liens avec l’industrie, financement de l’étude, peer review) est en ce cas problématique, alors que cet institut universitaire d’une grande université est sans doute l’un des centres

³ International Conference on Grey Literature in 1997 (ICGL Luxembourg definition, 1997 - Expanded in New York, 2004.

de recherche le plus important sur les questions extractives. Ce document est transparent sur les rapports de « knowledge partner » avec ICMM - International Council on Mining and Metals.

Un exemple d'institution publique : Chevrel, S., Charles, N., Christmann, P., Lamouille, B., Blanchard, F., Guillaneau, J. C., & Kister, P. (2017). Le concept de « mine responsable » . *Parangonnage des initiatives mondiales (coll. La mine en France, tome 9). Ministère de l'Économie et des Finances.*

Le critère de l'indépendance (liens avec l'État, avec l'industrie, financement de l'étude, *peer review*) est en ce cas problématique. Réalisé par le BRGM, par une équipe mélangeant scientifiques (école des mines, etc.) et hauts fonctionnaires (soit de l'économie soit des mines), le document rend compte (« objectivation ») d'un concept créé par 9 des plus grandes sociétés minières mondiales, puis repris par l'ICMM, l'organisation patronale mondiale de la mine, et l'ensemble des sociétés minières désormais. Mais le document participe aussi à la diffusion de ce concept comme norme de l'industrie extractive.

Un exemple de texte normatif : Commission Européenne, proposition de RÈGLEMENT DU PARLEMENT EUROPÉEN ET DU CONSEIL établissant un cadre visant à garantir un approvisionnement sûr et durable en matières premières critiques et modifiant les règlements (UE) n° 168/2013, (UE) 2018/858, (UE) 2018/1724 et (UE) 2019/1020, COM/2023/160 final

Le critère de l'indépendance est en ce cas aussi problématique, alors que c'est peut-être le document le plus important d'une expertise sur les terres rares, mais qui n'a pas fait l'objet de commentaire scientifique. Ne pas le citer serait rater une source d'information essentielle (dans l'exposé des motifs notamment ou les rapports d'information (parlement euro, français, etc.) et dans les débats qui l'accompagnent).

Écriture et modalités de travail

Des plénières mensuelles ont réuni les pilotes scientifiques, le groupe d'expert.e.s et la MPES pour partager une direction commune, les méthodologies et le contenu scientifique émergeant du travail d'expertise.

Entre l'étape du tri des références et celle de la lecture, une plénière a permis de structurer un plan squelette au sein des trois axes. En fin d'étape de lecture, les expert.e.s ont partagé les éléments-clés qui ressortaient à large maille des publications qui leur avaient été attribuées. Des connexions ont pu être établies collectivement entre ces éléments-clés, relevant des corroborations et des contradictions. Ces ateliers ont donné l'occasion de redessiner et préciser le plan du rapport. Surtout, ils ont permis de sortir des silos disciplinaires et adopter la vision systémique et transversale à atteindre. Enfin, le plan a évolué une dernière fois lors de la phase d'écriture de la synthèse, notamment par la formation d'un chapitre supplémentaire (chapitre I. Usages, ressources et enjeux géopolitiques).

En respect avec le **principe d'impartialité, la rédaction s'est appuyée sur les ressources scientifiques réunies pour le rapport et non sur le seul avis d'expert.e.s.**

Avant de faire état d'un corpus scientifique, une mise en contexte a été nécessaire. Des sources ont été citées même si elles ne faisaient pas partie du corpus assemblé initialement. Ces compléments ont alors été référencés dans la bibliothèque Zotero (par ex. « la France est le second territoire marin » est introduite avec les références *ad hoc*). Des ressources autres que scientifiques ont pu être utilisées pour la contextualisation ou l'identification de manques de connaissances. Certaines informations ont été indiquées dans les limites de connaissances scientifiques avec d'éventuelles applications industrielles ou autres éléments qui se placent dans un contexte plus large.

L'intégration de notes d'expert.e.s contributeur.rice.s sur des points précis a été réalisé par l'expert.e référent.e qui a pu en proposer une version synthétique et les combiner à d'autres notes de rédaction en les rendant accessibles à l'ensemble du groupe.

Tout élément de l'argumentaire est sourcé. Toute conclusion a été établie sur la base de publications scientifiques. Les éventuelles controverses scientifiques et zones d'ombre sont décrites au fil de l'argumentaire. Dans la mesure du possible les incertitudes ont été qualifiées de façon à moduler la force des conclusions. Un résumé et une conclusion ont été produits à la fin de chaque section, permettant au groupe d'expert.e.s de développer une hauteur de vue et de faciliter la rédaction de la synthèse.

L'écriture du rapport a été collective : chaque section a été rédigée sur un espace de travail collaboratif sécurisé sur la plateforme Résana. Deux responsables, SD et SHS, ont été nommés pour chaque axe afin de coordonner l'écriture, organiser des groupes de travail et faire émerger les éléments principaux et les aspects interdisciplinaires.

Enfin, un **processus de relectures croisées** a été mis en place : les sections ont été relues par au moins deux autres expert.e.s, afin de respecter le **principe d'impartialité** de la charte du CNRS. En plus des expert.e.s du core groupe et des pilotes scientifiques, le chef de projet, la MPES et le Comité de suivi de l'ESCo (constitué de représentants des Instituts du CNRS) ont participé au processus de relecture de la synthèse et du résumé.

Équations de recherche et blocs de mots-clés

Axe 1 : Sciences dures

Equation : Bloc 0 OR Bloc 1 OR Bloc 2 OR Bloc 3

Bloc 0 :

RE free / REY free / non rare earth(s) / less rare earth(s) / low rare earth(s) / low REE / rare earth(s) free / earth metal rare free / rare metal earth free / REE element(s) free / REE metal(s) free / REE oxide(s) free / REE mineral(s) free / light REE(s) free / heavy REE(s) free / middle REE(s) free / 4f element(s) free / REE(s) free / LREE(s) free / HREE(s) free / MREE(s) free / lanthanide(s) free / lanthanoid(s) free / yttrium free / lanthane free / lanthanum free / cerium free / praseodyme free / praseodymium free / neodyme free / neodymium free / promethium free / samarium free / europium free / gadolinium free / terbium free / dysprosium free / holmium free / erbium free / thulium free / ytterbium free / lutetium free / (non RE) AND rare earth(s)

Bloc 1 :

RE lean / REY lean / rare earth(s) lean / earth metal rare lean / rare metal earth lean / REE element(s) lean / REE metal(s) lean / REE oxide(s) lean / REE mineral(s) lean / light REE(s) lean / heavy REE(s) lean / middle REE(s) lean / 4f element(s) lean / REE lean / REEs lean / LREE(s) lean / HREE(s) lean / MREE(s) lean / lanthanide(s) lean / lanthanoid(s) lean / yttrium lean / lanthane lean / lanthanum lean / cerium lean / praseodyme lean / praseodymium lean / neodyme lean / neodymium lean / promethium lean / samarium lean / europium lean / gadolinium lean / terbium lean / dysprosium lean / holmium lean / erbium lean / thulium lean / ytterbium lean / lutetium lean

Bloc 2 :

reducing RE use(s) / reducing rare earth use(s) / reducing REE use(s) / reducing RE usage(s) / reducing rare earth usage(s) / reducing REE usage(s) / reducing RE consumption(s) / reducing rare earth consumption(s) / reducing REE consumption(s) / reducing RE dependence(s) / reducing rare earth dependence(s) / reducing REE dependence(s) / reducing RE level(s) / reducing rare earth level(s) / reducing LREE level(s) / reducing RE concentration(s) / reducing rare earth concentration(s) / reducing REE concentration(s) / reducing RE content / reducing rare earth content / reducing REE content

Bloc 3 :

alternative(s) to rare earth(s) / alternative(s) to earth metal rare / alternative(s) to rare metal earth / alternative(s) to REE element(s) / alternative(s) to REE metal(s) / alternative(s) to REE oxide(s) / alternative(s) to REE mineral(s) / alternative(s) to light REE(s) / alternative(s) to heavy REE(s) / alternative(s) to middle REE(s) / alternative(s) to 4f element(s) / alternative(s) to REE(s) / alternative(s) to LREE(s) / alternative(s) to HREE(s) / alternative(s) to MREE(s) / alternative(s) to lanthanide(s) / alternative(s) to lanthanoid(s) / alternative(s) to yttrium / alternative(s) to lanthane / alternative(s) to lanthanum / alternative(s) to cerium / alternative(s) to praseodyme / alternative(s) to praseodymium / alternative(s) to neodyme / alternative(s) to neodymium / alternative(s) to promethium / alternative(s) to samarium / alternative(s) to europium / alternative(s) to gadolinium / alternative(s) to terbium / alternative(s) to dysprosium / alternative(s) to holmium / alternative(s) to erbium / alternative(s) to thulium / alternative(s) to ytterbium / alternative(s) to lutetium

Axe 1 : Sciences humaines et sociales**Equation : (Bloc 0 OR Bloc 1) AND Bloc 2****Bloc 0 :**

rare earth(s) / earth metal rare / rare metal earth / lanthanide / lanthanoid / REE element(s) / REE metal(s) / REE oxide(s) / REE mineral(s) / light REE(s) / heavy REE(s) / middle REE(s) / REE(s) / LREE(s) / HREE(s) / MREE(s) / terre(s) rare(s) / yttrium / lanthane / lanthanum / cerium / praseodyme / praseodymium / neodyme / neodymium / promethium / samarium / europium / gadolinium / terbium / dysprosium / holmium / erbium / thulium / ytterbium / lutetium / 4f element(s) / strategic metal(s) / strategic mineral(s) / strategic material(s) / strategic raw material(s) / critical metal(s) / critical mineral(s) / critical material(s) / critical raw material(s) / scarce metal(s) / scarce mineral(s) / scarce material(s) / scarce raw material(s) / metal(s) scarcity / mineral(s) scarcity / material(s) scarcity / raw material(s) scarcity / matière(s) première(s) stratégique(s) / matériau(x) stratégique(s) / minerais(s) stratégique(s) / metal stratégique / métaux stratégiques / minerais(s) rare(s) / metal rare / métaux rares / matière(s) première(s) critique(s) / matériau(x) critique(s) / minerais(s) critique(s) / metal critique / métaux critiques / rareté matière(s) première(s) / rareté matériau(x) / rareté minerais(s) / rareté metal / rareté métaux

Bloc 1 :

computer hard disk(s) / computer hard drive(s) / electric vehicle(s) / electric car(s) / hybrid vehicle(s) / permanent magnet(s) / windmill turbine(s) / wind mill turbine(s) / aimant(s) permanent(s) / disque(s) dur(s) ordinateur(s) / éolien* / véhicule(s) électrique(s) / véhicule(s) hybride(s) / voiture(s) électrique(s) / voiture(s) hybride(s)

Bloc 2 :

sobriety / soberness / sobriete
 frugality / frugalite
 frugal consumption / innovation(s) / fabrication / equipment(s) / manufacturing / mode / adaptation
 degrowth / de growth
 alternative(s) from growth / to growth
 deprioritiz* economic* growth
 reduce / reduced / reducing material(s) abundance
 reduce / reduced / reducing natural resources
 decline / declined / declining material(s) abundance
 decline / declined / declining natural resources
 finiteness / finitude / finite / scarce / restricted resources
 consumerism / consumerisme / behaviourism / behaviorism

consumer(s) / customer(s) / consommateur(s) acceptance / acceptability / preference(s) / choice(s) /
 choose / choosing/ choix / select / selection / behavior(s) / behaviour(s) / comportement(s)
 dispensable use
 nudge / nudging
 second life / 2nd life / second hand / secondhand / seconde main / seconde vie
 wastage / gaspillage
 eco friendly / ecofriendly / environmental(ly) friendly accepta* / attitude(s) / behavior(s) / behaviour(s)
 social movement(s) / contestation(s) / accepta*
 mouvement(s) social(aux) / contestation(s) sociale(s)
 green / greener attitude(s) / behavior(s) / behaviour(s)
 low tech attitude(s) / behavior(s) / behaviour(s)
 disnovation / innovation disruptive
 BATNEEC / best available techn* not entailing excessive cost
 resource(s) / ressource(s) ownership / propriete(s)
 responsible / sustainable resource(s)
 ressource(s) responsable(s) / durable(s)
 responsible / sustainable sourcing
 approvisionnement(s) / achat(s) responsable(s)
 alternative resource(s)
 ressource(s) alternative(s)
 sustainable development goal(s)
 informal economy / economie informelle / grise
 tracability / traceability / tracing / tracabilite traffic(s) /trafic(s)
 transparency / transparence / corruption / illegal* mine / mines / mining
 war / conflict(s) / blood / guerre mineral(s) / ore(s)
 sustainable / responsible / green consumption
 reduce / reducing / ethic* consumption
 consommation durable / responsable / ethique
 pro environmental(ly) / proenvironmental(ly) technologies / practices / attitudes / behavior(s) behaviour(s)
 product(s) resiliency / resilience / fair trade
 eco design / ecodesign / ecoconception / eco conception
 environmental(ly) friendly alternative(s)
 obsolescence
 geoethic* / geo ethic*
 ethic practice(s) / business / management / consumption / issues / behavior(s) / behaviour(s)
 sustainable / responsible progress(es) / innovation(s)
 policy(ies) / politic progress(es) / innovation(s)
 sustainable / responsible policy(ies) / politic*
 chang* of customer(s)
 ethic sourc* material(s)
 sustainabl* sourc* material(s)
 product(s) made of sustainable material(s)
 re open* / reopen* / reouverture(s) / re ouverture(s) / quota(s) mine / mines / mining
 closure / close* / fermeture(s) / interdiction / prohibition / prohibited mine / mines / mining
 licence(s) / license(s) to operate / exploitation

Axe 2 : Sciences dures

Equation : (bloc 0 AND (bloc 1 OR (bloc2 AND (bloc3 OR bloc 4)))) OR ((bloc 3 OR bloc 4) AND bloc 5) OR bloc 6

Bloc 0 :

rare earth / rare earths / earth metal rare / rare metal earth / lanthanide* / lanthanoid* / REE elements / REE element / REE metals / REE metal / REE oxides / REE oxide / REE minerals / REE mineral / light REE / heavy REE / middle REE / light REEs / heavy REEs / middle REEs / terre rare / terres rares / élément terrestre rare / éléments terrestres rares / REE léger / REE lourd / REE moyen / REE légers / REE lourds / REE moyens / REE / REEs / LREE / HREE / LREEs / HREEs / yttrium / lanthane / lanthanum / cerium / praseodyme / praseodymium / neodyme / neodymium / promethium / samarium / europium / gadolinium / terbium / dysprosium / holmium / erbium / thulium / ytterbium / lutetium / cérium / praséodyme / praséodymium / néodyme / néodymium / prométhium / lutétium / lutécium / 4f element*/4f series element*

Bloc 1 :

circular economy / industrial ecology / industrial metabolism / eco design / ecodesign / life cycle assessment / life cycle analysis / material(s) flow analysis / material(s) flow assessment / short loop recycling / closed loop recycling / closed loop (associé à recycling reuse "re-use") / closes loop (associé à recycling reuse "re-use") / end of life recycling rate(s) / EOL-RR / old scrap ratio / recycled content / recycling input rate(s) / recycling metrics / hibernating stocks / metal(s) life cycle / urban mining / urban mine(s) / waste(s) valorization / waste(s) valorisation / waste(s) recycling / waste(s) recovery (exclusion : waste heat recovery) / waste(s) resource(s) (exclusion : waste of scarce resources) / waste(s) reuse (exclusion : (wastewater* "waste water" "waste waters")) / waste(s) re use (exclusion : (wastewater* "waste water" "waste waters"))

Bloc 2 :

resource(s) recovery / recovery strategy/ies / recovery process(es) / recovery technology/ies / recovery technique(s) / recycling strategy/ies / recycling technology/ies / recycling technique(s) / recycling process(es) / sustainable extraction / sustainable recovery / sustainable recycling / sustainable leaching / selective leaching / selective extraction / recycling behavior/behaviour / formal recycling / informal recycling / sorting / dismantling / disassembly / dismounting / crushing / shredding / hydrometallurgy(ical) / hydro-metallurgy(ical) / biohydrometallurgy(ical) / bio hydrometallurgy(ical) / pyrometallurgy(ical) / pyro metallurgy(ical) / pyrohydrometallurgy(ical) / pyro-hydrometallurgy(ical) / biopyrohydrometallurgy(ical) / bio-pyro-hydrometallurgy(ical) / solvometallurgy(ical) / solvo-metallurgy(ical) / ionometallurgy(ical) / iono-metallurgy(ical) / bioleaching / bacterial leaching / microbial leaching / molten salt / molten salts / bioinspired extraction / bioinspired recovery / bioinspired recycling / bio-inspired extraction / bio-inspired recovery / bio-inspired recycling

Bloc 3 :

e-waste(s) / electronic waste(s) / waste electrical and electronic equipment(s) / WEEE(s) / magnetic waste(s) / waste magnet(s) / waste phosphor sludge(s) / waste phosphor powder(s) / MSW bottom ash(es) / municipal solid waste bottom ash(es) / incinerator bottom ash(es) / incineration bottom ash(es) / MSW fly ash(es) / municipal solid waste fly ash(es) / incinerator fly ash(es) / incineration fly ash(es) / incineration residue(s) / municipal solid waste(s) / combustion waste(s) (exclusion : "coal combustion") / military waste(s) / hospital effluent(s) / wastewater* waste water(s) / fume* / gaseous effluent(s) / end of life product(s) / end of life equipment(s) / residual waste(s)

Bloc 4 :

batterie* battery / fuel cell(s) / catalyst* catalytic converter(s) / electro catalyst(s) electrocatalyst* photocatalyst* photo catalyst(s) / photo electro catalyst(s) photoelectrocatalyst* / cathod ray tube(s) / television* / computer hard disk(s) computer hard drive(s) / computer monitor(s) computer screen(s) / quantum computing quantic computing qubit* quantum technology/ies / head phone(s) headphone* mobile phone(s) smart phone(s) smartphone* cellular phone(s) / dispersive uses / rare earth doped "rare

earth doping" dopant* / electrical and electronic products / generator* / electric motor(s) / electric vehicle(s) / hybrid vehicle(s) / photo voltaic photovoltaic* solar panel(s) solar cell(s) / wind turbine(s) / energy efficient lighting(s) low energy lighting(s) / eco lighting(s) economic lighting(s) / fluorescent lamp(s) fluorescent lighting(s) / fluorescent tube(s) / leds light emitting diode(s) / fluorescent powder(s) / green phosphor(s) red phosphor(s) luminophor* / high temperature superconductor(s) / high performance magnet(s) / Superconducting magnet(s) / permanent magnet(s) / ((NdFeB "Nd-Fe-B" Nd₂Fe₁₄B "neodymium-iron-boron" "neodyme-iron-boron" RE₂Fe₁₄B Pr₂Fe₁₄B) AND magnet(s)) / magnetic refrigeration magnetorefrigeration magneto refrigeration / optical refrigeration / refrigeration equipment(s) / magnetic resonance imaging / mri imaging / contrast agent(s) / taggant* / missile(s) guidance system(s) / radar system(s) / optical fiber(s) / laser* / polishing powder(s) / polishing waste(s) / refractory brick(s)

Bloc 5 :

rare earth extraction / rare earth recycling / rare earth recovery / rare earth leaching
(Liste répétée avec chaque élément du bloc 0)

Bloc 6 :

rare earth recyclability / rare earth recyclabilities / rare earth reusability / rare earth reusabilities / rare earth re usability / rare earth re usabilities / rare earth recyclage / rare earth recycling / rare earth recycled
(Liste répétée avec chaque élément du bloc 0)

Axe 2 : Sciences humaines et sociales

Equation : (bloc 0 OR bloc 1 OR bloc 2 OR bloc 3) AND bloc 4 AND bloc 5

Bloc 0 :

rare earth / rare earths / earth metal rare / rare metal earth / lanthanide* / lanthanoid* / REE elements / REE element / REE metals / REE metal / REE oxides / REE oxide / REE minerals / REE mineral / light REE / heavy REE / middle REE / light REEs / heavy REEs / middle REEs / terre rare / terres rares / élément terrestre rare / éléments terrestres rares / REE léger / REE lourd / REE moyen / REE légers / REE lourds / REE moyens / REE / REEs / LREE / HREE / LREEs / HREEs / yttrium / lanthane / lanthanum / cerium / praseodyme / praseodymium / neodyme / neodymium / promethium / samarium / europium / gadolinium / terbium / dysprosium / holmium / erbium / thulium / ytterbium / lutetium / cérium / praséodyme / praséodymium / néodyme / néodymium / prométhium / lutétium / lutécium / 4f element*/4f series element*

Bloc 1 :

strategic metals / strategic metal / strategic minerals / strategic mineral / strategic materials / strategic material / strategic raw materials / strategic raw material / critical metals / critical metal / critical minerals / critical mineral / critical materials / critical material / critical raw materials / critical raw material / scarce raw materials / scarce raw material / scarce metals / scarce metal / scarce minerals / scarce mineral / scarce materials / scarce material / resources scarcity / resource scarcity / metals scarcity / metal scarcity / minerals scarcity / mineral scarcity / materials scarcity / material scarcity / ressource stratégique / matériau stratégique / minéral stratégique / métal stratégique / ressources stratégiques / matériaux stratégiques / minéraux stratégiques / métaux stratégiques / matière première stratégique / matières premières stratégiques / ressource rare / matériau rare / minéral rare / métal rare / ressources rares / matériaux rares / minéraux rares / métaux rares / matière première rare / matières premières rares / ressource critique / matériau critique / minéral critique / métal critique / ressources critiques / matériaux critiques / minéraux critiques / métaux critiques / matière première critique / matières premières critiques / rareté matière(s) première(s) / rareté matériau(x) / rareté minerai(s) / rareté métal/aux

Bloc 2 :

e-waste(s) / e déchet(s) / electronic waste(s) / waste electrical and electronic equipment(s) / WEEE(s) / déchet(s) électrique(s) / déchet(s) électronique(s) / magnetic waste(s) / déchet(s) magnétique(s) / waste

magnet(s) / déchet(s) aimant(s) / waste phosphor sludge(s) / waste phosphor powder(s) / MSW bottom ash(es) / municipal solid waste bottom ash(es) / cendre(s) résiduelle(s) MSW / incinerator bottom ash(es) / cendre(s) résiduelle(s) incinérateur / incineration bottom ash(es) / cendre(s) résiduelle(s) incinération / MSW fly ash(es) / municipal solid waste fly ash(es) / cendre(s) volante(s) MSW / incinerator fly ash(es) / cendre(s) volante(s) incinérateur / incineration fly ash(es) / cendre(s) volante(s) incinération / incineration residue(s) / résidu(s) incinération / municipal solid waste(s) / déchet(s) solide(s) urbain(s) déchet(s) municipal/aux solide(s) / combustion waste(s) (exclusion : "coal combustion") / déchet(s) combustion (exclusion : combustion charbon) / military waste(s) / déchet(s) militaire(s) / wastewater* waste water(s) / eau(x) usée(s) / hospital effluent(s) / effluent(s) hospitalier(s) / fume* / gaseous effluent(s) / effluent(s) gazeux / end of life product(s) / produit(s) eol / produit(s) fin de vie / end of life equipment(s) / équipement(s) eol / équipement(s) fin de vie / residual waste(s) / déchets ultimes

Bloc 3 :

batterie* battery / fuel cell(s) / pile(s) combustible / catalyst* catalytic converter(s) / convertisseur(s) catalytique(s) catalyseur(s) / electro catalyst(s) electrocatalyst* photocatalyst* photo catalyst(s) / electrocatalyseur(s) photocatalyseur(s) / photo electro catalyst(s) photoelectrocatalyst* / photoelectrocatalyseur(s) / cathod ray tube(s) / tube(s) cathodique(s) / television* / computer hard disk(s) computer hard drive(s) / disque(s) dur(s) ordinateur / computer monitor(s) computer screen(s) / écran(s) ordinateur / quantum computing quantic computing qubit* quantum technology/ies / ordinateur(s) quantique(s) technologie quantique / head phone(s) headphone* mobile phone(s) smart phone(s) smartphone* cellular phone(s) / téléphone(s) mobile(s) téléphone(s) portable(s) / dispersive uses / usages dissipatifs usages dispersifs / rare earth doped "rare earth doping" dopant* / electrical and electronic products / generator* /générateur* / electric motor(s) / moteur(s) électrique(s) / electric vehicule(s) / véhicule(s) électrique(s) / hybrid vehicule(s) / véhicule(s) hybride(s) / photo voltaic photovoltaic* solar panel(s) solar cell(s) / photovoltaïque / panneau(x) solaire(s) cellule(s) solaire(s) / wind turbine(s) / éolien / energy efficient lighting(s) low energy lighting(s) / eco lighting(s) economic lighting(s) / éclairage(s) basse consommation / éclairage(s) basse énergie / lampe(s) basse consommation / lampe(s) basse énergie / fluorescent lamp(s) fluorescent lighting(s) / lampe(s) fluorescente(s) / éclairage(s) fluorescent(s) / fluorescent tube(s) / tube(s) fluorescente(s) / leds light emitting diode(s) / diode(s) électroluminescente(s) / fluorescent powder(s) / poudre(s) fluorescente(s) / green phosphor(s) red phosphor(s) luminophor* / high temperature superconductor(s) / supraconducteur(s) haute température / high performance magnet(s) / aimant(s) haute performance / Superconducting magnet(s) / aimant(s) supraconducteur(s) / permanent magnet(s) / aimant(s) permanent(s) / ((NdFeB "Nd-Fe-B" Nd₂Fe₁₄B "neodymium-iron-boron" "neodyme-iron-boron" RE₂Fe₁₄B Pr₂Fe₁₄B) AND magnet(s)) / magnetic refrigeration magnetorefrigeration magneto refrigeration / réfrigération magnétique / optical refrigeration / réfrigération optique / refrigeration equipment(s) / magnetic resonance imaging / mri imaging / imagerie irm / imagerie résonance magnétique / contrast agent(s) / agent(s) contraste / taggant* / marqueur* / missile(s) guidance system(s) / système(s) guidage missile(s) / radar system(s) / système(s) radar / optical fiber(s) / fibre(s) optique(s)* / laser* / polishing powder(s) / poudre(s) polissage / polishing waste(s) / déchet(s) polissage / refractory brick(s) / brique(s) réfractaire(s)

Bloc 4 :

circular economy / économie circulaire / industrial ecology / écologie industrielle / industrial metabolism/métabolisme industrielle / eco design / eco conception / ecodesign / ecoconception / life cycle assessment / life cycle analysis / cycle de vie / material(s) flow analysis / material(s) flow assessment / analyse flux matières / short loop recycling / recyclage boucle courte / closed loop recycling / closed loop (associé à recycling reuse "re-use") / closes loop (associé à recycling reuse "re-use") / recyclage boucle fermée / end of life recycling rate(s) / EOL-RR / old scrap ratio / proportion vieux déchets / recycled content / contenu recyclé / recycling input rate(s) / taux recyclage / recycling metrics / métriques recyclage / hibernating stocks / metal(s) life cycle / urban mining / urban mine(s) / mine(s) urbaine(s) / waste(s) valorization / valorisation déchet(s) / waste(s) valorisation / waste(s) recycling / recyclage déchet(s) / waste(s) recovery (exclusion : waste heat recovery) / récupération déchet(s) / waste(s) resource(s) (exclusion : waste of scarce resources) / waste(s) reuse (exclusion : (wastewater* "waste water" "waste waters")) / waste(s) re use (exclusion : (wastewater* "waste water" "waste waters")) / réutilisation déchet(s) / ré utilisation déchet(s) / resource(s) recovery / recovery strategy/ies / recovery process(es) /

recovery technology/ies / recovery technique(s) / recycling strategy/ies / recycling technology/ies / recycling technique(s) / recycling process(es) / sustainable extraction / sustainable recovery / sustainable recycling / sustainable leaching / extraction durable / récupération durable / recyclage durable / lixiviation durable / selective leaching / selective extraction / extraction sélective / lixiviation sélective / recycling behavior/behaviour / comportement recyclage / formal recycling / informal recycling / recyclage formel recyclage informel / calcul impact

Bloc 5 :

competitiveness/competitive market(s)/market competition/ competitiveness/compétitivité / externalities / externalité* / duty of vigilance/ duty of alertness/ obligation de vigilance/d'information / value chain / chaîne valeur / supply chain / chaîne de valeur globale / reverse logistics / logistique inversée / invisible work / travail invisible / transparenc* / triple-capital accounting / comptabilité en triple capital / environmental social governance/ gouvernance sociale environnementale / (corporate) social responsibility(ies) / responsabilité sociale / ESG criteria / critère ESG / societal challenge / défi sociétal / défi social / social cost coût social / economic resource scarcity potential / greenwashing green washing / écoblanchiment / éco blanchiment / compensation* / equity équité / market * marché / cost* coût* / réglementation* réglementaire* / regulatory framework(s) / legislation* / législati* / legal framework(s) / judicial / judiciaire / public action(s) / action(s) publique(s) / politique(s) publique(s) / public politics / public policy(ies) / government policy(ies) / government politics / governmental policy(ies) / governmental politics / government(al) support(s) / supportive government(s) / soutien(s) gouvernemen(al) / political support(s) / policy support(s) / politics support(s) / soutien(s) politique(s) / political incitation(s) / incitative policy(ies) / incitation(s) politique(s) / politique(s) incitative(s) / criticalit* criticité / techno economic assessment / techno economic analysis

Axe 3 : Sciences dures

Equation : Bloc 0 AND ((Bloc 1 AND Bloc 2) OR (Bloc 1gme AND Bloc 2g) OR Bloc 2me)

Bloc 0 :

rare earth(s) / earth metal rare / rare metal earth / lanthanide / lanthanoid / REE element(s) / REE metal(s) / REE oxide(s) / REE mineral(s) / light REE(s) / heavy REE(s) / middle REE(s) / REE(s) / LREE(s) / HREE(s) / MREE(s) / yttrium / lanthane / lanthanum / cerium / praseodyme / praseodymium / neodyme / neodymium / promethium / samarium / europium / gadolinium / terbium / dysprosium / holmium / erbium / thulium / ytterbium / lutetium / 4f element(s)

Bloc 1 :

primary / secondary resource(s) / primary / secondary source(s) / ressources primaire(s) / secondaires(s) / sources primaire(s) / secondaire(s) / bio ore(s)

(mining / extractive / extraction / minerals industry(ies) / industries minière(s) / industrie extractive / extraction / industrie(s) minierai(s)) AND (coproduct(s) / co product(s) / by-product(s) / coproduit(s) / co produit(s) / sous-produit(s) / sludge(s) / boue(s) / AMD(s) / industrial waste-water(s) / wastewater(s) / industrial waste(s) / industrial effluent(s) / eaux usée(s) industrielle(s) / effluent(s) industriels)

mine(s) / mining co-product(s) / coproduct(s) / mine(s) / mining by-product(s) / coproduit(s) / co produit(s) minier / mine(s) / sous-produit(s) minier / mine(s) / mine(s) / mining sludge(s) / boue(s) mine(s) / minière(s) / tailing(s) / stérile(s) miniers / mining / mine waste(s) / déchet(s) minier(s) / mine(s) / mining / mine residue(s) / résidu(s) minier(s) / mine(s) / acid mine drainage / mine(s) / mining amd / exhaure(s) mine acide(s) / drainage(s) minier(s) acide(s) / mine(s) waste-water(s) / wastewater(s) / mine(s) effluent(s) / mining waste-water(s) / wastewater(s) / mining effluent(s) / eau(x) usée(s) minière(s) / mine(s) / effluent(s) minier(s) / mine(s) / bauxite residue(s) / résidu(s) bauxite / red mud(s) / boue(s) rouge(s) / smelting slag(s) / scorie(s) fonderie / furnace slag(s) / scorie(s) fourneau / mining scrap(s) / dechet(s) exploitation minière / rebut(s) miniers / mineral waste(s) / rock(s) waste(s) / ore(s) / low-grade(s) / mine / mining / minerals deposits / gisement(s) miniers / mines / dépôt(s) miniers / carbonite* / laterite* / bauxite* / regolith* /

pegmatite* / phosphorite* / hyperalkaline rock(s) / hyper alkaline rock(s) / roche(s) hyperalkaline(s) / hyperalkaline(s) / iron oxide copper gold ore deposits / IOCG / placers / ion-adsorption type deposits / monazite / phosphogypsum / phosphogypse / xenotime / apatite / bastnaesite / bastnasite / synchisite / zircon / eudialyte / allanite / Fe-Mn oxyhydroxide(s) / fluorite / deep sea deposit(s) / resources / mud(s) / nodules / minerals / deep ocean deposit(s) / resources / mud(s) / nodules / minerals / marine deposit(s) / placer(s) / resource(s) / mud(s) / nodules / minerals / sea floor / seafloor deposit(s) / resources / mud(s) / nodules / minerals / ocean floor / oceanfloor deposit(s) / resources / mud(s) / nodules / minerals / sea bed / seabed / deposit(s) / resources / mud(s) / nodules / minerals / subsea / subsea / deposit(s) / resources / mud(s) / nodules / minerals / under sea / undersea deposit(s) / resources / mud(s) / nodules / minerals / deep sea / deep ocean / sea floor / seafloor / ocean floor / oceanfloor ore(s) / polymetallic / poly metallic nodules / nodules polymétalliques / ferromanganese / ferro manganese crust(s) / Fe-Mn crust(s) / croute(s) / encroulement(s) ferromanganesifere(s)

Bloc 2 :

responsible / zero carbon / low carbon / sustainable / green mine / responsible / zero carbon / low carbon / sustainable / green mines / responsible / zero carbon / low carbon / sustainable / green mining / responsible / zero carbon / low carbon / sustainable / green extracti* / recovery strategy(ies) / process / processes / technology (ies) / technique(s) / recycling strategy(ies) / process / processes / technology (ies) / technique(s) / extraction strategy(ies) / process / processes / technology (ies) / technique(s) / separation strategy(ies) / process / processes / technology (ies) / technique(s) / sustainable extraction / recovery / recycling / separation(s) / leaching / selective extraction / leaching / crushing / shredding / flotation / beneficiation / hydrometallurgy(ical) / hydro metallurgy(ical) / biohydrometallurgy(ical) / bio hydrometallurgy(ical) / bio hydro metallurgy(ical) / pyrometallurgy(ical) / pyro metallurgy(ical) / pyrohydrometallurgy(ical) / pyro hydrometallurgy(ical) / pyro hydro metallurgy(ical) / biopyrohydrometallurgy(ical) / bio-pyro-hydro-metallurgy(ical) / solvometallurgy(ical) / solvo metallurgy(ical) / ionometallurgy(ical) / iono metallurgy(ical) / geometallurgy(ical) / geo metallurgy(ical) / remediation / bioremediation / bio remediation / bio sorption / biosorption / bioadsorption / bio adsorption / biosorbent(s) / bio sorbent(s) / bioadsorbent(s) / bio adsorbent(s) / lanmodulin / LanM / lanmodulin / lanthanide binding tag(s) / bioleaching / bio leaching / biolixiviation / bio lixiviation / bacterial / microbial leaching / lixiviation bacterienne / microbienne / phytomining / phyto mining / agromining / agro mining / hyperaccumulation / hyperaccumatator / hyperaccumulating / hyper accumulation / hyper accumatator / hyper accumulating / phytoremediation / phyto remediation / phytoextraction / phyto extraction / biomining / bio mining / bioinspired / bio inspired mining / extraction / separation(s) / recovery / recycling / biologically inspired mining / extraction / separation(s) / recovery / recycling / biomimetism / bio mimetism / biomimetic mining / extraction / separation(s) / recovery / recycling / biomimicry / bio mimicry mining / extraction / separation(s) / recovery / recycling / bioinspiration / bio inspiration mining / extraction / separation(s) / recovery / recycling / synthetic biology mining / extraction / separation(s) / recovery / recycling / geoinspired / geo inspired mining / extraction / separation(s) / recovery / recycling / geomimetism / geo mimetism / geomimetic mining / extraction / separation(s) / recovery / recycling / geomimetic(s) / geo mimetic(s) mining / extraction / separation(s) / recovery / recycling / geomimicry / geo mimicry mining / extraction / separation(s) / recovery / recycling / geoinspired / geo inspired mining / extraction / separation(s) / recovery / recycling / geoinspiration / geo inspiration mining / extraction / separation(s) / recovery / recycling

Bloc 1gme :

ore(s) / low grade(s) / mine / mining / mineral deposit(s) / carbonite* / laterite* / bauxite* / regolith* / pegmatite* / phosphorite* / hyperalkaline rock(s) / hyper alkaline rock(s) / roche(s) hyperalkaline(s) / hyperalkaline(s) / iron oxide copper gold ore deposits / IOCG / placers / ion-adsorption type deposits / monazite / phosphogypsum / phosphogypse / xenotime / apatite / bastnaesite / bastnasite / synchisite / zircon / eudialyte / allanite / clay / Fe-Mn oxyhydroxide(s) / fluorite / deep sea deposit(s) / resources / mud(s) / nodules / minerals / deep ocean deposit(s) / resources / mud(s) / nodules / minerals / marine deposit(s) / placer(s) / resource(s) / mud(s) / nodules / minerals / sea floor / seafloor deposit(s) / resources / mud(s) / nodules / minerals / sea floor / seafloor deposit(s) / resources / mud(s) / nodules / minerals / ocean floor / oceanfloor deposit(s) / resources / mud(s) / nodules / minerals / deep sea / deep ocean / sea floor / seafloor / ocean floor / oceanfloor ore(s) / sea bed / seabed / deposit(s) / resources / mud(s) /

nodules /minerals / subsea / subsea / deposit(s) / resources / mud(s) / nodules /minerals / under sea / undersea deposit(s) / resources / mud(s) / nodules /minerals / polymetallic / poly metallic nodules / nodules polymétalliques / ferromanganese / ferro manganese crust(s) / Fe-Mn crust(s) / croute(s) / encroulement(s) ferromanganesifere(s) / asteroid mineral(s) / space resource(s) minerals / extraterrestrial / extra terrestrial deposit(s) / resource(s) / minerals

NOT

Chondrite (s) normalized / normalised / level(s) / ration

Bloc 2g :

bio availability / bioavailability / ore(s) exploration / determination / resource(s) potential assessment / ore reserve(s) estimation / ore(s) grade(s) / resource(s) exploration / exploitation / ore deposit(s) characterization / mineral resource(s) mapping / map / deposit(s) mapping / map / ore(s) mapping / map / geologic(al) / prospectivity / mineral(s) / lithologic(al) mapping / prospectivity modelling / map / geologic(al) reconnaissance / survey(s) / geophysical / geo physical prospection / prospecting / survey(s) / signature(s) / prospection / prospecting technique(s) / exploration(s) technique(s) / non invasive / noninvasive / non destructive / nondestructive exploration / technique(s) / hyperspectral / hyper spectral imaging / imagery / sensor(s) / survey(s) / remote sensing / radiometric survey(s) / method(s) / gamma ray survey(s) / gravity survey(s) / method(s) / magnetic survey(s) / method(s) / electromagnetic / electro magnetic survey(s) / soil magnetic susceptibility / geochemical / geo chemical method(s) / prospection / technique(s) / core drilling / drilling core(s) / drill core(s) / deep drilling / core logging / core / rock chip(s)

(lithology(ies) / lithogeochemistry / litho geochemistry / lithogeochemical / litho geochemical / lithogeophysics(al) / litho geophysics(al) / tracer element(s)) AND exploration

(supervised / unsupervised /non supervised / semi supervised / deep learning / logic regression / support vector machine(s) / neural network(s) / neural net(s) /learned / random forest(s) / bossting / XGBoost Adaboost / k-means clustering / k-means algorithm / KNN algorithm / k-nearest neighbors / classifier / hierarchical clustering / cluster analysis / Self-organizing map(s) / Kohonen map(s) / network(s) / Naive Bayes algorithm / decision tree / algorithm / boosted tree(s) / fuzzy inference / clustering / genetic / learning algorithm) AND exploration

Bloc 2me :

deep sea mining / mine / exploration / exploitation / exploiting / deep ocean mining / mine / exploration / exploitation / exploiting / marine mining / exploration / exploitation / seafloor / sea floor mining / mine / exploration / exploitation / exploiting / oceanfloor / ocean floor mining / mine / exploration / exploitation / exploiting / seabed / sea bed mining / mine / exploration / exploitation / exploiting / subsea / sub sea mining / mine / exploration / exploitation / exploiting / undersea / under sea mining / mine / exploration / exploitation / exploiting / asteroid(s) mining / mine / exploration / exploitation /exploiting / space mining / exploration / extraterrestrial / extra terrestrial mining / exploration / exploitation /exploiting

Axe 3 : Sciences humaines et sociales

Equation : (bloc 0 AND bloc 1 AND bloc 2) OR (bloc 0 AND bloc 3)

Bloc 0 :

rare earth(s) / earth metal rare / rare metal earth / lanthanide / lanthanoid / REE element(s) / REE metal(s) / REE oxide(s) / REE mineral(s) / light REE(s) / heavy REE(s) / middle REE(s) / REE(s) / LREE(s) / HREE(s) / MREE(s) / terre(s) rare(s) / yttrium / lanthane / lanthanum / cerium / praseodyme / praseodymium / neodyme / neodymium / promethium / samarium / europium / gadolinium / terbium / dysprosium / holmium / erbium / thulium / ytterbium / lutetium / 4f element(s) / strategic metal(s) / strategic mineral(s) / strategic material(s) / strategic raw material(s) / critical metal(s) / critical mineral(s) / critical material(s) / critical raw material(s) / scarce metal(s) / scarce mineral(s) / scarce material(s) / scarce raw material(s) /

metal(s) scarcity / mineral(s) scarcity / material(s) scarcity / raw material(s) scarcity / matiere(s) premiere(s) strategique(s) / materiau(x) strategique(s) / minerai(s) strategique(s) / metal strategique / metaux strategiques / matiere(s) premiere(s) rare(s) / materiau(x) rare(s) / minerai(s) rare(s) / metal rare / metaux rares / matiere(s) premiere(s) critique(s) / materiau(x) critique(s) / minerai(s) critique(s) / metal critique / metaux critiques / rarete matiere(s) premiere(s) / rarete materiau(x) / rarete minerai(s) / rarete metal / rarete metaux

Bloc 1 :

primary / secondary resource(s) / primary / secondary source(s) / resources primaire(s) / secondaires(s) / sources primaire(s) / secondaire(s) / bio ore(s) / bio minerai / biominerai

(mining / extractive / extraction / minerals industry(ies) / industries miniere(s) / industrie extractive / extraction / industrie(s) minerai(s)) AND (coproduct(s) / co product(s) / by-product(s) / coproduit(s) / co produit(s) / sous-produit(s) / sludge(s) / boue(s) / AMD(s) / industrial waste-water(s) / wastewater(s) / industrial waste(s) / industrial effluent(s) / eaux usee(s) industrielle(s) / effluent(s) industriel(s))

mine(s) / mining co-product(s) / coproduct(s) / mine(s) / mining by-product(s) / coproduit(s) / co produit(s) minier / mine(s) / sous-produit(s) minier / mine(s) / mine(s) / mining sludge(s) / boue(s) mine(s) / miniere(s) / tailing(s) / sterile(s) miniers / mining / mine waste(s) / dechet(s) minier(s) / mine(s) / mining / mine residue(s) / residu(s) minier(s) / mine(s) / acid mine drainage / mine(s) / mining amd / exhaure(s) mine acide(s) / drainage(s) minier(s) acide(s) / mine(s) waste-water(s) / wastewater(s) / mine(s) effluent(s) / mining waste-water(s) / wastewater(s) / mining effluent(s) / eau(x) usee(s) miniere(s) / mine(s) / effluent(s) minier(s) / mine(s) / bauxite residue(s) / residu(s) bauxite / red mud(s) / boue(s) rouge(s) / smelting slag(s) / scorie(s) fonderie / furnace slag(s) / scorie(s) fourneau / mining scrap(s) / dechet(s) exploitation miniere / rebut(s) miniers / mineral waste(s) / rock(s) waste(s) / ore(s) / low-grade(s) / mine / mining / minerals deposits / gisement(s) miniers / mines / depôt(s) miniers / gisement(s) marins / oceaniques / sous marins / deep-sea deposit(s) / resources / mud(s) / nodules / minerals / deep-ocean deposit(s) / resources / mud(s) / nodules / minerals / marine deposit(s) / resources / mud(s) / nodules / minerals / marine placer(s) / marine resources / resources / mud(s) / nodules / minerals / seafloor / sea floor deposit(s) / resources / mud(s) / nodules / minerals / oceanfloor / ocean floor deposit(s) / resources / mud(s) / nodules / minerals / seabed / sea bed deposit(s) / resources / mud(s) / nodules / minerals / subsea / sub sea deposit(s) / resources / mud(s) / nodules / minerals / undersea / under sea deposit(s) / resources / mud(s) / nodules / minerals / polymetallic / poly metallic nodule(s) / nodules polymetalliques / ferromanganese / ferro manganese / Fe-MN crust(s) / croutes / encroutement(s) ferromangesifere(s) / asteroid(s) minerals / space resource(s) / minerals / extraterrestrial / extra terrestrial deposit(s) / resource(s) / minerals / mining / mine / mines / industry(ies) resource(s) / mineral(s) industry(ies) resource(s) / mining industry(ies) resource(s) / extractive industry(ies) resource(s) / mining / mine / mines / mining industry(ies) / extractive industry(ies) / extraction industry(ies) / minerals industry(ies) remediation / mining / mine / mines / mining industry(ies) / extractive industry(ies) / extraction industry(ies) / minerals industry(ies) rehabilitation / mining / mine / mines / mining industry(ies) / extractive industry(ies) / extraction industry(ies) / minerals industry(ies) decontamination / mining / mine / mines / mining industry(ies) / extractive industry(ies) / extraction industry(ies) / minerals industry(ies) depollution / mining / mine / mines / mining industry(ies) / extractive industry(ies) / extraction industry(ies) / minerals industry(ies) revegetation / mining / mine / mines / mining industry(ies) / extractive industry(ies) / extraction industry(ies) / minerals industry(ies) restoration / mining / mine / mines / mining industry(ies) / extractive industry(ies) / extraction industry(ies) / minerals industry(ies) relinquishment / postmining / post mining / rare earth(s) manufacturing

(mining / mine / mines / extrative industry(ies) / extraction industry(ies) / minerals industry(ies)) AND (minimizing environment(al) impact(s) / risk(s) / environment(al) impact(s) / risk(s) minimization / reducing environment(al) impact(s) / risk(s) / environment(al) impact(s) / risk(s) reduction)

Bloc 2 :

economic(al) value(s) / economic(al) valuation / economical valuation / evaluation(s) economique(s) / valeur(s) economique(s) / investment(s) / investissement(s) / capital income / variety of capitalism / variete

capitalisme / value(s) distribution / repartition de valeur(s) / profit sharing / partage profit(s) / participation benefice(s) / accounting valuation / accounting value(s) / accounting valuation(s) / evaluation(s) comptable(s) / valeur(s) comptable(s) / comptabilite / cost benefit / cout benefice / resource(s) rent(s) / extractive rent(s) / extractive income(s) / rente(s) extractive(s) / extractive transparency / revenue(s) transparency / income(s) transparency / transparence extractive / transparence revenus / corporate regulation(s) / corporate legislation(s) / corporate legislative / corporate responsibility(ies) / corporate(s) regulation(s) / corporate(s) legislation(s) / corporate(s) legislative / corporate(s) responsibility(ies) / companies regulation(s) / companies legislation(s) / companies legislative / companies responsibility(ies) / responsabilite entreprises / reglementation entreprises / legislation entreprises / mineral economie(s) / metal economie(s) / minerais economie(s) / mineral economic(s) / metal economic(s) / minerais economic(s) / mineral management / mineral gestion / metal management / metal gestion / minerais management / minerais gestion / global value chain(s) / chaine(s) valeur / supply chain(s) / chaine(s) approvisionnement / gigafactory(ies) / giga factory(ies) / criticality / criticalite / mineral sovereignty (ies) / metal sovereignty (ies) / souverainete minerale / souverainete miniere / duty(ies) vigilance / due vigilance / duty(ies) diligence / due diligence / duty(ies) alertness / due alertness / obligation(s) diligence / obligation(s) vigilance / devoir de vigilance / willingness to pay / volonte de payer / consentement a payer / disposition a payer / remediation plan(s) / plan remediation / protected space(s) / protected area(s) / protected zone(s) / protected environment(s) / espace(s) protege(s) / european regulation(s) / european legislation(s) / european law(s) / european commission / european research council / EU law(s) / droit europeen / legislation(s) europeenne(s) / reglementation(s) europeenne(s) / conseil europeen / commission europeenne / legal / legally / reglementation(s) / legislative / legislation(s)

Bloc 3 :

responsible mining / responsible mine(s) / responsible extraction / extracting / extractive / exploitation miniere responsable / zero carbon mining / zero carbon mine(s) / zero carbon extraction / extracting/extractive / low carbon mining / low carbon mine(s) / low carbon extraction / extracting/extractive / sustainable mining / sustainable mine(s) / sustainable extraction / extracting / extractive / exploitation miniere durable / green mining / green mine(s) / green extraction / extracting / extractive / exploitation miniere verte / native population(s) / native people / native community(ies) / population(s) native(s) / communautaire(s) native(s) / autochtone population(s) / autochtone people / autochtone community(ies) / population(s) autochtone(s) / communautaire(s) autochtone(s) / indigenous population(s) / indigenous people / indigenous community(ies) / population(s) indigene(s) / communautaire(s) indigene(s) / local population(s) / local community(ies) / population(s) locale(s) / communautaire(s) locale(s) / first nation(s) / premiere(s) nation(s) / sacrificed territories / territoires sacrifies / war mineral(s) / minerais(s) guerre / reindustrialisation / re industrialisation / reindustrialisation / re industrialisation / onshoring / resettlement / green capitalism / green extractivism / green colonialism / mining capitalism / mine(s) capitalism / capitalisme vert / eco-capitalisme / colonialisme vert / extractivisme vert / capitalisme minier / extractivism policy(ies) / extractivist policy(ies) / politique(s) extractiviste(s) / mining externalities / mine(s) externalities / externalite(s) miniere(s) / social license(s) to operate / permis social operation / permis social exploitation / corporate social responsibility(ies) / responsabilite sociale entreprise(s) / corporate economic responsibility(ies) / responsabilite economique entreprise(s) / energy transition rights / energetic transition rights / droits transition energetique / governance / gouvernance / green deal / pacte vert / digital product passport(s) / passeport(s) numerique(s) produit(s) / mining code / mining contract(s) / mining authority(ies) / code minier / contrat(s) minier(s) / autorite(s) miniere(s)

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