United Nations ECE/ENERGY/GE.3/2024/6

Economic and Social Council

Distr.: General
8 February 2024

Original: English

Economic Commission for Europe

Committee on Sustainable Energy

Expert Group on Resource Management

Fifteenth session
Geneva, 22-26 April 2024
Item 6 of the provisional agenda
Responsible resource management: Development and deployment of the United Nations Resource Management System

Optimizing Resource Management for Critical Raw Materials: A Case Study of the Application of the United Nations Resource Management System with Cornwall Regional Government, United Kingdom

Prepared by Eva Marquis, Camborne School of Mines and Environment and Sustainability Institute, University of Exeter, United Kingdom; Frances Wall, Camborne School of Mines and Environment and Sustainability Institute, University of Exeter, United Kingdom; Nathan Cudmore, Cornwall and Isles of Scilly Local Enterprise Partnership, United Kingdom; and Karen Hudson-Edwards, Camborne School of Mines and Environment and Sustainability Institute, University of Exeter, United Kingdom

Summary

This case study explores the application of the United Nations Resource Management System (UNRMS) to critical raw materials (CRM) projects in Cornwall, United Kingdom. Published in 2022, the UNRMS Principles and Requirements provide a comprehensive resource management system for sustainable development that supports and enables the implementation of the 2030 Agenda for Sustainable Development. This pioneering case study involved introducing UNRMS to regional stakeholders and mapping its principles and requirements to the region. This region is historically famous for mining, and with the increasing demand for metals for the energy transition, there has been a renewed interest in metals exploration and mining project development. The study found that UNRMS identified strengths, weaknesses, and recommendations for sustainable development. It also highlighted the importance of flexibility and the involvement of key stakeholders in the implementation of UNRMS. Overall, this case study is the first application of UNRMS to a region, and it has shown the potential for resource management improvement and sustainable development.

Contents

I. Introduction and rationale for the case study

1. Critical Raw Materials (CRMs) are fundamental to achieving the targets of the Paris Agreement and the UN Sustainable Development Goals (SDGs). There has been a push for diversification of CRM supply chains, an increase in the primary and secondary CRM resources, and tracking of in-use or dormant stocks of these materials. In conjunction with this, the prevailing take-make-waste linear economy is incompatible with achieving some SDGs and operations within planetary boundaries.[1] Circular Economy has been proposed as a mechanism to aid sustainable development,[2] with core principles focusing on material longevity in the economy, natural capital regeneration, and eliminating waste and pollution. A potential disconnect exists between circular economy and CRM supply in that the availability of CRM needs to increase to enable the manufacturing of low-carbon technologies to facilitate the 'green transition' to combat climate change; however, primary mining is required to improve this availability. These new stocks must come into a more circular economy (CE) to be reused, remanufactured, and recycled, as highlighted in the European Union's Critical Minerals Act and the UK's Critical Minerals Strategy.[3]

2. As CRM extraction from primary mineral resources is necessary for achieving sustainable development ambitions, there is a need to reassess how these resources are viewed. They sit within a spatial and temporal ecosystem of activities that may act in synergy or competition. A complex array of environmental, social, governance and economic factors determine whether to develop a resource project. The resource project development must have a net positive benefit for sustainable development.

3. South West England is experiencing a resurgence in exploring and developing CRM projects (Figure I). Much of this activity is concentrated in the county of Cornwall. The Cornwall and Isles of Scilly Local Enterprise Partnership have included "Geo-Resources"[4] as one of the five 'Distinctive opportunities/USPs' highlighted in the region's Local Industrial Strategy.[5]

4. The United Nations Resource Management System (UNRMS) is a voluntary global standard for sustainable integrated resource management within the framework of public, private and civil society partnerships that uniformly apply to all resources.[6] UNRMS aims to balance economic development, environmental sustainability and social responsibility in integrated resources management, in line with the Sustainable Development Goals (SDGs) and the Paris Agreement. UNRMS is based on the United Nations Framework Classification for Resources (UNFC), a universally acceptable and internationally applicable scheme for classifying, accounting and reporting all energy and mineral resources.[7] UNRMS provides a set of principles and requirements that guide the planning, design, operation and closure of resource extraction and processing activities.

5. UNRMS has been applied to South West England's CRM projects in this case study. This application has enabled the identification of where alignment exists between the region and the principles of UNRMS and where further strengthening activity is required. The study

[1] Rockström, J., Steffen, W., Noone, K. *et al.* A safe operating space for humanity. *Nature* **461**, 472–475 (2009). https://doi.org/10.1038/461472a

[2] Schroeder, P., Anggraeni, K. and Weber, U. (2019), The Relevance of Circular Economy Practices to the Sustainable Development Goals. *Journal of Industrial Ecology*, **23**, 77-95. https://doi.org/10.1111/jiec.12732

[3] UK Department for Business and Trade and UK Department for Business, Energy & Industrial Strategy (2022) UK Critical Minerals Strategy, https://www.gov.uk/government/publications/uk-critical-mineral-strategy.

[4] Geo-Resources or Geological Resources: underground natural capital. Includes metalliferous and industrial, mineral resources and reserves, geothermal resources, landscape and associated cultural and heritage features, *etc.*

[5] Cornwall and Isles of Scilly Local Enterprise Partnership (2022) Local Industrial Strategy https://cioslep.com/wp-content/uploads/2021/03/LEP-industrial-strategy-30.09.22.pdf

[6] United Nations Resource Management System https://unece.org/sustainable-energy/unfc-and-sustainable-resource-management/unrms

[7] United Nations Framework Classification for Resources https://unece.org/sustainable-energy/sustainable-resource-management/united-nations-framework-classification

used a preliminary assessment methodology to evaluate the alignment of existing systems with the UNRMS principles and requirements. The method involved selecting a set of principles and requirements from UNRMS and assessing the extent to which they were being implemented in the mining industry in Cornwall. The assessment was based on a review of existing data and information, as well as consultations with stakeholders in the mining industry. The study also identified gaps and areas for improvement in the existing system and recommended how to address them.

6. The stakeholders involved in the mining industry in Cornwall include mining companies, local government, regional development agencies, environmental groups, and local communities. These stakeholders have different interests and perspectives on the future of the mining industry in Cornwall.

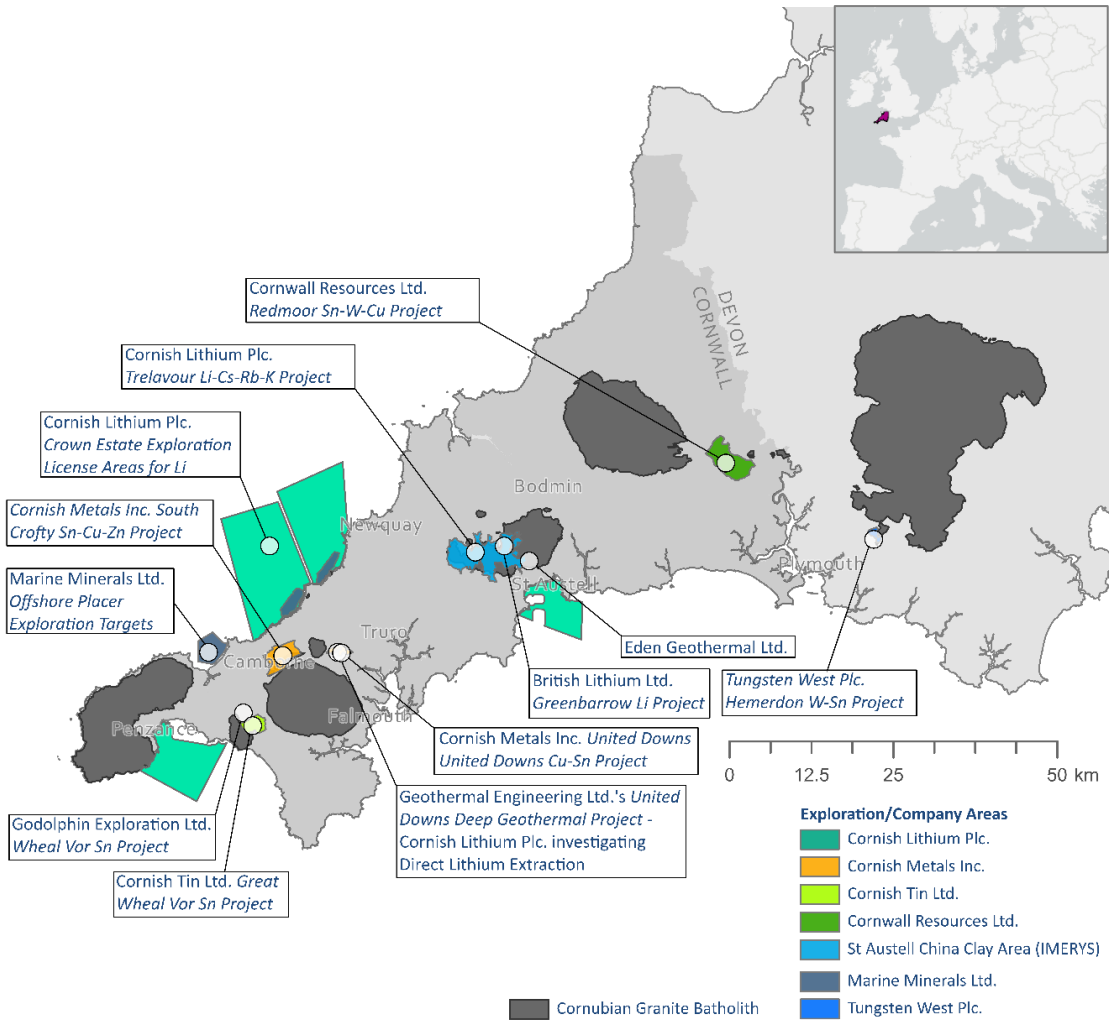
7. The UNRMS framework was applied to the CRM resources in South West England from a Cornwall-centric perspective. It provided valuable insights and recommendations for improving the sustainability of CRM projects. The study also demonstrated the potential of UNRMS as a tool for stakeholder engagement and collaboration, as well as for monitoring and reporting on resource management performance. The study highlighted the need for further development and refinement of UNRMS, especially regarding its applicability to different types of resources and regions and its alignment with existing standards and initiatives. The study also suggested some areas for future research and application of UNRMS, such as developing indicators, metrics and benchmarks, conducting pilot projects and case studies in other regions, and exploring the linkages between UNRMS and the SDGs.

II. Cornwall's Geological Resources and Critical Minerals

8. South West England, especially Cornwall, has various resources (metalliferous, industrial rocks and minerals, geothermal, solar, wind, *etc*.) available to support the UK Government's ambitions to transition to Net Zero and Paris Agreement targets to varying degrees. Most resources are related to the Cornubian Granite Batholith (Figure I), which has acted as a source of heat, minerals, and metals. Circulation of fluids in and around the granites has given rise to many styles of CRM mineralization - from lithium in granites and brines to tin and tungsten in mineralize structures near the surface and at depth (Figure II). Exploration companies active in South West England have defined mineral resources of ~450 kt lithium (Li), ~440 kt tungsten tri-oxide (WO_3), and ~190 kt tin (Sn; see Supplementary Information I). In addition to CRM, there is a range of additional, interconnected resources (Figure II). One such resource is kaolin or 'china clay', which has been extracted in the county since the late 1700s and remains an important industry in Cornwall. Studies have shown the potential for CRM production from the china clay tailings. Now flooded, many historic mine workings are potential low-enthalpy (temperature) geothermal reservoirs that could be used to heat homes, reducing the reliance on oil, gas, and electricity for heating. At depth, there is potential production of both heat and energy from geothermal fluids circulating in the granites at ~5 km. These higher-enthalpy geothermal projects have a planned capacity of up to 5 MW electricity and 20 MW thermal energy (heat) per site[8] (Figure I).

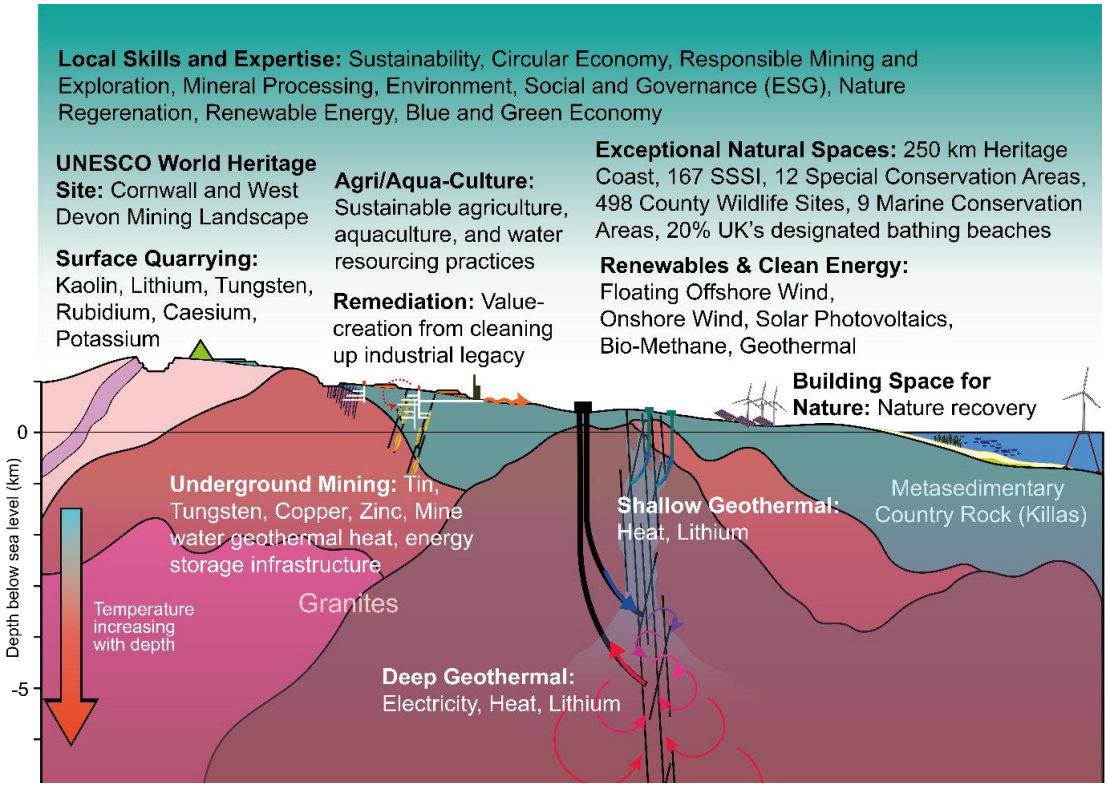
[8] Wardell Armstrong (2021) Penhallow Geothermal: Project Description, Planning Policy and Socio-Economics: available at https://planning.cornwall.gov.uk/online-applications/files/9D6052BDC749653E4CA13EC3342620CA/pdf/PA21_09826-PROJECT_DESCRIPTION__PLANNING_POLICY_AND_SOCIO-ECONOMICS-5973926.pdf

Figure I
Map of South West England with locations of Critical Raw Material Projects and Target Areas (as of January 2023)



Note: Advanced geothermal projects (those with boreholes) are shown for context. The inset (top right) shows the location of the region with respect to Europe. Sources of 'Exploration/Company Areas' have been collated from publically available reports (see Supplementary Information I for report sources), the Crown Estate Open Data Portal (https://opendata-thecrownestate.opendata.arcgis.com/), and St Austell China Clay Operational Areas as defined in the Cornwall Council (2022) "St Austell China Clay Restoration and Tipping Supplementary Planning Document (SPD)" (https://www.cornwall.gov.uk/planning-and-building-control/planning-policy/adopted-plans/st-austell-china-clay-restoration-and-tipping-supplementary-planning-document).

Figure II
Schematic cross-section of South West England



Note: The schematic depicts the diverse geological, natural, heritage, and cultural assets of South West England, showcasing the region's unique geological history, with the Cornubian Granite Batholith as a prominent feature.

9. The impacts and relationship between the various Geo-Resource and other natural capital-based activities, such as renewable energy, farming, fishing and tourism, may be synergetic or competitive. Relationships may be competitive when an alternative use effectively sterilises a potential CRM resource (e.g., new developments such as solar farms overlying lithium mica tailings dams) or synergetic where CRM recovery is enhanced, or made possible by further development (*e.g.*, combined direct lithium extraction and geothermal energy generation). An integrated understanding of natural capital, sustainable development solutions, and the associated social and economic environments is necessary. As such, the application of UNRMS is well suited to this region.

10. As of January 2023, eight companies are actively exploring or developing regional CRM projects. These projects range from early-stage exploration through to developments nearly ready to start. In addition, several novel resources and pilot plant projects are in progress for new extraction technologies (Technology Readiness Level (TRL) 4 to 6;[9] UNFC F2.1 to F1.3).[10] The authors mapped most project activity to the UNFC Categories: E – economic, environmental, social viability; F – technical feasibility; G – degree of confidence (see discussion of UNFC in section VIII). The primary resources under investigation are lithium, tin, and tungsten; At the same time, potential co- and by-products reported include caesium, rubidium, copper, zinc, industrial rocks and minerals, and geothermal energy (heat and electricity). There are also metal occurrences within historic mine wastes across the region classified under UNFC criteria as E3 F4 G4. Due to limited data availability, quantities are highly uncertain.

[9] Technology Readiness Levels (TRLs) are a way of measuring the maturity of a technology or a product. They range from 1 (basic principles observed) to 9 (product on market). The European Union uses TRLs to assess the readiness of technology for the market and to define the scope and goals of its funding programmes1. TRLs help to evaluate the progress and risks of a project.

[10] UNECE (2022) UNFC Guidance Europe https://unece.org/sites/default/files/2022-10/Revised_UNFC_Guidance_Europe_as_of_19.October.2022.pdf

11. Only CRM occurrences have been considered in this study. There are active projects for geothermal (Heat/Energy), Floating Offshore Wind (FLOW), biofuels, hydrogen economy and water resources, which could be considered in future assessments.

III. Socio-economic background in Cornwall – the sustainable development challenges

12. Cornwall's population increased by 7.1 per cent from 2011 to 570,300 in 2021.[11] Demographics are also changing, with a growing elderly population. Between 2011 and 2021, while people aged 65 to 74 rose by 25.9 per cent, those aged 35 to 49 fell by 8 per cent. At the same time, and counter to the rest of the UK, the percentage of households in social and privately rented housing increased to 12.8 per cent and 19.7 per cent, respectively. Many workers in Cornwall are part-time (34.5 per cent) or self-employed (23.6 per cent). The largest employment sectors are Wholesale, Retail, and Automotive Trades (18.4 per cent), Health and Social Work (16.6 per cent), and Accommodation and Food Services (15.7 per cent).[12]

13. In the 18th and 19th Centuries, the metalliferous mining region comprising Camborne, Pool, Illogan and Redruth (CPIR) had one of the highest land prices in the UK. At this time, tin and copper mining created wealth, which, in effect, were the critical raw materials of the Industrial Revolution. As the local industry declined, mass emigration, referred to as the Cornish Diaspora, ensued, taking the Cornish mining community to more than 175 destinations, all globally linked to Cornish Mining.[13] Tin prices fell dramatically in the 1980s when the tin price cartel ended, and the last metalliferous mine, South Crofty (Pool), closed in 1998. While the CPIR is still Cornwall's most significant community network population, with over 60,000 residents,[14] several districts are among the most deprived 10 per cent of the UK.[15]

14. Now a popular holiday destination, Cornwall receives an estimated 4.5 million overnight visitors (*cf.* day-visitors) per year[16] who enjoy the coastline, countryside, history and heritage. In 2018, the visitor economy accounted for 9 per cent of the gross value added (GVA) areas, with visitor spending in Cornwall and the Isles of Scilly (CIoS) of £2 billion. Although a significant employer, creating 44,500 jobs in the county, it is the lowest productivity sector.[7] Mining is a core part of the region's heritage. In 2006, the United Nations Educational, Scientific and Cultural Organization (UNESCO) inscribed a Cornwall and West Devon Mining Landscape World Heritage site, covering multiple heritage sites distributed across the region.

15. Connectivity and the installation of superfast broadband have helped Cornwall develop over the past five years. Cornwall has a growing number of digital technology businesses, with growth in this area being one of the highest rates in the country. New and growing industries include digital creative and spaceport. Marine engineering is also necessary, and there is an opportunity to engage with floating offshore wind deployment in the nearby Celtic Sea.

[11] UK Office for National Statistics – How life has changed in Cornwall: Census 2021 (https://www.ons.gov.uk/visualisations/censusareachanges/E06000052/)

[12] NOMIS – Labour Market Profile Cornwall (Accessed 15/05/2023 - https://www.nomisweb.co.uk/reports/lmp/la/1946157349/report.aspx?#ls)

[13] Cornish Mining World Heritage: Map of the Diaspora - https://www.cornishmining.org.uk/about/about-the-whs/what-makes-it-special/map-of-diaspora

[14] Cornwall Council: Data, maps and infographics - https://www.cornwall.gov.uk/health-and-social-care/public-health/joint-strategic-needs-assessment/data-maps-and-infographics/

[15] Index of Multiple Deprivation (2019) - https://www.cornwall.gov.uk/media/eqmfzauq/imd_2019_jsna.png

[16] https://cioslep.com/wp-content/uploads/2021/03/LEP-industrial-strategy-30.09.22.pdf https://www.exeter.ac.uk/media/universityofexeter/esi/pdfs/SVEE_Sustaining_The_Visitor_Economy_Cornwall_REPORT_FINAL.pdf https://cioslep.com/wp-content/uploads/2021/03/LEP-industrial-strategy-30.09.22.pdf

16. Although new opportunities are emerging, Cornwall remains one of the poorest regions in the UK, with the GVA per head of population being 30 per cent below the UK average in 2020.[17] Median gross weekly earnings for full-time workers in Cornwall was £564, 88 per cent of the UK average. In contrast, in March 2022, the average house price in Cornwall was £300,422 (UK average of £274,011).[18]

17. Mining and quarrying activities are a small but consistent portion of the CIoS economy, contributing £87 million GVA at current basic prices in 2017 (0.8 per cent).[19] IMERYS continues to employ 830 people in over 20 mining and processing facilities in Cornwall, producing over 600 thousand tonnes of kaolin annually, the third largest world production of beneficiated kaolin after Brazil and the USA,[20] ceramics, in paints, plastic, rubbers, cosmetics, pharmaceuticals and in paper and cardboard production.[21]

18. A feature of CIoS mining heritage is a cluster of over 100 companies and organizations undertaking business related to Geo-Resources. These businesses, most of which are Small and Medium Enterprises (SMEs, <250 employees) and Microbusiness, are brought together under the Cornwall Mining Alliance (CMA)[22] – a not-for-profit organization established by the Cornish Chamber of Mines and Minerals and Camborne School of Mines (CSM), with help from the UK Department of Trade, in 2016 to bring together the cluster of expertise Cornwall has in the mining sector. Camborne School of Mines (CSM), now part of the University of Exeter, is integral to the region's mining legacy. It is world-famous in the industry and ranks fifteenth for Mining and Minerals.[23]

IV. Cornwall and the Isles of Scilly Regional Government Vision

19. The regional government is Cornwall Council, comprising elected Councillors and executive and administrative staff. In December 2020, the CIoS Leadership Board[24] adopted the Cornwall Plan 2020-2050.[25] The plan sets out the shared vision for the region to create: *"a creative carbon neutral economy", "sustainable food, land and seas", "thriving places with decent homes", "education, equality and entrepreneurship", "healthy, safe, resilient communities",* and *"a digital revolution for sustainable living."*

20. The CIoS Local Enterprise Partnership (LEP) is the lead regional organization coordinating efforts on economic development. The LEP set out five distinct regional opportunities in the 2022 Local Industrial Strategy for CIoS: *"*Geo-resources" (including CRM), "Clean Energy", "Data and space", "Visitor economy", and "Agri-food". The Geo-Resources sector had previously been excluded from regional priorities. However, the rise in exploration activity, together with studies of Geo-Resources and links to other European mining regions,[26] led to the recognition of the opportunity.

21. The University of Exeter (CSM) collaborates with the CIoS LEP to advise on CRM and sector development. In 2022/23, this included a part-time secondment of University Researcher Eva Marquis to the CIoS LEP as their "Technology Metal Advisor". Application

[17] Data source: https://www.ons.gov.uk/employmentandlabourmarket/peopleinwork/labourproductivity/datasets/subregionalproductivitylabourproductivitygvaperhourworkedandgvaperfilledjobindicesbyuknuts2andnuts3subregions

[18] UK House Price Index (accessed 15/05/2023; https://landregistry.data.gov.uk/app/ukhpi)

[19] Office for National Statistics dataset: Regional gross value added (income approach) https://www.ons.gov.uk/economy/grossvalueaddedgva/datasets/regionalgrossvalueaddedincomeapproach

[20] https://www.imerys.com/united-kingdom

[21] IMERYS – Kaolin - https://www.imerys.com/minerals/kaolin

[22] Cornwall Mining Alliance: https://cornwallminingalliance.org/

[23] https://www.qschina.cn/en/university-rankings/university-subject-rankings/2023/mineral-mining-engineering

[24] Cornwall and Isles of Scilly Leadership Board - https://www.cornwall.gov.uk/the-council-and-democracy/cornwall-and-isles-of-scilly-leadership-board/

[25] https://letstalk.cornwall.gov.uk/cornwall-plan

[26] Mining and Metallurgy Regions of Europe (MIREU) Project - https://mireu.eu/regional-profiles

of UNRMS was planned into the secondment and the collaboration of this case study, building on previous research on the region's Geo-Resources development. The authors and partners had good experience in the Geo-Resources sector, including geological, mining, environmental and socio-economic knowledge. The secondee was researching the application of circular economy principles to exploration and mining in Cornwall for the Interdisciplinary Circular Economy Centre for Technology Metals (Met4Tech). Other research team members have also been involved in developing the Cornwall Mining Alliance and other regional development projects (Mining and Metallurgy Regions of EU (MIREU), Smart and Green Mining Regions of the EU (REMIX)). Therefore, connections to several key regional partners representing a range of stakeholders for the case study were in place, which aided the deployment of the study – for a region without an existing network of partners and associated stakeholders, further stakeholder mapping would be required. The key partners engaged in this specific study are listed in Table 1.

Table 1
Key partners engaged in this initial application of UNRMS

Stakeholder (s)	*Description*
Cornwall and Isles of Scilly Local Enterprise Partnership	Private sector-led partnership between the private and public sectors. Responsible for setting and driving the economic strategy for Cornwall and the Isles of Scilly. This includes determining local priorities and overseeing activities to drive growth and create high-quality local jobs.
Camborne School of Mines, University of Exeter	University is located in South West England, with a campus in Cornwall, of which CSM is situated in the Department of Earth and Environmental Sciences.
Cornwall Council	Unitary authority for Cornwall. This includes the Minerals Planning Authority, which oversees planning applications related to mineral exploration and development in the county.
Cornwall Mining Alliance	A cluster of businesses located in Cornwall and South West England that undertake business activities related to minerals and mining.
Cornish Chamber of Mines and Minerals	Chamber works to support the region's existing and potential mining and mineral interests by working closely with mineral developers and regulatory bodies.

22. To develop these sectors, the CIoS LEP commissioned several reports on regional strategic projects,[27] one of which is the opportunity offered by the growing interest in lithium, tin and tungsten exploration. Key challenges to sustainable sector growth were documented and encompass a range of development needs, some of which are highly sector-specific whilst others span across sectors – *i.e.*, talent pipeline, infrastructure requirements and energy costs. To describe the multi-dimensional challenge to various stakeholders from both technical and non-technical backgrounds, UNRMS was used to review the needs for CRM resource development in Cornwall.[28]

V. A new summary diagram for UNRMS

23. The 12 principles and 54 underlying requirements of UNRMS provide a comprehensive framework for the sustainable management of resources in a region. However, UNRMS implementation must first be understood by local, regional and national stakeholders. In this assessment of UNRMS, the 12 principles have been organized into categories and sub-categories to illustrate how they fit with the ambitions and discussions around the implementation of the SDGs (Figure III):

[27] CIoS Strategic Projects - https://cioslep.com/impact/strategic-projects/
[28] CIoS LEP Technology Metal Opportunity Report - https://cioslep.com/wp-content/uploads/2023/02/Cornwall-and-the-Isles-of-Scilly-Tech-Metals-Opportunity.pdf

Priority Determination articulates the role of the body adopting UNRMS in managing resources and a summary of the policies and strategies related to managing resources. This principally outlines the body(s) responsible for coordinating resource management plus the legal and strategic frameworks that resource management will support.

- Principle 1: State rights and responsibilities in the management of resources.

Fundamental Principles are our four groups of principles relating to Environmental, Social and Governance (ESG), as this is a term recognized by industry and investors, and economics, in particular, 'Circular Economy' as the UNRMS principles relating to economic aspects are aligned with circular principles (Figure III).

Environment

- Principle 2: Responsibility to the Planet.

Social

- Principle 4: Social Engagement
- Principle 9: Health and Safety.

Governance

- Principle 3: Integrated and Indivisible Management of Resources.

Circular Economy

- Principle 5: Service Orientation for the Use and Reuse of Resources
- Principle 6: Comprehensive Resource Recovery
- Principle 7: Value Addition
- Principle 8: Circularity.

Facilitating Principles map across the *Fundamental Principles* and are necessary for implementing those principles, strengthening the responsible management of resources and sustainable development of a region:

- Principle 10: Innovation
- Principle 11: Transparency
- Principle 12: Continued Strengthening of Core Competencies and Capabilities
- A 13th principle, 'Collaboration', was added for this study and thus included in Figure III. Principle added to highlight the need for cross-sector and institutional collaboration, for example, collaboration and knowledge sharing between the partners (Table 1) engaged in this study.

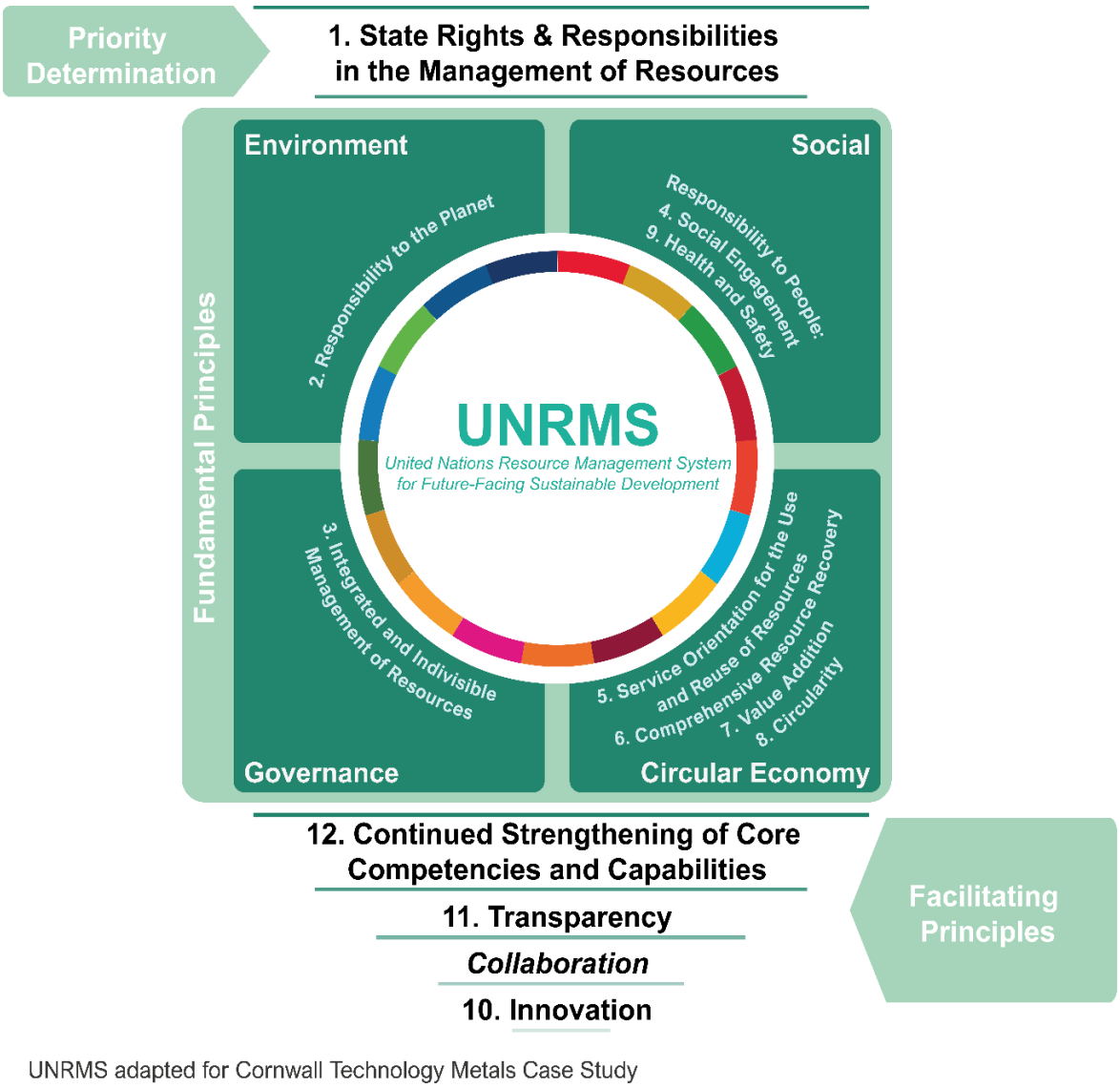
24. The *Fundamental Principles* map to Environmental, Social and Governance (ESG) core part values, an increasingly significant aspect of sustainable investment and financial management, which has progressively entered the common parlance of exploration and mining companies and investors, as well as shaping the economic metrics of resource management (Figure III). Economic and financial risk and performance indicators are aligned under ESG with Circular Economy principles to support materials stewardship. The diagram also identifies the requirement to clearly understand the vision and responsibilities of the overseeing body, *i.e.*, *Priority Determination*, and the need to develop *Facilitating Actions* that consider the *Fundamental Principles*. This would support the development of actions relating to principles within the Environment, Social, Governance and Circular Economy group aspects that align with requirements of UNRMS principles relating to transparency, continued strengthening of core competencies and capabilities, and innovation.

25. Rather than a pathway through the principles, as depicted by the UNRMS Fundamental Principles diagram,[29] the authors' interpretation of UNRMS uses a 'top-down to bottom-up' approach (Figure III). 'Top-down' refers to the *Priority Determination*, *i.e.*,

[29] https://unece.org/sustainable-energy/unfc-and-sustainable-resource-management/unrms

the State's rights and responsibility in managing resources and what the objectives of implementing a resource management system aim to achieve. 'Bottom-up' refers to the *Facilitating Principles*, *i.e.*, the actions implemented concerning transparency, innovation and continuous strengthening of core competencies and capabilities to enable a resource management system to be implemented while building and strengthening the *Fundamental Principles* related to environment, social, governance and circular economy.

Figure III
Categorizing UNRMS Principles: Priorities, Fundamentals, and Actions



Note: This illustration categorizes UNRMS principles into priorities, fundamentals, and actions. One additional "Fundamental Principle" is specific to the Cornwall Technology Metals Case Study (shown but not discussed).

VI. Mapping of UNRMS to the existing system in Cornwall

26. Not all UNRMS requirements need the same level of attention in every application. Organizations, structures, and frameworks that align with the UNRMS requirements may already be in place or can be easily adapted for UNRMS implementation, meaning these do not have to be developed 'from scratch'. For example, in the UK, there are substantial health and safety laws and regulations, with a dedicated health and safety inspectorate that ensures standards are adhered to. Thus, this aspect requires less focus for UNRMS implementation.

27. For Cornwall, organizations, policies, and strategies (at national and regional levels) were mapped against the UNRMS principles and requirements. A qualitative ranking system from 1 to 5 was used to indicate the fit of current initiatives, bodies, and policies with the UNRMS principles and requirements, with one indicating these are fit-for-purpose in the current system and five indicating that requirement is missing from the current system (Table 2). From this mapping exercise, strengths and weaknesses could be identified (Table 3). This preliminary assessment indicates that although the UK and, by extension, Cornwall have robust regulatory frameworks, there are barriers to sustainable development arising in Fundamental Principles. Especially about "Circular Economy" (service orientation, value addition, and circularity were all rated 4 or 5), as well as some areas for improvement in aspects of "Responsibility to the planet", "Transparency", and "Continuous strengthening of core competencies and capabilities".

28. An important finding was the need for a strategic environmental assessment for the region and individual project environmental impact assessments. Progress toward an integrated resource management system for the region has been made through the recent Deep Digital Cornwall project, which created a proof of concept for a Deep Digital Cornwall 3D/4D model and digital twin of the region.[30] Further development of such a system would enable the inclusion of all natural resources in CIoS, which could be used to develop and assess sustainable development scenarios for policy testing and decision-making.

29. This is the first assessment of aligning existing initiatives, bodies, and policies with the UNRMS principles and requirements. A recommendation for the next steps is a further detailed assessment, with relevant stakeholders and potentially external expertise in selected principles and requirements highlighted in this study.

Table 2
Definitions for Qualitative Ranking

Rank	*Definition*
1	Fit for purpose
2	Present - not always fit for purpose
3	Could be improved or Informal
4	Mostly Missing or Inconsistent Application
5	Missing

[30] https://deepdigitalcornwall.org

Table 3
Preliminary mapping of UK/Cornwall Critical Raw Materials regulatory, governance, and industry ecosystem to UNRMS principles and requirements

Principle	*Requirements*	*Ranking*
State rights and responsibilities in the management of resources	(a) National policy and strategy: To support the implementation of sustainable resource management aligned to the 2030 Agenda for Sustainable Development;	2
	(b) Compliance with regulations: Establish regulatory bodies which are responsible for sustainable resource management;	3
	(c) Coordination: Coordination with different authorities responsible for regulating sustainable resource management;	2
	(d) Provision of technical services: Providing technical services needed for sustainable resource management;	3
	(e) Adherence to international obligations and arrangements for international cooperation.	2
Responsibility to the planet	(a) Long-term cost-benefit analysis concerning planet-people-prosperity;	3
	(b) Strategic environmental assessments: A Strategic Environmental Assessment (SEA) is a systematic process for evaluating the environmental implications of a proposed policy, plan or programme and provides means for looking at cumulative effects and appropriately addressing them at the earliest stage of decision-making alongside economic and social considerations;	5
	(c) Climate change-related activities: All activities align to Nationally Determined Contributions (NDCs), investor and company vision, and climate change policies;	3
	(d) Resource and energy use efficiency: Actions to reduce resource and energy inputs used to produce resources;	3
	(e) Greenhouse Gas (GHG) Intensity indicator: expressed in g CO_2 eq/MJ;	5
	(f) Water use and management: Ensure water inputs are optimized and released to the environment and managed according to country legislation;	4
	(g) Land use and management: Actions to minimize or optimally manage the land footprint;	4
	(h) Management of all residues and effluents in an appropriate manner;	2
	(i) Biodiversity conservation and enhancement activities: All activities in the area to conserve and enhance biodiversity;	2
	(j) Periodic sustainability reporting for various purposes.	3
Integrated management of resources	(a) Information platform, data interoperability, dashboard: Availability of accurate and complete information on the area and project promptly to help in decision making;	5
	(b) Estimation of resources and assigning the degree of confidence in the estimated quantities according to UNFC;	4
	(c) Opportunity and Risk management: identification, evaluation, and prioritization of opportunities and risks followed by coordinated and economical application of resources to minimize, monitor, and control the probability or impact of unfortunate events, including resource-based conflicts, and to maximize the realization of opportunities;	2
	(d) Productivity: Ensuring required measures to enhance production efficiency. Often, a productivity measure is expressed as the ratio of aggregate output to a single input or an aggregate input used in a production process, i.e., output per unit of input, typically over a specific period;	2
	(e) Preventing illicit financial flows, Base Erosion and Profit Shifting (BEPS): Illegal capital flight. Domestic tax BEPS occur due to multinational enterprises exploiting gaps, and mismatches between countries' tax systems affect all countries. Developing countries' higher reliance on corporate income tax means they suffer from BEPS disproportionately;	2
	(f) Sustainable investment framework: A set of standards for a company's operations that socially conscious investors use to screen potential investments;	2
	(g) Artisanal and small-scale mining (ASM): If ASM is present in the area, it should be integrated with the development programmes;	*NA*

Principle	*Requirements*	*Ranking*
Integrated management of resources (*cont.*)	(h) Competent and qualified assessments: All criteria necessary to ensure the quality of data and information provided;	2
	(i) Monetary provision for the decommissioning of facilities, including closure and decommissioning plans from the start of the operation. The plans should be updated continually.	3
Social Engagement	(a) Human rights-based protocols to prevent child and forced labour and safeguard employee rights;	1
	(b) Indigenous populations: In alignment with the United Nations Declaration on the Rights of Indigenous Peoples;	3
	(c) Stakeholder capitalism: Orientation to serve the interests of their stakeholders such as customers, suppliers, employees, shareholders and local communities;	3
	(d) Communications and outreach.	3
Service orientation for the use and reuse of resources	(a) Resource as a Service model: Resource as a Service (RaaS) is a business model whereby customers pay for a value-added product or service, such as heat, light or mobility, without buying the resources. Life cycle environmental and waste management recycling could be part of a long-term service contract.	5
Comprehensive resource recovery	(a) By- and co-product management: Maximizing the utility of all by- and co-products;	5
	(b) Land value release/ land value capture: Optimize land use by releasing it from inefficient use.	5
Value addition	(a) Nexus approach: Determine how activities are diversified to support various areas of the economy;	5
	(b) Feasibility studies: Detailed studies that investigate the evaluation of resource and energy efficiency, productivity and consideration of all outcomes;	4
	(c) Assessment and public reporting of upstream, side stream and downstream possibilities;	4
	(d) Manage all upstream, side stream and downstream linkages in resource management;	4
	(e) Supply chain optimization aims to ensure the optimal operation of the supply chain;	4
	(f) Life cycle assessments: Methodology for assessing environmental impacts associated with all the resource utilization life cycle stages.	4
Circularity	(a) Waste hierarchy model: The "waste hierarchy" ranks waste management options according to what is best for the environment. It gives top priority to preventing waste in the first place;	5
	(b) Design for circularity: Design out waste and pollution; keep products and materials in use, and regenerate natural systems;	5
	(c) Anthropogenic resource management: Use of residues as secondary resources.	5
Health and Safety	(a) Crisis management, emergency response: Emergency Response Preparedness actions to foresee emergencies that are likely to occur and pre-plan critical components of a reply, including innovative monitoring and digitalized feedback systems;	1
	(b) Safety Protocols: System for protective actions to reduce existing or unregulated risks;	1
	(c) Worker and population health standards: Adherence to international and national standards and regulations to protect workers and the population;	1
	(d) Tailings and residue management: Safety of tailings and residues and critical evaluation of the impacts from different use of residues, mainly anthropogenic resources.	2
Innovation	(a) Models of innovation through combining hybrid technologies and approaches applicable to diverse technologies;	3
	(b) Build-Measure-Learn: A method to gain quick feedback on the utility of a new product or service;	1
	(c) Development of Minimum Viable Products (MVPs): a prototype that is evaluated solely for internal quality;	1
	(d) Innovation accounting. A quantitative approach allows seeing whether innovations bear fruit and create learning milestones.	1

Principle	*Requirements*	*Ranking*
Transparency	(a) Supply chain transparency and traceability: Supply chain transparency requires companies to know what is happening upstream, side stream and downstream in the supply chain and communicate this knowledge internally and externally; (b) Due diligence: Investigation, audit, or review performed to confirm facts or details; (c) Governments should assess and report company upstream, side stream and downstream linkages, as well as their supply chain due diligence processes; (d) Data quality: Confirming accuracy and precision; legitimacy and validity; reliability and consistency; timeliness and relevance; completeness and comprehensiveness; availability and accessibility; and granularity and uniqueness; (e) Competent and qualified assessments.	4 3 4 2 3
Continuous strengthening of core competencies and capabilities	(a) Institutional strengthening (ICE-SRMs): Creation of institutions with a long-term mission to build sustainable value and change the world for the better; (b) Re-Skilling: Preparing workers for the end of the project and just transitions.	3 3

VII. UNFC and UNRMS Interplay: Integrated management of resources

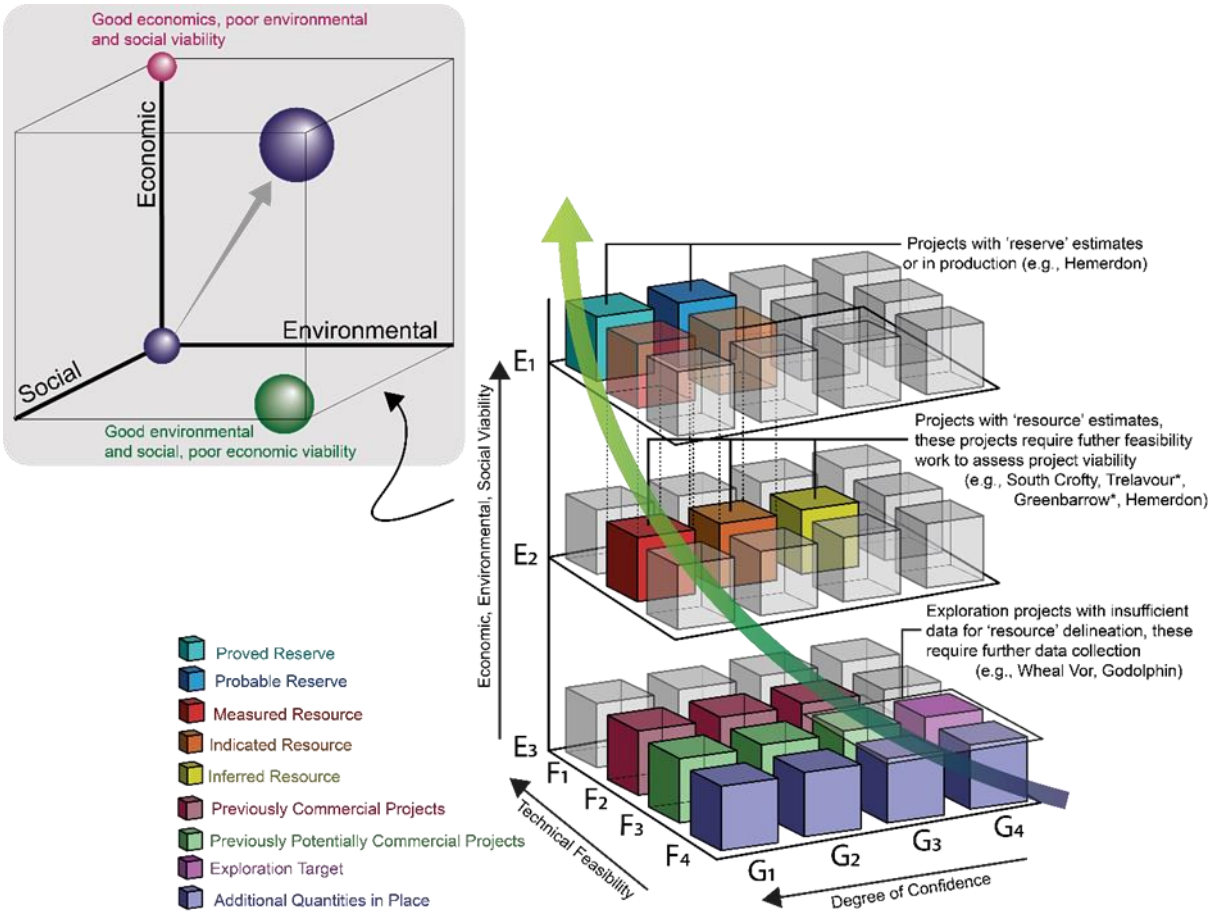
30. The minerals projects in Cornwall have been mapped to UNFC using the UNFC-CRIRSCO Template 2015 Bridging Document[31] (Figure IV). The projects under active exploration can be mapped from published Committee for Mineral Reserves International Reporting Standards (CRIRSCO) information because the companies in Cornwall use NI 43-101 and the Australasian Joint Ore Reserves Committee (JORC) codes. Older projects that have been less active recently and mine waste were classified directly to UNFC. The UNFC classification distinguishes the Tungsten West project at Hemerdon (Devon), which is ready to start as soon as suitable finance is in place; the projects for tin, tungsten and lithium in granite mica ‘on route’ through development and the early-stage tin exploration projects at Wheal Vor and Godolphin. The projects that plan to extract lithium from brine already have E2/3 and F3 values, but although some lithium concentrations are published for these brines, formal resource and reserve estimates have yet to be determined, partially due to the novelty of these occurrences, and therefore the authors classified these projects as G4.

31. Direct mapping from the CRIRSCO information on resources to UNFC indicates project progress; however, it masks some critical information that may be missing from CRIRSCO standard-compliant reports. This was particularly relevant to the E-axis, where transferring a CRIRSCO-compliant resource to the equivalent E-axis location may not fully articulate a project's environmental and social viability (Figure IV).

32. As a result, UNFC is used to develop a baseline understanding of the current system; however, UNRMS should guide the information used to classify projects' environment and social sustainability in the context of regional and local needs. There needs to be a clear understanding of the differing scopes of these systems and their interplay. UNFC classifies what resources are available and project progress within the current system; UNRMS is a forward-planning decision-making tool that builds on UNFC but also provides feedback to UNFC by developing and strengthening the system in which the resource projects operate, thus influencing the modifying factors impacting resource projects.

[31] UNECE (2015) Bridging Document between the Committee for Mineral Reserves International Reporting Standards (CRIRSCO) Template and the United Nations Framework Classification for Resources (UNFC) - https://unece.org/DAM/energy/se/pdfs/UNFC/UNFC_specs/Revised_CRIRSCO_Template_UNFC_Bridging_Document.pdf

Figure IV
Mapping between UNFC and CRIRSCO-compliant reporting standards



Note: The mapping provides a simple framework for categorising mineral resource estimates in the UNFC space. However, the direct mapping of resource classifications (inferred, indicated, measured resources, and proven probable reserves) conflates aspects of geological confidence and modifying factors.

33. In CIoS, this is exemplified by several requirements for developing a sustainable CRM industrial sector, such as:

- *Talent pipeline* – a core part of competency and capability building, requiring employees with the relevant skill set is crucial for project development. In Cornwall, and more broadly, South West England, there is a need to provide residents with stable employment in well-paid careers, which the CRM sector could provide if successful. Developing these skills requires long-term training, from school to professional qualifications. For nascent industries, such as the proposed re-establishment of metal mining in Cornwall, that do not have a talent pool with the required skills, formal training and up-skilling programmes will be needed for a company to progress a mineral resource project. There is a risk that without these skills in the local population: (a) companies may bring in expertise from outside of the region, which may cause tension between local communities and economic migrants, (b) value generated by these jobs is not available in its highest form to local communities (i.e., although they may benefit from money being spent by workers this will be at a reduced level), and (c) increased stress will be exerted on a constrained infrastructure and housing system. These risks and tensions can be explored by applying UNRMS, and plans to alleviate and mitigate negative impacts can be developed on a regional/national basis
- *Strategic Environmental Assessment* – going beyond single project environmental impact assessment (EIA) to systems-level modelling of the combined impact of

strategic developments, enabling forward-looking scenario modelling to reduce risk and unintended negative consequences and highlighting non-economic/technical critical path barriers to sustainable regional development

- *Value addition through adjacent opportunities* – assessment of the other forms of 'value' that can be captured and aid sustainable development. Developing a database of potential products for adjacent industry use as well as intangible value addition (i.e., follow-on positive impact such as the land value addition from reducing contamination) and second life planning (i.e., what is the best use of the site after first use, and how can the design of the first project factor in the second life use)
- There is an opportunity for UNFC to explore the value addition of a project - assessing not only the volume/quantity of resources available but also the impact of developing the resource/project on sustainable development at various levels
- The transition toward a sustainable mining industry in Cornwall is a promising avenue that could create new jobs and economic opportunities. Focusing on producing CRM for high-tech products and renewable energy technologies could be particularly lucrative. Adopting a circular economy approach that prioritizes service orientation, value addition, and circularity could benefit the region's mining industry. This strategy could help minimize waste and maximize resource efficiency, leading to cost savings and increased competitiveness. The mining industry's potential for innovation and technological advancement has the potential to yield new products and markets
- Some of the technological innovations and currently accepted practices that are being trialled in Cornwall about mineral extraction are:
    - Direct lithium extraction (DLE): This process employs technologies that selectively extract lithium from geothermal waters without evaporation ponds or large amounts of chemicals (*e.g.,* ion exchange, sorption, membranes). Cornish Lithium is testing this technology at its pilot plant at United Downs to produce battery-grade lithium hydroxide
    - Modernisation and reopening of existing mines: A feasibility study is in progress for the South Crofty project, one of the world's oldest tin mines, which will assess the implementation of modern environmental and safety standards, such as water treatment, ventilation and automation for future mine development
    - Sensor-based sorting: This technology uses sensors, such as X-ray, optical or infrared, to detect and sort different types of minerals based on their physical or chemical properties. Tungsten West has trialled this technology to separate wolframite-rich ore at its Hemerdon project, reducing energy consumption compared to conventional methods
    - Geophysical exploration: Cornish Lithium and Cornwall Resources have employed geophysical, such as airborne electromagnetic and high-resolution gravity, methods to identify potential lithium-rich geothermal water-bearing structures and granite upwelling related to polymetallic (W, Sn, Cu) mineralisation which could provide a sustainable source of tungsten and lithium as well as heat and power.

34. The mining industry in Cornwall could explore various possibilities for extracting minerals, such as bio-processing and using novel leaching agents to reduce costs and improve environmental credentials, although these require proving at scale. Such innovations also have the potential to be applied to the remediation of contaminated sites and the recovery of valuable metals from electronic waste. Novel mining methods in development, such as narrow vein mining and in-situ extraction technologies, can potentially selectively extract ores and metals with a minimal waste footprint. Such selective mining can access critical metals while reducing material volumes sent for comminution (crushing and grinding), a key energy usage, and thus greenhouse gas emissions, a hotspot in the mining process. However, such technologies are at an early TRL and require significant investment and testing for upscaling and deployment.

35. Artificial Intelligence (AI) could have numerous applications in the mining industry, such as improving exploration and discovery, optimizing production and processing, enhancing safety and security, reducing environmental impacts, and increasing efficiency and profitability. AI could also enable new forms of collaboration and communication between humans and machines and among different stakeholders in the mining sector.

36. Stakeholder engagement and consultation are vital to the decision-making process, as they can help identify and implement industry-accepted practices. Stakeholders are the individuals or groups that have an interest or influence in the outcome of a project or activity, such as investors, regulators, customers, suppliers, employees, communities, and civil society. By engaging and consulting with stakeholders, the industry can:

- Gain valuable insights and feedback on different stakeholder groups' needs, expectations, and concerns
- Build trust and credibility with stakeholders and foster positive relationships and partnerships
- Develop the social licence to operate and reduce the risk of conflicts or disputes. Improve the quality and effectiveness of the project or activity and increase the chances of success and sustainability.

37. Transitioning to a sustainable mining industry in Cornwall will require significant investments in new technologies, infrastructure, and training. These barriers would require policy interventions and stakeholder engagement to overcome.

VIII. UNFC and Circular Economy: Value Addition, Service Orientation, Comprehensive Resource Recovery, and Resources as a Service

38. Circularity is vital to the Cornwall Plan 2020-2050 and the UK's Critical Minerals Strategy. The adoption of CE practices is nascent in the mining sector. Barriers to developing CE practice in the mining industry include regulation and the industry's conservative nature.[32] Aspects of CE are unconsciously embedded in some practical aspects of the mining and metals industry (e.g., recycling of process water and chemicals and reduced energy consumption) to enhance project value and improve environmental and social impact. Additionally, there are some global examples of value addition through vertical integration and multinational companies participating in both primary (mining and refining) and secondary (recycling and refining) resource recovery, such as Ecobat[33] and Glencore.[34] However, this has been driven by supply security requirements[35] and a result of company mergers rather than a direct ambition to enhance circularity.

39. As a result, systemic implementation of CE practice within the primary metal extraction sector is slow.[34, 35] For effective CE performance, methods are best applied during the earliest phases of the design stage of a mining project.[36] This requires exploration of scenarios and innovations for CE to be investigated during project development's exploration, economic assessment, scoping, pre-feasibility, feasibility and implementation stages. Additionally, a CE project cannot occur in isolation. The system it is part of must also be set up for CE practices – requiring a systems analysis approach. Therefore, there are different

[32] Cisternas, L. A., Ordóñez, J. I., Jeldres, R. I., & Serna-Guerrero, R. (2022). Toward the implementation of circular economy strategies: An overview of the current situation in mineral processing. Mineral Processing and Extractive Metallurgy Review, 43(6), 775-797.

[33] Ecobat: https://ecobat.com/

[34] Glencore: https://www.glencore.com/

[35] Financial Times (2022) “Carmakers switch to direct deals with miners to power electric vehicles” https://www.ft.com/content/a8e0f1bb-f69a-4a77-b762-02f957e47f5c

[36] de la Torre de Palacios, L., & Rodríguez, J. A. E. (2022). In mining, not everything is a circular economy: Case studies from recent mining projects in Iberia. Resources Policy, 78, 102798.

levels of CE, some of which can be addressed on a mine site scale. In contrast, others require the alignment of varying system parts. In CE terminology, these scales are referred to as:[37]

- *Micro* (individual enterprise/product): Technologies to reduce water consumption (back-filling to improve stability [*partial CE*]), by- and co-product recovery
- *Meso* (eco-industrial parks, 'regional level'): Using mine wastes as feedstock for other sectors (chemicals, construction); Repurposing of mine wastes for CO_2 sequestration; energy storage capacity, re-mining mine wastes (waste valorization), value addition (mining cluster development)
- *Macro* (entire economy): Resource-as-a-Service, dematerialization, End-of-Life extension.

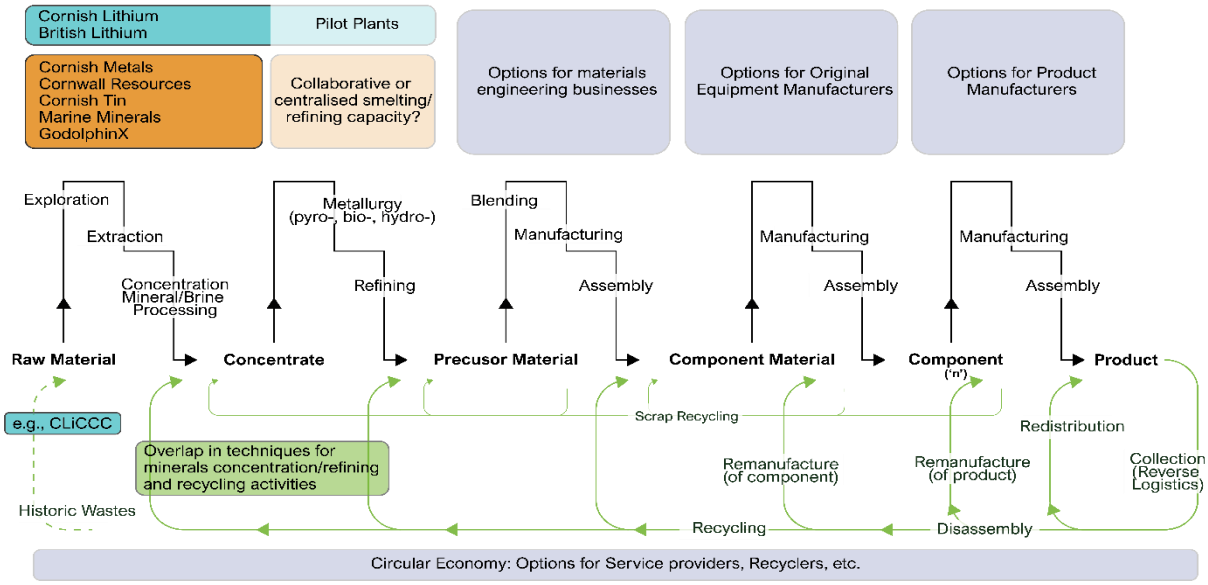
40. There is a disparity between the economic viability indicated by UNFC (and respective CRIRSCO standards) and the 'Circular Economy' advocated for in UNRMS. A resource cannot be termed without a reasonable prospect of economic extraction. Currently, the economic viability is measured concerning a linear economy – as the business models and regulatory systems in place for resource projects are developed on this linear basis. Aspects of value addition and comprehensive resource recovery necessary for the integrated management of resources are not always specified in CRIRSCO-compliant reports, as CRIRSCO reporting does not address non-sale products. As such, these data are unavailable for UNRMS implementation and solely rely on CRIRSCO-compliant reports. These are the differing purposes of the UNFC and CRIRSCO Template. UNFC is best used by regional/national governments and their geological surveys to understand what resources are available to them as they develop strategies for sustainable development. In contrast, the primary purpose of the CRIRSCO reporting codes is to provide transparent, material, and qualified/competent assessments of projects for investor decision-making. However, there are cross-cutting themes in both, with the core difference in purpose resulting in studies with different scopes and emphases.

41. Knowledge gaps remain on the maturity of the up-and down-stream value chains (Figure V) around the projects mapped to UNFC. Of particular interest for Cornwall are 1) the ability of renewable energy to support metalliferous projects and 2) the potential for value upgrade (i.e., production of higher value products or more excellent range of products) and, thus, the value return to the environment, nature and communities directly impacted by extractive activities. Understanding these adjacent aspects of the value chain makes it easier for regional and national governments to support capacity building for responsible resource management (including infrastructure, people, skills, *etc*.)

42. UNRMS provides a broader viewpoint than UNFC and has highlighted where further investigation is helpful for responsible resource management.

[37] De Jesus, A., Antunes, P., Santos, R., & Mendonça, S. (2018). Eco-innovation in the transition to a circular economy: An analytical literature review. *Journal of cleaner Production*, *172*, 2999-3018.

Figure IV
Schematic illustration of key technical 'nodes' within a technology-critical mineral-based circular economy industrial ecosystem



IX. Conclusions for Cornwall

43 The application of UNRMS provided a comprehensive framework, covering a wide range of principles, for developing recommendations to support the sustainable development of the region's mineral resources. Furthermore, UNFC is a valuable tool for comparing the level of development of the projects in Cornwall.

44. This study highlighted that a Strategic Environmental Assessment would be beneficial, as it would better consider how to encourage downstream extension of the value chain. Upgrading the regional electrical grid infrastructure is essential in enabling projects to fulfil their potential.

45. The environmental, social, and governance principles are generally better covered than those related to circular economy. There are good potential synergies between projects and opportunities for by-products and the use of mine waste. More vertical integration and adding downstream processing, the following steps, and regional manufacturing would enable materials recycling and other circular economy interventions.

46. The study found that although the UK and, by extension, Cornwall have robust regulatory frameworks, there are barriers to sustainable development arising from fundamental principles related to the Circular Economy, as well as some gaps in aspects of responsibility to the planet, transparency, and continuous strengthening of core competencies and capabilities. The study recommends further detailed assessment, with relevant stakeholders and potential external expertise, in selected principles and requirements highlighted in this study. The study also identified the need for a strategic environmental assessment for the region and individual project environmental impact assessments.

47. The Cornwall mining industry is looking into various innovations. In addition, the mining industry could explore multiple possibilities for the extraction of minerals, including bioleaching and selective mining methods. Bioleaching is environmentally friendly and cost-effective, while selective mining has the potential to reduce the environmental footprint of materials for the green economy. However, both methods pose significant challenges and risks. AI has numerous applications in the mining industry, such as improving exploration and discovery, optimizing production and processing, enhancing safety and security, reducing environmental impacts, and increasing efficiency and profitability.

48. Stakeholder engagement and consultation are significant, as the region has diverse and complex socio-economic and environmental challenges. Cornwall has a rich mining

heritage and a history of social and environmental challenges. Cornwall has a strong sense of identity and culture and needs economic development and innovation. Cornwall has various natural resources but is also responsible for protecting and conserving them. Therefore, engaging and consulting with stakeholders in Cornwall can help ensure that the mining industry is aligned with the regional vision and values and contributes to Cornwall's well-being and prosperity.

49. The mining industry in Cornwall can transition to a more sustainable future by:

- Adopting UNRMS to balance economic development, environmental sustainability, and social responsibility
- Applying innovative and low-carbon technologies for CRM exploration, extraction, processing and recycling
- Engage with stakeholders, such as investors, regulators, customers, suppliers, employees, communities, and civil society, to gain valuable insights and feedback on different stakeholder groups' needs, expectations, and concerns
- Protect and conserve the natural and cultural heritage of the mining landscapes, which are recognized as World Heritage Sites by UNESCO.

50. The study suggests that a sustainable mining industry in Cornwall could create new jobs and economic opportunities, particularly in producing CRM for high-tech products and renewable energy technologies. The study also highlights the mining industry's potential for innovation and technological development, which could lead to new products and markets. However, the study also notes that transitioning to a sustainable mining industry may require significant investments in new technologies, infrastructure, and training, which could have short-term costs. Overall, the potential for job creation and economic growth in Cornwall's sustainable mining industry depends on various factors, including policy interventions, stakeholder engagement, and technological innovation.

X. Conclusions for development/refinement of UNRMS

51. A simple and effective graphic is needed to help introduce the UNRMS document to new users. The authors developed a concise visualization (Figure III), which also serves as a simple toolkit. It proved effective in condensing the introduction to UNRMS to a single sentence, something like ‘a set of twelve principles that cover the ESG issues well-known to mining companies plus circular economy and key facilitating principles including innovation, skills, transparency and collaboration’. We added collaboration as a distinct phrase on our diagram.

52. A clear and consistent terminology and definition of key concepts and terms used in UNRMS, such as resource, resource management, resource efficiency, resource security, resource governance, *etc*., are required. This helps avoid confusion and ambiguity among users and stakeholders and ensures a shared understanding and language for communication and collaboration.

53. A set of indicators, metrics and benchmarks for measuring and reporting the performance and progress of the implementation of UNRMS based on the principles and requirements should be developed. This could help evaluate the effectiveness and impact of UNRMS and identify the strengths, weaknesses, opportunities and challenges for improvement. The indicators, metrics and benchmarks should be relevant, reliable, comparable and verifiable. They should cover the economic, environmental and social dimensions of resource management.

54. A guidance document or a toolkit for applying UNRMS to different types of resources and regions, with examples and case studies. This could help illustrate how UNRMS can be adapted and customized to suit each resource and region's specific context and needs and showcase the best practices and lessons learned from existing or potential applications. The guidance document or toolkit should also provide practical tips and recommendations for engaging and consulting with stakeholders, conducting gap analysis and action planning, monitoring and reporting on performance, and facilitating learning and feedback.

55. UNRMS goes further with its principles related to circular economy. Some of these, such as comprehensive resource recovery, might be put under ESG, but resource servitization especially is additional.

56. It is essential that ‘few people have heard of UNRMS’, but ‘everyone has heard of the Sustainable Development Goals’. UNRMS does not map directly to the SDGs (apart from the colour scheme). A graphic linking the SDGs to UNRMS would be helpful. After this case study, the authors have started to develop this kind of graphic and suggest this would be a valuable output from the UNRMS Subgroup of the United Nations Economic Commission for Europe (ECE) Expert Group on Resource Management.

57. The application of UNRMS worked well at the regional, i.e., subnational, level. It proved a valuable framework for discussing regional integrated resource development/management and checking actions and scope against a robust framework, keeping the remit broad and avoiding focusing too much on one or two single issues at the expense of the more extensive view of sustainable development. This is useful to regional government, including economic development, planning and environment and sustainability departments.

58. A key part of UNRMS is its use as an *à la carte* menu, which can be shaped to match priorities. The fact that it is not an auditable system makes it easier to apply in various situations.

59. It is also essential that given the flexibility, with some experience in the practitioner team and ideally a toolkit.

60. UNRMS can be self-applied, at least in the first instance, without external consultants.

61. UNFC is also helpful in comparing projects. Companies use other systems, such as the CRIRSCO Template for minerals, so these data must be transferred to UNFC. This seems an activity principally the preserve of Regional/National Geological Surveys.

XI. Acknowledgements

62. This case study received funding from the UK Research and Innovation (UKRI) Interdisciplinary Circular Economy Centre for Technology Metals (Met4Tech) EP/V011855/1 and the Cornwall and Isles of Scilly Local Enterprise Partnership. Geo-Resources companies in Cornwall are thanked for their cooperation and help with data. Mr. Harikrishnan Tulsidas, Economic Affairs Officer, ECE, provided valuable help and advice with the case study and this report.

XII. Supporting Information

63. A summary of primary Geo-Resources in South West England and a narrative on UNFC classification (UNFC mapping of primary Geo-Resources in South West England) are included in Annexes I and II respectively.

64. Commentary on applying a qualitative ranking to the technology-critical metal industrial ecosystem in Cornwall and the Isles of Scilly is provided in a separate document (https://unece.org/sed/documents/unrms-case-study-supplementary-information).

Annex I

Summary of primary Geo-Resources in South West England

Company(s)	*Project – mineralization style*	*Effective date*	*Tonnage (Mt)*	*Concentration/ Grade (per cent)*	*Contained Metal (rounded down - hard rock in kt, fluid hosted/ micaceous residues in tpa)*	*Product at point of sale*	*Standard/Code*	*Type*
Imerys British Lithium Ltd.,[a]	Greenbarrow – Li mica granite and pegmatite	18/05/2023	160.8	Li_2O 0.536	400 kt Li	Lithium compound concentrate in the form of lithium carbonate	JORC / PERC	Inferred
Cornish Lithium Plc.[b]	Trelavour Li – Li mica granite	02/12/2012	51.7	Li_2O 0.24; Rb 0.11; Cs 0.0066; K 3.93	56.8 kt Li; 56.8 kt Rb; 5.17 kt Cs; 2031 kt K	Lithium compound concentrate in the form of lithium carbonate/ hydroxide	JORC (report not in the public domain)	Inferred
Cornish Lithium Plc. / GeoCubed[c]	Shallow Geothermal Brines (various locations)	na	na	undisclosed	undisclosed	Lithium compound concentrate	na	na
Cornish Metals Ltd.[d]	South Crofty Upper Mine – polymetallic sulphide veins	27/10/2023	0.260	0.99 SnEq, (0.69 Sn, 0.78 Cu, 0.59 Zn)	2.58 kt SnEq (1.79 kt Sn, 2.03 kt Cu, 1.53 kt Zn)	Cassiterite plus Cu and Zn sulfide concentrates (product/concentrate grade: 59 per cent SnEq – *PEA, 2017*)	NI 43-101	Indicated
		27/10/2023	0.465	0.91 SnEq, (0.66 Sn, 0.63 Cu, 0.63 Zn)	4.24 kt SnEq (3.07 kt Sn, 2.92 kt Cu, 6.92 kt Zn)			Inferred
	South Crofty Lower Mine – Sn-rich quartz-tourmaline veins	27/10/2023	2.896	1.50 Sn	43.6 kt Sn			Indicated
		27/10/2023	2.626	1.42 Sn	37.4 kt Sn			Inferred
Cornwall Resources Ltd.[e]	Redmoor – greisen bordered sheeted vein system with later cross-course veins	16/05/2019	7.2	WO_3 0.59; Sn 0.1; Cu 0.39	33.6 kt W; 7.2 kt Sn; 28.0 kt Cu	Cassiterite, wolframite, and Cu sulphide concentrate	JORC	Inferred Mineable, Inclusive
Geothermal Engineering Ltd.[f]	United Downs Deep Geothermal Project (UDDGP): Energy + Lithium	na	na	0.022 to 0.026 Li	undisclosed	Lithium compound concentrate	na	na
Marine Minerals Ltd.[g]	Offshore Sn Placer	1980s (2012)	1	2.2 Sn	22 kt Sn	Cassiterite concentrate	Non-compliant *(EIA Scoping Report)*	na

Company(s) [REF]	*Project – mineralization style*	*Effective date*	*Tonnage (Mt)*	*Concentration/ Grade (per cent)*	*Contained Metal (rounded down – hard rock in kt, fluid hosted/ micaceous residues in tpa)*	*Product at point of sale*	*Standard/Code*	*Type*
Tungsten West Ltd.[h]	Hemerdon – greisen bordered sheeted vein system (in granite and surrounding country rock, plus granite stockpiles and mine waste tailings from previous mining and mineral processing activities)	01/03/2021	34.1	WO_3 0.18; Sn 0.03	*Included in resource estimates*	Wolframite (product grade: 55 per centWO_3) and cassiterite concentrates (product grade: 55 per cent Sn)	JORC	**Proved *(inclusive of modified resources)*
		01/03/2021	29.1	WO_3 0.18; Sn 0.03	*Included in resource estimates*			**Probable *(inclusive of modified resources)*
		07/12/2020	42.5	WO_3 0.17; Sn 0.03	57.3 kt W; 12.7 kt Sn			** Measured
		07/12/2020	123.6	WO_3 0.13; Sn 0.03	127 kt W; 37.0 kt Sn			** Indicated
		07/12/2020	161.9	WO_3 0.1; Sn 0.03	128 kt W; 48.5 kt Sn			Inferred

Note: All links accessed 05/12/2023.

[a] Imerys British Lithium (2023): https://imerysbritishlithium.com/lithium-exploration/mineral-resource-estimate/

[b] Cornish Lithium - Trelavour (2021): https://cornishlithium.com/company-announcements/cornish-lithium-announces-maiden-jorc-resource-for-the-trelavour-project/

[c] GeoCubed (2021): https://geocubed.co.uk/

[d] AMC Consultants (2023): South Crofty Tin Project – Mineral Resource Update NI 43-101 Technical Report - https://cornishmetals.com/site/assets/files/5449/south_crofty_tin_project_mineral_resource_update_ni_43-101_technical_report_sedarb.pdf

[e] Strategic Minerals/Cornwall Resources (2019) – Redmoor: Redmoor mining scoping study leads to positive financial assessment [Redmoor Scoping Study Update - https://www.strategicminerals.net/investors/rns-announcements.html]

[f] Geothermal Engineering Limited: https://geothermalengineering.co.uk/lithium/

[g] Marine Minerals (2012): Goodman, L., 2012, North Cornwall Marine Minerals Environmental Impact Assessment Scoping Report for Marine Minerals Limited, 16th November 2012, MML Marine Scoping Report.

[h] Tungsten West (2021): https://www.tungstenwest.com/project + AIM Admission Document (2021) https://www.tungstenwest.com/aim-admission-document

Annex II

UNFC mapping of primary Geo-Resources in South West England

Company(s)	*UNFC*	*E*	*E - commentary*		*F - commentary*		*G - commentary*
British Lithium Ltd.	E2 F2 G3	E2	CRIRSCO Template Bridging - report unseen	F2	CRIRSCO Template Bridging - report unseen	G3	CRIRSCO Template Bridging - report unseen
Cornish Lithium Plc.	E2 F2 G3	E2	CRIRSCO Template Bridging - report unseen	F2	CRIRSCO Template Bridging - report unseen	G3	CRIRSCO Template Bridging - report unseen
Cornish Lithium Plc. / GeoCubed	E2 F3 G4	E3	Exploration drilling targeting prospective structures has been undertaken, but abstraction facilities at scale on these sites are not yet under development.	F3	Technologies are being tested at Direct Lithium Extraction Pilot Plant. These technologies have been proven at laboratory scale but require scaling to commercial feasibility.	G4	There are no recent reports on lithium concentrations. There are historically reported concentrations of lithium content in the brines. However, there is no published resource estimate as the volume of brine and stability of lithium concentrations have not been reported.
Cornish Metals Ltd.	E2 F2 G2	E2	CRIRSCO Template Bridging	F2	CRIRSCO Template Bridging	G2	CRIRSCO Template Bridging
	E2 F2 G3	E2	CRIRSCO Template Bridging	F2	CRIRSCO Template Bridging	G3	CRIRSCO Template Bridging
	E2 F2 G3	E2	CRIRSCO Template Bridging	F2	CRIRSCO Template Bridging	G3	CRIRSCO Template Bridging
	E2 F2 G2	E2	CRIRSCO Template Bridging	F2	CRIRSCO Template Bridging	G2	CRIRSCO Template Bridging
Cornwall Resources Ltd.	E2 F2 G3	E2	CRIRSCO Template Bridging	F2	CRIRSCO Template Bridging	G3	CRIRSCO Template Bridging
Geothermal Engineering Ltd.	E2 F3 G4	E2	There is an active geothermal power pilot plant on site abstracting waters from depth, aiming to extract lithium. The resource will likely be permitted, with a Direct Lithium Extraction pilot plant adjacent to the Geothermal plant.	F3	Technologies are being tested at Direct Lithium Extraction Pilot Plant. These technologies have been proven at laboratory scale but require scaling to commercial feasibility.	G4	There are reported concentrations for the lithium content in the brines. However, there is no published resource estimate as the volume of brine and stability of lithium concentrations have not been reported.
Marine Minerals Ltd.	E3 F3 G4	E3	The project has not undertaken a feasibility study. Social and environmental acceptability require assessment.	F3	The area has been historically mined, but there is no feasibility study.	G4	Historic mining activities previously extracted Sn. Exploration with cores has taken place, but a CRIRSCO-compliant report has not been completed, and the publicly available data is insufficient to assess resource confidence.
Tungsten West Ltd.	E1 F1 G1	E1	CRIRSCO Template Bridging	F1	CRIRSCO Template Bridging	G1	CRIRSCO Template Bridging
	E1 F1 G2	E1	CRIRSCO Template Bridging	F1	CRIRSCO Template Bridging	G2	CRIRSCO Template Bridging
	E2 F2 G1	E2	CRIRSCO Template Bridging	F2	CRIRSCO Template Bridging	G1	CRIRSCO Template Bridging
	E2 F2 G2	E2	CRIRSCO Template Bridging	F2	CRIRSCO Template Bridging	G2	CRIRSCO Template Bridging
	E2 F2 G3	E2	CRIRSCO Template Bridging	F2	CRIRSCO Template Bridging	G3	CRIRSCO Template Bridging