Creating a low carbon, environmentally sustainable and socially just value chain for rare earth magnets

Background to Project

The Project, entitled "Creating a low carbon, environmentally sustainable and socially just value chain for rare earth magnets" was funded by Innovate UK under the circular critical materials supply chains (CLIMATES) programme.

The Project aimed to explore the potential effectiveness of socio-economic extended input-output modelling and to explore the possible overall impacts of potential interventions across the rare earth magnet value chain to decrease negative and increase positive economic impact whilst measuring the overall impact without focusing only on a single measure such as carbon reduction or job creation.

Route2's innovative Value2Society™ (V2S) framework was used as the basis for impact measurement throughout the Project. The platform assesses impacts across six major capital categories in global value chains, providing an analytical tool of substantially greater depth than Gross Value Add (GVA); which is the common method of measuring economic contribution.

The unique partnership that delivered this Project brought an innovative skill set and approach. Pensana, already a leader in the rare earth sustainability space, provided upstream and midstream expertise; Polestar, through its innovative Polestar 0 carbon-neutral car design provided input from the viewpoint of an OEM; and Route2, with its in-depth Value2Society impact modelling platform provided detailed socio-economic impact data. Academic expertise was provided by specialist teams from the University of Hull and University of Leeds. Information on the partners can be seen in Figure 1.

UNIVERSITY OF LEEDS	The Sustainability Research Institute (SRI) addresses a wide range of global challenges. Its 67 staff focus on participatory research with the project team specializing in extractive industry governance, social impacts of mining, and critical mineral flows in low-carbon infrastructure.
Route2	Route2 is a market leader in Impact Valuation, specializing in sustainability performance assessment using its proprietary Value2Society™ framework. It applies economic modeling, bespoke methodologies and scenario analysis to provide clear, data-driven insights for businesses across industries including mining and energy.
PENSANA Plc	Pensana, a London-listed company, is developing one of the world's largest rare earth deposits in Angola. The fully permitted Longonjo project, with a 20+ year mine life, will produce Mixed Rare Earth Carbonate for export into the global market
Polestar	Polestar, a Swedish EV brand backed by Volvo and Geely, focuses on sustainability and innovation. It aims to create a climate-neutral car by 2030, prioritizing circularity, renewable energy, and transparent Life Cycle Assessments to drive a cleaner automotive future.
UNIVERSITY OF HULL	The Electrochemical Engineering and Industrial Solutions Group at the University of Hull has over 25 years in discovering technical breakthroughs and developing and innovating early-stage and turnkey products for the extractive, sensors and instrumentation and process industries.

Figure 1- Project Partners

Raw Data and Data Analysis

Route2's input-output model estimated impacts across the neodymium iron boron (NdFeB) magnet value chain and valued them using Route2's economic valuation methods to estimate the Value2Society of the value chain from extraction through to end-of-life.

The model utilised industry inputs from specific data provided by Pensana for their mining and mid-stream operations and from Polestar's automotive manufacturing use and end-of-life phases.

Social Impact Measurement

One of the major findings from the Project was the lack of depth and definition available into the quantification and measurement of social impacts. This was reinforced further within the wider literature. Route2 and University of Leeds worked closely together to create a series of new indicators, update existing

indicators and develop a "lens of analysis" which considers multiple measures to develop an economic impact measure of Community Relations. This is an area where extra research should be considered.

Impact Identification Opportunities and Selection of Opportunities for Modelling

A key part of the Project was to utilise the findings from the data analysis to drive the identification of potential opportunities to reduce negative impact and increase positive impact across the value chain. Additionally, the data analysis highlighted weaknesses in the method especially in countries with diverse economies where national averages were used that did not necessarily consider activity specifics (e.g. Child Labour).

Impacts were identified across two workstreams, environment and carbon (headed by University of Hull) and social (headed by University of Leeds) and the initial stage involved a broad literature review, including a patent review, and sector specific research with support from Polestar and Pensana. This stage produced lists of all available opportunities which could be enacted (one for social and one for environment and carbon opportunities). These were then trimmed down to 15 final interventions which were analysed in the next phase of the Project. These 15 interventions were selected based on the subjective opinions of the Project team considering feasibility, availability of socio-economic data and market and stakeholder demand and interest.

These 15 interventions were remodelled by Route2's team using their V2S framework. Where the intended intervention did not align to the software, new indicators were created and relevant existing indicators were enhanced, allowing the software to develop more granular data specific to the production of rare earth magnets. The full list of interventions can be seen in the appendix.

Data Analysis of Selected Interventions

The fifteen selected interventions for modelling were taken forward as scenarios to be analysed by Route2.

These interventions were approached in three different ways: firstly development of new indicators to be added into Route2's V2S model; secondly updates to the quality and depth of existing indicators in the V2S model and finally theoretical scenarios developed based on the list of potential interventions identified in the previous stage of the Project. The analytical findings are shown in figure 2.

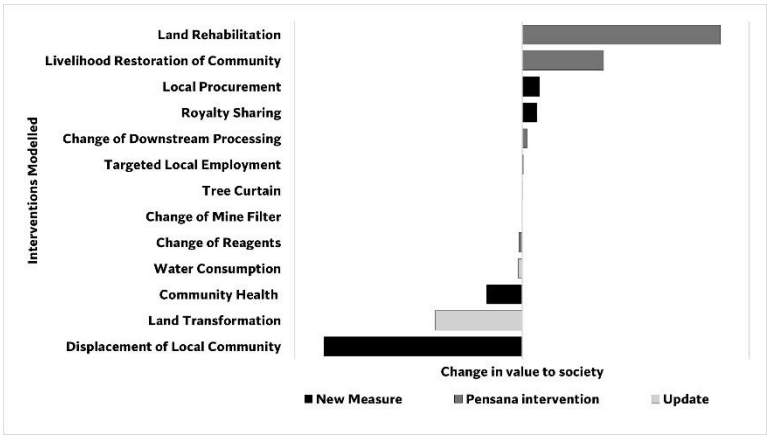

Figure 2 – Histogram showing the estimated economic impact of 13 modelled interventions

Benefits of Project and Next Steps

- This Project has further confirmed the socio-economic benefits that will be delivered as part of Pensana's sustainability strategy.
- The research has validated the use of socio-economic impact analysis as a vehicle to effectively measure the value2society of mining activities in developing countries.
- Whilst opportunities for further research should be explored, this Project has demonstrated that socio-economic analysis can be applied to a critical minerals value chain.

- The project has developed a new measure of community wellbeing, filling a gap in understanding. This is an opportunity for further development.
- This Project has taken steps to address the gap in quantifiable data protocols and established measurement protocols, especially in the sphere of social impact measurement.
- New technological proposals which were identified at impact opportunity identification will be further explored.

The work can further benefit Pensana and Polestar as part of their partnership to drive the full EV value chain to zero greenhouse gas emissions.

Appendix A - Short List Description

Intervention	Type	Description
Change of Downstream Processing	Modelled Scenario	Changes in the electrolysis stage of processing which reduces the emission of greenhouse gases and impact of waste.
Change of Mine Filter	Modelled Scenario	The mine filter is changed to one which requires replacing less frequently. Therefore, the estimated annual waste generation attributed to the mine filter is reduced.
Change of Reagents	Modelled Scenario	One selected alternative sourcing route for a reagent was chosen. This was a change of production method.
Community Health	New bespoke indicator	The Community Health Indicator considers the impact of the mine on the local community in terms of health outcomes such as prevalence of HIV/AIDS, depression and alcohol dependency. It uses the number of displaced people as a proxy for the size of the local community affected by the mine in terms of HIV/AIDS and depression. Research on alcohol dependency is found only within miners and so the estimated number of employees from the IO model is used to estimate this impact. These assumptions could be improved with better data.
Displacement of Local Community	New bespoke indicator	The displacement of local community includes lost property, lost livelihoods, loss of education, loss of economic right to the land, and the wellbeing cost of associated depression. The loss of economic right to the land considers the loss of the potential for the community to use the land for mining purposes either now or in the future. It is estimated by using the proxy of a benchmark value of the expected royalties to communities after displacement. All estimates (except property loss) are annualised, but these costs are expected to repeat each year after displacement.
Jobs for Local Community	New bespoke indicator	Jobs for local community considers the financial value of wages, the wellbeing benefit of the wages and the local multiplier effect of spending these wages within the community. The multiplier effect is calculated based on statistics for spending on food, rent, clothing and entertainment which are assumed capture all local purchases. The wellbeing benefit is based on the health utility of income – a coefficient that quantifies how income changes affect health outcomes.
Land Rehabilitation	New bespoke indicator	Land rehabilitation shows the ecosystem benefit of rehabilitating post-mining to various land types: agricultural land, cropland, forest, industrial land, natural land and pasture. Average agricultural land is a mix of cropland and pasture based on national land use mix. When comparing against indicators, only the forest scenario was chosen to be represented against other indicators. The valuation also assumes the land can immediately be converted to the chosen land type.
Local Procurement	New bespoke indicator	Local procurement values the total financial expenditure with local businesses as well as the multiplier effect of this spending in the community, which captures local employees and local suppliers of the local business initially purchased from. 'Local' is determined to be Longonjo for this indicator. The amount spent with businesses in Longonjo is estimated by using a population distribution across Angola.

Restoration of the Local Community	New bespoke indicator	The restoration of the local community captures the benefit of the restoration of livelihoods (through the Anchor Farm Scheme) and the purchase of equivalent property. The benefit of the Anchor Farm Scheme is estimated using the financial spending and Social Return on Investment (SROI) values for agricultural projects in Lower Middle-Income countries. The value of the property given is assumed to be equivalent to the value of the property lost by being displaced.
Royalty Sharing	New bespoke indicator	Royalty sharing captures the royalty payments expected to be paid to the local community from the mine and their multiplier effect in the local community. It is a benchmark estimate of the Angolan legal royalty payment requirement of 5% of revenue and a proxy estimate for the proportion of this royalty received by the local community. This proxy is based on the legal requirement of Ghana (chosen to be a representative proxy because of income and geography) which states that 10% of royalty payments must be given to the local community.
Tree Curtain	New bespoke indicator	The tree curtain indicator considers the benefit of a tree corridor (a line of planted fruit trees) and an area of rewilding. The impacts of the tree curtain fall under indicators already captured within this analysis which are listed as sub-indicators. The economic valuation for these impacts therefore follows the valuation pathway of these three indicators. The economic benefit however requires a new bespoke valuation which has been researched and developed specifically for this indicator. It captures the financial benefit of fruit bearing trees which assumes the fruit is picked by the local community and either eaten or sold.
Community Relations	New lens of analysis	Community relations considers the impact of the mine on one specific stakeholder: the local community. Community relations is very difficult to directly measure through quantification. However, it can be understood by considering the balance of quantifiable impacts that affect the local community. This lens-of-analysis captures the impacts felt by the local community across all indicators. It includes indicators: ambient air pollution, community health, displacement of local community, jobs for local community, land rehabilitation, land transformation, local procurement, restoration of local community, royalty sharing, tree curtain, and water consumption. A reduction in the negative impacts on the local community or an increase in the positive impacts would show an improvement in community relations and vice versa.
Child Labour	Update to existing indicator	The number of child labourers in the direct and upstream of the mine are re-estimated. Research suggests the majority of child labour in the mining sector occurs at the Artisanal Mining Scale (ASM) scale. The upstream estimate uses national statistics to estimate a child labourer/worker ratio. This is combined with the IO model estimate of number of employees upstream to re-calculate the number of child labourers upstream.
Land Transformation	Update to existing indicator	The previous land transformation calculation included only cropland. This calculation includes multiple land cover types and updates the input for cropland. The input for the overall size of the land is also increased based on better data.
Water Consumption	Update to existing indicator	The water consumption indicator was updated to include a more geographically specific estimate of the water scarcity factor.