

# Dysprosium Oxide Production from Rare- earth Chloride Mixture

PEP Review 2026-06

**Sayanasri Varala**, Principal Research Analyst, Process Economics Program

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## Glossary

|                    |                                                   |
|--------------------|---------------------------------------------------|
| \$/h               | Dollars per hour                                  |
| \$/Mgal            | Dollars per thousand gallons                      |
| \$/Mlb             | Dollars per thousand pounds                       |
| \$/t               | Dollars per metric ton                            |
| Aq                 | Aqueous                                           |
| BFW                | Boiler feedwater                                  |
| bhp                | Brake horsepower                                  |
| BLI                | Battery limits investment                         |
| °C                 | Degree Celsius                                    |
| capex              | Capital expenditure                               |
| cfm                | Cubic feet per minute                             |
| ¢/kWh              | Cents per kilowatt-hour                           |
| ¢/lb               | Cents per pound                                   |
| CLD                | Central Lanthanide Deposit                        |
| cm                 | Centimeters                                       |
| ¢/Mgal             | Cents per thousand gallons                        |
| Conc.              | Concentrated                                      |
| EPC                | Engineering, procurement and construction         |
| ETP                | Effluent treatment plant                          |
| EV                 | Electric vehicle                                  |
| °F                 | Degree Fahrenheit                                 |
| FCC                | Fluid catalytic cracking                          |
| FOB                | Free/freight on board                             |
| FRP                | Fiber-reinforced plastic                          |
| ft                 | Feet                                              |
| G&A                | General and administrative                        |
| g/L                | Grams per liter                                   |
| gal                | Gallons                                           |
| gal/lb             | Gallons per pound                                 |
| gpm                | Gallons per minute                                |
| HEV                | Hybrid electric vehicle                           |
| hp                 | Horsepower                                        |
| HRECl <sub>3</sub> | Heavy rare-earth chlorides                        |
| HREE               | Heavy rare-earth element                          |
| HVAC               | Heating, ventilation and air conditioning         |
| IUPAC              | International Union of Pure and Applied Chemistry |
| kg                 | Kilograms                                         |
| kg/h               | Kilograms per hour                                |
| kPa                | Kilopascals                                       |
| kW                 | Kilowatt                                          |
| kWh                | Kilowatt-hour                                     |
| lb                 | Pounds                                            |
| lb/h               | Pounds per hour                                   |
| lb/lb              | Pounds per pound                                  |
| LPS                | Low-pressure steam                                |
| LREE               | Light rare-earth element                          |
| μ                  | Micron                                            |
| m                  | Meters                                            |
| Mlb/h              | Thousand pounds per hour                          |
| MMBtu/h            | Million British thermal units per hour            |
| MMlb/y             | Million pounds per year                           |
| MREE               | Middle rare-earth element                         |
| Mt/Mt              | Thousand metric tons per thousand metric tons     |
| N                  | Normality                                         |
| opex               | Operating expenditure                             |

|                     |                                             |
|---------------------|---------------------------------------------|
| Org                 | Organic                                     |
| OSBL                | Outside battery limits                      |
| PEP                 | Process Economics Program                   |
| PFD                 | Process flow diagram                        |
| Ppt                 | Precipitate                                 |
| psia                | Pounds per square inch absolute             |
| psig                | Pounds per square inch gauge                |
| RE                  | Rare earth                                  |
| RECl <sub>3</sub>   | Rare-earth chlorides                        |
| REE                 | Rare-earth element                          |
| REM                 | Rare-earth mineral                          |
| REO                 | Rare-earth oxide                            |
| RE(OH) <sub>3</sub> | Rare-earth hydroxide                        |
| ROI                 | Return on investment                        |
| ROM                 | Run-of-mine                                 |
| SED                 | Samarium, europium, dysprosium, and terbium |
| sq ft               | Square feet                                 |
| SS                  | Stainless steel                             |
| TBP                 | Tributyl phosphate                          |
| t/d                 | Metric tons per day                         |
| t/h                 | Metric tons per hour                        |
| t/t                 | Metric tons per metric ton                  |
| t/y                 | Metric tons per year                        |
| TFC                 | Total fixed capital                         |
| TREO                | Total rare-earth oxide                      |
| vol.                | Volume                                      |
| w.r.t.              | With respect to                             |
| wt%                 | Weight percent                              |
| y                   | Years                                       |

# Abstract

Advancements in green technologies, and expansion of the electronics and automotive industries, are the primary driving factors promoting the significance of rare-earth minerals (REMs). The market for rare-earth elements (REE), particularly dysprosium (Dy), is expected to expand significantly as attention turns to renewable energy sources. Dysprosium is the critical constituent in the manufacturing of high-performance permanent magnets (neodymium-iron-boron [NdFeB] magnets), which are primarily critical for applications in electric vehicles (EVs), wind turbines, consumer electronics, and other high-tech products. Nearly 70%-80% of the total value of the rare-earth oxide (REO) sector is derived from the market for permanent magnets.

The production of dysprosium oxide from the heavy rare-earth chloride mixture is discussed elaborately in this review. To produce  $\text{Dy}_2\text{O}_3$  from heavy rare-earth chloride ( $\text{HRECl}_3$ ), the feed with a concentration of 31 grams per liter (g/L) is subjected to solvent extraction (five stages) with 2.2M PC88A in kerosene (20% saponification degree), followed by scrubbing (three stages) and stripping (three stages) steps, resulting in the individual separation of  $\text{DyCl}_3$  from the  $\text{HRECl}_3$  mixture. The other  $\text{HRECl}_3$  (Eu, Sm, and Tb) concentrate in the raffinate. The extracted  $\text{DyCl}_3$  is further precipitated using oxalic acid via precipitation, followed by calcination, to produce dysprosium oxide ( $\text{Dy}_2\text{O}_3$ ). The mixed rare-earth chloride (containing Eu, Sm, and Tb) concentrate is further concentrated via evaporation, followed by crystallization, to produce mixed  $\text{RECl}_3$ .

This review includes an economic evaluation for an ancillary facility in a mineral processing plant, at a US Gulf Coast (USGC) location, that can produce 0.07 million pounds per year [MMlb/y] (30.76 metric tons per year [t/y]) of  $\text{Dy}_2\text{O}_3$  from the  $\text{HRECl}_3$  mixture. The technology presented here would be of great interest to industrial sectors and grassroots plants willing to produce  $\text{Dy}_2\text{O}_3$  from  $\text{HRECl}_3$  concentrate (obtained from monazite ore processing). We have estimated the capital expenditure (capex) and operating expenditure (opex) for the process to produce 0.07 MMlb/y of  $\text{Dy}_2\text{O}_3$  from  $\text{HRECl}_3$  at a USGC location, using a PEP Cost Index of 1,608 (fourth quarter of 2024).

The process flow diagrams, material balance, major equipment list with specifications, cost information for battery limits, variable costs, capex and opex, and total production costs are evaluated in this analysis. The technological and economic assessment of the process is the Process Economics Program (PEP)'s independent interpretation of a potential commercial process. Each of these is based on information presented in open literature, such as patents and technical articles, and may not reflect in whole or in part the actual plant configuration. We do believe that these sources are sufficient to represent the process and process economics within the range of accuracy necessary for the economic evaluation of a conceptual process design.

# Contacts

## **Sayanasri Varala**

Principal Research Analyst, Process Economics Program  
[sayanasri.varala@spglobal.com](mailto:sayanasri.varala@spglobal.com)

## **Rajiv Narang**

Executive Director, Global Head, Process Economics Program  
[rajiv.narang@spglobal.com](mailto:rajiv.narang@spglobal.com)

## CONTACTS

**Europe, Middle East, Africa:** +44 (0) 203 367 0681

**Americas:** +1 800 332 6077

**Asia-Pacific:** +60 4 296 1125

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