The Tradeoffs of Rare Earth Metals

Grade/ Grade Band: MS/HS	**Topic:** Natural Resources and Human Impacts

Brief Lesson Description: Students use simulations and research to describe trade-offs of mining Rare Earth Metals.

Performance Expectation(s):

HS-ESS3-2 Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.[Clarification Statement: Emphasis is on the conservation, recycling, and reuse of resources (such as minerals and metals) where possible, and on minimizing impacts where it is not. Examples include developing best practices for agricultural soil use, mining (for coal, tar sands, and oil shales), and pumping (for petroleum and natural gas). Science knowledge indicates what can happen in natural systems—not what should happen.]

MS-ESS3-3 Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment. [Clarification Statement: Examples of the design process include examining human environmental impacts, assessing the kinds of solutions that are feasible, and designing and evaluating solutions that could reduce that impact. Examples of human impacts can include water usage (such as the withdrawal of water from streams and aquifers or the construction of dams and levees), land usage (such as urban development, agriculture, or the removal of wetlands), and pollution (such as of the air, water, or land).

MS-ESS3-4 Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems. [Clarification Statement: Examples of evidence include grade-appropriate databases on human populations and the rates of consumption of food and natural resources (such as freshwater, mineral, and energy). Examples of impacts can include changes to the appearance, composition, and structure of Earth's systems as well as the rates at which they change. The consequences of increases in human populations and consumption of natural resources are described by science, but science does not make the decisions for the actions society takes.]

Specific Learning Outcomes:

1. Students will understand the significance of rare earth elements (REEs) in modern technology.
2. Students will evaluate competing design solutions for the development, management, and utilization of REEs.
3. Students will analyze the cost-benefit ratios of various solutions.

Narrative / Background Information

Prior Student Knowledge:

Students should have a basic understanding of what elements and minerals are, including the periodic table and how elements are classified. Additionally, awareness of how human activities, like mining, can impact the environment is helpful.

Science & Engineering Practices:	**Disciplinary Core Ideas:**	**Crosscutting Concepts:**
Engaging in Argument from Evidence Evaluate competing design solutions to a real-world problem based on scientific ideas and principles, empirical evidence, and logical arguments regarding relevant factors (e.g. economic, societal, environmental, ethical considerations) (HS-ESS3-2) Construct an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem. (MS-ESS3-4) **Constructing Explanations and Designing Solutions** Apply scientific ideas or principles to design an object, tool, process or system. (MS-ESS3-3)	**ESS3.A: Natural Resources** All forms of energy production and other resource extraction have associated economic, social, environmental, and geopolitical costs and risks as well as benefits. New technologies and social regulations can change the balance of these factors. (HS-ESS-3-2) **ESS3.C: Human Impacts on Earth Systems** Human activities have significantly altered the biosphere, sometimes damaging and destroying natural habitats and causing the extinction of other species. But changes to Earth's environment can have different impacts (negative and positive) on different living things. (MS-ESS3-3) Typically, as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise. (MS-ESS3-3 and MS-ESS3-4)	**Cause and Effect** Relationships can be classified as causal and correlational, and correlation does not necessarily imply causation. (MS-ESS3-3) Cause and effect relationships may be used to predict phenomena in natural or designed systems. (MS-ESS-3-4) ***Connections to Engineering, Technology, and Applications of Science*** **Influence of Science, Engineering and Technology on Society and the Natural World** Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks. (HS-ESS3-2) Analysis of costs and benefits is a critical aspect of decisions about technology. (HS-ESS3-2)

	ETS1.B: Developing Possible Solutions When evaluating solutions it is important to take into account a range of constraints including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts (Secondary to HS-ESS-3-2)	The uses of technologies and any limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. Thus technology use varies from region to region and over time. (MS-ESS3-3) All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment. (MS-ESS3-4) ***Connections to the Nature of Science*** **Science Addresses Questions About the Natural and Material World** Science and technology may raise ethical issues for which science, by itself, does not provide answers and solutions. (HS-ESS3-2) Science knowledge indicates what can happen in a natural system–not what should happen. The latter involves ethics, values, and human decisions about the use of knowledge. (HS-ESS3-2) Many decisions are not made using science alone, but rely on social and cultural contexts to resolve issues. (HS-ESS3-2) Scientific knowledge can describe the consequences of actions but does not necessarily prescribe the decisions that society takes. (MS-ESS3-4)

Possible Preconceptions/Misconceptions:

1. Students might think rare earth elements (REEs) are rare in the Earth's crust.
2. Students may believe all REEs have the same properties and uses.
3. Students might assume that extracting and recycling REEs is straightforward and similar to recycling common materials like paper or plastic.
4. Students might believe that e-waste recycling always successfully recovers all valuable materials.
5. Students may think that REEs can be easily substituted with other materials in technology.
6. Students might not be aware of the significant environmental degradation and pollution associated with REE mining.
7. Students may underestimate the economic factors involved in REE extraction and recycling, assuming it's more about availability.

LESSON PLAN – 5-E Model

ENGAGE: Opening Activity – Access Prior Learning / Stimulate Interest / Generate Questions:

Start the lesson by showing the video "Why we need Rare Earth Elements?" to engage students in the topic. Following the video have a class discussion on the following prompts:

1. ***What are rare earth elements?***
2. ***Why are they important in modern technology?***
3. ***What challenges might we face in obtaining these elements?***

EXPLORE: Lesson Description – Materials Needed / Probing or Clarifying Questions:

Students will conduct a simulation to understand the process of extracting REEs using common materials.

- **Setup:**
  - Fill plastic containers with sand mixed with iron filings (representing rare earth elements mixed in soil). Record the amount of Iron added to each container so students can determine how successful they are in extracting the desired materials.
  - Provide magnets wrapped in aluminum foil (to represent tools used in extraction).
  - Provide Tweezers and plastic straws to represent manual extraction tools.
- **Procedure:**
  - Direct Students to use magnets to separate iron filings from the sand.
  - Next, they should use tweezers and plastic straws to further refine and separate the REEs.
  - As students complete each step, they should collect data on the amount of REEs extracted and the time taken for each part of the process.
- **Discussion:**
  - ***Compare the efficiency of different methods by different groups.***
  - ***Discuss the challenges faced during extraction.***
  - ***Ask students to explain what kinds of environmental impacts are caused by mining the REEs.***

EXPLAIN:
Students will complete a reading to learn about the science of Rare Earth Elements. Distribute one handout (digitally or on paper) for each student to complete. Students will read "The Science of Rare Earth Elements" as they complete the handout.

After students complete the handout, have a discussion about their answers and reactions to the text. Possible prompts include:

1. ***What are some specific examples of how rare earth elements are utilized in everyday technologies? How do these applications impact our daily lives?***
2. ***Discuss the environmental concerns associated with the mining and refining of rare earth elements. How can these challenges be mitigated while meeting the growing demand for REEs?***
3. ***How does the global supply chain of rare earth elements impact international relations and trade dynamics? What are the geopolitical implications of countries' reliance on REEs?***
4. ***Consider the ethical implications of the environmental and social impacts of rare earth element mining. How should companies and governments balance economic benefits with ethical responsibilities?***
5. ***Predict future advancements in technology that could reduce our dependence on rare earth elements. What alternatives or innovations might emerge to address both technological needs and environmental concerns?***

ELABORATE: Applications and Extensions:
Students will complete a research activity and create a poster presentation to compare a variety of strategies for developing, managing, and utilizing Rare Earth Elements.

- **Group Work:**
  - Divide students into small groups.
  - Assign each group a different design solution for developing, managing, and utilizing REEs. Group topics can include:
    - Electronic Waste Recycling
    - Alternative Materials Research
    - Sustainable Mining Practices
    - Urban Mining Initiatives
    - Geopolitical Strategies for Supply Chain Diversification
    - Biomining and Biotechnology
    - Efficient Use of Rare Earth Elements and Product Design
    - International Collaboration and Policy
  - Groups research their assigned solution, considering factors such as cost, environmental impact, and feasibility. Groups should make predictions about how each solution will impact a growing need for REEs as world populations grow.
  - **Presentation:**
    - Each group creates a poster summarizing their findings.
    - Groups present their posters to the class.
- **Discussion:**
  - ***Which solutions seem most viable and why?***
  - ***How do cost-benefit ratios affect decision-making in resource management?***

EVALUATE:

Formative Monitoring (Questioning / Discussion):

Questions throughout the lesson in ***bold and italics*** can be used to check students' understanding throughout the lesson. You can also assess student understanding through participation in discussions and activities, data recording and analysis during the Explore section, and group presentations and posters in the Elaborate Section.

Summative Assessment (Quiz / Project / Report):
Have students write a research paper or create a presentation summarizing the uses of REEs in technology, the environmental and economic challenges associated with their extraction and processing, and proposed design solutions for sustainable management. Encourage them to include specific examples and data to support their points. You can use this Rubric to assess.

Elaborate Further / Reflect: Enrichment

Select one or more of the following activities to extend student learning:

1. Invite a guest speaker from the mining industry or a local university to discuss current research and practices in REE extraction.
2. Plan a field trip to a local recycling facility to learn about electronic waste management and the recovery of rare earth elements.
3. Have students complete the Role Playing Game "The Case of the Rare Earth Metals" to consider the varying perspectives of different stakeholders involved in the production/use of Rare Earth Elements.
4. Host an e-waste drive to collect and properly recycle electronics.

SOCIAL EMOTIONAL LEARNING ACTIVITY

CASEL Competency Addressed: Self-Awareness and Self-Management

1. Introduction

Hook: Show images or a short video clip that highlights the excitement around new smartphone releases (e.g., a commercial for the latest iPhone).Discussion Prompt: Ask students, ***"What emotions do you feel when you see a commercial for the latest smartphone?"*** Write their responses on the whiteboard.

2. Defining Wants vs. Needs

- Activity: On the whiteboard, draw two columns labeled "Wants" and "Needs."
- Group Brainstorm: Have students call out what they think are "wants" and "needs" in the context of electronic devices. Write their responses in the appropriate columns.
    - Examples of Wants: Latest features, brand prestige, peer influence.
    - Examples of Needs: Functional phone for communication, necessary apps for school/work, safety features.
- Discussion***: Discuss the differences between the items in the two columns. Emphasize that while wants can enhance our experience, needs are essential for basic functionality.***

3. Reflection Activity

- Handout: Give each student a handout with the following reflection questions:
    1. Why do I feel the need to upgrade to the newest device?
    2. How often do I upgrade my electronic devices, and what usually motivates my decision?
    3. What are some potential environmental and social impacts of frequently upgrading electronic devices?
    4. How can I determine if I truly need a new device or if it is just a want?
- Individual Reflection: Allow students a few minutes to quietly reflect and write down their answers.

4. Group Sharing and Discussion

- Pair Share: Have students pair up and share their reflections with a partner.
- Class Discussion: Invite a few students to share key points from their discussions with the whole class. Use these prompts to guide the discussion:
    - What are some common reasons we upgrade our devices?
    - What new insights did you gain from reflecting on your own consumption habits?
    - How can we balance our wants and needs when it comes to electronic devices?

5. Conclusion and Mindfulness Strategies

- Wrap-Up Discussion: Summarize the main points discussed:
    - The importance of distinguishing between wants and needs.
    - The environmental and social impacts of frequent upgrades.
- Mindfulness Strategies: Share strategies for making more mindful decisions about upgrading devices:
    - Delay the decision by a few days to see if the desire persists.
    - Research the environmental impact of electronic waste.

- Consider alternative actions like repairing current devices or buying used ones.

- Closing Thought: Encourage students to think about how their personal choices can contribute to sustainability and responsible consumption.

INTERDISCIPLINARY CONNECTIONS/IDEAS

English Language Arts: Students write a persuasive essay on whether the benefits of REE mining outweigh the environmental and social costs. They should use evidence from their research to support their arguments. Students peer review each other's essays, focusing on the clarity of arguments, use of evidence, and persuasive techniques.

Mathematics: Provide students with data sets on the amount of REEs extracted from various sources, the costs associated, and the efficiency rates of different recycling methods. Students use statistical methods (mean, median, mode, standard deviation) to analyze the data. They create graphs and charts to visually represent their findings. Discuss the implications of their analyses. For example, how does the cost-efficiency of different extraction methods compare? What trends do they observe in recycling rates over time?

Social Studies: Students analyze different government policies related to REE mining and recycling (e.g., subsidies, tariffs, environmental regulations). They debate the effectiveness and consequences of these policies from various perspectives (economic, environmental, social).

Materials Required for This Lesson/Activity	
Quantity	**Description**
1 per group	Plastic Container
1 bag per class	Playground Sand
1 Container per class	Iron Filings
1 per group	Magnet covered in Aluminum Foil
1 per group	Tweezers
1 per group	Straw
1 per class	Electronic Balance to share between groups
1 per group	Stopwatch

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