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Department of Sustainable Energy Engineering  
Indian Institute of Technology Kanpur

Proposal for a New Course

SEE 636

Course Title	Critical Material Resources for Clean Energy Transition
Number	SEE xxx
Credits (L-T-P [C])	3-0-0-0 [9]
Departments proposing the course	: Sustainable Energy Engineering
Name of the Proposer	: Sheo Shankar Rai
Offered for	PG students
Prerequisite(s) for the course	: None
Faculty members interested in teaching	: Sheo Shankar Rai, Ashish Garg
Other Departments/Programmes of whose the students are expected to take up the course	: Geo-Sciences, ME, EE, CE, SPASE

**Course Objectives**

The course on "Critical Material Resources for Clean Energy Transition" aims to provide a comprehensive understanding of the sustainable energy landscape, with a specific focus on **critical materials that are needed for clean energy transition**. The program will cover topics such as the availability and production of critical minerals for making these materials, mineral and material processing techniques, and their applications in various sustainable energy technologies across various clean energy technologies. This postgraduate-level course will equip students with the essential knowledge and skills to assess the requirements of critical materials for energy transition, identify the sources as well as navigate the technical as well as commercial challenges posed by the requirement of **critical material resources**. These challenges include managing technological advancements, addressing environmental impacts, dealing with geopolitical pressures, and understanding the regulatory frameworks that govern the **sustainable energy sector**.

**Expected Learning Outcomes**

The course will provide a strong and holistic knowledge base and skills to the students on Critical Material Resources required for the development of Clean Energy Technologies. This includes an in-depth understanding of their source and availability, production processes, processing methods, applications in various Sustainable Energy Technologies, Supply Chain, Environmental and Social Impact, and application of AI & ML. The course will provide students with the essential knowledge and skills to navigate the technical and management challenges, technological advancements, environmental issues, geopolitical pressures, and regulatory complexities specific to the Sustainable Energy Sector and Critical Material Resources.

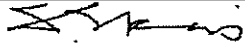

**Course outline**

Sr. No.	Broad Title	Topics	No. of 1 h Lectures (Total: ~40)
1.	An introduction to Sustainable Energy Value Chain	<ul style="list-style-type: none"> <li>- Global Energy System and their Economics</li> <li>- Problem of conventional energy</li> <li>- Climate issues</li> <li>- Clean Energy Transition: Global and Indian perspective.</li> <li>- Defining the critical minerals and materials</li> <li>- Clean Energy Value Chain with emphasis on the use of critical materials and minerals</li> <li>- Achieving NetZero.</li> </ul>	6
4.	Mineral Requirements for Clean Energy Transition.	<ul style="list-style-type: none"> <li>- Low Carbon Power Generation including photovoltaics (1G to 3G)</li> <li>- Energy Network.</li> <li>- Electric Vehicles and Battery Storage.</li> <li>- Hydrogen: Electrolysers and Fuel cells</li> <li>- Electro and photocatalysis for energy applications</li> <li>- CCUS</li> </ul>	6
2.	Sustainable and Responsible Development of Critical Material Resources. (Primary sources)	<ul style="list-style-type: none"> <li>- Role of Critical Mineral in Clean Energy Transition: Global and Indian Perspective</li> <li>- Critical Mineral Value Chain.</li> <li>- Exploration</li> <li>- Planning and Extraction Technology of Critical Minerals</li> <li>- Availability of Critical Minerals <ul style="list-style-type: none"> <li>• Lithium</li> <li>• Cobalt</li> <li>• Nickel</li> <li>• Mn</li> <li>• Copper</li> <li>• Rare Earth Minerals</li> </ul> </li> <li>- Mineral Development and Climate Change. <ul style="list-style-type: none"> <li>• Sustainable Development of Mineral Resources.</li> </ul> </li> <li>- Critical Mineral Resources of Deep Sea. <ul style="list-style-type: none"> <li>• Key Drivers</li> <li>• Deep-Sea Mineral Extraction Technology.</li> <li>• Challenges associated with the Extraction of Deep-Sea Mineral</li> <li>• Environmental Impacts of Deep-Sea Mining</li> <li>• Regulatory Framework of Deep-Sea Mining.</li> </ul> </li> <li>- Critical Mineral Resources from Space. <ul style="list-style-type: none"> <li>• Key Drivers</li> <li>• Potential Space Resources</li> <li>• Potential Resources of Asteroids</li> <li>• Advantages and Dis-advantages of Asteroid Resources</li> <li>• Discovery and Characterization of Asteroid Resources</li> <li>• Mineral Exploration and Extraction Technology for Asteroid Resources.</li> <li>• Challenges associated with the Extraction of Asteroid Resources</li> <li>• Regulatory Framework of Asteroid Mining</li> </ul> </li> </ul>	12

3	Processing of Critical Material Resources ( <b>Primary sources</b> ).	Introduction to Processing Technology for Critical Materials from the Minerals - Pyrometallurgy - Hydrometallurgy - Bio metallurgy	4
5.	Secondary Sources of Materials: Metal Recycling Technology	- Need of secondary sources - India relevance - Circular Economic Model of Waste Management. - Technologies for Metal Recovery from Waste.	3
6.	Environmental and Social Impact Assessments	- Assessment of Environmental Impact - Assessment of Social Impact	2
7.	Supply Chain of Critical Material Resources	- Supply Prospects of Critical Materials. - Geo-political Scenarios. - Approaches to Ensure Reliable Supply of Critical material. - Prospects of Recycling in Critical Material Supply Chain.	6
8.	Summary	Putting everything together	1

**Textbooks, reference books, suggested readings and any other references**

- Sustainable Energy Systems and Applications (Springer) : by Ibrahim Dincer, Calin Zamfirescu (Author).
- Asteroid Mining 101 – Wealth for New Space Economy by John S Lewis.
- *R. Sharma, Deep-sea mining: Economic, technical, technological, and environmental considerations for sustainable development, Mar. Technol. Soc. J. 45 (2011) 28–41. doi:10.4031/MTSJ.45.5.2.*
- Critical Minerals for India, Report of the Committee on Identification of Critical Minerals, Ministry of Mines, Govt. of India, June 2023.
- The Role of Critical Minerals in Clean Energy Transitions, World Energy Outlook Special Report, International Energy Agency (IEA), March 2022.
- Critical Minerals Market Review 2023, International Energy Agency (IEA).
- Net Zero by 2050 A Roadmap for the Global Energy Sector, International Energy Agency (IEA).
- Clean Energy Transitions Programme, Annual Report 2023, International Energy Agency (IEA).
- Greening the Renewable Value Chain: China Experience, Briefing Paper, June 2024, World Economic Forum in Collaboration with Boston Consulting Group.
- Latest Research Papers on relevant topics.

Course proposed by	Forwarded by	This course is approved/ <del>not</del> approved
 (Sheo Shankar Rai)	Convener, DPGC (SEE)	 Chairman, SPGC