Task 3. Request for Proposals:
Sodium Sulfate for a Circular Economy–Community-based Solutions

Proposed, developed, and sponsored by Freeport-McMoRan

Task

Freeport-McMoRan Inc. (FMI) is challenging your team to develop a process for utilizing one of their non-hazardous by-products that normally ends up in a landfill, anhydrous sodium sulfate salts, in a product that can create a local industry and job opportunities for marginalized communities near an FMI processing facility.

Background

Sodium sulfate is utilized in a wide cross-section of industries. Known applications depend on the degree of hydration of the salt and include latent-heat storage systems for storing low-grade solar heat, glass making, textile dyeing, detergent processing, paper making, laxatives, removing overdosed drugs from the body, and as a drying agent.

This list is not all-inclusive; teams are urged to research innovative uses for anhydrous sodium sulfate or its constituents that will result in an economically viable product. The ability to use sodium sulfate in a beneficial application can solve multiple social and environmental issues including increasing business/job opportunities in a disadvantaged community, preserving a valuable resource, decreasing FMI's carbon footprint by reducing transport of the product to a landfill, and reducing the volumes of materials that are disposed of in that manner.

<u>Sodium Sulfate: Forms and Characteristics</u>

Most sodium sulfate is mined and found naturally as decahydrate sodium sulfate (a hydrous form also known as the mineral mirabilite). However, sodium sulfate is sometimes produced as a by-product of certain chemical processes. Depending on processing, the resulting salt will be either decahydrate or anhydrite (the anhydrous form of sodium sulfate). The latter is the case at the Freeport-McMoRan's Copper Refinery and Rod Mill in El Paso, Texas.

At FMI's facility, the zero-discharge Water Recovery Plant (WRP) crystallizes the anhydrous form of sodium sulfate at a temperature of 100°C. (See Figure 1.) Note that decahydrate precipitates at lower temperatures. Anhydrous sodium sulfate is hygroscopic and disassociates in water to yield sodium and sulfate ions. [1]

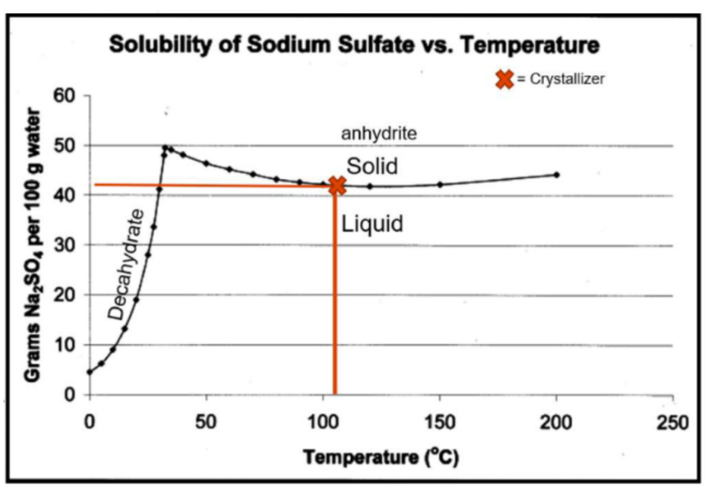

Figure 1. Phase diagram of sodium sulfate reflecting the near-100°C crystallization temperature to form the anhydrous salt.

Document updated 7/28/23 to correct weight of salts sent to landfills and to clarify the community involvement plan.

FMI Water-Recovery Plant Operations and Recovery of Anhydrous Sodium Sulfate

At Freeport-McMoRan's El Paso, Texas copper refinery and rod mill, anode copper is electro-refined to cathode (99.99% pure copper). Within the refinery is a water-recovery plant (WRP) (Figure 2) that enables the refinery and rod mill to maintain zero discharge on its water processes. Non-hazardous anhydrous sodium sulfate is produced as a by-product at their WRP.

FMI's refining processes include a nickel carbonate process. This is the refinery's acid bleed, where metals, sulfates, and sulfuric acid are neutralized with soda ash to produce insoluble metal carbonates that are filtered out of solution as saleable products. The remaining filtrate from this process (a solution containing 20 g/L Na, as Na_2SO_4) is sent to the WRP for further processing.

The WRP utilizes a Mechanical Vapor Recompression (MVR) evaporator and crystallizer. The MVR evaporator engages a falling-film reactor for optimum heat transfer, and the process recovers pure water as a distillate. This water is primarily used in the power plant's waste-heat boiler to generate steam that is used throughout the operations. Any excess water is added to the refinery's condensate tanks where it is used for washing anode scrap, cathodes, cells, APU elution solution, the autoclave slime press, and electrode contacts. The brine solution from the evaporator is continuously sent to a forced-feed MVR crystallizer, where the non-hazardous anhydrous sodium sulfate crystallizes out of solution and is removed using a centrifuge. These sodium sulfate salts are then rolled off into bins for disposal.

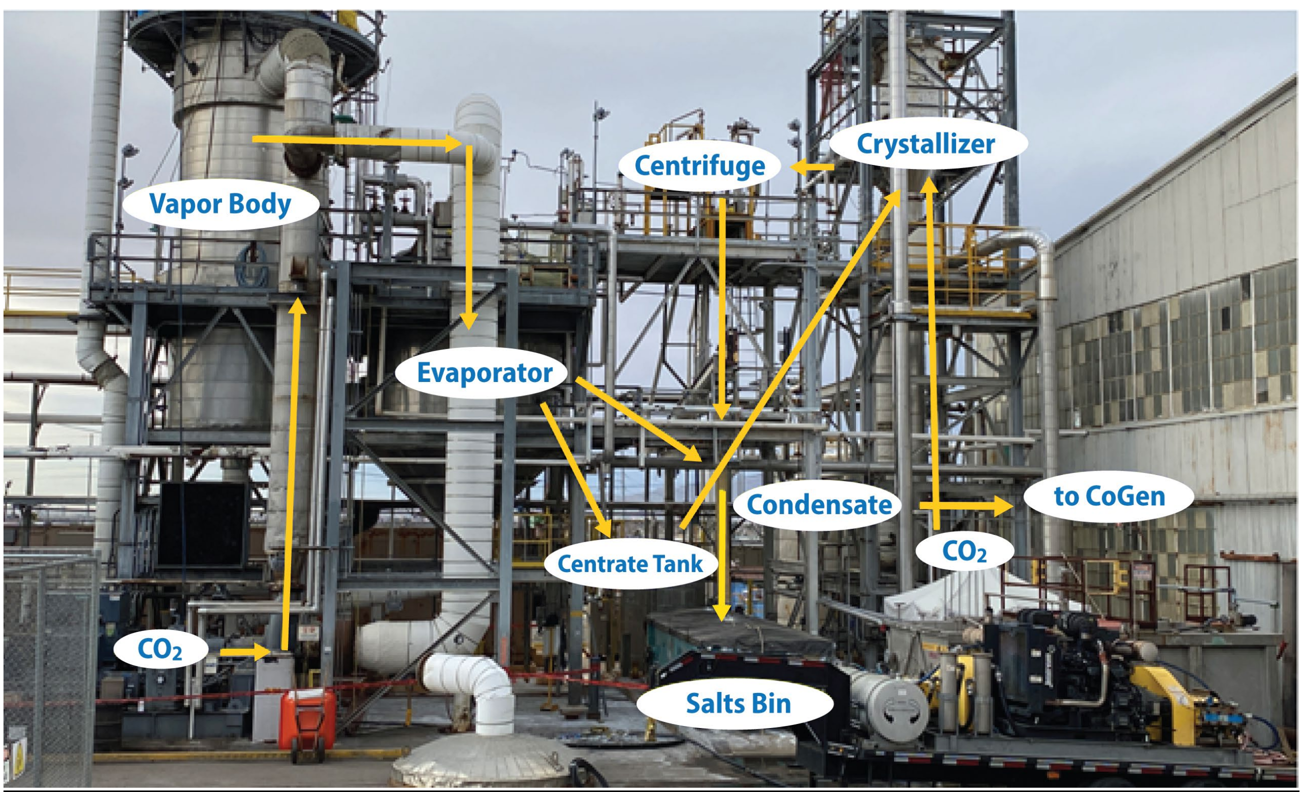

Figure 2. Freeport-McMoRan Water-Recovery Plant (WRP), El Paso, Texas.

Community Involvement Considerations

FMI is committed to working with local communities and Indigenous Peoples in the areas where they operate to build resilience and well-being. Partnering with communities to increase resilience includes creating opportunities, activities and skills that increase community-level capacity to maximize the economic opportunities created by and beyond mining to increase long-term socioeconomic benefits. Efforts are focused on three primary areas 1) education and skill-building, 2) economic opportunity, and 3) community-level leadership and capacity building. Within each of these three areas is a fundamental commitment to enable the skills of individuals and communities necessary to achieve the overarching goal of resilience. [2]

In this spirit, the Freeport-McMoRan Copper Refinery and Rod Mill invites teams to propose a processing facility to engage a disadvantaged community and elevate income levels through development of a small industry. Teams are given full freedom to select the location of their facility, whether offsite or onsite at the WRP. Wherever the teams choose to locate their facility, they will engage the chosen community in its development and operation. Teams may wish to consult resources such as EJ Screen and EnviroAtlas. [3, 4]

WERC requires a public involvement plan for this project (see Team Manual for more information). The plan, submitted with the technical report, will include the team's proposed strategy for engaging the community in planning and decision making, and will also address Freeport-McMoRan's three primary community focus areas listed above (as applicable). Teams are asked to base their community involvement plans on demographic research, and refrain from conducting actual community outreach for their research and/or project development.

Figures A-1 and A-2 (see Appendix 2) provide siting of the facilities in context of the local area. Teams are invited to tour the facility (just a one-hour drive from Las Cruces) during the contest. Email WERC to make arrangements.

Towards a Circular Economy

Annually, approximately 3.6 million pounds (120 roll-off bins, each containing 20 cubic yards) of nonhazardous sodium sulfate salts are generated by the WRP. Currently, FMI is transporting these salts to a landfill. The cost of transport plus the landfill disposal fees is estimated to be $120,000 per year.

Looking toward a robust circular economy, Freeport-McMoRan is seeking designs for beneficial use of this by-product. Your team's solution will support the local community by setting up a local industry and providing job opportunities for communities near the FMI processing facility.

Your team's proposed use of the sodium sulfate should support environmental sustainability. In your environmental impact report, include an estimate of the fraction of the total annual sulfate salt generated by FMI that your process consumes, and estimate the environmental impact (reduced CO_2 emissions, reduced landfill waste, etc.) of your proposed solution. (See Appendix 1 for landfill transportation data.)

Problem Statement
Propose a design for processing anhydrous sodium sulfate salts to create an economically viable product that can be produced on or off site of the Freeport-McMoRan refinery and rod mill.

Solutions should be innovative and cost effective to optimize the value of the sodium sulfate. The amount of product produced annually should track with FMI's current production rates of anhydrous sodium sulfate salts. The design should have a positive environmental impact, reducing the carbon footprint and the burden on landfills while finding a beneficial use of a non-hazardous resource.

The proposed site should be based on economics, environmental impact, waste management, circular economy considerations, jobs, and social justice.

Design Requirements:
Your proposed design should provide specific details and outcomes as follows.

- Describe the product, including how it can be sold at a profit.
- Include a process-flow diagram of your process(es), complete with mass and energy balances.
- Establish that your team's proposed rates of production will balance with FMI's sodium sulfate salt production rate of 3.6 million pounds/year.
- Assess the environmental impacts of your solution.
- Propose a community involvement plan that outlines how your team's plans engage a local community to implement and operate the facility.
- Address any waste products or by-products that may be produced from your process.
- Present a Techno-Economic Assessment and Analysis (TEA) of your design. Consider adding a business/economics major to your team to help with this. The TEA will include your estimate of capital costs (CAPEX) and operational costs (OPEX) for a full-scale solution and appropriate graphical representation of your cost data.
    - Assume that anhydrous sodium sulfate will be provided at $1/ton.
    - Consider: Any waste-disposal rates, energy and labor costs, depreciation or capital, value-added by turning the raw material into a more valuable product, maintenance of the facility, handling of hazardous waste, if applicable.
    - Operating costs: In addition to other operating costs that your team identifies, include these operating costs: staff labor rate of $50/hour; solids disposal costs ($70/ton); energy requirements (cost/yr and Kwh/yr): industrial natural gas rate (research and state in $/MM BTU); electricity rate of $0.10/kWh. Include transportation costs.
- Address safety aspects of operating your technology. Safety issues for both the full-scale design and the bench-scale demonstration should be addressed in both the written report and the Experimental Safety Plan (ESP).
- To be considered for the WERC P2 Award, in a separate section of the report (titled "Pollution Prevention"), document success in improving energy efficiency, pollution prevention, and/or waste minimization, as it applies to your project.
- Discuss the intangible benefits of your team's solution, if any.

Bench Scale Demonstration
Bench-scale demonstrations will serve to illustrate the design considerations listed above.

The bench-scale setup should demonstrate your team's design for producing a product made from anhydrous sodium sulfate. Teams will bring to the contest (when feasible—see ESP, below) equipment and supplies needed to demonstrate production of their chosen product at the bench scale.

WERC will provide before the contest:
Prior to the contest, and after team registration, each team will be shipped up to 5 kg of anhydrous sodium sulfate from FMI's refinery and rod mill. This can be used for testing your production plant. Email us at werc@nmsu.edu to request your sample after your team has registered.

WERC will provide at the contest:
At the contest, WERC will provide each team with up to up to 5 kg anhydrous sodium sulfate from FMI's refinery and rod mill for use in the bench-scale demonstration (more sodium sulfate available on request).

Teams will provide at the contest:
Teams will bring to the contest all equipment, supplies, and materials (except sodium sulfate, which will be provided by WERC) needed to demonstrate production of their chosen product (subject to ESP and contest commissioning approval). Any equipment requiring more than 110 V must be approved during the ESP process.

In addition to the bench-scale demonstration, teams may include video productions, computer simulations, tabletop displays, and scale or architectural models to assist in the presentation; these inclusions can be beneficial to your presentation but shall not be substitutes for the bench-scale demonstration.

30% Project Review
Submission date: March 1, 2024 (you may submit earlier if you wish to receive feedback sooner).

Submit the 30% Project Review as early as possible. It should not exceed four pages. Although the review is not scored, your team will receive feedback from the judges for improving your project. You are allowed to change your plans after submitting it. Include as many items listed below as possible. The first two items listed below are the bare minimum submission requirement. The more detail provided in your review, the better direction you will get from the judges. [See Team Manual for more information.]

As available, please include:

- ***Table of Contents*** planned for the technical report (place topics in order, one line per topic)
- ***A brief description of your project:*** One bulleted list outlining: planned solution to the problem and any anticipated drawbacks.
- ***The current schematic of your planned process flow or block diagram*** with mass and energy balances, as available.
- ***Preliminary data and/or calculations that support the proposed design***. This might include expected chemical reactions (reactants, reaction times, etc.), flow volumes and rates, etc.
- ***Any cost estimates that show feasibility of the project.*** This will give your team and the judges a chance to consider modifications that might improve feasibility of the project.

Experimental Safety Plan (ESP)
The ESP outlines your team's plans for safely operating your bench-scale demonstration at the contest. This document is submitted in February (see dates below). Instructions are provided in the team manual. The Team Leader, or a designated team member, shall attend a mandatory short course that outlines the ESP process. Teams will not be able to run a bench-scale demonstration if the ESP is not received by the deadline. Your team should follow your school's safety procedures while conducting tests prior to attending the contest.

Evaluation Criteria
Each team is advised to read the 2024 Team Manual for a comprehensive understanding of the contest evaluation criteria. As described in the manual, there are five events: a written report, a formal oral presentation, a demonstration of your technology using a bench-scale representation, a poster presentation, and a Flash Talk. Evaluation criteria used by the judges are described in the Team Manual.

For a copy of the Team Manual, Public Involvement Plan, and other important resources, visit the WERC website: Guidelines | werc.nmsu.edu

Your response to the problem statement will be evaluated on the following points.

- Potential for full-scale production of a beneficial product or material including ease and practicality of implementation, maintenance, cost/benefits, and expected reliability.
- Thoroughness and quality of the process-flow diagram.
- Effective community engagement.
- Thoroughness and quality of the economic analysis.
- Originality and innovation represented by the proposed technology.
- The results of your bench-scale demonstration. In particular, successfully developing a product made from anhydrous sodium sulfate.
- Other specific evaluation criteria that may be provided at a later date (check FAQs online regularly).

Short Courses
WERC is offering two short courses:

- *Mandatory:* Preparing the Experimental Safety Plan. The Team Leader, or a person assigned by them, must attend the course prior to submitting the ESP (and before February 20, 2024).
- *Optional:* Environmental Health and Safety (EH&S) Topics. The course is designed to prepare teams to complete the EH&S portion of their technical report. Course fees will be waived for contest-registered students, faculty, and judges. Watch the WERC website for schedules and registration information. Individuals who complete the course can earn a digital badge to add to their professional development portfolio.

Dates, Deadlines, FAQs (*dates subject to change—watch website FAQs*)

- Today: Email us to let us know you are interested in this task. We will contact you with breaking news.
- As soon as your team completes registration, email us to:
    - request 5 Kg of anhydrous sodium sulfate.
    - reserve a place in a tour of the Freeport-McMoRan Refinery and Rod Mill (date/time TBA)
- December 1 – March 31, 2023: Optional On-demand Course: WERC Safety and Environmental Topics. See Team Manual for more information.
- October 15, 2023 - December 31, 2023 – Early Bird Registration (discount applies).
- December 1, 2023 - February 20, 2023: Mandatory On-demand Course: Preparing the Experimental Safety Plan. See website and Team Manual for information.
- February 15 - 24, 2024: Experimental Safety Plan (ESP) due.
- March 6, 2024: 30% Project Review due.
- March 8, 2024: Final date to register a team.
- March 31, 2024: Technical Report due
- Weekly: Check FAQs weekly for updates:
    - Task-specific FAQs: 2024 Tasks/Task FAQs
    - General FAQs: 2024 General FAQs
- All dates or task requirements are subject to change. Check FAQs for updates online.

References

[1] PubChem. Sodium Sulfate. Sodium Sulfate | Na2SO4 | CID 24436 - PubChem (nih.gov)

[2] Freeport-McMoRan 2022 Annual Report on Sustainability, p. 71. 2022-annual-report-on-sustainability.pdf (fcx.com)

[3] EPA. EJ Screen. Environmental Justice Screening and Mapping tool. https://www.epa.gov/ejscreen

[4] EPA. EnviroAtlas. https://www.epa.gov/enviroatlas

Appendix 1: Transportation to Landfill

1. Truck information (truck model (or size, engine, weight [unloaded or loaded with the salts]).
    a. Year: 2011
    b. Make: Kenworth-Single roll off truck
    c. Type: TK T800
    d. Tare: 18,418
    e. Gross Weight 64,000
    f. Fuel: Diesel
2. Number of roll-off bins of sodium sulfate that one truck can haul.
    a. Only one roll-off bin on truck (TXDOT weight limitations)
3. Distance from the refinery/rod mill to the landfill.
    a. Approximately 40 miles roundtrip

Appendix 2: Aerial Photos of the Freeport-McMoRan Facility

Figure A-1. Site of the Freeport-McMoRan Copper Refinery and Rod Mill, El Paso, Texas. Red box indicates the location of the refinery.

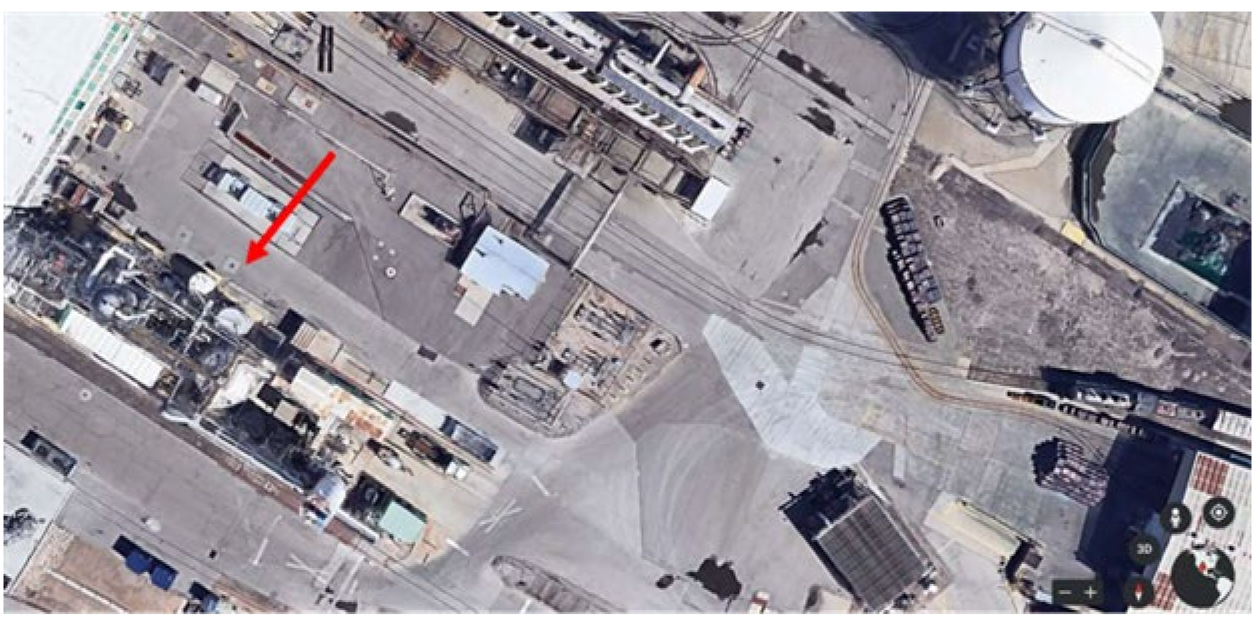

Figure A-2. Enlarged view of red-boxed area in Figure A-1 showing Freeport-McMoRan Copper Refinery and Rod Mill Water Recovery Plant (WRP) (indicated by red arrow, left).