Environmental Topic: Managing Emerging Waste Streams

Project Title: Sustainable Management of Wastes from Energy Resources

Project Deliverables: Project deliverables will include:

- ITRC Guidance document addressing:
    - Management of waste including recycling, reuse, and waste disposal that are generated by energy production sources with a focus on wastes from renewable energy production. Solar cells, electric vehicles and lithium batteries, wind turbines, and geothermal systems, critical minerals and materials, and coal combustion residuals (CCR) will be included. The guidance will include best management practices, recycling potential and beneficial reuse options and technologies, closure practices, potential impacts and risks to human and environmental health, remediation methodologies, and stability.
    - Status of current regulations in place regarding renewable energy and other energy production waste disposal and/or recycling (Federal, State, Tribal, International)
- Fact Sheets
- Web-based training

The deliverables will include a comprehensive look at energy production waste streams. Information will include types of waste generated, recycling and reuse potential and waste management best practices and technologies. Web-based training will be developed in short informational videos, fact sheets, or presentation training style with potential case studies.

State Team Leaders: Team Leaders will be sourced for interest by ITRC.

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Problem Statement: The transition to renewable energy sources from traditional energy production requires the management of new and legacy waste streams through practical investigation and remediation methodologies. Many of these waste streams contain compounds that are harmful to the environment and human health. Recent and future rulemakings and policy decisions concerning the disposal of these waste streams – including CCR, solar panels, and lithium batteries - will create significant financial challenges to states and their communities for managing, investigating, and mitigating previously closed facilities. Environmental impacts will need to be mitigated while also considering costs, community impacts, and sustainability of the final remedies.

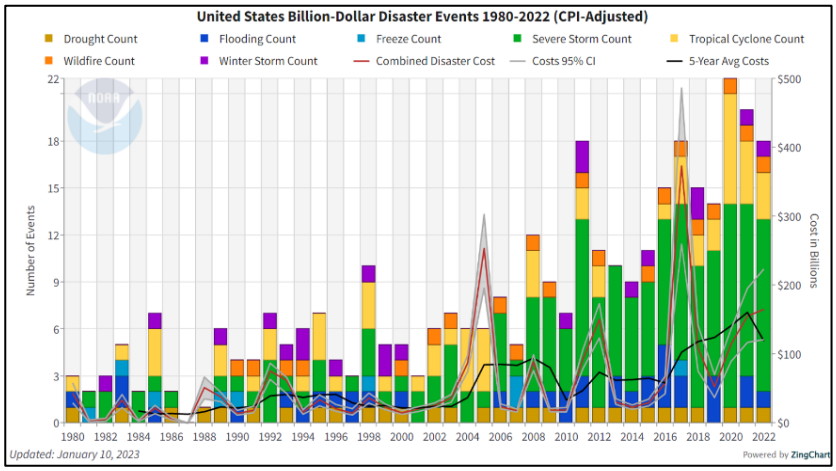
According to the US. Energy Information Administration (EIA), renewable energy sources accounted for 21.4 % of total electricity generation in 2023 (US EIA, AEO 2023). These renewable energy sources include solar, wind and geothermal. In addition to waste streams associated with electricity generation, there has been a rise of electric vehicle use with their associated rechargeable batteries. According to Experian Automotive's Market Trends third quarter 2023 report, approximately 1% of all registered vehicles on the road in the U.S. are electric. This is approximately 3 million new and used electric cars on the road today with potential for more as the industry grows. Critical minerals and materials (CMM) are essential to sustainable energy transition and with that transition is also the need for the management

of the waste associated with mining and potential recovery of these minerals. CMM recovery opportunities may exist with contaminated sites requiring remediation.

The service life of renewable energy materials such as solar panels and wind turbine towers and blades ranges from 20 to 25 years. According to the EPA, the United States will have as much as one million total tons of solar panel waste by 2030, and as many as 10 million total tons of solar panel waste by 2050. Electric car batteries have a service life between 8 and 12 years, with an estimated 550,000 reaching end of life each year (EPA). These estimates are likely conservative due to obsolescence. A study published in Resources, Conservation and Recycling indicates over 2 million tons of U.S. Wind turbine blades are expected to retire by 2050 (Cooperman et al, 2021).

Recycling options are available for many components of renewable energy sources, but sufficient capacity is an issue. As of 2023, there are only five companies listed by the Solar Energy Industries Association as capable of providing recycling services for solar panels (Hurdle, 2023). According to the International Council on Clean Transportation, recycling capacity in the US for EV batteries is approximately 105,150 tons annually, with anticipated recycling plants boosting the recycling capacity to 652,293 tons by 2030 (Tankou et al, 2023). However, end of life EV batteries waste is estimated to be near 1.3 million tons by 2050. Many renewable energy components will ultimately enter landfills as a cost-efficient option for dealing with the waste. Disposal can range from $2-$5 per solar panel as solid waste, more if it is considered hazardous waste, but recycling can cost as much as $18 per panel.

In addition to the anticipated increase in waste from renewable energy sources, natural disaster events are also generating unprecedented waste and debris that ultimately end in landfills. According to Climate.gov, produced by NOAA, in 2022 alone, the U.S. experienced 18 separate weather and climate disasters totaling at least a billion dollars in damage. The following chart, courtesy of NOAA NCEI, shows the increase in frequency as well as costs of weather and climate disasters from 1980 to 2022. With many public and private buildings utilizing renewable energy resources, such as solar panels, opportunities for recycling and beneficial reuse should be examined in natural disaster clean-up strategies.



Current landfill capacity varies across the U.S. with remaining capacity up to 22 years. This is based on average waste and does not account for the additional waste streams of climate disasters and renewable energy development.

Region	Remaining Capacity (years)	Annual rate of loss
Northeast	8	-5.0%
Southeast	14	-2.5%
Midwest	11	-4.0%
Western	22	-1.5%
Pacific	17	-1.9%
USA	15	-2.6%

Landfill capacity as of 2021. Courtesy of Waste Business Journal.

In conclusion, many states and communities do not have clear guidance or regulations on waste management from energy production, including legacy and renewable energy sources, some of which could be considered hazardous waste. ERIS also identified managing waste streams related to renewable energy sources as the top waste and remediation research need in its latest state survey report (ERIS 2022). The team's purpose is to develop comprehensive guidance to provide technical resources, strategies, and information on managing these emerging waste streams.

Additional Information: EPA is working on a comprehensive electric battery guidance (est. 2026) could be referred or incorporated

Brief literature review:

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ASTSWMO. Emerging Wastes from Renewable Energy Sources Fact Sheets. November 2022. https://astswmo.org/emerging-wastes-from-renewable-energy-sources-fact-sheets/

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Hurdle, J. As Millions of Solar Panels Age Out, Recyclers Hope to Cash In. YaleEnvironment360. February 28, 2023. https://e360.yale.edu/features/solar-energy-panels-recycling

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US EPA. Disposal of Coal Combustion Residuals from Electric Utilities Rulemakings. Retrieved June 27, 2024. https://www.epa.gov/coalash/coal-ash-rule

Woods, B. 2023. Recycling ‘end-of-life’ solar panels, wind turbines, is about to be climate tech’s big waste business. CNBC. Published Sat, May 13 20239:30 AM EST, Updated Mon, Nov 27 202311:57 AM EST. https://www.cnbc.com/2023/05/13/recycling-end-of-life-solar-panel-wind-turbine-is-big-waste-business.html