

# NEXUS

*and the*

# Zero-Waste Grand Challenge

A Partnership between the Colorado School of Mines and  
the National Renewable Energy Laboratory

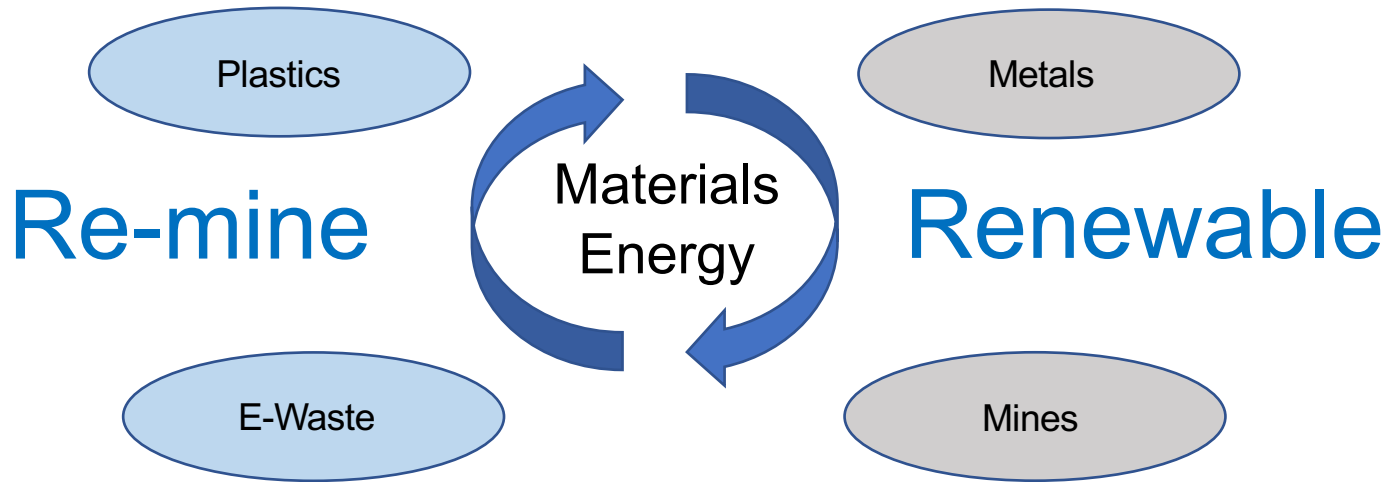
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# The Circular Economy: Re-mining Materials and Embedded Energy



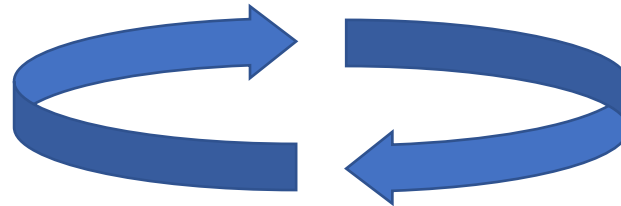
# NEXUS Expertise

- **Technical:** Extraction, separations, renewable energy technologies, recycling, additive manufacturing
- **Analyses:** Techno-economic, life cycle, environmental impact
- **Policy:** Mines Payne Institute for Public Policy

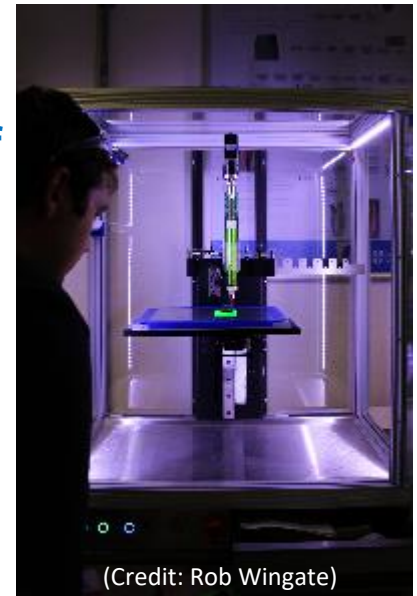
# Example of Re-mining to Advanced Manufacturing



Selective extraction (re-mining) of elements from e-waste



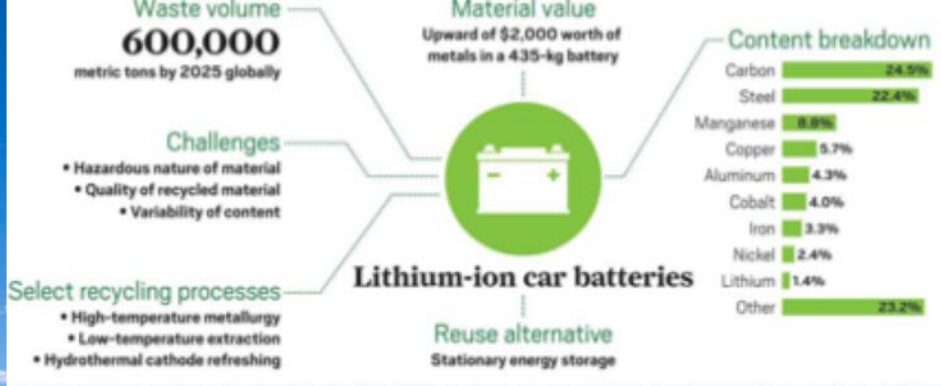
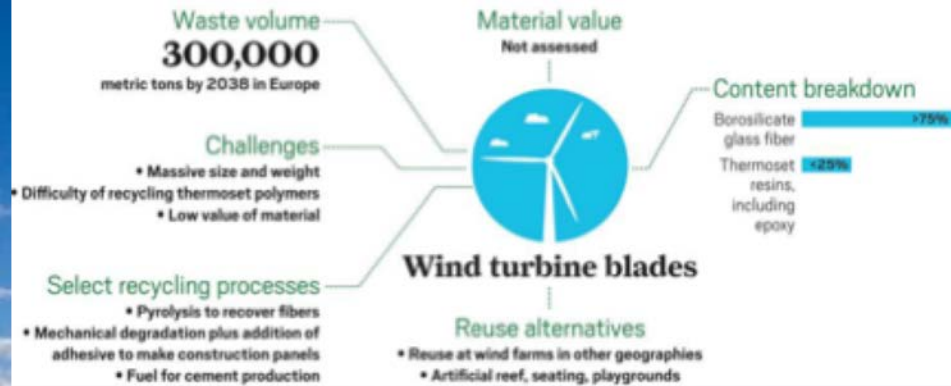
Using the solutions of extracted material as ink for advanced manufacturing of new device designed for reuse



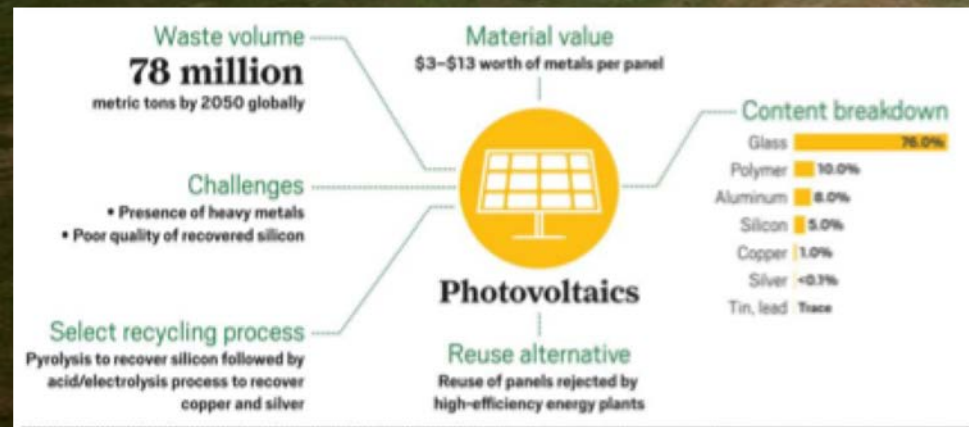
# Workshops:

## Identifying Grand Challenges for NEXUS

- Held first NEXUS workshop in September 2018
  - ✓ *Limits to Waste: Pushing Materials Manufacturing Towards Zero Waste for a Sustainable Future*
- Several national speakers in focus areas
  - ✓ E.g., electronic waste, reuse of closed and abandoned mines, plastics recycling and in metal recycling
- In this area, our combined strengths and interests are clearly greater than either institution alone.
- We are leveraging our expertise in analysis, technology, and policy.



Some big challenges are ahead



# Advanced Energy Materials and Technologies

## Why It's Important

Advanced energy technologies

- Require **materials limited in supply**
- Generate complex heterogeneous wastes
- Use **large energy inputs for extraction/purification**

## Capabilities

- Analysis: techno-economic, systems, scenarios, supply chain, markets
- Materials design, discovery, and processing
- Advanced **device design, fabrication, testing, and certification**
- Advanced **characterization, imaging, and spectroscopy**
- Materials and device durability and reliability
- Domain expertise in PV, fuel cells, electrolysis, batteries, and energy systems

## NREL Research

- New **concepts, approaches**, and understanding for recovery and recycle, materials substitution, device/system design, **advanced manufacturing processes**, and accelerated deployment

## Focus Area: Lithium-ion batteries

- Goal: Increase value of EV batteries at end-of-life without compromising safety or the environment
- design for reduced material use in manufacturing
- Design for reuse in vehicle or refurbished for use in other products (storage)
- Evaluating cost of recovering battery materials at end of life
- Evaluating case for reusing batteries at the pack-level
- Evaluating how to re-purpose a vehicle pack, or individual components

# Composites and Polymers

## Why It's Important

Expected significant growth

- Adds to massive complex heterogeneous wastes impact on landfills and oceans
- Largely once-through economy
- Number of needs overlap with NREL expertise

## Capabilities

- Advanced analysis (TEA, LCA, ...)
- Interfacial biological and chemical catalysis
- Synthetic biology, systems biology, enzymology
- Advanced synthesis, chemical and materials processing
- Advanced imaging and characterization
- Advanced composites
- Structural analysis and testing

## Outcome

New concepts and technologies for:

- Reclamation, cost-effective recycle, and upcycling of existing composites & plastics
- Next-generation feedstocks, composites, and plastics including bio-based systems
- Advanced manufacturing—On-site manufacturing of recyclable wind-turbine blades

**Focus Area: Advanced wind-turbine blade composites**

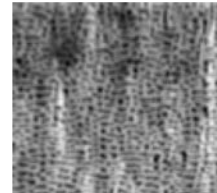
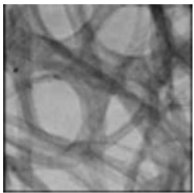


# Leveraging Existing Programs & Collaborations

- **International Center for Multiscale Characterization (ICMC)**
- **Federal grants and other ways to work with the Labs**
  - Small Business Innovation Research (SBIR)
  - Small Business Technology Transfers (STTR)
  - Technology Commercialization Fund (collaboration to commercialize lab IP)
  - NREL Commercialization Assistance Program (NCAP)
  - Wells Fargo Innovation Innovator
  - Shell GameChangers Powered by NREL
- **Other federal opportunities**
  - Reducing Embodied-Energy And Decreasing Emissions (REMADE) Institute
  - Proposal calls from Solar Energy Technologies Office (SETO)
- **Unique educational collaborations**
  - e.g., Advanced Energy Systems (AES)

# ICMC: Solving Materials Innovation Challenges Through Multiscale Analysis

- Multimode, multiscale characterization for energy-related materials (photovoltaics, batteries, fuel cells, lightweight alloys, composites, membranes, geological materials, power electronics).
- Expertise across a wide range of applications and 10 orders-of-magnitude state-of-the-art imaging (meters to Angstroms)
- Industrial engagement and local, national, and international collaborations and visitors/exchanges
- Leverage advanced instrumentation
- Working at the frontier of imaging **functional properties** of materials—the next step beyond traditional excellence in understanding structure and chemistry.



# NREL/Federal Commercialization Programs

## Wells Fargo Innovation Incubator (IN<sup>2</sup>)

Supports early-stage commercial building technology companies through technology development, validation, and pilot opportunities.



Provides grants to small businesses or individuals to aid in developing and commercializing new energy ideas.



## Shell Game-Changer Powered by NREL

Partners early-stage companies with NREL expertise and facilities to advance emerging clean-energy technologies toward market application



## Technology Commercialization Fund

Leverages DOE funding to help national labs partner with industry to de-risk early-stage promising energy technology toward market deployment.



# Advanced Energy Systems (AES)

## A unique interdisciplinary Ph.D. program

- Promotes research, and discoveries in advance energy sciences
- Develops and analyzes technologies that enable sustainable management of the environment and natural resources
- Integrates economics and policy into technical advances and analysis in energy science and engineering.

## A non-thesis M.S. program

- Promotes training in advanced analytical skills across disciplines relevant for assessing and developing energy technology
- Integrates economics and policy into analysis in energy science and engineering.

# Uniqueness of the Ph.D. Program

## Unique research and educational environment for students across multiple disciplines

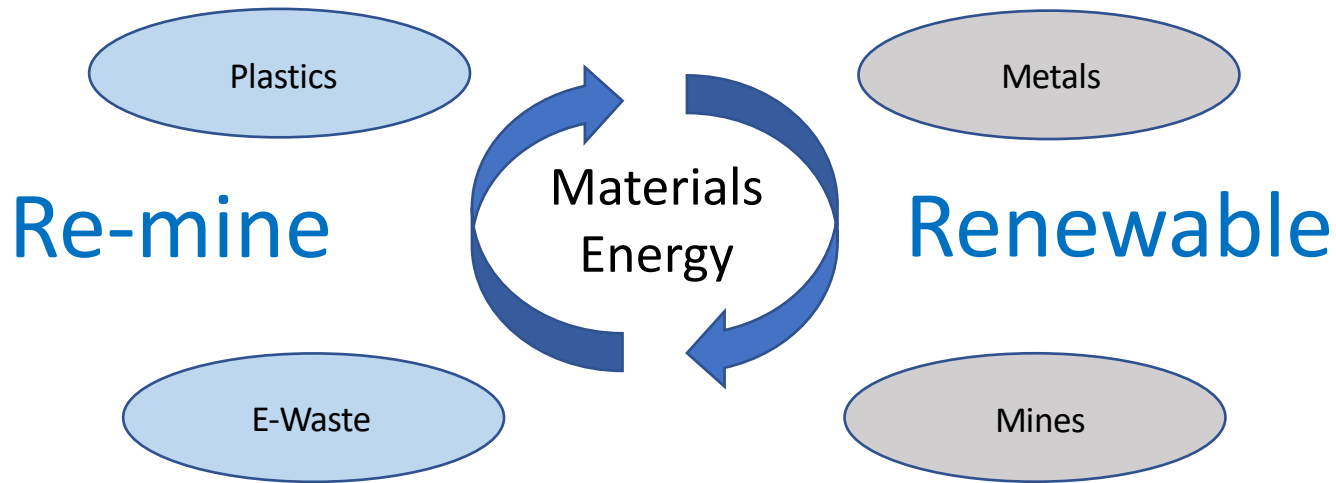
- Joint supervision by Mines and NREL supervisors
- No boundary between university and national lab—access to resources and expertise from groups at NREL and Mines
- Learning community among peers from different disciplines addressing challenges in energy technology development and analysis
- Possible internships at an industry or utility with interest in deploying the research technology

# Going Forward...

## *A Challenge and a Leadership Opportunity for Colorado*

- Establish framework for continued engagement in pursuing common goals.
  - Hold collaborative workshops/studies as an opportunity for State engagement.
  - Engage university and national lab expertise.
  - Help Colorado businesses engage in this emerging area.
- Collaborate to grow and engage the workforce of the future.

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Thank you for your time.