COLORADO SCHOOL OF MINES
EARTH • ENERGY • ENVIRONMENT

Rethinking the Energy Future

August 25, 2022

AGNC
2022 ECONOMIC DEVELOPMENT SUMMIT:
TRANSFORMING THE ENERGY ECONOMY

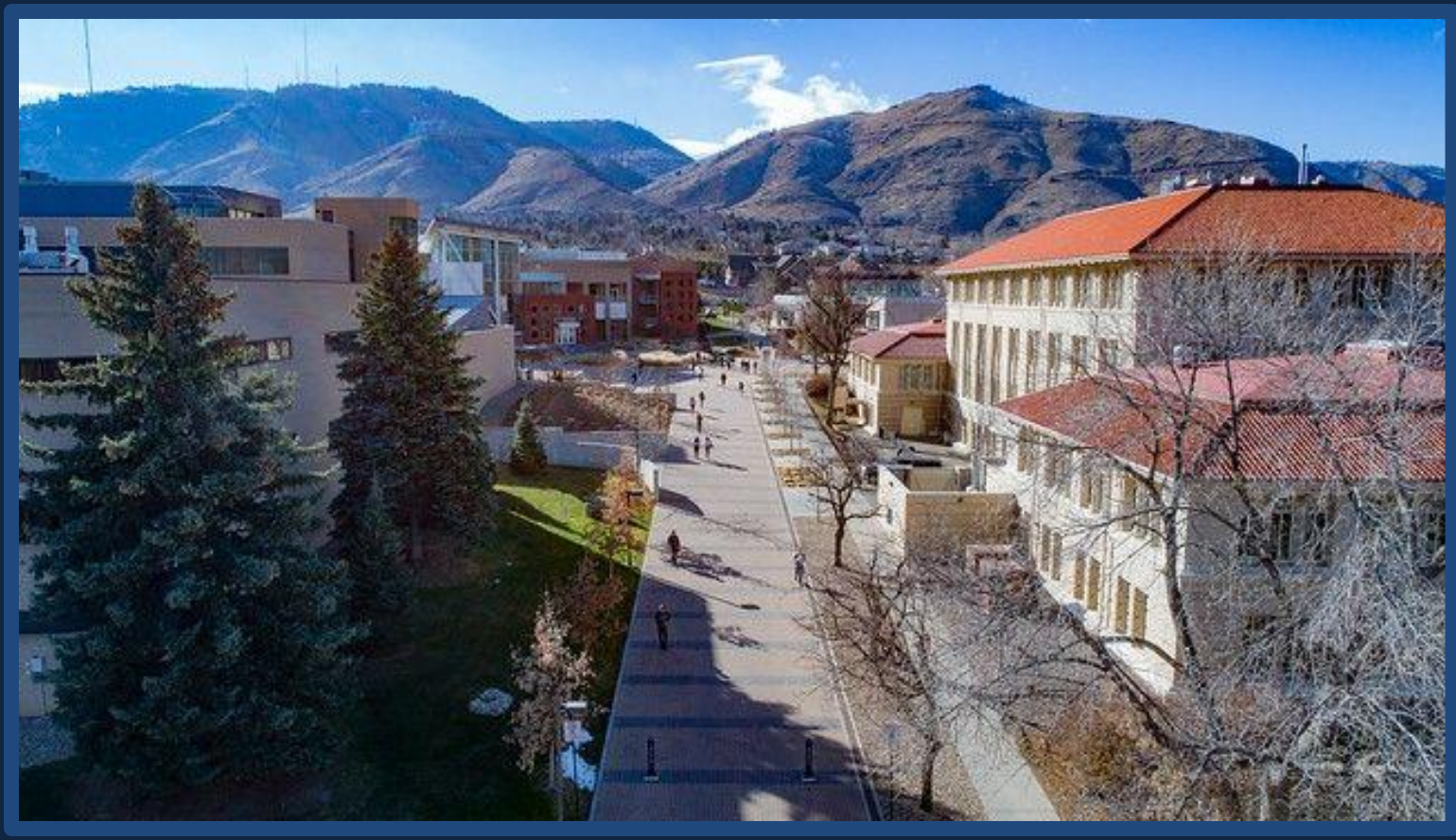
The Payne Institute *for* Public Policy

COLORADO SCHOOL OF MINES
EARTH • ENERGY • ENVIRONMENT

Gregory Clough
Deputy Director, Payne Institute for Public Policy
Colorado School of Mines

COLORADOSCHOOLOFMINES.

EARTH • ENERGY • ENVIRONMENT



COLORADO SCHOOL OF MINES
EARTH • ENERGY • ENVIRONMENT

- **Founded in 1874**
- **#3 Elite Energy Universities (American Energy Society)**
- **#4 Engineering school in US (Money Magazine)**
- **R1 Carnegie top tier research university**

The Payne Institute *for* Public Policy

COLORADO SCHOOL OF MINES
EARTH • ENERGY • ENVIRONMENT

COLORADO SCHOOL OF MINES
EARTH • ENERGY • ENVIRONMENT

Activities

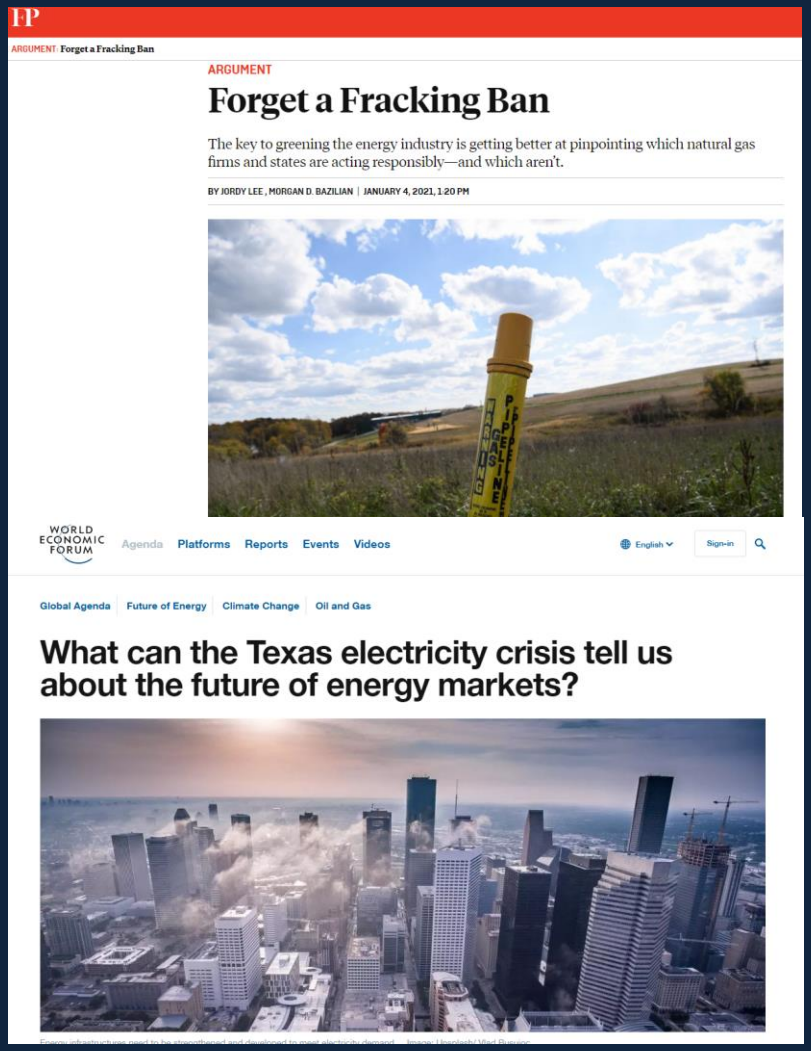
Bringing together global energy thought leaders and Colorado School of Mines students and faculty through Research, Education, Meetings and Outreach.

Research & Data
Access to Mines' applied knowledge and data-driven approach to shape a net-zero energy future

Education
Investing in teaching the future energy leaders across the energy system at the intersection of science, technology and policy

Meetings
Bringing together the top minds from academia, industry, government and civil society to support global energy decision makers

Research



ARGUMENT: Forget a Fracking Ban

ARGUMENT

Forget a Fracking Ban

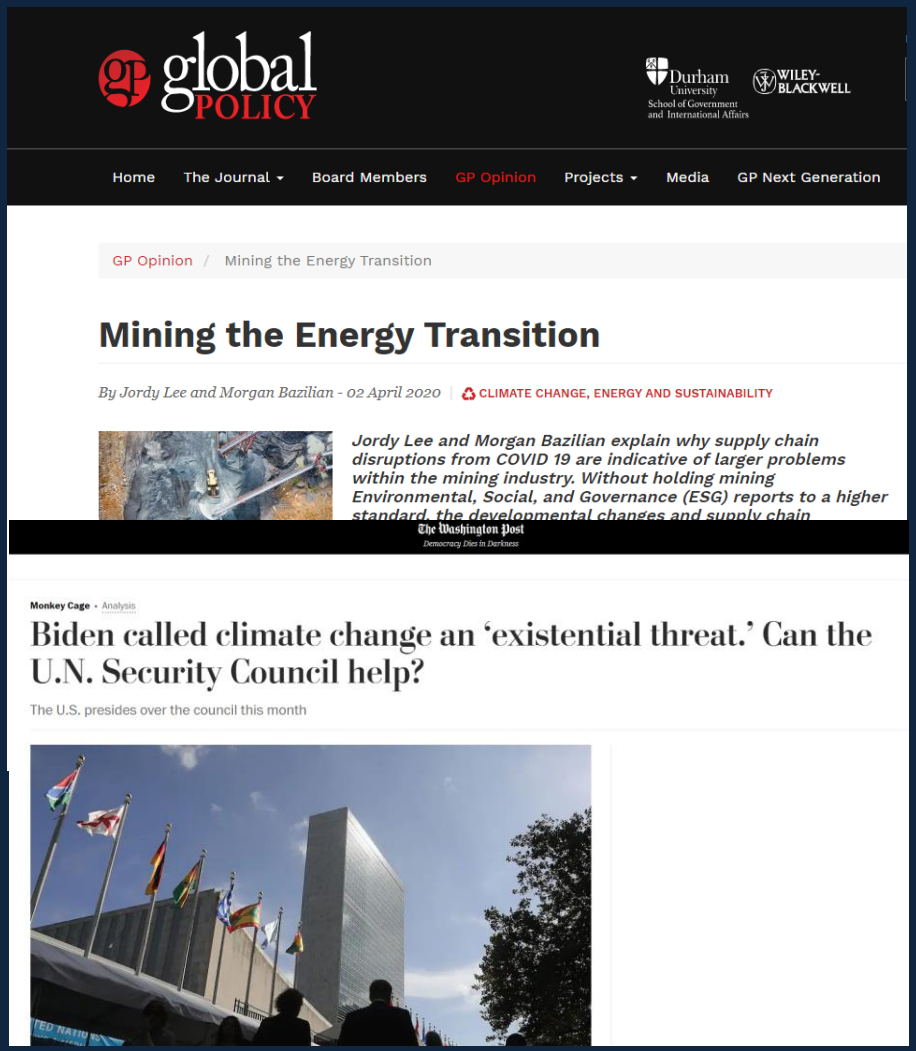
The key to greening the energy industry is getting better at pinpointing which natural gas firms and states are acting responsibly—and which aren't.

BY JORDY LEE , MORGAN D. BAZILIAN | JANUARY 4, 2021, 1:20 PM

WORLD ECONOMIC FORUM Agenda Platforms Reports Events Videos English Sign-in

Global Agenda | Future of Energy | Climate Change | Oil and Gas

What can the Texas electricity crisis tell us about the future of energy markets?



global POLICY

Durham University School of Government and International Affairs

WILEY-BLACKWELL

Home The Journal Board Members GP Opinion Projects Media GP Next Generation

GP Opinion / Mining the Energy Transition

Mining the Energy Transition

By Jordy Lee and Morgan Bazilian - 02 April 2020 | CLIMATE CHANGE, ENERGY AND SUSTAINABILITY

Jordy Lee and Morgan Bazilian explain why supply chain disruptions from COVID 19 are indicative of larger problems within the mining industry. Without holding mining Environmental, Social, and Governance (ESG) reports to a higher standard, the developmental changes and supply chain

The Washington Post
Democracy Dies in Darkness

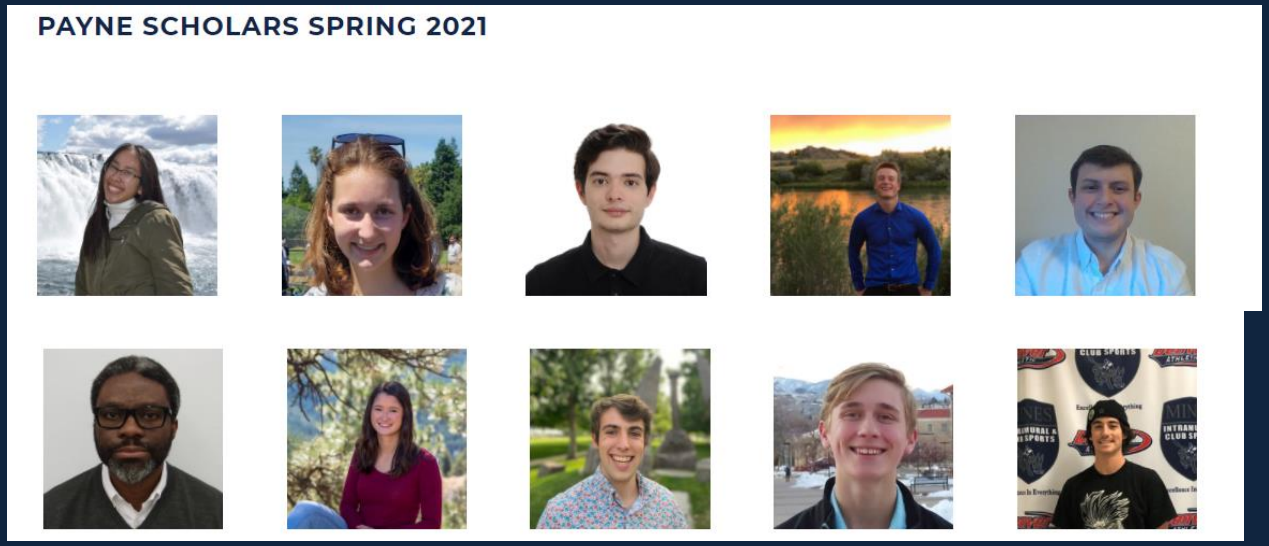
Monkey Cage • Analysis

Biden called climate change an 'existential threat.' Can the U.N. Security Council help?

The U.S. presides over the council this month

Education

The Payne Scholars program gives students the opportunity to perform research, collaborate across campus and engage with a broad network of international experts on global policy challenges.



“You all are among the most welcoming and considerate people I have gotten to work with. The projects I took part in these last few months have been rewarding and a great help in my professional development. Thank you.”

Meetings & Events

Connecting Payne Institute Energy research with global experts to give Colorado School of Mines greater visibility in global energy conversation.

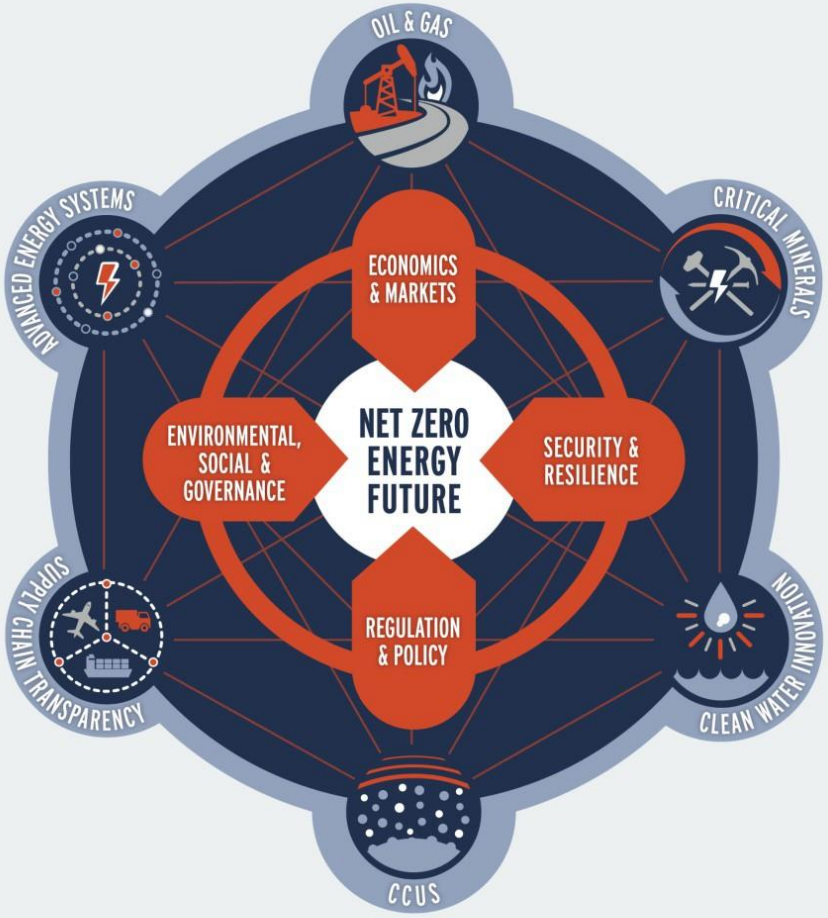
Scientific, Data Driven Approach to the Energy Future

Global Energy Future Initiative

Meeting the Net Zero Challenge

COLORADO SCHOOL OF MINES

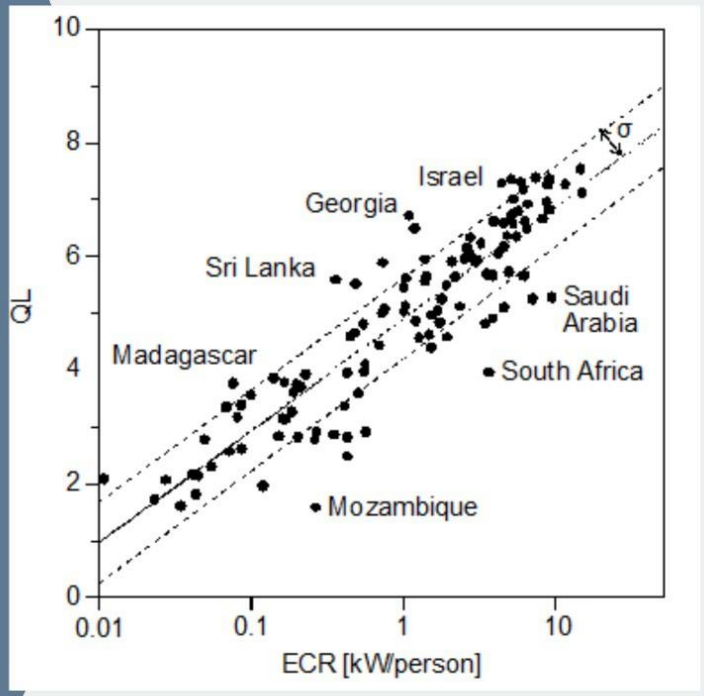
global@mines.edu



How can we create a sustainable energy future?

- Our energy future needs:
  - Energy demands to power a growing, global population
  - Sustainable
  - Limit environmental and social impact
- The Grand Challenge: Net zero carbon emissions

Quality of Life Correlates with Energy Use



Pasten and Santamarina, 2012

Oil and Gas

“The rise in US production of tight oil and shale gas since 2010 is the largest parallel increase in oil and gas output in history”

International Energy Agency, World Energy Outlook, 2018

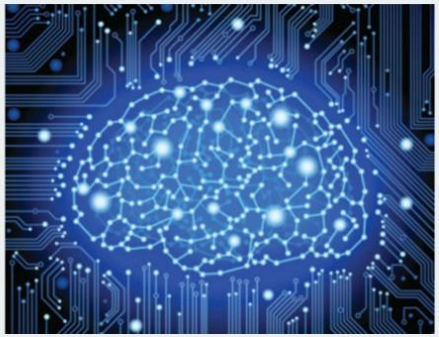
“The risk of climate change is clear and the risk warrants action. Increasing carbon emissions in the atmosphere are having a warming effect.”

“We know enough based on the research and science that the risk is real and appropriate steps should be taken to address that risk.”

ExxonMobil

Monitoring GHG Emissions

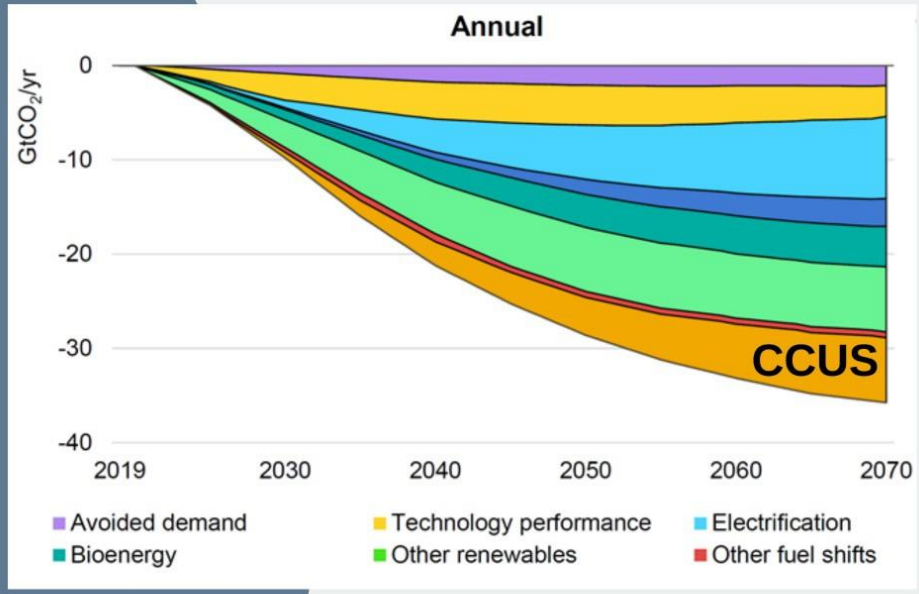
- Energy Data Science and Analytics Institute
  - Developing computational tools to utilize massive, diverse data, gain operational efficiency, and minimize environmental impact



Carbon Capture Utilization and Storage (CCUS)

Reaching net zero will be virtually impossible without CCUS (2020 IEA Special Report on CCUS)

NAE Grand Challenge



Mines new iniatives

CCUS at scale

We develop practical solutions to meet the global need for a carbon neutral energy system. We develop the leaders who will be required to meet this grand challenge.

- Mines CCUS Innovation Center
  - Interdisciplinary RTT Research Center involving twelve departments
  - Biannual CCUS Expo
- Fully online educational program
  - Short courses, graduate certificate, MSNT
- Mines Integrated CCUS Initiative
  - Payne Institute Seminar Series

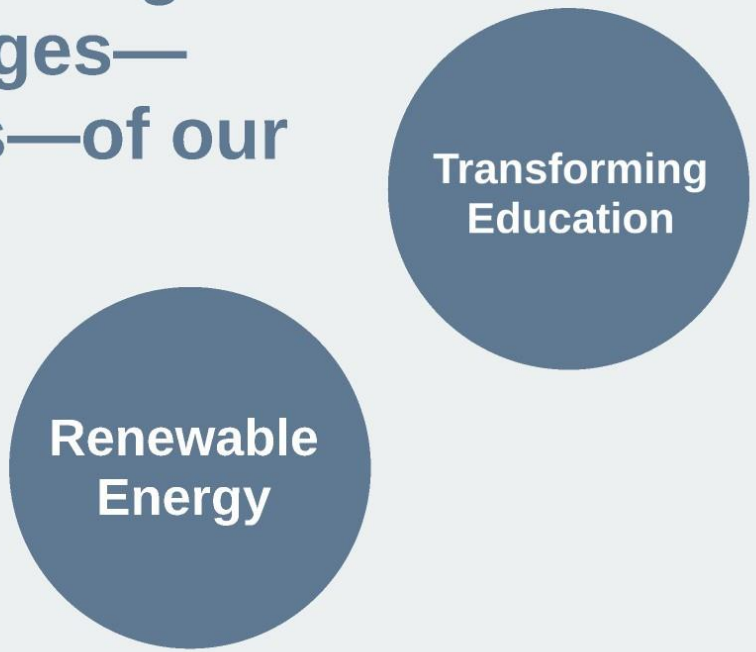
Current Strengths

- Bio-capture
  - Upgrade to fuels and other products
- Capture Membranes
- Blue Hydrogen
- Geologic Storage and Monitoring
- Non-geologic Storage
- Carbon economics and policy

COLORADO SCHOOL OF MINES

Low Carbon and Renewables

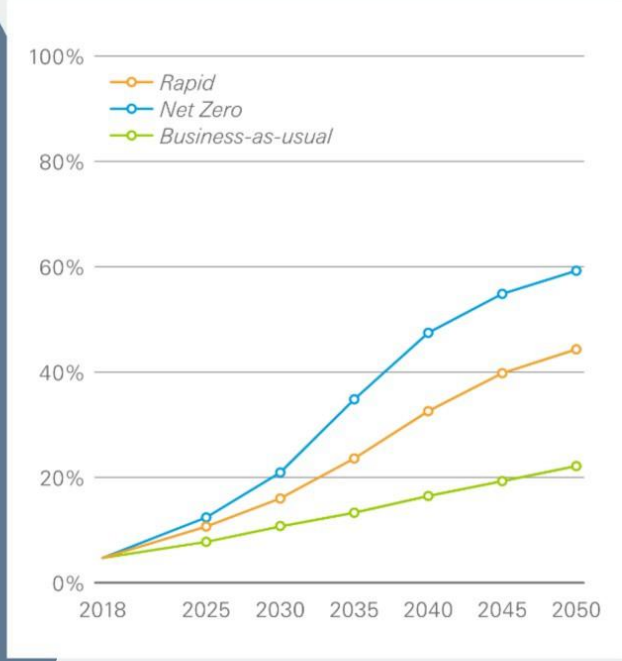
Developing sustainable energy infrastructure that fosters economic growth while reducing environmental impact is among the most pressing challenges—and greatest opportunities—of our time



Shares of Primary Energy: Renewables

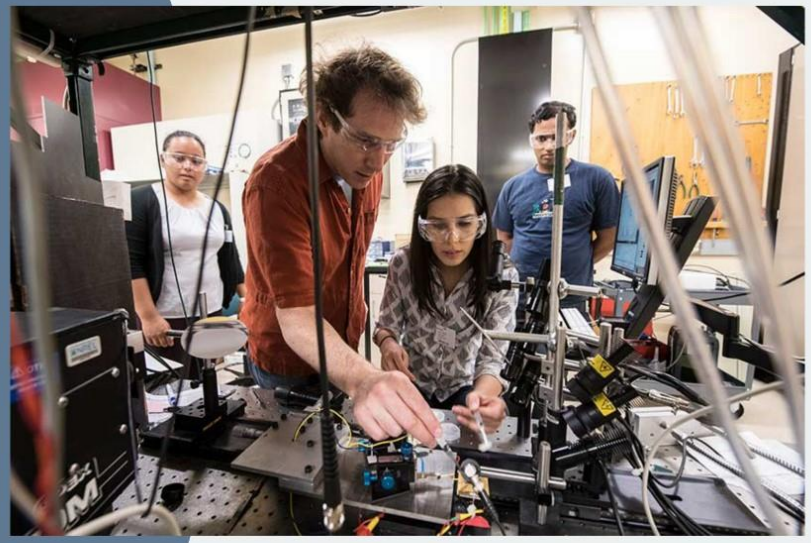
2020 BP Energy Outlook

Areas of Research



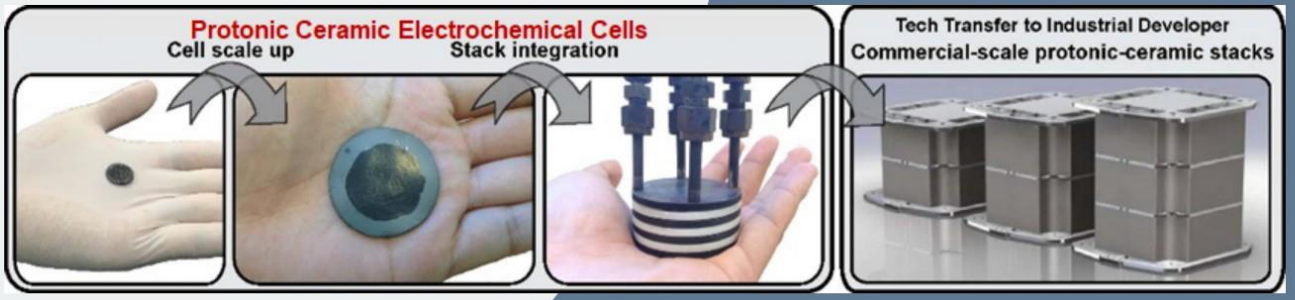
National Renewable Energy Lab (NREL)

Mines and National Renewable Energy Laboratory are partnering on the Advanced Energy Systems PhD and MS Programs focused on developing future energy thought leaders.

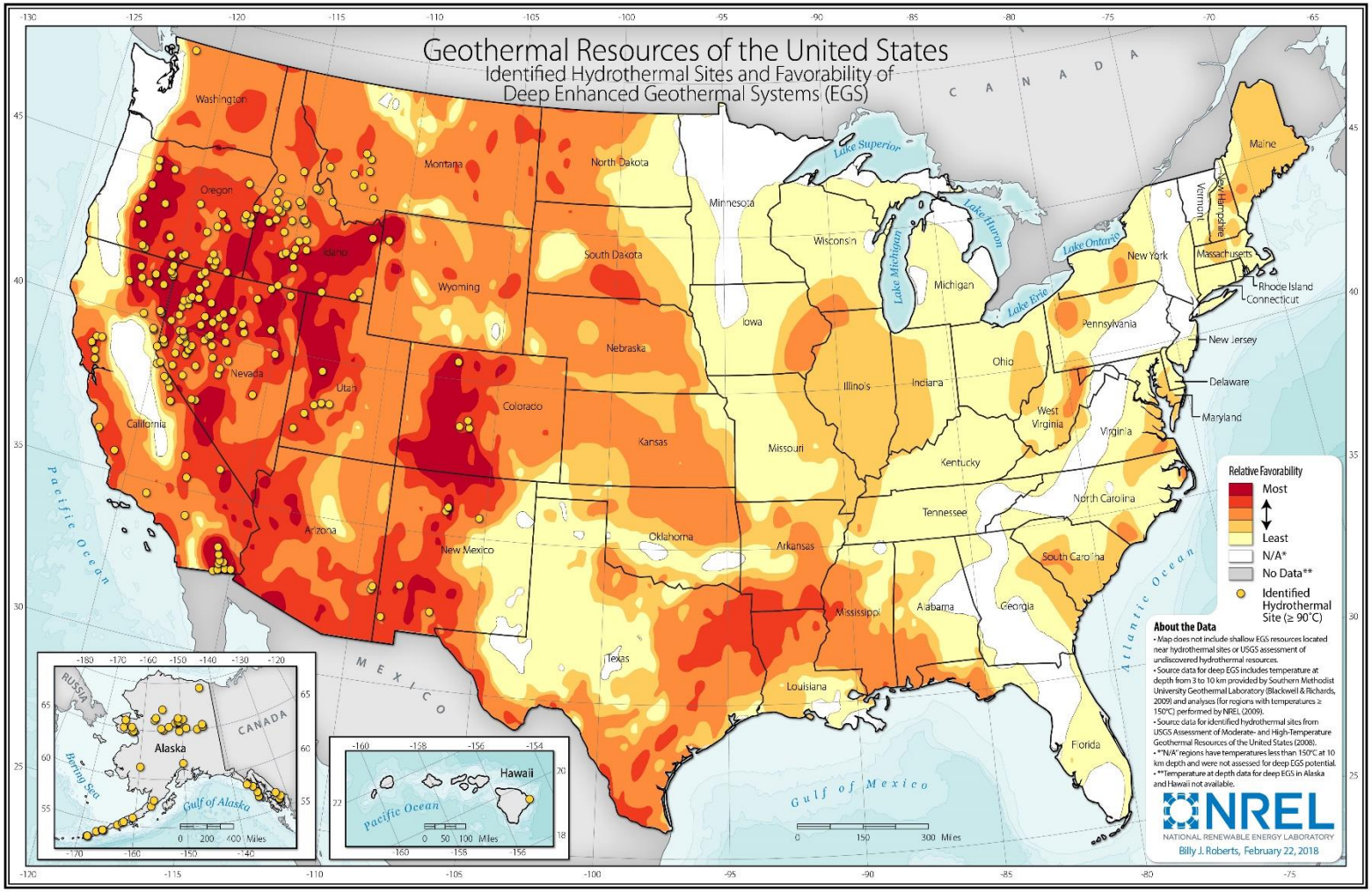


Advanced Energy Systems

- Colorado Fuel Cell Center
- Proton Conducting Ceramics
- Blue and Green Hydrogen
- Biofuels
- Advanced Geothermal Systems



Geothermal Energy



Minerals and Metals

"[W]ind turbines, solar power stations and other facilities ... will require vast amounts of metals and other raw materials"

Vidal et al., 2013, Nature Geoscience

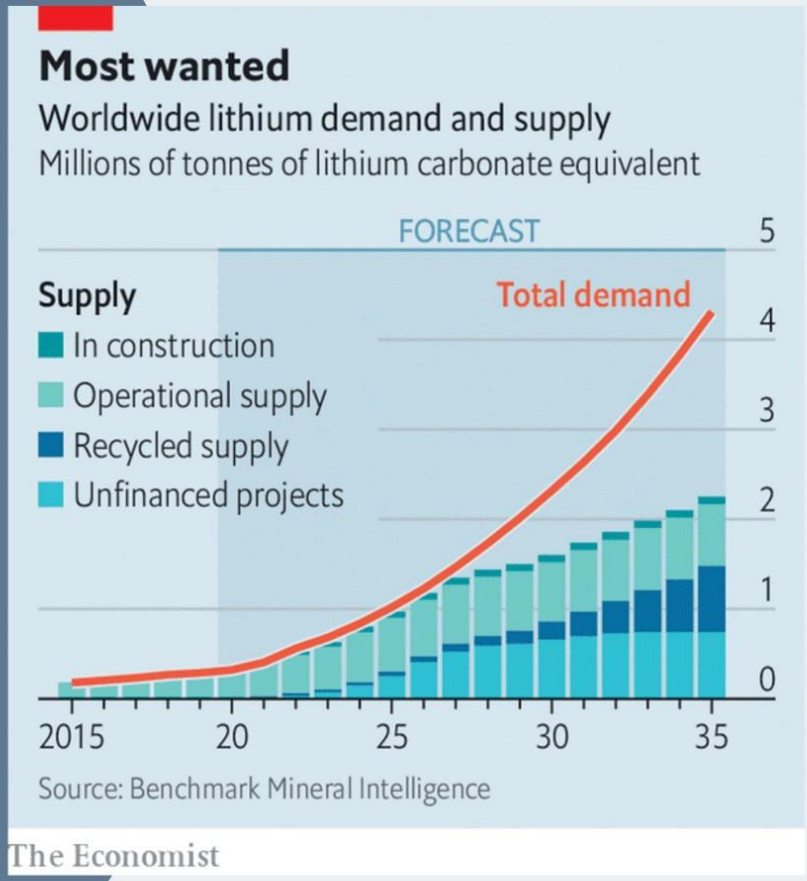
Metals and Minerals Demand Growth

"A shift to renewable energy will replace one non-renewable resource (fossil fuel) with another (metals and minerals)."

Vidal et al., 2013, Nature Geoscience

We must quickly transition to low carbon technologies for extraction of metals and minerals, while managing environmental and social impacts

Mines new initiatives



Responsible Critical Elements

- How do we determine the most efficient, equitable, and sustainable approaches to obtain the metals needed for the energy transition?

Elizabeth Holley *Ore Geology* | Sebnem Duzgun. *Mining Eng.* | Priscilla Nelson *Geotech. Eng.* | Erik Spiller *Metallurg. Eng.* | Robin Bullock *Env. Eng*

Rod Eggert *Mineral Econ.* | Nicole Smith *Anthropology* | Kathy Hilimire *Sustainability* | Rebecca Clausen *Env. Sociology* | Sara Hastings-Simon *Public Policy*

- Integrated socio-technical evaluation of three possible modes of critical element supply
  - New main product operations
  - Byproducts from existing mines
  - Recovery from historic wastes

Top: Mines students at a large gold mine in Nevada that hosts low-grade cobalt. Could it be recovered?

Bottom: Cobalt mining from tailings in Missouri (V. Kemper, Daily Journal)

Sustainable Metals and Minerals

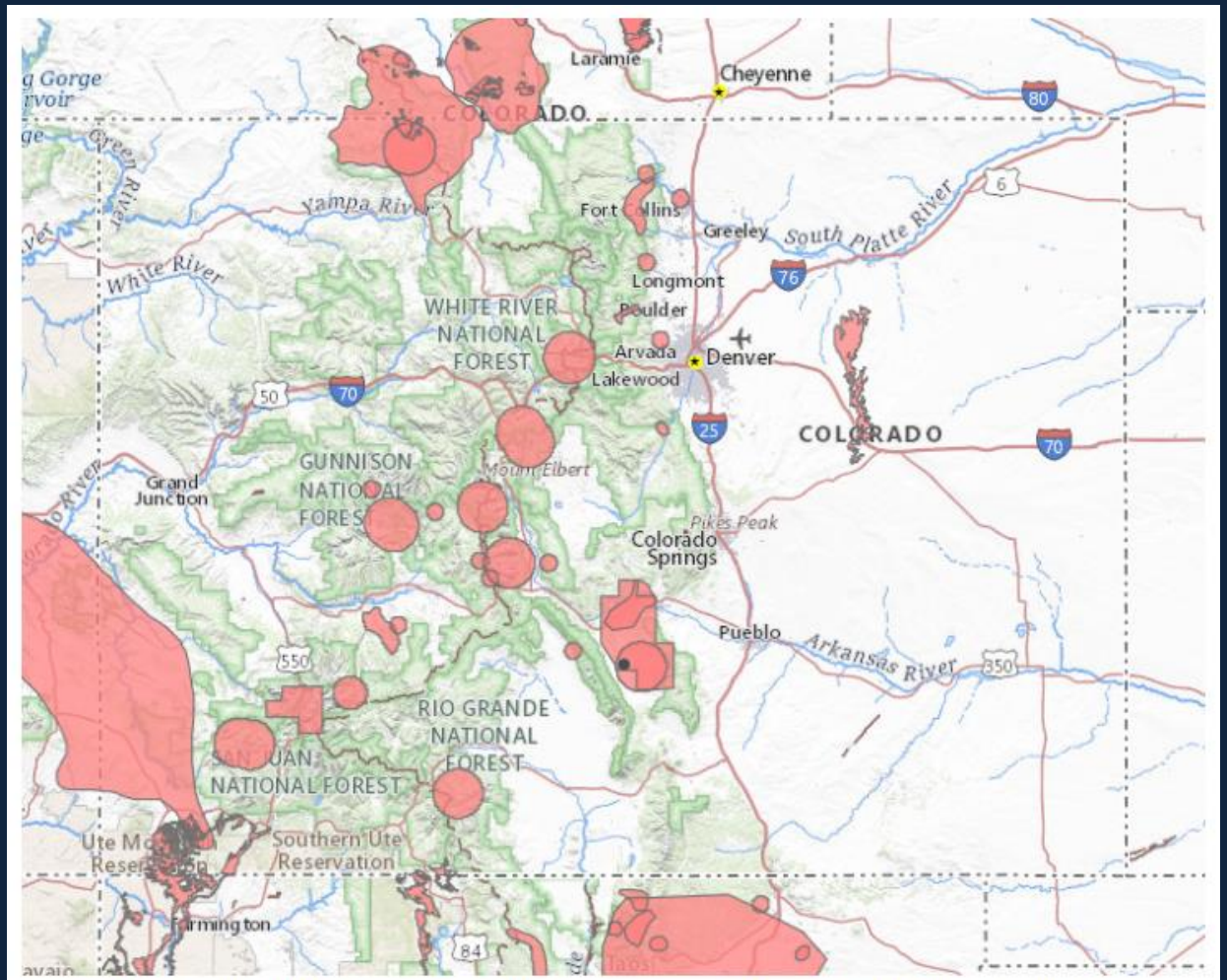
- Research roadmap for net-zero mining
- Mines Minerals Model
- ESG Mining Hub
  - Enabling net-zero mining
  - Maximizing resource identification and extraction
  - Limiting environmental/social impact
  - Creating economic and policy solutions
  - Improving quality of life for mine workers

USGS Energy and Minerals Center

USGS Energy and Minerals Research Facility on the Colorado School of Mines Campus

By **Communications and Publishing** MARCH 25, 2022

Critical Minerals Colorado



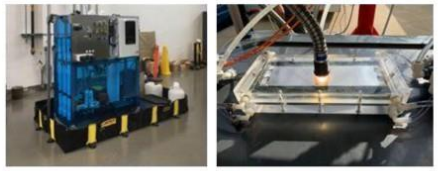
Earth MRI data highlights focus areas in Colorado for critical minerals. The black dot near the center, bottom shows Westcliffe.

Clean Water Innovation

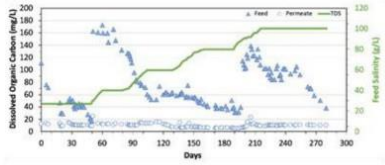
Examples of Water Treatment Research

PI: Tzahi Cath

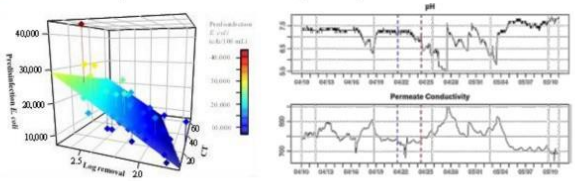
- Off the grid desalination systems powered by solar energy for remote communities
  - Autonomous systems
  - Very high water recovery (low brine production)
  - Smart control systems for self process optimization



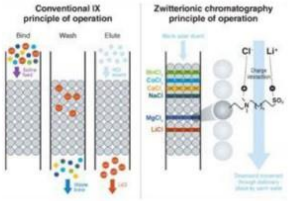
- Treatment of complex industrial wastewater
  - Biological treatment of O&G produced water
  - Operating in extreme environments (>100 g/L salinity)



- Data-driven process control for early detection of system failure and water quality forecasting
  - Advancing machine learning and self-correction
  - Process optimization in complex systems



- Resource recovery from water and wastewater
  - lithium, ammonia, phosphorous, iodide

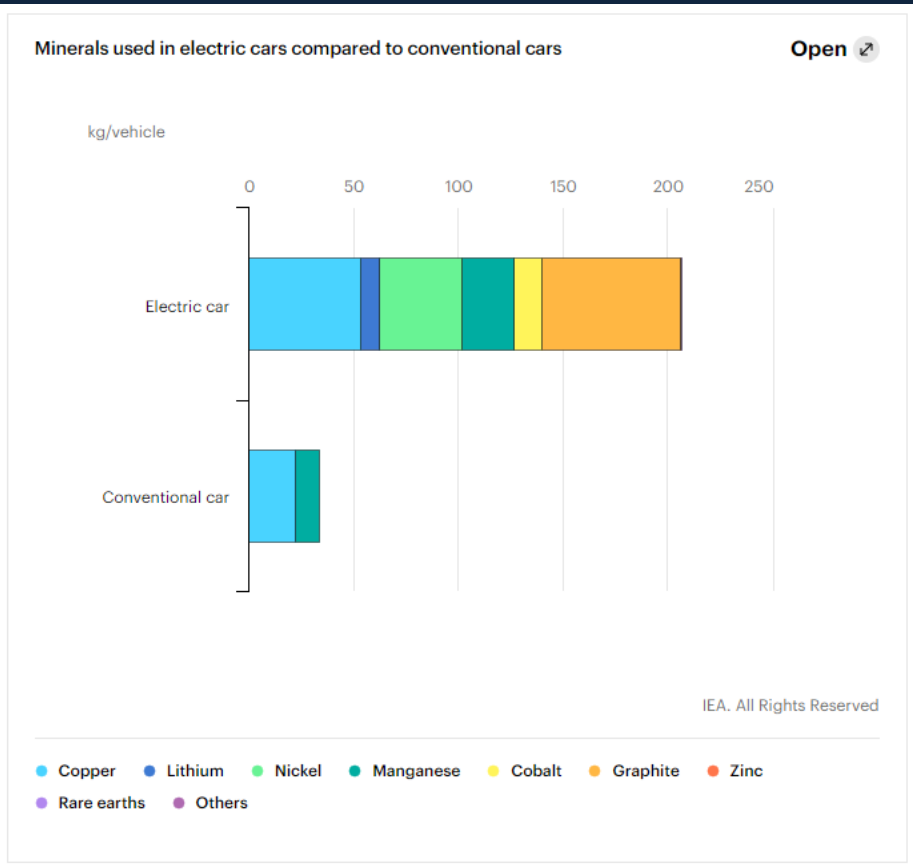


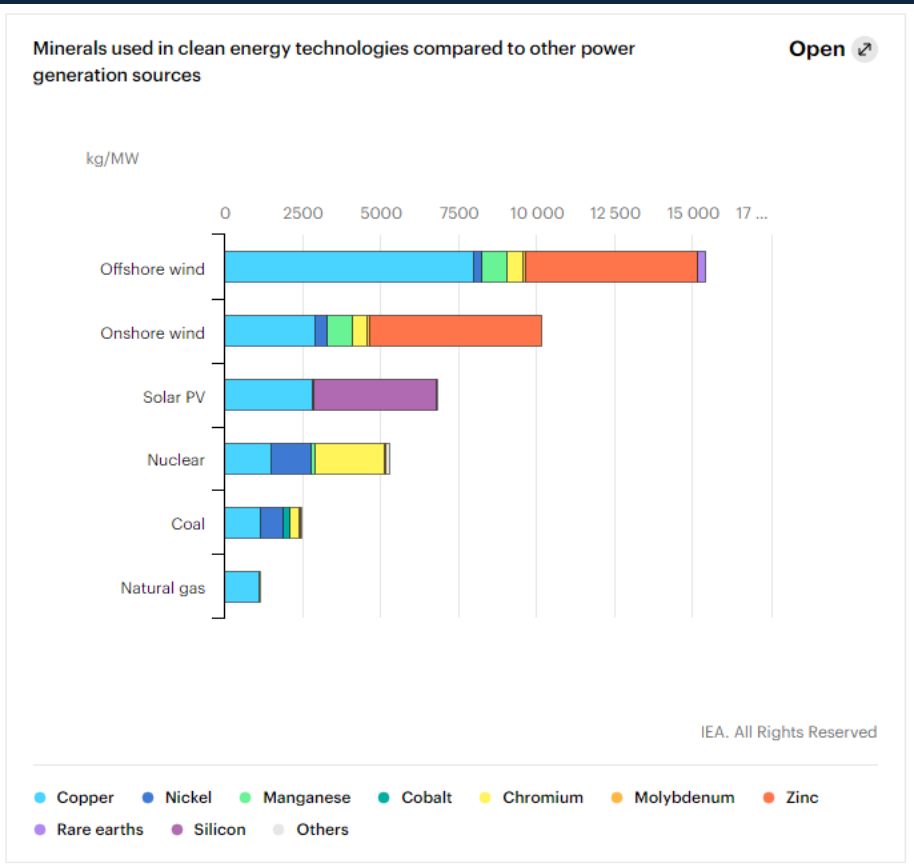
Supply Chain

Supply Chain Transparency Initiative

1. Material Foundations
2. Emissions & ESG
3. Illicit Supply Chain and ASM

Material Foundations





Supply Chain Emissions

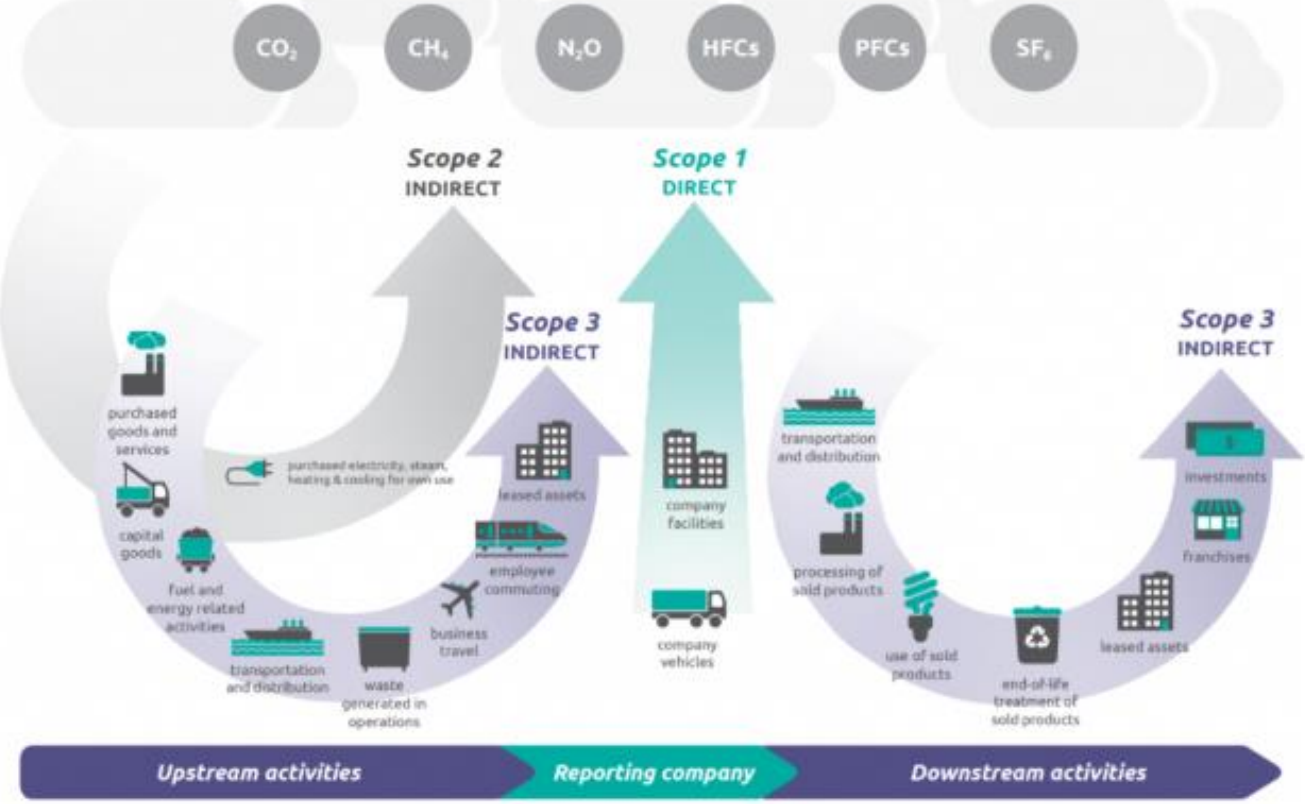
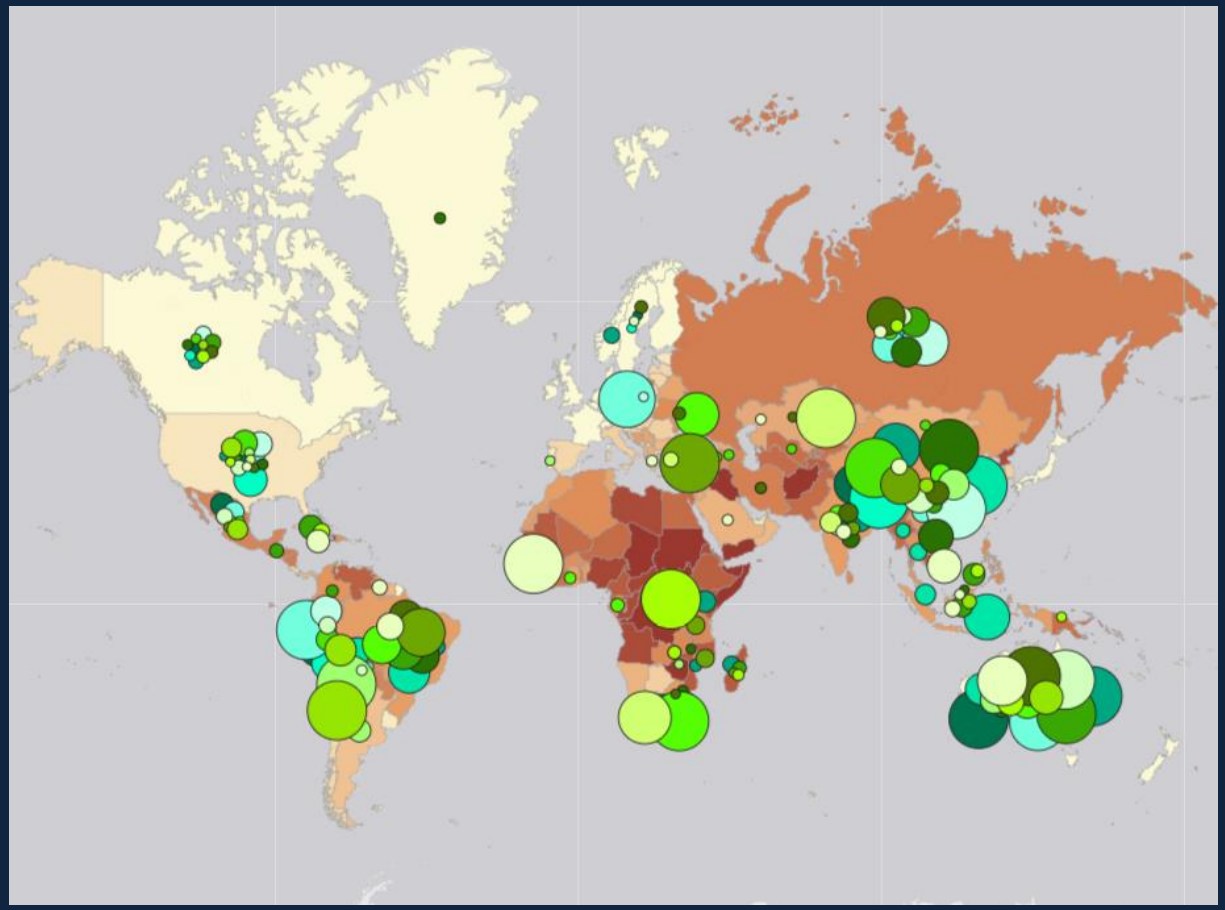


Figure 1: Scope 3 emissions as defined by the Greenhouse Gas Protocol

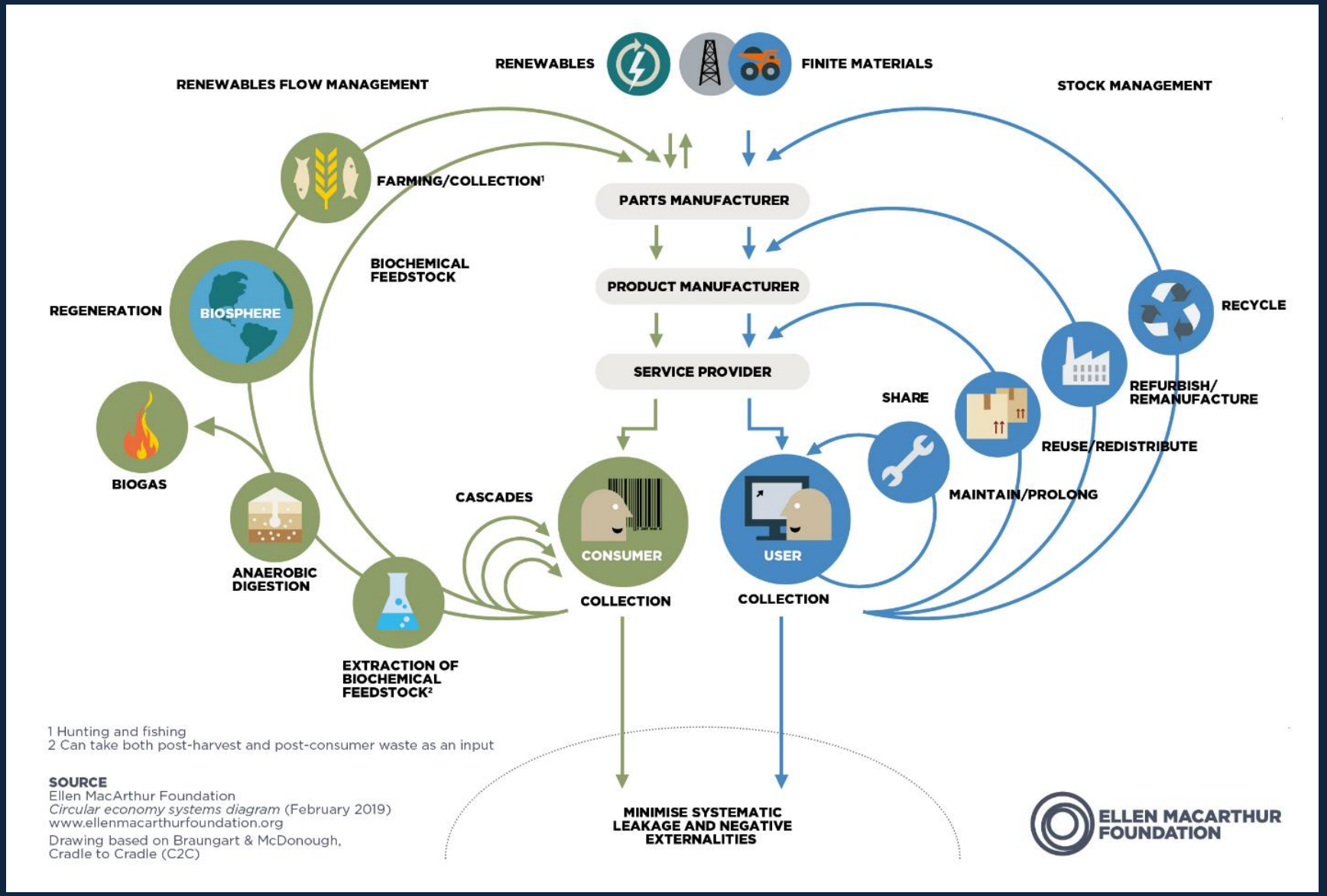
Illicit Supply Chain and ASM

Global reserves of minerals required for green energy technologies overlaid with fragility and corruption measures. Source: Fund for Peace, 2018; Transparency International, 2017; U.S. Geological Survey, 2018.



International Institute for Sustainable Development

Circular Economy



Thank You!

Gregory Clough
Deputy Director, Payne Institute
Email: gclough@mines.edu