Written Testimony of Michelle Michot Foss, Ph.D.
Fellow – Energy, Minerals & Materials
Rice University's Baker Institute for Public Policy, Center for Energy Studies

Before the
Committee on Energy and Natural Resources
United States Senate
Hearing to Examine the Use of Energy as a Tool and a Weapon
March 10, 2022 at 10:00 am
366 Dirksen Senate Office Building

Chairman Manchin, Ranking Member Barrasso, and Members of the Committee, thank you for inviting me to participate on this panel.

The rush is on to promote "energy transition strategies" and green deals as panaceas for geopolitical tensions. Backers hope to ride herd on optimism that governments would aggressively embrace these concepts in pandemic recovery stimulus plans. So far, all that has happened is a reality check for investors as over-promising and under-delivery has eroded the pandemic run-up in "clean tech" valuations (Figure 1).

The underlying truths are much more complex. The notion of "ensuring energy security" here and abroad exists within a context of sometimes-harsh realities. Ignoring, avoiding or discounting these realities raises the specter of failures in strategies and tactics. A distinct threat in pushing on energy transition "strings" is that we simply transfer geopolitical risk and uncertainty from the devils we know to those we don't.

- Energy density matters (Figure 2). The trade-offs between legacy fuels and systems and alternative energy technologies (wind, solar, electric vehicles, chemical battery energy storage in general) are harsh.

- Lower energy density implies greater materials intensity.
    - Energy density shortcomings show up most strongly in transport – only larger, heavier EV batteries can approach the performance of gasoline for range and towing, testing vehicle weight and adding to materials intensity.
    - In electric power, it simply takes more equipment, more infrastructure, more components to replace the intrinsic concentration of stored energy in fossil fuels and uranium (Figure 3). Roughly 78,000 wind turbines at more than 1,400 sites contribute about 8% of U.S. net generation while the more than 6,000 natural gas units at about 1,800 locations contribute almost 40%. The existing gas fleet could deliver more if operated at closer to base load. Meanwhile, it would take nearly 460,000 wind turbines to achieve 50% of current net generation.
    - Sophisticated grids and controls are needed to fully accommodate intermittent, diverse energy sources and device-grid interactions. Unless or until "V2X" (vehicles to anything) can be mastered, EVs represent a large new source of power consumption.
    - Nor does use of alternative energy eliminate the need for traditional resources. *Beyond the important functions of back up and balancing for reliability hydrocarbons, in particular, are*

essential feedstocks for materials that make "alt energy" technologies functional in the first place.[i]

- Greater materials intensity means a potentially large "call" on raw materials that, in accelerated scenarios, will stress supply chains, put pressure on prices and increase geopolitical tensions. I was a peer reviewer for the International Energy Agency's report, *Mineral Requirements for Clean Energy Transitions*. If anything, their estimates of *quadrupling* demand for minerals in the strongest scenarios *understate* the impact of an energy transition push. This is because non-energy consumption of minerals and materials also is growing rapidly. Worldwide, total non-fuel minerals tonnage has grown nearly as fast as electric power supply and faster than petroleum and natural gas (Figure 4). Plastics and resins are the fastest growing major commodity group (Figure 5). From thermoset plastics for wind turbine blades, to Plexiglas for solar panels, to most of the content in EVs – hydrocarbon-based materials constitute essential ingredients in the energy transition landscape. This heightens the importance of understanding global oil and gas supply chain dynamics and economics, and preserving the integrity of this vital industry and its service providers.
    - Activism against mining, minerals processing and related businesses is strong. The roughly 2.5 billion tonnes of usable non-fuel minerals requires extraction of about 20 times more rock, on average. For some key minerals, waste volumes are upwards of 1,000-1,500 tonnes per tonne of recovered metal. The distribution of minerals throughout Earth's crust is uneven. Ore grades for many key minerals already are low (Figure 6); low ore grades mean more waste, more energy for extraction and processing and more emissions. Going forward, the industry faces challenges in sustaining existing operations as properties mature and greater costs and uncertainties in pursuing new deposits of equivalent grades. Difficulties in gaining access and achieving new projects along with political risk and uncertainty in myriad countries (including the U.S.) is translating into longer cycle times for new critical minerals supplies and impacting corporate and sovereign credit ratings.
    - Quality of metals and materials is a vital concern for many industries, like batteries and semiconductors. Achieving levels of purity required for many applications is pushing the industry toward more expensive, energy intensive processing as operators compete to sell to these premium markets.
    - Diverse groups are directing more attention toward the large footprints of alt energy facilities, the impact of these facilities on everything from view sheds to ecosystems, their attributed emissions burdens and their life cycle waste streams. Overall, "sustainability" of the gamut of alt energy technologies and their supply chains, including decommissioning and capacity for recycling, reuse or ultimate disposal lags far behind promotion of these technologies. We line out these disparities in a new report.[ii]

- China's dominance, influence over and outright control of sensitive materials and technologies and the alt energy landscape, in general, raise particularly acute tests for trade, defense and diplomacy.[iii] Chinese interests control the bulk of existing, new and planned battery manufacturing, upwards of 80-90% in total. We are monitoring Chinese strategies over key minerals and will soon issue a detailed report on nickel.
    - China now has a monolithic state-owned entity (SOE) for rare earth elements (lanthanoids), the China Rare Earth Group Co. Ltd., established December 23, 2021. The conglomerate was created by combining three out of the "Big 6" REE producers (Minmetals, CHALCO, Ganzhou Rare Earths). The SOE will account for approx. 62% of China's national medium/heavy rare earths supplies (enhanced pricing over dysprosium and terbium); approximately 40% of all Chinese REE (light, medium, and heavy); and will also hold 31% of

China's mining quota, and 29% of China's smelting quota. The State-owned Assets Supervision and Administration Commission (SASAC) holds largest stake at 31.21%.
    - China controls two-thirds of global REE production. China likely is not afraid to use REE as leverage; in 2010, China [protested Japans nationalization of the Senkaku Islands] by stalling REE exports from their stockpiles.

- When it comes to oil and gas, the "net zero" math is especially fraught (Figure 7). For all of its ups and downs, global oil and gas industry upstream capital spending to discover and prove up new resources averaged well over $600 billion per year 2010-2021. That spending enabled current production of more than 100 million barrels per day of oil equivalent. Producers must monetize all molecules in order to generate sufficient revenue to cover costs and return a profit. Sales of energy (petroleum fuels and natural gas) provide the bulk of monetization. The assumption in extreme scenarios is that the industry can reduce oil supply to about *one-third of current output* while *eliminating* fuels sales from its revenue streams and *doubling* non-fuel (chemicals for vital materials) production. Implicit in these assumptions are that nearly every well drilled is successful and that resulting production slates are fully predictable (for those who prefer that the industry only produce natural gas and natural gas liquids for petrochemicals). I maintain that these assumptions are untenable.

- In all of this, we are leaning the hard way that citizens and voters have quite diverse views, opinions and preferences. Beyond the narrow focus on emissions and climate people care about many things and public reactions are unpredictable. Energy use is growing in ways that are not fully reflected in outlooks and scenarios. From video streaming and smartphones to cryptocurrency mining, new energy demands also represents new consumption of materials. Alt energy technology is presented as "cheap" when that is far from the truth – the full cost of utilizing intermittent and materials intense sources is hidden in rate making and subsidies.[iv] Carbon pricing and taxing transfer to the cost of energy and goods for customers and consumers exacerbating dissatisfaction and inflation stress. The promise of green jobs in the future does not compensate for high paying jobs lost today, affecting many communities.

- With these and many other harsh realities in mind, we have defined the potential for an "energy transition valley of death" (Figure 8)[v] as societies and their governments stumble to push alt energy technologies deeper into the global mix. In many respects, the easy, low hanging fruit has been captured. Since the 1880s, inventions and commercialization of internal combustion engine vehicles and central generation of electric power mainly using coal and water (hydro) dominated the energy landscape. Only in recent years have incursions been made. While sales of EVs of various types have captured imaginations, EVs now comprise about 1% of the global light duty passenger fleet of around 1.4 billion. Utility scale wind and solar are estimated to comprise about 9% of global electric power generation. Lofty goals are to move these market shares to much more aggressive levels, even to 100% in some instances, at least for developed countries.

- The tenuous nature of energy transition viewpoints creates a bottom line – we force fossil fuels out of the energy mix at our peril.[vi] This means several things from a policy/regulatory standpoint.
    - Attention to the integrity of industry investment – especially for oil and gas, operators from the largest to smallest need to continue to invest, frameworks that facilitate risk taking and reward, access to potential locations for production replenishment. Better understanding of the full oil and gas value chain is essential.

- In the U.S. and beyond, oil and gas producers need access to diverse markets and customers need access to affordable, competitive supplies, meaning the ability to locate and build new pipelines, expand existing conduits and improve shipping lanes and capacity.[vii]
- The good ideas and actions over the years for improving and maintaining transparency around oil and gas operations and operators and use of these important resources need to be encouraged and continued – including the phase out of subsidies that provide politically expedient support for demand but that also serve to discourage much needed investment downstream.
- Creative thinking for cost effective emissions reductions with logical deployment of recovered materials needs to continue. We have our own ideas to offer in the form of carbon capture and redeployment as black carbon, BCarbon soil amendments including how we can couple BCarbon with hydrogen.[viii]
- Finally, key to the future is for decision makers to pursue a “materials first” approach to policy and strategy for energy and other dynamic industries like semiconductors and electronics.[ix] Unless high integrity materials supply chains can be built, enlarged, sustained, maintained all bets are off.

Figure 1

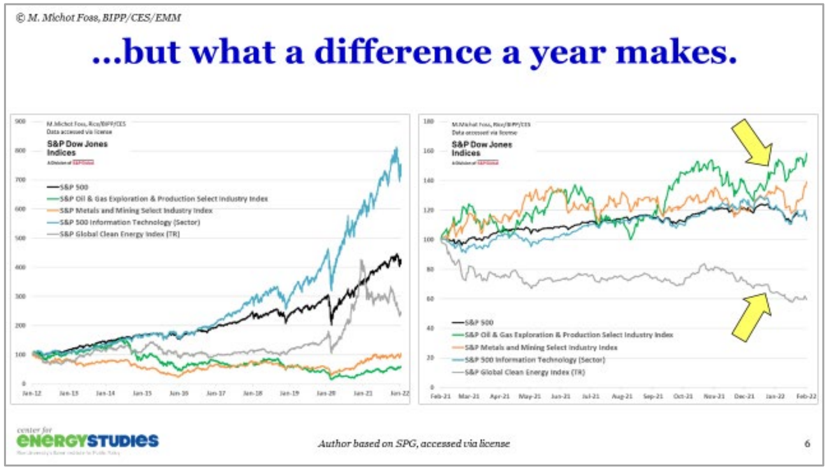


Figure 2

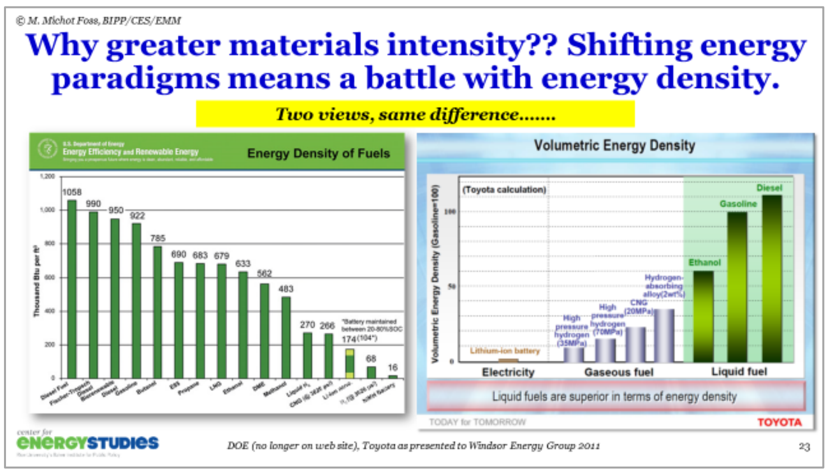
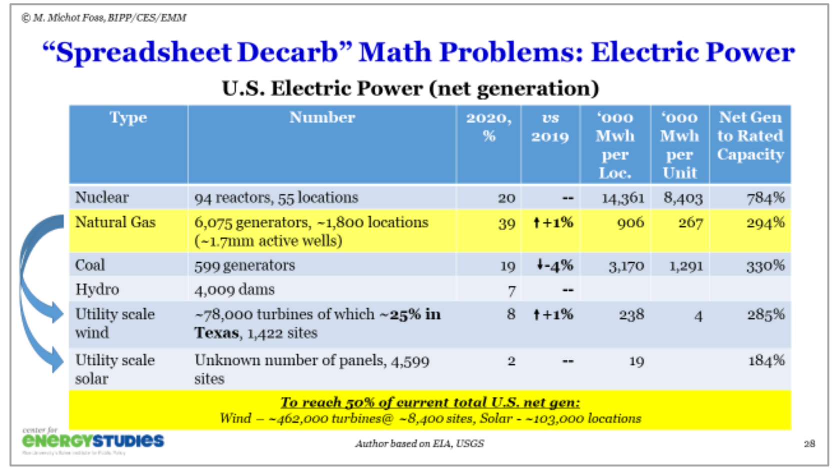


Figure 3


© M. Michot Foss, BIPP/CES/EMM

“Spreadsheet Decarb” Math Problems: Electric Power

U.S. Electric Power (net generation)

Type	Number	2020, %	vs 2019	‘000 Mwh per Loc.	‘000 Mwh per Unit	Net Gen to Rated Capacity
Nuclear	94 reactors, 55 locations	20	--	14,361	8,403	784%
Natural Gas	6,075 generators, ~1,800 locations (~1.7mm active wells)	39	↑+1%	906	267	294%
Coal	599 generators	19	↓-4%	3,170	1,291	330%
Hydro	4,009 dams	7	--			
Utility scale wind	~78,000 turbines of which ~**25% in Texas**, 1,422 sites	8	↑+1%	238	4	285%
Utility scale solar	Unknown number of panels, 4,599 sites	2	--	19		184%

To reach 50% of current total U.S. net gen:
Wind – ~462,000 turbines@ ~8,400 sites, Solar - ~103,000 locations

center for ENERGY STUDIES — *Author based on EIA, USGS* — 28

Figure 4

Figure 5

Figure 6

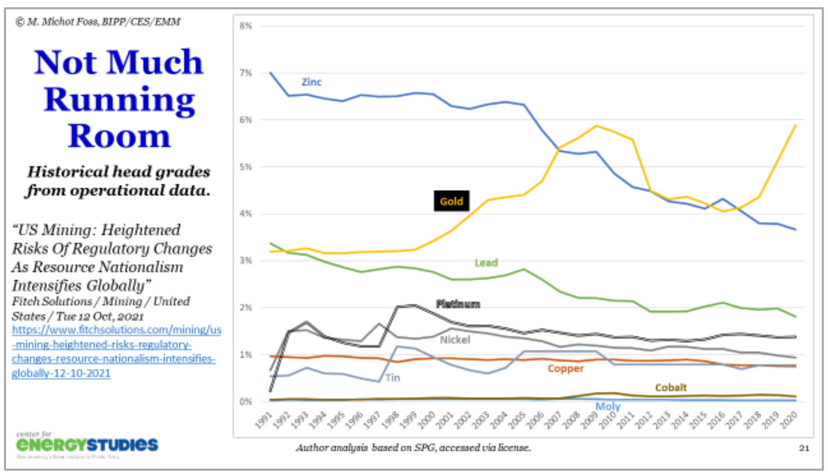


Figure 7

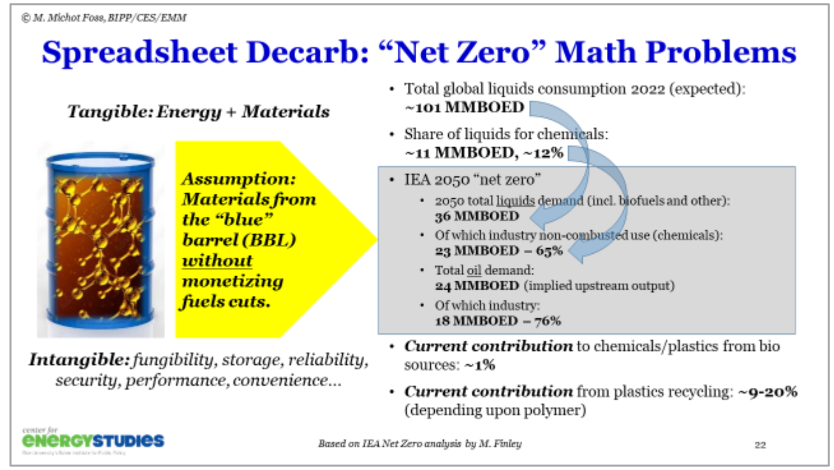


Figure 8

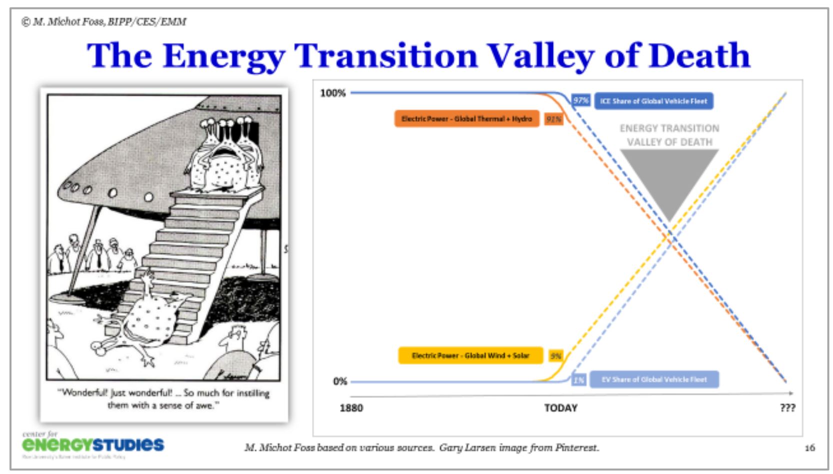
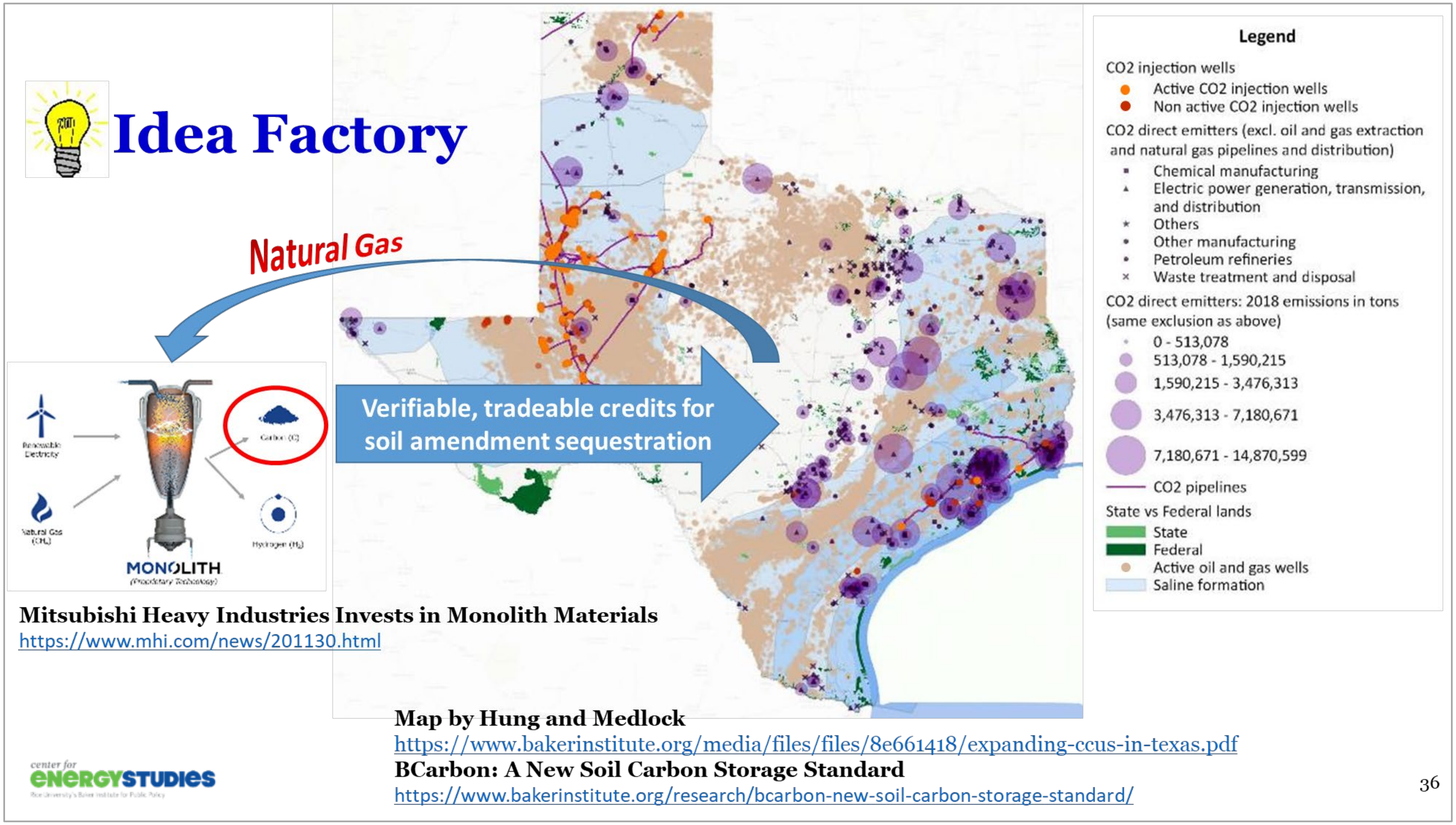


Figure 9


Idea Factory
Natural Gas
Renewable Electricity
Natural Gas (CH4)
Carbon (C)
Hydrogen (H2)
MONOLITH
Verifiable, tradeable credits for soil amendment sequestration
Legend
CO2 injection wells
Active CO2 injection wells
Non active CO2 injection wells
CO2 direct emitters (excl. oil and gas extraction and natural gas pipelines and distribution)
Chemical manufacturing
Electric power generation, transmission, and distribution
Others
Other manufacturing
Petroleum refineries
Waste treatment and disposal
CO2 direct emitters: 2018 emissions in tons (same exclusion as above)
0 - 513,078
513,078 - 1,590,215
1,590,215 - 3,476,313
3,476,313 - 7,180,671
7,180,671 - 14,870,599
CO2 pipelines
State vs Federal lands
State
Federal
Active oil and gas wells
Saline formation
Mitsubishi Heavy Industries Invests in Monolith Materials
https://www.mhi.com/news/201130.html
Map by Hung and Medlock
https://www.bakerinstitute.org/media/files/files/8e661418/expanding-ccus-in-texas.pdf
BCarbon: A New Soil Carbon Storage Standard
https://www.bakerinstitute.org/research/bcarbon-new-soil-carbon-storage-standard/
center for ENERGY STUDIES
36

[i] Michelle Michot Foss, 2021, "The "criticality" of minerals for energy transitions. Hydrocarbons? Yes, hydrocarbons", *Forbes*/Baker Institute for Public Policy blog, February 8, https://www.bakerinstitute.org/research/the-criticality-of-minerals-for-energy-transitions-hydrocarbons-yes-hydrocarbons/.

[ii] Rachel A. Meidl, Michelle Michot Foss and Ju Li, 2022, *A Call to Action for Recycling and Waste Management Across the Alternative Energy Supply Chain*, Baker Institute for Public Policy Report 03.03.22, https://www.bakerinstitute.org/media/files/files/7e2cf654/bi-report-030222-ces-recycling-wm.pdf.

[iii] Michelle Michot Foss, 2021, *Minerals & Materials Supply Chains – Considerations for Decarbonizing Transportation*, before the U.S. House Subcommittee on Energy, Hearing on "The CLEAN Future Act: Driving Decarbonization of the Transportation Sector", May 5, https://www.bakerinstitute.org/research/minerals-materials-supply-chains-considerations-for-decarbonizing-transportation/. Sam Geall, Rebecca Peters, and Byford Tsang; Andrew Erickson and Gabriel Collins, 2021, Can America Trust China to Fight Climate Change?, *Foreign Affairs*, July 23, https://www.bakerinstitute.org/research/can-america-trust-china-fight-climate-change/. Gabriel Collins and Andrew S. Erikson, 2021, *China's Climate Cooperation Smokescreen*, August 31, Baker Institute for Public Policy report, https://www.bakerinstitute.org/research/chinas-climate-cooperation-smokescreen/. Andrew S. Erikson and Gabriel Collins, 2021, A Dangerous Decade of Chinese Power Is Here, *FP*, October 19, https://www.bakerinstitute.org/research/dangerous-decade-chinese-power-here/. Gabriel Colllins and Andrew S. Erikson, 2021, *U.S.-China Competition Enters the Decade of Maximum Danger*, Baker Institute for Public Policy report, December 20, https://www.bakerinstitute.org/research/us-china-competition-enters-decade-maximum-danger/.

[iv] Competitiveness of Renewable-Generation Sources, 2018, Bureau of Economic Geology – The University of Texas at Austin (research led by Michelle Michot Foss), https://www.beg.utexas.edu/files/energyecon/CEE_Research_Note_Competitiveness_Generation_Apr18.pdf. Gürcan Gülen, 2019, Net Social Cost of Electricity: Policy Smog and Waning Competitive Markets, Lack of Consumer Participation, Importance of the Grid, and Scalability Challenge, BEG Udden Series, https://store.beg.utexas.edu/special-books/3777-us0007-net-social-cost-of-electricity.html.

[v] Gabriel Collins and Michelle Michot Foss, 2022, The Global Energy Transition's Looming Valley of Death, Baker Institute for Public Policy Report 01.27.22, https://www.bakerinstitute.org/media/files/files/51d51fff/bi-report-012722-ces-global-energy.pdf.

[vi] Gabriel Collins and Michelle Michot Foss, 2022, Want to Derail the Energy Transition? Take Fossil Fuels Out of the Mix, FP/Argument, January 14, https://www.bakerinstitute.org/research/want-derail-energy-transition-take-fossil-fuels-out-mix/.

[vii] *Monetizing Natural Gas in the New "New Deal" Economy*, 2021, eds. Michelle Michot Foss, Anna Mikulska, Gürcan Gülen, Palgrave Macmillan, https://link.springer.com/book/10.1007/978-3-030-59983-6.

[viii] Kenneth B. Medlock III and Keily Miller, 2021, Carbon Capture in Texas, Baker Institute for Public Policy reports and materials, January 27, https://www.bakerinstitute.org/research/carbon-capture-texas/. Jim Blackburn and Kenneth B. Medlock III, 2020, BCarbon: A New Soil Carbon Storage Standard, Baker Institute for Public Policy Working Paper, October, https://www.bakerinstitute.org/media/files/files/3fa11a03/bcarbon-a-new-soil-carbon-storage-standard-1.pdf,

[ix] Michelle Michot Foss, 2021, Minerals and Materials for Energy: We Need to Change Thinking, Baker Institute for Public Policy, Recommendations for the Biden Administration, January 22, https://www.bakerinstitute.org/research/minerals-and-materials-energy-we-need-change-thinking/.