Additional ITIAC Draft Recommendations for Final Report

Specific Industries

Aluminum

- **Recommendation:** DOE should continue and expand its support for key emissions-reducing technologies in the aluminum industry, including inert anodes that do not break down during the smelting process, mechanical vapor recompression (MVR) to produce steam for use in alumina refining, electric alumina calcination, and furnaces that use electricity, hydrogen, or other non-emitting fuels. To overcome cost barriers, DOE should support projects that aim to drive down the costs of all these types of equipment, as well as hydrogen electrolyzers.
- **Recommendation:** DOE should help ensure the domestic supply of aluminum by funding technologies or programs to improve aluminum recycling rates, address impurities and improve recycled aluminum quality, and enable landfill mining (extracting aluminum from landfills).
    - **Rationale:** Secondary aluminum production involves only around 5% of the energy use and emissions as primary aluminum production. The U.S. is projected to generate sufficient scrap aluminum to meet its aluminum needs if issues of contamination and the mixing of different alloy grades can be addressed. U.S. landfills are estimated to contain around 90 million tons of aluminum (with a further 2.5 million tons added each year). By way of comparison, the U.S.'s annual production was under 1 million tons of primary aluminum and 3 million tons of secondary aluminum in 2021.

Pulp and Paper

- **Recommendation:** DOE should invest in development and deployment of Mechanical Vapor Recompression (MVR) heat recovery technology for paper drying and Yankee hoods.
    - **Rationale:** MVR uses electrically driven compressors and a working fluid to capture low-quality heat and turn it into higher quality steam suitable for pulp and paper processes. This process is efficient and does not emit air pollution. As an additional benefit, at times of peak electricity demand, a pulp and paper facility could switch to their gas-fired steam system and turn

off the compressor, reducing peak load on the grid. Similar heat stacking principles could combine heat pump technologies and MVR to convert high-humidity, high-temperature vacuum exhaust into electricity.

Data Centers

- **Recommendation:** DOE should support work to fill knowledge gaps in data center design and operation, particularly as it relates to data centers' energy efficiency and integration with communities and the electric grid. DOE should assist grid operators and regulators in developing policies and rate plans that reward data centers for operating as flexible loads that help balance the grid, avoid contributing to net peak demand, and address electricity supply adequacy by making better use of existing generation and transmission resources at off-peak times. There are a variety of spatial and temporal load shifting mechanisms that data centers can use to increase their electricity demand flexibility, especially when focusing on tasks such as AI model training or cryptocurrency mining, where no human user is waiting on an immediate response.[1]

Controlled Environment Agriculture

- **Recommendation:** DOE should continue its exploration of the market and technical challenges facing the controlled environment agriculture (CEA) industry, reflecting findings of the U.S. CEA Market Accelerator (an initiative run jointly by Resource Innovation Institute, Lawrence Berkeley National Lab, FarmTech Society, and 1% for the Planet). DOE's work should explore differences between rural and urban CEA, including both conventional greenhouses and vertical agriculture, and identify the optimal sizes of facilities in each of those modalities. DOE should also consider options for CEA space heating using alternatives to propane including hydronic heating using high-efficiency boilers and/or heat pumps and systems that recover waste heat from co-located industrial facilities or data centers. Additionally, DOE should support automation and robotics as a means of addressing workforce constraints in CEA operations.

Coal and Coke Use for Steel Production

- **Recommendation:** Owing to the smaller sizes of blast furnaces in the United States, there is the potential to use coal blends. A suggestion is to apply artificial intelligence

[1] Tyler Noris, Tim Profeta, Dalia Patino-Echeverri, and Adam Cowie-Haskell. 2025. Rethinking Load Growth: Assessing the Potential for Integration of Large Flexible Loads in US Power Systems. Nicholas Institute for Energy, Environment & Sustainability, Duke University.
https://nicholasinstitute.duke.edu/publications/rethinking-load-growth

(AI)/machine learning (ML) to develop synthetic coals and even bio-coke blends for use as coke. Industry has plenty of data but not enough analysis tools to design new blends.

- **Recommendation:** Consideration should be given to supplying coal in composition (enriched carbon content) and physical properties (large sizes and in densified state) consistent for use as charge material with scrap to supplement the use of injection carbon in electric arc furnaces to control scrap melting and foaming.
- **Recommendation:** Consideration should be given for supplying coal or coal blends for PCI (pulverized coal injection) for use in raceway in blast furnaces.
- **Recommendation:** Specialized training courses/modules through e.g., the Association for Iron & Steel Technology (AIST) for cokemaking and with insight into process automation and repair.
- **Recommendation:** Regional/local U.S. standards are extremely stringent. Can openly available standards be used to compare with other countries to show that U.S. products are cleaner and thus more competitive (referring not only to coal but also the end product steel).

Cross-Cutting Technologies

Carbon Capture and Use or Storage (CCUS)

- **Recommendation:** In collaboration with academia, industry, and its national labs, DOE should continue and expand its support for technologies to achieve the following goals associated with carbon capture and storage (CCS) deployment: (a) reducing the costs of retrofitting carbon capture technology in existing industrial facilities; (b) facilitating access to CO_2 transportation to geological storage in different regions, accounting for where industrial facilities are located or clustered; (c) developing innovative solutions required for certain subindustries (such as cement-making and primary steel-making) to efficiently capture CO_2 emissions from their waste gas streams; and (d) mitigating risks of CO_2 transport and storage, such as preventing leakage.
    - **Rationale:** Carbon capture and storage (CCS) has been demonstrated at commercial scale and can provide a low-cost option for mitigating emissions

from otherwise difficult-to-decarbonize industrial sectors and processes.[2,3,4] It represents an added cost, but it can sometimes provide the lowest levelized cost of CO_2 abatement, particularly for industrial processes that produce high-purity byproduct CO_2 streams (such as the synthesis of ethanol, ammonia, and ethylene oxide) and for large-scale, capital-intensive subindustries that require high stream factors (i.e., 24/7 operation) to remain economically competitive.[5]

- **Recommendation:** DOE should develop and release a toolkit to enable structured evaluation of carbon capture technology versus other emissions-reducing technology options for different subindustries at the project level, to help industrial firms understand when carbon capture technology is the best fit for a specific project. The toolkit should also help firms estimate the impacts of proposed CCS projects on communities with regard to employment opportunities and environmental outcomes (such as changes in non-CO_2 pollutant emissions).
- **Recommendation:** To facilitate carbon capture and use (CCU), DOE should continue and expand its support for improving efficiency and yields for CO_2 conversion to products using thermo-, electro-, photo-, and plasma-based chemical pathways. DOE should encourage co-location of CO_2-using industries with carbon capture projects to make optimal use of infrastructure for CO_2 capture and transport.
    - **Rationale:** CO_2 capture and utilization (CCU) can be advantageous where access to geologic storage is not feasible or where products are made that incorporate oxygen as well as carbon (such as organic and mineral carbonates, carboxylic acids, and polyols). It can also be useful in the

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[2] U.S. Department of Energy. 2025. Transformative Pathways for U.S. Industry: Unlocking American Innovation. https://www.energy.gov/eere/iedo/articles/transformative-pathways-us-industry-unlocking-american-innovation
[3] U.S. Department of Energy. 2023. Pathways to Commercial Liftoff: Industrial Decarbonization. https://liftoff.energy.gov/wp-content/uploads/2024/02/LIFTOFF_DOE_Industrial-Decarbonization_REV022724.pdf
[4] M. Pisciotta, S. Swett, H. Pilorgé, S. Patel, J. Wilcox, U.S. CCS Ladder for Industrial Decarbonization, October 25, 2024 https://kleinmanenergy.upenn.edu/commentary/blog/u-s-ccs-ladder-for-industrial-decarbonization/
[5] Friedl, G., Reichelstein, S., Bach, A. et al. Applications of the levelized cost concept. J Bus Econ 93, 1125–1148 (2023). https://doi.org/10.1007/s11573-023-01171-7

manufacture of synthetic fuels for energy services that cannot readily be decarbonized via electrification or hydrogen.[6,7]

Critical Materials Supply and Demand

- **Recommendation:** DOE should publish a comprehensive study covering the following materials-related topics. First, DOE should identify the materials critical to U.S. industry and which subindustries rely on those materials. Second, DOE should coordinate with the Department of Defense to identify materials critical to national security and the military. Third, DOE should identify materials important for the other technologies recommended in this Industrial Technology Innovation Advisory Committee report, such as materials required for grid infrastructure, thermal batteries, etc. For each of the materials so identified, the study should consider if material availability and price will be important constraints on large-scale deployment of the relevant technologies or equipment, what alternative material options exist, and ways that DOE can support technologies that alleviate any bottlenecks or address areas of concern. The Advanced Materials and Manufacturing Technologies Office (AMMTO) and the Critical Materials Innovation Hub (CMI) should lead or participate in these analyses as appropriate.
- **Recommendation:** DOE should continue and expand its support for technologies that increase the supply of critical materials. This includes technologies that make the recycling of critical materials easier and more cost-effective (such as by improved separation of impurities), technologies that locate critical mineral deposits, and technologies that enable critical minerals to be extracted cost-effectively and in a way that doesn't harm the environment or nearby communities. In cases where material refining or manufacturing capacity is an important constraint (as in certain high-grade electrical steels), DOE should support technologies to improve U.S. material refining and manufacturing capacity. DOE should also continue and expand its support for technologies that allow equipment to use less of the most expensive and hardest-to-source materials, such as by substituting more accessible materials or via material efficiency (product designs that use less material without sacrificing product quality or performance). DOE should provide support through the Advanced Materials and Manufacturing

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[6] National Academies of Sciences, Engineering, and Medicine. 2023. Carbon Dioxide Utilization Markets and Infrastructure: Status and Opportunities: A First Report. Washington, DC: The National Academies Press. https://doi.org/10.17226/26703

[7] National Academies of Sciences, Engineering, and Medicine. 2024. Carbon Utilization Infrastructure, Markets, and Research and Development: A Final Report. Washington, DC: The National Academies Press. https://doi.org/10.17226/27732

Technologies Office (AMMTO), the Critical Materials Innovation Hub (CMI), the Office of Clean Energy Demonstrations (OCED), the Loan Program Office, and other offices as appropriate.

Liquified Natural Gas

- **Recommendation:** DOE should continue and expand its support for technologies to achieve the following goals associated with liquified natural gas (LNG): (a) improving the energy efficiency of the compression and refrigeration processes at LNG liquefaction facilities; (b) reducing methane leakage at liquefaction and export facilities; and (c) separating noble and commercially valuable gases from natural gas during the liquefaction process. Additionally, DOE should assess the economic and environmental benefits of liquefaction and export facilities relying on grid electricity rather than consuming a portion of the natural gas for their energy needs.
    - **Rationale:** Most U.S. LNG facilities are powered by electricity generated onsite from natural gas, with typical consumption rates ranging from 7% to 15% of the natural gas delivered to the facility.[8] Most of this electricity is used for cooling and compression. Several liquefaction process configurations are in use that trade off energy use and capital cost, and with additional research, further improvements are possible. A few operating facilities use grid-supplied electricity, reducing combustion by-products and improving air quality near the facilities. Methane leakage from LNG facilities can be significant (though smaller than leakage from natural gas production), so technologies to reduce leakage could recover sellable product while reducing methane emissions. Also of note, the potential exists to collect noble and rare gases that are mixed with raw natural gas and can be separated during liquefaction, potentially providing a source of gases that are important in a range of industrial applications, such as semiconductor manufacturing.[9]
- **Recommendation:** DOE's Office of Fossil Energy and Carbon Management (FECM) should consider the potential for LNG exports to increase natural gas prices for domestic industries and harm U.S. manufacturers' competitiveness when making public interest determinations on applications to export LNG.

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[8] U.S. Energy Information Administration. Updated June 2024. Natural Gas Explained: Liquefied Natural Gas. https://www.eia.gov/energyexplained/natural-gas/liquefied-natural-gas.php

[9] ExxonMobil. 2022. Labarge: Helium Explained. https://corporate.exxonmobil.com/what-we-do/materials-for-modern-living/labarge-helium-extraction-energy-production-wyoming

- **Rationale:** DOE is legally required to determine whether applications to export LNG to a country with which the U.S. does not have a free trade agreement are in the public interest.[10] LNG exports tend to increase domestic natural gas prices by linking U.S. gas prices to international market prices, which are significantly higher. This can have negative competitiveness impacts on U.S. firms that consume natural gas. This includes most U.S. manufacturing facilities, but impacts would be greatest on major natural gas consumers with small profit margins, like U.S. chemical companies and fertilizer manufacturers.

Nuclear Energy and Heat for Industry

- **Recommendation:** DOE should directly support implementation and demonstration of advanced nuclear technology in the U.S. for gigawatt-scale industrial petrochemical and refining, clean hydrogen production, and other large industrial heat/steam users. DOE should also consider nuclear energy for data centers and for other industries with expected future growth and whose energy needs are a good match for nuclear. Where possible, DOE should explore projects that integrate new nuclear technology with other technologies (e.g., thermal energy storage) and that co-locate nuclear with industrial facilities that can take advantage of nuclear's heat and electricity output in an optimized energy system.
  - **Rationale:** First-of-a-kind costs, public acceptance, and permitting delays make industry hesitant to invest in nuclear technology, despite having the highest steam factor for 24/7 energy, which is needed for capital-intensive industry. Land use for nuclear power is minimal, making it an attractive choice for industrial complexes serving major metropolitan areas, especially those experiencing growth in power demand for AI and electrified transportation. Current deployment of new nuclear technology is primarily occurring in China; advancing domestic capability is of strategic value to the U.S.

- **Recommendation:** DOE should support best practices and innovative models (such as those identified by DOE's Advanced Nuclear Pathways to Commercial Liftoff report and the Nuclear Energy Advisory Committee's January 2025 letter to the Secretary) to ensure DOE-funded nuclear projects for industry are delivered on-time and on-budget. Recommendations include: better sharing and allocation of costs and risks across multiple roles involved in project development, utilizing consortium approaches, using an integrated project delivery model, and

[10] DOE Office of Fossil Energy and Carbon Management. Liquefied Natural Gas (LNG). https://www.energy.gov/fecm/liquefied-natural-gas-lng

standardization of reactor designs and equipment. DOE should also support ongoing efforts by the Nuclear Regulatory Commission to modernize and optimize licensing reviews of advanced reactors to follow a technology-inclusive, performance-based, and risk-informed framework that could be standardized, simplified, and digitized in the future.

Additional Documents for Recommended Documents Section

LNG

- U.S. Department of Energy. 2024. Energy, Economic, and Environmental Assessment of U.S. LNG Exports. https://www.energy.gov/sites/default/files/2024-12/LNGUpdate_SummaryReport_Dec2024_230pm.pdf

CCUS

- National Academies of Sciences, Engineering, and Medicine. 2023. Carbon Dioxide Utilization Markets and Infrastructure: Status and Opportunities: A First Report. Washington, DC: The National Academies Press. https://doi.org/10.17226/26703
- National Academies of Sciences, Engineering, and Medicine. 2024. Carbon Utilization Infrastructure, Markets, and Research and Development: A Final Report. Washington, DC: The National Academies Press. https://doi.org/10.17226/27732