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Accelerating Investment and Trade: Opportunities for U.S. Industry in the Advanced Energy Transition

For the Climate Leadership Council

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1 Background and Research Context

Countries around the world are investing in a broad array of advanced energy technologies, including advanced electric power generation, energy storage, electric vehicles, industrial efficiency, and carbon capture and sequestration technologies. This transition is driven by multiple factors (which vary by country) such as the increasingly urgent need to contain energy costs, ensure reliable, affordable energy access, and satisfy emissions reduction targets.

There is a substantial market opportunity for the producers of advanced energy technologies and their material suppliers – an opportunity expected to grow significantly in the coming years.

Recent analysis demonstrates that while the U.S. is a major supplier of fossil fuels, it is a relatively small player in exports of advanced energy technologies.¹ While some countries have implemented more ambitious industrial strategies to develop advanced energy manufacturing and supply chain sectors, the U.S. market has been stymied by headwinds from non-market economies and an inconstant domestic policy environment. For example, China is rapidly expanding its manufacturing capacity and has positioned itself as a major supplier in the advanced energy supply chain. Market economies with durable policies supporting advanced energy technology, such as Germany and Japan, have also outpaced the U.S. in advanced energy exports despite being smaller economies overall.

This analysis, commissioned by the Climate Leadership Council, examines how **supportive domestic and trade policies to advance U.S. industry competitiveness** can provide economic opportunities for U.S. industry in a decarbonizing global economy. By accelerating investment in and improving the competitiveness of key industry sectors, the U.S. can potentially capture more of the market for basic commodity manufacturing, advanced energy technologies, and decarbonization equipment, both domestically and internationally. Additionally, this research examines the impact of the U.S. developing a “champion” sector for U.S. energy leadership using direct air capture (“DAC”) as the example leading sector. While DAC is explored in this analysis, other advanced energy technologies with similar levels of investment could create similar economic impacts. Other potential sectors could include small modular reactors, large-scale carbon capture and sequestration, and advanced biofuels.

Cambridge Econometrics’ E3ME macroeconomic simulation model is used to estimate the economic effects of policy scenarios through 2050. A policy scenario is compared against a baseline (representing current policy trajectories and economic trends absent the interventions included in the policy scenario) to provide insight into the scale of opportunities that U.S. industry could realize through supportive domestic policy and international partnership.

The macroeconomic modeling of the policy scenario provides an indication of the economic opportunity that could be realized by industrial and trade strategies oriented around competitiveness.

¹ Climate Leadership Council, *Prioritizing American Interests: A New Strategy for Global Decarbonization*, September 2024, https://clcouncil.org/media/2024/12/Prioritizing-American-Interests_Dec2024.pdf

2 Economic Modeling Methodology

The economic modeling framework employed in this analysis is an *impact evaluation*, in which differences between a policy scenario and a baseline scenario are assessed to understand the effects of proposed policy interventions. The baseline and policy scenarios evaluated were developed in collaboration with the Climate Leadership Council (the Council). Drawing upon external data, literature, and both organizations' expertise in economic and energy policy and macroeconomic analysis, the policies considered in these scenarios were translated into model inputs (such as investments, changes in industry costs, fiscal policy, and changes in import/export prices).

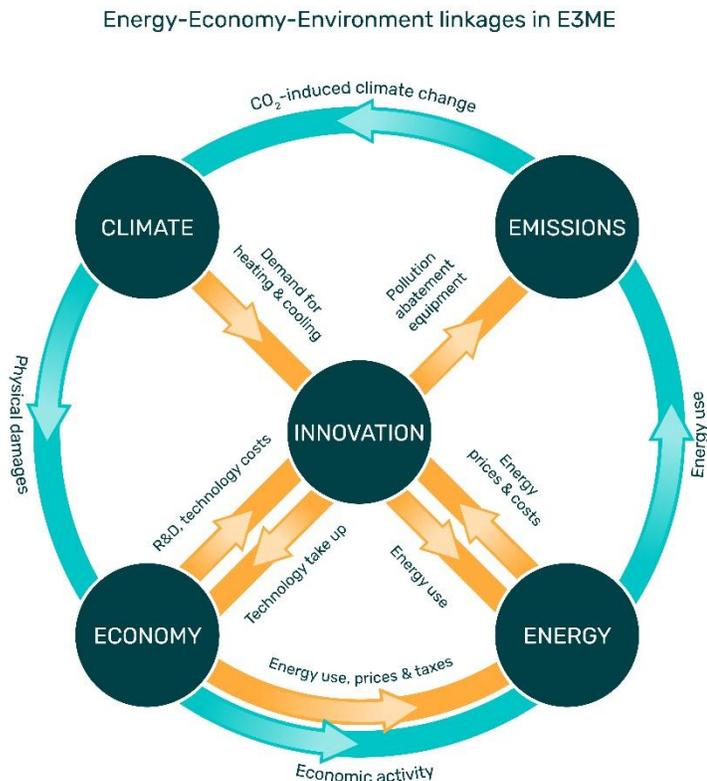
The baseline scenario represents what would happen in the absence of new policy interventions. It includes existing trends, policies, and economic relationships, and serves as a reference point for comparison. The policy scenarios incorporate the effects of a set of policies and simulate how the economy would respond if the proposed intervention were implemented. The impact of the policy is then measured as the difference between the outcomes in the policy scenario and the baseline scenario. This analytical framing thus focuses on estimating the efficacy of the policies based on the effect on key outcomes, rather than providing a forecast of future performance.

The economic impact modeling is carried out using Cambridge Econometrics' E3ME macroeconomic model. E3ME² is a global, macro-econometric model (i.e., a macroeconomic model with a strong econometric foundation) developed by Cambridge Econometrics. It is designed to analyze the interactions between the economy, energy systems, and the environment, particularly in the context of policy assessment and scenario analysis. It is used to assess the impacts of climate and energy policies, technological transitions, and economic shocks. E3ME integrates economic, energy, and environmental modules into a single framework spanning more than 70 regions and 40 distinct industry sectors,³ enabling it to simulate multidimensional effects of policy changes across economic sectors and global regions. The model's relationships are shown in Figure 2.1.

² Cambridge Econometrics, E3ME, <https://www.e3me.com/>

³ While the full set of E3ME industry sectors is used in the modeling process – and thus referred to in the scenario design considerations – results are presented using aggregated sectors for ease of presentation.

Figure 2.1 Overview of relationships in E3ME model



Source: Cambridge Econometrics

E3ME includes endogenous⁴ representations of technological change, in which innovation and technological adoption are influenced by policy and economic conditions; path dependency, in which economic outcomes depend both on historical trajectories and current conditions; and feedback loops, where interactions between the economy, energy use, and emissions are modeled dynamically, capturing two-way effects.

E3ME is grounded in post-Keynesian economics and econometric modeling. Unlike Computable General Equilibrium (“CGE”) models, which rely on assumptions of perfect markets and equilibrium, E3ME uses historical data to estimate behavioral relationships and does not assume full employment or market clearing. This structure allows the model to better reflect real-world dynamics, such as involuntary unemployment and investment driven by demand rather than supply-side constraints.

While E3ME is empirically driven, it is important to note that reliance on historical data limits its ability to estimate future developments, especially in rapidly changing sectors such as advanced energy technology. Consistent with the design of this research, E3ME is designed for scenario analysis – i.e., assessing the effect

⁴ i.e., values which are determined by other variables in the model, rather than historical data or assumptions imposed from outside the model.

of a policy or policies against a baseline and/or alternative policies – rather than precise forecasting. The model outputs represent plausible outcomes under specific assumptions, rather than predictions of what will happen.

Additional information on E3ME is available in Appendix 1 and in the publicly available E3ME model documentation.⁵

⁵ See <https://www.camecon.com/e3me> and Cambridge Econometrics E3ME Model Manual, December 2022, <https://www.camecon.com/hubfs/E3MEManual2022-1.pdf>.

3 Baseline Scenario

The baseline scenario is based on the E3ME “current policies” baseline and is consistent with global warming of around 3°C by 2100. This scenario represents a business-as-usual (“BAU”) trajectory in which policies that have been implemented in the past continue to have an effect in future years. However, no additional policies (including stated ambitions and targets and recently announced policies) are introduced.

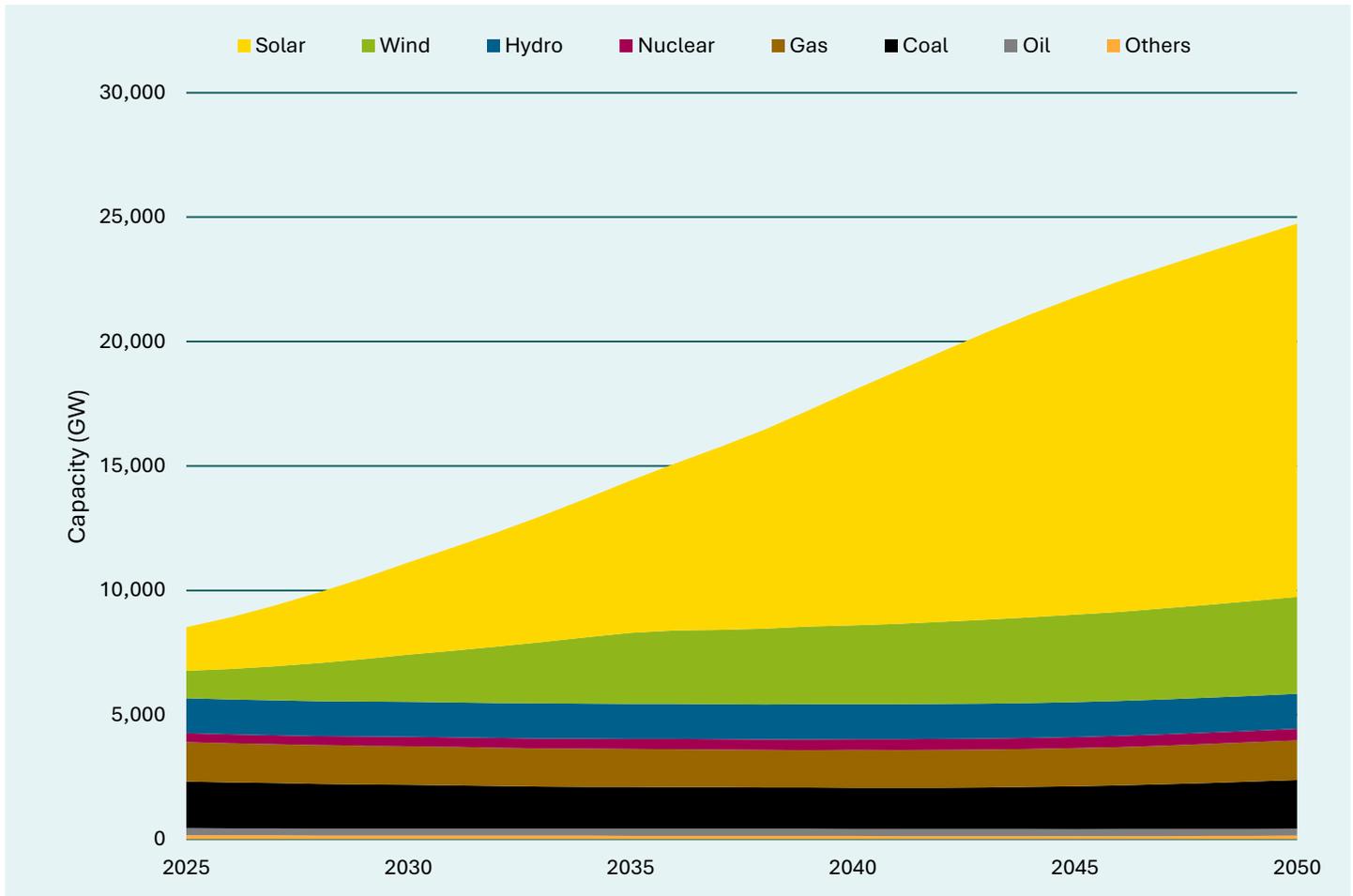
Many of the economic trajectories in the baseline are calibrated to historical data and future growth rates implied by external projections from sources including the International Energy Agency (“IEA”) and the World Bank. Notably, however, the power generation system and passenger vehicle transport are modeled endogenously using the Future Technology Transformation (“FTT”) sub-models within E3ME. The trajectories for these sectors and their associated emissions pathways are driven by endogenous resource cost curves and learning-by-doing effects, which are independent of new policy implementation.

The main implication of carrying forward the impacts of past policies into the future is that the energy and technology transition does take place in the baseline, however at a slower pace than stated ambitions. Thus, while this scenario reflects a global trend towards decarbonization and technology switching based on historic market trends – in particular, growth in solar and wind generation, and adoption of electric vehicles – it is not as ambitious as would be required to meet global emissions commitments made through forums like the Paris Agreement.

Additionally, the E3ME baseline has been revised to constrain the deployment of wind and/or solar in markets that are approaching capacity constraints projected by Thunder Said Energy.⁶ Practically, these revisions reflect a more conservative view of the potential for wind deployment in the US, and wind and solar deployment in China and India. The limits imposed on total capacity for these technologies lead to the affected regions maintaining a somewhat greater reliance on fossil fuel-based generation than in the default E3ME baseline. Nevertheless, there is still strong growth in wind and solar generation across all markets that are not at risk for violating potential capacity constraints. This strong deployment pattern reflects energy market preferences, price dynamics, and national policies captured by the E3ME baseline. The global electricity generation profile used in this analysis is presented in Figure 3.1.

⁶ <https://thundersaidenergy.com/>

Figure 3.1 Global Electricity Generation Capacity by Energy Source (Baseline)



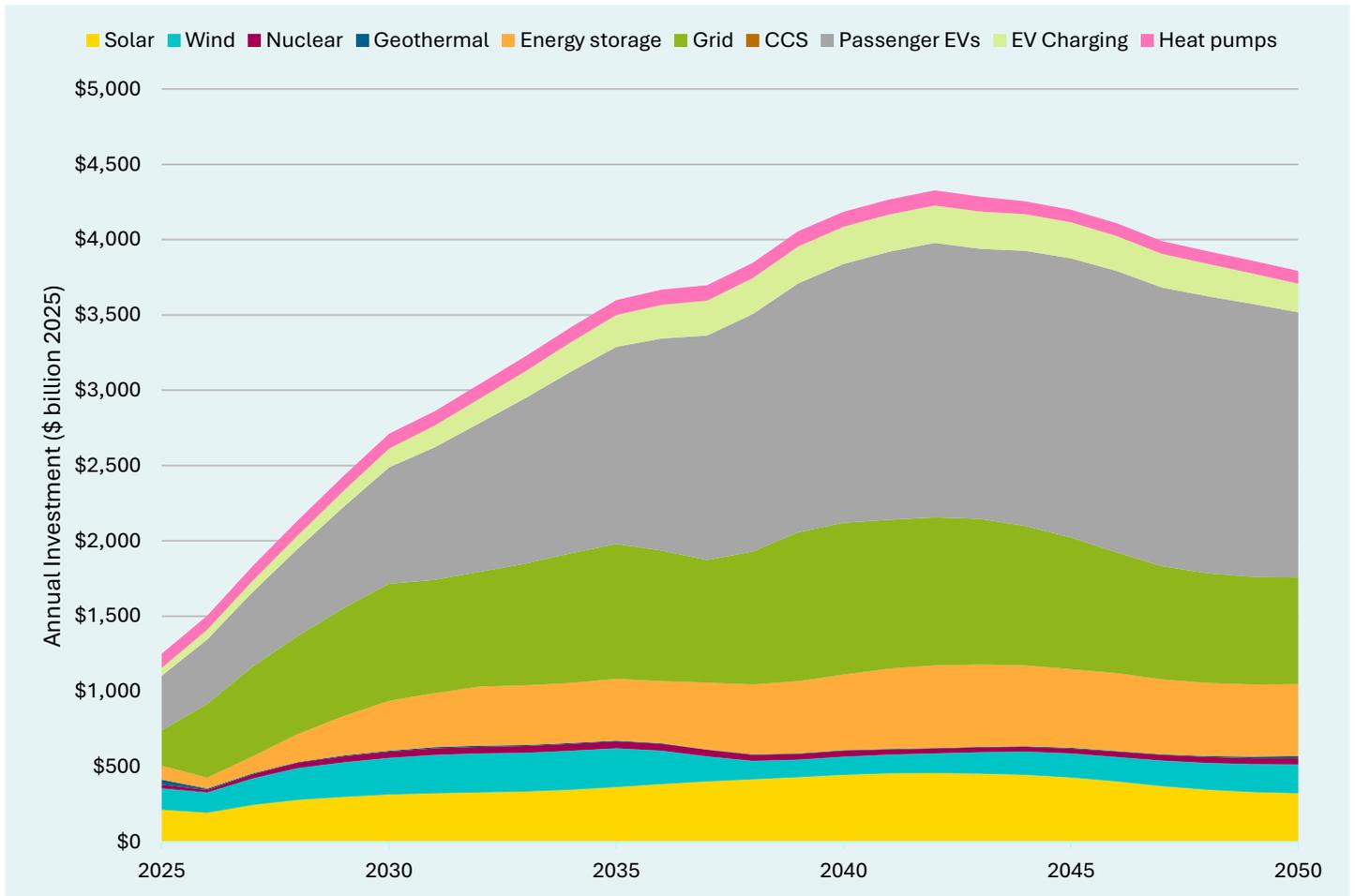
Source: Cambridge Econometrics

Note: Other sources represent less than 2% of total capacity.

The global energy transition presents a vast economic opportunity – even under the more modest baseline assumptions. The total investment in energy systems is estimated based on investment costs represented in E3ME for selected advanced energy technologies – in particular, power generation, passenger electric vehicles, and space and water heating – and estimates of the ancillary expenditures associated with these technologies. Examples include investment in electric grid infrastructure and electrification of certain industrial processes, such as relatively low-temperature process heat in food processing. Drawing on this data, annual investments in the baseline scenario exceed \$2.5 trillion by the end of this decade and exceed \$3.5 trillion by 2035 (as shown in Figure 3.2). Cumulative investment in these advanced energy technologies in the baseline scenario is estimated to exceed \$85 trillion over the next 25 years. It is important to note that not all advanced energy investments are represented in these figures, and including a wider range of

advanced energy investments (such as ocean energy like tidal and wave power or mass desalination in certain global regions) may showcase an even greater market opportunity.⁷

Figure 3.2 Global Annual Investment in Selected Decarbonization Technologies (Baseline)



Source: Cambridge Econometrics

⁷ For example, prior research by CLC, drawing upon information published by Bloomberg NEF, cites an opportunity of more than \$215 trillion in investments over the next 25 years. (Climate Leadership Council, *Prioritizing American Interests: A New Strategy for Global Decarbonization*, September 2024, https://clcouncil.org/media/2024/12/Prioritizing-American-Interests_Dec2024.pdf, p. 7.)

4 Domestic Policy Scenario

U.S. policy plays a pivotal role in shaping the domestic economic conditions influencing the development and deployment of advanced energy technologies and industries. This scenario examines a suite of policies designed to enhance industrial competitiveness through investment, innovation, and support for domestic advanced energy industries. These policies will drive additional domestic investment in energy and other infrastructure, support the domestic manufacturing base, and position the U.S. to innovate, produce, and export the novel energy solutions preferred by a changing global market while retaining its competitive position in more traditional energy markets. This analysis focuses on the sectors most impacted by the proposed policy suite, including electric utilities, fossil fuels and mining, chemical manufacturing, metals manufacturing, and machinery and electronics manufacturing.

4.1. Domestic Policy Scenario – Inputs

Permitting Reform

Permitting reform – i.e., changes in the laws, regulations, and administrative procedures that govern how infrastructure and energy projects are reviewed and approved by government agencies – aims to make the permitting process faster, more predictable, and less burdensome. Permitting reform may include streamlining environmental reviews, reducing legal delays, and consolidating or improving review efforts across federal and state agencies.⁸

From an economic perspective, permitting reform is a key tool to accelerate infrastructure development, reduce project costs, and enhance market efficiency. In the U.S., the permitting process for energy and infrastructure projects is often lengthy and fragmented, leading to delays that increase costs and deter investment. For example, utility-scale renewable power projects take an average of four years to complete with permitting alone consuming a significant portion of that time. Transmission lines, which are essential for integrating renewable energy into the grid, can take up to ten years to permit and build.⁹ According to McKinsey & Company; the average permitting time for manufacturing projects is between two and three years; between four and five years for broadband and telecommunications, oil and gas extraction, and transportation; and between eight and nine years for mining.¹⁰ These delays hinder energy system and industrial capacity expansion – and slow economic growth.

By streamlining permitting processes, governments can reduce uncertainty and incentivize industrial investment, which can lead to increased economic productivity, lower costs to domestic energy and material suppliers, and more competitive domestic industries. These changes then may help to improve the position of U.S. industry at a global scale, both by improving the ability of domestic industry to supply domestic demand

⁸ American Chemistry Council, The Broad Benefits of Updated Permitting Policies, December 4, 2024, <https://www.americanchemistry.com/better-policy-regulation/energy/resources/the-broad-benefits-of-updated-permitting-policies>

⁹ World Resources Institute, US Clean Energy Goals Hinge on Faster Permitting, February 9, 2023, <https://www.wri.org/insights/clean-energy-permitting-reform-us>

¹⁰ Bob Sternfels, Adi Kumar, and Brodie Boland, “Unlocking U.S. federal permitting: a sustainable growth imperative,” July 28, 2025, <https://www.mckinsey.com/industries/public-sector/our-insights/unlocking-us-federal-permitting-a-sustainable-growth-imperative>

(thereby reducing reliance on imports) and by improving the ability of U.S. industry to compete in the export market.

In this research, permitting reform is focused specifically on industrial manufacturing and energy sectors.¹¹ Permitting reform is envisioned as lowering the effective cost of capital for these sectors, enabling greater build-out of production capacity and ultimately more competitive (i.e., lower) sales prices, both domestically and in export markets.

The magnitude of the impact on costs is estimated through three main steps:

Step 1: Estimate the approximate effect of permitting reform on the cost of capital. The effect of permitting reform on the cost of capital is drawn from a study by McKinsey & Co., which estimates that U.S. projects often overrun preliminary budgets by more than 80%.¹² While some of the causes of budget overruns cited are not likely to be impacted by permitting reform (such as inaccurate surveys and unavailable utility records), permitting reform may nevertheless alleviate project delays and make moving through the various stages – including planning, surveying, design, and construction – more streamlined. For this analysis, the 80% overrun cost estimate provided by McKinsey is halved to 40% to approximate the potential impact of permitting reform on capital costs.

Step 2: Estimate the capital intensity of output for the affected industry sectors. This measure provides an indication of the extent to which changes in the cost of capital will drive changes in industry output, given each sector's input mixture of capital, labor, and intermediate components and services. The capital intensity of output was estimated in collaboration with the Council using data published by the U.S. Bureau of Labor Statistics¹³ and mapped to the E3ME industry sector definitions. The capital intensity of output estimated through this process ranges from approximately 8% to 35% across the industry sectors modeled as significantly affected by permitting reform in this scenario.

Step 3: Scale the impact of permitting reform over time. This step reflects that benefits of permitting reform are likely to phase in when projects complete permitting and advance toward expanding infrastructure and productive capacity. This factor begins at 50% in 2026 and grows to 100% by 2050.

The overall effect of permitting reform is therefore estimated as the product of the values estimated in steps 1, 2, and 3, for each industry and year. The estimated impact of permitting reform ranges from approximately 2% to 7% in 2026, growing to 3% to 15% by 2050 across the affected industry sectors. These values are used to modify the domestic and export prices in E3ME for the affected industries.¹⁴ As a result, U.S. production in these sectors is less expensive as an input for downstream manufacturing and is more competitive in the export markets.

¹¹ Coal mining; oil and gas extraction; other mining; wood and paper products manufacturing; manufactured fuels; pharmaceutical product manufacturing; chemical product manufacturing; rubber and plastics manufacturing; nonmetallic mineral product manufacturing; basic metal manufacturing; and metal goods manufacturing.

¹² "Infrastructure and energy capital projects are notorious for being significantly delayed and over-budget. How can we mitigate these risks?" Prezerv. October 18, 2021. <https://prezerv.ai/index.php/2021/10/18/infrastructure-and-energy-capital-projects-are-notorious-for-being-significantly-delayed-and-over-budget-how-can-we-mitigate-these-risks/>

¹³ <https://www.bls.gov/emp/data/input-output-matrix.htm>

¹⁴ In E3ME, fossil fuel and mining exports are not determined using export prices. For these sectors, the impact of permitting reform is multiplied by econometrically estimated export price elasticities to yield an estimated impact on total exports. This method – while not fully endogenous – is conceptually similar to the treatment for other sectors affected by permitting reform.

Continuation of Bipartisan Tax Policies for Advanced Energy Industries and Manufacturing

Favorable tax policies can lower investment costs and spur investment and adoption across targeted sectors. Reducing the cost of advanced energy generation and reducing costs to invest in industrial modernization – either via investment or production tax credits – can help to make these globally important goods and technologies more cost competitive.

By lowering operational costs and encouraging increasing adoption – which in turn leads to learning-by-doing effects, efficiencies, and scale, further lowering technology costs, targeted tax credits can enhance the competitiveness of the U.S. industrial sector from commodity manufacturing through advanced energy technology delivery.

The impact of continuing bipartisan tax policies is modeled using a suite of tax incentives, based on those included in the Inflation Reduction Act and One Big Beautiful Bill Act, including: a 30% investment tax subsidy for advanced energy technology deployment; production tax incentives of 1.5 to 2.75¢ per kWh for biomass, biogas, hydropower, and nuclear;¹⁵ \$300 million per year in investment carbon capture technologies; and nearly \$4 billion in annual subsidies to modernizing the industrial sector, split proportionally based on output between the other mining, nonmetallic mineral products, electronics, electrical engineering and instruments, metal goods, and mechanical engineering sectors.¹⁶

Research and Development Support

Government support for research and development (“R&D”) can help to enhance industry competitiveness by reducing the financial risks associated with innovation. Many private firms – especially small and medium-sized firms – may lack the resources necessary to invest in long-term or high-risk R&D projects. This may be especially true for projects associated with newer energy technologies, which already carry a degree of uncertainty. By providing grants, tax incentives, or direct funding, governments can stimulate innovation that might not otherwise occur. This support contributes to greater deployment of advanced energy technologies and novel supply chain solutions. “Learning-by-doing” effects – i.e., increased efficiency and productivity and reduced costs as a result of accumulated experience in production – may help to further increase productivity and the U.S. market share for advanced energy over time.

In this analysis, the U.S. government and industry together invest 0.15% of U.S. GDP on R&D annually through 2050. Of this, half (0.075%) is allocated to R&D initiatives specifically aimed at advanced energy technologies. The increased investment is distributed across power generation technologies to give greater weight to technologies with smaller existing capacity bases from which to grow. This R&D support is modeled in E3ME as a reduction in investment costs.

The remaining half of R&D expenditure is allocated to manufacturing industry sectors¹⁷ based on each sector’s share of emissions, representing that the more emissions-intensive industries will invest more in R&D. For these sectors, R&D support is modeled as an exogenous increase in investment. Increased

¹⁵ Production credits are modeled using E3ME estimates of electricity generation.

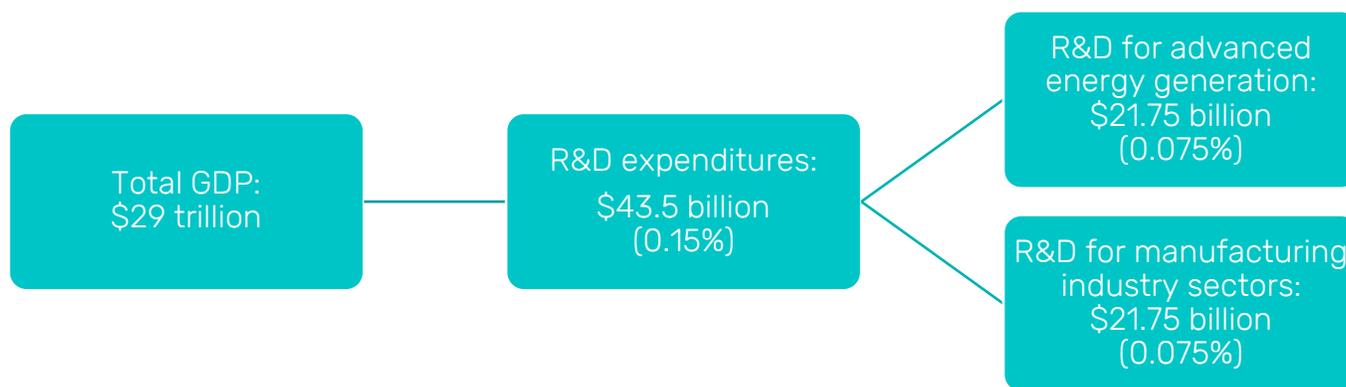
¹⁶ These tax subsidies expire according to current law, for purposes of modeling the potential beneficial effects of these subsidies, these tax policies remain in place through 2050. To include these in the E3ME analysis, the tax expenditures are offset through marginal tax increases.

¹⁷ These sectors include coal, oil & gas, other mining, wood and paper, manufactured fuels, pharmaceuticals, chemicals, rubber and plastics, nonmetallic mineral products, basic metals, and metal goods.

investment expands the productive capacity of these sectors, supporting domestic demand and improving U.S. industry's ability to capture export opportunities.

R&D support is divided among public and private expenditures so that 20% is publicly funded through marginal tax increases; the remaining 80% of investment in R&D is privately funded, with costs borne by the industries implementing these R&D initiatives.

Figure 4.1 Annual R&D Expenditures (Indicative Calculation based on 2024 GDP)



Pollution Import Fees

Pollution import fees (PIF) are being explored by a diverse group of countries, including the United States. They can be designed to simultaneously address three concerns: (1) level the playing field for domestic industries subject to stricter environmental regulations and investor expectations than foreign counterparts; (2) hold foreign firms accountable for their larger contributions to global emissions; and (3) address carbon leakage (i.e., the pattern of production shifting to countries with less stringent environmental, emissions, and labor policies and therefore potentially lower operating costs).

PIFs have the potential to help address the “carbon loophole,” the 25% of global emissions associated with internationally traded goods.¹⁸ This policy can create market space for global providers that market goods with a lower emissions profile and so will carry no or lower liability under a pricing regime. Prior research indicates that the United States is a carbon efficient manufacturer that could benefit from such a policy. For example, American manufacturers produce the same value of goods with just 25% of the emissions that markets like China and India require.¹⁹ Introducing a price at the border can reduce imports of emissions-intensive goods, increase domestic manufacturing capacity, and increase the profitability of American firms.²⁰ Pollution import fees also increase the cost of foreign goods relative to domestically-made products; that price impact may be passed on to businesses and consumers that continue relying upon more emissions-intensive imports.

¹⁸ Ali Hasanbeigi and Aldy Darwili, Global Efficiency Intelligence, *Embodied Carbon in Trade: Carbon Loophole*, November 2022, <https://static1.squarespace.com/static/5877e86f9de4bb8bce72105c/t/63731458d779ae3326ae956f/1668486265199/Embodied+Carbon+in+Trade+Carbon+loophole.11.10.2022.pdf>

¹⁹ Climate Leadership Council, *America's Carbon Advantage 2025*, March 2025, https://clcouncil.org/media/2025/06/2025-Carbon-Advantage_report-1.pdf

²⁰ CRU Consulting, *Opportunities for US-EU steel trade Agreement*, December 2022, https://clcouncil.org/media/2024/04/Opportunities_for_US-EU_steel_trade_agreement.pdf

In this scenario, pollution import fees are imposed by the U.S. on all trade partners based on relative carbon intensity for a set of energy-intensive imports across these manufacturing sectors: chemical manufacturing; nonmetallic mineral products manufacturing; basic metal products; metal goods; machinery; electronics; and electrical instruments.

The pollution import fees are calculated based on the relative pollution intensity of production of the exporting country relative to the U.S. using E3ME data on CO₂ emissions and output. These fees are implemented as a series of exogenous changes to the prices of U.S. imports from the affected countries.

U.S. Direct Air Capture Investment

This study chooses an example sector of advanced energy technology – in this case, direct air capture – to examine the impact that developing a “global champion” technology would have on the U.S. economy. DAC is an intriguing possibility for this sector, though other sectors where the U.S. has a strong foundation include next-generation nuclear reactors, carbon capture and sequestration, and advanced biofuels.

Investment in DAC is a response to the understanding that the U.S. is well-positioned to lead DAC development at scale. Uniquely, DAC is location-independent and can therefore be deployed where it is most cost-effective due to physical and/or economic conditions – and the U.S. has abundant geological storage formations and reliable, low-cost energy supplies.²¹ These advantages could also be relevant to other advanced energy technology like carbon capture or the hydrogen economy.

The private sector is responding to a consensus goal of removing 10 gigatons of CO₂ per year by 2050²² – around 20% of current global annual emissions.²³ Growing to this scale will require patient capital, a supportive policy framework, and ongoing innovation. However, when the cost of CO₂ removal using DAC falls below the cost of alternative emission reduction strategies,²⁴ the industry stands to grow exponentially. Projections suggest that prices under voluntary carbon markets, currently the primary driver for CO₂ removal, will potentially reach \$238/ton in 2050.²⁵ As present investments scale of DAC decreases, DAC-based carbon removal would provide a cost-effective approach to emissions abatement and a profitable opportunity for

²¹ Breakthrough Energy, Third Way, and Boston Consulting Group, Potential for U.S. Competitiveness in Emerging Clean Energy Technologies, September 2022, <https://web-assets.bcg.com/fc/d4/9a39f69141d9aab29f41900712ad/how-the-us-can-win-in-six-key-clean-technologies-r.pdf>

²² National Academies of Sciences, Engineering, and Medicine. 2019. *Negative Emissions Technologies and Reliable Sequestration: A Research Agenda*. Washington, DC: The National Academies Press. <https://doi.org/10.17226/25259>, p. 9 (“If the goals for climate and economic growth are to be achieved, negative emissions technologies will likely need to play a large role in mitigating climate change by removing ~10 Gt/y CO₂ globally by mid-century and ~20 Gt/y CO₂ globally by the century’s end.”)

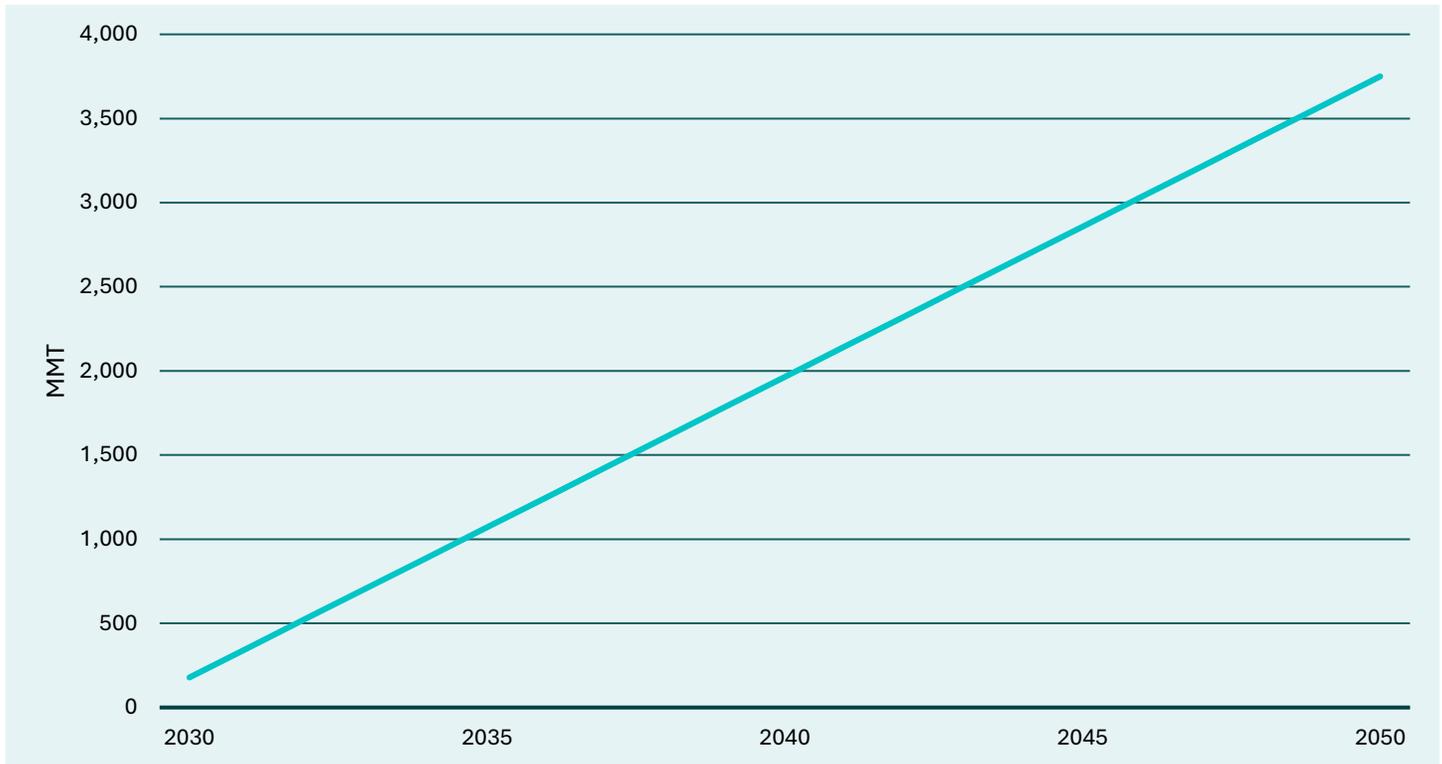
²³ Rhodium, Global Greenhouse Gas Emissions: 1990-2022 and Preliminary 2023 Estimates, November 2024, <https://rhg.com/research/global-greenhouse-gas-emissions-1990-2022-and-preliminary-2023-estimates/> (“Our preliminary estimates for 2023 indicate that global GHG emissions rose by 1.2% over the previous year, reaching 51.8 gigatons of CO₂-equivalent on net.”)

²⁵ Carbon Credits Face Biggest Test Yet. Could Reach \$238/Ton in 2050, According to Bloomberg NEF Report, February 6, 2024, <https://about.bnef.com/blog/carbon-credits-face-biggest-test-yet-could-reach-238-ton-in-2050-according-to-bloombergnef-report/>

early investors. An industry capable of delivering gigaton-scale CO₂ removal could be worth up to \$1.2 trillion by 2050.²⁶

This scenario projects, based on IEA data,²⁷ by 2050, U.S. DAC projects could have a cumulative annual CO₂ removal capacity of 3.75 gigatons, as shown in Figure 4.2.

Figure 4.2 Cumulative U.S. DAC Capacity (Million Metric Tons)



Source: Cambridge Econometrics & Climate Leadership Council analysis

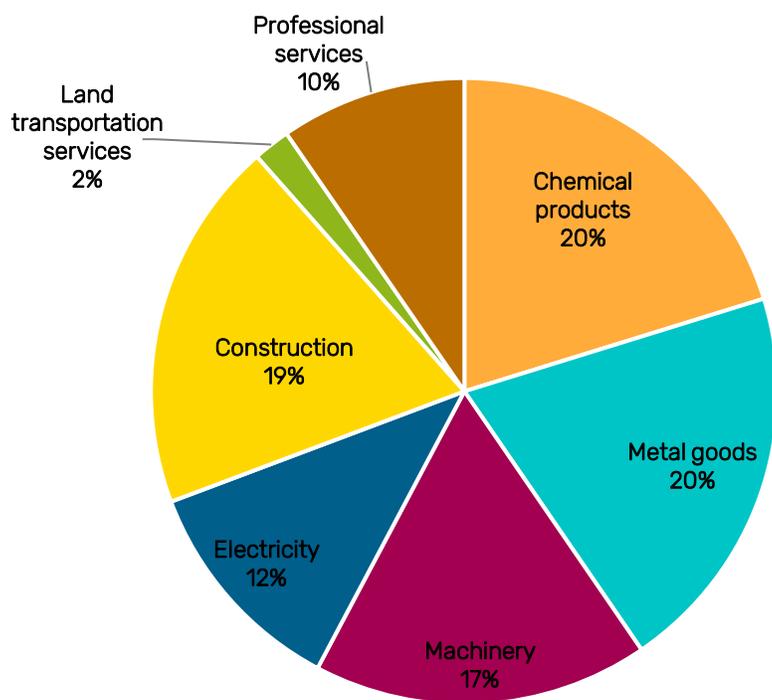
²⁶ McKinsey Sustainability, Carbon Removals: How to scale a new Gigaton industry, December 2023, <https://www.mckinsey.com/capabilities/sustainability/our-insights/carbon-removals-how-to-scale-a-new-gigaton-industry>

²⁷ International Energy Agency (IEA) (April 30, 2025). CCUS projects around the world are reaching new milestones, <https://www.iea.org/commentaries/ccus-projects-around-the-world-are-reaching-new-milestones>; International Energy Agency (IEA). Direct Air Capture – A Key Technology for Net Zero (revised Oct. 2024), https://iea.blob.core.windows.net/assets/9766b4da-a5e3-4d76-874d-aa286e333956/DirectAirCapture_Akeytechnologyfornetzero.pdf; International Energy Agency (IEA) (2024). Direct Air Capture. IEA Energy System Series. <https://www.iea.org/energy-system/carbon-capture-utilisation-and-storage/direct-air-capture>
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DAC investment costs are estimated based on IEA data to decrease to \$105 per ton of CO₂ captured by 2030, and to \$85 per ton of CO₂ captured by 2050.²⁸ Based on the cumulative DAC capacity needs presented in Figure 4.2, annual DAC expenditures are projected to grow steadily from \$19 billion in 2030 to more than \$300 billion by 2050.

While DAC is not directly represented as a technology or industry sector in E3ME, investment in DAC can be modeled by distributing the total investment to the industry sectors that align with DAC development – namely chemical products, metal goods, machinery, electricity,²⁹ construction, land transportation services, and professional services (including engineering). The investment profile for DAC used in this analysis is presented in Figure 4.3.

Figure 4.3 DAC Investment by Economic Sector



Source: Cambridge Econometrics, drawing on Wilcox, J. (2019). Direct Air Capture. Workshop on Deep Decarbonization, National Academy of Sciences. Available online at: https://sites.nationalacademies.org/cs/groups/depssite/documents/webpage/deps_195085.pdf

²⁸ International Energy Agency, *Direct Air Capture: A key technology for net zero, October 2024*, https://iea.blob.core.windows.net/assets/9766b4da-a5e3-4d76-874d-aa286e333956/DirectAirCapture_Akeytechnologyfornetzero.pdf, p. 42

²⁹ The investments on captive renewable energy capacity needed for DAC is included in the total DAC investment costs, rather than within the electricity technological transformation model within E3ME.

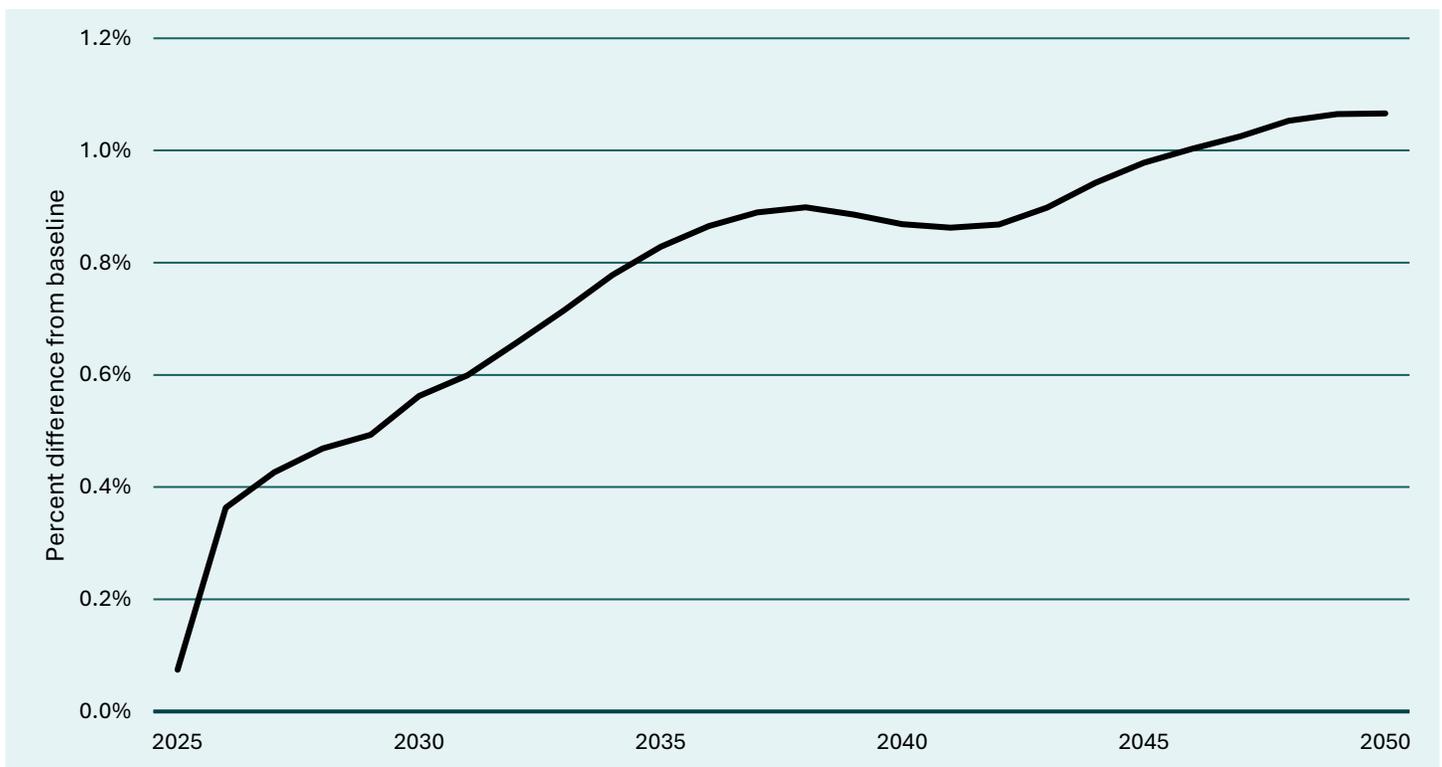
4.2. Domestic Policy Scenario – Results

Impact on U.S. GDP

Under the U.S. domestic policies considered in this scenario, American manufacturing across the industrial sector and in the industries supplying advanced energy technologies and DAC are estimated to experience growth in domestic investment, overall economic output, and export opportunities. Due to the broad nature of permitting reform in particular, positive impacts extend to the U.S.' fossil fuel and mining industries (including extraction, production, and transport). The positive effects of these policies are slightly modulated by indirect and induced impacts from pollution import fees, which marginally increase import costs and costs of production in downstream sectors.³⁰

The overall effect of the domestic policy suite is positive, with GDP estimated to increase over baseline by 0.8% (around \$245 billion) by 2035, and 1.1% (around \$425 billion) by 2050, as shown in Figure 4.4.

Figure 4.4 Impact on U.S. GDP in Indicated Year (Percent Difference from Baseline – Domestic Policy Scenario)



Source: Cambridge Econometrics

³⁰ Indirect effects are the changes in economic activity from increased (or decreased) business-to-business purchases in the supply chain as a result of the direct changes in industry activity. Induced effects are the changes in household spending of increased (or decreased) labor income of employees within directly and indirectly impacted industry sectors. The economic modeling conducted in this analysis reflects the direct, indirect, and induced impacts collectively.

Impact on U.S. Investment

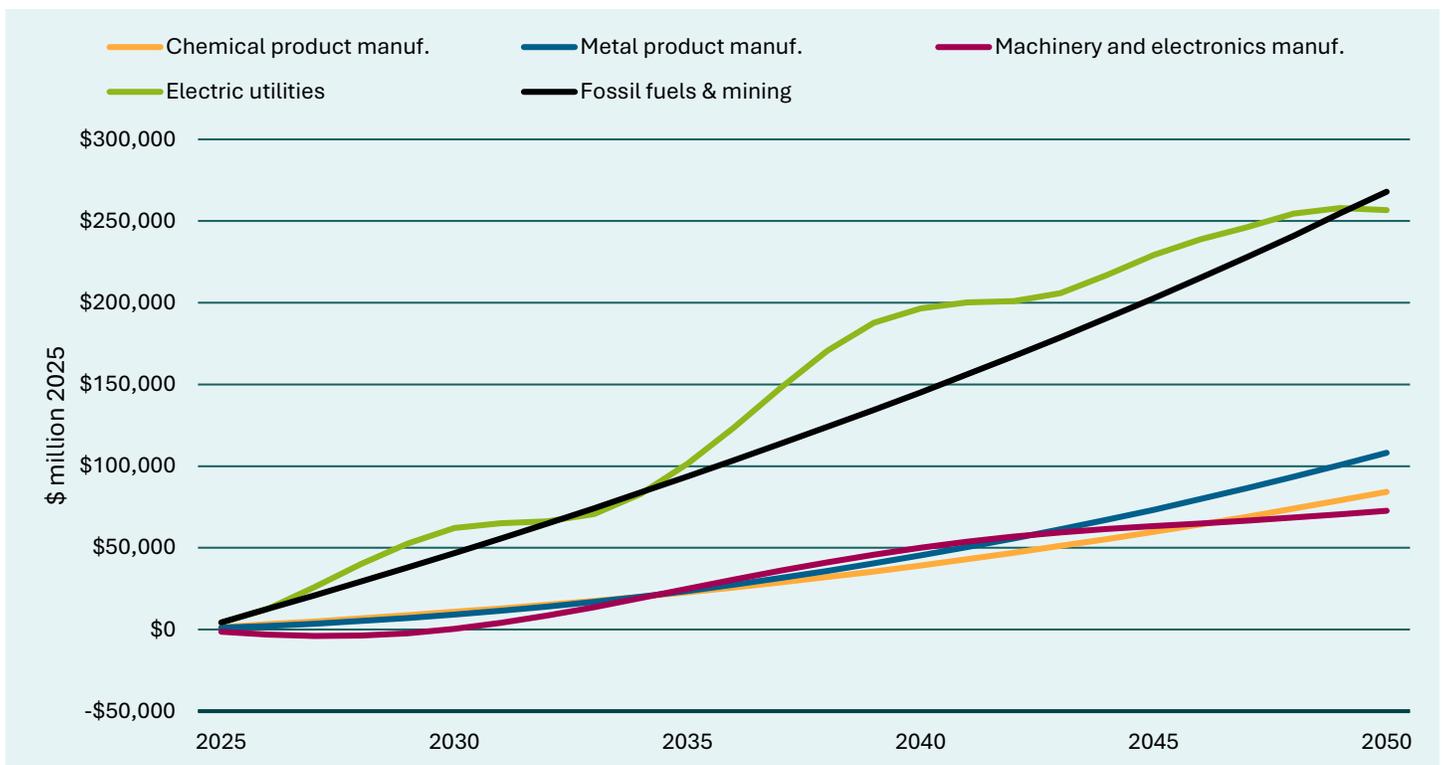
The five economic sectors most directly impacted by the policy measures considered in this scenario – chemical product manufacturing, metal product manufacturing, machinery and electronics manufacturing, electric utilities, and fossil fuels and mining – are all estimated to increase investment in response to the policy measures in this scenario.

The strongest investment response is in the electric utilities sector, which is estimated to increase investment (compared to the baseline) by a cumulative sum of more than \$100 billion by 2035 and \$250 billion by 2050.

The metal product manufacturing, chemical product manufacturing, and machinery and electronics manufacturing sectors – all of which are key suppliers for advanced energy manufacture, the energy system, fuels and mining, and DAC projects – are each estimated to see a cumulative increase in investment (compared to the baseline) of more than \$20 billion by 2035 and more than \$70 billion by 2050.

Driven by the effect of permitting reform, the fossil fuel and mining sector is estimated to experience a strong, positive impact. Cumulative investment in this sector is estimated to increase (compared to the baseline) by around \$90 billion by 2035 and \$260 billion by 2050.

Figure 4.5 Cumulative Impact on U.S. Investment, by Sector (Difference from Baseline – Domestic Policy Scenario)



Source: Cambridge Econometrics

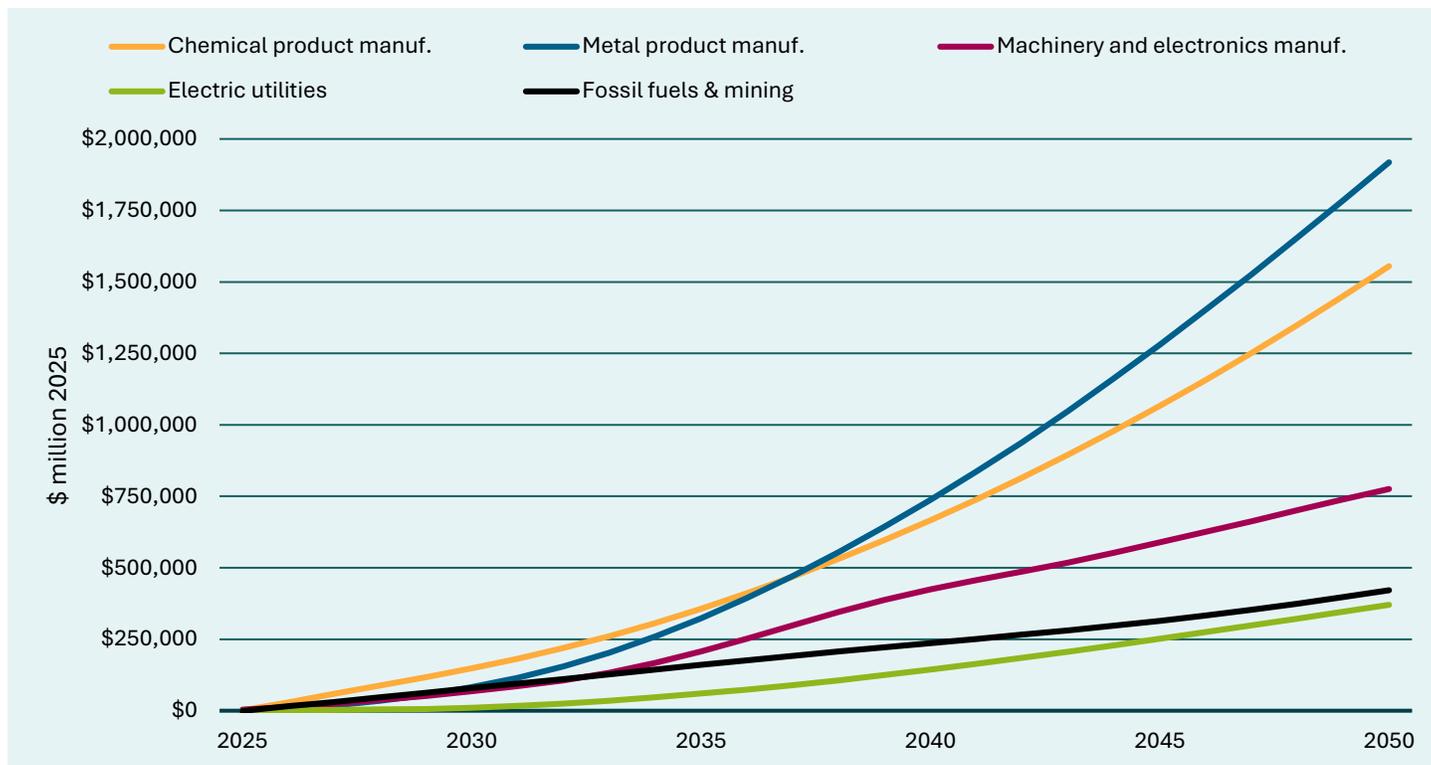
Impact on U.S. Output

Total U.S. economic output is estimated to increase in response to the policy suite, with a strong positive impact for the five key sectors most directly impacted by these policies.

The impact on output (relative to the baseline) is strongest in the metal product manufacturing sector, with an estimated cumulative increase in output of around \$320 billion by 2035 and \$1.9 trillion by 2050 (see Figure 4.6). The chemical product manufacturing sector is estimated to experience a similar growth in output of around \$350 billion by 2035 and \$1.5 trillion by 2050. Output in the machinery and electronics manufacturing, fossil fuels and mining, and electric utilities sectors is also estimated to increase compared to the baseline. As with investment, the strong growth in output in these sectors is driven both by the effect of domestic policies (e.g., permitting reform) in improving the efficiency and competitiveness of these industries, and due to increased demand for these industries' products by advanced energy, manufacturing, and DAC investments.

Across all industry sectors, the cumulative effect of the domestic policy scenario on U.S. economic output is approximately \$2.6 trillion by 2035 and \$11 trillion by 2050, with the five sectors presented below accounting for more than 40% of the overall gain in output. Other sectors linked to economic activity more generally, such as services, distribution and retail, and construction are estimated to experience gains in output as the economy as a whole grows. These sectors supply the intermediate inputs, goods, and services required by the industries benefiting directly from the policies and also benefit from additional consumer spending resulting from greater employment and wages.

Figure 4.6 Cumulative Impact on U.S. Output, by Sector (Difference from Baseline – Domestic Policy Scenario)



Source: Cambridge Econometrics

Impact on U.S. Exports

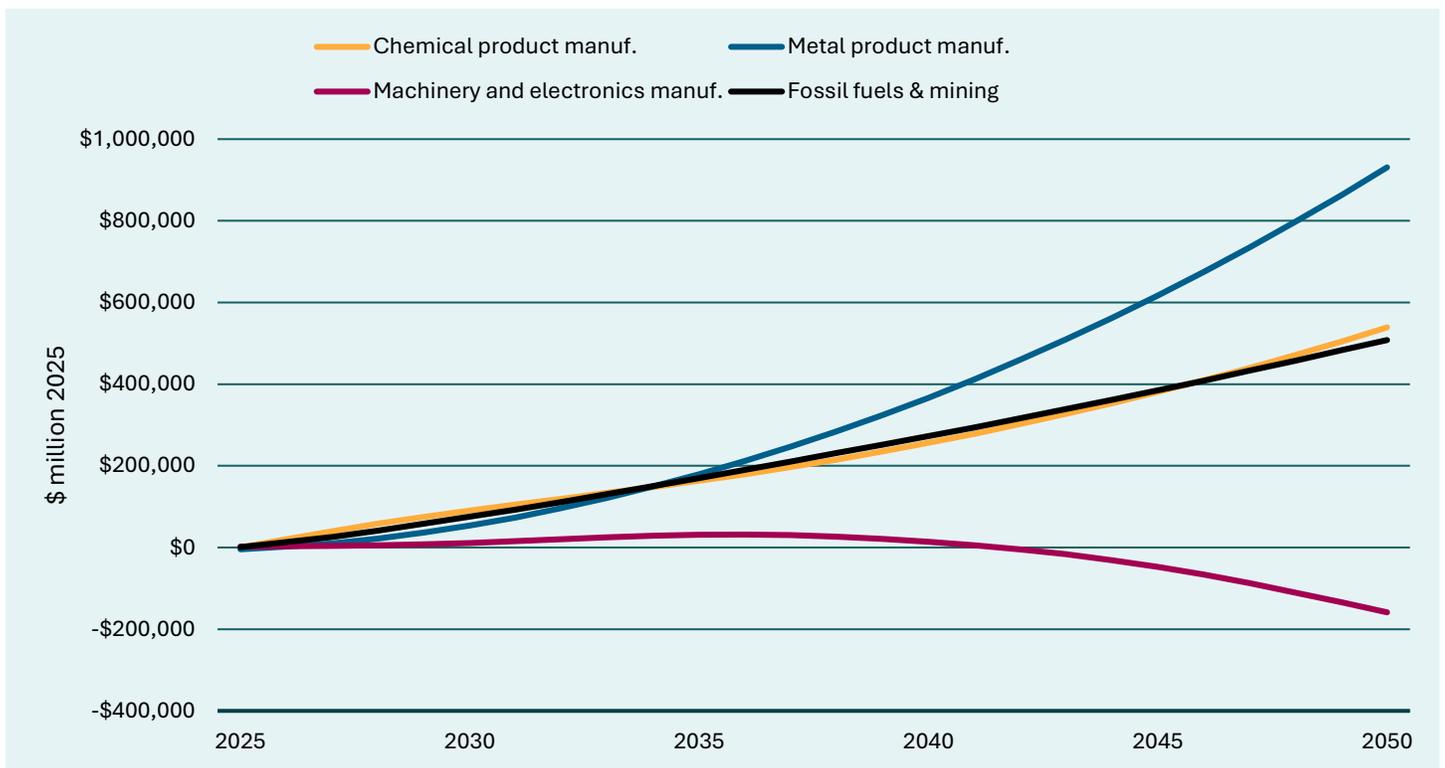
The policies considered in this scenario have a strong, positive impact on the U.S.' ability to compete in the export market. Across the key economic sectors most directly impacted by these policies (those captured above but excluding electric utilities which is not robustly traded), cumulative net exports increase (compared to the baseline) by around \$540 billion by 2035 and \$1.8 trillion by 2050 (see Figure 4.7).

Gains in net exports are primarily driven by sectors where increased investment and supportive domestic policy lead to greater productivity – in particular, in the metal product manufacturing and chemical product manufacturing sectors, both of which provide key inputs to DAC, advanced energy projects, and a more active industrial sector. The growth in net exports is strongest in the metal product manufacturing sector, which is estimated to see a cumulative gain in net exports of around \$180 billion by 2035 and \$930 billion by 2050. The chemical product manufacturing and fossil fuels and mining sectors are also estimated to see a substantial increase in net exports, each with a cumulative impact of around \$160 to \$170 billion by 2035 and \$500 to \$550 billion by 2050. In addition, domestic demand for fossil fuels decreases and U.S. fossil fuel production shifts more toward exports than domestic consumption, increasing net exports relative to the baseline.

Across all industry sectors, the policies in this scenario are estimated to lead to a cumulative increase in U.S. net exports of around \$450 billion by 2035 and \$1 trillion by 2050.

While these policies have a generally positive impact on the U.S.' net exports (both in total, and in the sectors most directly affected by the policy suite), there are potential offsetting impacts due to cost effects. As designed in this analysis, pollution import fees imposed on upstream sectors (e.g., metal manufacturing) raise input costs and therefore overall prices in downstream manufacturing sectors that rely on those inputs, such as motor vehicle manufacturing. Additionally, this scenario assumes that imported finished products (such as motor vehicles) are not subject to pollution import fees on their materials and components, thereby leading to a cost increase in affected U.S. sectors that is not reflected by increased import prices. It is worth noting that under an alternative definition of pollution import fees, the magnitude of this impact may differ.

Figure 4.7 Cumulative Impact on U.S. Net Exports, by Sector (Difference from Baseline – Domestic Policy Scenario)



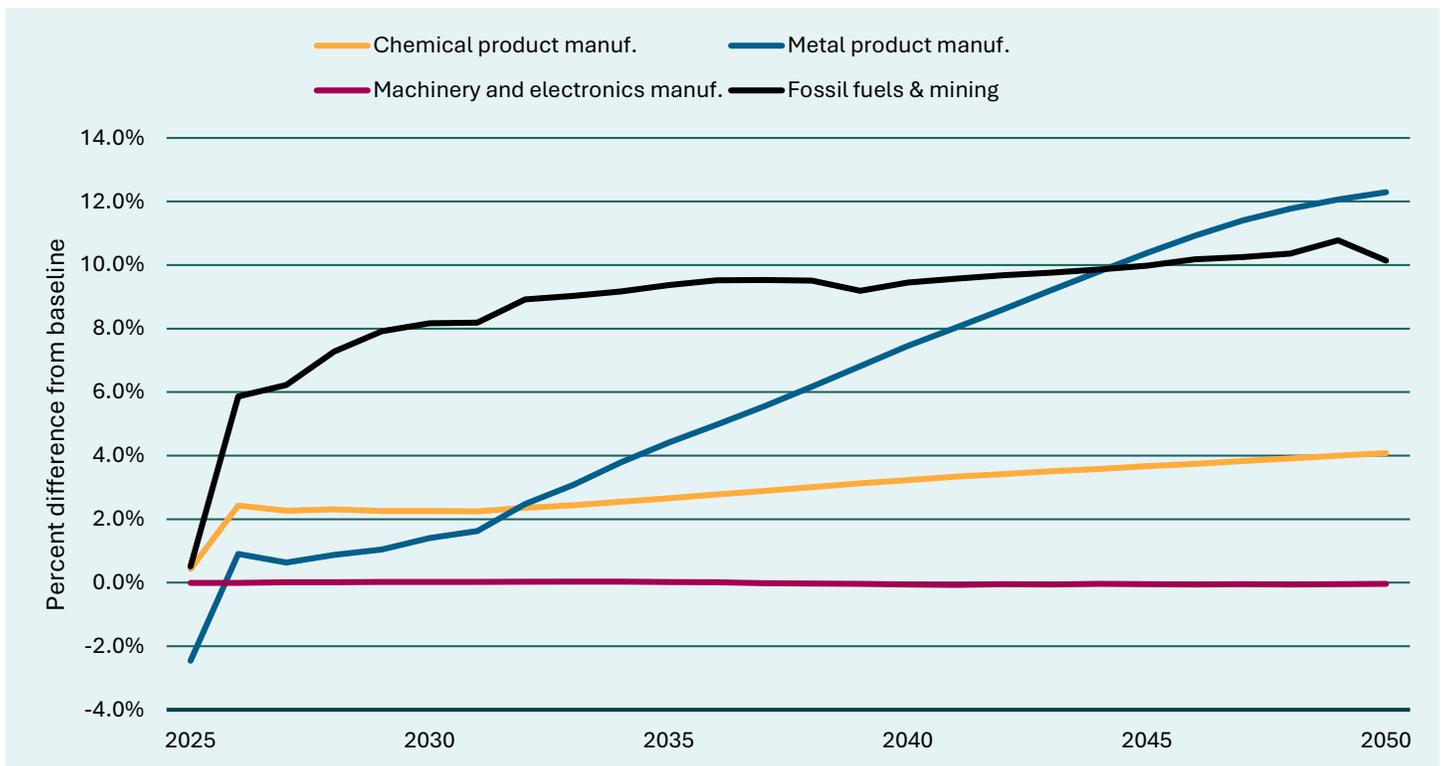
Source: Cambridge Econometrics

As a result of this scenario's domestic policy suite, the U.S. is estimated to increase its share of global exports in three key industry sectors: metal product manufacturing, chemical product manufacturing, and fossil fuels and mining. (As noted above, the effect of these policies on U.S. exports of machinery and electronics is less pronounced; as such, the U.S.' share of global exports in this sector is relatively unaffected.)

The U.S.' share of global exports of fossil fuels and mining products is estimated to increase (compared to the baseline) by a relatively consistent amount, of around 9% by 2035 and 10% by 2050 – increasing the U.S. share of global exports from around 4.2% to 4.6% in 2035, and in 2050, from around 3.4% of global exports to 3.7% of global exports.

The U.S.' share of global metal product exports is estimated to grow steadily over time, driven especially by the escalating impact of permitting reform on the sector's ability to compete in export markets. By 2035, the U.S.' share of global metal product exports is estimated to increase, compared to the baseline, by around 4.4% (from around 4.9% to 5.2%); by 2050, the U.S. share of global exports is estimated to increase by more than 12% (from around 4.9% to 5.5%).

Figure 4.8 Impact on U.S. Share of Global Exports, by Sector (Percent Difference from Baseline – Domestic Policy Scenario)



Source: Cambridge Econometrics

Summary of Domestic Policy Scenario Impacts

The total effects of this policy scenario on net exports, GDP, and output are positive. The policies evaluated in this scenario demonstrate that supportive domestic policy and a pollution import fee can lead to substantial economic opportunities for key industry sectors. Policies aimed at stimulating investment in U.S. industries across basic manufacturing and advanced energy technologies can help increase overall economic output

and improve the U.S.' export position, relative to a baseline scenario in which these policies are absent. Table 4.1 presents an overview of the estimated impact of these policies, compared to the baseline, in 2035 and 2050 (note that while the preceding sections present *cumulative* impacts on output and net exports, these figures are for the individual years indicated).

These policies complement the sizeable investment in DAC, which stimulates economic activity in many of the same economic sectors. The effects of supportive domestic policy and DAC investment are therefore synergistic, with both actions contributing to increased economic performance in a similar set of industry sectors. PIFs, as designed in this analysis, are likely to have some economic tradeoff – especially in the short term – as overall prices for downstream U.S. industries increase. However, these negative impacts are outweighed by the positive effects of other policy measures.

Table 4.1 Summary of Estimated Economywide Impacts (Difference from Baseline - Domestic Policy Scenario)

Economic Indicator	2035	2050
U.S. GDP	0.8%	1.1%
U.S. Output	\$180 billion	\$320 billion
U.S. Net Exports	\$65 billion	\$100 billion

These figures represent the estimated increase in the given economic indicator in the year indicated (i.e., these figures are not cumulative).

5 Summary of Findings

There is a tremendous economic opportunity in growing global demand for advanced energy technologies and the industrial commodities essential to support accelerating economic development. For the U.S., this market opportunity represents a strategic moment to lead in energy innovation and to capture a substantial share of emerging global markets. This macroeconomic analysis demonstrates the uplift made possible by a suite of enabling domestic policies and economic partnerships within a Trade Club to jointly address economic headwinds created by high-emissions and non-market economies.

While some of the shift toward advanced energy is driven by inherent economic factors, **supportive domestic policy can provide greater benefits to American industry than would be realized without policy intervention.** Well-designed policies can improve the competitiveness of U.S. industry, expand the economy at large, and allow the U.S. to strengthen its export position and capture a greater share of the global market in key industry sectors.

Policy can also aid with the development of U.S. leadership in emerging advanced energy technologies such as next-generation nuclear reactors or direct air capture. This report uses the latter as its example, though other technologies of a similar scale of research, investment, and deployment could have comparable impacts on U.S. GDP and economic growth between now and 2050.

Direct air capture (DAC) stands out as a promising area for economic development as philanthropy and industry integrate DAC investments into their climate mitigation approaches. Investment in domestic DAC infrastructure could leverage abundant geological storage formations and low-cost energy supplies to stimulate growth across multiple supporting sectors, many of which overlap with other advanced energy supply chains.

Strategic domestic policy actions, including permitting reform, the continuation of bipartisan tax policies, and research support for U.S. industry are estimated to lead to positive impacts across commodity manufacturing, the energy industry, advanced energy technologies, and the U.S. economy more broadly. The **estimated impacts of the domestic policies considered in this analysis** for the U.S., relative to a business-as-usual baseline, include:

- **Increase in GDP** of around 0.8% by 2035 and 1.1% by 2050.
- **Increase in net exports** of around \$450 billion by 2035 and \$1 trillion by 2050 across all sectors of the economy.
- **Increase in net exports** of metal products, chemical products, machinery and electronics, and fossil fuels and mining of around \$450 billion by 2035 and \$1.8 trillion by 2050.
- **Increase in the U.S.' share of global exports in key sectors**, including metal products, chemical products, machinery and electronics, and fossil fuels and mining.

The economic modeling conducted for the domestic policy scenario demonstrates the potential for the U.S. to improve its competitive position by providing American firms with more tools to lead. As countries enact more ambitious energy policies, the associated economic opportunities will fall to countries that are prepared to not only meet domestic needs but also supply critical products on the global market. This research provides an

initial indication of the types of policies the U.S. could implement to position itself to capitalize on this opportunity.

Appendices

Appendix 1 E3ME

E3ME is a computer-based model of the world's economic and energy systems, and the environment. It was originally developed through the European Commission's research framework programs and is now widely used for policy assessment, forecasting, and [research purposes](#). E3ME was used to assess the European Commission's 2030 and 2050 emission reduction targets. It was also recently used by the World Bank to model different pathways to carbon neutrality in China.

The full model manual is available at the model website www.e3me.com.

Appendix 1.1 Main purpose

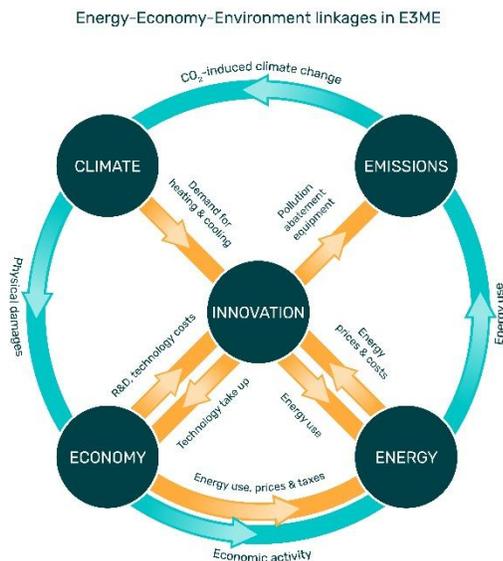
E3ME has been designed to assess the impacts of climate change mitigation policy on the economy and the labor market. The basic model structure links the economy to the energy system to ensure consistency between economic and physical indicators. E3ME can provide comprehensive analysis of policies in each of its 71 regions:

- direct impacts, for example reduction in energy demand and emissions, fuel switching and renewable energy
- secondary effects, for example on fuel suppliers, energy prices and competitiveness impacts
- rebound effects of energy and materials consumption from lower prices, spending on energy or other economic activities
- overall macroeconomic impacts; on employment and the economy at a high level of sectoral detail and (where data allow) household income group

Appendix 1.2 Theoretical underpinnings

E3ME is designed primarily as an empirical tool. It draws on the Cambridge (UK) tradition of macroeconomics, supplemented by more recent applications of complexity theory to economics. The key properties of the model include recognition of fundamental uncertainty, possible non-rational behavior and market structures determined by the available data. The model has been shaped to meet the needs of policy makers, both in terms of the types of scenarios assessed (e.g., a wide range of market-based and regulatory climate policies) and output indicators (e.g., detailed employment, unemployment and measures of inequality). E3ME incorporates bottom-up technology models of four major energy-using sectors³¹ (power, personal transportation, steel and household heating). These models follow the 'S-shaped' diffusion paths of new technologies as they gain market acceptance and incorporate cost reductions through learning rates.

³¹ Called the FTT (Future Technology Transformation) models. See, e.g., [Mercure et al \(2014\)](#) for details.



Source: Cambridge Econometrics

E3ME is often compared to Computable General Equilibrium (CGE) models. In many ways the modelling approaches are similar; they are used to answer similar questions and use similar inputs and outputs. However, there are important underlying differences between the modelling approaches. In a typical CGE framework, optimizing behavior is assumed, output is determined by supply-side constraints and prices adjust fully so that all available capacity is used. In E3ME the determination of output comes from the demand side of the economy, and it is possible to have spare economic capacity. It is not assumed that prices always adjust to market clearing levels.

The differences have important practical implications, because they mean that in E3ME regulation and other policies could potentially lead to increases in output, if they are able to draw upon the available spare

economic capacity. The role of the [financial sector](#) is key (see the model manual for further details).

The econometric specification of E3ME gives the model a strong empirical grounding. E3ME uses a system of error correction, allowing short-term dynamic (or transition) outcomes, moving towards a long-term trend. The dynamic specification is important when considering short and medium-term analysis (e.g., in [Covid-19 recovery](#)).

Appendix 1.3 Basic structure and data used

The structure of E3ME is based on the system of national accounts, with further linkages to energy demand and environmental emissions. The labor market is also covered in detail, including both voluntary and involuntary unemployment. The other econometrically estimated equations cover the components of GDP (consumption, investment, international trade), prices, energy demand and materials demand. Each equation set is disaggregated by region and by sector.

E3ME's historical database covers the period 1970–2018 and the model projects forward annually to 2050. Apart from the IEA energy balances and prices, the model's data is based entirely on freely available information from international sources and national statistical agencies. Gaps in the data are estimated using customized software algorithms.

Appendix 1.4 Model dimensions

The main dimensions of E3ME are:

- 71 regions – all major world economies, the EU28 and candidate countries plus other countries' economies grouped
- 44 industry sectors, based on standard international classifications
- 28 categories of household expenditure

- 25 different users of 12 different fuel types
- 22 power generation technologies
- 14 types of air-borne emission (where data are available) including the 6 GHG's monitored under the Kyoto Protocol