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Review

Electrification to maximize positive climate impacts: A narrative review of the U.S. Inflation Reduction Act

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Abstract: Background: Before passage of the 2022 Inflation Reduction Act (IRA), the U.S. was projected to reduce its greenhouse gas emissions by 24%–35% below 2005 levels by 2030. The IRA put the U.S. on track to reduce its emissions by 35%–41% below 2005 levels by 2030, depending on the assumptions. However, recent federal policy reversals put these goals in serious doubt. Most of the important climate change provisions of the IRA attempt to accelerate the renewable energy transition and increasingly electrify the nation's energy system, which includes a significant expansion of the nation's transmission capacity and electric vehicle (EV) fleet. **Methods:** A narrative review is conducted of the major elements of the IRA that pertain to climate change mitigation, integrating analyses and insights from legal, economic, policy, and technical literatures. **Results:** Several challenges are identified that should be addressed in order to help lower emissions. Policy recommendations proposed include giving significantly more attention and support to the role played by the Federal Energy Regulatory Commission and state public utility commissions in catalyzing the clean energy transition, mining reform focused on energy critical elements, and promoting EV charging and heat pump usage to maximize their greenhouse gas emissions benefits. Also important is enabling state governments to increase their partnership with federal policy makers in the clean energy transition. **Conclusion:** While the IRA is a landmark law that will help the U.S. meet any climate change goals, additional policies will be needed for the full potential of the IRA to be realized.

Keywords: Inflation Reduction Act (IRA); renewable energy; electrification; electric vehicle (EV); transmission planning; Federal Energy Regulatory Commission

1. Introduction

Hardly a day goes by when we are not reminded that the climate crisis is not something that may hypothetically happen in a distant future but rather is already here and now [1]. Moreover, there is a growing consensus that the increasing frequency and intensity of extreme weather worldwide can be attributed to global climate change in many cases [2–4]. Based on strong scientific consensus [5], almost 200 global leaders and the European Union came together to adopt the Paris Agreement in late 2015, which following the ratification process entered into force on November 4, 2016. Only three members of the United Nations Framework Convention on Climate Change have yet to ratify the agreement - Iran, Libya & Yemen [6].

The Paris Agreement, also called the Paris Accords or the Paris Climate Accords, was groundbreaking by establishing for the first-time targets and timetables for reductions in carbon dioxide and several other climate warming greenhouse gas emissions for all countries [7]. The Paris Agreement set a goal of emissions reduction to keep the rise in global surface temperatures well below 2 °C (3.6 °F) above pre-industrial levels, and preferably 1.5 °C (2.7 °F). As a result, greenhouse gas emissions need to be cut by around 50% by 2030 and reach net-zero emissions by around 2050 [7].

Each country and party to the Agreement has committed to these goals in terms of their nationally determined contribution (NDC), which is updated over time. An NDC is each party's climate-related target for greenhouse gas emissions reduction. However, while the Paris Agreement's reporting processes are legally binding, the obligation to meet an NDC is not. In practice, the Agreement relies on peer pressure among signatories to nudge parties to meet their obligations [8]. Thus far 145 countries have pledged or are considering reaching net-zero emissions by 2050 [9]. While emissions reductions by all parties is important, over half of the cumulative greenhouse gas emissions since 1850 are accounted for by three countries and the European Union (EU) alone: United States, China, and Russia [10].

As shown in **Table 1**, the NDCs are a mixed bag with varying baselines and target years used. Leading the way are the European Union, UK, Japan, South Korea, Brazil and Russia, with emissions reduction targets of 50% or more, and originally the U.S. [11]. On the other hand, China, Indonesia and India will continue to grow their emissions in the short-term. However, U.S. President Trump by Executive Order in January 2025 withdrew the U.S. from the Paris Agreement for a second time [12]. The U.S. withdrawal raises serious doubts about its commitment to the Paris Agreement (which it was not on target to meet anyways) though it has not updated its NDC [13]. It should be noted that a subsequent President could rejoin the Paris Accords, as occurred during the Biden Presidency. Nevertheless, in order to meet the ambitious goals of the Paris Agreement it would be necessary for the U.S. and the world to rapidly decarbonize their energy systems, greatly increase energy efficiency, and significantly expand the use of carbon-free energy sources such as renewable and nuclear power [14]. Yet without further reforms, achievement of the climate goals of the Agreement is highly unlikely [15].

The structure of the paper is organized as follows. Section 2 briefly reviews the significant challenge of creating a rapid energy transition, since the historical experience is generally slow. In sections 3 and 4, we provide a narrative review of the major elements of the 2022 Inflation Reduction Act (IRA) that pertain to climate change mitigation, integrating analyses and insights from legal, economic, policy, and technical literatures that are relevant to this topic. In addition to the many provisions supporting and promoting renewable energy, hydrogen energy, nuclear power, and energy efficiency, among the most important provisions are those designed to enable substantial growth in the electric vehicle (EV) market and greatly expanding transmission capacity. Section 4 also reviews the principal challenges that may stymie the IRA effectiveness. These challenges include slow siting and connection of new renewable energy sources to the grid; slow development of new regional and interregional electricity transmission lines for renewable energy; overreliance on foreign mining for critical minerals and rare earth elements needed for EVs and offshore wind turbines; and the need to assure that the expanded use of critical technologies such as EV charging and heat pump use will significantly lower greenhouse gas emissions. In section 5, we propose four sets of recommendations for solving these challenges facing the IRA. Some of the most important recommendations will require significant reform to the Federal Energy Regulatory

Commission, which will need to play a much more active part in the clean energy and electrification transition. In the conclusion, we note that while the IRA is a landmark law that will play a critical role in the ability of the U.S. to reduce its greenhouse gas emissions, without additional reforms the U.S. policy will not be fully effective. Fortunately, a variety of policy and institutional reforms have been identified that have the potential to greatly increase the strength of the IRA.

Table 1. Nationally determined contribution of selected major countries and regions to reduce greenhouse gas emissions.

Country/region	**Emissions reduction target**	**Year**
U.S.	61–66%*	2005–2035
China	7–10% from peak levels	2035
European Union	66.25–72.5%	1990–2035
Russia	65–67%	1990–2035
India	45% reduction in emissions intensity of Gross Domestic Product	2005–2030
Brazil	59–67%	2005–2035
Indonesia	8.0–17.5% below business as usual	2019–2035
Japan	73%	2013–2040
South Korea	53–61%	2018–2035
Canada	45–50%	2005–2035
UK	81%	1990–2035

* expected to be revised with the U.S. again withdrawing from the Paris Agreement.
Source: [13].

2. The vexing challenge of creating a rapid energy transition

The historical experience with energy transitions is mixed. First, most energy transitions have occurred naturally and slowly over 80 to 400 years, and vary by sector [16]. Second, there appear to be physical laws restricting the rate at which new energy technologies can be deployed, based on the rate of capital investment in industrial capacity, which are extremely difficult to overcome [17]. An exhaustive review conducted by Shell International of the development and deployment of new energy technologies in the 20th Century found that it took about 30 years for new technologies that were available in principle to grow exponentially to reach “materiality” and become widely available, defined as delivering ~1% of the world’s energy mix. Following that, growth slowed to a linear rate until the final market share was reached. This inertia was due to constraints in ramping up industrial capacity and slow turnover rates for energy capital goods, including the electricity sector [17].

An examination of the growth rates of wind and solar photovoltaic (PV) usage confirms these findings. Wind power, e.g., which accounted for over 3% of U.S. primary energy use in 2024 has experienced an average annual global growth rate of 13% from 2013–2023 that was fairly steady in most years [18]. Solar PV has fared somewhat better, owing to the dramatic decline (80+%) in production costs since 2010 [19], leading to an average annual growth rate of 25.9% over the same period (though again at a fairly steady linear rate). Solar now accounts for over 2% of U.S. primary energy use [18]. Other rapidly growing energy technologies in recent years, such as EVs and natural gas fracking, also exhibit linear and not exponential growth rates. An implication of these findings is that it may be more important to focus on increased energy efficiency and reduced consumption, which are not subject to the same constraints, and as will be noted is a key focus of the IRA.

The U.S. Energy Independence and Security Act of 2007 (EISA) created a Renewable Fuel Standard (RFS) that set an annual production goal of 36 billion gallons of advanced biofuels (e.g., from cellulosic materials and biomass-based diesel) by 2022, to transition away from corn as the primary U.S. ethanol feedstock [20]. Advanced biofuel production would have the largest greenhouse gas reduction benefits. However, the U.S. program has been a dismal failure, with commercial success only occurring in Brazil with ethanol produced from sugarcane straw and bagasse as well as minor operations in Scandinavia [21,22]. Despite the development of a few U.S. cellulosic ethanol plants from 2013–2019, scaling up and profitably marketing the technology has been challenging. Nineteen years after the passage of EISA there is no U.S. commercial cellulosic ethanol production and nearly all fuel ethanol is still made from corn kernel starch, with only modest greenhouse gas benefits [23].

This poor experience will need to be learned from and overcome if the U.S. is to rapidly transition to reliance on carbon-free energy sources other than biofuels in order to adequately respond to the climate crisis. For instance, a recent study by the Lawrence Berkeley National Laboratory that consolidates findings from six recently published techno-economic models shows that the U.S. can cut its greenhouse gas emissions in half by 2030, but will need to double the renewable energy capacity built each year and transition predominantly to EVs within the next decade or so [24]. The IRA provides substantial funding and incentives to help meet these goals as well as increased electricity transmission capacity, based largely on already proven technologies.

3. Background: increased electrification and the climate change-related provisions of the Inflation Reduction Act and related laws

Given the failure of the market for advanced biofuels to develop based on renewable energy sources (according to the Energy Information Administration in 2025 total biofuels accounted for just 6% of U.S. transportation energy use [25], a figure that has grown slowly over the past decade), and the rapid decline in lithium ion battery costs, policy makers have shifted to increased electrification of light duty vehicles and the energy system more generally. Indeed, an increasingly electrified energy system in the U.S. and the world have been anticipated by several major studies of energy transitions [26–30]. Not surprising, major U.S. federal legislation has followed to reflect this assumption.

Three major laws with important electrification provisions to help enable a clean energy transition were passed in the last six years. First, the Energy Act of 2020 included major provisions and over $2 billion in funding for modernizing the electric grid and increasing energy storage capabilities, as well as a mandate to increase renewable energy development on public lands [31]. These provisions will help integrate the growing number of EVs and smart charging practices into the grid.

Second, the 2021 Infrastructure Investment and Jobs Act (IIJA) section 40106 included loan authorizations up to $2.5 billion to facilitate building new transmission lines, and strengthened the unused backstop siting authority for the Federal Energy Regulatory Commission (FERC) in a National Interest Electric Transmission Corridor (NIETC) [32,33]. A NIETC is a geographic region designated by the U.S. Department of Energy (DOE) with serious transmission limitations where the FERC may need to issue federal permits, and in some cases grant eminent domain authority to purchase property if state and local governments fail to issue timely permits. IIJA section 40103 also authorized the DOE to administer a $10.5 billion Grid Resilience and Innovation Partnerships (GRIP) grant program [32].

Most recently, the landmark Inflation Reduction Act (IRA) was approved in 2022, which took effect on January 1, 2023. Irrespective of President Trump's withdrawal of the U.S. from the Paris Agreement, the IRA has had over two years of aggressive implementation and momentum towards reaching its goals. The IRA is the single largest U.S. climate change-related legislation ever passed. Most of its greenhouse gas benefits are expected through its roughly two dozen tax incentives (**Table 2**) [34,35]. All told, over 80% of the total spending is in the form of tax credits, primarily for solar, wind, nuclear power, and clean hydrogen, plus an additional $27 billion Greenhouse Gas Reduction Fund, which is a program to launch and leverage private funding for clean energy projects to be called "Green Banks" at the national and local levels [35]. In addition, fully electric vehicles (not counting hybrids) were anticipated to grow from an 8% market share in 2023 to more than half of new vehicle sales by 2029, and be increasingly charged based on renewable energy [36][1]. However, given recent changes to federal energy policy this assessment is overly optimistic. Overall, the IRA is predicted to be cost-effective, by lowering energy costs for households and businesses and resulting in negative prices in some wholesale markets. The macroeconomic effects of the climate provisions are expected to be relatively small. In addition, the implied average abatement costs of IRA's economy-wide climate provisions range from a low $42 to $102 per metric ton of CO_2 reduced [34,37,38].

The IRA also included $2 billion under section 50151 in direct loans to fund transmission projects in a designated NIETC and $760 million under section 50152 for grants to facilitate the siting of new wind power transmission lines [41]. An additional $100 million will fund interregional and offshore wind power transmission planning, modeling, analysis and stakeholder convening under section 50153 [41].

Before the IRA's passage, the U.S. was on track to reduce its greenhouse gas emissions by 24%–35% below 2005 levels by 2030 without new policies. This was largely because of slower economic growth, higher fossil fuel prices, higher state-level Renewable Portfolio Standards, and new greenhouse gas emissions and fuel economy standards for light-duty vehicles under the IIJA. Multiple IRA climate change-related provisions led to projections of the U.S. reducing its emissions by 35%–41% below 2005 levels by 2030, and 43%–48% below 2005 levels by 2035, depending on the assumptions [42]. Given recent changes in federal energy policy, however, these projections are unlikely to be met. Nonetheless, the pertinent IRA provisions will accelerate the rate of renewable energy development (primarily wind and solar power) along with a large expansion of the transmission grid to support this growth along with a steady increase in the EV fleet.

Table 2. Key climate mitigation provisions of the IRA.

Section number & title	Provision	Revenue (-) or appropriations (+) $ billions 2022–2031
13101: Renewable energy production credit	Extends & modifies production tax credit for renewable energy	-51.1
13102: Renewable energy investment credit	Extends & modifies investment tax credit for renewable energy, geothermal heat pumps	-14
13301: Nonbusiness energy property credit	Extends, increases & modifies tax credits to residences for energy efficiency incl. heat pumps	-12.5
13302: Residential clean electricity credit	Extends & modifies tax credit for solar, small wind, storage, geothermal heat pumps, biomass	-22
13701: Clean electricity production credit	Production tax credit for zero emission electricity	-11.2
13702: Clean electricity investment credit	Technology-neutral investment tax credit for zero emission energy/storage	-50.9
13401: Clean vehicle credit	Extends & modifies electric & fuel cell vehicle purchase tax credit	-7.5
13402: Used clean vehicle credit	Electric & fuel cell vehicle credit for purchasing previously owned ones	-1.3
13403: Commercial clean vehicles	Electric & fuel cell vehicle credit for commercial vehicles	-3.6
13404: Alternative fuel refueling property credit	Extends & modifies tax credit for charging or refueling at home or business	-1.7
50121: Whole house home energy rebates	Rebates to homeowners from state energy offices for HVAC, heat pumps, etc.	-4.3
50151: Transmission facility financing	Loans for transmission corridor in a NIETC	+2.0
50152: Interstate transmission line siting	Grants to facilitate siting of interstate transmission lines	+0.8
50153: Interregional & offshore wind transmission line planning	Funding for planning, modeling & analysis	+0.1
13501: Advanced energy project credit	Tax credit for advanced energy projects to produce, process, refine or recycle specified advanced energy property	-6.3
13502: Advanced manufacturing production credit	Production tax credit for solar, wind, & battery components, power inverters & critical minerals	-30.6

Source: [35,40].

Besides the significant funding for clean energy use, EVs, and electricity transmission projects discussed above and shown in **Table 2**, additional funding of note includes: $2.9 billion for domestic clean fuel production, over $36 billion for home energy efficiency and supply improvements (including battery storage technology), $3.2 billion for industrial carbon oxide or direct air capture and storage at existing fossil fueled power plants, $16.4 billion for rural clean energy funding, and authorization for the Department of Interior (DOI) to issue offshore wind leases on the Outer Continental Shelf. Also, a new methane emission excise tax was established that applies to petroleum and gas wells.

Additionally, some provisions of the IRA may increase greenhouse gas emissions, including a requirement for the DOI to offer 60 million acres of offshore oil & gas lease sales each year for a decade as a prerequisite to issuing leases or rights-of-way for any new wind or solar energy, plus three offshore oil & gas lease sales that had been previously cancelled under the 2017–2022 five-year offshore oil & gas leasing program. The royalty rate has been increased for these sales, and will also apply to gas that is consumed or lost by venting, flaring, or negligent releases during upstream operations [35]. Also, the IRA has incentives for clean hydrogen energy, though hydrogen leakage can indirectly increase global warming by extending the lifetime of methane and other greenhouse gases [43].

A fourth important law approved in 2022 should be briefly mentioned, which was the CHIPS and Science Act. This law includes $39 billion in subsidies for domestic semiconductor chip manufacturing, a 25% investment tax credit for manufacturing costs, and $13 billion for semiconductor research and workforce training, which supports the domestic EV industry [44].

3.1. Recent changes in federal energy policy, 2025–2026

As noted earlier, following President Trump's election in 2024 he withdrew the U.S. from the Paris Agreement. In addition to his dismissal of the climate problem and emergency, he has expressed strong opposition to EVs and large-scale renewable energy development, especially wind power and to a lesser extent solar power and passed a series of Executive Orders to attempt to implement such policies and to instead promote fossil fuels and nuclear power. However, the recent evidence on renewable energy and EV development and markets shows that these actions may slow the clean energy transition, but not stop it.

The so-called One Big Beautiful Bill Act of 2025 included numerous provisions that repealed many residential and business tax credits for renewable energy, energy efficiency, EVs and charging infrastructure in 2025–2027 [45]. Most of these technologies, however, are already cost-effective without tax credits and it is unclear if these repeals will have any material effect on their continued growth. The EIA, e.g., has noted that the vast majority of new electricity capacity installed in the U.S. since 2021 has been carbon-free renewables, especially wind and solar power, which is expected to continue over the near future [46]. As for EVs, following a record-breaking year for U.S. sales in 2024, sales fell 4% in 2025 following policy changes and large investment pullbacks [47]. However, EV production in China, the global leader, is surging with affordable prices, strong performance and export markets and flash (super-fast) charging [48]. While these vehicles cannot now be imported into the U.S. that could change in a future U.S. Administration, especially if China builds a U.S. manufacturing plant. Additionally, there have been multiple lawsuits filed by a coalition of clean energy groups opposing the efforts of the Trump Administration to cancel large wind and solar power projects on federal lands and offshore waters. Most recently, in April 2026, a federal Judge issued a preliminary injunction to block many of these restrictions, rendering future clean energy policy highly uncertain [49].

4. Four electrification challenges

4.1. Slow siting & connection of renewable energy resources to the grid

There are far more than enough renewable energy resources that could be deployed for the U.S. to meet ambitious climate targets [50], as well as potential new nuclear power plants. Unfortunately, due to suboptimal wind speeds, siting constraints and other factors, not all these clean energy sources are economical and readily available to develop. However, numerous clean energy projects have been proposed across the country, primarily wind and solar power, and energy storage capacity (mostly battery arrays). In contrast, no nuclear power plants are currently under construction in the U.S., though over 20 new nuclear reactors have been proposed and many other nuclear power plants have had their capacity increased or life extended [51,52]. Among proposed new wind, solar and energy storage projects, however, there is a significant potential capacity backlogged in siting and transmission interconnection queues, mostly in the Western and Midcontinent states, which slows the rate of clean energy transition [53]. The development of new transmission lines has been similarly stymied. In this subsection, we consider the twin problems of how the current renewable energy and transmission line project siting regimes stifle the pace of development, and the lengthy transmission interconnection queues.

Many energy projects experience the “not in my backyard” or NIMBY syndrome, where local public opposition, often significant (including legal challenges), develops. Renewable energy projects and new transmission lines are no exception. For example, some people complain that solar energy farms cause glare and glint, and wind farms cause shadow flicker, can harm bird and bat populations, disrupt scenic vistas, threaten local place identity, and often export the energy and economic benefits elsewhere [54,55]. Energy storage arrays may be considered unsightly to some people. As for transmission lines, in addition to concern over aesthetics, some have argued that the lines have negative effects on property values and increase human health risks such as from electromagnetic fields [56,57].

State and local governments take the lead role in siting and permitting renewable energy facilities and transmission lines since land use in the U.S. is regulated primarily at state and local levels, e.g., by state public utility commissions (PUCs) [58]. This process varies from state to state, but typically allows for significant stakeholder input to raise concerns to government officials. The only major exception to the state and local primacy is the licensing of hydroelectric facilities, which falls under the purview of FERC. In general, regulatory variability and fragmentation is rampant and contributes to barriers and delays in approving new energy projects [59]. An exception is New York State’s Accelerated Renewable Energy Growth and Community Benefits Act of 2020. This model law centralized the State’s siting process in a new Office of Renewable Energy Siting; requires the Office to develop uniform design and operational standards; directs projects to areas of low environmental impact; requires host community benefits; accelerates the review and permitting process; creates an intervener fund; and allows the State to override local restrictions that it deems unreasonable [59].

Federal public lands also have significant potential for renewable energy development, though until recently the federal government prioritized fossil fuels projects. However, the federal lands identified as high priority for renewable energy projects are modest, and little leasing has been done to date. For example, after excluding critical natural habitats, wilderness areas and areas with existing rights-of way, the U.S. Department of Interior’s Bureau of Land Management (BLM) has set aside just 700,000 acres as designated leasing areas for solar energy, and none for wind (although BLM leases other lands for wind and geothermal energy as well as solar). This compares with the U.S. Environmental Protection Agency's estimate that there are 44 million federal acres with renewable energy potential [60]. BLM enacted comprehensive reforms in 2024 called the Conservation and Landscape Health Rule. The new rule reduced acreage rents and capacity fees by 80% to promote wind and solar development [61]. Additionally, it allows clean energy project developers to offset any adverse effects on important natural resources through compensatory mitigation on public lands, called restoration and mitigation leasing [61].

Until recently, federal priority for wind energy has been offshore, where the government administers over 1.7 billion acres on the outer continental shelf, which was traditionally focused on oil and gas leasing. Even so, only around 1% of these acres have been leased for wind energy so far, totaling 185 wind farms, with only two completed small wind projects currently operating off the Atlantic Coast as of 2026. However, five large commercial offshore wind projects are currently in the construction phase (**Table 3**) off of Massachusetts, Rhode Island, Virginia, New York, and Connecticut [62]. Moreover, offshore wind farms are costly and have supply chain challenges. To receive the go-ahead, offshore wind projects must be permitted by the Bureau of Ocean Energy Management (BOEM), which President Trump strongly opposes, as well as the appropriate state agency.

Even if new clean energy capacity is sited and built, there may still be significant delays in obtaining approval for interconnecting to the transmission grid system. Irrespective of whether a new project is proposed by a utility, independent power producer, or private developer, independent system operators (ISO) and regional transmission organizations (RTO) require all projects seeking connection to the grid to undergo a system impact study before they can be built [53]. These studies determine what new transmission upgrades, if any, may be required before grid connection is allowed, their costs, and who pays for them, with wind energy projects taking the longest time to complete.

Unfortunately, the interconnection process is slow, costly, and wait times may be increasing. There has been a substantial increase in interconnection requests since 2013, especially for solar energy and energy storage projects. The average wait time in the interconnection queue for clean energy projects is currently 4.5 years, up from 3 years in 2015, with the largest projects taking the longest time to reach commercial operation (these data only cover solar, wind, natural gas, and energy storage projects, though the number of new gas projects accounts for just 9% of the total capacity). Moreover, just 19% of the more than 19,500 clean energy projects that requested an interconnection during 2000–2019 had reached commercial operation by the end of 2024, while more than 70% were withdrawn [53]. At the end of 2024 there were over 10,300 projects seeking grid operation nationwide, accounting for almost 1400 GW of generation capacity and around 890 GW of energy storage [53]. Solar energy and energy storage projects by far dominate the queue (**Table 3**). By comparison, the total U.S. electric generating capacity at the end of 2024 was 1230 GW [63]. Thus, the energy capacity of still active projects in the interconnection queue technically exceeds the installed capacity of the nation's entire power plant fleet[2].

Table 3. Queued clean energy projects by technology and U.S. region at the end of 2024 (GWe).

Regional grid*	**Onshore wind**	**Offshore wind**	**Solar**	**Natural gas**	**Battery storage**
West non-ISO	63.6	0	223.4	13.2	266.6
Southeast non-ISO	2.6	0	77.1	46.0	30.7
CAISO	9.6	0	90.9	3.5	167.1
ERCOT	32.0	0	139.4	22.8	151.6
SPP	30.4	0	57.9	15.1	38.5
MISO	54.1	0	242.2	26.4	113.2
PJM	12.8	22.8	103.4	7.9	64.3
NYISO	4.5	18.8	16.9	1.2	37.1
ISO-NE	2.8	15.8	5.3	0.1	21.6
Total	212.4	57.4	956.5	136.2	890.7

* U.S. states included in each regional grid:
West non-ISO: All or parts of Washington, Oregon, California, Nevada, Idaho, Montana, Wyoming, Utah, Colorado, Arizona, New Mexico.
Southeast non-ISO: All of Florida, Georgia, Alabama, South Carolina, Tennessee, and parts of North Carolina, Mississippi, Kentucky, and Missouri.
CAISO: California (California Independent System Operator), and a small part of Nevada. However, CAISO also operates the Western Energy Imbalance Market, which also includes utilities from Arizona, New Mexico, Idaho, Utah, Montana, Wyoming, Oregon and Washington.
ERCOT: Electric Reliability Council of Texas.
SPP (Southwest Power Pool): all of Kansas and Oklahoma, and parts of Missouri, New Mexico, Texas, Arkansas, Louisiana, South Dakota, North Dakota, Montana, Minnesota, Iowa, Wyoming, and Nebraska.
MISO (Midcontinent Independent System Operator): all of Michigan, Minnesota, and Wisconsin, and parts of Arkansas, Illinois, Indiana, Kentucky, Louisiana, Mississippi, Missouri, Iowa, Montana, North Dakota, South Dakota, Texas.
PJM (originally Pennsylvania & New Jersey, then the Pennsylvania-New Jersey-Maryland interconnect- ion); currently all of Pennsylvania, New Jersey, Maryland, Washington, D.C., Delaware, West Virginia, Ohio, most of Virginia & Kentucky, and parts of Illinois, Indiana, Michigan, North Carolina & Tennessee.
NYISO: New York (New York Independent System Operator).
ISO-NE (Independent System Operator of New England): Massachusetts, Connecticut, Rhode Island, New Hampshire, Vermont, Maine.
Source: [53].

The FERC tried to streamline the interconnection process in its final rule on Generator Interconnection reform, Order No. 2023, which took effect on November 6, 2023 [64]. For instance, the rule requires transmission providers to study clean energy projects in large batches or “clusters” in a first-ready, first-served process, rather than one by one as was done in the past. The former approach made sense when traditional large energy projects were proposed in smaller numbers as opposed to multiple, much smaller wind, solar PV, and battery storage projects. In addition, the rule seeks to increase the speed of interconnection queue processing by imposing firm deadlines and penalties if transmission providers fail to complete interconnection studies on time (with some exceptions). It also seeks to decrease speculative entry into the queues while moving a higher percentage of queued projects to completion. Furthermore, the rule incorporates technological advancements into the interconnection process to require transmission providers to allow projects to co-locate on a shared site behind a single point of interconnection and share a single interconnection request, thereby removing barriers for co-located resources by creating a more efficient standardized procedure for such configurations. Recognizing the power grid impacts of nonsynchronous wind, solar, and battery storage resources, the rule requires that transmission providers provide more granular and accurate modeling data about these resources and follow capability standards to ensure electric system reliability.

4.2. Slow development of new regional and interregional transmission capacity

Given the massive clean power and energy storage capacity that is already queued up, there is an urgent need for new transmission capacity [65]. This need can be considered on two parallel levels: new transmission capacity that is needed within each grid region, and the interregional transmission capacity needed to facilitate the transfer of clean and carbon free power from resource abundant regions to regions with less carbon free resources but greater power demand. However, as noted earlier, opposition to transmission projects by the public, or even governors and competing utilities (including legal challenges) may stifle the pace of transmission line siting and approval. Opposition may be especially pronounced for interregional projects, due to the benefit and cost discordance between electricity supply and demand regions.

In light of the challenges faced by the transmission sector, the DOE undertook a major review of over 120 industry modeling and other reports published since 2018 that considered the national transmission system needs [66]. In addition to greater access to clean energy, the DOE notes that expanded transmission capacity has many other benefits, including: improved grid resilience and reliability, reduced transmission congestion and power curtailments, increased access to cost-effective power generation sources for high cost regions such as New York, the Mid-Atlantic states, and California, and support for increased electrification more generally. These benefits are especially pronounced for interregional transmission.

The DOE model identified the most significant transmission additions to be needed in Texas, the Plains, Mountain, Midwest, and Southeast regions[3]. Overall, 47,300 GW-miles of new transmission will be needed nationwide by 2035 under moderate load and high clean energy assumptions, for a 57% growth from today's U.S. transmission system. The largest growth in interregional transmission transfer capacity will be needed between New York and New England, the Midwest and Mid-Atlantic, and the Plains and Midwest, for a total of over 120 GW by 2035 [66]. These assumptions however are probably optimistic. Even so, transmission investments have been steadily declining since 2015. Significant increases in transfer capacities will also be needed between Texas and Mexico, and several U.S. regions and Canada for Canadian hydropower. Notably, the transmission capacity expansion modeled under the high clean energy growth scenarios will not be realized without additional policies [66].

Unfortunately, the siting and approval of interregional transmission capacity is fragmented and slowed by dominant parochial interests in local utility service territories [67]. The historical monopoly franchise right granted to investor-owned utilities (IOUs) included transmission lines (although many non-utilities now own the lines), and their linkages with neighboring utilities transformed the IOUs to interstate system operators and power wholesalers [67]. While the FERC issued four orders from 1996 to 2011 that attempted to open interstate power systems to competition, this effort has largely failed. For example, FERC Order 1000 issued in 2011 required RTOs and ISOs to create regional transmission plans and develop projects through competitive processes, and reformed cost allocation rules, but many states have responded by passing protectionist laws and policies that give their own IOUs the right of first refusal (ROFR) on in-state portions of RTO and ISO-planned projects that connect to their existing transmission lines, a right that Order 1000 had removed at the federal level [33,68]. Moreover, the RTOs and ISOs are still subject to the balkanized transmission supply and demand balancing incumbent obligations of their member IOUs [69]. As a result, IOUs often pursue inefficient small, localized transmission projects while not pursuing more efficient interregional projects. One of the reasons for this is existing transmission planning often understates the value of new transmission infrastructure since around half of the marginal value of transmission in providing congestion relief occurs during extreme grid conditions and high-value periods that account for only 5% of hours but are challenging to model [70]. Also, while FERC has removed certain barriers to entry for non-IOU developers, it has yet to foster a development process that stimulates significant non-IOU interregional transmission projects [67,71].

FERC has recognized some of the shortcomings in the existing transmission planning process. Consequently, it issued a new rule on May 13, 2024, Order No. 1920 to accelerate regional transmission planning and address long-term cost allocation. The rule seeks to develop transmission plans for at least 20 years into the future, to be updated every three years, and to reform the cost allocation rules [72]. However, implementation has been slow.

4.3. U.S. reliance on foreign sources for energy critical elements

Critical minerals are any mineral resources that are considered essential to the functioning of a country’s economy, in short or no supply in a country or overly expensive to mine, and whose supply chain may be disrupted. As a result, what is considered to be a critical mineral is country-specific and can change over time. Examples in the U.S. include aluminum, manganese, nickel, graphite, cobalt, platinum, silicon, and lithium [73]. Rare earth elements (REEs) are a subcategory of 15 critical minerals known as the Lanthanide series plus scandium and yttrium that while not actually rare in the Earth’s crust are generally not found in concentrated clusters or in a pure elemental state and are difficult to mine [74]. No readily available substitutes exist for most REEs. As shown in **Figure 1**, several of the REEs plus many other critical minerals are needed for clean energy and electrification technologies, which are sometimes called energy critical elements (ECEs). The U.S. imports more than 90% of most of its ECEs from a few other countries and thus this raises energy security risks as well as opportunities [75–78].

Considering the group of technologies needed to electrify the energy system and significantly increase production of renewable energy resources, most of the ECE concern exists for EVs and offshore wind turbines [79]. For EVs, eleven different critical minerals are needed. These include lithium, nickel, cobalt, and graphite for the lithium-ion batteries; the REEs neodymium, praseodymium, dysprosium, and terbium for high-performance permanent magnets in EV motors [75]; silicon carbide for power electronics to increase EV efficiency, power density, and vehicle performance; magnesium for light weighting the EV chassis; and gallium nitride as a substitute for silicon semiconductors to enable quicker EV charging and longer-range driving. While this issue is not yet compromising the IRA implementation a very high supply risk is expected over the next decade for neodymium, praseodymium, dysprosium, and terbium (**Figure 1**). Former President Biden invoked Section 303 of the Defense Production Act of 1950 on March 31, 2022, in part to support the domestic ECE supply for EV batteries as well as stationary energy storage batteries [80]. Other options include greatly increasing the recycling rate for batteries, and supporting the development and deployment of REE-free EV motors [81].

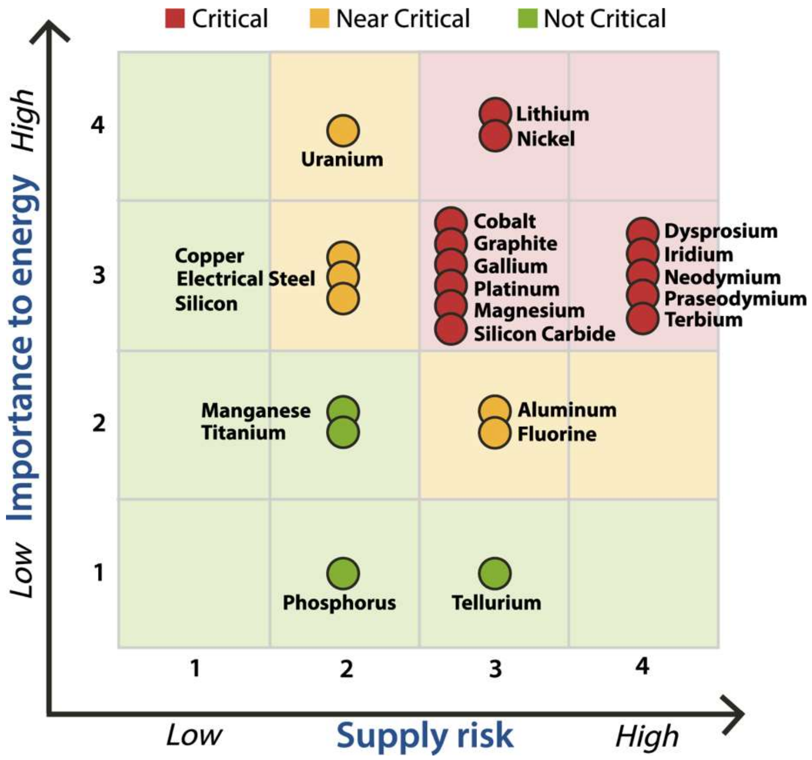

Figure 1. Energy critical elements required for electrification & clean energy, 2025-2035.

Source: [79]. Figure redrawn by Jill Gotschalk.

Offshore wind turbine generators also use REEs such as neodymium, praseodymium, dysprosium, terbium, as well as gallium, plus other less critical materials, in their magnets to increase performance and stability. In the case of solar energy, the key critical mineral of interest is gallium, though silicon, the most common material in PVs, will become near critical in the medium term (**Figure 1**). Gallium arsenide is increasingly used as a doping agent in PV solar cells that results in greater stability and much higher voltage, and thus a much higher energy conversion efficiency [82].

Electricity transmission and distribution systems are reliant on two critical minerals that have a relatively high supply risk: silicon carbide for high-voltage direct current converters, which helps to integrate renewable energy resources into the grid; and nickel, which is needed for silver-nickel alloys used in electric breakers and switches. As noted earlier, for stationary energy storage batteries, lithium, nickel, cobalt, and graphite are required just as they are for EV batteries [79].

The use of critical minerals in several other clean energy technologies should be noted. These include natural graphite as a moderator in nuclear reactors; gallium in LED (light-emitting diode) lighting, and gallium nitride and silicon carbide in consumer power electronics; cobalt, nickel, platinum, and iridium in hydrogen electrolyzers, which can be used to convert renewable or nuclear sources of electricity into green hydrogen; and cobalt, nickel, platinum, and graphite in fuel cells, which can be used with green hydrogen to produce electricity [79].

Thus, the ECE that are essential for the U.S. economy's clean energy and electricity sectors are largely imported and supplies are vulnerable, with a few countries dominating (**Table 4**). For example, China accounts for the vast majority of supplies of gallium, graphite, magnesium, silicon carbide, and REEs, and from August 2023 to November 2025 restricted exports of gallium, graphite, germanium (a critical mineral but not an ECE), and REEs to the U.S. to varying degrees [83,84]. The REE reliance upon China is even greater when one considers that China accounts for 85% of REE refining (processing) and 92% of REE magnet production [85]. Other dominant producers include South Africa (platinum and iridium), Congo (cobalt), Indonesia (nickel), and Australia (lithium). Due to these concerns, critical minerals were covered as part of the large Advanced Manufacturing Production Tax Credit as part of Section 13502 of the IRA (**Table 2**), though the wind turbine components may become ineligible after December 31, 2027.

Table 4. Energy critical elements in the U.S. and leading international producers in 2022.

Elements	Leading Producers
Lithium	Australia 47%, Chile 30%, China 15%, Argentina 5%
Nickel	Indonesia 48%, Philippines 10%, Russia 7%, New Caledonia 6%
Cobalt	Democratic Republic of Congo 68%, Indonesia 5%, Russia 5%
Graphite	China 65%, Mozambique 13%, Madagascar 8%, Brazil 7%
Gallium	China 98%, Russia 1%
Platinum	South Africa 73%, Russia 10%, Zimbabwe 8%
Iridium	South Africa 89%, Zimbabwe 8%
Magnesium	China 90%, Russia 5%
Silicon Carbide	China 45%, Norway 8%, Japan 6%, Mexico 4.5%
Rare Earths (incl. Terbium (Dysprosium, Neodymium, Praseodymium)	China 70%, U.S. 14%, Australia 6%, Myanmar 4%

Source: [75].

Given the minimal level of U.S. ECE output, especially for REEs, which is only produced from the Mountain Pass Mine in California's Mojave Desert, there is significant concern about supply vulnerability and reliance on China. The Mountain Pass mine first opened in 1952 and supplied most of the world's REEs from 1965 until 1995, when China emerged as the dominant global producer and processor. Following a toxic waste spill in 2002 the Mountain Pass mine closed, but reopened in December 2010 [86]. There are plans by its operator MP Materials to expand production and open a new metal, alloy, and magnet production plant in Ft. Worth, Texas to enable the U.S. to have greater control of the supply chain, especially for energy magnets [85]. Still, there is a currently a pressing need to expand U.S. production and especially critical mineral processing to increase energy supply security. The DOE has been supporting the development of domestic processing capacity and alternative sources of ECEs for several years, including significant funding from the IIJA and IRA [32,35].

4.4. EV charging & heat pump use may not always reduce emissions much

Given the diversity of energy sources used to generate electricity in the U.S., many scholars have raised concern about whether critical technologies such as the use of EVs for a much higher percentage of the motor vehicle fleet and electric heat pumps will always reduce greenhouse gas emissions. This is an important IRA implementation issue. The major advantage of EVs with respect to the climate is their use of electricity for power instead of high emission sources such as gasoline and diesel fuel. However, electricity sources vary from zero emissions nuclear power, hydroelectricity, and other renewables to the greenhouse gas emitting fossil fuels, with coal combustion having the highest carbon dioxide (CO_2) emissions. While the manufacture of EVs creates around 80% more emissions than gasoline and diesel fueled cars, research has shown that EVs will generate fewer CO_2 emissions over their driving lifetimes than gasoline or diesel-burning cars under nearly any conditions. The largest proportion of EV emissions come from the energy used to charge their batteries [87,88].

Heat pumps, which can provide both heating and air conditioning, are another increasingly popular technology that can lower CO_2 emissions, depending on their energy source and what technology they are replacing for space and water heating in buildings. Former President Biden again invoked the Defense Production Act and on November 17, 2023, DOE announced $169 million in funding to stimulate domestic production of electric heat pumps [89]. One study found that 70% of U.S. homes could reduce emissions by installing a heat pump [90]. Another recent study examined a variety of types of heat pumps replacing natural gas boilers, a common conventual heating technology, which is location specific. The most favorable regions for heat pump adoption were found to be the Northeast and Pacific Northwest, especially when replacing lower efficiency gas furnaces with high efficiency heat pumps [91]. However, this study also showed that in many states if a lower efficiency heat pump replaces a higher efficiency gas furnace the CO_2 savings will be lower [91].

There are large variations in electricity sources used in different U.S. regions. For example, over half the electricity used in the Northwest, most West North Central states, and a few eastern states is carbon free (**Table 5**). Emission-free hydroelectricity dominates in states such as Washington, Oregon, Idaho, Montana, and Vermont, while many West North Central states are leading users of wind power. Several eastern states have a high dependence on nuclear power, e.g., New Hampshire, Maryland, New Jersey, South Carolina and Tennessee, plus Illinois, while California and New York use a mix of clean electricity sources (**Table 5**). At the other end of the spectrum, nine states generate less than 20% clean electricity, including the Appalachian coal states of West Virginia, Kentucky, and Ohio. Therefore, EV charging and heat pump use in different regions could result in vastly different reductions in CO_2 emissions.

Table 5. Queued clean energy projects by technology and U.S. region at the end of 2024 (GWe).

State	Renewable %	Nuclear %	Total carbon-free energy %
Alabama	9.2	31.1	40.3
Alaska	29.7	0	29.7
Arizona	20.5	26.9	47.4
Arkansas	10.6	24.8	35.4
California	42.6	8.5	51.1
Colorado	43.4	0	43.4
Connecticut	3.5	37.4	40.9
Delaware	4.9	0	4.9
Florida	8.2	10.9	19.1
Georgia	11.9	34.0	45.9
Hawaii	37.0	0	37.0
Idaho	68.5	0	68.5
Illinois	14.7	53.3	68.0
Indiana	14.3	0	14.3
Iowa	66.1	0	66.1
Kansas	52.2	15.7	67.9
Kentucky	6.9	0	6.9
Louisiana	2.8	20.4	23.2
Maine	66.9	0	66.9
Maryland	10.8	41.2	52.0
Massachusetts	18.9	0	18.9
Michigan	11.3	21.1	32.4
Minnesota	33.9	21.7	55.6
Mississippi	4.2	14.4	18.6
Missouri	27.4	15.5	42.9

Table 5. (*Continued*).

State	**Renewable %**	**Nuclear %**	**Total carbon-free energy %**
Montana	56.4	0	56.4
Nebraska	36.2	16.2	52.4
Nevada	43.7	0	43.7
New Hampshire	16.5	56.0	72.5
New Jersey	4.0	45.0	49.0
New Mexico	52.2	0	52.2
New York	29.8	21.5	51.3
North Carolina	13.9	32.0	45.9
North Dakota	39.6	0	39.6
Ohio	5.4	12.6	18.0
Oklahoma	44.9	0	44.9
Oregon	65.7	0	65.7
Pennsylvania	3.9	30.3	34.2
Rhode Island	11.8	0	11.8
South Carolina	6.9	54.1	61.0
South Dakota	81.2	0	81.2
Tennessee	13.5	39.0	52.5
Texas	39.0	7.0	46.0
Utah	20.7	0	20.7
Vermont	99.9	0	99.9
Virginia	13.0	26.3	39.3
Washington	73.2	7.5	80.7
West Virginia	6.6	0	6.6
Wisconsin	14.1	15.3	29.4
Wyoming	30.5	0	30.5

Source: [92,93].

Thus, consideration of state-level variations in clean energy use and CO_2 emissions is important, even in light of interstate electricity transfers through RTOs or ISOs. For example, dirty coal or natural gas generated electricity is frequently exported from Pennsylvania to Ohio while clean hydroelectric power generated in Washington or Oregon is often imported by California. The primary permitting of energy projects occurs at the state level, and thus state PUCs play an important role in determining if clean electricity projects are sited, approved, and the power is generated, irrespective of where the electricity is ultimately consumed.

CO_2 emissions from EV charging and heat pump usage can also vary based on the time of day or night, although the effect of seasonality is negligible. For example, it has been shown that emissions will be lower if EVs are charged midday when it is sunny in regions that use more solar energy, e.g., California, Nevada, and Hawaii [94]. Alternatively, overnight charging leads to lower emissions in regions that rely heavily on nuclear, hydroelectric, or wind power, such as New York, Illinois, Texas, and West North Central states. For states with the highest use of carbon-free energy, the time of charging will not matter much. Also, for regions that may greatly expand their use of solar energy, such as the Southeast, the best time to charge EVs and use heat pumps may shift over time.

5. Discussion: policy recommendations for increased electrification based on rapid growth of renewable energy use

The foregoing analysis of U.S. progress in meeting ambitious greenhouse gas emissions reduction goals is encouraging but much more needs to be done. A rapid transition to much greater use of clean and renewable sources of energy is envisioned, though past energy transitions have been slow. Over two dozen tax credits and other provisions under the IRA will help. Critical components of plans to decarbonize the economy include increasing the electrification of the energy sector and greatly increasing the adoption rate of EVs, which are linked to the climate goals and support mechanism for expanding the use of renewable and other clean energy sources under the IRA. However, there is much uncertainty over how effective the clean energy, electrification, and climate provisions of the IRA will be. Fortunately, there is a significant opportunity to fine tune this landmark legislation to help ensure that the most optimistic estimates of emissions reduction are met or surpassed. This will require policymakers to take concrete steps to meet the four challenges we have highlighted that are inherent in the effort to increase the electrification of the energy sector. Consequently, we have identified four sets of policy recommendations for ensuring that increased electrification of renewable and clean energy sources occurs on the largest possible scale over the next decade.

5.1. FERC reform part 1: Fully implement and expand upon FERC's order on improvements to clean energy generator interconnection procedures and agreements

The FERC has historically been a largely overlooked regulatory body that needs to play a much larger role in catalyzing the clean energy transition. The agency is aware of the challenges in meeting the nation's clean energy, electrification, and climate goals and has studied these issues in the last few decades. As a regulatory and non-policy making body, FERC has not been tasked with the legislative mandates and resources to play a major role in the clean energy transition. This will need to change. FERC took an important step in issuing Order 2023 on Improvements to Generator Interconnection Procedures and Agreements in the summer of 2023. Policymakers need to expedite the full implementation of this rule to ensure that the long wait times and significant interconnection queues for clean energy projects become a thing of the past.

However, implementing Order 2023 will not be enough, and FERC should implement a variety of novel ideas to reform the interconnection process [95]. For example, policymakers should explore options for identifying and allocating the costs of proactive transmission investments for clean energy projects. In addition, it would be extremely helpful if generators were given the option to connect to the transmission system without paying for congestion-related upgrades, for energy-only interconnection service. Also, there remains a pressing need to improve the scope, accessibility, quality, and standardization of data on projects in the interconnection queues, such as project attributes and cost estimates. Moreover, policymakers should seek to better coordinate and align data inputs, assumption and process timing between the interconnection and transmission planning processes (see below). Finally, an important queue management solution would be to expand and better use the existing fast-track options (and create new ones) for generator interconnection of clean energy projects.

5.2. FERC reform part 2: Fully implement the transmission planning rule, embrace non-wire technology and reconductoring, and greatly expand PUC staffing for transmission specialists

Policymakers should support the full and rapid implementation of FERC's transmission planning and cost allocation rule 1920 as soon as possible. Implementation of the rule will have several important benefits for the clean energy transition. First, it will help ensure that transmission providers will engage in longer term planning to accommodate changing energy resources, demands, and technologies, which includes a much higher use of renewable resources.

Also, a variety of non-wire technologies and reconductoring of existing lines should be actively promoted. Doing so will more quickly enable low-cost grid decarbonization with renewable resources by increasing the transmission corridor capacity by using existing structures and reducing line losses, while lowering CO_2 emissions, other environmental impacts, and avoiding permitting challenges. For example, advanced conductors can carry twice as much power as conventional conductors [96]. With reconductoring, existing transmission lines could be replaced with aluminum conductor composite cores (ACCs) that are strung along existing transmission towers in existing rights of way, with upgraded terminal equipment as needed. While ACCC wires are more expensive than existing steel-core wires, they can add new capacity at less than half the cost of new lines and be implemented much quicker [96].

In addition, the rule proposes a mechanism to determine a transmission cost allocation method when the applicable states are unable to agree. Moreover, much more needs to be done to adequately incentivize interregional transmission projects and to enable their timely construction, for example performance or incentive-based ratemaking. Also, since it is unlikely that there are enough qualified transmission specialists on the staffs of the federal and state public utility commissions (PUCs) to review the expected large increase in proposed transmission projects, a large increase in staffing and funding for transmission specialists should be strongly supported.

5.3. Mining reform for energy critical elements and the Defense Production Act

The severely antiquated General Mining Law of 1872 is the operational framework for the mining of energy critical elements (ECE) in the country, which has remained largely unchanged for over 150 years. Given this, policymakers should pass comprehensive legislation to update the institutional framework for mining hard rock minerals, including critical minerals needed for clean energy and electrification technologies [97]. Such legislation should include the setting of reasonable royalty rates on hard rock mining and a clear process to protect public lands that are not appropriate for such mining, while also ensuring an accountable mining industry. A streamlined permitting framework is called for but one that protects the environment by requiring sustainable mining standards [98]. Moreover, adequate staffing to review mining permit applications and their environmental impacts should also be addressed.

Even if mining reform legislation is passed, there is an urgent need to address the lack of significant domestic production of ECEs in the U.S. and the overreliance upon foreign imports for domestic supply, especially from China (**Table 4**). Former President Biden invoked the Defense Production Act on March 31, 2022, to strengthen the U.S. industrial base for large-capacity batteries. This action covered lithium, nickel, cobalt, graphite, and manganese, and authorized the U.S. Department of Defense to undertake feasibility studies and modernization projects for mature mining, beneficiation, and value-added processing projects to increase productivity, environmental sustainability, and workforce safety. It also allows for by-product and co-product production at existing mining, mine waste reclamation, and other industrial facilities. It would be helpful if this action was expanded to explicitly cover domestic production of other energy critical elements with high supply risk, e.g. the REEs, gallium, magnesium, and silicon carbide. A follow-up domestic minerals production order by President Trump issued on March 20, 2025, may help, but it was vague about what critical minerals would be covered [99].

5.4. Promote state EV charging and heat pump usage to maximize CO_2 emissions reduction

The time of day or night that people charge their EVs or heat or cool their homes is a behavioral issue, which is a critical implementation issue of the IRA. Homeowners with rooftop PV may charge their EVs at home off of clean energy, but outside of California and Hawaii relatively few homes in the country have rooftop PV systems. While EVs can be programmed through vehicle or smart phone apps to charge when clean energy use in the electric grid is highest, and several electric heat pumps have programmable thermostats, many people may be unaware of the best times to charge EVs or to use electric heat pumps. In addition, many EV smart charging apps and EV charging stations encourage people to schedule charging when electricity prices are lowest, which may be a different time from when electricity use is cleanest.

Consequently, federal and state policymakers should promote the widespread dissemination of information on the times of day and night when the electric grid is most reliant on clean energy sources, such as renewable and nuclear energy technologies. This can be done by requiring state PUCs to have their regulated electric utilities provide disclosures with electric bill mailings on the hourly pattern of clean vs. fossil fuel energy use in their jurisdictions, to be updated monthly. In addition, the clean energy disclosures should encourage ratepayers to shift their EV charging and electric heat pump usage to occur during times of higher usage of clean energy sources whenever possible. Significant and simultaneous expansion of EV fast charging could lead to another problem, namely thermal overload and aging of distribution transformers. This can be addressed by shifting charging times to non-peak hours, and where this is infeasible replacement of traditional transformers with solid-state transformers [100].

6. Conclusion

While the Inflation Reduction Act of 2022 (IRA) is a landmark law that will help the U.S. meet ambitious climate change goals (with or without its formal participation in the Paris Agreement), it will not be enough. Additional policies will be needed for the full potential of the IRA to be realized. As a start, it is critical that policymakers consider a range of actions to increase the effectiveness of the IRA. This will require a comprehensive review of a wide range of policies and programs for their climate mitigation efficacy. For example, the FERC will play an increasingly central role in the clean energy and electrification transition, and has already begun to implement a series of rules that are designed to expedite and improve the interconnection of renewable energy and energy storage technologies to the electric grid, and to increase the siting and approval of interregional transmission lines. These rules will require close attention and adequate resources assigned to the FERC and state public utility commissions (PUCs) to assure their rapid and effective implementation.

The supply chain of energy critical elements (ECEs) needed for clean energy technologies and electrification technologies also deserve greater attention, especially for EVs, offshore wind turbines, and electric transmission and distribution systems. Given the heavy reliance of the U.S. on China and other foreign countries for the majority of the ECEs, greater domestic mining should be strongly encouraged. In the interim, President Trump should clarify that his invoking of the Defense Production Act will help strengthen the U.S. industrial base by targeting the production of rare earth elements (REEs) and other overlooked ECEs.

Finally, with the anticipated large increase in the use of EVs, electric heat pumps, and other clean energy technologies consumers should be strongly encouraged to use them in conjunction with clean energy sources. While some states are already highly reliant on clean energy such as from renewable or nuclear sources, in other places consumers can adjust their behavior to lower and minimize their greenhouse gas emissions.

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Notes

[1] It should be noted that the nuclear power ($30 billion) and clean hydrogen ($13.2 billion) tax provisions are not expected to provide significant climate mitigation benefits, at least not by 2030. The overall estimate of the IRA's spending impact varies, from $783 billion to $1.2 trillion [39].

[2] Comparing capacity factors of intermittent electricity resources with traditional thermal generation is complicated and in some respects an apple to oranges comparison, and revision of how generating capacity is accredited is ongoing throughout the U.S. Still, the sheer scale of clean power generation projects in the interconnections queues is impressive and unprecedented.

[3] The power grid in Texas, the Electric Reliability Council of Texas (ERCOT), is unique in that it is largely cut off from neighboring states and the Western and Eastern Interconnections.

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