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Biden's climate agenda: The most ambitious ever, or overlooking key technological bottlenecks?

Kyle S. Herman

Science Policy Research Unit (SPRU), University of Sussex Business School, Jubilee 367, Brighton, BN1 9SL, United Kingdom

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ABSTRACT

The White House claims that Biden's Climate Agenda is "the most ambitious ever." While the Inflation Reduction Act (IRA) and the Infrastructure Jobs Act (IJA) indeed do earmark billions of dollars for clean energy technologies, they also direct substantial sums of public money to conventional energy and fossil fuels. In comparison, energy storage technologies and projects—which are critical to renewable energy technologies and electric vehicles—are set to receive a much smaller amount. This marks a potentially substantial bottleneck that could eventually derail the administration's climate ambitions. By triangulating three sources of data: policy documents and funding commitments, trends in emissions reductions, and innovation, this article finds that Biden's Climate Agenda might not be as ambitious as the White House claims.

1. Introduction

Renewable energy technologies (RETs) are critiqued for being unreliable due to their intermittency. As the argument goes, the sun does not always shine nor does the wind always blow [1]. According to this view, therefore, RETs cannot fully replace conventional energy systems and fossil fuels. An opposing view recognises that the transition to RETs will require restructuring infrastructure, energy markets, and institutional arrangements; after such restructuring, there will only be "few, if any technical limits to the planned system integration of RE technologies across the very broad range of present energy supply systems worldwide" [2; pg. 4]. The argument that renewables will not eventually replace fossil fuels is, according to the second view, therefore a "false impression due mainly to the lack of understanding that a reliable, cost-effective utility scale storage technology does actually exist" [3, pg. 389].

From this perspective, the missing technological ingredient is widespread development and deployment of Energy Storage (ES) [4]. This requires public funding, including for research and development, and demonstration (RD&D)—and project funding, including grants and loans. Though RD&D and innovation for ES technologies has accelerated in the last two decades, ES is not a new type of technology. The world's first rechargeable battery was invented by Gaston Plante in 1859 (electrochemical storage), dams have stored energy for centuries (mechanical storage), while humans have effectively stored thermal energy in rocks since the Neanderthals roamed far and wide (thermal storage). In modern times, the deployment of ES has important climate benefits because of its close connection to the penetration of RETs—e.g., for residential and commercial clean energy, and electric vehicles [5]. ES, moreover, effectively reduces operational costs, enables transmission, and can also increase security of energy supply [6]. In short, investment, innovation and deployment of ES is vital for achieving 100 % renewable energy systems [7].

The aim of this article is to empirically explore the claim that the Biden Administration's climate and energy policies are the most ambitious ever by analysing three types of data: policies and funding, emissions and technological deployment, and innovation. The extent to which the Administration's climate policies induce innovation, and reduce emissions over time, is a challenging research question [8]. To confront this challenge, this study introduces two novelties within this research domain: first, we leverage Natural Language Processing (NLP) to more deeply explore the funding on offer. Second, we triangulate data—on funding, greenhouse gas emissions (GHGs), and technological innovation measured using patents—to assess the extent to which, and potential for, the Administration's Climate Agenda to deliver on emissions reductions and innovation.

The US rejoined the Paris Climate Agreement days after Biden became president in January 2021. As of February 2024, 72 countries have set goals to achieve net zero GHGs, most by the year 2050 [9]. Though net zero remains a controversial term, giving prominence to some unproven carbon reduction technologies, it remains a cornerstone of the Paris Climate Agreement [10]. Shortly after rejoining Paris, the

E-mail address: K.Herman@sussex.ac.uk.

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Biden Administration committed to 100 % clean energy by 2035 [11], and ushered in several monumental pieces of related legislation: the Chips and Science Act (CSA), the Infrastructure Investment and Jobs Act (IIIJA), and the Inflation Reduction Act (IRA), each with substantial public subsidies channelled into myriad types of energy technologies and related infrastructure—including RETs, ES, Direct Air Capture (DACs), Carbon Capture and Storage (CCS), as well as conventional fossil fuels (CFFs) [12].

The White House claims that the Biden Administration's Climate Agenda is "the most ambitious climate, conservation, and environmental justice agenda in history" [13]. Although at first glance, based on the size of energy subsidies under these three pieces of legislation—totalling $314,477,000,000 based on our calculations and supplemented by others—this claim would seem to ring true, scratching below the surface reveals some nuance to these subsidies. The data show that a fair share of funding is directed to conventional fossil fuel and nuclear energy. Yet technological innovation for DACs and CCS still lag far behind RETs and ES—meaning that it is unclear if such funding for the former two will lead to significant emissions reductions. Considering the potential funding and innovation mismatches, there are two further risks: underfunding ES will limit the widespread penetration of RETs, while overfunding conventional energy technologies could crowd-out the clean energy transition by delaying the net-zero energy transition [14].

The article is structured as follows. The next section presents the methods and framework for analysis. Section 3 provides the results, with a series of depictions of the data presented longitudinally. Section 4 is the discussion, and Section 5 is the conclusion.

2. Methods

Innovation and deployment of energy technologies and infrastructure requires substantial public investment [15]. The so-called "carrots" on offer under the Biden Administration are appealing, but they warrant careful investigation [16]. To assess Biden's Climate Agenda, we structure our investigation by way of an empirical case study delineated over three separate domains relevant to energy and climate: (1) policies and funding, (2) emissions and energy technology deployment, and (3) technological innovation.

The first was investigated through policy documents, of which 30 were obtained starting from the Infrastructure Jobs Act (passed on November 15, 2021). We then applied Natural Language Processing (NLP) to extract relevant policies and funding. We downloaded the documents, then uploaded them into Provalis Wordstat® [17], enabling extraction of key quantitative and qualitative datapoints, such as funding committed, and expectations about technological innovation from policymakers. The second data domain was estimated by drawing on the data from five agencies: the US Environmental Protection Agency (EPA), the US Department of Energy (DoE), the US Environmental Information Administration (EIA), the US Office of Fossil Energy and Carbon Management (OFECM) and the US Office for Clean Energy Demonstrations (US-OECD). Innovations are estimated by patents filed under the USPTO, with data extracted from the OECD. We then interpret these data to understand the level of ambition, specifically how this translates into potential emissions reductions and innovation inducement.

3. Results

To reiterate, we present the results according to the framework outlined in Section 2: (1) policies and funding; (2) emissions and deployment, (3) innovation. Each subsection includes figures and data to supplement the discussion of the results.

3.1. Policies and funding

From 2021 to 2022, the US Federal Government introduced three

Table 1
Policies and funding for energy technologies under the Biden Administration.

Type	Funding	Amount ($ millions)
ES	Critical material innovation, efficiency, and alternatives (2022)	$230
ES	Critical material innovation, efficiency, and alternatives (2023)	$100
ES	Critical material innovation, efficiency, and alternatives (2024)	$135
ES	Critical material innovation, efficiency, and alternatives (2025)	$135
ES	Critical material supply chain research facility: USC 1606	$40
ES	Critical material supply chain research facility: USC 1606	$35
ES	Rare earth mineral security: usc 13,344 (2022)	$23
ES	Rare earth mineral security: usc 13,344 (2023)	$24.2
ES	Rare earth mineral security: usc 13,345 (2024)	$25.4
ES	Rare earth mineral security: usc 13,346 (2025)	$26.6
ES	Rare earth mineral security: usc 13,347 (2026)	$27.8
ES	Energy storage demonstrations projects: usc 1732	$355
ES	Long duration demonstration initiative and joint program usc 1732d	$150
ES	DOE advance clean energy storage (ACES)	$504
ES	US-OECD pumped hydro	$10
ES	Distributed energy systems demonstrations grant	$50
	Total ES funding	**$1871**
FF	Advanced fossil energy projects	$8500
CCS	Carbon capture	$2500
CCS	Carbon capture prize	$100
CCS	Carbon capture demonstration and pilot programs usc 16,292	$387
CCS	Carbon capture demonstration and pilot programs usc 16,293	$200
CCS	Carbon capture demonstration and pilot programs usc 16,294	$200
CCS	Carbon capture demonstration and pilot programs usc 16,295	$150
CCS	Carbon capture demonstration projects program: 1692 b2c	$937
CCS	Carbon capture demonstration projects program: 1692 b2c	$500
CCS	Carbon capture demonstration projects program: 1692 b2c	$600
CCS	Carbon storage validation and testing	$2500
CCS	Carbon capture demonstration projects program, US-OECD	$2537
CCS	CO2 Transportation	$2100
CCS	CO2 pipeline infrastructure	$2500
DACS	Direct air capture	$3500
DACS	Direct air capture technologies prize (pre-commercial): *sec* 41,005, usc 16,298	$15
DACS	Direct air capture technologies prize (commercial): *sec* 41,005, usc 16,298	$100
FF	New carbon management	$1200
CCS	Production credit for CCS	$3000
EOR	EOR: $35 per ton of carbon captured*	–
CCS	CCS: $85 per ton of carbon captured*	–
DACS	DACS: $180 per ton of carbon captured*	–
CCS	CCUS: $60 per ton of carbon captured8	–
	Total CCS/DACS/FF funding	**$31,526**
CE	Clean energy generation (tax credits)	$131,000
CE	Clean fuels	$19,000
CE/EE	Clean energy and energy efficiency	$37,000
CE	Clean energy manufacturing	$37,000
EE	Energy efficiency	$11,000
E	Electricity grid	$1650
H	Hydrogen hubs plan	$10,000
H	Clean hydrogen electrolysis program	$1000
CE	Clean energy demonstrations on mine land	$500
RET	Renewable energy technologies	$30,000
H	Green hydrogen production credit: $4/kg*	–
	Total clean energy funding	**$278,150**
N	Advanced nuclear reactor demonstrations (2022)	$511
N	Advanced nuclear reactor demonstrations (2023)	$506

(*continued on next page*)

Table 1 (*continued*)

Type	Funding	Amount ($ millions)
N	Advanced nuclear reactor demonstrations (2024)	$636
N	Advanced nuclear reactor demonstrations (2025)	$824
N	Advanced nuclear reactor demonstrations (2026)	$453
	Total new nuclear energy funding	**$2930**

Sources: Collected from public documents and databases, and tabulated using natural language processing (NLP).

* Total funding unavaible and will depend on deployment of these technologies.

major public funding mechanisms for energy technologies and infrastructure: "the brains" of the Chips and Science Act (CSA), worth $54 billion; the Infrastructure Investment and Jobs Act (IIIJA)—the "backbone"—which directs $98 billion for clean technology and industrial decarbonisation infrastructure; and the Inflation Reduction Act (IRA), or the "engine" estimated to result in more than $360 billion for clean technology R&D, infrastructure, and demonstration projects [18, pg. 12]. We disaggregate the funding opportunities—or regulatory "carrots"—according to four categories: Energy Storage (ES), Conventional Fossil Fuels (CFF)—which includes carbon capture and storage (CCS), direct air capture (DACs), and enhanced oil recovery; Clean Energy (CE), which includes energy efficiency, green hydrogen, and renewable energy; and, Nuclear Energy (NE). Based on NLP of available documents, we estimate the following total funding for each technology

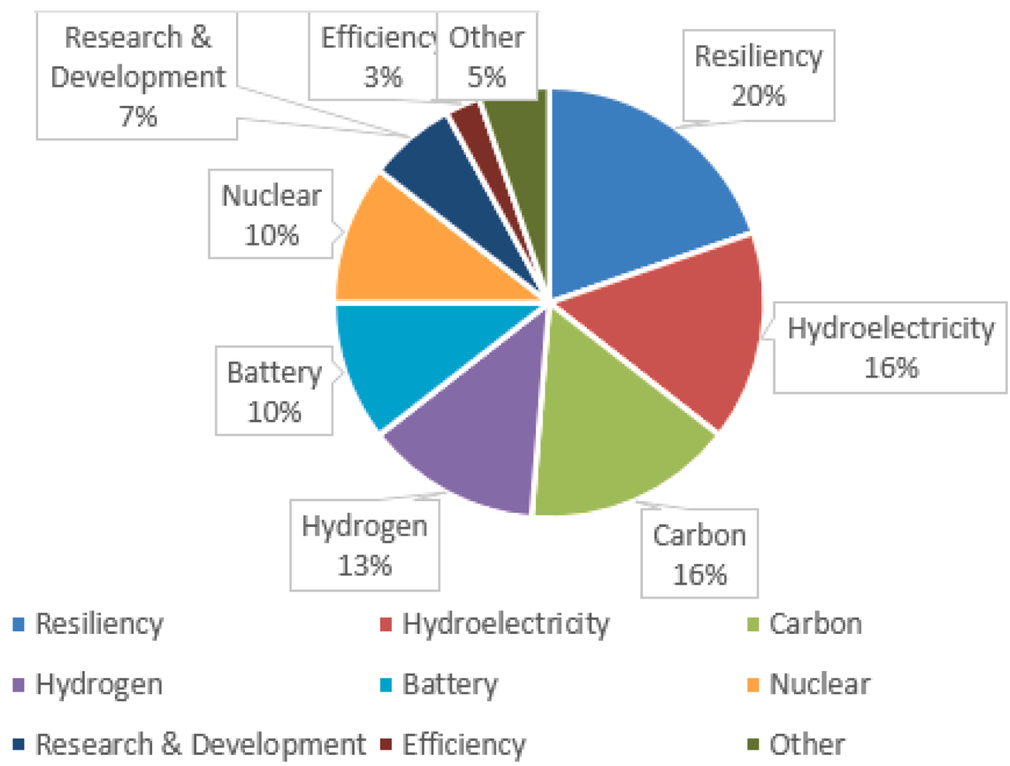

Fig. 1. Planned energy funding under the IJA/IRA (billions of USD, 2022 estimates).
Source: McKinsey & Company, 2023.

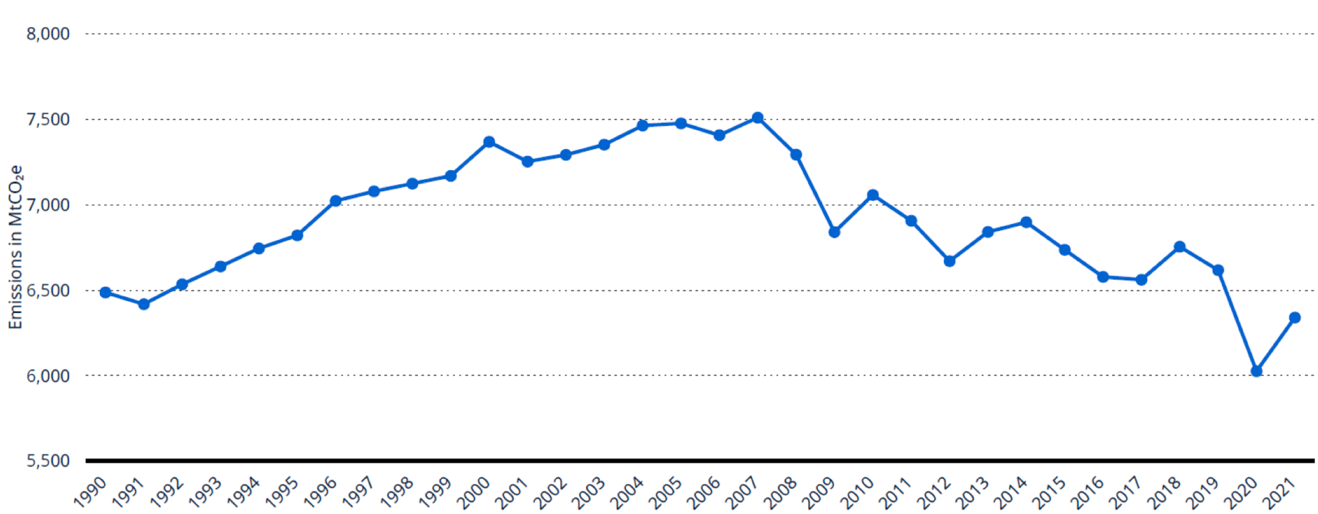

Fig. 2. US carbon equivalent emissions, million metric tons per year (1990–2021).
Source: US EPA, 2023.

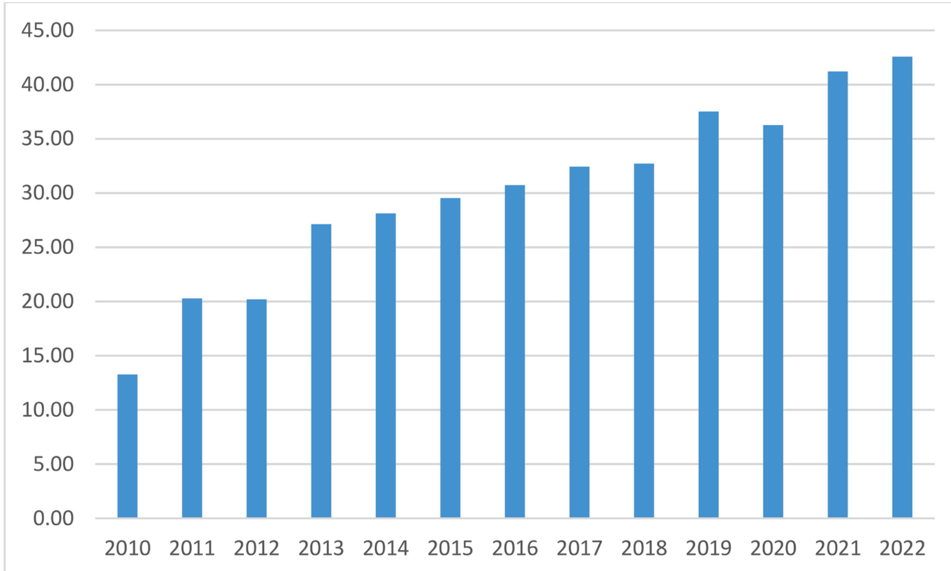

Fig. 3. Capacity of CCS (2010–2022) in million metric tons per year.
Source: Total metric tons captured using CCS from 2010 to 2022. Source: Global CCS Institute (2023).

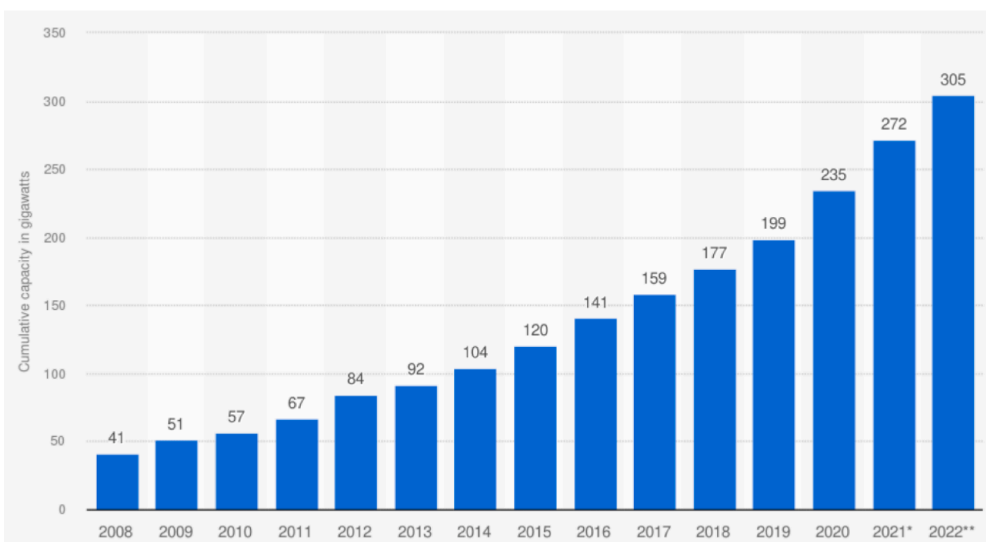

Fig. 4. US Renewable energy capacity in gigawatts (2008–2022).
Source: Bloomberg NEF, 2022.

vector: $1.871 billion for ES, $31.526 billion for CFF, $278.15 billion for CE, and $2.93 billion for NE. While funding for CFF dwarfs ES and NE, CE is clearly set to receive the most [19]. Nevertheless, tax credits for CCS and DACs might substantially expand the final total for CFF (Table 1 and Fig. 1) [19].

3.2. Emissions and deployment

We now investigate greenhouse gas emissions (GHGs), the main target of climate legislation since they lead to climate change. Since 2008, US emissions from energy have declined slightly, though natural gas emissions (which also includes methane emissions) have increased. On the other hand, coal, petroleum and other liquids' emissions have trended downward down (Fig. 2). As discussed below, the reduction in emissions is largely attributed to fuel switching and renewable energy, rather than CCS and other carbon dioxide removal technologies (CDRs) [20].

As outlined in Table 1, CCS technologies and projects are set to receive handsome subsidies under Biden's Climate Agenda—totalling $18.21 billion— DACs will receive $4.815 billion, though DACs hubs are also expected to receive an additional $3.5 billion. Though the capacity of CCS in the US has steadily increased since 2010 (Fig. 3), the quantity captured remains infinitesimally small in comparison to total emissions from fossil fuels. CCS currently captures 0.75 % of total GHGs, or 45 out of 6000 million metric tons per year. CCS therefore has a long way to go before making any significant dent in GHG abatement [21].

Renewable energy is growing steadily, though it requires a substantial increase in ES capacity in the coming years to reach 2030 emissions reduction goals under the US Nationally Determined Contributions (NDCs) submitted to the UNFCCC (Fig. 4) [22].

Now let us review ES in the US. ES is still dominated by vintage hydro pumped storage projects (Fig. 5), despite modest public investments in new energy storage technologies (e.g., batteries, capacitors, and other electrochemical and electromechanical storage facilities). Though

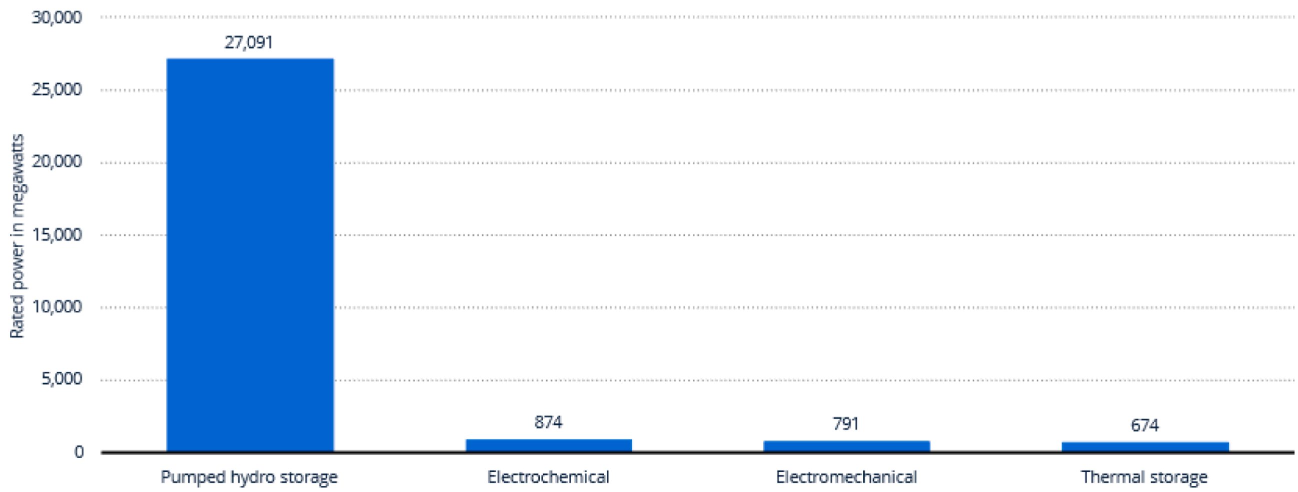

Fig. 5. Rated power of ES in the US, by technology in Megwatts (2021).
Source: Statista, 2024.

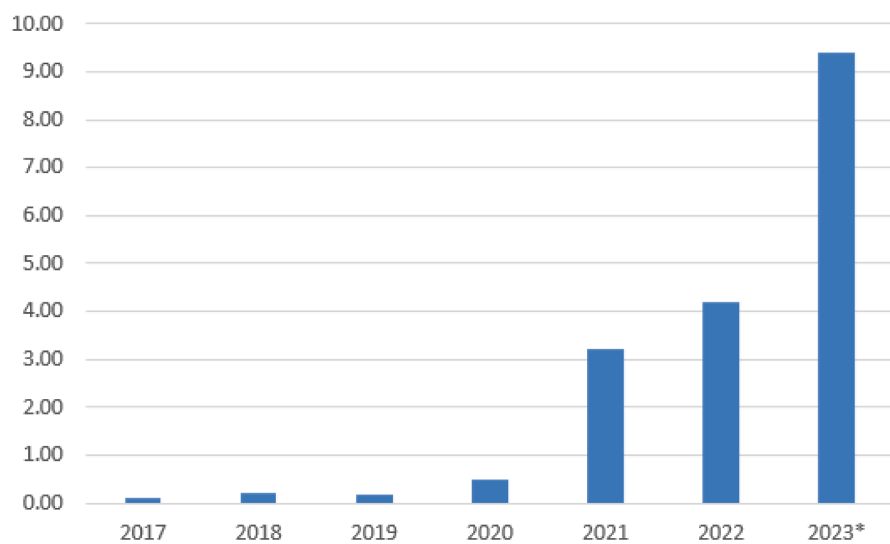

Fig. 6. Annual battery capacity additions in Gigawatts (2017–2022).
Source: EIA.

pumped hydro storage is important, these facilities are geographically constrained to locations that have access to large or dams, which are often not located adjacent to largescale renewable energy plants—e.g., in the deserts in Western states.

Nevertheless, and providing some evidence that Biden's Climate Agenda is benefiting ES, in 2023 the EIA estimated a marked uptick in battery storage capacity, increasing to nearly 10 gigawatts (Fig. 6). Battery storage, in addition, is expected to reach 27 GW by 2031 [23]. Notwithstanding ES capacity additions in recent years, the US, surprisingly, still trails behind other countries with far less renewable energy and energy storage demand (Fig. 7).

3.3. Innovation

We now look at innovation, as proxied by patents [24]. As depicted in Fig. 8, batteries are the most protected ES innovation—likely driven by electric vehicles (EVs)—while capacitors, thermal, and mechanical energy storage have experienced a much smaller rate of innovation since 1995.

Now, let's compare total ES with CCS patenting. Since rapid development of ES is expected to similarly drive RETs—which would have the effect of reducing the need for CCS connected to CFFs—we draw a comparison between innovation in CCS and ES (Fig. 9). As shown, ES innovation, as proxied by patents, is far greater than CCS. Indeed, CCS innovation has remained flat since 2000, while ES experienced a market increase from 2008 to 2013, and has remained steady at around 1500 patents per year since 2012. This implies that, while ES innovation is accelerating, CCS is not—which matters since CCS remains a niche technology that is not uniformly proven at commercial scale [25].

4. Discussion

Biden's climate policies since 2021 are ambitious. The IIJA and the IRA have, indeed, earmarked substantial funding towards energy technologies. Are they the most ambitious ever? To address this question, we investigated policies and funding, emissions and deployment, and innovation. We showed that both CEs and CFFs dominate the total funding, with ES and NE receiving a much smaller proportion of the total (see Fig. 10). The total numbers for CFFs are unclear—but might indeed rise immensely in coming years—since future tax rebates depend on the performance of CCS, DACs, and enhanced oil recovery (EOR).

Though we have shown that Biden's Climate Agenda offers

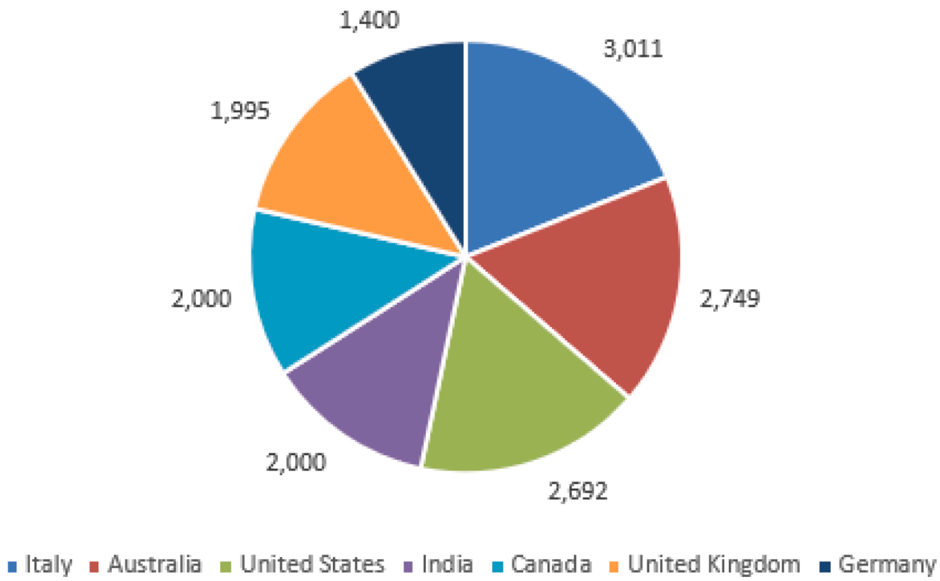

Fig. 7. Capacity of electrochemical energy storage projects worldwide, in megawatts (2022).
Source: PTR Energy Storage Service Trends, 2023.

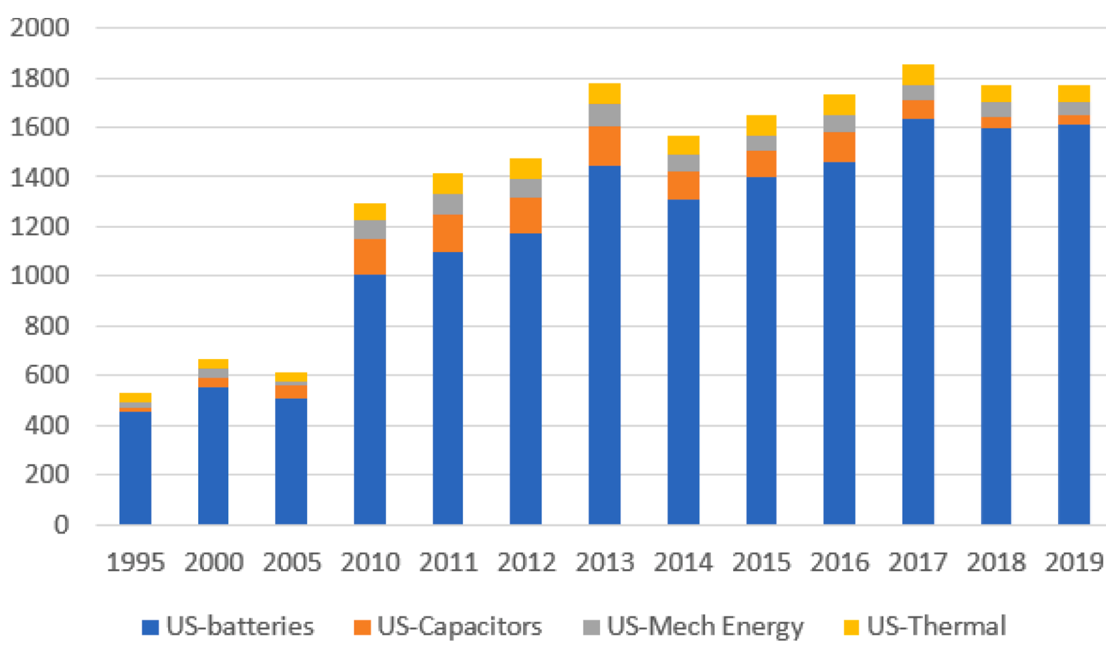

Fig. 8. US energy storage patents (1995–2019).
Source: OECD statistics (https://stats.oecd.org/).

favourable funding to CFFs and related technologies (e.g., CCS, DACs, and EOR), there is a strong argument to be made that the IRA and the IJA would not have passed the Republican-dominated Congress without handsome subsidies to the fossil fuel industry [26]. Nevertheless, the dearth of funding for ES could well serve as a major bottleneck for deployment of CEs and RETs. This is a major shortcoming and may delay part of the $278 billion funds for clean energy project development since largescale RET projects might not be feasible without innovation and financial support for ES.

In addition, the $31.5 billion initially earmarked for CFFs could increase substantially—the total of which remains unknown since this funding will be delivered via the IRS and future tax breaks. The irony is that this might increase rather than reduce inflation [27]. Not only CFF and related technologies, but also massive build-out of new pipeline infrastructure is required for CCS, DACs, and blue hydrogen, making it even more unclear what the total subsidies will amount to for CFFs [28]. While it is true that U.S. emissions have plateaued in the last decade, this cannot be attributed to largely untested DACs and CCS installations—indeed, CCS makes up less than 1 % of carbon reductions [29]. On the other hand, RETs—which currently account for 21 % of total electricity production—have proven to reduce emissions dramatically [30]. Two other socioeconomic concerns are also relevant. First, European countries have been put on the backfoot, with many companies stating that they will relocate to the US since Biden's policies will offer more attractive subsidies [31]. In addition, though the IRA might lead to a reduction in emissions, inflation itself might erase these benefits by reducing the overall investment directed towards CETs, as well as ES [32].

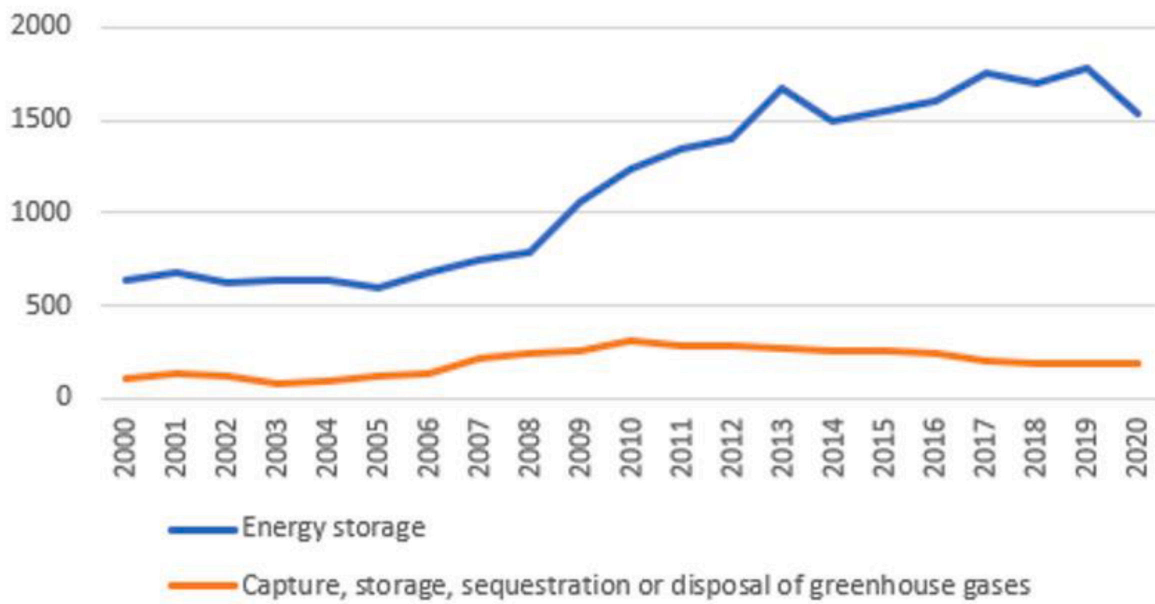

Fig. 9. US Energy Storage vs. CCS patenting (2000–2020).
Source: OECD statistics (https://stats.oecd.org/).

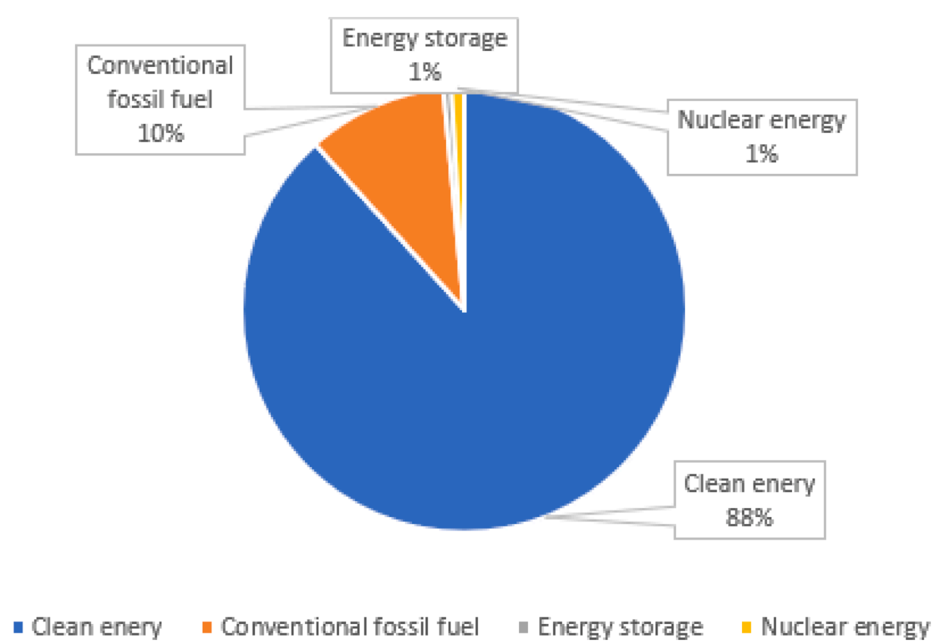

Fig. 10. Distribution of funds under the IRA/IJA (2023).
Source: Author's compilation of data from five US government agencies.

A more ambitious climate policy would rest on the innovation potential of energy storage technologies, which demonstrate stable patenting trends in the last decade, and will be the backbone for CEs and RETs [33]. Clearly, the private sector understands this, shown in sustained ES investments (see Fig. 11). It is therefore high-time that US public funds get channelled much more aggressively into three ES vectors: research and development (R&D), project grants and support, and support for basic materials and manufacturing [34]. The last has, indeed, garnered much attention in the last year though, based on current ES deployment, additional support is needed [35].

5. Conclusion

This study investigated three separate domains relevant to energy and climate under Biden's climate initiatives: (1) policies and funding, (2) emissions and deployment, and (3) innovation. Though the White House claims that Biden's climate policies are "the most ambitious ever," the data show that this is might not pan out. To be sure, the penetration of renewable energy is accelerating thanks to deployment of ES; indeed, Bloomberg (2023) estimates that private investment in US battery supply chains reached $92 billion during Biden Administration's tenure [36]. Therefore, not only from an innovation perspective, but also from an economic perspective, it would appear that ES should be a climate policy prerogative—yet it is not under current policies. In

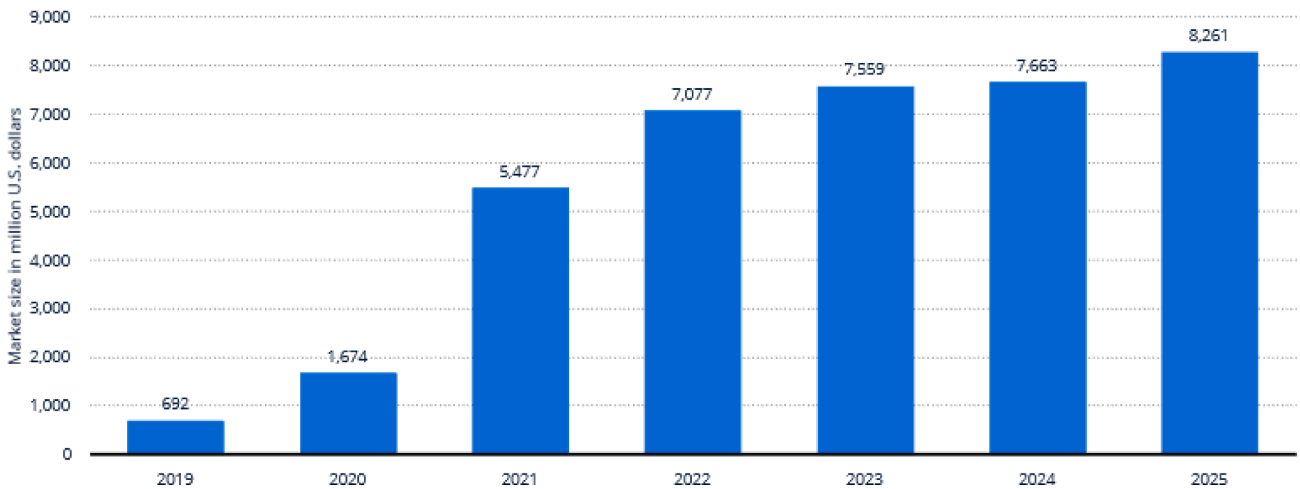

Fig. 11. U.S. Energy storage investment, 2019–2025 (in million U.S. dollars).
Source: Wood Mackenzie, 2023.

addition, the funds for ES (and clean energy) might be in jeopardy should opposition ensue in the US Senate in 2024, or if Trump gets re-elected.

Under Biden's Climate Agenda, the fossil fuel industry is set to receive substantial subsidies to experiment with technologies such as CCS and DACs. These investments are not only very risky—since only a handful of operational CCS plants and several DAC demonstration plants currently exist [37]—but also might crowd out clean energy and ES alternatives [14,38]. The overarching issues is that these projects will also require massive funding for carbon pipeline and storage infrastructure [39], which otherwise might be better spent on rapidly scaling up energy storage technologies.

There are several limitations of this study. First, Biden's Climate Agenda is ongoing, and many of the subsidies are yet to be given, in particular for the CFF industry [40]. In addition, the total funding provided through tax credits for CCS and DACs will not be known until 2030, the year they are set to expire [41]. Though these technologies might be needed to reduce emissions in hard-to-abate sectors, their future costs and technological performance remain largely unknown [42]. In addition, the emissions reduction potential of any of the technologies being funded remains unknown, since it is contingent upon future innovation and technological performance [43]. Finally, future studies could extend this one in several directions. First, there is a need to uncover what funds have already been delivered. Second—since the rapid deployment of CETs and ES would reduce the need to rely on carbon removal technologies— researchers could focus directly on the comparison of funding and innovation with respect to carbon dioxide removal technologies (e.g., CCS and DACs), on the one hand, and ES technologies, on the other.

CRediT authorship contribution statement

Kyle S. Herman: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare no conflict of interest.

Data availability

Data will be made available on request.

Ethical statement

The authors declare no conflict of interest.

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