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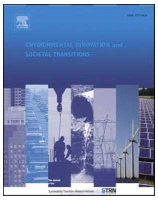

Research article

How public policy and public salience interact with the energy transition: The case of commercial-scale battery storage adoption

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ABSTRACT

This article analyzes potential policy drivers affecting the adoption of commercial-scale battery storage (CSBS) technologies across high-income countries within the context of the energy transition from 1992-2018 with panel econometric methods. We first estimate a standard technology diffusion model and then investigate various factors that could “shift” the diffusion curves. The first main set of results suggests a positive relationship between public salience and CSBS adoption. The second set of results investigates how latent energy market reactions may influence CSBS adoption. Those results show, surprisingly, no relation or a weak negative relation between the structure of the energy mix and CSBS adoption. The third set of results investigates the effect of public policies: targeted vis-à-vis broad innovation policies. Here, the results indicate a relationship between higher RD&D expenditures for electricity storage and greater rates of CSBS adoption.

1. Introduction

As variable renewable energies (VRE) expand, new flexibility solutions are needed to maintain grid stability. Energy storage is among the most discussed options, valued for enabling VRE integration as an architectural technology, supporting decentralized supply, and aligning with market-oriented, technological policy approaches (Andersen et al., 2023; Ganowski and Rowlands, 2020; IEA, 2024; Waterson et al., 2022). This study examines the factors influencing national adoption of commercial-scale storage technologies, distinguishing their role as an architectural technology from core technologies of VRE diffusion. We assess the impact of electricity system demand, innovation and industrial policy, public salience, and political preferences. Our findings suggest that green and ethnic party support, along with targeted RD&D in electricity storage, accelerate storage deployment. In contrast, liberal political preferences, latent market demand, and broader innovation policies show no significant effect.

Electricity storage offers diverse applications—from residential buildings to industrial sites and utilities—by stabilizing the grid and reducing electricity costs (Castagneto Gissey et al., 2019; Sterner et al., 2019). Yet, despite its potential, grid-connected commercial-scale battery storage has not yet played a major role in energy systems (Dougherty et al., 2021; IEA, 2022a). In industrial and grid-side contexts, storage enhances reliability and power responsiveness (Ornetzeder et al., 2019), while in the residential sector it enables prosumer participation and a decentralized energy transition (Kairies et al., 2019; Kloppenburg et al., 2019). Because energy systems are shaped by diverse institutional, political, and technical dynamics, policy designs must be context-specific. However,

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cross-border transfer of effective policies remains difficult, complicating efforts to set international standards (van den Bergh et al., 2020). This article identifies shared policy drivers and energy systems conditions across high-income countries.

While first studies on diffusion within a national framework for small storage systems are published (Brown, 2022; Kairies et al., 2019), the global diffusion of grid-connected storage technologies has only been descriptively empirically analyzed (Buß et al., 2016; IEA, 2022b) but—to our knowledge —not yet using inference methods. Other studies, using patent-data, focused only on the innovation side (e.g., Fabrizio et al., 2017; Feng and Lazkano, 2022), while others model potential future developments (Han et al., 2024; Parra and Mauger, 2022). Thus, there is a literature gap for inference studies on influencing factors on the diffusion of larger energy storage system technologies, which go beyond private dwellings, which we call here commercial-scale battery storage (CSBS). This article seeks to address that gap by asking: **What policy drivers influence the diffusion of commercial-scale battery storage systems (CSBS) across high-income countries?** To address this, we analyze potential policy drivers — including social, economic, and energy system conditions — influencing CSBS diffusion across high-income countries from 1992 to 2018, using panel econometric methods. We first estimate a standard technology diffusion model and then investigate various factors that could “shift” the diffusion curves. The first main set of results suggests a positive relationship between public salience and CSBS adoption. We use several proxies for public salience of environmental issues, decentralization and pro-technology preferences that correlate strongly with CSBS adoption. The second set of results investigates how latent energy market reactions may influence CSBS adoption. Those results show, surprisingly, no relation between the structure of the energy mix and CSBS adoption. The third set of results investigates the effect of increased targeted and broad innovation policies, including RD&D spending and guaranteed feed-in tariffs. Here, the results indicate a relationship between higher RD&D expenditures for electricity storage and greater rates of CSBS adoption.

The study also has some limitations: data availability confines the scope of our analysis to 24 OECD countries over 26 years (1992 – 2018). While we estimate potential influences on storage diffusion accelerations over this time period, we do not forecast future diffusion, nor do we normatively ascertain the extent to which promotion of energy storage is optimal from a public policy point of view. Our objective is to better understand which factors have led to the expansion of energy storage over the last decades.

The article is structured as follows: we begin with a literature review that outlines theoretical perspectives on the socio-technical nature of energy transitions, which inform our understanding of how multiple factors—such as institutions, technologies, and public discourse—interact to shape technology diffusion. This theoretical lens guides the development of our analytical framework and the selection of key policy drivers examined in the empirical analysis. We then describe our methods and data, followed by the presentation of panel regression results. We start with a baseline diffusion model and then analyze how policy drivers—including social, economic, and energy system conditions—may shift diffusion trajectories. Lastly, we compare our findings with those of related studies and discuss them in light of broader debates about the role of policy in the diffusion of commercial-scale battery storage (CSBS).

2. Literature review

2.1. Technology diffusion in energy transitions

Technological change is inherently socio-technical in nature when it is closely tied to society, especially during shifts in technology that also involve changes in institutions, practices, and governance (Geels et al., 2017a).

Energy transitions—such as the transition from fossil-based systems to renewable energy—are a particular case. Energy technologies were considered to take a particularly long time to diffuse. They were typically very large-scale, thus taking a long time to build and having a long lifespan (Gross et al., 2018, p. 2011; Popp et al., 2011; Verdolini et al., 2018). Moreover, they were and are such essential parts of infrastructures that societies are deeply locked into fossil-fuel energy systems (Hughes, 1983; Negro et al., 2012). However, recent examples of rapid energy transitions (Sovacool and Geels, 2016) demonstrate that social tipping points exist, upon which non-linear shifts from fossil to renewable energies occur suddenly (Alkemade et al., 2024). Conversely, empirical evidence suggests that the acceleration of niche innovations predominantly involves technologies that do not necessitate a comprehensive transformation of existing systems (Geels and Turnheim, 2022; Newell et al., 2022).

Here, the conceptualization of architectural technologies by Andersen et al. (Andersen et al., 2023) proves valuable, as it distinguishes between core and architectural technologies (see also Christensen, 1992). The former “directly help the system service its societal function,” such as power plants in electricity supply, while the latter facilitate productive interplay among core technologies to form a larger, seamless system” such as converter technologies or energy storage (Andersen et al., 2023). Moreover, the complementarities between architectural and core technologies are on the system level rather than on the technology level (Andersen et al., 2023; Markard and Hoffmann, 2016). Thus, the energy transition is a systems transition in which the system architecture is altered through interactions between several (sub-)systems, encompassing both technological and social aspects (Andersen et al., 2023; Bettin, 2020).

Although the energy transition is not centered on individual technologies (Geels and Turnheim, 2022), analytically focusing on specific architectural technologies is valuable from a policy perspective. As key enablers, these technologies integrate and support others, making them leverage points for accelerating systemic change. A problem structured in this way, along with an accompanying policy solution, can be more easily communicated in the policy arena (Turnbull and Hoppe, 2019) while still contributing to a system-changing policy mix.

Comparing the diffusion of individual technologies is limited due to differences in their functions within larger systems or their value-laden nature. There are differences in the diffusion process depending on the type of technological innovation. For example, the diffusion of consumer products shows different dynamics than that of industrial goods (Bianchi et al., 2017; Herbig, 1991; Schiavone and Simoni, 2019). According to some studies, industrial products are less dependent on opinion leaders (Day and Herbig, 1990).

Thus, the situational context of a particular technology within the socio-technical system varies, depending on its maturity, markets, and interdependent technologies. Consequently, it is not always possible to generalize insights from other (energy) technologies. This is particularly true given the architectural nature of battery storage in the energy system (Andersen et al., 2023), for which diffusion patterns were not adequately analyzed in the literature.

However, analyses of the diffusion of other energy technologies highlight the importance of interactions between multiple processes (Geels and Ayoub, 2023; Markard and Hoffmann, 2016), such as cross-technology legitimacy feedbacks (Thonig and Lilliestam, 2024).

Technology development and diffusion are heavily influenced by self-reinforcing processes where cumulative causation can lead to virtuous or vicious cycles. Here, “acceleration in system change may occur when functions interact and lead to virtuous cycles.” (Hekkert et al., 2007, p. 427) These mechanisms are central to understanding tipping points—critical moments at which a system shifts into a new state—as is sought in the context of the energy transition (Alkemade et al., 2024).

2.2. *External influences*

Innovation studies emphasize the importance of these internal dynamics and self-reinforcing processes. Still, various forms of external factors also influence the development and diffusion of technology.

External factors operate through various mechanisms, including what the literature terms "external links," landscape factors, and "structural couplings" that share common elements across actors, networks, institutions, and technologies (Bergek et al., 2015). The literature identifies different types of contextual structures that can influence innovation system dynamics: interactions between different (technological) innovation systems, pre-existing infrastructures and institutional arrangements, and context structures related to the provisioning of system-level assets and capabilities (Bergek et al., 2015; Geels and Ayoub, 2023).

2.2.1. *Country-specific vs. global factors*

A key distinction in understanding external influences concerns the spatial scale of their operation. Technology adoption processes exhibit significant variation between countries due to slowly changing national and regional conditions, including institutional frameworks, policy environments, and socio-political contexts (Hansen et al., 2024; Verdolini et al., 2018). These country-specific factors create the foundation for differential adoption patterns across national contexts, with policy scalar orientation playing a particularly important role in technology legitimacy.

Simultaneously, the interconnected nature of global innovation systems means that certain external influences operate symmetrically across countries. Global events such as technological breakthroughs, international price movements, or worldwide shifts in innovation trajectories affect diffusion processes similarly across national contexts (Binz and Truffer, 2017). Contemporary research suggests these global dynamics can create social tipping points that accelerate transitions when combined with appropriate local conditions (Alkemade et al., 2024).

2.3. *Situating our approach in relation to existing frameworks*

This study draws inspiration from the technological innovation systems (TIS) analytical framework while integrating insights from innovation studies and political studies approaches, positioning itself firmly within the broader transition studies literature. Although our approach aligns with certain elements of the systematic six-step TIS process outlined by Bergek et al. (2008)—particularly in defining the technological scope (Step 1), identifying inducement and blocking mechanisms (Step 5), and specifying policy issues (Step 6)—it deviates substantially from traditional TIS methodology in several key respects. Most notably, our panel econometric approach does not provide the detailed structural component analysis typical of TIS studies, thereby forgoing the systematic mapping of actors,

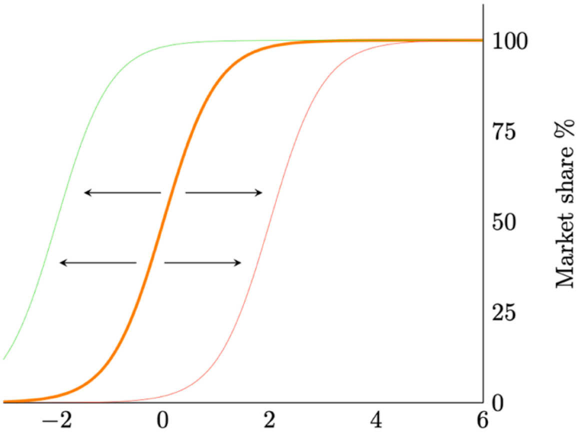

Fig. 1. Shifting the Diffusion Curve.

networks, and their interactions that characterizes Steps 2 and 3 of the TIS framework. Instead, institutions are incorporated through the analysis of formal policy instruments and public issue salience as a proxy for informal institutional dynamics. This methodological choice stems from the scope of our analysis, which examines technology diffusion across multiple countries over an extended period—a scale that necessitates a more aggregated analytical approach than the granular, case-study methodology often employed in TIS research. Rather than attempting a direct quantification of TIS functions as pursued in some simulation studies (e.g., Walrave and Raven, 2016; Wang et al., 2017), our econometric framework operates at a different level of abstraction, enabling systematic cross-national comparison while sacrificing the detailed system-level insights that characterize traditional TIS analysis.

3. Analytical framework

Our analytical approach focuses specifically on country-varying external factors that can potentially "shift" technology diffusion curves through policy intervention or changes in the energy system (Fig. 1). This analytical strategy enables us to identify specific external mechanisms through which national policies, institutional arrangements, and socio-political conditions can accelerate or hinder the adoption of commercial-scale battery storage technologies, providing actionable insights for policy design and implementation.

Broader landscape factors—such as global climate discourse or international technology prices—while important for overall diffusion dynamics typically fall outside the direct scope of national energy and innovation policy (Geels, 2024). These global influences are controlled for in our study design through time-fixed effects, allowing us to isolate the impact of nationally variable factors that policymakers can potentially influence.

Studying the diffusion of VRE technologies like CSBS suggests a focus on various socio-technical elements. These include social acceptance and political support (Edelenbosch et al., 2018; Nemet, 2006), as societal endorsement is critical in different contexts, e.g., as a catalyst for cross-sectoral institutional work (Käsbohrer et al., 2024). Techno-economic factors within the energy system, which point to path dependencies and lock-ins, as well as new system-level changes such as increased intermittency due to VRE (Alkemade et al., 2024), must also be considered. Furthermore, CSBS often involves demonstration projects and requires specific attention to R&D dynamics. Policy support and the opposing factors within each of these dimensions must also be analyzed to fully understand the challenges and opportunities in deploying such technologies effectively.

3.1. Public issue salience

Utilities use some CSBS for technical reasons. However, a long tradition of managerial research suggests that decision-makers in companies are additionally influenced in their adoption decisions by a zeitgeist (Alvarez and Porac, 2020; Simon, 1979). In the case of new forms of electricity storage, we assume concerns for green issues, preferences for decentralization, and pro-technology innovation attitudes as supporting of such technologies, all topics under which the issue is discussed within academia (see also Ganowski and Rowlands, 2020; López Prol and Schill, 2021). Thus, the public salience of these issues possibly affects potential adopters' attitude towards new technology, as it also influences public opinion (Burstein, 2003), policy (Bromley-Trujillo and Poe, 2020; Zawadzki et al., 2022), and increases the likelihood of an adoption-decision (Horbach and Rammer, 2018). Thus, societal debates play a crucial role in shaping preferences and influencing policy agendas. As operator consortia of CSBS often have a partial involvement of the public sector, as is typical for utilities (World Bank, 2019), public opinion is particularly important for decision-making.

This study uses proxies for public issue salience as there is currently insufficient data available—i.e., with many countries and more extended time series to capture the public salience, as is often the case (Oehl et al., 2017). We proxy for public salience with the political preferences of the public, measured by the share of party votes in elections.

Regarding environmental and green issues, research suggests that Green parties are generally congruent with their voters on environmental issues (Costello et al., 2021). Also, climate change experiences such as temperature anomalies show, under favorable economic conditions, an effect on Green party votes (Hoffmann et al., 2022), stressing this assumed relationship between environmental concerns and Green party votes. Thus, we use Green party votes as a proxy for the salience of environmental issues.

When it comes to the issue of decentralization, under which energy storage is heavily discussed (Schmid et al., 2017; Schumacher et al., 2019), economic right parties favor decentralization more than the economic left and culturally liberal parties more than culturally conservative ones (Toubeau and Wagner, 2015). Thus, decentralization salience is not simply measurable by using mainstream party groups. However, the existence of regionally rooted ethnic com- munities, like the Scots in the UK, Corsicans in France, or Basques in Spain, can bolster the appeal of identity-based reasoning (Toubeau and Wagner, 2015). Consequently, decentralization may become a component within a larger trend of 'ethnicization' of political dynamics. Then, in these nations, decentralization primarily involves the symbolic acknowledgment of national diversity and the creation of regional governance frameworks aligned with national communities. Thus, we use ethnic party votes—preferences for "regionally based ethnic groups that display distinct cultural and political identities and articulate different policy preferences" (Toubeau and Wagner, 2015)—as a proxy for salient decentralization.

Moreover, as other research notes (e.g., Carley and Miller, 2012; Vasseur, 2014), the presence of classically liberal politicians and environmental movement organizations is a driver for more renewable energy-friendly policies. Following previous research, we thus investigate (classically) Liberal party votes as a proxy for preferences toward technological and market-driven solutions to societal problems.

3.2. Latent market reactions

Beyond societal factors, the energy system itself is undergoing a transition, resulting in structural changes such as shifts in the energy mix driven by the broader energy transition (IEA, 2022a). These changes lead to (i) more opportunities for the integration of new technologies such as CSBS and to (ii) potentially larger demand for CSBS as they help reduce VRE risks and thereby provide security of energy provision (Andersen et al., 2023; IEA, 2024). These risks increase, particularly in the case of changes in the energy system, because other market participants, such as demanders and network operators, have not yet been able to react adequately to the added VREs.

Overall, these risks are increasingly manifesting in higher electricity prices (Castagneto Gissey et al., 2019; Davies et al., 2019; Hartner and Permoser, 2018) and higher spending on grid compensation measures (IEA, 2019). Capacity markets still need to be improved to better accommodate storage (Waterson et al., 2022), which current policy proposals, such as the new suggested network code by ACER (2022) for demand response, aim to achieve. The direct study of the effect of ancillary service prices on electricity markets in general and balancing markets in particular had to be omitted due to insufficient data availability for the covered countries and years.

While battery (cell) prices heavily affect adoption and use (IEA, 2022b), they tend to be global and show only limited variation between countries. Thus, they are only indirectly influenced by national innovation and energy policies. In our study design, we focus on nationally changeable factors and therefore cannot show the effect of globally changing factors, as these are controlled for through the fixed effects.

Two forms of VRE and their impact on CSBS adoption should be highlighted in particular: photovoltaic (PV) and wind energy. Wind energy is mainly organized in large projects and rarely on a small scale. Conversely, PV is found in large energy parks and small residential and commercial projects alike (IEA, 2024). One can assume that energy systems with higher wind and PV energy shares show higher battery storage diffusion rates. However, some evidence suggests that wind power increases volatility on the macro scale, while solar power decreases volatility because of merit-order effects (Kyritsis et al., 2017). Additionally, solar power generation has low variability while wind power tends to have higher variability leading to more adjustment of residual power for wind power. This effect becomes even stronger in off-peak hours (Kyritsis et al., 2017). Another study further emphasizes a more nuanced connection between energy prices and energy storage innovation (Feng and Lazkano, 2022). While they could show an increase in energy storage patenting with increasing average energy prices, the increase in electricity prices would lead to a reduction in the share of storage patents relative to electricity patents. One explanation could be as conventional generation becomes more expansive due to increasing VRE, more investment is undertaken in conventional generation to improve efficiency and reduce costs.

These first indicative results taken together show a nuanced and complex techno-economic relationship between battery storage and VRE.

3.3. Private and public expenditure in energy research, development, and demonstration

The academic literature is not entirely clear on all the relevant drivers of renewable energy diffusion (Bourcet, 2020). Amongst the agreed upon ones, expenditure in research, development, and demonstration (RD&D) is an essential factor for innovation (Acemoglu et al., 2016; Aghion et al., 2016) and subsequent growth (Comin and Mestieri, 2014). Moreover, the salience of issues, public opinion, and the existing condition of the energy system influence private investment decisions in renewable energy technologies — and are, in turn, shaped by them (Dasgupta and De Cian, 2018; Masini and Menichetti, 2013).

However, only a few countries constitute a substantial amount of global RD&D expenditures (Keller, 2004). As typically measured with patent data, changes in innovation do not automatically translate into increased diffusion of technological innovations (e.g., Lanjouw et al., 1998; Negro et al., 2012). Thus, the link between RD&D expenditure and the self-reinforcing innovation dynamics and technology diffusion is only indirect.

For energy storage, public RD&D on innovation still has to be determined as the potential benefits have spillover effects to multiple sectors (Popp, 2019) as first evidence suggests that energy storage can bolster both renewable and conventional electricity (Lazkano et al., 2017). Regardless, some studies indicate that innovation policy can increase domestic innovation for energy storage (Fabrizio et al., 2017), which makes it potentially more competitive in the future (Kittner et al., 2017), as costs for stationary battery storage are expected to fall (Ziegler and Trancik, 2021).

3.4. Targeted vs. broad policies

There is a longstanding discussion on which policies influence renewable energy deployment the most, with no clear consensus emerging (Peñasco et al., 2021; Polzin et al., 2019). In particular, the debate on the effectiveness between policies targeting specific technologies and broad policies that aim to change the general market conditions in favor of a particular trajectory is an old one in energy, environmental, and research policy.

We argue that (governmental) RD&D is a targeted form of innovation policies. Usually, these funds are set up so that only particular technologies are financed. Thus, from looking at RD&D funding for storage technologies, we can see the impact of targeted innovation-supporting policies, as argued above. However, energy policies tend to be broad and change the conditions for all energy technologies. This does not imply that it creates a level playing for all but can change it in favor of particular energy production, transmission, or consumption forms. However, even within energy policy, some tend to be broader, e.g., tradeable energy certificates, than others, e.g., feed-in tariffs, (Johnstone et al., 2010). The most discussed and tried renewable energy policies are guaranteed feed-in tariffs. These were often found to be highly conducive to renewable energy adoption (Hille et al., 2020; Polzin et al., 2015).

In contrast to the adoption of renewable technologies, the economic rationale for adopting energy storage technologies is that they provide a hedge against the fluctuating generation of these usually variable renewable energies. Thus, a guaranteed feed-in tariff for renewable should be a disincentive for energy storage technologies.

3.5. Opposing influences

Finally, from a political economy point of view, there are always winners and losers with every new development, such as due to technological innovations (Turnheim and Sovacool, 2019). We suppose that losers from technological innovation would oppose it and may be able to block its acceleration (Olson, 2022; Parente and Prescott, 2002, 1999). The losers from energy storage diffusion may likely be among incumbents who provide alternatives to the proposed CSBS (Andersen et al., 2023). Many of these incumbents might be interested in locking the development into the current status quo (see Seto et al., 2016). Examples include operators of gas-fired power plants, pumped hydro storage plants, and distribution grids (Gallo et al., 2016). Although they do not possess precisely the same technological properties nor provide the same services as CSBS, e.g., because of slower reaction time (Sterner and Thema, 2019), incumbents in these industries may oppose energy storage diffusion and act to prevent its acceleration.

Other opponents may be found in political groups that have been tradition- ally opposed to an energy transition. In particular, right wing political parties in OECD countries have been hostile towards pro-environmental policies (Lockwood and Lockwood, 2022).

We thus test whether the installed capacity of “losing” industries or the vote shares for right-wing parties (excluding the classically liberal parties) have negative effects on the acceleration of energy storage diffusion.

3.6. Assumed and studied mechanisms

Taking everything together, we consider the following transmission mechanisms for influences (positive or negative) on CSBS diffusion on the background of existing innovation activities – the various external influences that shift the diffusion curve. They differ via their transmission and are depicted in Fig. 2. The first transmission mechanism is directly between increased public issue salience and CSBS adoption. Growing concerns about environmental issues or increasing positive attitudes towards technological innovations as societal solutions shift expectations of adopters of CSBS and make innovative renewable energy-related (architectural) technologies more interesting to try out (Andersen et al., 2023). Thus, to conform to the public perception of storage technologies as future-oriented and the next logical step to get into, adopters of CSBS invest in these technologies.

Secondly, we theorize that increasing issue salience incites latent market demand for renewable energies, such as wind and solar PV (Horbach and Rammer, 2018). It is important to emphasize that market demand for RE is also heavily influenced by other factors (Shivakumar et al., 2019). Increasing adoption of these technologies translates to a demand for different storage technologies, e.g., CSBS, out of technical requirements, which would reflect their architectural nature (Andersen et al., 2023).

The third transmission we theorize and study in this article relates to policies. Again, as we know from political science literature, public support and issue salience usually have a substantial influence on the adoption and implementation (or blockage) of policies (Alvarez and Porac, 2020). These policies, if implemented, can, in turn, influence CSBS adoption—for example, by easing regulatory conditions or introducing restrictive legislation—typical forms of niche empowerment (Smith et al., 2012). In this context, we examine

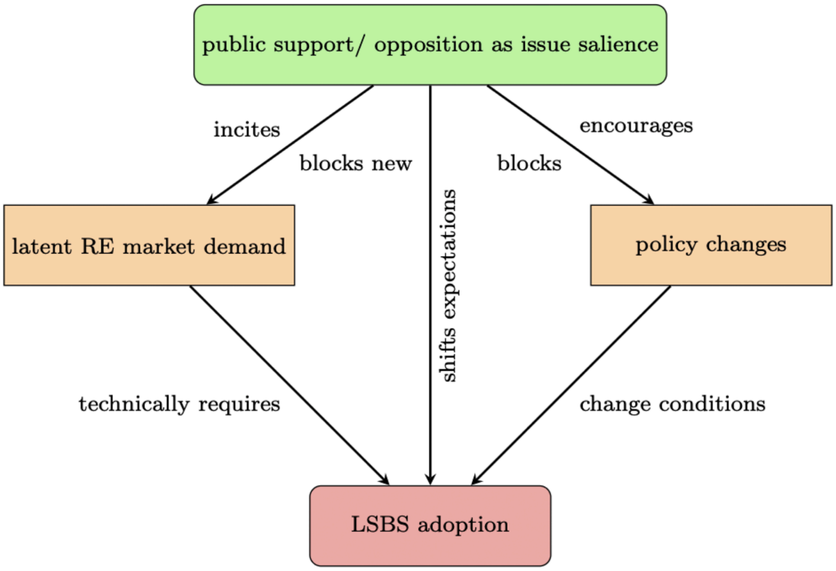

Fig. 2. Assumed and studied mechanisms for CSBS adoption.

specific innovation policies and broader energy policies that may potentially affect CSBS adoption.

Most of the variables studied here relate to innovation functions in the TIS-framework to varying degrees, such as CSBS diffusion and the latent energy market to market formation, public issue salience to legitimation and direction of search, as well as R&D expenditure to both resource mobilization and knowledge development. However, as the approach here is different in scope and granularity from typical TIS studies, the goal here is not to investigate the relationships between different TIS innovation studies but to focus solely on cross-country comparable influences on CSBS adoption.

4. Data and methods

4.1. Data sources and construction

For this study, we merged data on energy storage projects from three sources: first, from the global storage exchange, which is managed by Sandia National Laboratories on behalf of the United States Department of Energy (DoE, 2017; Hernández et al., 2016) and downloaded in 2020; second, data used in a report by the European Commission (2020); third, data for Germany provided by the German Association of Energy Storage (BVES, 2020). Other reliable databases on storage projects, to our knowledge, were not publicly available. We verified the plausibility of all these entries, adjusted them through desk research, and removed redundancies.

For the individual projects, partly different information was available for the construction. While only the announcement day was registered in some cases, in others, only the commissioning or the start of construction was noted. For many projects, however, all data was available. Commissioning was set as the decisive date for the energy stores to standardize the entries. The missing dates were estimated and imputed using linear regression with kW size as an independent variable. The mean duration from announcement to commissioning was 1.42 years, and from the beginning of construction to commissioning, 0.72 years.

To capture all storage projects larger than typical residential installations, we established a threshold that excludes single-family residential systems while encompassing commercial, industrial, and utility-scale projects. Residential battery systems typically provide around 5 kW of power with 10-15 kWh of energy capacity, as exemplified by systems like the Tesla Powerwall 2 and LG Chem RESU 10H (Fields, 2023), while market analysis indicates that residential installations are generally less than 30 kWh (Jarbratt et al., 2023). In contrast, commercial and industrial battery installations typically range from 30 kWh to 10 mWh (Jarbratt et al., 2023), encompassing a broad spectrum of applications from small commercial systems between 50 kW and 200 kW (Symtech Solar, n.d.) to utility-scale mega-projects exceeding 225 MW. While the U.S. Energy Information Administration defines large-scale or utility-scale systems as those exceeding 1 MW in power capacity (EIA, 2020), our analysis aggregates projects across multiple scales rather than treating them individually. Importantly, our dataset validation supports this approach: the first quartile of project sizes was 55 kW, confirming that a 50 kW threshold effectively captures the commercial-scale battery storage systems we sought to analyze while excluding residential installations. This threshold aligns with industry practice, where 50 kW represents a standard entry point for commercial battery energy storage systems (Bowen et al., 2019; Ritar Power, 2024). Consequently, all storage projects built with electrochemical storage of kW $\geq$ 50 were aggregated at year and country level from this new database.

Every country-year pair with no new storage projects listed in the database was coded as zero. To address systematic reporting issues in storage projects across certain countries, we introduce fixed effects into the regression model to control for these systematic gaps.

The index for new storage in the year-country panel was normalized to ten million inhabitants per country to ensure comparability. This standardization meant that some smaller countries had to be excluded from the analysis. These countries had very few and small

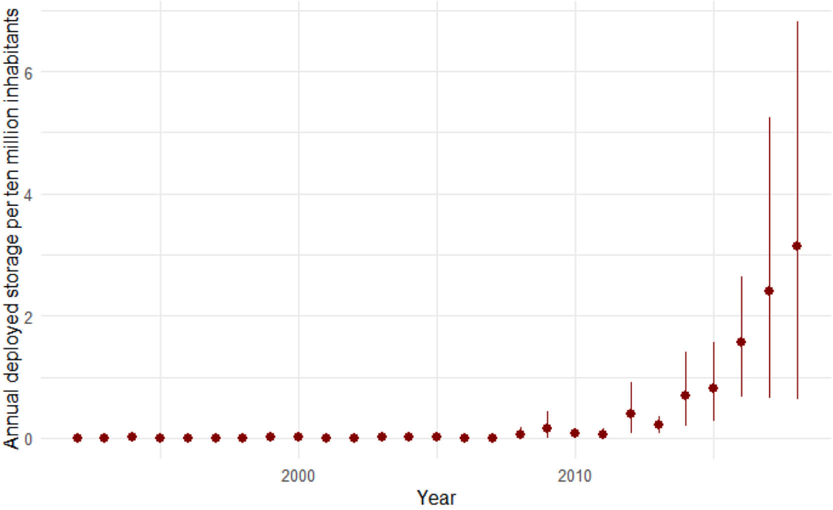

Fig. 3. Mean and 95% Confidence Interval of Dependent Data Showing Heterogeneity of CSBS diffusion.

projects installed, but they were no longer comparable due to their small populations. Only high-income countries (HICs), as defined by the World Bank (2020), were considered for this analysis. One notable exclusion of the focus on HICs is the People's Republic of China, which has several storage projects listed. Still, it only plays a minor role in the global country comparison due to its large population and the subsequently low standardized CSBS score. A complete list of countries is in Appendix A. We have trimmed the sample to ensure that the country coverage across datasets is the same.

Overall, the overview of CSBS diffusion in high-income countries (Fig. 3) indicates that the development has accelerated globally, particularly since the 2010s. This acceleration comes from the improvements in battery technological developments and falling prices for lithium-ion cells (Davies et al., 2019). Despite the heterogeneity in diffusion patterns across years, a clear upward trend is evident.

4.2. Variable definitions and measurements

Table 1 presents summary statistics of the variables used in this study. Alongside the change in CSBS normalized per million inhabitants, calculated using World Bank data from 2020b (Δ CSBS), and the cumulated CSBS normalized per million inhabitants representing the stock of CSBS (stock CSBS), we incorporated several independent variables. First, we considered proxies for public salience. Election data from CPDS (Armingeon et al., 2022) was utilized to determine the share of green, ethnic, and liberal party voters. Second, we incorporated IEA data on research, development, and demonstration (RD&D) expenditures for battery storage, electricity storage, and energy storage, along with the proportion of grid RD&D relative to public energy technology RD&D expenditures (IEA, 2023a). These Fig.s are derived from central and federal government budgets as well as budgets of state-owned companies. It is important to note that these expenditures cover various research-related activities related to the mentioned topics and serve as a valuable proxy for RD&D expenditures. Third, we incorporated globally comparable data on annual power production from wind, photovoltaic (PV), hydropower, and gas (IEA, 2023b). In addition, we use the OECD data on guaranteed feed-in tariffs for renewables (OECD, 2020) and the experimental OECD data set on tax rebates for companies having private RD&D expenditures (OECD, 2023) to cover other forms of innovation policies.

4.3. Econometric Approach and Model Specification

This article aims to unravel factors where policy and by policy targetable factors can influence (e.g., accelerate or dampen) the

Table 1
Descriptive statistics of used variables.

Description	N	Mean	Std. dev.	Min.	Median	Max.
Dependent Variables, Source: DoE (2017); EC (2020); BVES (2020)						
Δ CSBS	646	0.6	4.1	0.0	0.0	58.7
CSBS stock	567	1.7	7.9	0.0	0.0	123.1
Δ CSBS $\geq$ 500kW	646	0.6	4.1	0.0	0.0	60.7
Electoral Data, Source: CPDS (Armingeon et al., 2022)						
% green vote	670	3.6	4.1	0.0	2.6	21.0
log(1+x) % green vote	670	1.1	1.0	0.0	1.3	3.1
% liberal vote	670	16.6	16.1	0.0	12.1	53.9
log(1+x) % liberal vote	670	2.2	1.4	0.0	2.6	4.0
% ethnic vote	670	2.1	4.1	0.0	0.0	20.3
log(1+x) % ethnic vote	670	0.6	1.0	0.0	0.0	3.1
RD&D Expenditure (USD), Source: IEA (2023a)						
Battery storage RD&D	233	5.3	15.8	0.0	0.0	117.5
log(1+x) Battery Storage RD&D per capita	233	1.1	1.6	0.0	0.0	4.8
Electricity storage RD&D	240	6.4	19.8	0.0	0.0	219.8
log(1+x) Electricity Storage RD&D per capita	240	1.3	1.8	0.0	0.0	5.0
Energy storage RD&D	499	7.6	20.4	0.0	1.3	316.3
log(1+x) Energy Storage RD&D per capita	499	2.1	1.7	0.0	2.3	5.4
Grid RD&D	504	12.8	39.7	0.0	3.3	753.6
log(1+x) Grid RD&D per capita	504	2.8	1.9	0.0	3.3	8.3
Energy Production Statistics, Source: IEA (2023b)						
Produced wind electricity	456	11,044.4	22,964.9	2.0	11,628.5	105,045.0
log(1+x) wind produced per capita	456	6.7	1.6	0.2	7.0	10.3
Produced solar electricity	456	8,362.1	24,886.2	2.0	9,541.5	150,042.0
log(1+x) solar produced per capita	456	5.3	2.7	0.2	6.2	10.4
Produced pumped hydroelectricity	437	1,176.5	1,781.3	2.0	405.0	8,947.0
log(1+x) pumped hydro per capita	437	3.1	1.9	0.1	3.5	7.7
Gas produced electricity	456	5,591.6	4,226.6	55.0	4,775.0	15,039.0
log(1+x) gas produced per capita	456	5.7	1.1	3.1	5.9	8.5
Policy Variables, Source: OECD (2020)						
Feed-in tariffs for RE	432	0.2	0.3	0.0	0.1	3.0
Tax rebates for innovation	430	0.5	0.5	−0.1	0.4	1.7

Notes: Complete descriptive statistics for all variables used in the analysis. Sources abbreviated: DoE = Department of Energy; EC = European Commission; BVES =

diffusion of CSBS beyond endogenous self-reinforcing dynamics, thus shifting the adoption curve (Fig. 1). Therefore, the following models control for endogenous innovation dynamics. This builds on the so-called Bass diffusion model (Bass, 1969) that attempts to forecast and estimate adoption of (end-user) technologies (see also Mahajan et al., 1995). It is one of the most cited works in business economics and marketing and has been further developed for various specific cases.

However, for this study, a simple baseline Bass model is sufficient, as the regression models applied are not for future adoption curves but rather an analytical tool to uncover the dynamics of past CSBS adoption. The starting point is the Bass model, which estimates the magnitude of the effects of innovation and network effects of imitation. Eq. 1 shows a Bass model for which an S-curve displays an initial slow uptake of a particular innovation until it reaches a turning point, after which a faster diffusion is assumed.

$$y_t = pm + (q - p)Y_{i,t} - \frac{q}{m}(Y_{i,t})^2 \tag{1}$$

Here, y is the change in technology adoption, q is the coefficient of internal influence (innovation), p is the coefficient of external influence (imitation), m *is* the market potential, Y *is* the cumulated diffusion of the technology, and Y^2 is the cumulated diffusion of the technology squared.

For this article, we omit the detailed imitation and innovation coefficients and incorporate the basic structure of Eq. 1 into a panel regression model, as shown in Eq. 2. As we are interested in observing factors that shift the adoption curve, we control for the “endogenous” innovation activity by including the stock of CSBS and its square.

Moreover, we are interested in variables that vary over time. Thus, stable country characteristics are excluded. Also, we assume a correlation between the country error term and predictor variables. This is why we control for entity effects by keeping them fixed, allowing us to assess the net effect of the predictor variables on the outcome variables. Also, we are not concerned with time effects when special events coincide across all countries. Therefore, we control for time effects that introduce unexpected variations that are common across countries. Consequently, we employ a two-way fixed effects (FE) regression model, which includes time and entity fixed effects, to mitigate omitted variable bias from unobserved variables that are constant over time and unobserved across countries (Stock and Watson, 2015; Wooldridge, 2010).

The final base model (Eq. 2) is a Bass-model-inspired two-way FE panel regression model designed to capture the effects of policy drivers — including social, economic, and energy system conditions — on a global scale on the adoption of CSBS technologies beyond country-specific cumulative dynamics. Thus, we estimate external factors that shift the adoption curve.

$$\Delta CSBS_{it} = b * StockCS2BS_{i,t-1} + c \; * StockCSBS^2_{i,t-1} + \beta x_{i,t} + CountryEffect_i + TimeEffect_t + u_{i,t} \tag{2}$$

5. Regression analysis

As described in section 4, we estimated an average duration from project announcement to commissioning of 1.41 years. Based on this, we assume an average time of 2 years from the decision to build a large battery storage project to its commission. Thus, we consider two scenarios for the decision-makers regarding available information: (a) the information available at the time of the decision, such as issue salience, electricity prices, and policies, or (b) information about the future that informed actors can already infer, such as the energy mix in two years from projects that are started building at the time of decision. We code the commissioning time as t and the decision time as $t - 2$.

For the estimation, heteroscedasticity corrected and robust standard error

(HC 1 as conventionally used in STATA) and also serial corrected standard error (following Beck and Katz, 1995; Zeileis, 2004) was used. We tested for non-stationarity of the dependent variable using the Augmented Dickey-Fuller test (Dickey and Fuller, 1979; Stock

Table 2
Base panel regression model (FE) with the influence of existing CSBS stock on new CSBS covering 1992–2018 using standardized betas.

	$\Delta CSBS$
$StockCSBS_{t-1}$	0.439**
	(0.262)
$StockCSBS^2_{t-1}$	0.217
	(0.213)
Years	26–27
Countries	24
Time FE	✓
Country FE	✓
N	646
$R2$	0.357
Adjusted $R2$	0.302
F Statistic	164.984***
	(df = 2; 594)

Notes: Standard errors in parentheses. *p < 0.1; **p < 0.05; ***p < 0.01

and Watson, 2015) and rejected the null hypothesis that the time series is non-stationary (see Appendix Table B.18).

Table 2 shows the basic model. The presented basic structure shows that with an adjusted $R^2 = .302$, the influence factor $StockCSBS_{t-1}$ is with $p < .1$, but the $StockCSBS_{t-1}^2$ is not predictive for the adoption of CSBS. Here, we cover the years from 1992-2018. However, for some variables, only shorter time series were available.

5.1. *Public issue salience*

The results in Table 3 show the impact of the public salience of environmental issues, as measured by the share of voters supporting green, liberal, and ethnic parties, on CSBS diffusion. Due to the highly skewed nature of the data, we log-transform the data on vote share via $log(1 + x)$. The more people vote for green or ethnic parties, the more CSBS projects are adopted, while votes for more liberal parties decrease the adoption of CSBS projects. We estimate each party's vote share individually before including them all in the final column's specification. The estimates show a positive effect of the share of green voters at the time of decision with $p < .01$, a negative effect of the share of liberal voters with $p < .1$, and a positive effect of the share of ethnic party votes with $p < .01$.

This relationship suggests that decision-makers in CSBS-adopting organizations are influenced at the time of the decision $t-2$ by issues that are salient in the population. One possible motivation for decision-makers to adhere to these salient themes is to make an innovative and sustainable impression on employees and funding agencies. Moreover, through the often-given direct involvement of the public sector in the projects, it is also likely that influence on decision-makers is exercised through this route. Indeed, another possible explanation for the correlation found above is that it is not so much the salience of green, ethnic, or liberal issues in the population but rather the political influence of green, ethnic, or liberal parties that is crucial for more CSBS diffusion. To investigate this alternative explanation, we controlled for the influence of green seats (Table B.13). However, the results indicate that the relationship cannot be attributed to the direct political influence of parliamentarians from the party groups. There is no significant relationship between the seats of green or liberal politicians in parliament and CSBS diffusion, regardless of the political system.

5.2. *Latent market reactions*

We also investigate structural factors in the energy system that potentially explain the demand for CSBS. One goal is to see if there is currently a demand for energy storage from the energy market due to a demand for flexibility. Therefore, the levels of both PV and wind electricity are investigated as influencing factors of CSBS adoption. Also, we consider potential alternative flexibility measures in the energy system and their possible impact on CSBS adoption. Due to the highly skewed nature of the data, we log-transform the data on wind and PV production levels normalized for inhabitants via $log(1 + x)$. Because we assume that the amount of planned electricity generation will be available when the project is finished, this section's independent variable is not lagged.

Table 4 also shows an overview of the estimated impact of electricity generation changes from both PV and wind to the baseline on the diffusion of CSBS. At the same time, the cumulative innovation dynamics are controlled for. As can be seen in the estimated models, wind and solar electricity show no significant effect on CSBS adoption. The same goes for the alternative flexibility options pumped hydro storage and power from gas. In a robustness check with an alternative specification considering only CSBS with a capacity > 500 kW, this result could be confirmed (see Table B.9). Using growth rates of wind or solar-PV electricity, no effect on CSBS diffusion could be measured (see Table B.15). Thus, we see no evidence for the importance of a country's latent energy markets.

Table 3

Share of green, liberal and ethnic party voters on CSBS diffusion.

	$\Delta CSBS$			
	(1)	(2)	(3)	(4)
$StockCSBS_{t-1}$	0.844**	2.357***	0.780**	2.373***
	(0.473)	(0.695)	(0.464)	(0.619)
$StockCSBS_{t-1}^2$	0.670	−3.970**	0.769	−4.034**
	(0.746)	(2.135)	(0.730)	(1.889)
$\%\ VoteGreen_{t-2}$	0.138**		0.263***	
	(0.075)		(0.089)	
$\%\ VoteLiberal_{\ t-2}$		−0.202*		−0.157*
		(0.105)		(0.093)
$\%\ VoteEthnic_{t-2}$			0.477***	0.540***
			(0.202)	(0.184)
Years	24–25	24–25	24–25	24–25
Countries	24	24	24	24
Time FE	✓	✓		✓
Country FE	✓	✓		✓
N	598	440	598	440
R2	0.365	0.207	0.373	0.260
Adjusted *R2*	0.307	0.108	0.316	0.163
F Statistic	105.020***	33.964***	108.409***	27.309***
	(df = 3; 547)	(df = 3; 390)	(df = 3; 547)	(df = 5; 388)

Notes: Standard errors in parentheses.

$^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$

Table 4
Influence of wind and solar electricity and the alternative flexibility options pumped- hydro storage and gas power at adoption point on CSBS diffusion with standardized betas.

	$\Delta CSBS$				
	Renewables		Alt. Flexibilities		
	(1)	(2)	(3)	(4)	(5)
$StockCSBS_{t-1}$	0.928**	0.925**	0.923**	0.930**	0.922**
	(0.522)	(0.530)	(0.540)	(0.520)	(0.550)
$StockCSBS^2_{t-1}$	0.538	0.542	0.547	0.534	0.546
	(0.805)	(0.815)	(0.828)	(0.803)	(0.842)
$logProdWind_t$	−0.023				−0.024
	(0.048)				(0.056)
$LogProdSolar_t$		−0.012			−0.008
		(0.073)			(0.071)
$PumpedHydro_t$			0.041		0.032
			(0.157)		(0.157)
Gas_t				0.091	0.098
				(0.189)	(0.222)
Years	19	19	19	19	19
Countries	24	24	23	24	23
Time FE	✓	✓	✓	✓	✓
Country FE	✓	✓	✓	✓	✓
N	456	456	437	456	437
$R2$	0.355	0.355	0.352	0.356	0.353
Adjusted $R2$	0.286	0.286	0.281	0.287	0.277
F Statistic	75.437***	75.406***	71.094***	75.746***	35.457***
	(df = 3; 411)	(df = 3; 411)	(df = 3; 393)	(df = 3; 411)	(df = 6; 390)

Notes: Standard errors in parentheses.
$^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$

5.3. *Targeted vs. broad policies*

This sub-section sheds light on how targeted and broad policies promote the adoption of CSBS projects. As a targeted policy, the first set of analyses examines the impact of RD&D expenditures per capita on electricity storage on CSBS adoption. Alternative specifications are in Table B.17. Due to the right-skewed nature of the expenditures distributions and because relative changes are of

Table 5
Influence of targeted RD&D expenditures and the broad innovation policies guar- anteed feed-in tariffs and tax rebates for innovation expenditures on CSBS diffusion with standardized betas.

	$\Delta CSBS$				
	Targeted		Broad		
	(1)	(2)	(3)	(4)	(5)
$StockCSBS_{t-1}$	2.133***	0.771*	0.979*	1.091*	1.820***
	(0.637)	(0.446)	(0.539)	(0.561)	(0.585)
$StockCSBS^2_{t-1}$	−1.449*	0.746	0.453	0.286	−1.024
	(0.815)	(0.578)	(0.824)	(0.846)	(0.826)
$ElstoRDD_{t-2}$	0.247**				0.398*
	(0.106)				(0.225)
$GridRDD_{t-2}$		0.022			0.011
		(0.048)			(0.126)
$FIT\ _{t-2}$			0.017		0.108
			(0.060)		(0.311)
$TaxRebate_{t-2}$				0.173	0.092
				(0.132)	(0.279)
Years	2–23	17	13–15	13–15	2–15
Countries	24	24	24	24	23
Time FE	✓	✓	✓	✓	✓
Country FE	✓	✓	✓	✓	✓
N	218	473	408	358	154
$R2$	0.350	0.335	0.354	0.356	0.308
Adjusted $R2$	0.155	0.256	0.280	0.275	0.047
F Statistic	29.960***	70.800***	66.694***	58.476***	8.250***
	(df = 3; 167)	(df = 3; 422)	(df = 3; 365)	(df = 3; 317)	(df = 6; 111)

Notes: Standard errors in parentheses.
$^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$

primary interest, we log-transformed the variable via $log(1 + x)$. Again, the analysis focuses on the impacts of RD&D expenditures at the time of the investment decision for the new CSBS at $t - 2$.

As alternative broad policies, we examined the energy policy of guaranteed feed-in tariffs, which is much discussed in the renewable context, and tax rebates for innovation and research activities for corporate expenditures, which can be attributed to innovation policy. These alternative specifications are in Table B.16.

The results in Table 5 show that more RD&D expenditures in electricity storage correlates with an increase of CSBS at $p < 0.05$. While the causal relationship between RD&D expenditures for electricity storage and CSBS diffusion may seem obvious, results must be taken with caution as it is also likely that parts of the expenditure will be for other storage technologies (e.g., small-scale residential storage). In the case of the broad policies, both for the guaranteed feed-in tariffs for renewables, which should be regarded more as energy policy, and for the tax rebates for innovation expenditures, an innovation policy, no significant correlations with the spread of CSBS are estimated in our analysis.

5.4. *Opposing influences*

In the previous tables, we have also investigated counteracting shifting factors to explain the diffusion (or lack thereof) of CSBS. The basic assumption here was that a more substantial diffusion of alternatives or policy measures supporting alternatives has a negative effect on the diffusion of CSBS. Thus, we assume the same transmission mechanism, only with opposing factors, for each possible influence. We, therefore, investigated RD&D expenditures in electricity grids as a direct innovation policy measure into an alternative flexibility option. To assess the influence of the latent energy market, we examined the installed capacity levels of gas-fired power plants and pumped hydro storage plants (PHS). While CSBS does not provide the same technological services for the grid as alternative flexibility measures such as PHS and electricity out of gas, they are nonetheless considered in public debates as potential substitutes for each other. The results show that—controlling for the endogenous innovation dynamics—and applying HC1 robust estimates again, no significant effect on CSBS diffusion could be found. Those results confirm the hypothesis that these flexibility measures fulfill different functions within the energy systems. For salient issues, we identified politically opposed groupings. Here, we identified the significant negative effect of liberal pro-market issue salience on CSBS diffusion. Other oppositional policy groups, which stand for other salient policy issues, were also investigated but did not show significant results in our modeling and were therefore excluded. These results are presented in the Appendix, Table B.14.

Just as with the analysis of the other shifting factors, we assume that at the time of the CSBS project's decision, the capacity expansion at the time of its commission is already foreseeable. Therefore, PHS and gas capacity in two years is assumed to be known at the time of the decision (see Table 4).

5.5. *Summary of appendix*

The appendix provides an overview of the included countries. In addition, there are robustness checks of an alternative specification of the dependent variable in which only storage systems $\geq 500kW$ were considered. The results of this alternative specification show the robustness of the public issue salience and targeted innovation policies. In addition, we provide evidence that the results hold

Table 6
Comparison of influencing factors with standardized betas.

	$\Delta CSBS$				
	(1)	(2)	(3)	(4)	(5)
$StockCSBS_{t-1}$	2.197***	1.910***	3.700***	1.992***	3.702***
	(0.592)	(0.564)	(0.757)	(0.542)	(0.685)
$StockCSBS^2_{t-1}$	−1.523**	−1.163	−6.461***	−1.262*	−6.526***
	(0.753)	(0.721)	(1.845)	(0.689)	(1.611)
$\%\ VoteGreen_{t-2}$	0.329**			0.260*	0.448***
	(0.166)			(0.154)	(0.168)
$\%\ VoteEthnic_{t-2}$		1.405***		1.207**	1.379**
		(0.505)		(0.493)	(0.619)
$\%\ VoteLiberal_{t-2}$			−0.704**		−0.390
			(0.343)		(0.243)
$ElstoRDD_{t-2}$	0.306***	0.232**	0.239*	0.281**	0.270**
	(0.115)	(0.106)	(0.131)	(0.113)	(0.135)
Years	2–23	2–23	1–18	2–23	1–18
Countries	24	24	21	24	21
Time FE	✓	✓	✓	✓	✓
Country FE	✓	✓	✓	✓	✓
N	218	218	154	218	154
$R2$	0.372	0.380	0.312	0.393	0.375
Adjusted $R2$	0.179	0.190	−0.003	0.202	0.072
F Statistic	24.576***	25.445***	11.883***	21.388***	10.317***

Notes: Standard errors in parentheses.
$^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$

even when additional controls for country and GDPpc are added or the biggest country in the sample (the US) is excluded from the sample. Additionally, we provide information on additional, theoretically plausible influences, such as other mainstream party votes related to other salient societal issues, renewable growth as another way to capture the energy system, different forms of guaranteed feed-in tariffs, or other storage-related RD&D expenditures.

5.6. Comparison of influencing factors

To compare the effect size of the analyzed factors in this article, Table 6 presents selected policies and issue salience factors for which this study established significant relations. As before, we standardize the variables and make the strength of the effect and thus, the relative importance of the factors β on different dimensions comparable. Their unit is standard deviations.

Table 6 shows combined results for the targeted innovation policy direct RD&D expenditure in electricity storage with each significant factor by themselves and all of them together. Using both shares of Green Party votes as a proxy for green issue salience with RD&D, we observe positive effects with $p < .05$ for both. For ethnic party votes and RD&D, we see a positive effect with $p < .01$ for ethnic party votes and a positive effect with $p < .05$ for RD&D. In contrast, when taking the share of liberal party votes as a proxy for liberal and pro-market sentiments and RD&D together, the share of liberal votes has a negative effect on $\Delta CSBS$ with $p < .05$ while RD&D is not significant. Taking the three different votes and RD&D into one model shows positive effects with $p < .01$ for green issue salience and with $p < .05$ for ethnic votes and a positive effect for RD&D with $p < .05$. However, the liberal vote does not significantly affect

$\Delta CSBS$. When considering all but liberal votes in the model, we see the model with the highest $adj.R^2$ of 0.202, a positive effect of green votes with $p < .1$, of ethnic votes with $p < .05$, and RD&D with $p < .05$. These results suggest a positive effect of green issue salience and decentral ethnic issue salience together with RD&D expenditure on CSBS diffusion.

The resulting models also show the suitability of the used Bass-model inspired control with $StockCSBS_{t-1}$ and $StockCSBS_{t-1}^2$. While in base mode (Table 5.1), only $StockCSBS_{t-1}$ was significant. In the later models, we observe that the slope term is insignificant when tested solely for votes (Table 3) but significant when tested for RD&D expenditures. Additionally, it had a negative effect, a characteristic of the S-curve, which is visually identifiable in Fig. 3. Thus, considering the final model, using a Bass-model-inspired control to account for existing innovation activities allows for identifying additional factors that “shift” the curve.

6. Discussion of results

We suspected three broad sources of positive influence: the proclivity of adopting organizations to prioritize their public image and engage in early learning and experimentation, thereby positioning themselves for future developments; the innovation policies that governments have introduced; and the economic viability due to the structure of the status-quo energy system. Furthermore, we discussed the possibility of negative or opposing influences on CSBS diffusion.

6.1. Public issue salience

Public issue salience is an essential driver for policy adoption. One of the aims of this article was to assess the importance of the public salience of environmental issues on the diffusion of CSBS. The findings provide an initial indication that public issue salience has been a driver for CSBS diffusion and a primary motive for adopters. This reasoning aligns with diffusion theory (Rogers, 2003), political science (Bromley-Trujillo and Poe, 2020; Burstein, 2003), or with transition study approaches (Geels et al., 2017b), but contrasts with some studies from economics (e.g., Herbig, 1991; Schiavone and Simoni, 2019). Thus, although CSBS is an architectural technology and an industrial product, the behavior toward it is similar to that observed with consumer-level renewable energy technologies.

The results demonstrate a relationship between the share of green voters— which was used as a proxy for a general attitude towards green perceived technologies following Costello et al. (2021)—and the adoption of CSBS. This analysis assumes that environmentally concerned people consider energy storage an environmentally beneficial technology. In discourses, these perceptions of energy storage tend to be constructed as innovative and green in media outlets (Bakaki et al., 2019; Ganowski and Rowlands, 2020) and by intermediary actors in polycentric arrangements (Devine-Wright et al., 2017).

Furthermore, the results also reveal a statistical relationship between the share of ethnic party votes and $\Delta CSBS$. Based on our assumption that ethnic party votes approximate decentralization salience, the results of our study suggest a positive effect of decentralization tendencies on decentralized energy technologies such as energy storage. However, the results should be taken with caution for several reasons. Firstly, ethnic party votes are not present to a significant extent in all relevant countries. Secondly, these parties naturally have a wide range of interests. Nevertheless, it is plausible that regionalization and the decentralization of power structures (Toubeau and Wagner, 2015) are reflected in the field of energy by using decentralized energy technology (e.g., Brown et al., 2020; Funcke and Bauknecht, 2016). Energy storage is interesting from security, decentralization, and flexibility perspectives, which support renewables, but not exclusively (Crabtree, 2015).

A different perspective emerges when considering the votes of the Liberal Party, which were used as a proxy for the salience of technology optimism and pro-market attitudes. In the isolated analysis (Table 3), there is even a significantly negative effect on $\Delta CSBS$. This suggests that support from this sector is more opposed to storage solutions. However, the results from the overall analysis (see Table 6) do not confirm the significance of this effect but rather suggest that these explanations remain insufficient. What is certain, though, is that contrary to the original assumption, there is no positive effect on CSBS stemming from the salience of belief in technical and market-driven solutions.

Consequently, while our findings broadly confirm that political support and enabling policies facilitate the diffusion of CSBS, certain nuances in our results contribute important insights to the broader scholarly discourse. Specifically, regarding political variables, our analysis reveals that vote shares for green and ethnic parties are significant predictors of CSBS diffusion, whereas their parliamentary representation is not statistically significant. We interpret this as evidence that public salience, as proxied by vote shares, matters more than actual political representation.

Previous studies have not found a systematic relationship between policies and citizens' preferences for renewable energy policies (Stadelmann-Steffen and Eder, 2020), which is justified by the limited literacy of the general public regarding energy issues (Brounen et al., 2013; Stadelmann-Steffen and Dermont, 2018). Some studies, however, found that positive attitudes toward green issues were conducive to the diffusion of renewables (Horbach and Rammer, 2018). Thus, based on the results of this study, there is an initial indication that adopters of CSBS—an industrial product rather than a consumer product—respond to public opinion by using their adoption to publicly appear green, supportive of decentralization, and aligned with the prevailing zeitgeist.

6.2. *Latent market reactions*

The types of energy storage systems considered in this study were those for medium- and large-scale projects. Therefore, it could be assumed that the diffusion of wind energy has a more extensive influence on the diffusion of CSBS than PV. In contrast to the results of Hartner and Permoser (2018), we were unable to establish a positive relationship between PV diffusion and storage.

For the overall energy system, Zerrahn et al. (2018) show that electricity storage is vital for the renewable energy transition. However, additional measures, such as curtailment, still play a role, and even in high renewable diffusion scenarios, storage demand remains limited. Moreover, architectural technologies may not have been important for system change during the observed years. The results of this study empirically suggest no relationship between changes in PV levels and CSBS adoption. One possible explanation is that, for the observed period, the investment decision for CSBS is viewed by investors as an alternative to solar PV rather than a complement due to its technological nature. This hypothesis, based on our results, aligns with Côté and Salm (2022) who identify high returns on investment as the primary motive for CSBS investors. Thus, reaching economies of scale in operation might be more important than the exact technological choice.

Moreover, following the argument by Thonig and Lilliestam (2024) our results suggest that, during the observed period, CSBS technologies experienced negative cross-technology feedback from more dynamic technologies, such as PV and wind.

6.3. *Targeted vs. broad policies*

Commonly quantifiable measures for policies such as technology-push policies (RD&D expenditure) and technology demand policies such as feed-in tariffs do not appear to influence the overall diffusion of CSBS. Although technology demand policies appear to affect the diffusion of renewables in general (Carley et al., 2017), the relationship with architectural technologies such as CSBS is unclear. However, as technology-push policies, such as RD&D expenditure, are only drivers in a few countries (see Keller, 2004), their influence is not yet fully determined in this analysis and requires further research.

Moreover, this study established a relationship between additional RD&D expenditure in electricity storage technologies and CSBS diffusion. The results are not surprising since higher research expenditures tend to increase the probability of demonstration projects and foster learning (Edelenbosch et al., 2018). However, as the comparison made clear, the results are of lower magnitude than for public issue salience. Therefore, in general, more far-reaching policy implications can only be determined to a limited extent.

Overall, policies are still quite heterogeneous and difficult to compare across many countries. Thus, singling out one measure for a policy, such as RD&D expenditure, can only capture part of the picture. Moreover, the policy mix literature suggests that bundles of policies typically influence a specific objective, such as the diffusion of renewable energies (Rogge and Reichardt, 2016). Therefore, quantitatively grasping the overall policy mix to test the impact of CSBS diffusion remains an open task.

As the literature has found that other enabling policies have had an impact in different contexts, these results support the previously mentioned fact that it is important to evaluate the determinants of technology diffusion at the level of individual technologies rather than within the broader framing of ”energy innovation”. In this sense, we learn as much from variables that are not statistically significant as we do from variables that are.

6.4. *Opposing influences*

Besides the influences that are likely to induce diffusion, this study considered further factors. In all three dimensions, (1) public issue salience, (2) latent energy market, and (3) broad vs. targeted policies, we examined opposing factors, which represented incumbent technological alternatives or presumably opposing political groupings, in addition to the more likely diffusion-promoting influences.

Besides the results of the Liberal Party votes, as discussed in Section 6.1, the results in Section 5.5 did not show any influence of these alternatives and opposing factors. Thus, for (1) voting results, parliamentary seats, and cabinet composition from other political parties, we could not find any negative influence on CSBS diffusion. The same was true for (2) energy mix. Moreover, there was no evidence that changes in alternative flexibility technologies, such as gas and pumped hydro storage power plants, impacted CSBS diffusion. *RD&D* expenditure on flexibility alternatives, such as energy grids (3), was also not found to be related to CSBS diffusion.

6.5. Theoretical implications

Although our analysis ultimately did not reveal significant differences in the diffusion patterns between widely deployed technologies such as photovoltaics and wind power, and so-called architectural technologies such as commercial-scale energy storage, it should nonetheless be understood as reinforcing and supporting research approaches that foreground architectural technologies—particularly in the context of systemic socio-technical transitions such as the energy transition—as a central object of inquiry (see, i.a., Andersen et al., 2023; Bettin, 2020). As is often the case, our findings underscore the irreplaceable value of empirical investigation.

Furthermore, the study underscores the evolving role of transition studies as a converging research field that integrates theoretical and empirical insights from political science, economics and management, as well as engineering and the natural sciences. While theoretical frameworks such as the Technological Innovation Systems (TIS) approach provided an essential conceptual anchor for our analysis, a replication in the form of a quantitative regression study was not feasible within the scope of this research. Whether such a replication is possible at all remains an open question for future inquiry.

6.6. Limitations and future research

We acknowledge that commercial-scale battery storage systems exhibit considerable heterogeneity in terms of ownership structures, operational control, and integration with existing energy infrastructure. While some battery installations represent genuinely decentralized technologies with local ownership and community control—aligning with energy democracy narratives—others constitute large-scale utility-owned assets that may reinforce existing centralized power structures rather than challenge them. Our analysis aggregates all battery storage projects ($\geq$ 50 kW) to the country-year level and does not differentiate between these distinct configurations due to data availability constraints. The databases used in this study do not consistently provide sufficient information on ownership structures, operational control arrangements, or the degree of integration with local versus centralized grid infrastructure. This represents an important limitation of our approach, as the relationship between public issue salience (particularly regarding decentralization preferences) and battery adoption may vary substantially depending on whether projects embody decentralized energy democracy ideals or represent utility-scale infrastructure investments. The same can be said for RD&D expenditures and the conditions of the energy system. Future research with more reliable granular project-level data on ownership and control structures would provide valuable insights into how different battery configurations relate to varying political and social preferences for energy system organization.

7. Conclusion and policy implications

7.1. Summarizing conclusion

In this study, we examined how issue salience, broad policy measures, and the structural conditions of the energy system acted as key policy drivers—including socio-economic and energy-related factors—influencing the diffusion of commercial-scale battery storage across 24 high-income countries. Controlling for classical diffusion dynamics, we investigated how these drivers could ’shift’ diffusion curves, highlighting factors that national policies could influence and that indicate opportunities for building alliances within policy arenas.

First, we found that public salience of environmental and decentralization issues positively affected the diffusion of commercial-scale battery storage technologies. These results suggest that appearing green and self-reliance-enhancing is also a driving force behind the adoption of commercial-scale battery storage. For the salience of pro-market and technology-optimism issues, we observed mixed results hinting at a negative effect. Second, this study found evidence that policies targeting the diffusion of renewable energy did not also positively influence the diffusion of commercial-scale battery projects. Additionally, the level of wind and PV electricity had no effect, underscoring the still-developing systemic importance of commercial-scale battery storage as an architectural technology. The study could not establish any systematic relationship between potential substitute flexibility options, such as pumped hydro storage or electricity from gas. Third, traditional targeted innovation policies such as expenditures in RD&D as technology-push policies positively affected commercial-scale battery storage diffusion. Conversely, broad technology-pull policies for renewable energies that affect the latent energy market, such as guaranteed feed-in tariffs, showed no effect.

7.2. Policy Implications

Our results highlight that conventional energy policies during the observed years have not addressed the growing need for flexibility solutions required for a fully renewable energy system in the future. This paper provides evidence that technology-push innovation policies can impact and serve as a potential lever for encouraging flexibility technologies.

Additionally, the results of our study highlight the value-laden societal dimensions of energy and innovation policy, which appear to respond to salient societal concerns and issues. In principle, this is good news, but the devil is always in the detail. From a business and innovation policy perspective, a multi-stack value proposition for commercial-scale battery storage is likely only somewhat aligned with energy policy objectives of providing affordable, reliable, and secure electricity.

Moreover, this study’s results highlight the importance of social factors, such as public issue salience, and indicate that public perceptions play a crucial role in diffusing early-stage experimental technologies, including commercial-scale battery storage. Thus, informing about concrete societal challenges and how such technologies can tackle them can encourage resource mobilization. Initiatives such as the US Department's of Energy *Energy Storage for Social Equity Initiative* that engage directly with populations together with multi-stakeholder platforms such as the US *ESS program* and the EU *Battery Alliance* are prime examples of such an approach.

CRediT authorship contribution statement

Steffen Simon Bettin: Writing – review & editing, Writing – original draft, Validation, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Michael Thomas Dorsch:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Investigation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Data Info

Table A.7 provides an overview of the high-income countries, as classified by the 2020 World Bank, which are included in this study.

Table A.7
Overview of included countries.

Australia	Austria	Belgium	Canada
Switzerland	Czechia	Denmark	Spain
Estonia	Finland	France	United Kingdom
Greece	Hungary	Ireland	Japan
Luxembourg	Netherlands	New Zealand	Norway
Portugal	Slovakia	Sweden	United States

Notes: 24 OECD high-income countries included in the analysis covering 1992–2018 (World Bank Classification 2020).

Appendix B. Robustness Analysis

Different specifications of the dependent variable CSBS diffusion were chosen to test the robustness of the results. For the main analysis, we initially examined all storage facilities with $kW > 50$ under the assumption that these facilities are typically grid-useful. However, we now only aggregated all facilities with $kW > 500$. The previous results were retested (Tables B.8, B.9, B.10,B11,B12).

These results show that the findings are also robust to the main changes in our original definition of what constitutes CSBS. Thus, the number of green voters and RD&D expenditures for electricity storage technologies still seem to influence the diffusion of CSBS. In contrast, changes in wind and solar electricity production do not influence CSBS diffusion. This difference in results, as mentioned above, suggests a potential weakness in the findings regarding the apparent negative relationship between CSBS diffusion and solar production.

Table B.15 also presents an alternative power system specification based on the growth rates for wind and solar power. However, these variants do not show a significant relationship between the increase in their growth rate and the diffusion of CSBS.

Table B.8
Comparison of different salient factors on CSBS with $\geq$ 500kW diffusion.

	Δ CSBS ≥ 500kW			
	(1)	(2)	(3)	(4)
$StockCSBS_{t-1}$	0.508*	0.472*	1.426***	1.434***
	(0.273)	(0.268)	(0.411)	(0.365)
$StockCSBS^2_{t-1}$	0.003	0.004	−0.027**	−0.028**
	(0.005)	(0.004)	(0.014)	(0.012)
$\%\ VoteGreen_{t-2}$	0.579*			1.111***
	(0.314)			(0.368)
$\%\ VoteLiberal_{t-2}$		−0.853*		−0.667*
		(0.443)		(0.391)
$\%\ VoteEthnic_{t-2}$			1.981**	2.230***
			(0.842)	(0.755)
Years	24-25	2-25	24-25	2-25

(continued on next page)

Table B.8 (*continued*)

	Δ *CSBS* $\geq$ *500kW*			
	(1)	(2)	(3)	(4)
Countries	24	23	24	23
Time FE	✓	✓		✓
Country FE	✓	✓		✓
N	598	440	598	440
*R*2	0.344	0.205	0.352	0.258
Adjusted *R*2	0.285	0.160	0.292	0.160
F Statistic	95.796*** (df = 3; 547)	98.907*** (df = 3; 547)	98.907*** (df = 3; 547)	26.970*** (df = 5; 388)

Notes: Standard errors in parentheses.
$^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$

Table B.9
Influence of wind and solar electricity and the alternative flexibility options pumped- hydro storage and gas power at adoption point on CSBS diffusion with standardized betas.

	Δ*CSBS*				
	Renewables		Alt. Flexibilities		
	(1)	(2)	(3)	(4)	(5)
$StockCSBS_{t-1}$	0.557*	0.559*	0.560*	0.556*	0.555*
	(0.306)	(0.302)	(0.301)	(0.312)	(0.318)
$StockCSBS^2_{t-1}$	0.002	0.002	0.002	0.002	0.002
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
$ProdWind_{\ t}$	−0.050	−0.050			−0.034
	(0.303)	(0.303)			(0.296)
$ProdSolar_t$	−0.102	−0.102			−0.111
	(0.202)	(0.202)			(0.235)
Gas_t			0.362		0.384
			(0.791)		(0.928)
$PumpedHydro_t$				0.178	0.145
				(0.655)	(0.654)
Years	19	19	19	19	19
Countries	24	24	24	23	23
Time FE	✓	✓	✓	✓	✓
Country FE	✓	✓	✓	✓	✓
N	456	456	456	437	437
*R*2	0.334	0.334	0.335	0.331	0.332
Adjusted *R*2	0.262	0.263	0.263	0.257	0.253
F Statistic	68.631*** (df = 3; 411)	68.667*** (df = 3; 411)	68.925*** (df = 3; 411)	64.682*** (df = 3; 393)	32.254*** (df = 6; 390)

Notes: Standard errors in parentheses.
$^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$

Table B.10
Influence of targeted RD&D expenditures and the broad innovation policies guaranteed feed-in tariffs and tax rebates for innovation expenditures on CSBS with $\geq$ 500kW diffusion.

	CSBS >= 500KW diffusion				
	Targeted		Broad		
	(1)	(2)	(3)	(4)	(5)
$StockCSBS_{t-1}$	1.253***	0.469*	0.589*	0.654**	1.065***
	(0.364)	(0.257)	(0.312)	(0.325)	(0.326)
$StockCSBS^2_{t-1}$	−0.010**	0.003	0.002	0.001	−0.007
	(0.005)	(0.004)	(0.005)	(0.005)	(0.005)
$ElstoRDD_{t-2}$	1.041**				1.637*
	(0.441)				(0.948)
$GridRDD_{t-2}$		0.090			0.045
		(0.203)			(0.532)
$FIT_{\ t-2}$			0.078		0.468
			(0.254)		(1.309)
$TaxRebate_{t-2}$				0.710	0.366
				(0.552)	(1.171)
Years	2–23	2-25	17	13–15	2–15
Countries	24	24	24	24	23
Time FE	✓	✓	✓	✓	✓

(*continued on next page*)

Table B.10 (*continued*)

	CSBS >= 500KW diffusion				
	Targeted		Broad		
	(1)	(2)	(3)	(4)	(5)
Country FE	✓	✓	✓	✓	✓
N	218	473		408	358
*R*2	0.331	0.314	0.333	0.335	0.286
Adjusted *R*2	0.130	0.232	0.256	0.251	0.015
F Statistic	27.484***	64.253***	60.715***	53.240***	7.398***
	(df = 3; 167)	(df = 3; 422)	(df = 3; 365)	(df = 3; 317)	(df = 6; 111)

Notes: Standard errors in parentheses.
$^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$

Table B.11
Comparison of influencing factors with standardized betas and gdppc and population as control.

	$\Delta CSBS$			
	(1)	(2)	(3)	(4)
$StockCSBS_{t-1}$	2.437***	2.183***	3.758***	3.727***
	(0.679)	(0.654)	(0.962)	(0.814)
$StockCSBS^2_{t-1}$	−1.806**	−1.486*	−6.396***	−6.523***
	(0.858)	(0.830)	(1.919)	(1.678)
GDPpct	−0.00002	−0.00002	−0.00001	0.00000
	(0.00004)	(0.00004)	(0.00004)	(0.00003)
Populationt	−0.00000	−0.00000	−0.00000	−0.000
	(0.00000)	(0.00000)	(0.00000)	(0.00000)
% $VoteGreen_{t-2}$	0.295*			0.448***
	(0.170)			(0.172)
% $VoteEthnic_{t-2}$		1.323***		1.369**
		(0.513)		(0.625)
% $VoteLiberal_{t-2}$			−0.737*	−0.402
			(0.414)	(0.286)
$ElstoRDD_{t-2}$	0.307***	0.241**	0.236*	0.268**
	(0.114)	(0.106)	(0.128)	(0.132)
Years	24-25	2-23	2-23	1-18
Countries	24	24	24	21
Time FE	✓	✓	✓	✓
Country FE	✓	✓	✓	✓
N	218	218	154	154
*R*2	0.378	0.378	0.313	0.375
Adjusted *R*2	0.177	0.189	-0.021	0.054
F Statistic	16.587***	17.255***	7.819***	7.590***
	(df = 6; 164)	(df = 6; 164)	(df = 6; 103)	(df = 8; 101)

Notes: Standard errors in parentheses.
$^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$

Table B.12
Comparison of influencing factors with standardized betas excluding countries with no CSBS activity.

	$\Delta CSBS$				
	(1)	(2)	(3)	(4)	(5)
$StockCSBS_{t-1}$	1.233***	1.087***	1.216***	1.122***	1.121***
	(0.378)	(0.377)	(0.409)	(0.355)	(0.354)
$StockCSBS^2_{t-1}$	−0.009*	−0.007	−0.009	−0.008	−0.008
	(0.005)	(0.005)	(0.006)	(0.005)	(0.005)
% $VoteGreen_{t-2}$	1.990**			1.661*	1.565
	(1.006)			(0.950)	(1.045)
% $VoteEthnic_{t-2}$		3.901**		3.318**	3.329**
		(1.550)		(1.521)	(1.511)
% $VoteLiberal_{t-2}$			−0.697		−0.348
			(0.761)		(0.857)
$ElstoRDD_{t-2}$	1.561***	1.172**	1.297**	1.471**	1.498***
	(0.585)	(0.526)	(0.549)	(0.572)	(0.571)
Years	2–23	2–23	2–23	2–23	2–23
Countries	20	20	20	20	20
Time FE	✓	✓	✓	✓	✓
Country FE	✓	✓	✓	✓	✓
N	191	191	191	191	191

(*continued on next page*)

Table B.12 (*continued*)

	$\Delta CSBS$				
	(1)	(2)	(3)	(4)	(5)
$R2$	0.364	0.366	0.343	0.383	0.384
Adjusted $R2$	0.154	0.157	*0.127*	0.174	0.170
F Statistic	20.430*** (df = 4; 143)	20.623*** (df = 4; 143)	18.634*** (df = 4; 143)	17.619*** (df = 5; 142)	14.643*** (df = 6; 141)

Notes: Standard errors in parentheses.
$^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$

Table B.13
Share of green, liberal and ethnic party seats on CSBS diffusion.

	Δ *CSBS*			
	(1)	(2)	(3)	(4)
$StockCSBS_{t-1}$	0.508* (0.273)	0.472* (0.268)	1.426*** (0.411)	1.434*** (0.365)
$StockCSBS^2_{t-1}$	0.003 (0.005)	0.004 (0.004)	−0.027** (0.014)	−0.028** (0.012)
$SeatsGreen_{t-2}$	0.040 (0.131)			0.018 (0.126)
$SeatsLiberal_{t-2}$		−0.113 (0.097)		−0.104 (0.092)
$SeatsEthnic_{t-2}$			0.459** (0.191)	0.452** (0.189)
Years	24-25	24-25	24-25	24-25
Countries	24	24	24	24
Time FE	✓	✓		✓
Country FE	✓	✓		✓
N	598	598	598	598
$R2$	0.357	0.361	0.377	0.381
Adjusted $R2$	0.298	0.303	0.320	0.322
F Statistic	101.155*** (df = 3; 547)	103.107*** (df = 3; 547)	110.189*** (df = 3; 547)	67.023*** (df = 5; 545)

Notes: Standard errors in parentheses.
$^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$

Table B.14
Share of left-socialist, right, and conservative voters on CSBS diffusion with standardized betas.

	Δ *CSBS*		
	(1)	(2)	(3)
$StockCSBS_{t-1}$	0.508* (0.273)	0.472* (0.268)	1.426*** (0.411)
$StockCSBS^2_{t-1}$	0.003 (0.005)	0.004 (0.004)	−0.027** (0.014)
$VoteLeftSocialist_{t-2}$	−0.031 (0.182)		
$VoteConservative_{t-2}$		0.189 (0.324)	
$VoteRight_{t-2}$			0.013 (0.134)
Years	24-25	5-25	24-25
Countries	24	18	24
Time FE	✓	✓	
Country FE	✓	✓	
N	598	408	598
R2	0.357	0.373	0.357
Adjusted R2	0.298	0.296	0.298
F Statistic	101.156*** (df = 3; 547)	71.831*** (df = 3; 363)	101.072*** (df = 3; 547)

Notes: Standard errors in parentheses.
$^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$

Table B.15
Influence of wind and solar electricity growth (1+x) at the decision point on CSBS diffusion with standardized betas.

(*continued on next page*)

Table B.15 (*continued*)

	$\Delta CSBS$	
	Solar-PV	Wind
	$\Delta CSBS$	
	Solar-PV	Wind
$StockCSBS_{t-1}$	0.844**	2.357***
	(0.473)	(0.695)
$StockCSBS^2_{t-1}$	0.670	−3.970**
	(0.746)	(2.135)
$Solargrowth_{t-2}$	−0.0003	
	(0.007)	
$WindGrowth_{\ t-2}$		0.001
		(0.007)
Years	16	16
Countries	24	24
Time FE	✓	✓
Country FE	✓	✓
N	384	384
$R2$	0.353	0.353
Adjusted $R2$	0.275	0.275
F Statistic	62.208***	62.208***
	(df = 3; 342)	(df = 3; 342)

Notes: Standard errors in parentheses.
$^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$

Table B.16 shows the influence of guaranteed feed-in tariffs on $\Delta CSBS$. Feed-in tariffs can be differentiated by the renewable energy source they target, typically solar or wind, and by the guaranteed length and amount of the particular feed-in tariff. We tested for them all.

Table B.16
Shows the influence of guaranteed feed-in tariffs on $\Delta CSBS$.

	$\Delta CSBS$			
	Amount USD		Guaranteed Length	
$StockCSBS_{t-1}$	1.023***	1.042***	1.024***	1.036***
	(0.377)	(0.379)	(0.377)	(0.383)
$StockCSBS^2_{t-1}$	−1.286	−1.303	−1.287	−1.297
	(0.801)	(0.802)	(0.800)	(0.804)
$FiTsolar_t$	0.150			1.661*
	(0.167)			(0.950)
$FiTwind_t$		−0.147		3.318**
		(0.298)		(1.521)
$FiTsolar_t$			0.009	
			(0.010)	
$FiTwind_t$				−0.002
				(0.025)
Years	18	18	18	18
Countries	24	24	24	24
Time FE	✓	✓	✓	✓
Country FE	✓	✓	✓	✓
N	432	432	432	432
$R2$	0.110	0.109	0.111	0.109
Adjusted $R2$	0.012	0.011	0.012	0.010
F Statistic	16.040***	15.901***	16.101***	15.855***

Notes: Standard errors in parentheses.
$^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.
Feed-in tariffs can be differentiated by the renewable energy source they target, typically solar or wind, and by the guaranteed length and amount of the particular feed-in tariff. We tested for them all.

We test for three different RD&D expenditure measures that potentially influence CSBS diffusion directly. (A) battery technology in general, (B) electricity storage technologies, and (C) all energy storage technologies (Table B.17). However, as there are several other applications for batteries, e.g., in cars or mobile devices, or several different forms of energy storage, e.g., heat storage, the insignificant results for battery RD&D and energy storage RD&D expenditure are not surprising as their impact on CSBS is not direct.

Table B.17
Influence of different kinds of research and development expenditures log(x+1) on CSBS diffusion with standardized betas.

	Δ CSBS		
	(1)	(2)	(3)
$StockCSBS_{t-1}$	0.508*	0.472*	1.426***
	(0.273)	(0.268)	(0.411)
$StockCSBS^2_{t-1}$	0.003	0.004	−0.027**
	(0.005)	(0.004)	(0.014)
$BatteryRDD_{t-2}$	0.201		
	(0.138)		
$ElStoRDD_{t-2}$		0.247**	
		(0.106)	
$EnStoRDD_{t-2}$			0.014
			(0.048)
Years	1-23	2-23	2-25
Countries	24	24	24
Time FE	✓	✓	
Country FE	✓	✓	
N	212	218	467
R2	0.333	0.350	0.332
Adjusted R^2	0.125	0.155	0.251
F Statistic	26.744*** (df = 3; 161)	29.960*** (df = 3; 167)	68.791*** (df = 3; 416)

Notes: Standard errors in parentheses.
$^*p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

Table B.18
Overview of the Results of the Augmented Dickey-Fuller Test.

Lag order	Dickey-Fuller	p-value
10	-7.4664	0.01
8	-8.0968	0.01
0	-15.358	0.01

Data availability

Data will be made available on request.

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