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How the process of transitions shapes the politics of decarbonization: Tracing policy feedback effects across phases of the energy transition

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ABSTRACT

Policy feedback has been applied as a theoretical concept in exploring the political dynamics of domestic energy transitions. However, theory-oriented work is needed to apply the concept to studies of technological change processes. This article explores two technology feedback effects – technology maturity and socio-technical fit – that add external pressure for policy adaption. These are theorized as enabling a correction mechanism through learning that can partly counter positive policy feedback effects. Thus, the co-evolution process between renewable energy policy instruments and technologies is conceptualized as involving increasing return processes leading to sticky policies, balanced by correction mechanisms that support a more plastic view on policies. This argument is explored through a longitudinal case study of the co-evolution of policy instruments and solar photovoltaics in California.

1. Introduction

Recent decades have seen a revolution in the development and deployment of individual renewable energy (RE) technologies, making solar photovoltaic and onshore wind competitive in many markets [1]. This has been accompanied by a global shift in RE policy instruments, from qualitative policy instruments like feed-in-tariffs (FITs) towards more market-based policy instruments [2]. Another indication of changing technological conditions is the shift from evaluation of RE policy effectiveness in driving investments to structural impacts on the electricity market, reflecting the challenges that large shares of intermittent renewable generation create for managing the power grid [3]. Has there also been a shift in policy preferences among key stakeholders as technological conditions change, with policies co-evolving with technological developments?

In contrast to the idea of policy/technology co-evolution, policy feedback theory holds that once a policy is adopted, it is likely to generate self-reinforcing effects that entrench key actors' preferences and constrain later rounds of decisionmaking [4,5]. Originally developed within the context of social policy, policy feedback has been suggested useful for studying the evolution of RE policies and acceleration of technological change processes [6,7]. However, applying this logic to the study of technology change is not straightforward. For instance, technological advances are likely to engender new opportunities or challenges that in turn require policy innovation or redesign of existing policies [8]. More conceptual and empirical work is needed to integrate technological change into the study of policy feedback effects [6].

To that end, this article analyzes the potential of RE policies to generate self-reinforcing processes, drawing on two literatures—policy feedback effects and socio-technical transitions—to clarify and theorize the function of mechanisms linking policies and technologies. Policy feedback theory analyzes how RE policies, once adopted, may set in motion effects that change actors' cost-benefit calculations of policy change, leading to sticky policies. If such self-reinforcing processes unfold, this may entail considerable political effects. However, technological change processes are defined by technological dynamics as well [8–10]. In the power sector, external pressure for policy adaption and innovation is high. This empirical investigation analyzes *how techno-economic dynamics influence policy feedback over time, as a transition process in a domestic power system unfolds. Are the preferences of key stakeholders in an energy transition shaped around policies, or technologies?*

Here I argue that, when technology feedback causes significant learning among key stakeholders, it functions as a corrective mechanism to positive policy feedback effects. Thus, RE policy development is more likely to follow a functional pattern of adaption than path-dependent stabilization of early policy designs and choices. That does not mean that transitions do not involve politics. Structural power relationships underpinning the energy system dominate also after the adoption of RE policies. It is difficult to separate a mechanism such as learning from such structural power perspective. The political contestation over knowledge generation is itself a reason why policies are

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slow to adapt to technological changes.

My empirical focus is the development of RE policies in California, and the growth of its solar photovoltaic (PV) industry. RE policy instruments are limited to the main state-level policy instruments, statutes as well as regulation that govern the procurement of solar PV. The favorable political environment for climate and clean energy policies in California can be traced back to previous policy decisions, some dating back to the 1970s [11–13]. However, these studies have not examined how the process of transition shapes the politics of transitions. California's long commitment to supporting solar PV development enables a longitudinal explorative study of the co-evolution of RE policy instruments and solar PV—from an early phase, when the technology was supported by a set of policy instruments targeting the solar rooftop market, to a utility-scale generation resource that competes with other RE technologies under the state's renewable portfolio standard (RPS). Particularly since 2010, the solar boom in California has brought significant solar deployment on both sides of the meter, leading to overgeneration of solar and negative prices at certain times of the day [14]. Decisionmakers are now trying to catch up and formulate new responses.

Mapping RE policy evolution in California along with distributed and utility-scale solar reveals the following policy pattern: 1) expansion of complementary policy instruments for distributed and utility-scale solar; 2) a shift from policy instruments stimulating generic growth to more advanced instruments for aligning RE deployment with the needs of utilities or system operators; and 3) greater interaction among RE policy instruments. These patterns unfold in an interdependent relationship between internal policy characteristics and technology feedback effects. Furthermore, I note how technology dynamics bring diversification in policy preferences among stakeholders.

Following this introduction, Section 2 outlines the two analytical perspectives on policy stability and plasticity. Section 3 briefly presents the case and Section 4 the method. The main section, Section 5, goes on to explore the evolution of RE policies in California in interaction with the growth of the state's solar PV industry. Section 6 discusses the drivers for policy stickiness and plasticity and Section 7 concludes, suggesting the benefit of modeling the co-evolution of policy and technology as involving development of a market as a distinct political institution.

2. Analytical perspectives

To study RE policy instrument development along with solar PV in California, I draw on two different strands of research: the literature on *policy feedback,* with its focus on endogenous processes generated from within initial policies leading to sticky policy institutions; and the literature on *socio-technical transitions,* where policies are assumed to evolve according to a functional reasoning. Building on this reasoning I suggest two *technology feedback effects* and argue that RE policy development is likely to be defined by the external pressure generated from such technological dynamics.

2.1. Policy feedback, path dependency and sticky institutions

"Policy feedback effect" refers to the many ways that policies, through their design and implementation, generate effects that serve to uphold and protect the continuation of those policies [4,15]. Instead of treating policies as the outcome of the policymaking process, policies are incorporated as inputs to such processes, highlighting how polices act as institutions or "politically consequential structures" [4: 624] that can fundamentally reshape the political environment. The concept can be traced back to several sources within political science [16]. Pierson's [4] seminal work identified two main mechanisms—resources effects and interpretative effects—through which policies can influence political involvement and demands among individuals and the policy elite [17]. First, policies can generate means and incentives for political activity by, for instance, distributing new resources to social groups, transforming or expanding state capacities and encouraging individuals to act in specific ways. Second, policies can serve as sources of information and meaning, affecting political learning and attitudes. "For the electorate, policies may produce cues that help them develop political identities, goals, and strategies." [4: 619]

Scholar found policy feedback theory an attractive explanation for the evolution and stability of social welfare policies. Policies that start out small can end up having significant political effects, if conditions are right for self-reinforcement [18,19]. This suggests a path-dependent process of policy development: adopted policies generate effects that constrain future policy choices, increasing the likelihood of status quo or expansion [4]. Pierson's later work opened the black box of path dependency and largely shaped our understanding of such processes as sustained by endogenous, increasing-return processes [20]. Such situations involve historical processes characterized by initial contingency, where small early events generate large effects and lock-in [21]. Although developed in the context of formal institutions, the same logic could apply to public policies [20,22].

However, not all policies are subject to increasing-return processes [23]. Scholars have also studied negative feedback effects, endogenous effects that undermine institutional stability [24,25], and emphasize the interrelationship between feedback effects, context and outcome [26,27]. As argued by Hacker [19: 247] "while the prospects of internal policy change are shaped by a policy's specific characteristics, formal policy change depends principally on whether the basic political structure and partisan context privileges the status quo." Most historical institutionalists expect a wide array of possibilities of policy development; only one is resistance to change and lock-in [28].

A new strand of scholarship seeks to apply policy feedback theory to the study of RE policy instruments. This literature returns to the study of how policies affect mobilization and group power, finding that RE policies are important to develop constituencies, producer groups in particular, which then take an interest in the continuation of such policies [13,29]. Jacobsson and Lauber [30] include universities and research institutions in their analysis of solar and wind diffusion in Germany, noting the wide array of institutions that co-evolve with technologies. Furthermore, the policy design has been found to influence the momentum for change by generating or undermining local support for RE projects [31–33]; funding renewables over electricity rates can lead to public pushback as electricity rates increase [30].

These contributions are part of a research agenda for historical institutionalism and energy transitions and describes a potential approach forward to decarbonize the power sector or "path creation" [7]. Following the same logic as social policies, initial RE subsidy schemes may generate new demand for clean-energy policies and as such continue to accelerate decarbonization processes urgently needed to meet climate-mitigation goals. However, there are also reasons to expect RE policy development to develop differently from social welfare policies, which are likely to be resilient as they concern the long-term needs of families. RE policies, often subsidies, are less visible to the general public but are likely to affect interest groups [34]. As a decarbonization strategy its success depends on the ability of incumbents to counter mobilize [13].

Energy transitions are long-term processes. Identifying a positive feedback effect at an early phase of RE development does not necessarily mean that this process will be sustained. Instead it leads to the impression that decarbonization processes are set on autopilot once positive feedback effects kick-in, undermining the political leadership required to navigate long-term transition processes and interest conflicts between different low-carbon energy solutions. Further, comparing differences in the persistence of policies, Rose and Davies [35] found that market forces stimulate policy choice. Thus, there might be other factors that drive transition dynamics than initial policies—in particular, technologies are likely to generate dynamics that require active policy adaption and innovation (see below).

2.2. Technology feedback, technological change and policy plasticity

The proliferation of RE policies raises new questions: does technological change set in motion effects that can shift key actors' policy preferences, thereby creating feedback into subsequent policy developments? [8,9]. Does technology feedback lead to policy plasticity, enabling policy adaption and revision in response to technology and associated market changes? To explain such dynamics I draw on the innovation and transition literature [36,37]. Socio-technical systems are commonly understood as the "linkages between elements necessary to fulfill societal functions" [38: 900]. Theories of socio-technical transitions often employ a multi-level perspective, where new technologies develop within niches which are upscaled to replace existing technological regime [36]. Innovation is understood as co-evolutionary processes of technologies, organizations, institutions, user practices and business strategies [39].

Hoppmann et al. [8] argue that, given the complexity of the power sector, RE policy evolution is likely to be shaped by "policy-makers' limited capacity and foresight." They see learning as a key mechanism linking policy and technology, where learning is "affected by the dynamics of and interdependencies within the socio-technical system that policy-makers intend to change" [8: 1424]. As the FIT for solar PV in Germany underwent legislative changes in response to the effects it generated, technological progress gradually made policymaking increasingly reactive to these changes.

The idea of "learning" supports the view of transitions as a trial-and-error process, where decisionmakers steer socio-technical systems towards more sustainable practices, using policies as strategic tools. As such this mechanism is underpinned by a functionalist reasoning.[1] In political science, Peters and Pierre [41] have revisited such a functional reasoning on governance, seeing evaluation and learning as among the five key elements of effective governance. Similarly, focusing on internal policy effects that may require formal policy maintenance, Mettler [28] holds that governance and maintenance of policies are prerequisites for their long-term viability. Thus, while rooted in policy feedback theory she also highlights the functional dimension of policies.

Locating learning within a functional reasoning has implications for the study of RE policy evolution. Instead of path dependency, this reasoning assumes a continuous process of policy-making that allows for learning and adjustments, closely related to the logic of incrementalism [41]. Here, learning can be understood as a correction mechanism leading to "pressures that 'select' for institutional effectiveness over time" [20: 106]. In developing his theory of path dependency, Pierson [20] sought to counter functionalist reasoning, expecting revision to prove difficult as institutional resilience increased: according to the theory of positive feedback effects, the presence of correction mechanisms must be explained, not assumed.

From the transition and innovation literature, there are at least two *technology feedback effects* with possible implications for policy preferences and policy innovation, indicating learning as a corrective mechanism to policy inertia and entrenchment [8,42,43]. First as individual technologies mature, they move into a growth phase where several reinforcing market factors kick in, leading to lower costs [44]. As technologies mature, more market-based policy instruments can also effectively drive RE deployment [33] bringing more options in the choice of RE policy supporting schemes. Economists have also developed a body of research that provides a template for policy design. As technologies mature, the optimal policy changes, from instruments setting the price to volume [2,45].[2]

The second dynamic is triggered by the degree of socio-technical fit: how readily the technology can be integrated with the existing domestic power sector. Renewables are expected to deliver not only clean electricity, but also reliable and affordable electricity. Today's power sector evolved with dispatchable energy sources that could respond to changes in demand, serving customers at any time. Increasing the share of intermittent renewable resources leads to less responsive and flexible supply, requiring new forms of system innovation [46]. System-builders bring together different domains, to enable the system to function as a whole [36]. At an early phase of technology development, the policy objective might be to promote the growth of renewables: if successful, this will require new policy responses for the system to continue to deliver high-quality energy services.

Both technology maturity and socio-technical fit can put pressure on decisionmakers to adapt policy instruments or policy innovation. The first feedback is related to the idea of "effective implementation of innovation" [47: 978]. Various actors—economists, research institutes, but also decisionmakers themselves—have an interest in seeking to minimize the use of public funds to achieve a given policy goal. If set to high subsidies can also overstimulate the market, leading to backlash against RE policies. Poor socio-technical fit might generate an even stronger basis for adapting policies because the power sector consists of institutions and stakeholders—independent system operators, utilities, regulators—with responsibilities and roles in maintaining system viability. Also, to stay popular with their voters, decisionmakers are likely to prefer policies that maintain affordable and reliable electricity. When these effects influence market participants, any unintended consequences will probably be identified more rapidly than in the case of, say, social welfare policies.

To summarize, policy feedback as an analytical concept draws attention to characteristics and possibilities intrinsic to policies themselves, whereas technology feedback effects focus on characteristics of technologies and socio-technical change processes (Table 1). Including technology feedback effects is important because: 1) policy development unfolds within a dynamic context that requires active maintenance and innovation of policy instruments to function as intended and 2) instead of actors adapting their preferences to existing RE policies, technologies can be a source of preference change, independent of policy design.

Analyzing these processes together is relevant: "theory building would benefit from recognizing when distinct explanations are at work so that we can theorize those processes and hypothesize how these distinct processes interact with path dependence" [21: 313]. If policy and technology feedback effects are complementary without interaction effects, technology feedback effects can be added to the model without changing the initial mechanism [48]. If, however, they strengthen or weaken initial policy feedback effects, they must be endogenized. There might for instance be a point where positive feedback effects have gained so much traction that the effectiveness of learning as a correction mechanism declines.

3. The case

For insights into the evolution of RE policies and technologies, I examine the case of California and solar PV, where the high level of state capacity has enabled the implementation of environmental policies, facilitating the ability to learn and adapt policies [49]. This case is also expected to capture both technology feedback effects. California had a role in the early development of solar PV [50] which allows for a longitudinal study of policy development, from solar PV as an immature technology to a global commodity. Solar PV, which began as a behind-the-meter resource, now thrives as a utility-scale resource understood as generation connected to the transmission network.

As shown in Fig. 1, policy instruments for solar have been updated or changed several times; others have been added and ended, for both behind-the-meter solar and utility-scale solar. Additionally, California experimented with policy instruments to stimulate solar in front of the

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[1] However, innovation scholars draw, *inter alia,* on evolutionary economics that do not assume rational design see e.g. Wendt [40].

[2] I am grateful to an anonymous reviewer for pointing this out.

Table 1
Two dimensions of policies: acting as institution and their function.

Perspectives	Feedback effects	Outcome of interest
Positive policy feedback effects leading to sticky institutions	Resources effects Interpretative effects	Political outcomes e.g. mobilization of new interest groups and the remaking of politics
Technology feedback effects requiring policy adaption and change to ensure functional policies	Technology maturity Socio-technical fit	Technological outcomes e.g. growth of new technologies or the power system's ability to deliver energy services

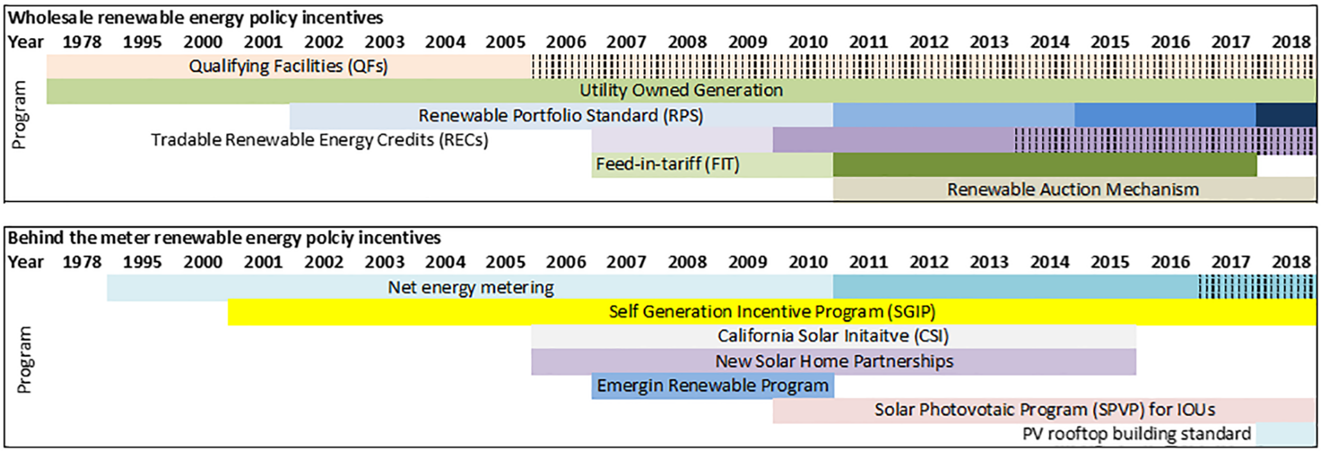

Fig. 1. Renewable Energy Policy Development in California*. * Stripes indicate program contraction, darker color a program expansion. Source: Adapted from Rogers et al. [51].

meter, connected to the distribution system (FITs and Renewable Auction Mechanism). Gradually, California went from a situation where solar accounted for only a minor share of the generation mix to today where behind-the-meter solar accounts for 15 percent of total renewable generation and utility-scale solar 35 percent [52]. A major challenge now facing energy decisionmakers is the over-generation of solar and subsequent negative prices [14]. The technological context has changed significantly, providing an opportunity to analyze the interaction of policy and technology feedback effects.

4. Method

This study uses a single case-study research design that allows for an in-depth explorative approach of RE policy development and the growth of solar PV [53]. I apply historical analysis and process tracing to capture "causal mechanisms in action" [54: 9]. In theory-centric case studies, causal mechanisms are understood as systematic or generalizable "pathways whereby X contributes to producing Y" [55: 12], but they are not theorized as sufficient to *explain* Y.

My study draws on extensive document studies, of policies, regulatory procedures, news articles and secondary sources. I started by mapping the evolution of policy instruments used to incentivize renewable generation (see Appendix for a historical overview),[3] documenting key arguments and the actors in favor or opposition. The document studies are complemented by semi-structured interviews, conducted in two rounds. First with a broad set of power-sector stakeholders to gain in-depth understanding of the actor landscape and political debates. The second round focused on the growth of the solar industry, evolution of distinct procurement mechanisms and recent responses to the rapidly changing technological conditions. An anonymized list of the interviewees can be found under references.

5. Solar to scale in California

5.1. Co-evolution of policies and rooftop solar PV

The initial policy demand for solar PV in California came from grassroots organizations and the California Solar Industry Association (CALSEIA). CALSEIA represented solar hot-water companies and saw the potential of expanding into solar PV in the 1990s [13]. At that time, the PV market was mainly limited to off-grid systems; the cost of batteries created an additional barrier for uptake (Interview). To reduce system cost, the solar industry promoted a novel approach, where the PV owner received credits for excess generation to be deducted from their electricity bills on a kWh basis. This Net Energy Metering (NEM) policy allowed customers to use the grid as backup, effectively compensating a wholesale commodity at retail rate [56].[4]

With the investor-owned utilities' (IOUs) focus on deregulation, CALSEIA successfully advocated for a NEM program in 1995 [13]. The first policy was designed for residential solar and wind up to 10 kW with a cap on 0.1% of IOU peak demand. California's three incumbent IOUs and large energy consumers opposed the bill, arguing that it would generate a cost-shift between customers. Stokes [13] mentions two reasons why it still received political support: the impacts would be minimal, and the policy did not require additional public funds. Thus, the negative feedback effect caused by cost-shift was already recognized at this point, but was deemed acceptable. The policy itself was never designed for massive deployment of customer-sited solar.

As part of implementing the policy, the IOUs added interconnection measures that reduced customer participation. CALSEIA sponsored two subsequent bills to clarify interconnection (Appendix Table A1). The California Public Utilities Commission (CPUC) banned the imposition of customer charges [57] and standardized interconnection for

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[3] Legislation and bill analysis can be found at http://leginfo.legislature.ca.gov/. The bill analysis (BA) is referenced as "BA date", where date corresponds to the date used at http://leginfo.legislature.ca.gov/.

[4] The value of NEM for the individual PV owner depends on many factors, including size of system, consumption pattern, electricity rates, weather, and seasonal variations.

installations offsetting on-site load.[5] NEM and interconnection developed in tandem. Among the benefits the solar PV industry received at this early stage was exemption from paying costs associated with interconnection studies, distribution system modifications, and application review fees. As the market has matured, some of these exemptions have been removed, while the NEM structure has remained.

The failed deregulation and subsequent electricity crisis in early 2000 made solar attractive for customers [58]. Decisionmakers also looked towards distributed generation to reduce peak demand, with the intent of NEM updated to include "reduced demand for electricity during peak consumption periods" (AB1x29). Two measures were hurriedly enacted during the electricity crisis [59]. In response to the governor's call for load control, the regulators initiated a rebate program for various behind-the-meter technologies administered by the IOUs. The majority went to PV installations. Further, NEM system size was expanded to 1 MW, allowing larger customers to benefit from the program. By mid-decade, the state's developing PV market had hundreds of installers serving NEM customers, and total PV capacity of 250 MW [60]. Despite having the most expansive NEM program, California lagged behind Japan and Germany in numbers of solar installations [61].

The major political and economic de-locking for solar PV came with the election of Governor Schwarzenegger (Rep.) in 2003 [13, 59, Interview]. He championed solar PV and was willing to use his political clout against IOU resistance. Formulating a vision of one million solar rooftops, the Schwarzenegger administration proposed a $3.3 billion ratepayer-funded effort to install 3000 MW of new DG (SB 1 2005). The inspiration came from an environmental organization, Environment California, which had drafted a proposal requiring solar in all new buildings by 2006 (SB 289) [59], a vision realized in 2018 when the California Energy Commission (CEC) updated the state building code. Around the same time, the solar industry saw new financial innovation: the development of tax-credit financing and the leasing model, which transformed the market and brought in mainstream capital market institutions (Interview).

The adoption of the rebate program known as California Solar Initiative (CSI) entailed an intense political fight between IOUs resisting any decentralization of the power sector and what grew to become "the broadest coalition of any bill that I can think of in history" (Senator Kevin Murray (Dem.), quoted in [62]. The IOUs pitted Republicans against Democrats by using labor unions to demand certification of electrical workers, which the Republicans were unwilling to accept [59]—a tactic the IOUs continue to use in fights over solar rooftop legislation (Interview). Several design features of the program were noteworthy. First, the rebate was not limited to homeowners buying solar installations, but included third-party providers like leasing companies. Almost 45% of the solar PV systems installed were owned by a third party, consolidating the leasing companies' market and political power. Second, the IOUs were to serve as program managers, as in previous rebate programs. This created cumbersome bureaucratic processes and criticism within the solar industry [59]. Third, the rebates were designed to decline with expected cost-reduction. The policy was never intended to be permanent, but to generate a market for a new technology. An example of how technology maturity can be integrated into policy design. In retrospect, a fourth implication of the policy design became evident: there were no provisions on curtailment. As pointed out by one interviewee, with solar PV mushrooming beyond imagination, Californian system operators today have almost 9.5GW of rooftop solar capacity that they cannot control [52].

When the state administration started to draft a program to meet the governor's ambitions, a FIT was not considered. As explained by Johnstone [59], FIT effectiveness was not yet obvious, and was more politically complicated to maneuver. The rebate program could build upon the existing one authorized during the electricity crisis. Moreover, when flaws became apparent, few were willing to discuss a new policy approach, recalling the many years of political fighting involved in getting the rebate program adopted. This shows how early policy decisions limited policy innovation, but due to the political context rather than specific policy design choices.

The rebate program marked a turning point for the rooftop PV industry in California. However, with the rebates declining over time, NEM and federal tax credits became the most important supporting schemes for the solar PV industry [63]. Thus, instead of a positive policy feedback effect impacting the rebate program in next round of policymaking, we see the growth of a solar industry now more capable of protecting NEM. Further, NEM expanded from a relatively concentrated solar-specific interest to include other beneficiaries beyond residential customers. Larger electricity users, particularly agriculture industry, schools, and local government mobilized and lobbied for separate NEM programs (Appendix Table A1).

The politics of NEM evolved around two dimensions. First, as the solar industry was about to reach the NEM cap, they went to the legislature to ask for an expansion (Interview). Eventually they worked through the CPUC to change the way the cap was calculated. Second, the sensitive relationship between PV adoption and electricity rates (Interview). The complicated relationship became evident during implementation of the rebate program. To receive the rebate, customers were required to switch to time-of-use (TOU) rate, which charged more for electricity during peak hours. The intention was to match solar electricity production with peak demand [64]. This led to higher electricity bills for certain customers when they installed PVs. Prioritizing growth, the legislature passed an urgency measure authorizing CPUC to delay TOU implementation (AB 1714).

The value of solar PV and the role of NEM as amplifying negative effects of customer-sited generation have generated a national, still ongoing, industry and academic discussion. California is a special case, as the negative effects of NEM were accelerated by the rate structure. In 2001, to protect low-income ratepayers from price fluctuations, policymakers froze rates for electricity use within the two lowest rate tiers (AB1x1). As residential customers in the top two tiers saw their electricity rates increase, the value of NEM also increased. A report ordered by the regulators showed a cost-shift between customer groups, due mainly to the current rate design [65]. Several interviewees argued that NEM, coupled with the freeze on electricity rates, had turned a progressive rate structure to a regressive one. However, the rooftop solar PV industry disagreed with the methodology used, and the political fight over the correct methodology for valuing solar continues (Interview).

Instead of addressing NEM directly, decisionmakers started to adapt the rate structure and terms of interconnection. Initially, rate reform did not mobilize the solar industry (SB 695). However, realizing the potential negative impacts of rate reform, the rooftop solar industry worked through the governor's office and succeeded in securing a more favorable mandate for which the regulators would assess future retail-rate design (AB 327) [13,66]. In the ensuing proceedings, the CPUC rejected the utilities' proposal and retained the basic NEM structure. However, by deciding that all unavoidable charges were to be paid on customers' gross consumption, they effectively ended retail-rate compensation [66]. In addition, regulators asked IOUs to consolidate the tiered rate structure and begin the process towards implementation of TOU rates.

Whereas early solar policies stimulated generic growth, the future of distributed solar in California is increasingly determined through new regulatory procedures aimed at maximizing solar value to the grid (Distribution Resources Plan R.14-08-013 and Interconnection Rulemaking 17-07-007). Calls for aligning pricing of DG and power-system operations have also come from system operators who fear that

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[5] Rule 21 is the tariff that sets the metering and operating standards for self-generation facilities interconnected to the utility distribution system. For development of interconnection standard see https://www.cpuc.ca.gov/Rule21/.

Table 2
Overview of supporters and opponents for key RPS policies.[1]

Bill	Year	Position	ENGOs	Env. Justice	Health	Business	*IOUs/EN*	*Renewable*	Labour unions	Government	*Energy Agencies*	Consumer protection	Other	Total
SB 1078 (Sher)	2002	Proponents	4			5		*5*		3	*1*	1		13
		Opponents				4	*4*		5	3	*3*			12
SBX1-2 (Simitian)	2011	Proponents	12		2	25	*2*	*21*	10	4	*1*	2	3	58
		Opponents				10				1				11
SB350 (De León)	2015	Proponents	47	11	32	97	*3*	*30*	40	24	*3*	2	53 (1)	306
		Opponents				46	*6*		1	1			8	56
SB100 (De León)	2018	Proponents (2)	29	6	19	15		*9*		4	*3*	2	2	77
		Opponents				23	*2*							23
AB 813 (Holden)	2018	Proponents	4	2		13	*1*	*5*		5	*5*		2	26
		Opponents	47 (3)	3		3		*1*	4	7	*7*	2	4	70

Source: Author counted the number of opponents and proponents based on the most recent bill analysis.

[1] (1) Mostly individuals. (2) The bill was supported by more stakeholders in earlier bill analysis, this number based on the most recent one. Opponents belong mainly to the agriculture industry. (3) 43 out of 47 environmental organizations are grassroots organizations.

increased amounts of DG may affect power-sector reliability [67]. In 2017, the California Independent System Operator (CAISO) changed its tariffs to encourage “distributed energy resources providers” to participate directly in the wholesale market, but attracted few participants. Among the barriers was higher compensation from NEM [68].

These new processes are contested. In 2017, when the 100% RPS was debated, labor unions wanted a provision in the bill limiting CPUC ability to expand programs for distributed generation [69]. There are, however, also indications that IOUs themselves have changed their approach to distributed generation. In 2017, SCE filed a rate case for funding upgrades of their distribution system [70]. This reorientation was hardly generated endogenously from the initial policies: it might represent a shift in strategy towards accommodation of a techno-economic trend the IOUs could not block.

Early solar PV policies in California opened the power sector to a new group of actors. Their success, however, has depended largely on political support, and is also a consequence of the market niche enjoyed by rooftop solar. As shown below, the growth of utility-scale solar resulted in solar PV per kWh declining rapidly compared to rooftop solar, and has entailed difficult discussions about the use of public funds. With the success of utility-scale solar, solar rooftop is no longer compared to gas but to alternative utilization of the same technology. In this competitive landscape, the solar industry is repositioning itself as provider of grid flexibility. CALSEIA recently changed its name to California Solar and Storage Association (CALSSA) and sponsored a bill to create a subsidy scheme for batteries following the design of the solar rebate program from 2006. With solar booming, there is little political willingness to support generation technologies. However, new market opportunities have emerged with small-scale battery storage.

5.2. *Co-evolution of policies and utility-scale solar PV*

Policies for solar PV connected to the distribution grid and utility-scale solar have evolved under the main policy instrument for renewables in California, Renewable Portfolio Standard (RPS). In early 2000 supporting schemes for solar PV was limited to 1 MW systems and the PV industry coalesced around smaller projects (Interview). This changed with the adoption of the RPS. With the transition towards utility-scale solar PV came the development of a new set of solar PV developers with interests more aligned with the IOUs.

The RPS concept was initially developed by the wind industry in California, and introduced by the biomass industry (Appendix Table A2). Thus, there is a direct link to the early RE boom in the 1980s, as the established industry, mobilized together with environmental non-government organizations and consumer protection organizations for a RPS in the 1990s [13]. Indeed, one argument was that the RPS would support the re-powering of some of the wind projects that had closed down [71]. When the RPS was first introduced, solar PV was still viewed as risky; it was not represented in the RPS coalition.

The coalition failed to get the RPS included as part of the deregulation process in California. However, the ensuing electricity crisis opened new opportunities [13]. With wholesale prices skyrocketing, and billions spent on electricity, state policymakers viewed long-term contracts as an important strategy to protect ratepayers from price volatility. RPS consisted of two policies: IOUs were required to meet 20% of retail sales with renewable resources by 2017 (later advanced to 2010), and long-term procurement planning by the state’s three IOUs (SB 1078 and AB 57).

The RPS established a market for renewables by incentivizing long-term contracts between IOUs and above-market price independent power producers through competitive bidding. The market price was estimated by the regulators, and the cost funded as a surcharge on electricity rates. The cost-recovery process was designed to function as a cost-containment mechanism (SB 1078). If the available funds were exhausted, the IOUs’ procurement obligation ended. The IOUs were willing accept the RPS with cost-containment, based on experience from the early RE boom that had left them with above-market contracts (Interview). Legacy contracts from this period also counted towards the RPS. SCE in particular had no problems accepting the bill, with 18% renewable contracts already in its portfolio (Interview).

Unlike other leading renewable economies, California’s decision-makers used the regulated monopoly model to implement public policy goals instead of breaking up existing power structures. After the electricity crisis, stakeholders were unwilling to discuss any wholesale market revisions (Interview). Going further back, Karapin [12] notes how the governor in the 1970s had wanted to encourage greater third-party participation, but that the IOUs put pressure on the state legislature. The result was a more strategic role for the IOUs, similar to the role they would play in implementing the RPS.

RPS adoption played out between the renewable industry, environmental and consumer protection organizations, against the IOUs, electrical-worker unions and public-owned utilities (POUs) (Table 2). The next decade showed deep political divisions among key stakeholders in how to implement the program [13]. The legislature sought to develop in-state renewable generation, whereas the governor was willing to use renewable energy credits (REC) opening for out-of-state resources. Both parties supported accelerating the RPS to a 33% RPS, but disagreed on flexibility and the cost of compliance terms. When Governor Brown (Dem.) took office in 2011, the legislature’s position won. A focus on in-state development aligned labor-union interests with RPS through a resource effect (Table 2).

The RPS was entirely new and required intense involvement by state agencies in realizing the vision. For the regulators this included defining rules for competitive bidding and compliance, and how to calculate purchase obligations. Two interviewees described how these processes gradually became largely institutionalized. Moreover, the

RPS requires grid infrastructure development and land-siting policies [56]. Agencies evaluated the impact of increased renewables, noting some barriers [60]. Energy agencies, with private and public utilities, initiated a proactive joint planning process to identify resources and transmission solutions [72]. This initiative engaged a broad set of stakeholders to balance environmental considerations with renewable development by fostering collaboration [73]. The governor set the goal to reduce permitting time by 50% in defined renewable zones and directed the creation of protected areas in the Mojave Desert (Exec. Order S-14-08).

The early solicitation processes received bids from many different technologies, including a group of solar PV developers that recognized the potential for larger PV projects. However, within the industry, stakeholders still saw solar thermal as the winning solar technology. In 2008, a handful of solar thermal companies had formed the Large-scale Solar Association (LSA) and debated whether to include PV members. No one at that time believed that solar PV would succeed at scale (Interview). However, in 2010–2012, most solar developers started to transition away from solar thermal to solar PV. Some developers had no prior stakes in the technology and could shift easily, but most solar thermal companies went bankrupt (Interview). This shift to solar PV reflects market competition. The IOUs bought whatever type of technology could offer the lowest bid; they were also willing to accept riskier projects, including hitherto-unforeseen big solar PV projects. The first decade of the 2000s was mostly about getting the regulatory framework in place. In that period, PV costs came down, leading to massive development of solar projects. Almost all of the installed capacity of utility-scale solar (12.8GW) came online after 2010 [52].

It was early recognized that long-term contracting was not suited to support wholesale solar PV installations connected to the distribution system. Negotiating contracts under RPS took years and was too expensive for small-scale operators. The early collaborative energy planning initiative was also criticized for focusing on utility-scale generation [73]. Gradually, the procurement mechanisms under RPS evolved into different contractual mechanisms [74]. These were not meant to substitute, but to develop different market segments mostly for PV. The growth in procurement contracts cannot be understood solely as the result of effective lobbying by the solar industry: also important was the willingness of decisionmakers to develop RE at a time when growth was their main concern. Particularly under Governor Schwarzenegger (2003–2010), RPS had become a strategic component of California's climate strategy [75]. This added pressure to accelerate RE deployment. The state energy agencies argued that meeting these ambitious targets required a FIT [60]. The governor used the regulators to implement a FIT, later adopted by the legislature: however the FIT was set too low [59]. The high cost of land close to urban centers was also a barrier (Interview).

After the FIT was implemented, the regulators opened a new inquiry into expanding the FIT to systems larger than 1.5 MW [76]. Based on a public service staff-developed proposal, the Renewable Auction Mechanism utilized a standard contract but relied on market-based pricing. The local solar industry under CALSEIA and other grassroots organizations advocated for an administratively determined fixed-rate FIT, but other solar parties supported the auction mechanism because it would avoid ratepayer backlash against high rates, as had happened in Spain and Italy [77]. The solar industry is by now no longer one coherent technology specific interest group.

These additional procurement mechanisms led to several projects, but the PPA remained the main procurement mechanism. The PPA contract cost declined from 0.14$/kWh in 2007 to around 0.5$/kWh in 2017 [78], and rate-payer costs "found acceptable" (SB350 BA04062015). Politically, California's policymakers have continued to build their renewables strategy around the RPS. Through an interpretative policy feedback, the continuing increase in renewable adoption has strengthened policymaker perceptions of RPS as an effective instrument. Responding to industry interests and IOUs advocating for a GHG emissions cap instead of a 50% RPS, Senator Kevin de León (Dem.) stated: "These policies will drive innovation here, bring investment here, bring jobs here, and bring revenue here" (SB 350 BA07102015). The RPS is valued for many of the same benefits as associated with the FIT and with success decisionmakers have not been interested in reconsidering other approaches. In this instance, technology maturity has strengthened the policy feedback effect.

The deployment of solar PV on both sides of the meter exceeding all expectations has led to new market conditions, with over-generation at certain times leading to a growing gap between morning and evening prices, compared to midday (Duck-curve). With additional solar coming online, the trend has led to new debates on policy revision. These discussions are driven by grid-management concerns but are also a regulatory issue for the CPUC and market participants (Interview). Politically, the strongest signal of shift in policy focus was the expressed intent to develop a regional wholesale market to facilitate increased quantities of intermittent renewable energy (SB 350). Even with gubernatorial backing, the creation of a regional power market has failed thus far (AB 813). Particularly the labor unions have been strong opponents, fearing loss of jobs, while the utility-scale renewable industry itself has downplayed the focus on in-state development (Interview). As shown in Table 2, the initiative also mobilized new actors favoring a more decentralized approach. The grid system operator has managed to side-track these political contestations, developing an energy imbalance market that offers a regional solution to system imbalances [79].

The RPS procurement program has remained largely intact—one reason being that IOUs have not held auctions since 2016. California's electricity market is rapidly changing, with new community choice aggregators (CCAs) taking over most of the IOUs customers [80]. However, all load-serving entities are required to comply with the RPS mandate. The way the policy is implemented it has a built-in incentive that discourages curtailment: even with negative prices, developers may put solar online as long as the renewable-energy credit value is higher than the negative price (Interview). The early market design has been successful, but was also simple, merely incentivizing the purchase of renewables as opposed to a specified type of power, energy capacity, or responsiveness to market signals.

Instead of formal policy changes, the response has come in the marketplace (Interview). Older contracts have been renegotiated to include curtailment; newer contracts build in some off-taker curtailment. The cost of these changes will eventually be distributed across all ratepayers, increasing the cost of the RPS. In addition, new solar projects are built with batteries. California has a limited storage incentive program, designed similarly to the RPS as a procurement mandate [81]. The main incentive to install batteries, however, comes from the market. By adding storage, two interviewees argue that producers can shift some of the load to later in the day, when the value of their product is higher. Moreover, advanced inverters and PV control systems can turn PV into a flexible utility-scale resource (Interview). Here industry is working with ENGOs and research teams to find new solutions [82,83].

The growth of CCAs has led to uncertainty in the market and a slowdown in procurement. With the need to accelerate procurement, the LSA sponsored the latest RPS bill (SB100) that advanced the renewables procurement target to 60% by 2030 and a 100% carbon-neutral grid by 2045 (Interview). For the first time, the policy design indicates a break with a path-dependent process of increasing RE goals. A 100% carbon-neutral goal allows greater flexibility as to the types of technologies that will make up the final power-mix. Fearing reliability and stranded assets, IOUs and POUs opposed the bill, which received support from the CCAs, ENGOs as well as trade unions and the Independent Energy Producers Association (IEPA). The IEPA reflects the transformation of California's energy system, historically representing gas developers and increasingly utility-scale solar.

These new targets are now driving a set of discussions about what needs to be bought and when conducted under a new procedure, Integrated Resources Planning (IRP), initiated as part of SB350 (Interview). The legislation provides regulators with greater authority to determine the portfolio needed to deliver on a set of public policy goals, from GHG mitigation to resource adequacy and reliability. California is currently transitioning from the RPS long-term procurement process to the IRP process (Interview). In this context, also solar thermal power might experience a revival [84]. Although more expensive, this technology can deliver more stable electricity over the course of the day than solar PV.

6. Discussion

This article has analyzed the degree of stability and/or plasticity of RE policy instruments alongside technology development. From policy feedback theory, RE policies can generate effects that gradually lead to policy entrenchment. These effects can be traced back to internal characteristics of the initial policy. As this concerns policy development within the context of technological change processes, I hold that the technology feedback effects lead to pressure for more active management of policy instruments, theorized as taking place through the mechanism of learning. In this perspective, policy development can be conceptualized as an incremental learning process, not a path-dependent, locked-in process.

Three patterns can be noted from this empirical study of RE policy development and solar PV in California. First, we see a gradual expansion of the initial policy instruments and in number of policy instruments. Starting out with NEM, solar rooftop PV developed together with increased system size, NEM cap and numbers of customer classes. As well as clarification and standardization of interconnection standards, various rebate programs, and most recently the integration of solar PV into building codes. Similarly, in addition to increasing the RPS goal, RPS implementation has involved experimentation with various procurement mechanisms and the development of land-policy and transmission planning. Unlike the first set of policy instruments specifically targeted at developing solar PV, RPS was initially developed by other RE interests. However, within a technology-neutral incentive system that encourages producers to compete on price, there has been a rapid shift among producers, from concentrated solar thermal to PV as the technology matured.

This expansion of policy instruments is aligned with the logic of positive policy feedback effects. However, such expansion cannot always be traced back to characteristics of the initial policy, but rather to the need for complementary policies to support market formation for solar PV. While producer groups were central in identifying market barriers, this expansion has also entailed close coordination with decisionmakers and has been proactively promoted by Californian energy agencies. The use of the IOUs to implement RE policies illustrates the active role California's decisionmakers have played in the decarbonization of the state's power sector, and supports the argument that the ability of policies to generate increasing return processes depends largely on the surrounding political context.

The growth in policy instruments may suggest that it is not the stability of a single policy instrument that is of interest, but rather a set of complementary policy instruments that enable the formation of markets, consolidating the political position of producer groups. This is aligned with the recent call by innovation scholars for studies of RE policy-mixes, with ongoing debates about how to define the concept [85]. There seem to be at least two different types of policy-mixes: one related to the set of RE subsidies (see Fig. 1) and another set of complementary policies necessary to develop a market for RE technologies (land policy, interconnection standards, etc.). Unlike subsidies, the second set of policies starts from a technology perspective, focused on what is needed to develop the market for this technology.

A second pattern is a shift from policy instruments designed to stimulate generic growth towards more advanced policy instruments aimed at aligning RE deployment with utility or system operator needs: this reflects a shift in policy priority from growth to integration. For instance, whereas decisionmakers were willing to put TOU rates on hold as part of the implementation of the solar rooftop rebate program, TOU are now rolled out to all NEM customers. The most recent expansion of the RPS into a 100% low-carbon energy goal indicates a shift, away from a path-dependent process towards a RE system to one that allows for greater flexibility in implementing a decarbonized power system.

This second pattern suggests policy responsiveness to technology change. Most significantly, this shift has incentivized new forms of policy innovation. Underway are new regulatory procedures that take a holistic approach to resource procurement and distribution planning. There is a key difference between early policy initiatives, under which the regulators administratively set procurement targets based on public policy goals, and recent policy developments that require such targets to be set on the basis of system needs. However, this shift does not automatically lead decisionmakers to adapt the initial policy instruments—for instance, the contractual mechanisms under the RPS still incentivize producers to sell generation to the grid, even at negative prices. Instead we see a market response: producers and utilities have added curtailment to the contracts and are considering the move towards capacity payments. Furthermore, there is a difference between direct subsidy schemes that have ended, and policy instruments such as tariffs including NEM that continue to evolve but are adapted to reflect changing policy priorities.

This shift from growth to integration has political implications because the alignment between stakeholder interests and decisionmaker objectives changes over time. For instance, with decisionmakers' willingness to supply RE subsidies declining, the solar PV rooftop industry is now looking towards batteries as a new growth market. This shift also has implications for the type of constellation of actors needed to drive transitions forward. Part of the success of the RPS was the positive resource effect generated by designing the RPS around in-state RE development, which also led labor unions to support the RPS. Today, in-state development is less important for the utility-scale RE industry, which supports the development of a regional market to generate new opportunities for export. Thus policy preferences reflect new technological and market conditions. Interestingly, the labor unions have obstructed this policy initiative, which indicates that their preferences are less dependent on technology characteristics.

Thirdly, we can note the growing interaction between new and existing policy instruments, as with the interaction between NEM and retail rates, adding further pressure for managing the initial solar rooftop incentive system, as well as between policy instruments for distributed and utility-scale renewables. Mettler calls this a *lateral effect,* when unrelated policies influence the development of the first: "As the interdependencies between policies grows, so do the consequences of the first policy" [28: 374]. Such interaction effects are also a reflection of market competition. Previously, there was room for a range of technologies, utilized at different points across the system, and ownership structures. However as RE grows, competition increases between these alternatives. Moreover, with interaction effects, the source of policy change may come from other stakeholders than those initially opposed to the policy. For instance, the rapid expansion of rooftop solar PV made system operators concerned about the impacts on the larger power system.

These patterns unfold in an interdependent relationship between internal policy characteristics and external transition characteristics. For instance, California's solar rooftop incentive schemes never involved a requirement that system operators could curtail this resource. Today, in addressing the new challenge of over-supply at certain times of the day, system operators are left with the option of curtailing utility-scale solar. On the other hand, because the main rebate program for solar PV was designed with a declining rebate structure and the RPS as a technology-neutral marketplace, there was no need for decisionmakers to manage these policy instruments as the technologies matured. Otherwise, internal policy design could have stimulated rent-seeking behavior.

Moreover, these patterns are not inconsistent with the growth of new producer groups as necessary for expansion of RE policies [13,29]. However, there is a difference between the expansion of actors involved in energy-policy design (policy feedback effect), and the stability of early policies. Technological change brings diversification and a demand for updating and expanding policies, while some groups continue to benefit from the initial policies and seek extension. Particularly vulnerable are the early solar rooftop companies serving the residential market, as they lack the same opportunities to benefit from economies of scale as solar PV companies serving commercial and industrial customers, or utility-scale solar PV developers. Importantly, policy instrument reform or even removal does not necessarily indicate a contraction of the political project to decarbonize the power sector. In fact, the shift from growth to integration indicates a deepening of the transition, as the incentive system governing the power sector is increasingly designed to facilitate high levels of intermittent RE.

Unlike social welfare policy that provides programs for the mass public, producer groups are far more strategic actors who seek to develop solutions to ongoing challenges that will also enable them to gain market shares and profit. Moreover, although producer groups lock in investment based on initial RE policy design, it is easier to coordinate and design solutions that are palatable to the actors involved. Future research could benefit from drawing more explicitly on the political economy of regulation [86,87], where regulators and producer groups develop a symbiotic relationship over time. On the other hand, the support for solar PV rooftop exhibits some of the same characteristics as social welfare programs—granting consumers direct benefits—which is also one reason why NEM has proved so sticky. The problem with NEM is that, unlike social welfare policy, it has been regressive due to the complicated interaction with underlying rate structure. However, the value of distributed solar remains contested. Heavy pressure to develop policies and standards that allow the system to continue under the existing design and operational philosophy (socio-technical fit) may also limit broader institutional innovation [88].

This explorative case study of the co-evolution of policies and PV in California has documented the development of at least two clusters of producer groups: rooftop or distributed solar, and utility-scale solar. Both deploy PV but have different interests regarding policy instruments and the role of the grid. Sets of actors cluster around particular forms of utilizing technologies. As transitions advance, conceptual frameworks need to integrate the mosaic of interests: RE cannot be treated as one unit within a single climate coalition. In California there seem to be at least two climate coalitions: one looking inwards for local solutions, the other outwards for regional solutions. Nor can RE producers be assumed to represent the public interest, particularly with increased competition between different low-carbon technologies and solutions.

Introducing technology as a driver in and of itself also suggests that incumbents might change interests independent of policy design. There are indications of such shifts as solar PV matures, becoming a utility-scale resource. However, the IOUs continue to press for more flexible policy instruments. Explicit support for expansion of the RPS came when transportation was added in 2015, indicating the need to link power-sector decarbonization and electrification of transportation to see policy preference change. Further research is needed to clarify the mechanisms behind changes in utility policy preferences.

7. Conclusion

The case of California shows that policy feedback and technology feedback operate alongside each other. The preferences of some groups continue to form around initial policies: producer groups tend to respond more to technological and market changes by supporting updates and more advanced policy instruments consonant with new challenges. Moreover, rapidly changing technological contexts call for rethinking early policies. This suggests a more functional perspective than that offered by the policy feedback concept. Such a functional perspective appears better suited for integrating technological changes that can also drive policy development and highlights the role of decisionmakers. However, we have noted several instances of policy stickiness. Political responses to technological changes often build on existing policy instruments and do not come instantly: time is needed to reorient and adapt initial policy initiatives. Sometimes the market seems much quicker to respond.

Instead of searching for stability generated from within a particular policy, future research would benefit from modeling the co-evolution of policies and technologies as involving the development of markets as a distinct political institution. Tracing the development of RE policies and solar technology in California has shown how two distinct markets have evolved: one for behind-the-meter and the other utility-scale solar PV. Once a market is established, this generates effects that make it difficult for decisionmakers to dismantle it. Policies may be adapted or even removed, and new policies added. In this process, the market is the stabilizing equilibrium of interest.

A focus on markets as institutions offers several advantages for the study of RE policy development and the interaction between policies and technologies. First, it shows that the development of markets is a public policy choice. The solar industry in California has developed within two distinct markets—rooftop and utility-scale. There have been efforts to develop mid-sized solar closer to load; these efforts have led to some projects, but not thriving markets. Second, it brings a focus on producer groups that have established themselves within a specific market as the actors linking policy and technology. Such producer groups might be willing to switch between technologies, as from solar thermal to solar PV, or to add new technologies, like batteries, for additional customer value. Producer groups emerge as far more strategic actors than what traditional policy feedback literature might indicate. They do not simply form preferences around a given policy: their interest lies in developing a particular market where they can grow and profit. Third, the focus of the market is also aligned with the recent call to study technologies together with policy-mix. This could also encourage scholars to pay attention to the cost of capital and the financial sector, an approach missing in much of the literature on RE policies and technologies. Finally, a focus on market formation draws attention to state capacity. Historical institutionalism has traditionally focused on state capacity in terms of social welfare policy and warfare—but the development of markets also requires state capacity [89]. Thus, a focus on markets can open a new area of inquiry for historical institutionalists.

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.

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Appendix

Interviews (California)

I-1: Energy expert, April 6, 2017 (phone)
I-2: Solar trade association, May 16, 2017
I-3: Senator office, Chief of staff, May 17, 2017 & March 20, 2018 (phone)
I-4: Energy expert, May 18, 2017
I-5: Consumer protection organization, June 2, 2017
I-6: Environmental organization, June 14, 2017
I-7: Low-income solar provider, June 15, 2017
I-8: Solar advocacy organization, June 23, 2017
I-9: Public owned utility, June 23, 2017 (phone)
I-10: Energy expert, June 29, 2017
I-11: Energy expert, June 22, 2017
I-12: Rooftop solar company, June 28, 2017 (phone)
I-13: Rooftop solar company, July 5, 2017 & February 26, 2020 (phone)
I-14: Energy producer trade association, February 8, 2018 (phone)
I-15: Energy agency, February 27, 2018 (phone)
I-16: Utility-scale solar developer, February 25, 2020 (phone)
I-17: Energy agency, February 26, 2020
I-18: US research institute, March 5, 2020 (phone)
I-19: Solar trade association, March 5, 2020 (phone)
I-20: Utility-scale solar developer March 6, 2020 (phone)

Table A1
Behind-the-meter renewable generation policy and regulatory development.

Year	Policies/Regulation	Source	Description
1995	SB 656 (Alquist)	CALSEIA	NEM program for residential customers with PV systems of 10 kW or less located at the customer's premise and intended to offset part or all of the customer's own electrical requirements. Applies for all electric utilities that offer residential electrical service.
1998	AB 1755 (Keeley)	CALSEIA	Add small wind systems and small commercial customers, reinstate tax exemption (to 2005) and specify annual billing cycles. Require utilities to provide a standard NEM contract for all eligible NEM customer generators and provided protection from fees larger generators have to pay.
1998			Emerging Renewables ("Buydown") CEC began offering rebates for grid-connected on-site systems (less than 30 kW) in the service territories of the three largest IOUs in 1998 funded by a public goods charge.
2000	AB 918 (Keeley)	CALSEIA	Revise and clarifies the method of calculating NEM bills.
2001	ABX1-29 (Kehoe)	Author	Temporarily expand the NEM program to all customers with a solar and wind system of 1 MW or less located on customeŕs owned, leased or rented premise, intended to offset customeŕs own demand. Protection from stand-by charges on the electricity generation capacity or kWh produced.
2001	AB 970 (Ducheny)	Author	Require the CPUC to initiate certain load control and distributed generation activities within 180 days. CPCU adopt a rebate program for on-site systems up to 1 MW, rebates offered depend on whether renewable or non-renewable. See also CPUC Decision 01-03-073.
2002	AB 58 (Keeley)	Author	Preserves single meter net metering up to 1 MW from previous bill, with TOU rate schedule for systems between 10 kW and 1 MW and introduce co-metering (compensation based on generation only). System cap raised. Establish timeframe of max. 30 days for NEM application processing. Tasks CPUC to conduct cost-benefit study.
2002	AB 2228 (Negrete McLeod)	Inland Empire Utilities Agency	Establish a pilot program (until January 2006) for biogas digester customer generators of up to 1 MW, intended to offset customers own electricity consumption using a time-of-use meter. Co-metering, separate cap. Renewed in 2005 with AB 728 (Negrete McLeod).
2003	AB 1214 (Firebaugh)	California Cast Metals Association	Pilot program for fuel cells similar to biogass digesters (AB 2228). Co-metering, separate cap. Co-sponsors: San Diego City and East Bay Municipal Utility District. Renewed in 2005 (AB 67 Levine) and 2009 (AB 1551 Committee on Utilities and Commerce).
2003	SB 289 (XX)	Environment California	Requiring all new homes to built in the state after 2006 to be built with PVs. SB 289. Stopped at committee stage.
2005	SB 816 (Kehoe)	City of San Diego	Establish a separate limit of NEM capacity of 50 MW for the San Diego and Electric Company service territory. Co-sponsor: San Diego Gas & Electric.
2005			In January 2005, CPUC opens a proceeding asking parties how to best design a solar initiative. The proceeding leads to staff white paper issued in June of 2005. When the Legislature fail to adopt the SB1 in 2005, CPUC created the California Solar Initiative

(*continued on next page*)

Table A1 (*continued*)

Year	Policies/Regulation	Source	Description
			(CSI) a $3.2 billion rebate program for solar PV. Incentives reduced annually. Goal to create a 3,000MWof distributed generation and a self-sustaining solar PV industry.
2006	SB1 (Murray)	Author	Establish the Governor's Million Solar Rooftops proposal, implemented by regulation the previous year (CSI). As part of the California Solar Initiative rebate program for PV installed by end-customers NEM cap increased from 0.5% to 2.5% of the utility's aggregate customer peak demand. To receive the solar rebate the customer were required to switch to TOU.
2007	AB 1714 (Committee on Utilities and Commerce)	Schwarzenegger Administration	Authorized CPUC to delay implementation of TOU.
2007	CPUC Decision (D.07–10-032)		Directs the IOUs to integrate customer demand-side programs, such as energy efficiency, self-generation, advanced metering, and demand response, in a coherent and efficient manner.
2008	AB 2466 (Laird)	City of San Jose	Allow local governments to distribute bill credits from a renewable energy system within the government's geographical boundary, across more than one meter. TOU tariff, max system size 1 MW. Cap 250 MW.
2009	AB920 (Huffman)	Environment California	Establish a new class of customers: net-surplus generation customers. Beginning January 2011 net surplus generation customers can either roll over bill credits or receive compensation for net excess generation over the year.
2009	SB 695 (Kehoe)	Author	Removed the freeze on rates and replaced it with a rate formula that allowed for gradual increase. Since 2001 rates for the highest tier of usage had at least doubled and for some more than tripled, whereas most of the residential usage was within tier 1 and 2.
2010	AB 510 (Skinner)	Solar Alliance	Increase the cap to 5% of an electric corporatiońs aggregate customer peak demand. Initially included a provision about type of contractor who could install PV systems larger than 250 kW, CALSEIA against. Co-sponsor: City of San Jose.
2011	SB 489 (Wolk)	California Agriculture and Climate Network	Revise the definition of eligible customer-generator to renewable technologies defined as under California's RPS. Small-scale hydro is not eligible to participate under NEM.
2012	SB 594 (Wolk)	Author	Authorize eligible customer-generators with multiple meters to aggregate electrical load of the meters against one generation facility on the same property. Only under condition that no cost-shift occur. Net surplus customer compensation prohibited.
2012	CPUC (Decision 12-05-036)		CPUC adopt a new calculation of peak demand effectively doubling the state's 5% cap. The CPUC also ordered a new cost-benefit analysis and stat that the NEM program would be suspended in 2014 pending the outcome of future Commission proceedings to be undertaken in the wake of the study.
2012	AB 2514 (Bradford)	Author	Required a study of the costs and benefits of NEM, and the cost of service to NEM customers, to be completed and presented to the legislature by October 2013.
2013	AB 327 (Perea)	Author	Establish two regulatory procedures: rate reform and NEM successor tariff. CPUC required to grandfather existing NEM customers and develop a new NEM tariff. Each IOU requested to switch over to NEM 2.0 on July 1, 2017 or after their NEM capacity exceeded 5% aggregated customer peak demand. Distributed resources planning (DRP) introduced as part of the bill. requires that the California Public Utilities Commission (CPUC) design a program for utilities to create distribution resources plans (DRPs) that incorporate distributed energy resource planning into the normal distribution grid planning process.
2013	AB 217 (Bradford)	GRID Altern-atives	Extended the CSI low-income program with new funding, to continue until funds exhausted or until 2021.
2015	CPUC (Decision D.15.07-001)		CPUC asked the IOUs to consolidate the tired rate structure and begin the process towards implementation of TOUs rates. Also permit IOUs to make request for fixed charges. CPUC issues a revised decision (Rulemaking 12–06-013) that would order: no fixed charges in the near term, minimum bills, reduce number of tiers to two, default time of use rates, interim TOU pilots.
2016	CPUC decision (16-01-044)		NEM successor tariff (NEM 2.0) Maintained the basic NEM structure with retail compensation. However, non-bypassable charges measured on "netted out" quantity of energy consumed within a 1 h meter interval (residents) and 15 min interval (commercial) effectively ending retail rate compensation. Transition to TOU rates, interconnection fee depending on system size.
2016	CPUC decision (D16.-12-036)		Approved a competitive solicitation framework and a utility regulatory incentive mechanism pilot which will facilitate on a pilot basis the deployment of DERs to displace or defer the need for capital expenditures on traditional distribution infrastructure.
2018	CEC decision		CEC approved the 2019 Building Energy Efficiency Standards that will require all low-rise residential buildings (three stories or less) must have solar PV starting in 2020. Community-solar systems could meet the requirement if found to provide similar benefits (energy savings, bill reductions, durability). The CEC also created a solar plus storage option to give credit toward the new Standards.

Table A2
Utility scale RE Policy development.

Year	Policy/Regulation	Source	Description
1995	AB 1202 (Woods)	Biomass industry	Renewable resource procurement target at 10% by 2002 and a biomass portfolio standard within this mandate.
2001	SB 532 (Sher)	Author	Extended existing RE programs and establish a 20% renewable procurement target by 2010 for all load-serving entities. Passed the Senate floor and two Assembly committees.
2001	SB 78x2 (Polanco)	Author	Establish a 10 to 20% renewable procurement target by 2010 for IOUs, as part of a bailout bill for Southern California Edison. Died on file.
2002	SB 1078 (Sher)	Author	Require 1% annual increase in procurement of eligible renewable resources by IOUs until 20% is procured from such resources. Direct CPUC to order IOUs to enter into long-term contracts with IPPs, cost containment request generators to request above market cost recovery through the supplemental energy payments (SEPs) program funded by Public Goods Charge (PGC). Chaptered.
2002	SB 1038 (Sher)		Restate the goal of current renewable energy programs funded by public goods charge (PGC) and require CEC to use a portfolio approach to achieve the programs' goals.
2002	AB 57 (Wright)	Author	Require CPUC to review and adopt a long-term contract procurement plan for IOUs. Contracts to be entered through open, competitive bidding process. The RPS part of the procurement plan. Chaptered.
2003	Energy Action Plan		Adopted by CPUC, CEC and the Power Authority (PA). Pledge that the agencies will accelerate RPS implementation to meet the 20% goal by 2010, instead of 2017. The Governor has also endorsed "20% by 2010" and proposed an additional goal of 33% by 2020.
2004	SB 1478 (Sher)	Author	Advance the deadline to achieve 20% renewable portfolio to 2010. When introduced included POUs. Require CEC to establish a renewable energy credit (REC) trading program. Vetoed by governor.
2006	SB 107 (Simitian)	Author	Codified the 20% RPS from 2017 to 2010 into law. Clarified and extended a flexible compliance mechanism for RPS that allows utilities to procure more generation in any one year than is necessary to achieve the yearly target and apply the excess amount toward shortfalls in the three preceding years ("banking"). Passed Senate floor same year, but stalled in the Assembly. Passed the Legislature at the end of the 2006 session. Chaptered.
2006	SB 1368		Prevents electric utilities from entering into long-term contracts or financial commitments with terms longer than five years for baseload electricity generation, unless the generation meets a performance standard for greenhouse gas emissions.
2006	AB 1969 (Yee)		Establish a FIT program (Re-MAT) for small renewable generators to sell power to the utility at predefined terms and conditions. The AB 1969 FIT program set the price paid to small generators at the level of the Market Price Referent (MPR). Implemented by CPUC in 2008 for systems smaller than 1,5MW and total procurement cap at 480 MW. The Federal Court found the program to violate PURPA and was stopped in 2017.
2007	SB 411 (Simitian)		Held in Assembly
2007	SB 1036 (Perata)		Modified the cost containment program (SEP). Electrical corporations are now required to seek approval of both the contract and cost recovery of any eligible above-market contract costs from the CPUC. The total cost limitation was not modified (total amount of eligible above-market contract costs electrical corporations may request is equivalent to the funds that would have been available under the SEPs program).
2008	Executive Order S-14-08		Establishes a target of 33% of retail sales from renewable energy by 2020 orders the creation of a streamlined process for approving renewable energy projects. Direct the California Air Resources Board (CARB) to adopt a regulation by July 2010 requiring the state's load-serving entities to reach that target.
2008	SB 14 (Simitian)/AB 64 (Krekorian)		Both established a 33% RPS goal. AB 64 dropped. SB (14) vetoed by Governor Schwarzenegger citing constraints on including out-of-state renewable energy sources under that bill.
2009	Executive Order S-21-09		Direct the CARB to adopt regulation using its authority for GHG reduction efforts provided by AB 32 (Nunez), increasing Californiás RPS to 33%. Highest priority given to those renewable resources that can be developed most quickly.
2009	SB 32 (Negrete McLeod)		Establish Re-MAT which replaced the FiT from 2006 and increased project size from 1.5 MW to 3 MW. An IOU procurement program that provides market-based adjusting prices for small RPS-eligible facilities (generating up to 3 MW) to sell renewable electricity to utilities under standard terms and conditions.
2010	SB 722 (Simitian)	Author	Passed the Assembly in the final hour of the 2009–2010 session, but failed to pass the Senate as the session came to a close at midnight Governor signalled unwillingness to sign without changes.
2010	Decision (D.) 10–12-048	CPUC	This decision authorizes a new procurement process called the Renewable Auction Mechanism, or RAM, for the procurement of smaller renewable energy projects that are eligible for the RPS Program. RAM evolved from the Commission's inquiry into expanding the existing feed-in tariff program for generators 1.5 MW and below, pursuant to Public Utilities Code Section 399.20 and Decision (D.)07–07-027. However, RAM is distinct from a feed-in tariff as that term has traditionally been used. While it is a streamlined contracting mechanism and utilizes a standard contract, RAM relies on market-based pricing, utilizes project viability screens, and selects projects based on least cost rather than on a first-come first-served basis at an administratively determined price. Direct the 3 IOUs to procure at least 1000 MW over the two next years.
2011	SB 1x2 (Simitian)	Author	Advance the RPS goal to 33% by 2020 (and 20% by 2013). Established a three portfolio content category for RPS procurement and sets minimum and maximum quantities of procurement in each category. (Following SB 722 (Simitian) from 2010). Signed by Governor Brown. Chaptered.
2011	SB 836 (Padillia)	Author	Require the CPUC to annually report the costs of all electricity procurement contracts under RPS and all costs for utility-owned generation approved by the CPUC. Chaptered.
2015	SB 350 (De León)	Author	Increase RPS goal to 50% and double statewide energy efficiency by 2030. The third goal 50% reduction in petroleum use in transportation dropped. Among other the bill also initiated a process to plan for regionalization of the grid (CAISO expansion), process for filing integrated resources plans (IRP) and study barrier for uptake of DG among low-income customers. Chaptered.
2018	SB 100 (De León)	Author	First introduced in 2017. Adopted 2018. Increase the RPs mandate to 60 by 2030 and establish a 100% clean energy mandate (non-carbon sources) by 2045.
2018	AB 813 (Holden)	Author	This bill would delegate to the California Energy Commission (CEC) the ability to authorize the transformation of the CAISO into a multistate regional transmission system, if specified requirements are satisfied.
2019	AB 56 (Garcia)	Author	Establish a new non-profit benefit corporation with the author to procure resources to specifically meet resource adequacy, reliability, and RPS requirements. The author will serve as a backstop procurement mechanism to fill unmet resource needs, given increasing fragmentation of the retail market.

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