Assessing potential for policy feedback from renewable energy incentive programs

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Climate advocates look optimistically to policy feedback as a mechanism for locking-in a decarbonization policy trajectory, but little research has examined whether and how climate legislation creates constituencies that could provide future political support. This article focuses on incentive programs supporting investment in solar PV and the potential for policy feedback through participating households. We first develop a framework of feedback potential that considers the *volume* and *partisanship* of incentive program beneficiaries and their *distribution* across electoral districts. We then apply the framework to New York State's solar PV incentive program, which enabled over 140,000 households to install solar PV. We find that the number of solar PV incentive beneficiaries is positively associated with Republican vote share, suggesting potential for a strong pro-solar constituency in the pivotal, Republican-led districts. Within electoral districts, however, beneficiaries skew Democratic, raising questions about the direction of policy feedback. The results carry implications for the kind of politics that incentives in the Inflation Reduction Act may set in motion in the coming years.

In the face of considerable political barriers to climate action, policy feedback has emerged as a key framework for climate advocates for designing a political strategy to accelerate the energy transition and "lock-in" a decarbonization trajectory[1–5]. The theory of policy feedback holds that the passage of specific legislation directly affects the attitudes, interests, and behavior of the electorate and other actors that can influence policy outcomes[6–8]. Initial legislative victories can thus create a constituency to bolster political power in future contests, allowing policy expansion and entrenchment[9]. Despite the prominence of the policy feedback framework in both scholarly and policy discourses about achieving a rapid energy transition, little research has directly examined whether and how actual climate legislation creates the types of electoral constituencies that would be effective in shaping future policy trajectories.

Here, we focus attention on a particular type of legislation—financial incentive programs targeted at end-consumers—and focus on potential feedback through the electorate. Financial incentive programs are a pillar of energy transition policy in the United States. Such programs have, for example, played an instrumental role in the emergence of self-sustaining electric vehicle (EV) and residential solar photovoltaics (PV) industries[10,11] and are a central piece of the Inflation Reduction Act (IRA), the signature climate bill passed by the Biden administration in 2022[12]. Researchers have suggested that broad public benefits from incentive programs may create important political support for entrenching energy transition policies,

especially in a political environment marked by high levels of partisan polarization[13–15].

We draw on the theory of policy feedback to, first, develop a framework for conceptualizing the potential for positive policy feedback that considers (1) the existing policy preferences of partisan elites, (2) the volume of beneficiaries, (3) the partisan make-up of the beneficiaries, and (4) the distribution of beneficiaries across empirical electoral districts. We then apply the framework in the context of an incentive program that supported the installation solar PV among 142,046 households in New York State. Across three types of electoral districts, US House of Representatives, NYS Assembly, and NYS Senate, we find that Republican-led districts, which could be decisive for future energy transition policy, have more PV incentive beneficiaries, suggesting a strong pro-solar constituency, but beneficiaries skew Democratic, raising concerns about the direction of policy feedback. We conclude by discussing the implications of these findings for the potential role of policy feedback in shaping a decarbonization policy trajectory in the United States.

Policy feedback theory holds that the end of one policy contest provides essential conditions for the next one[7,16]. The theory draws attention to how specific elements of enacted policies enable and constrain future political action. From this perspective, it is essential to consider the sequence of policymaking, because early policy outcomes can either reinforce or undermine future policy trajectories[1]. The ramp up of military spending

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during the Cold War provides an illustrative example. The federal defense dollars created public support for the military-industrial complex by building a broad, geographically distributed coalition composed of the beneficiaries of federal programs, including defense workers, military contractors, labor unions, and current and retired member of the military[17]. The so-called "warfare state" thus provided financial security for a large fraction of Americans and across every congressional district, ensuring that any proposed cut to defense spending would face a formidable political challenge. A second, canonical example of policy feedback is the Social Security Act of 1935. Although its passage was highly contested at the time, once in place, the broad base of material beneficiaries ensured that the programs became politically entrenched[18].

A parallel strategy may be available for building political support for an energy transition[9,19]. Policies that provide subsidies for renewable energy and energy-efficient technologies offer a straightforward example of how this might work. The financial incentives for the purchase of electric vehicles (EVs) increase the number of EVs on the road, but also increase the numbers of EV drivers and of workers at EV manufacturing plants, all of whom may support future initiatives to develop reliable EV-supporting infrastructure. Seen through the lens of policy feedback, the Inflation Reduction Act (IRA) could serve as a cornerstone of this political strategy. According to widely cited estimates, IRA will provide up to $1.1 trillion to U.S. households, businesses, and local governments to make investments in clean energy and energy efficiency[12]. In the process, the policy could expand its political constituency by giving firms, workers, unions, and end-consumers a material stake in the energy transition.

In this study, we will limit the scope of attention to mass politics (i.e., the electorate), setting aside the mobilization of organized interests in policy feedback, which has received attention elsewhere (e.g., ref. [4]). Researchers have identified several specific ways that public policies shape political participation and attitudes among the mass public. Scholars distinguish between resource and interpretive policy feedback effects[20]. Resource effects refer to the material benefits and costs that the policy implies for individuals. In this case, policies affect political behavior by raising the material stakes. Characteristics of program design influence the efficacy of resource effects. These include the program's size and ability of beneficiaries to recognize the benefits and to trace them to their source, the physical proximity of the beneficiaries, and modes of program administration[7]. Interpretive effects have a subjective element and depend on the process of political learning[20]. Interpretive effects depend on the message that individuals receive when they engage with the government program directly. Interpretive effects also depend on the policy's perceived effects for the broader community (such as one's town or the country as a whole), which individuals develop through political learning processes like engagement with mass communication and cues from elites[20].

Political polarization presents a unique set of challenges to designing legislation that yields positive policy feedback[3,21]. Political polarization in the United States has been accompanied by a politics that is becoming more nationalized, wherein national party elites have increasingly strong influence on the beliefs and preferences of partisans, while material interests and local context has diminished effect[22]. Relatedly, the rise of "negative" polarization—an affective hostility toward the out-party group—has made it more difficult for the party that passes a particular program to win out-party adherents even when the policy provides local benefits[23,24]. This pattern suggests that positive policy feedback will depend critically on managing the interpretive effects of legislation.

Policies thus shape the boundaries of their own political constituency in material and symbolic ways. But, in the context of a politically polarized public, what characteristics of a policy constituency enable it to provide effective political support for entrenching or expanding the policy? This is a critical question for understanding whether and how initial policies can anchor ambitious decarbonization policy trajectories. The present study evaluates the policy feedback potential from a New York State financial incentive program designed to support household investment in solar PV systems. Such programs exist across many states and are also a key

component of IRA, which includes incentives for PV and for many other renewable and energy efficient household technologies[12].

Next, we draw on policy feedback theory and explicitly incorporate political geography to develop a set of expectations about what constitutes an effective program constituency. Individuals who install a solar PV system through a financial incentive program gain a significant material benefit. They also learn about the solar industry and typically gain a positive, first-hand experience with the technology. For these reasons, beneficiaries of these programs could increase their support for future expansion and entrenchment of solar-friendly legislation[13,14]. Past empirical research tends to focus on the volume[8] and, to a lesser extent, partisanship[13] of constituencies that new policies mobilize. We argue, however, that a complete framework for assessing the potential for an effective policy feedback constituency must additionally consider the existing preferences of partisan elites and the distribution of beneficiaries across empirical electoral districts. These two factors are present in theoretical treatments of policy feedback theory[17,18], but are rarely explicitly incorporated in empirical studies of policy feedback and mass political behavior. Below we develop a framework for evaluating policy beneficiaries' potential to form an effective constituency for policy feedback that incorporates all four factors: (1) the existing policy preferences of partisan elites, (2) the volume of beneficiaries, (3) the partisan make-up of the beneficiaries, and (4) the distribution of beneficiaries across empirical electoral districts.

First, the existing policy preferences of partisan elites form an essential context for evaluating policy feedback. Under extreme political polarization, local elected officials tend to default to the national party's position on pollical issues, and this default preference is especially strong for highly salient political issues[22]. This makes it easier to secure future support for related policies among co-partisan elected officials and concentrates the need for building support for the program among out-partisans. In national debates, the Republican Party has tended to oppose subsidies for renewable energy technologies, especially when such supports are cast as climate change mitigation efforts[25]. The Democratic Party, on the other hand, has been overtly supportive of policies that incentivize investment in renewable energy[26]. The significant influence of national partisan preferences means that local Republican officials will require more pressure from their constituents to support (or at least not oppose) future solar-friendly legislation, whereas Democratic officials may support such legislation without local pressure.

Next, the volume and partisan composition of program participants within specific electoral districts determine the level of influence that the solar constituency will play. In terms of size, elected officials are more likely to respond to a larger, well-resourced segment of their electorate than a smaller and less resourced one[27]. We expect the volume of solar incentive program participants to track with several features of the natural, built, and social environment that have been found to be influential for PV adoption. Homeowner-occupied, low-rise single-family houses are best suited for installing residential solar PV systems[28]. Relatedly, a comprehensive study of residential solar installations in the United States found an inverse-U-shaped relationship between population density and solar deployment rates, with the peak adoption rates in suburban communities[29]. Socio-economic factors also matter, including residents' income, education, and race or ethnicity[13,30]. We expect electoral districts where these factors are more favorable to have larger numbers of households taking advantage of the solar PV incentive program.

In terms of partisan composition, elected officials are more likely to respond to the preferences of co-partisan constituents than to out-partisans. The major electoral risk facing most elected officials in the U.S. today is from a primary challenge[31]. This electoral reality ensures that elected officials depend primarily on support from co-partisans for re-election. Solar incentive beneficiaries will only form an effective policy constituency, if enough of them share the party affiliation of their elected officials. This is particularly important in Republican-led districts, where officials may

oppose future solar-friendly policy as a default. Indeed, if solar PV adopters skew dramatically Democratic, it could reinforce a politicized view of the policy and entrench Republican opposition.

Previous research appears to suggest that solar PV enjoys support from both Republican and Democratic voters. Studies that examine the partisan gap in household adoption of solar PV find only a modest gap favoring Democrats[13,15]. Mildenberger and co-authors interpret this result as implying a "growing constituency of relevance for policymakers on both sides of the ideological aisle."[13] But this previous research does not consider how solar PV adopters are distributed across empirical electoral districts. Political geography is essential to consider, because the statistical estimate of a modest partisan gap found in previous research can imply very different policy feedback potential.

To appreciate the importance of political geography, consider the three stylized patterns of electoral districts presented in Fig. 1. Each pattern includes two electoral districts a Republican-led one (top) and a Democrat-led one (bottom). The square cells in each district represent the district's voters, colored red and blue for Republican and Democratic supporters, respectively, and the sun symbols indicate solar PV adopters (and incentive beneficiaries) among the electorate. Note that each two-district pattern in Fig. 1 has the same total volume of solar adopters (20) as well as within-district parity in partisan PV adoption (i.e., each district has an equal proportion of Republican and Democrat PV adopters). However, the structure of between-district differences in adoption rates implies different policy feedback potential. In Pattern 1, the Republican-led district, has no PV adopters at all—partisan parity exists because no one adopts. No program beneficiaries are thus available in the district that most requires public support. By comparison, Patterns 2 and 3 are expected to have greater potential for policy feedback. In Pattern 2, each district has the same number of adopters, forming a modestly sized constituency in both districts, and in Pattern 3, all adopters concentrate in the Republican-led district, forming a potentially important, bipartisan constituency to sway the elected official in greatest need of political pressure.

While in Fig. 1 we assume that Republican and Democratic voters are equally likely to benefit from the solar incentive program, empirical studies document substantial between-community variation in the partisan gap as well as an average gap slightly favoring Democrats[13]. Therefore, the magnitude of the partisan gap within specific electoral districts could further influence the political potential of the district's solar beneficiaries. Consider the three stylized examples of Republican-led districts in Fig. 2, each one with ten PV installations. A Republican elected official may be pressured by a Republican or a bipartisan solar constituency (as in Pattern 1 and 2,

respectively), but the effect of a primarily Democratic constituency (as in Pattern 3) could be the opposite, reinforcing the view that solar PV subsidies represent a politicized program favored only by Democrats and unpopular with the Republican base.

The goal of the empirical analysis that follows is to assess the policy feedback potential from one prominent solar incentive program, taking into account the four elements highlighted here: of (1) volume, (2) partisanship, and (3) political geography, and (4) focusing special attention on the solar constituencies in Republican-led districts, which are expected to require more constituent pressure to support energy transition policies.

We analyze the composition and distribution of households who took advantage of New York State's financial incentive program to install a residential solar PV system. Deployment of residential solar technology is a key component to rapid energy transition scenarios in the U.S. and globally[32,33]. A solar PV incentive program offers an ideal setting for evaluating the potential for positive policy feedback for several reasons. First, such programs confer a large financial benefit to participants[34]. The benefit consists of large upfront savings on the system purchase, state and federal tax credits, and continued savings on the electricity bill, including through a net metering arrangement that pays New Yorkers for extra power they produce. Second, the benefit is easily traceable to government policy. Solar installers prominently advertise the state and federal incentives, making it clear to the solar-installing homeowner that they are beneficiaries of a government program. Finally, there is potential for powerful interpretive effects. Homeowners who install solar generally have positive experiences, finding their system to be reliable and cost effective. Positive experiences with renewable energy may lead homeowners to be more receptive to messages that emphasize the feasibility and imperative of energy transition policy[14].

Results

Who are the beneficiaries of the solar PV incentive program in New York and might they coalesce into a potent policy feedback constituency in future policy contests? To answer this question, we organize the analysis at the level of three different types of electoral districts: U.S. Congressional Districts, New York State Senate Districts (the upper legislative house), and New York State Assembly districts (the lower legislative house). The New York State Legislature and the U.S. Congress will play pivotal roles in deciding the future of decarbonization efforts. Across the different electoral districts, we measure (1) the volume of solar PV program beneficiaries and (2) their partisan affiliations. See the Methods section for details about the data and measurement.

Fig. 1 | Stylistic examples of three different distributions of solar adopters across a Republican- and Democrat-majority district. Each pattern shows two electoral districts a Republican-led one (top) and Democrat-led one (bottom). The cells in each district represent the district's electorate, colored red and blue for Republicans and Democrats, respectively, and the sun symbols indicate solar PV adopters (and incentive beneficiaries) among the electorate. Note that each pattern has the same total volume of solar adopters as well as within-district parity in partisan PV adoption (i.e., each district has an equal proportion of Republican and Democrat PV adopters). See text for details.
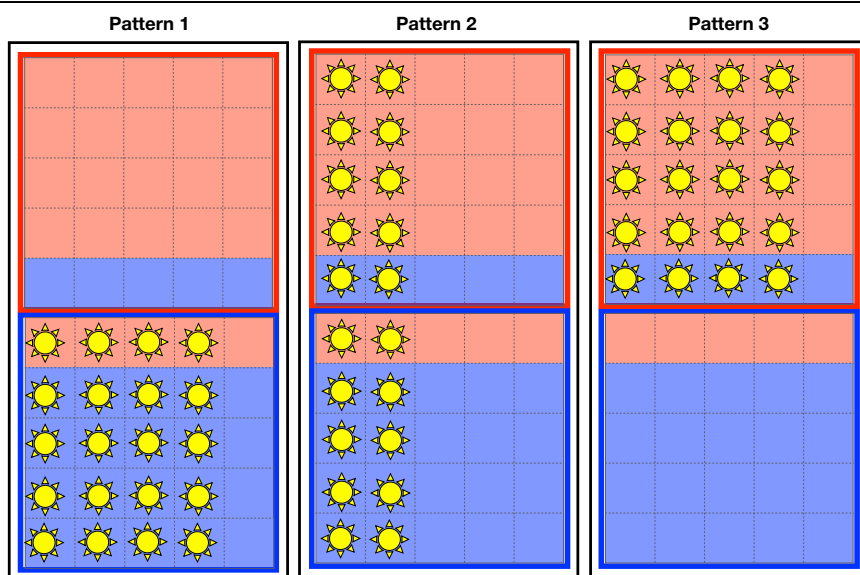
Fig. 2 | Stylistic examples of three distributions of solar adopters across three Republican-led districts with different partisan gaps in adoption. The cells in each district represent the district's electorate, colored red and blue for Republicans and Democrats, respectively, and the sun symbols indicate solar PV adopters (and incentive beneficiaries) among the electorate. Note that each pattern has the same total volume of solar adopters. Pattern 1 has a partisan gap favoring Republican voters, Pattern 2 has no partisan gap, and Pattern 3 has a partisan gap favoring Democratic voters.
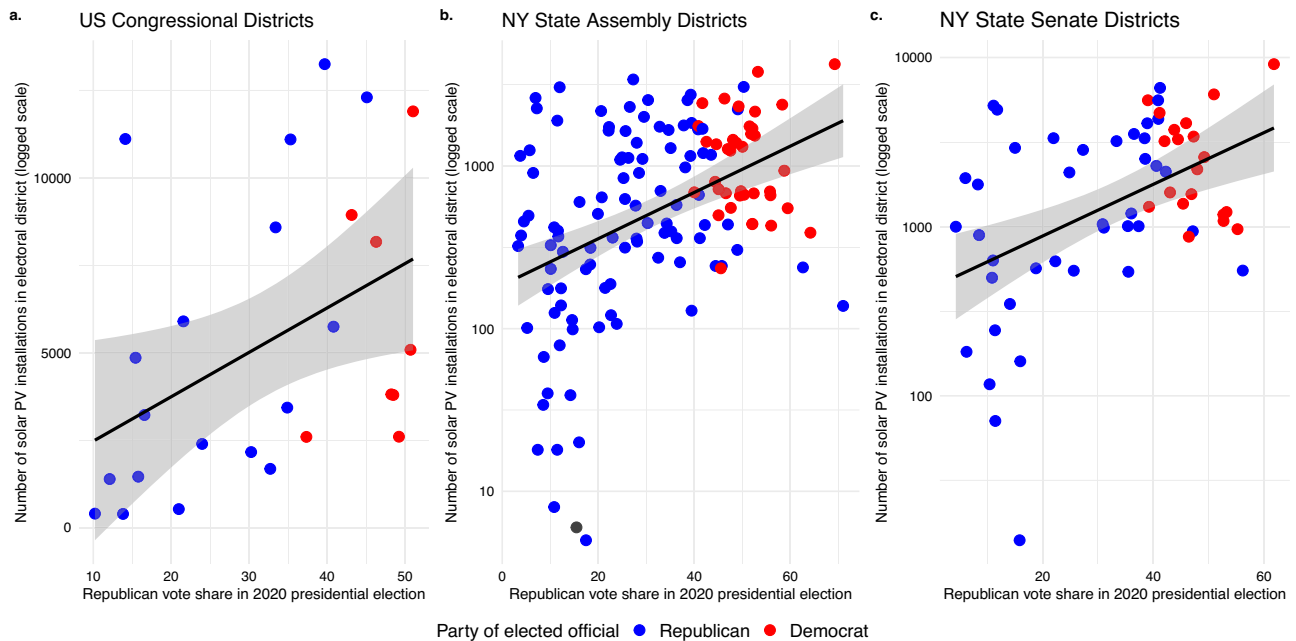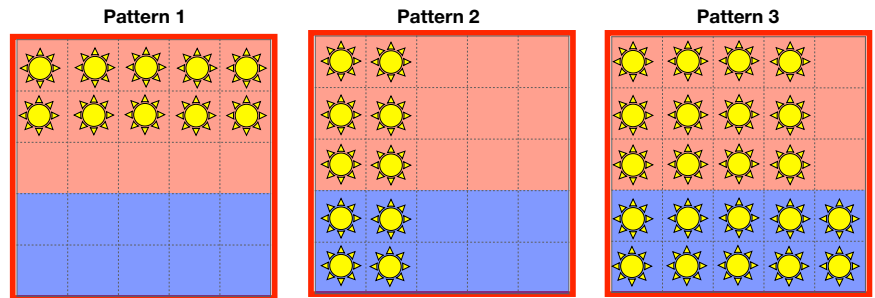

Fig. 3 | Relationship between Republican presidential vote share in 2020 and the number of solar PV installations in an electoral district. The relationship is presented separately for (**a**) U.S. Congressional districts, (**b**) NY State Assembly districts, and (**c**) NY State Senate districts. Points are colored according to party control (the single grey point if for an Assembly District for which party control could not be established). OLS regression line shown with 95% CIs.

We first examine the volume of PV projects across electoral districts. Figure 3 reports the relationship between district partisanship, measured as the Republican vote share in the 2020 presidential election, and the (logged) number of solar PV installations in the electoral district. Across all three types of electoral districts, greater Republican vote share is associated with greater participation in the PV incentive program. Among U.S. Congressional districts and NYS Senate districts, three of the top four districts with the highest solar deployment levels are led by Republican elected officials. The top two highest-deploying NYS Assembly districts are also Republican-led.

It appears, therefore, that Republican electoral districts have a larger pool of individuals who could form a political constituency in support of future solar-friendly policies. The observed pattern is not necessarily attributable to partisan preference for solar PV, because electoral districts differ in their housing stock, socio-demographic make-up, and other factors previously found to affect PV adoption rates. To better understand the relationship between district partisanship and volume of solar PV adopters, we fit negative-binomial count models predicting the number of PV installations in an electoral district as a function of Republican vote share, adjusting for the district's population density and its square, the rate of homeownership, and median income. Table 1 reports the results. The positive relationship between Republican vote share and solar PV deployment (Model 1 for each type of district) disappears after adjusting for the
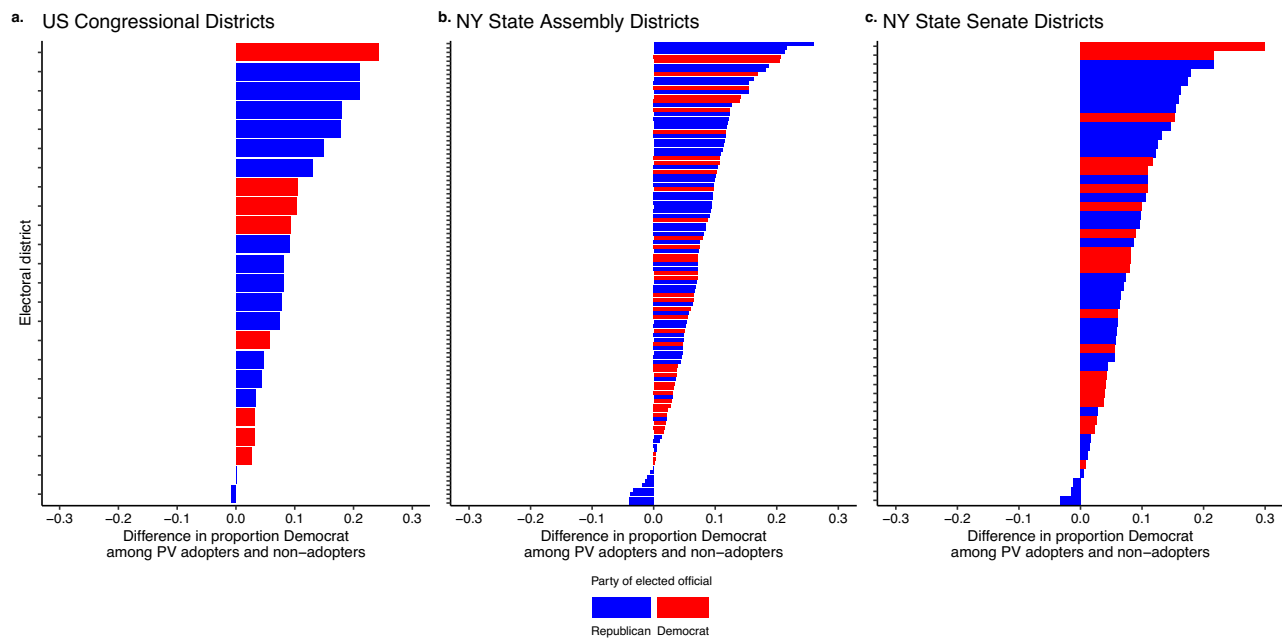
included co-variates (Model 2). In fact, the coefficient on Republican vote share is negative in the adjusted models across district types, although it is only statistically significant for NYS Assembly districts, where the sample size is largest ($n = 139$). Confounding the relationship between vote share and solar PV adoption were differences in population density and homeownership rates between Republican- and Democratic-leaning electoral districts. In line with previous findings, we estimate a curvilinear effect of population density, with middle-density, suburban-style communities hosting the most solar PV systems[29]. High-density, urban areas, which describes many electoral districts that are Democratic strongholds, have much lower PV installation rates. Low-density, rural areas also have lower rates, but this describes a relatively small number of electoral districts overall. Homeownership rates also positively predict PV installations, but the effect is only statistically significant for NYS Assembly districts.

Next, we examine the partisan composition of the PV adopters in each electoral district. Are PV adopters in Republican-led congressional districts representative of the district's Republican-leaning electoral constituency? Or are PV adopters more likely to be Democrats? To assess the partisan balance of PV-installing households, we use the three matched-samples, which pair each household that took advantage of the PV incentive program with a randomly selected, non-participating household from the same district. If beneficiaries of the PV incentive program are representative of the electoral constituency, then we should expect an approximately equal

Table 1 | Coefficient estimates from negative binomial model predicting the number of PV installations in an electoral district

	US Congress 1	US Congress 2	NY Assembly 1	NY Assembly 2	NY Senate 1	NY Senate 2
Republican vote % in 2020	0.027*	−0.006	0.018***	−0.016**	0.022**	−0.014
	(0.011)	(0.018)	(0.005)	(0.006)	(0.007)	(0.01)
Percent homeowners		0.013		0.029***		0.028
		(0.026)		(0.008)		(0.016)
Pop. density (1000/sq. mi)		0.005		0.008		0.015
		(0.038)		(0.011)		(0.020)
Pop. density^2		−0.001*		−0.0004***		−0.0005***
		(0.000)		(0.000)		(0.000)
Median income (10,000)		0.016		−0.003		0.010
		(0.083)		−0.033		(0.056)
Constant	7.627***	8.057***	6.235***	5.767***	6.956***	6.522***
	(0.389)	(1.244)	(0.177)	(0.401)	(0.264)	(0.739)
Observations	26	26	139	139	60	60
Akaike Inf. Crit.	496.8	488.3	2177.7	2077.2	1043.5	1007.1

Standard errors in parenthesis

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$

Fig. 4 | Differences in the proportion of homeowners who are registered Democrats between households that took advantage of the incentive program to install solar PV and randomly selected households from the same district who did not. The differences are presented separately for (**a**) U.S. Congressional districts, (**b**) NY State Assembly districts, and (**c**) NY State Senate districts. Positive differences indicate that PV-adopting households had higher proportions of homeowners registered as Democrats and negative difference indicate that non-adopting households had greater shares of Democrats. The color of each bar corresponds to the party of the local elected official (Republican = red; Democrat = blue).

distribution of partisan affiliations in the adopting and non-adopting sets of households. In each district, we calculate the average homeowner party affiliation proportions for PV adopting and non-adopting households.

Figure 4 plots the difference between these proportions across electoral district. In each plot, bars to the right of zero indicate that PV adopters in that district were more likely to be Democrats than randomly sampled non-adopters and bars to the left of zero indicate that PV adopters were less likely to be Democrats than the random sample of households. To reduce noise in the presented results, we limit the plots to districts with at least 200 PV installations. The bar colors in the plots identify the party of the elected official of each district. The pattern is unambiguous— except in a very small number of districts, PV adopting households are more likely to be Democrats than randomly selected households. Most notably, this result holds across *all* Republican-led Congressional (panel A), State Assembly (panel B), and State Senate districts (panel C). In many districts, the magnitude of these differences is substantial. The proportion Democrat is at least 0.10 higher among PV adopting households compared to non-adopters in three Republican-led Congressional districts, eleven Republican-led State Assembly districts, and six Republican-led State Senate districts. Of all Congressional districts, a Republican-led one has the largest imbalance— PV-adopting homeowners are 0.46 registered Democrats, whereas just 0.22 of randomly selected households are Democrats, a difference of 0.24.
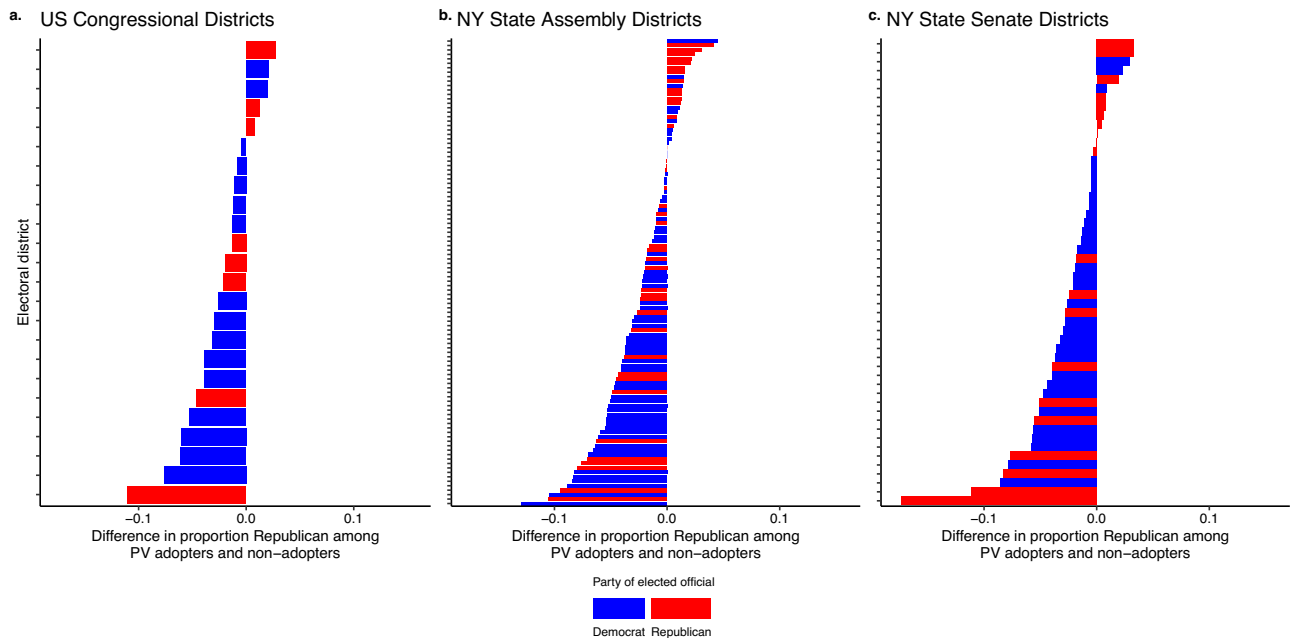
Fig. 5 | Differences in the proportion of homeowners who are registered Republicans between households that took advantage of the incentive program to install solar PV and randomly selected households from the same district that did not. The differences are presented separately for (**a**) U.S. Congressional districts, (**b**) NY State Assembly districts, and (**c**) NY State Senate districts. Positive differences indicate that PV-adopting households had higher proportions of homeowners registered as Republicans and negative difference indicate that non-adopting households had greater shares of Republicans. The color of each bar corresponds to the party of the local elected official (Republican = red; Democrat = blue).

Figure 5 presents the same set of plots showing the difference in proportion Republican between adopting and non-adopting households. There is clear evidence of a Republican imbalance as well. Republicans are underrepresented among PV adopters, relative to non-adopters in 76% of electoral districts, including in 63%, 63%, and 55% of Republican-led Congressional, NYS Assembly, and NYS Senate districts, respectively.

We quantify the average partisan imbalance between PV adopting and non-adopting households by using the set of matched datasets and regressing an indicator for PV adoption on household party affiliation shares using a linear probability model (LPM). Note that our goal here is not to estimate a causal effect of party affiliation, but simply to measure how representative, in terms of party affiliation, PV adopting-households are of the typical household in the electoral district. In addition to partisan preferences, the observed partisan gaps in PV adoption could be due to differences in homeowner characteristics (e.g., income, education), home characteristics (e.g., property type, home size). In other words, we are only concerned here with the composition of solar PV program constituency—who benefits, not why. For this analysis, we additionally break down the Democrat and Republican party affiliations by whether the voter recently participated in a primary election. Primary election participation indicates a more committed partisan and a more involved voter. The model also includes proportions of unaffiliated voters and Independent voters, as well as minor party affiliations, including the Working Families Party (a progressive third-party), Conservative Party (a party that positioned to the right of the Republican Party), the Green Party, and the Libertarian Party. Results are presented in Table 2.

The results are similar across the different types of districts. Consistent with previous findings[13], households owned by individuals who are not registered to vote (the reference group) are least likely to have a solar PV system. Among homeowners registered to vote, Republicans are the least likely to install solar PV, with only minor differences between those who participated in the primaries and those who did not. Democrats are much more likely to take advantage of the PV incentive program than expected by chance. Households with 100% of owners who are primary-voting Democrats have a probability of being PV adopters between 0.15 and 0.17 higher

(depending on the type of electoral district) than unregistered homeowners and non-primary Democrats have an increased probability in the 0.10–0.11 range. Minor parties suggest that there is a consistent gradient along the liberal-conservative dimension. Conservative Party affiliates are most like Republican party members, with coefficient estimates below all other types of voters except Republicans. Estimates for Independents and unaffiliated voters are between those of Republicans and Democrats, whereas Working Families Party and Green Party members, two parties positioned to the left of Democrats, have probabilities of being PV incentive beneficiaries that are consistently higher than even the primary-voting Democrats. Finally, Libertarian Party affiliates also have among the highest probabilities of using the incentive program to install solar—approximately on part with Working Families Party members.

The within-district partisan gaps favoring Democrats and other liberal parties are an important feature of the PV incentive program constituency, but it is also notable that Republican-led households still make up a sizeable share of PV adoptions in their respective districts. For example, although the Republican proportion of PV adopters does not reach the expected proportion based on the composition of the electorate, Republican PV adopters make up at least a third of all PV adopters in 5 of the 8 Republican-led Congressional districts, 22 of 43 Republican-led NYS Assembly Districts, and 9 of 20 NYS Senate Districts.

Discussion and conclusions

This article assessed the potential for policy feedback from a financial incentive program that supports household investment in renewable energy. We advanced a framework for measuring the potential effectiveness of a program constituency that considers the volume and partisanship of program beneficiaries, their distribution across empirical electoral districts, and the context of elite policy preferences. Applying the framework to the case of solar PV incentives, we found higher rates of program beneficiaries in districts that are more Republican, suggesting a potentially large pro-solar constituency in the politically important, Republican-led districts. Within districts, beneficiaries skew Democratic, however, which raises questions about the direction of policy feedback.

Table 2 | Coefficient estimates from linear probability model predicting PV installation

	US Congress	NYS Assembly	NYS Senate
Primary Republican prop.	0.042***	0.028***	0.028***
(Reference = Unregistered)	−0.005	−0.005	−0.005
Non-primary Republican prop.	0.048***	0.030***	0.040***
	−0.004	−0.004	−0.004
Primary Democrat prop.	0.173***	0.151***	0.161***
	−0.004	−0.004	−0.004
Non-primary Democrat prop.	0.112***	0.097***	0.111***
	−0.004	−0.004	−0.004
Unaffiliated prop.	0.097***	0.076***	0.092***
	−0.004	−0.004	−0.004
Conservative prop.	0.070***	0.038***	0.054***
	−0.011	−0.011	−0.011
Green Party prop.	0.237***	0.228***	0.216***
	−0.034	−0.034	−0.034
Independent prop.	0.080***	0.064***	0.090***
	−0.008	−0.008	−0.008
Libertarian prop.	0.188***	0.193***	0.203***
	−0.034	−0.034	−0.034
Working Families prop.	0.201***	0.199***	0.170***
	−0.021	−0.022	−0.021
Other party prop.	0.068*	0.084*	0.122***
	−0.033	−0.034	−0.035
Constant	0.430***	0.442***	0.434***
	−0.002	−0.002	−0.002
Observations	182,918	182,918	182,903
Adjusted R^2	0.013	0.01	0.012

Standard errors in parenthesis
*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$

Our framework and findings extend recent efforts to empirically measure the advocacy potential of solar PV adopters. Whereas previous research focused only on within-community differences in PV adoption[13], we highlight the theoretical importance of between-district differences as well and show that Republican-led districts hold an advantage in the volume of adopters, likely due to the more amenable housing stock found in such communities. Consistent with results by Mildenberger et al.[13], we find that PV adopters tend to be more politically active than non-adopters, which suggests a higher potential for advocacy by adopters. Our results provide a more nuanced picture of primary-voting patterns among PV adopters, however. Mildenberger and colleagues[13] reported a uniform effect of primary-voting on PV adoption across partisan affiliations, but we find that only Democratic primary voters are substantially more likely to be adopters compared to their non-primary voting counterparts. This suggests a somewhat less politically potent pro-solar, Republican constituency.

Our results carry important implications for the kind of politics that incentive-focused climate policies may set in motion. In the coming years, millions of Americans are slated to become beneficiaries of financial incentive programs funded by the Inflation Reduction Act (IRA), the 2022 legislation earmarking billions of dollars to support household investment in solar PV, electric vehicles, energy efficient electric appliances, and home energy efficiency retrofits. It is critical to understand how these benefits will be distributed and how to manage the interpretive effects of these programs. This article offers a framework for thinking about the potential for feedback effects of this policy. From a benefits perspective, it is important to ensure that decisive electoral constituencies, including voters outside Democratic strongholds, receive financial support. Due to the relatively higher home-ownership rates and more amenable housing stock for solar PV, in particular, there is good reason to believe that households in Republican-leaning districts will take advantage of the many home-improvement incentives. Electric vehicle adoption requires investment in charging infrastructure, and governments should be mindful to support investment across politically diverse regions. Equally important, however, are the interpretive effects—what voters come to subjectively believe about the program and its benefits for their community through experience with it as well as through engagement with political media. Government agencies implementing IRA must be mindful of possible political backlash. From this perspective, IRA incentives are much preferable to regulatory bans, such as bans of gas stoves, the mere mention of which produced immediate polarized backlash[35]. Because incentives through IRA produce direct savings and leave the choice with the homeowner, the program may help mute politicization and increase adoption by Republicans, who have been shown to be more attuned to the economic case for investment in energy technologies[15].

We note some important limitations of our study that should be addressed in future research. We leveraged high-resolution data on PV adoption to estimate the volume and partisan make-up of beneficiaries, but we focused on a single state, New York, which leans heavily Democratic. There is important regional heterogeneity in New York that allows us to explore patterns in Republican strongholds, but it is still possible that dynamics may differ in states with different partisan make-ups as well as with different policy designs and implementations. Additionally, we did not test whether and how policy beneficiaries changed their political behavior, which is necessary to close the cycle of policy feedback. Future research should thus seek to measure the effect of policy benefits on attitudes and behavior, and it should pay particular attention to heterogeneity along partisan lines. A recent study of Swiss voters provides some initial evidence, showing that the perceived effectiveness of prior benefit-conferring policies strongly predicts support for carbon pricing and, critically, that observed density of EV chargers, a material benefit of a specific transition policy, increases public support for carbon pricing in the transportation sector[14]. Even besides individual-level changes in attitudes and political behavior, however, much work remains to show that policy beneficiaries coalesce into effective policy constituencies. An effective constituency requires organization. How might the presence of specific organizations or social movements help to create a collective identity and provide the infrastructure to mobilize support for the next round of energy transition policies? To understand the effectiveness of policy feedback as a political strategy for locking in a decarbonization trajectory, future research should explore this and related questions.

Methods

We measure program participation and partisanship at the household level by combining three sources of administrative records. First, we used records from the New York State Energy Research and Development Authority (NYSERDA) to identify households participating in the solar incentive program. Second, we use a property file compiled from public tax assessment rolls and obtained from ATTOM Data Solutions, a company specializing in property information, to identify each residential property in New York State. Third, we obtained the voter registration file for New York State, which contains party registration information on each registered voter in New York State. We applied a probabilistic record-linking algorithm developed by Enamorado and colleagues[36] to merge the three datasets, creating a household-level dataset that identifies for each household in the property file, each homeowner's party registration (if registered to vote) and whether or not they received a solar PV incentive through NYSERDA to install a solar PV system as well as additional information about each solar PV projects. Next, for each electoral district, we identify the party of the local official elected in 2020 and the Republican and Democratic vote shares in the 2020 presidential election by aggregating precinct-level election results

from the MIT Election Data and Science Lab[37]. Finally, using geographic coordinates of each property and/or project, we joined the linked household-level dataset with a geographic boundary file of each of the three types of electoral districts.

We note several data limitations that introduce measurement error and restrict the available sample for the household-level analysis. The NYSERDA dataset did not contain street address information for 3.3% of the installed PV projects. In such cases, we used the Zip code to assign the project to an electoral district. When the Zip code crossed district boundaries, we assigned a proportional fraction of the project to each overlapping district. Due to similarity of addresses, input errors, and unconventional address formats some PV projects could not be reliably matched to a unique record. In any record-linking algorithm, there is an inherent trade-off between accuracy and coverage. We prioritize accuracy, which yields lower measurement error of party affiliation, but also increases the rate of false negatives. We reliably matched 91,459 projects to a unique address in the property file (69% of all projects with complete address information), and thus our household-level analyses are limited to this sample. Although this decreases the size of the available sample, we do not expect the restriction to bias our results, because the failure to match a project is related to address quality and non-uniqueness, variables that should be unrelated to party affiliation.

The resulting data thus enable us to achieve our two measurement objectives: (1) to examine the distribution of the subsidized PV systems across electoral districts and (2) to compare the partisanship of adopting households relative to non-adopting households in each district. For the first objective, we use three electoral-district level datasets (one for each type of district) and fit count models to identify the association between the partisan vote share and the number of PV projects in the district receiving incentives. We also adjust models for a district's demographic and built-environment characteristics, which we obtain from the 5-year 2020 American Community Survey (ACS). For our second objective, to compare the partisanship of adopting and non-adopting households, we construct three matched household-level samples, one for each type of district. For each sample, we pair a household that installed solar PV with a randomly selected household from the same electoral district that did not install solar PV (see ref. 13 for an analogous comparison strategy). If PV-installing homeowners are more likely to be Democrats than a randomly selected homeowner in the district, this would contribute to a local perception that the PV-incentive program primarily benefits Democrats and could signify a challenge to Republican support for solar-friendly policies.

Data availability
Addresses of solar PV projects in New York State are made available to the author through a non-disclosure data sharing agreement with NYSERDA and cannot be shared publicly. PV project information without addresses and contact information for making additional data requests are available at[38]. The author can make anonymized and/or aggregate data available upon reasonable request.

Code availability
The code used to produce the figures and tables in the manuscript is available at https://doi.org/10.7910/DVN/YDIKOC.

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Author contributions

F.A.D. designed the research, conducted the analysis, and wrote the paper.

Competing interests

The author declares no competing interests.

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