DEATH OF CALIFORNIA SOLAR?

The Impact of Net Metering Policy on Californian Solar Installations

By Rosie Ward

Since 1995, net metering policy has provided a constant incentive for customers of California's Investor-Owned Utilities (IOUs) to install solar panels. Under the IOUs' net metering programs, customers with solar systems receive a full retail rate credit for each unit of excess energy they generate and export back to the grid. This has allowed customers with an appropriately sized solar system to zero out their electricity bills, applying credits from hours when they generate excess solar energy towards the cost of non-solar energy use. However, in December 2021, the California Public Utilities Commission (CPUC) announced plans to significantly alter net metering policy beginning April 15, 2023. Under their new policy, colloquially referred to as "NEM3," export credits are aligned with utilities' avoided costs rather than customers' retail rates, resulting in a roughly 80% reduction in excess generation compensation. However, NEM3 only applies to new solar customers; customers who interconnected their system before April 15 were grandfathered into a full retail rate net metering program for 20 years, providing a major incentive to install solar before this date. This paper uses a difference-in-differences model approach to estimate the impact of the CPUC's announced plans to alter net metering programs on solar installation levels. The results suggest that the CPUC's plans spurred a statistically significant 0.396% point, or 31%, increase in month-over-month installation growth in the IOUs. This increase implies customers are responsive to changes in net metering policy and suggests decreases in Californian residential solar installations post-implementation of NEM3 are likely.

I. Introduction

In December 2022, over 1.6 million residential solar systems were installed throughout California.[1] To put this into context, at the time, there were just over 13.5 million occupied housing units in California; one in every nine Californian residences generated solar energy power.[2] California has more residential solar systems than any other US state and holds the second-place title for residential solar generation per capita (Hawaii tops this list).[3]

Several state and national policies have lessened financial barriers and driven residential solar adoption in California. For example, since 2005, individuals installing solar have received a federal income tax credit for

1 U.S. Energy Information Administration. "Annual Electric Power Industry Report, Form EIA-861 Detailed Data Files." www.eia.gov, March 1, 2023. https://www.eia.gov/electricity/data/eia861/.

2 U.S. Census Bureau, "HI | Occupancy Status." United States Census Bureau. Last modified 2020. https://data.census.gov/table?q=housing+units&g=0400000US06.

3 McCoy, Maria. "The State(s) of Distributed Solar — 2021 Update." Institute for Local Self-Reliance, 2022. https://ilsr.org/the-states-of-distributed-solar/.

26% to 30% of their installation costs.[4] At the state level, early system adoption was also heavily incentivized by Senate Bill 1 in 2006, which enacted Governor Schwarzenegger's landmark Million Solar Roofs Initiative and provided hundreds of millions in direct rebates for residential solar systems. In 2014, when the overwhelming majority of rebates financed by the program had been reserved and redeemed,[5] California had 12 times as much installed solar capacity than in 2006, and the cost of solar had dropped 45%.[6]

While rebates haven't been available for most Californians since 2014, net metering policy has provided a constant incentive to go solar since its initiation in 1995 under SB 656.[7] Under full retail rate net metering (NEM) programs, customers receive a credit for any excess energy their systems produce. They can apply these credits towards energy imports in a one-to-one fashion. For example, solar systems usually over-produce energy during the day, but customers must draw energy from the grid at night; with net metering, customers can cover their energy import costs with credits from hours when they generated surplus energy, often completely zeroing out their electricity bills. Minor edits have been made to California's NEM policies since 1995. Still, the crux of net metering—a full retail rate credit for kilowatts exported to the grid—remained unchanged until mid-April 2023.

In December 2021, the California Public Utilities Commission (CPUC), which regulates PGE, SCE, and SDGE, released a proposal to fundamentally alter the compensation that residential customers in these three utilities receive for exported solar energy.[8] PGE, SCE, and SDGE, California's three large investor-owned utilities (IOUs), provide power to the majority of Californians: 4.9 million Californians receive power from Pacific Gas and Electric (PGE), which primarily serves Northern California; 4.5 million residential customers receive power from Southern California Edison, which serves most of Southern California, and 1.3 million residential customers receive power from San Diego Gas and Electric, which serves the San Diego area.[9] Under the CPUC's revised NEM policy, colloquially referred to as "NEM3", IOU customers will no longer receive full retail rate compensation for excess energy. Instead, customers will receive a rate based on California's avoided cost calculator, which estimates the costs incurred by a utility to supply a kilowatt hour (kWh) of clean electricity.[10] On average, avoided cost rates are only 20% of retail electricity rates.[11]

NEM3 went into effect on April 15, 2023, replacing NEM2, the prior full retail rate policy. However, NEM3 only impacts new NEM customers; customers who installed solar systems before this date were grandfathered into NEM2 for a period of 20 years. This provided a substantial financial incentive to install a solar system before April 15, 2023.

This paper examines customers' responses to this incentive to install a system before NEM3 was implemented. If net metering programs do incentivize customers to go solar, IOU customers should have rushed to go solar and grandfather their systems into full retail rate net metering; there should be an increase in monthly

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4 Solar Energy Technologies Office. "Homeowner's Guide to the Federal Tax Credit for Solar Photovoltaics." US Department of Energy. Last modified March 2023. Accessed March 14, 2023. https://www.energy.gov/eere/solar/homeowners-guide-federal-tax-credit-solar-photovoltaics.

5 California Energy Commission. "Eligibility Criteria and Conditions for Solar Energy System Incentives - SB 1." California Energy Commission. Accessed March 13, 2023. https://www.energy.ca.gov/programs-and-topics/programs/new-solar-homes-partnership-program-nshp/eligibility-criteria-and.

6 Hallock, Lindsey, and Michelle Kinman. "California's Solar Success Story How the Million Solar Roofs Initiative Transformed the State's Solar Energy Landscape." 2015. Accessed December 2, 2022. https://environmentamerica.org/california/wp-content/uploads/2015/07/CA_Solar_Success_scrn_FINAL_7-7-2015.pdf. 5.

7 Ladisch, Mark, and Buck Hagood. "20 Years of Net Metering in California." Scott Madden Management Consultants, 2017. https://www.scottmadden.com/content/uploads/2017/05/ScottMadden_NEM_in_California_2017_0531.pdf. 1.

8 California Public Utilities Commission. "Customer-Sited Renewable Energy Generation." www.cpuc.ca.gov. Accessed March 19, 2023. https://www.cpuc.ca.gov/industries-and-topics/electrical-energy/demand-side-management/customer-generation.

9 U.S. Energy Information Administration. "Annual Electric Power Industry Report, Form EIA-861 Detailed Data Files."

10 California Public Utilities Commission. "Fact Sheet: Modernizing NEM to Meet California's Reliability and Climate Goals CPUC Issues Decision to Update the Net Energy Metering (NEM) Tariff to Support the Modern Grid the Decision Promotes Solar and Battery Storage, Supports Grid Reliability, and Controls Electricity Costs for All Californians," November 10, 2022. https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/energy-division/documents/net-energy-metering-nem/nemrevisit/final-december-2022-fact-sheet-nem.pdf, 2.

11 Thoubboron, Kerry. "NEM 3.0: What Does It Mean for You?" Energy Sage. Last modified January 17, 2023. Accessed March 14, 2023. https://news.energysage.com/net-metering-3-0/.

installations after the CPUC's NEM3 announcement. However, while there is a theoretical basis for attributing any increase in solar installations post December 2021 to the announced change in net metering policy, establishing causality is difficult. Many factors, such as the cost of solar systems or the investment tax credit, affect a customer's decision to install solar. If any of these factors also changed around December 2021, any observed trends in monthly solar installations cannot be fully attributed to changes in net metering policy.

Fortunately for policy analysis, the change in net metering policy is only being implemented in IOU territory—this enables comparing installation trends in PGE, SCE, and SDGE to an unaffected "control" utility. Specifically, suppose a non-CPUC regulated utility with retail rate net metering and IOUs followed the same installation trends before, but not after, the CPUC's announcement. In that case, any post-announcement divergence in monthly installation levels between the two utilities is likely attributable to the CPUC's announced policy change. This is the theory I employ in my analysis of monthly solar installations before and after the CPUC's NEM3 policy announcement. The Los Angeles Department of Water and Power (LADWP) serves as my counterfactual: my estimation of installation trends in IOU territory absent announced NEM changes. LADWP offers its customers retail rate net metering, but it has not announced changes to its energy export compensation structure.[12]

Specifically, I utilize a Difference-in-Differences regression approach to establish statistically significant causality between proposed net metering policy changes and monthly solar installation trends. My difference-in-differences models estimate the effect of the CPUC's NEM3 announcement on monthly solar installation levels as the difference in the change in monthly installation levels before and after the NEM3 announcement in the IOUs versus LADWP. The regression estimate is positive and statistically significant, suggesting customers have reacted to planned changes in net metering policy. This finding has potentially serious implications for California's solar industry—if customers are responsive to changes in net metering policy, a decrease in solar installations post NEM3 implementation is likely.

A. Paper layout

In the next section, I provide background information on the mechanics of net metering policies, and I follow this with a discussion of net metering policy changes. I then examine NEM3 in detail and present a brief discussion of the media coverage of this change.

Following these background sections, I summarize related literature and government and private sector predictions regarding the impact of net metering policy changes. I then outline my data and methodology for examining the impact of the NEM3 policy announcement on the number of solar installations.

After explaining my analysis methods, I include graphs of the number of monthly installations and the percentage change in total installations each month. I then present difference-in-differences regression results and discuss their implications. Finally, I briefly conclude and provide avenues for future research.

II. Net metering background: What, where, and when?

A. Net metering structure

Net metering allows customers with distributed electricity generation facilities to receive energy bill credits for surplus energy they feed back into their utility's electric grid. Strictly speaking, net metering customers receive the same rate per unit of exported energy that they would pay their utility for an identical quantity of energy, i.e. customers are compensated in a one-to-one fashion. This is the case regardless of whether a customer is on a tiered electricity rate, where the price of energy increases with monthly usage, or a time-of-use rate, where the price of electricity varies throughout the day; customers are always credited for exports based on the rate they hypothetically would have paid for energy imports at the same time. If the export compensation rate a customer

12 EnergySage. "2023 Los Angeles Department of Water and Power (LADWP) Net Metering." EnergySage. Accessed March 21, 2023. https://www.energysage.com/local-data/net-metering/ladwp/.

receives instead differs from their retail electricity rate, that customer is technically enrolled in a "net billing" program, not a net metering program. However, most government bodies and many academics covering the field label policies as "net metering" regardless of whether customers are offered the full retail rate. To be consistent with relevant literature, I adopt this latter flexible approach, but I always try to clarify the compensation structure.

Net metering programs let customers benefit from all the energy their solar systems produce regardless of whether their energy demand temporally aligns with their system's generation. Generally, solar systems produce more energy than customers use during daytime hours when the sun is shining and residents are out at school or work; customers usually accumulate energy export credits during these hours. When the sun sets and home energy use increases, solar system owners usually must draw traditional energy from the grid. This is when the benefits of net metering begin to kick in—customers can apply accumulated credits from surplus production earlier in the day towards their monthly electricity bills. In California, customers can also roll over any unused bill credits at the end of a month into the next month for 12 months, allowing many customers to fully balance their solar production and energy use over a year.[13]

However, after a twelve-month bill cycle, customers must fully "true up" any remaining bill credits or outstanding electricity payments with their utility. Net metering bill credits must be applied towards offsetting energy imports, so if customers have a surplus of credits after 12 months, they cannot receive full payment for these credits. Nonetheless, Californians can true up any balance of surplus energy at the net surplus compensation (NSC) rate. In 2022, this rate stood at approximately $0.02 to $0.03 per kWh.[14] This is much lower than the average residential retail rate in California, which was $0.24 per kWh as of December 2022.[15] However, in practice, few customers have large surplus energy balances at the end of a 12-month period. This is because customers must size their solar system to approximately meet their net load to participate in net metering.[16]

B. Net metering in California

Public Utilities Code (PUC) Section 2827 (c)(4)(A) requires all California "electric utilities" to offer their solar customers a full retail rate net metering contract.[17] Their definition of "electric utilities" includes all electrical corporations, publicly owned electric utilities, and electrical cooperatives except publicly owned electric utilities with more than 750,000 customers that also supply water. In practice, this means all California electric providers except LADWP are required to provide their customers with net metering. However, despite its statutory exemption, LADWP offers its customers a net metering option remarkably similar to NEM2. I will touch on their policy in further detail later.

While the addition of Section 2827 to the public utilities code required almost all utilities to establish NEM programs, there are limits to the section's mandates. All utilities not classified as a "large electrical corporation" are only required to provide net metering until the installed generating capacity of their customers' systems grows to exceed 5% of their aggregate peak electricity demand.[18] Given the high level of solar deployment in California, many California utilities have already exceeded the 5% cap, although many utilities continue to offer net metering voluntarily.[19]

PGE, SCE, and SDGE are California's only "large electrical corporations", defined as shareholder/investor-owned, CPUC-regulated utilities with over 100,000 California customers.[20] These utilities are subject to special

13 California Public Utilities Commission. "Customer-Sited Renewable Energy Generation."

14 California Public Utilities Commission. "Customer-Sited Renewable Energy Generation."

15 U.S. Energy Information Administration. "EIA - Electricity Data." Eia.gov, 2023. https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=epmt_5_6_a.

16 California Public Utilities Commission. "Customer-Sited Renewable Energy Generation."

17 Cal. Pub. Util. Code § 2827 (State of California 2019).

18 Cal. Pub. Util. Code § 2827.

19 "Bill Analysis: Hearings on SB 594 Before the Assembly Committee on utilities and Commerce," 2012 Leg. (Cal. June 25, 2012) (statement of Steven Bradford). http://www.leginfo.ca.gov/pub/11-12/bill/sen/sb_0551-0600/sb_594_cfa_20120622_170511_asm_comm.html.

20 "Bill Analysis: Hearings on SB 594 Before the Assembly Committee on utilities and Commerce,"

provisions in PUC Section 2827, which are specifically outlined in Section 2827.1.[21] Section 2827.1 requires the IOUs to continue offering net metering after exceeding the 5% aggregate peak electricity demand threshold, which each did in 2016 or 2017, and outlines updated objectives for the IOUs' net metering programs.[22] It is the CPUC's responsibility to develop net metering policy frameworks for uptake in the IOUs that meet statutory requirements as established in PUC § 2827 and § 2827.1.[23]

C. History of net metering policy

1. Net Metering 1.0 (NEM1)

Utilities have only reached their net metering caps in recent years; most utilities ran full net metering policies for twenty years before reaching the 5% peak demand threshold. Net metering was first established in California in 1995 through Senate Bill 656. This bill added Section 2827 to the Public Utilities Code, and in 1996 the CPUC enacted its first solar net metering program, referred to as "NEM1" today.[24]

Between 1996 and 2013, the California state legislature made small revisions to PUC Section 2827, but they kept the general structure of net metering—retail rate compensation for exported energy—intact. Most early net metering policy updates expanded the reach of net metering policies, either by making new technologies eligible, increasing the individual system capacity limit, or increasing the net-metered aggregate capacity cap over which utilities were allowed to discontinue net metering.

For instance, when net metering was first enacted, solar systems were the only eligible technologies. Instead, by 2011 all renewable generation facilities, biogas facilities, and fuel cells were eligible for net metering.[25] Likewise, when net metering was originally established, installed technologies had to be 10 kW or smaller, but in 2001, AB 29 increased the system capacity limit to 1 MW.[26] Additionally, utilities were originally allowed to discontinue NEM programs when the aggregate capacity of net-metered generation facilities reached 0.1% of their peak demand forecast for 1996.[27] In 2002, this cap was increased to 0.5%, in 2006 it was increased to 2.5%, and in 2010 it was increased to 5%, where it sits at present.[28]

The legislature also established two net metering sub-programs between 1996 and 2015, which continue today. In 2008, AB 2466 introduced virtual net metering (VNEM), which allows entities with multiple electric meters to distribute bill credits across each meter as desired.[29] Originally, only local governments were eligible for VNEM, but in 2011 the CPUC extended VNEM eligibility to all multi-tenant properties and distributed generation technologies.[30] VNEM has allowed households living in multifamily residences to share net metering benefits if their landlords install solar.

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21 Cal. Pub. Util. Code § 2827.

22 Esfahani, Asal, Cherie Chan, Christopher Westling, Erica Petrofsky, Joshu Litwin, Narissa Jimenez-Petchumrus, and Tory Francisco. "2021 California Solar Initiative Annual Program Assessment." California Solar Initiative Annual Program Assessment june 2021. California Public Utilities Commission, 2021. https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/energy-division/documents/csi-progress-reports/2021-csi-apa.pdf. 14.

23 California Public Utilities Commission. "Net Energy Metering Rulemaking (R.)14-07-002." www.cpuc.ca.gov. Accessed March 19, 2023. https://www.cpuc.ca.gov/industries-and-topics/electrical-energy/demand-side-management/customer-generation/net-energy-metering-rulemaking-r-14-07-002.

24 California Public Utilities Commission. "Customer-Sited Renewable Energy Generation."

25 Hearings on SB 489 Before the Assembly Committee on Natural Resources, 2011 Leg. (Cal. July 6, 2011).

26 Ladisch and Hagood. "20 Years of Net Metering in California." 2.

27 "An act to add Section 2827 to the Public Utilities Code, relating to public utilities.," S. 656, 1995 Leg. (Cal. Aug. 4, 1995). http://www.leginfo.ca.gov/pub/95-96/bill/sen/sb_0651-0700/sb_656_bill_950804_chaptered.html.

28 Ladisch and Hagood. "20 Years of Net Metering in California." 3.

29 "An act to add Chapter 7.5 (commencing with Section 2830) to Part 2 of Division 1 of the Public Utilities Code, relating to energy.," A. 2466, 2008 Leg. (Cal. 2008). http://www.leginfo.ca.gov/pub/07-08/bill/asm/ab_2451-2500/ab_2466_bill_20080928_chaptered.pdf.

30 Peevey, Michael. "Proposed Decision of Commissioner Peevey." Rulemaking 10-05-004. California Public Utilities Commission, 2011.

In 2012, the legislature passed SB 594, requiring utilities to establish net metering aggregation (NEMA) programs, which PGE, SCE, and SDGE did in 2013.[31,32] Under net metering aggregation tariffs, customers with multiple meters on the same or adjacent properties can use energy credits from their generation facility to serve the aggregated load behind all their meters.[33] This program has been especially useful for farmers who can, for instance, offset the electrical load from their homes and nearby irrigation pumps.[34]

2. Net metering 2.0 (NEM2)

In 2013, the California legislature passed AB 327. Rather than creating new net metering programs, AB 327 made revisions to existing components of Section 2827. The bill prevented the IOUs from discontinuing net metering once aggregate net-metered generation in their territories exceeded 5% of peak demand, which they could previously do. Instead, AB 327 ordered the IOUs to create a successor NEM program with an altered export compensation rate. The successor program, which was finalized in 2015, is colloquially referred to as "NEM2."

AB 327 was fueled by general concerns that NEM customers, particularly those successfully zeroing their electricity bills, were not paying for the grid infrastructure they still benefited from when they drew energy from the grid.[35] The state did not want to fully discontinue net metering in the IOUs when they reached the 5% cap, foreseeing the tremendous negative impact this would have on California's thriving solar industry. However, they did think changes were pertinent and called on the CPUC to establish an updated NEM program. The California legislature intended to fairly charge NEM customers for the grid benefits they received and provide customers compensation better reflecting the true value of their solar systems to the grid.

On July 10, 2014, the CPUC opened Rulemaking 14-07-002 to begin the process of designing a new net metering program.[36] After a year of proceedings, in December 2015, the CPUC released its proposed NEM2 decision (Decision 16-01-044), and the commission voted to approve the new program in January 2016.[37] They decided NEM2 would go into effect in an IOU when the utility exceeded the statutory net metering cap (5%) or on July 1, 2017, whichever came first.[38] Ultimately, NEM2 was enacted by SDGE on June 29, 2016, by PGE on December 15, 2016, and by SCE on July 1, 2017.

Despite the lengthy deliberations, NEM2 is structurally very similar to NEM1. NEM2 customers receive the same bill credits as NEM1 customers but cannot apply these credits towards certain "non-bypassable charges" (NBCs). There are four small NBCs—a Department of Water Resources bond charge, a public purpose program charge, a nuclear decommissioning charge, and a competition transition charge—and customers pay each per kWh of energy they draw from the grid. Because NEM2 customers cannot net out these charges, which amount to between $0.02 and $0.03 per kWh depending on the utility, the export compensation rate NEM2 customers receive is effectively their utility's retail rate minus the sum of all NBCs.[39] Given average electricity rates in California, this means NEM2 customers receive about 90% of their retail electricity rate per unit of exported

31 "An act to amend Sections 2827 and 2827.10 of the Public Utilities Code, relating to energy.," S. 594, 2012 Leg. (Cal. Sept. 27, 2012). https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201120120SB594.

32 California Public Utilities Commission. "Customer-Sited Renewable Energy Generation."

33 California Public Utilities Commission. "Net Energy Metering Rulemaking (R.)14-07-002."

34 California Public Utilities Commission. "Customer-Sited Renewable Energy Generation."

35 California Public Utilities Commission. "D.16-01-044: Decision Adopting Successor to Net Energy Metering Tariff." Rulemaking 14-07-002. California Public Utilities Commission, 2016. https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M158/K181/158181678.pdf.

36 California Public Utilities Commission. "Order Instituting Rulemaking to Develop a Successor to Existing Net Energy Metering Tariffs Pursuant to Public Utilities Code Section 2827.1, and to Address Other Issues Related to Net Energy Metering." R. 14-07-002. California Public Utilities Commission, 2014. https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M098/K303/98303355.PDF.

37 California Public Utilities Commission. "D.16-01-044: Decision Adopting Successor to Net Energy Metering Tariff."

38 Esfahani et al. "2021 California Solar Initiative Annual Program Assessment." 14.

39 Gong, Andrew, Christian Brown, and Samuel Adeyemo. "The Financial Impact of California's Net Energy Metering 2.0 Policy: Examining the Effects of Non-Bypassable Charges with Load Profiles and Systems Designed in Aurora." 2017. http://www2.greentechmedia.com/l/264512/2017-07-18/2lfcg. 6.

energy, a 10% reduction from NEM1.[40]

However, in practice, many net metering customers' bill savings are identical under NEM2 and NEM1. All IOU customers, whether enrolled in net metering or not, must pay a minimum electricity bill each month, and many NEM2 customers' monthly accumulated NBCs are close in value, or less than, this minimum bill.[41] When this is the case, a customer's NBC charge simply goes toward their minimum bill, so the NEM2 export compensation structure is equally attractive to NEM1. For customers with accumulated NBCs greater than their monthly minimum bill, the financial reduction in export compensation under NEM2 versus NEM1 is effectively equal to their accumulated NBCs minus their minimum bill. Minimum bills vary across IOUs but are roughly $10/month; once this is subtracted from customers' NBC charges, the impact of NBCs on customer bills is non-existent or small.[42] Therefore, despite the small NBCs, for simplicity and to highlight the compensation structure difference between NEM1 and NEM2 versus NEM3, I refer to NEM2 as a "full retail rate" net metering program.

In addition to NBCs, NEM2 customers are also required to pay a small one-time system interconnection fee. PGE's interconnection fee is $145; SCE's fee is $75, and SDG&E's fee is $132.[43] However, these fees are minor compared to the average cost of a 5 kW solar system in California, which was about $15,000 in 2022.[44]

Finally, NEM2 customers are required to take service on a time-of-use (TOU) electricity rate. In this rate structure, a customer's electricity rate varies throughout the day.[45] TOU rates are highest during peak demand hours – weekday afternoons and evenings – and lower during all other times.[46] However, many NEM1 customers were already on TOU rates because the peak periods largely align with peak insolation hours and rates are lowest during the night when solar systems are non-operative.[47]

3. Net metering 3.0 (NEM3)

Despite policy revisions, NEM2 failed to fulfill the statutory requirements of AB 327. Increases in NEM customer bills under NEM2 versus NEM1 were smaller than expected, explaining part of this failure, but the CPUC also intentionally limited the impact of NEM2.[48] In 2015, the CPUC lacked extensive data regarding the cost-effectiveness of NEM policies. Until they had better information, the CPUC decided to maintain the basic NEM structure. Instead, they pledged to initiate further NEM changes a few years in the future after conducting further analyses on the impact of net metering programs.[49]

In line with this schedule, in August 2020 the CPUC opened Rulemaking (R.) 20-08-020, initiating the process of creating NEM3.[50] In the following section, I explore NEM3 in greater detail.

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40 U.S. Energy Information Administration. "EIA - Electricity Data."

41 Gong, Brown, and Adeyemo. "The Financial Impact of California's Net Energy Metering 2.0 Policy: Examining the Effects of Non-Bypassable Charges with Load Profiles and Systems Designed in Aurora." 12.

42 Gong, Brown, and Adeyemo. "The Financial Impact of California's Net Energy Metering 2.0 Policy: Examining the Effects of Non-Bypassable Charges with Load Profiles and Systems Designed in Aurora." 8.

43 California Public Utilities Commission. "Customer-Sited Renewable Energy Generation."

44 Walker, Emily. "2021 Cost of Solar Panels in California | EnergySage." www.energysage.com, March 15, 2023. https://www.energysage.com/local-data/solar-panel-cost/ca/.

45 California Public Utilities Commission. "Customer-Sited Renewable Energy Generation."

46 California Public Utilities Commission. "Electric Rates." www.cpuc.ca.gov. Accessed March 21, 2023. https://www.cpuc.ca.gov/industries-and-topics/electrical-energy/electric-rates.

47 Gong, Brown, and Adeyemo. "The Financial Impact of California's Net Energy Metering 2.0 Policy: Examining the Effects of Non-Bypassable Charges with Load Profiles and Systems Designed in Aurora." 11.

48 California Public Utilities Commission. "D.16-01-044: Decision Adopting Successor to Net Energy Metering Tariff."

49 California Public Utilities Commission. "D.16-01-044: Decision Adopting Successor to Net Energy Metering Tariff." 86.

50 California Public Utilities Commission. "Order Instituting Rulemaking to Revisit Net Energy Metering Tariffs Pursuant to Decision D.16-01-044, and to Address Other Issues Related to Net Energy Metering." R. 20-08-020. California Public Utilities Commission, 2020. https://www.cpuc.ca.gov/nemrevisit.

III. NEM3: A break with policy precedent

A. Policy drivers and regulatory initiation

A number of statutory requirements, study findings, and general concerns about retail rate net metering shaped the structure of NEM3.

In 2009, the CPUC commissioned Energy and Environmental Economics, Inc. (E3) to produce a report on the costs and benefits of net metering.[51] Identifying NEM costs as the bill credits paid to NEM solar customers and NEM benefits as the avoided cost of procuring a unit of energy from elsewhere, the report estimated that the average net cost of NEM is $0.12 per kilowatt-hour (kWh) of energy exported.[52] Utilities recover their costs through electricity sales, so the report warned that this cost was being increasingly shifted onto non-net-metered ratepayers through higher electricity rates.

These findings were communicated to state legislators, who responded in 2013 by passing AB 327.[53] This bill tasked the CPUC with creating a new NEM program with costs approximately equal to the benefits of NEM to all customers and the electrical system. However, as described above, when the CPUC designed NEM2 in 2014, they had insufficient data to fulfill the requirements outlined in AB 327.

By 2020, the CPUC was better positioned to enact a major change to net metering policy. In 2018, the CPUC initiated the process of contracting an independent evaluation consultant to conduct a study on the costs and benefits of NEM2.[54] In November 2019, Itron, the independent consultant selected by the CPUC, released their draft research plan, and in August 2020, they released a first draft of their results.[55]

Itron conducted a series of cost-benefit analyses, each analyzing the costs and benefits of NEM2 to different groups. First, they conducted a participant cost test—a measure of the cost and benefits to individuals participating in NEM2. Their modeled benefits included bill savings from net metering and any state and federal rebate/credits, and costs included a customer's expenditures on their solar system.[56] Ultimately, they calculated an average benefit-cost ratio of 1.77, suggesting the benefits of enrolling in NEM far outweigh the costs for participants.[57]

To measure the impact of NEM on all utility customers, Itron also conducted a ratepayer impact (RIM) test; this test estimates the impact of a program on customer electricity rates due to changes in utility operating revenues and costs. Any RIM benefit-cost ratio under 1 indicates that utility costs under a program outweigh utility revenues and that the program will therefore increase bills for non-participating customers.[58] Itron found that the NEM2 average RIM benefit-cost ratio was 0.37 and that in total, residential NEM2 customers' bills were $618.6 million lower than their utilities' costs.[59] These results confirmed and quantified the cost shift caused by NEM2.

The third test Itron ran—a Total Resource Cost (TRC) test—provided the broadest view of the costs and benefits of net metering. Their TRC test accounted for the costs and benefits of NEM to both participants and their utility, including utility avoided costs, incremental billing costs, federal tax benefits, and installation

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51 Energy and Environmental Economics (E3). "Introduction to the Net Energy Metering Cost Effectiveness Evaluation." N.p.: California Public Utilities Commission, 2010.

52 Energy and Environmental Economics (E3). "Introduction to the Net Energy Metering Cost Effectiveness Evaluation." 7.

53 California Public Utilities Commission. "D.16-01-044: Decision Adopting Successor to Net Energy Metering Tariff." 86.

54 California Public Utilities Commission. "Decision Adopting Net Energy Metering Consumer Protection Measures including Solar Information Packet." California Public Utilities Commission, 2018. https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M230/K892/230892616.PDF. 45.

55 Itron. "Net Energy Metering Evaluation Draft Research Plan." 2020. https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/energy-division/documents/net-energy-metering-nem/nem-evaluation/nem-20-evaluation-draft-research-plan.pdf.

56 Itron, Energy and Environmental Economics, and Verdant Associates. "Net Energy Metering 2.0 Lookback Study." N.p., 2021. 7.

57 Itron et al. "Net Energy Metering 2.0 Lookback Study." 5.

58 Itron et al. "Net Energy Metering 2.0 Lookback Study." 8.

59 Itron et al. "Net Energy Metering 2.0 Lookback Study." 97.

expenditures.[60] Itron derived an average cost-benefit ratio of 0.84, finding that the costs of NEM to customers and utilities outweigh the benefits to participants.[61]

Finally, Itron evaluated the equity ramifications of this cost shift. They looked at the demographics of zip codes with NEM1 and NEM2 installations and overwhelmingly found that areas with high incomes, as well as areas with high homeownership rates, had higher percentages of NEM installations relative to California's population.[62] Essentially, costs were being shifted onto lower-income ratepayers.

1. Initiating policy changes

Equipped with this program cost data, on August 27, 2020, the CPUC opened Rulemaking 20-08-020, a "Rulemaking to Revisit Net Energy Metering Tariffs Pursuant to Decision D.16-01-044, and to Address other Issues Related to Net Energy Metering."[63] The commission finalized the scope of the rulemaking in November 2020, and they released a list of stakeholder-informed guiding principles in January 2021.[64] These principles largely echoed the requirements outlined in AB 327; they emphasized the commission's intention to design a net metering tariff that ensured greater equity among customers and maximized the value of solar generation to all customers and the grid.[65] While the guiding principles outlined the CPUC's general goals for a new net metering program, the CPUC did not adopt nor suggest their preference towards a specific export compensation structure.

From January to March 2021, parties developed and submitted proposals for a NEM successor program. Each party was given an opportunity to discuss and answer questions about their proposal in late March and late April.[66] The CPUC conducted a cost/benefit analysis of each and released the results in late May. Parties then gave opening testimony about the potential design of NEM3 in June 2022, and evidentiary hearings were held by the CPUC between July 26 and August 10, 2022.

Party inputs, study results, and statutory requirements all shaped the CPUC's NEM3 policy structure, which they released on December 13, 2021.[67]

B. First NEM3 proposed decision

1. Decision structure

The CPUC's NEM3 decision broke with traditional net metering policies in a few key areas: export compensation rates, electricity rates, and fixed charges.

Instead of basing export compensation rates on a customer's retail electricity rate, the CPUC proposed to base rates on utilities' avoided costs from procuring customer generation.[68] These rates would be set per hour and per month based on outputs from the CPUC's avoided cost calculator, which estimates system-level costs of providing electricity service as the sum of 9 components: line losses, ancillary services, distribution capacity, transmission capacity, generation capacity, energy, greenhouse gas costs (reflecting the cost of reducing carbon emissions from the electricity supply to meet California's climate goals), methane leakage (reflecting the additional

60 Itron et al. "Net Energy Metering 2.0 Lookback Study." 7.

61 Itron et al. "Net Energy Metering 2.0 Lookback Study." 5.

62 California Public Utilities Commission. "Net Energy Metering NEM 2 Evaluation." www.cpuc.ca.gov. Accessed March 23, 2023. https://www.cpuc.ca.gov/nem2evaluation.

63 California Public Utilities Commission. "Order Instituting Rulemaking to Revisit Net Energy Metering Tariffs Pursuant to Decision D.16-01-044, and to Address Other Issues Related to Net Energy Metering."

64 California Public Utilities Commission. "Proposed Decision Revising Net Energy Metering Tariff and Subtariffs." California Public Utilities Commission, 2021. https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M430/K903/430903088.PDF. 6.

65 California Public Utilities Commission. "Proposed Decision Revising Net Energy Metering Tariff and Subtariffs." 9.

66 California Public Utilities Commission. "R2008020 - Rulings." https://apps.cpuc.ca.gov/. Accessed March 23, 2023. https://apps.cpuc.ca.gov/apex/f?p=401:57::::::

67 California Public Utilities Commission. "R2008020 - Rulings."

68 California Public Utilities Commission. "Proposed Decision Revising Net Energy Metering Tariff and Subtariffs."

cost of methane leakage from natural gas), and cap and trade costs.[69] The avoided cost of electricity service varies seasonally and throughout the day, but in 2022, it averaged 4 cents to 6 cents per kWh during peak maximum sunlight and low energy usage hours—12 am to 4 pm and 10 pm to midnight—and 5 to 20 cents during peak energy use times—5 pm to 10 pm.[70] In 2022, avoided cost rates were about 20% of the retail electricity rate, which averaged $0.22–$0.36/kWh depending on the hour, season, and utility.[71] With their decision, the CPUC planned to remove a defining and attractive feature of NEM: the ability to export energy and use grid energy in a one-to-one fashion. Under ACC-based rates, customers would not feasibly be able to net out their electricity bills and would only receive roughly 20% of the export compensation offered in NEM1 and NEM2.

The decision also proposed changes to customers' electricity rates. NEM2 customers may take service on any time-of-use rate; instead, under NEM3, customers would have to use a highly differentiated time-of-use rate, which exaggerates the difference between the cost of electricity between peak and off-peak use times. For instance, rates range between 55 and 85 cents/kWh during peak times depending on the utility.[72] Late afternoon peak hours coincide with solar generation hours, so NEM2 customers on TOU rates are able to capture some benefits of peak pricing in the form of higher retail rate-based bill credits. However, because the CPUC proposed to decouple export and retail rates in NEM3, net metering customers would not enjoy this benefit and would face higher early evening electricity import costs.

The CPUC's third major break with net metering tradition came from proposed monthly fixed charges for net metering customers. Specifically, the commission outlined a plan to levy an $8.00 a month per kW installed solar capacity "grid participation charge" on NEM customers.[73] The average capacity of a solar system installed in California in 2022 was 6.2kW, representing an average $50/month charge.[74] However, the commission did offer a small "market transition credit" to reduce the initial impact of the policy. They proposed customers installing a solar system within the first year of NEM would receive an average $3/kW installed capacity credit each month for ten years.[75] This credit would be available for four years post-implementation, but the credit would drop 25% for new installers each year. Ultimately, the CPUC estimated the payback period of a solar system would increase from 6 years to 11 years on average with the market transition credit and nearly 13 years without.[76]

Nonetheless, increased payback periods are only half the story as to why customers likely reacted to the CPUC's NEM3 plans by rushing to go solar. The second crucial piece is grandfathering—the ability to install a system under NEM2 and remain a NEM2 customer post NEM3 implementation. Under the CPUC's proposed decision, customers would have until 120 days after their NEM3 plan was approved to interconnect a system and join their utility's NEM2 program.[77] If they met this deadline, they could remain NEM2 customers for 15 years. This created a substantial incentive to interconnect a solar system before the start of NEM3.

The CPUC had enough information to enact the above changes for the average customer. However, they elected to allow low-income virtual net metering (VNEM) customers to continue taking service under NEM2 indefinitely until they had further information on the benefits of low-income VNEM.[78] This was the only full exemption; customers enrolling in other NEM sub-tariffs—standard income VNEM and NEMA—would have to enroll in NEM3. The commission also exempted low-income customers from grid participation charges. However,

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69 Energy and Environmental Economics. "2020 Distributed Energy Resources Avoided Cost Calculator Documentation." N.p., 2020. 73.

70 Energy and Environmental Economics. "2022 Distributed Energy Resources Avoided Cost Calculator Documentation." N.p., 2022. 8.

71 Kennedy, Ryan. "Survey Says 95% of Shoppers Would Not Buy Solar under NEM 3.0." PV Magazine. Last modified January 13, 2022. Accessed March 24, 2023. https://pv-magazine-usa.com/2022/01/13/survey-says-95-of-shoppers-would-not-buy-solar-under-nem-3-0/.

72 California Public Utilities Commission. "Proposed Decision Revising Net Energy Metering Tariff and Subtariffs." 182.

73 California Public Utilities Commission. "Proposed Decision Revising Net Energy Metering Tariff and Subtariffs." 182.

74 Energy Markets & Policy. "Tracking the Sun Tool." https://emp.lbl.gov, 2022. https://emp.lbl.gov/tracking-sun-tool.

75 California Public Utilities Commission. "Proposed Decision Revising Net Energy Metering Tariff and Subtariffs." 182.

76 California Public Utilities Commission. "Proposed Decision Revising Net Energy Metering Tariff and Subtariffs." B2.

77 California Public Utilities Commission. "Proposed Decision Revising Net Energy Metering Tariff and Subtariffs." 185.

78 California Public Utilities Commission. "Proposed Decision Revising Net Energy Metering Tariff and Subtariffs." 139.

low-income customers would still be affected by the crux of the policy change: the shift from retail to avoided-cost export rates.

2. Proposed decision backlash

The CPUC could have voted to approve and adopt their NEM3 plans in their January 27, 2022 business meeting.[79] However, the CPUC's NEM3 decision sparked a wave of backlash. Politicians, celebrities, solar companies, and the general public criticized the policy for reducing the benefits of net metering so intensely and warned of the policy's potential impact on California's solar industry.[80]

On January 14, the CPUC released its first agenda for its January 27 meeting and did not include NEM3, providing its first indication of reconsideration and delay.[81] They followed this with a formal notice on February 3 that they would take "additional time to analyze the record and consider revisions to the proposed decision based on party comments."[82] In their notice, they also pledged to issue a ruling with further information on future rulemaking proceedings once they had conducted the additional analysis.

The CPUC made this update on May 9, 2022, issuing a ruling asking parties to submit further comments regarding the glide path (market transition credit) approach.[83] Comments were originally due on June 10th, and reply comments were due on June 24th. However, on June 2nd, the commission extended the reply comment deadline to July 1. Then to provide time for review, on August 25th, the CPUC passed a decision extending their original deadline for closing the NEM3 rulemaking from August 2022 to August 2023.[84] Statutory requirements forced the CPUC to pass this extension; this was not an indication a decision would be delayed an entire year. Experts in the field publicly speculated that the commission would decide within a few months, likely immediately following the November 8 general election.[85, 86]

In line with predictions, on November 10 the CPUC withdrew its December 2021 initial NEM3 proposal and released a new NEM3 proposed decision.[87] Just over a month later, on December 15, 2022, the commission approved their November proposal and enacted a new era of net metering.

C. Second proposed decision

Except for the grid participation charge, the final version of NEM3 retains every element of the first decision.

The grid participation charge was the focus of most solar industry-led protests. Solar associations labeled the fixed charges a "tax on the sun", and politicians, celebrities, and policy experts alike weighed in on the

79 California Public Utilities Commission. "Proposed Decision Revising Net Energy Metering Tariff and Subtariffs." 9.

80 Chediak, Mark. "Musk, Movie Stars Join Fight to Protect California Solar Subsidy." Bloomberg. Last modified January 12, 2022. Accessed March 18, 2023. https://www.bloomberg.com/news/articles/2022-01-12/musk-ruffalo-walton-line-up-to-oppose-california-solar-plan#xj4y7vzkg?leadSource=uverify%20wall.

81 California Public Utilities Commission. "Public Agenda 3501." California Public Utilities Commission, 2022a. https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M441/K154/441154267.pdf.

82 California Public Utilities Commission. "Net Billing Tariff." www.cpuc.ca.gov. Accessed March 24, 2023. https://www.cpuc.ca.gov/industries-and-topics/electrical-energy/demand-side-management/customer-generation/nem-revisit/net-billing-tariff.

83 California Public Utilities Commission. "Net Billing Tariff."

84 California Public Utilities Commission. "Order Extending Statutory Deadline." California Public Utilities Commission, 2022b. https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M496/K643/496643309.PDF.

85 Kennedy, Ryan. "California Set to Release Anti-rooftop Solar Net Metering Plan." PV Magazine. Last modified November 4, 2022. Accessed March 25, 2023. https://pv-magazine-usa.com/2022/11/04/california-set-to-release-anti-rooftop-solar-net-metering-plan/.

86 Misbrener, Kelsey. "New CPUC Proposed Decision on NEM 3.0 Expected by September 29." Solar Power World. Last modified August 22, 2022. Accessed March 25, 2023. https://www.solarpowerworldonline.com/2022/08/cpuc-proposed-decision-on-nem-3-expected-by-sept-29/.

87 California Public Utilities Commission. "Decision Revising Net Energy Metering Tariff and Subtariffs." California Public Utilities Commission, 2022c. https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M500/K043/500043682.PDF. 13.

tremendous impact it could have on California's solar industry.[88] Noting the general concern, the CPUC removed the charge from their final decision.

Nonetheless, the CPUC maintained the requirement for customers to take service on highly differentiated time-of-use rates and retained the crux of their first proposal—the avoided cost-based export compensation rate.[89] As a result, under both the CPUC's first and final NEM3 decisions, customers will receive about 20% of their retail electricity rate for energy exports, marking a major reduction in financial benefits versus NEM2.

However, customers enrolling in NEM3 during its first four years will enjoy a slightly higher export rate; this replaces the market transition credit outlined in the CPUC's first decision. Specifically, early customers will benefit from the CPUC's "ACC Plus Adder", a small additional credit per kWh of exported energy.[90] In the first year of NEM, this rate was set at an average of $.02/kWh across the three utilities for standard customers and $.06/kWh for low-income customers. As in the first decision, customers interconnecting in the first year of NEM3 will receive the adder advertised when they enrolled in NEM for a decade. The adder will be available for four years but will decrease by 25% for new customers each year.

Without grid participation charges, estimated system payback periods in the CPUC's final decision are slightly shorter than under their first. Specifically, the commission designed NEM3 such that, with the ACC adder, the payback period would be nine years. This is still a fifty% longer payback period than under NEM2.[91]

Finally, the CPUC elected to exempt additional groups from NEM3 in their final decision. While only low-income VNEM customers were exempted from NEM3 under the CPUC's first decision, all new VNEM and NEMA customers will be allowed to enroll in NEM2 for the foreseeable future.[92]

The commission set April 14, 2023, 120 days after they approved their second decision, as the official beginning of NEM3.[93] Customers interconnecting a solar system in the "sunset period" before this date would be NEM2 customers. Customers installing a system after April 14 would be California's first NEM3 customers.

D. Publicity: Were customers aware of policy changes?

The CPUC's plans represented a major break with historical net metering policy. Nonetheless, the customer group responding to changes in net metering policy were individuals without solar; their awareness of a relatively niche policy change cannot be taken for granted. Suppose news of the planned NEM policy change did not spread beyond solar-specific media sources to members of the general population. In that case, it's more unlikely that the announced shift to NEM3, versus other unexplained factors, is the cause of any post-announcement changes in solar installation levels.

However, the proposed shift to NEM3 received enough backlash from the California solar industry and its allies that it quickly made headlines in major news outlets. When the first iteration of NEM3 was announced in December 2021, organizations and individuals with a significant stake in the solar industry made their voices heard. In Early January of 2022, Elon Musk tweeted his 100 million followers, calling on California Governor Gavin Newsom to "stop the solar tax."[94] A day earlier, Newsom had himself voiced his concerns about the proposed NEM policy, admitting in a heavily publicized press conference that, after reviewing the proposed policy, he believed the CPUC had "some work to do."[95] Former Governor Arnold Schwarzenegger also pressured

88 Chediak, Mark. "Musk, Movie Stars Join Fight to Protect California Solar Subsidy."

89 California Public Utilities Commission. "Decision Revising Net Energy Metering Tariff and Subtariffs."

90 California Public Utilities Commission. "Decision Revising Net Energy Metering Tariff and Subtariffs." 177.

91 California Public Utilities Commission. "Decision Revising Net Energy Metering Tariff and Subtariffs." B5.

92 California Public Utilities Commission. "Decision Revising Net Energy Metering Tariff and Subtariffs."

93 California Public Utilities Commission. "Decision Revising Net Energy Metering Tariff and Subtariffs." 240

94 Lewis, Michelle. "Elon Musk Says California Proposal to Cut Solar Incentives Is a 'Bizarre Anti-environment Move.'" electric. Last modified January 12, 2022. Accessed March 18, 2023. https://electrek.co/2022/01/12/elon-musk-says-california-proposal-to-cut-solar-incentives-is-a-bizarre-anti-environment-move/.

95 Nikolewski, Rob. "Newsom: 'More Work to Be Done' on California Net Metering Solar Proposal." The San Diego Union-Tribune. Last modified January 11, 2022. Accessed March 18, 2023. https://www.sandiegouniontribune.com/business/story/2022-01-11/newsom-more-work-to-be-done-on-california-net-metering-solar-proposal.

the CPUC to revise their plans, writing a headline New York Times op-ed,[96] and Senator Dianne Feinstein made a press release urging CPUC president Alice Reynolds to pair back compensation cuts (Feinstein 2022).[97]

A number of celebrities also voiced their concerns, raising awareness of the policy change. On January 10, 2022, actor Mark Ruffalo asked his 8 million Twitter followers to speak out against the proposed policy change.[98] On January 11, actor Edward Norton also joined the Twitter conversation, warning that the proposed change would crush California's climate goals.[99] Even further broadening the audience, basketball player Bill Walton sent a letter to Governor Newsom urging change on January 12, 2022, and he linked the letter to his Facebook page.[100] Each of these celebrities reaches a sizeable Californian audience.

With celebrity and government attention, NEM3 began to feature in independent articles across local and national news sites. Since December 2021, the Wall Street Journal, Fox News, The Hill, Hollywood Reporter, the New York Times, Yahoo News, S&P Global, Washington Examiner, Reuters, the LA Times, CNBC, NPR, Forbes, and Bloomberg have published articles about NEM3. In addition, notable local papers have also covered the policy, including the San Francisco Chronicle, the San Diego Union-Tribute, SFGate, the Orange County Register, the Sacramento Bee, the Fresno Bee, the San Diego Reader, and Mercury News. With articles in local papers as well as national ones, there were many opportunities for customers to encounter an article about NEM3.

Beyond publicity on news sites, the Save California Solar Coalition, which includes hundreds of community groups, business partnerships, customer organizations, conservation groups, education districts, elected officials, public interest groups, and labor unions, launched a state-wide advertising effort to garner support for continuing NEM2.[101] They sponsored primetime television, cable, and radio advertisements informing Californians of the CPUC's plans' potential to significantly hurt California's solar industry.[102] Major solar installers, including Sunpower, NRG Clean Power, and SunRun, have also run far-reaching online and television advertisements encouraging customers to install solar "before it's too late."[103]

None of these examples confirm that a significant portion of the general public knew about NEM3; however, they increase the likelihood that a group of customers learned about and reacted to changes in net metering policy.

IV. Literature review

NEM3 marks a major departure from historical net metering policy structures; the export compensation rates under NEM3 are significantly lower than under NEM1 and NEM2, and many customers likely became aware of this. However, before presenting my analysis of the impact of the announced shift to NEM3 on solar installations, I provide a brief review of relevant literature exploring the impact of net metering policy on solar installations.

The impact of net metering policy changes in other utilities has been partially explored by academic, government, and private-sector researchers with an array of methodologies. Nonetheless, past research in the area

96 Schwarzenegger, Arnold. "Schwarzenegger: We Put Solar Panels on 1 Million Roofs in California. That Win Is Now under Threat." New York Times. Last modified January 17, 2022. Accessed March 19, 2023. https://www.nytimes.com/2022/01/17/opinion/schwarzenegger-solar-power-california.html.

97 Feinstein, Dianne. "Feinstein Urges Changes to Proposed CPUC Solar Energy Policy." News release. January 25, 2022. https://www.feinstein.senate.gov/public/index.cfm/press-releases?ID=31B23E67-A4BC-41A0-8DDD-42E2F72CE765.

98 Chediak, Mark. "Musk, Movie Stars Join Fight to Protect California Solar Subsidy."

99 Chediak, Mark. "Musk, Movie Stars Join Fight to Protect California Solar Subsidy."

100 Chediak, Mark. "Musk, Movie Stars Join Fight to Protect California Solar Subsidy."

101 Save California Solar. "Organizations & Community Leaders in Support of Solar Net Metering.docx." Google Docs, January 17, 2022. https://docs.google.com/document/d/1eB85J3qRSeFn6dz5mPG_un34s7Q5IJ4c/edit.

102 Save California Solar. "Save California Solar Launches Broadcast TV, Cable and Radio Ads Calling on CPUC and Governor Newsom to Reject Utility Profit Grab and Keep Rooftop Solar Growing and Affordable." PRNewswire. Last modified October 2021. Accessed March 19, 2023. https://www.prnewswire.com/news-releases/save-california-solar-launches-broadcast-tv-cable-and-radio-ads-calling-on-cpuc-and-governor-newsom-to-reject-utility-profit-grab-and-keep-rooftop-solar-growing-and-affordable-301410423.html.

103 "Act Now before Solar Savings in California Drop." SunPower. Accessed March 18, 2023. https://go.sunpower.com/net-metering-deadline/.

can broadly be classified into one of two strands: some papers predict solar adoption under altered net metering policies through employing adoption models, whereas others analyze the impact of a realized policy change after implementation.

A. Solar adoption modeling

To begin by discussing literature predicting solar adoption under different policy scenarios, in 2010, Drury et al. used the National Renewable Energy Laboratory's (NREL's) "SolarDS" model to forecast residential solar installation across the United States under different net metering structures. They predicted that annual installed capacity would be 67% higher in a scenario with net metering versus without, ultimately determining that net metering provides a substantial financial incentive to install solar which customers actually respond to.[104]

In 2011, Zhao et al. used a hybrid two-level modeling framework to predict solar installations under various policies: the lower-level model calculated the payback period of a solar installation under simulated policies, and the higher-level model predicted household adoption behavior based on this payback period as well as other factors such as household income, advertisement effects, and word-of-mouth effects. They predicted that if feed-in tariffs, which are similar to retail rate net metering, were reduced to 80% of their value, the percentage of the general population with installed solar systems after 20 years of the policy would be 5 percentage points lower than under a retail rate feed-in tariff scenario.[105] Their results suggest that the shift from NEM2 to NEM3, which will likewise result in customers receiving around 80% less compensation for energy exports, will negatively impact installation levels in the long term.

In 2015, Darghouth et al. used NREL's SolarDS model to predict nationwide residential solar deployment through 2050 under net metering with a $0.07/kWh compensation rate, intended to represent an average avoided cost-based rate, and net metering with a $0.15/kWh rate, intended to represent an average retail rate. They found that in 2050, nationwide solar deployment would be over 80% lower under the avoided cost rate scenario than the retail rate net metering scenario.[106]

In 2016, Barbose et al. instead used NREL's "dSolar" model, the improved and updated successor to SolarDS, to predict nationwide residential solar adoption under two main policy scenarios: elimination of retail rate net metering for wholesale rate compensation instead and indefinite continuation of retail rate net metering. They found that in the long run (30 years), compensating energy exports at the wholesale rate (similar to avoided cost rates) will lead to half as many solar installations versus scenarios with retail rate NEM.[107] Their results and those in Darghouth et al. suggest NEM policy has an appreciable impact on installation levels.

Focusing on California, but likewise employing NREL's dSolar model, as well as a Bass diffusion model and a threshold heterogeneity diffusion model, Dong et al. predicted California solar adoption under full retail rate net metering versus a "value of solar" rate. Value of solar rates are typically a little bit higher than an avoided cost rate (which NEM3 will provide customers) but lower than full retail rates. They predicted that installation levels would be 32% lower each year under a value of solar rate versus full retail rate net metering, reinforcing the general prediction in the literature that net metering policies meaningfully impact installation levels.[108]

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104 Drury, Easan, Paul Denholm, and Robert Margolis. "Modeling the U.S. Rooftop Photovoltaics Market." 2010.

105 Zhao, Jiayun, Esfandyar Mazhari, Nurcin Celik, and Young-jun Son. "Hybrid Agent-based Simulation for Policy Evaluation of Solar Power Generation Systems." Simulation Modelling Practice and Theory 19, no. 10 (2011): 2189-205. https://doi.org/10.1016/j.simpat.2011.07.005.

106 Darghouth, Naïm, Galen Barbose, Ryan Wiser, and Andrew Mills. "Net Metering and Market Feedback Loops: Exploring the Impact of Retail Rate Design on Distributed PV Deployment." Ernest Orlando Lawrence Berkeley National Laboratory, 2015. https://eta-publications.lbl.gov/sites/default/files/lbnl-183185_0.pdf.

107 Barbose, Galen, John Miller, Ben Sigrin, Emerson Reiter, Karlynn Cory, Joyce McLaren, Joachim Seel, Andrew Mills, Naïm Darghouth, and Andrew Satchwell. (2016). On the Path to SunShot: Utility Regulatory and Business Model Reforms for Addressing the Financial Impacts of Distributed Solar on Utilities (NREL/TP-6A20-65670). National Renewable Energy Laboratory. http://www.nrel.gov/docs/fy16osti/65670.pdf.

108 Dong, Changgui, Benjamin Sigrin, and Gregory Brinkman. "Forecasting Residential Solar Photovoltaic Deployment in California." Technological Forecasting and Social Change 117 (2017): 251-65. https://doi.org/10.1016/j.techfore.2016.11.021.

B. Ex post facto analyses

Instead of predicting the impact of policy changes, other authors have examined the effect of net metering policy changes post-implementation.

In 2010, Heavner et al. used monthly net-metered solar capacity data from the Energy Information Administration's (EIA's) Form 861-M to plot monthly solar system additions before and after NEM policy changes. Specifically, they graphed new residential installed capacity each month between 2011 and 2019 in 5 utilities that changed their net metering policy sometime between 2014 and 2017: Nevada Energy, the Salt River Project (SRP) in Arizona, Hawaiian Electric Company, Imperial Irrigation District, Turlock Irrigation District, and Modesto Irrigation District.[109] Each of these utilities shifted from retail rate net metering to a form of avoided cost-based net metering, reducing compensation rates by 50%–75% on average, and each utility grandfathered existing NEM customers into the higher compensation rate. Heavner et al. show that in each utility, there was a roughly 100% increase in monthly installed capacity in the months preceding an announced policy change and a steep and persistent drop in installations after the change.[110] These results indicate that customers are responsive to changes in NEM policy and that, if the announced shift to NEM3 does spur an increase in installations pre policy change, it may be followed by a complementary and persistent decrease in adoption levels.

A few months later, Dutzik et al. examined NEM policy changes across the same group of utilities, likewise utilizing EIA Form 861-M data. However, instead of plotting monthly installed capacity like Heavner et al., Dutzik et al. calculated and graphed the increase in installed solar capacity each month versus the monthly average over the preceding twelve months. However, they arrived at a similar conclusion: dramatic increases in monthly installed capacity are correlated with utilities announcing unfavorable policy changes, and dramatic decreases in monthly installed capacity are correlated with these policies actually going into effect.[111]

Dyreson et al. examined the SRP change in greater detail, but instead of using EIA data, they used the Lawrence Berkeley Lab's "Tracking the Sun" dataset of monthly installations in utilities across the US. The authors graphed the number of new installations each month before and after the new SRP NEM policy went into effect. They identified another Arizona utility – APS – that didn't make changes to their NEM policy and compared SRP installation trends against this utility. Confirming results across the literature, they first found that in SRP, but not in APS, a large group of customers installed systems in December 2014 in an expected rush to meet the deadline to grandfather a system into SRP's original net metering policy.[112] Their installation plots also highlight a 94% decrease in installations post policy change in SRP that did not occur in APS.[113] Additionally, they conducted a t-test on monthly installation rates under SRP's old and new net metering programs, determining that installation rates before and after SRP's policy change was implemented were significantly different ($p = 2e\text{-}9$).[114]

Finally, Satchwell et al. examined the Hawaiian Electric Company's NEM policy change in greater depth. Plotting quarterly data from the Hawaiian Electric Company's compliance filings, they found that, in the years preceding Hawaii's 2015 shift from a retail rate NEM program to an avoided cost-based NEM program (a roughly

109 Heavner, Brad, Julia Kantor, and Tim Lindl. "California Solar and Storage Association's Proposal for a Successor to the Current Net Energy Metering Tariff." Paper presented at Rulemaking 20-08-020, San Francisco, CA. https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M371/K904/371904829.PDF.

110 Heavner et al. "California Solar and Storage Association's Proposal for a Successor to the Current Net Energy Metering Tariff."

111 Dutzik, Tony, Bryn Huxley-Reicher, Laura Deehan, and Bronte Payne. "Rooftop Solar at Risk: Cuts to Net Metering Could Threaten California's Clean Energy Progress." Environment California, 2021. https://publicinterestnetwork.org/wp-content/uploads/2021/07/Rooftop-Solar-at-risk-final.pdf.

112 Dyreson, Ana, Chris Hoffman, Aaron Pritchard, and Amanda Schienebeck. "Effects of Salt River Project's Demand- Based Rate Change on the Rooftop Solar Market in Maricopa County, Arizona." UW-Madison, 2017. https://emp.lbl.gov/sites/default/files/uwisconsin-srp_solar_event_study_final051117.pdf.

113 Dyreson et al. "Effects of Salt River Project's Demand- Based Rate Change on the Rooftop Solar Market in Maricopa County, Arizona." 29.

114 Dyreson et al. "Effects of Salt River Project's Demand- Based Rate Change on the Rooftop Solar Market in Maricopa County, Arizona." 29.

60% reduction in rates), installation levels dropped in half.[115]

Similar to these latter studies, I analyze installation trends after an announced change to NEM policy. I also try to add a layer of confidence to my results by comparing installation trends in the IOUs to installation trends in a suitable control utility—LADWP.

C. Surveys and expert predictions

All of the above literature was published before the CPUC released its proposed NEM3 decision; the papers study the effect of net metering policies generally and not the impact of NEM3 specifically. However, since the release of NEM3, some private sector groups have employed modeling tools to predict the effect of NEM3 on solar installations.

Wood Mackenzie, a prominent global research, analytics, and consultancy business, conducts respected market research on the US solar market. In collaboration with the Solar Energy Industries Association (SEIA), Wood Mackenzie produces a quarterly US market solar insight report. They collect granular data from nearly 200 utilities, state agencies, installers, and manufacturers each month to produce these reports, which include market trend analyses, manufacturing and pricing updates, and demand forecasts.[116]

When the first NEM3 proposed decision was released, Wood Mackenzie predicted customer payback periods for a standard residential solar system would "increase from five to six years under current net metering to 14–15 years, depending on the utility."[117] The report authors explain this payback period is longer than the 10-year threshold they identify as the tipping point where customers are less inclined to purchase a solar system and installers are less likely to sell them. Ultimately, they determined that if the first NEM3 decision was adopted as proposed, the residential market would shrink to half its 2021 size by 2024, with a 53% year-on-year decline in installed capacity in 2023 in IOU territories and further declines in 2024. However, they also foresaw increased installations throughout 2022 as customers and installers rushed to interconnect systems under NEM2. Their predictions reveal a consensus among industry experts that customers would react to proposed NEM changes before and after policy implementation.

Any increase in installations caused by NEM policy changes between March and December 2022, the treatment period I analyze in my paper, reflects customers' reaction to the CPUC's first NEM3 proposed decision, not their second. However, of interest for likely trends post-December 2022 and April 2023 policy implementation, Wood Mackenzie also released updated predictions in December 2022 following the CPUC's second NEM3 proposed decision. The firm echoed their prediction for increased installation levels through Q2 2022 as customers rushed to grandfather their systems into NEM2 programs, and they predicted that NEM3 as approved will cause a 39% contraction in the California residential solar market in 2023.[118]

Supporting some of Wood Mackenzie's predictions, in January 2022, Solar Reviews, a leading website for solar panel installation reviews, conducted a customer survey eliciting California homeowners' views on proposed NEM changes. In total, 4,828 individuals responded to their survey, which they sent to all California homeowners who requested solar quotes through their website between January 2020 and December 2021.[119] Their first two survey questions asked homeowners whether they had installed or considered installing a solar system.

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115 Satchwell, Andrew J., Peter A. Cappers, and Galen L. Barbose. "Energy Analysis and Environmental Impacts Division Lawrence Berkeley National Laboratory." Lawrence Berkeley National Laboratory, 2019. https://eta-publications.lbl.gov/sites/default/files/sein_rate_design_trends_report_final_doe_approved.pdf.

116 Davis, Michelle, Sylvia Martinez, Zoe Gaston, Caitlin Connelly, Matthew Sahd, Max Issokson, Elissa Pierce, Chris Seiple, Shawn Rumery, Colin Silver, Tyler Thomoson, and Justin Baca. "US Solar Market Insight Executive Summary. Solar Market Insight Report 2022 year in review." 2023. https://storage.pardot.com/139231/16783127725ZK2dUon/USSMI_2022_YIR_ES.pdf. 2.

117 Lebbon, Vivien, Mark Thomton, Sonia Kerr, Alishia Markwell, and Kevin Baxter. "New NEM 3.0 Provisions 'Will Cut California Solar Market in Half by 2024.'" Wood Mackenzie. Last modified January 25, 2022. Accessed March 19, 2023. https://www.woodmac.com/press-releases/nem-3.0-pd-will-cut-california-solar-market-in-half-by-2024/.

118 Davis et al. "US Solar Market Insight Executive Summary. Solar Market Insight Report 2022 year in review." 11.

119 SolarReviews. "NEM 3.0 Survey," 2021. https://www.solarreviews.com/content/images/blog/SolarReviews_CASurveyReport.pdf.

If the homeowner replied yes to one of these above questions, which 4,979 respondents did, they progressed to survey questions three and four (NEM3 Survey 2021).[120] Question 3 asked homeowners whether they would still consider installing solar if they only received the average NEM3 avoided cost rate of $0.04–$0.05 per kWh exported versus the original rate of $0.22–$0.36. Question 4 asked respondents whether they would still consider installing solar if the rate was reduced to $0.04–$0.05/kWh and they had to pay the proposed monthly $8 per kW of installed solar capacity fee. In total, 68.4% of homeowners replied that they would no longer consider installing solar if the rate was reduced to $0.04–$0.05/kWh, but the monthly kW fee was not implemented, and 95.4% of respondents asserted they would no longer consider installing solar if both the kWh compensation rate and kW fee were introduced.

Solar Reviews' survey did not reach a representative sample of Californians, and their results also likely suffer from non-response bias. Nonetheless, Solar Reviews engaged a large sample of respondents who overwhelmingly suggested that net metering policy impacts an individual's decision to go solar. If these results are at least somewhat indicative of the general public's views, they support any finding that customers rushed to install solar before the NEM2 expiration date.

V. Methods and data

A. The counterfactual: LADWP

The number of monthly solar installations has increased in IOU territory since changes to NEM2 were announced. However, without comparing this increase to installation trends in utilities unaffected by net metering policy changes, it isn't easy to establish a causal link between the CPUC's NEM3 announcement and installation trends.

In an ideal world, a utility identical to the IOUs in all regards except exposure to the CPUC's NEM3 policy would exist. If this was the case, I could attribute any difference in installation trends between the IOUs and the hypothetical utility to the only difference between the groups: the announced change in net metering policy. Unfortunately, no such hypothetical utility exists, but the Los Angeles Department of Water and Power (LADWP) is the next best choice.

The state of California does not require LADWP to offer net metering.[121] Nonetheless, LADWP offers its customers a full retail rate net metering program. This program is very similar to NEM2. And importantly, LADWP has not announced any plans to change it. This makes LADWP a viable "control group" against which to compare IOU installation trends. I explore LADWP's suitability as a valid counterfactual in the next sections.

1. LADWP's net metering policy

LADWP has offered customers enrollment in its net metering program since 1999.[122] Under this program, NEM customers receive a full retail rate credit for each unit of energy they export to the grid; exports are credited in a one-to-one fashion. LADWP customers do not have to take service on TOU rates like NEM2 customers. However, average residential electricity rates in LADWP are within 20% of the average residential electricity rate in the IOUs.[123] Additionally, like NEM1 and NEM2, LADWP customers cannot offset a $10/month minimum bill with net metering credits.[124]

Unlike the IOUs, LADWP customers never receive net surplus compensation.[125] At the end of a month, if

120 SolarReviews. "NEM 3.0 Survey."

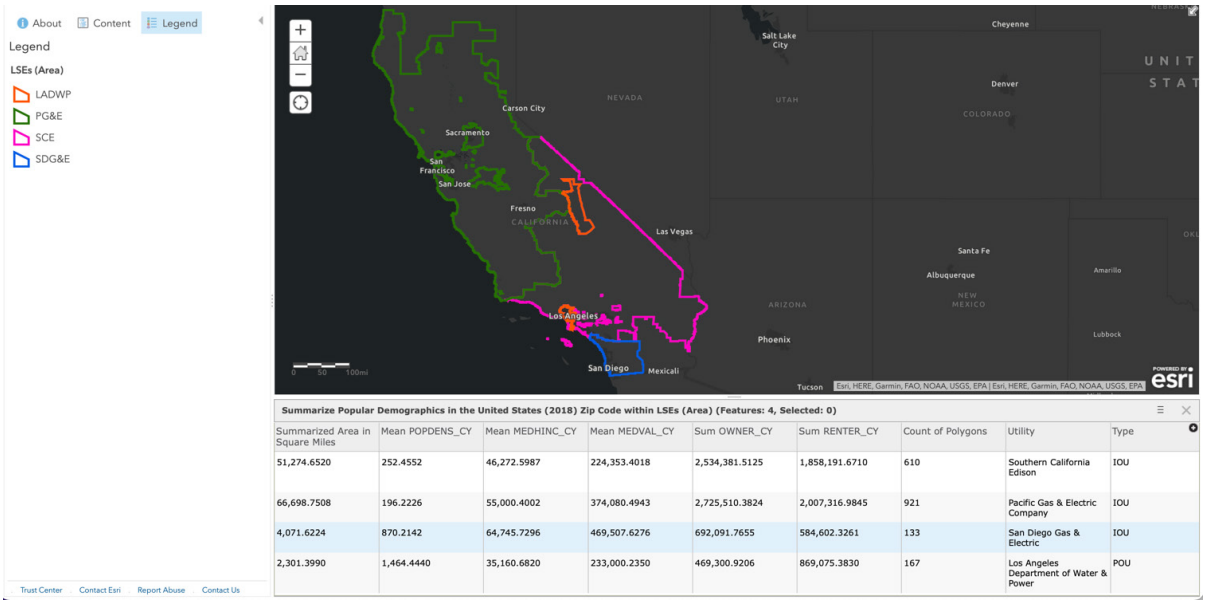
121 Cal. Pub. Util. Code § 2827.

122 EnergySage. "2023 Los Angeles Department of Water and Power (LADWP) Net Metering."

123 U.S. Energy Information Administration. "2021 Utility Bundled Retail Sales-Residential (Data from Forms EIA-861-Schedules 4A & 4D and EIA-861S)." Www.eia.gov, 2022. https://www.eia.gov/electricity/sales_revenue_price/pdf/table_6.pdf.

124 Zientara, Ben. "LADWP Solar Programs, Incentives, and Net Metering." SolarReviews. Last modified September 19, 2022. Accessed March 21, 2023. https://www.solarreviews.com/blog/going-solar-with-los-angeles-department-of-water-and-power.

125 Los Angeles Department of Water & Power. "EV / NEM / REO Rates | Los Angeles Department of Water and Power." www.ladwp.com, September 1, 2008. https://www.ladwp.com/account/customer-service/electric-rates/ev-nem-reo-rates.



Summarize Popular Demographics in the United States (2018) Zip Code within LSEs (Area) (Features: 4, Selected: 0)

Summarized Area in Square Miles	Mean POPDENS_CY	Mean MEDHINC_CY	Mean MEDVAL_CY	Sum OWNER_CY	Sum RENTER_CY	Count of Polygons	Utility	Type
51,274.6520	252.4552	46,272.5987	224,353.4018	2,534,381.5125	1,858,191.6710	610	Southern California Edison	IOU
66,698.7508	196.2226	55,000.4002	374,080.4943	2,725,510.3824	2,007,316.9845	921	Pacific Gas & Electric Company	IOU
4,071.6224	870.2142	64,745.7296	469,507.6276	692,091.7655	584,602.3261	133	San Diego Gas & Electric	IOU
2,301.3990	1,464.4440	35,160.6820	233,000.2350	469,300.9206	869,075.3830	167	Los Angeles Department of Water & Power	POU

Figure 1. Common Demographic Variables Summarized within Utility Boundaries. Underlying Data Sources: ESRI, & U.S. Census Bureau. (2022, January 30). Popular Demographics in the United States (2018); California Energy Commission. (2021, December 16). Electric load serving entities (IOU & POU). California State GeoPortal.

a customer has used more energy than they have exported to the grid, LADWP charges them for their net usage. If the customer instead has a credit balance, LADWP carries that balance over to the next month indefinitely; balances are not reset after 12 months like in the IOUs. However, it is rare for customers to have large net surpluses because, as is also the case in the IOUs, customers must approximately size their solar system to meet their net load to participate in net metering.

2. Other LADWP solar programs

There have also been no major changes to other LADWP solar policies that could drive anomalous installation trends.

In 1999, LADWP initiated its Solar Incentive Program (SIP), offering customers solar installation rebates.[126] These rebates were updated in 2007 to align with the California Solar Initiative. While this program helped customers cover the cost of early installations, LADWP stopped disbursing rebates in 2018, so this policy is not driving any installation trends over my study period.

Additionally, before the COVID pandemic, LADWP offered its customers the chance to participate in its Shared Solar Roofs program. Under this program, LADWP installs a solar system on a customer's roof in exchange for a flat monthly payment between $20 and $50 dollars.[127] Customers receive no benefits beyond this monthly bill reduction; all of the energy from the system on their roof is directed to the grid, not their home.

When the COVID pandemic hit, LADWP suspended this program for health and safety reasons, and as of December 2022, they had not reinstated the program nor announced any plans to do so (Zientara 2022).[128] Therefore, the suspension of the SSP program over my study period should not have caused any sharp changes in monthly installations in LADWP around the announcement of NEM3.

126 Wigness, Sam. "LADWP Solar Incentive Program Ends Beginning of 2019." Solar.com. Last modified November 3, 2022. Accessed March 21, 2023. https://www.solar.com/learn/ladwp-solar-incentive-program-ends-beginning-of-2019/.

127 Zientara, Ben. "LADWP Solar Programs, Incentives, and Net Metering."

128 Zientara, Ben. "LADWP Solar Programs, Incentives, and Net Metering."

3. Observable characteristics

Regarding its net metering and solar policies, LADWP makes an excellent counterfactual. Nonetheless, to ensure the suitability of LADWP as my control group utility, I also looked at key demographic and energy variables across IOU and LADWP territory. The IOUs and LADWP are similar in some areas but differ substantially in others.

LADWP is closer in size to the IOUs than any other utility in California; LADWP has 1,367,014 residential customers compared to PGE's 1,958,976, SDGE's 1,285,917, and SCE's 3,373,642 (2021 Utility 2022). As mentioned above, LADWP's average residential electricity rate is also similar to the IOUs' rates; in 2021 LADWP's average residential electricity rate was 21.19 cents/kWh, PGE's rate was 25.86 cents/kWh, SDGE's rate was 30.65 cents/kWh, and SCE's rate was 21.33 cents/kWh.[129]

However, LADWP and the IOUs differ substantially across other metrics. Notably, the number of net metering customers across the IOUs versus LADWP is drastically different.[130] There are about five times as many IOU customers as LADWP customers yet over twenty times as many net metering customers in the IOUs than in LADWP.

I also found differences in financial and demographic variables in LADWP's and the IOUs' territories that are often correlated with solar adoption levels. I used ArcGIS Online, a geospatial analysis platform, and data from the 2018 census to calculate the mean zip code-level population density, median household income, and median home value across the IOUs' and LADWP's territories, and I also calculated the total number of owner- and renter-occupied housing units.[131] I've included an image of my analysis layer in Figure 1, which aggregates these demographic variables in each utility's outlined territory.

I've included the statistics I calculated through ArcGIS, including standard errors (listed in parentheses), in Table 1 below. I also added a row for the number of residential customers, the average residential electricity rate, and the number of net metering customers in the IOUs versus LADWP, which I retrieved from the EIA's 2021 reports.

Where possible, I then conducted a t-test to see whether each variable significantly differs across the IOUs versus LADWP. The t-values are all significantly larger than 1.96, the threshold where it is possible to reject that the average of a variable in the IOUs and LADWP is the same with 95% confidence.

Table 1. Balance Table

Variable	IOUs	LADWP	t-score
Residential Customers	6,618,535.00	1,367,014.00	-
Electricity Rate (cents/kWh)	25.95	21.19	-
Residential Solar Net Metering Customers	1,462,073.00	67,882.00	-
Mean 2018 Zip Code Level Population Density	439.63 (792.49)	1,464.44 (4,236.27)	3.12
Mean 2018 Zip Code Level Median Household Income ($)	55,339.58 (13,880.75)	35,160.68 (30,000.55)	8.60

129 U.S. Energy Information Administration. "2021 Utility Bundled Retail Sales-Residential (Data from Forms EIA-861-Schedules 4A & 4D and EIA-861S)."

130 U.S. Energy Information Administration. "2021 Utility Bundled Retail Sales-Residential (Data from Forms EIA-861-Schedules 4A & 4D and EIA-861S)."

131 ESRI, and U.S. Census Bureau. "Popular Demographics in the United States (2018)." ArcGIS Online. Last modified January 30, 2022. Accessed March 21, 2023. https://services.arcgis.com/P3ePLMYs2RVChkJx/arcgis/rest/services/AGOL_Base_2018_Final/FeatureServer.

Variable	IOUs	LADWP	t-score
Mean 2018 Zip Code Level Median Home Value ($)	355,980.51 (131,993.15)	233,000.24 (331,422.72)	4.76
Total Owner-Occupied Housing Units 2018	5,951,983.66 (2,267.31)	469,300.92 (2,535.14)	26,889.47
Total Renter-Occupied Housing Units 2018	4,450,110.98 (1,530.87)	869,075.38 (3,688.44)	12,439.48

Underlying Data Sources: "2021 Utility Bundled Sales to Ultimate Customers-Residential." (2022, October 22). Energy Information Administration (EIA); ESRI, & U.S. Census Bureau. (2022, January 30). "Popular Demographics in the United States (2018)."

To reduce the effect of these differences on my analysis, I added utility-fixed effects to some of my regressions. I also conducted validity tests to ensure installation trends across the IOUs and LADWP were similar before NEM3 was announced.

B. The treatment period

After selecting my counterfactual, I next defined the treatment period. The CPUC's first NEM3 decision was released on December 13, 2021. However, the first effectively "treated" month is March 2022. This is because it takes between ten weeks and six months on average for a customer to complete each step of the solar installation process.[132] Specifically, it generally takes between a day and two weeks for a customer to choose an installer, one week for solar site assessment, two to three weeks for solar system design, two to seven weeks for gathering building and solar permits, one to four weeks for equipment delivery, one to three days for installation, one to two weeks for city inspection, and then finally two to six weeks for utility inspection and grid interconnection.

After adding a few days to the lowest estimate of nine weeks to allow time for news of NEM3 to have spread through the media, and accounting for the fact that permitting and installation times are usually slower over the holidays, the earliest date a customer reacting to NEM3 could feasibly have interconnected a solar system is March 2022. In the solar installation datasets I use, the interconnection date of a system is reported, not the date a customer initiates the process of installing a solar system. This is why the first month of the treatment period in my analysis is March 2022, not December 2021.

The roughly three-month delay between a hypothetical customer positively reacting to NEM3 and actually interconnecting their system also means that my analysis only captures customers' reactions to the CPUC's first NEM3 decision. With interconnection data post–December 2022, future analyses could capture customers' reactions to the CPUC's final NEM3 proposal. Such analyses might uncover a bigger treatment effect by virtue of including the final months new solar customers could enroll in NEM2. However, I would not expect any difference in the treatment effect between my analysis in this paper and an extended analysis to be driven by customers reacting to the specificities of the CPUC's first and second NEM3 decisions differently. The roughly 80% reduction in export credits under both NEM3 iterations provides a major incentive to install a system before NEM3 goes into effect; this general reduction in compensation, not policy specificities, is likely behind any customer's decision to adopt solar before the NEM2 sunset date. Nonetheless, I discuss this topic further after my results section.

Finally, I note that the CPUC opened R. 20-08-020 in November 2020 and released its guiding principles in January 2021, so it is possible customers foresaw significant net metering policy changes before the CPUC released their first NEM3 decision. If customers predicted that the CPUC would enact major changes to net metering programs and installed systems pre–March 2022 to get ahead of these changes, this would reduce the treatment effect I estimate. However, the CPUC's NEM3 rulemaking did not receive wide media coverage until the CPUC released its first NEM3 decision.

132 Lane, Catherine. "How Long Does a Solar Panel Installation Take?" SolarReviews. Last modified June 8, 2022. Accessed March 22, 2023. https://www.solarreviews.com/blog/solar-panel-installation-process.

C. Data sources and scope

1. Data time period

I gathered data on the number of net-metered residential solar systems in the IOUs and LADWP each month between January 2021 and December 2022. December 2022 was the last available month of data at the time of writing.

Monthly installation data are available for LADWP from 2011 onwards and for the IOUs from 1982 onwards. However, to try and isolate the impact of the announced NEM change and prevent other policy changes and events from potentially biasing my results, I used a much shorter time period than this. Notably, the COVID pandemic impacted solar installation levels in 2020; there was an anomalous drop in solar installations during the second quarter of 2020 as stay-at-home orders restricted selling and installing solar systems.[133] California eased lockdown measures in the summer of 2020, and installations rebounded towards the end of 2020. Beginning my analysis in January 2021 reduces the chance of COVID-related impacts inducing a bias in my results. Using January 2021 as the first month in my analysis also results in a roughly symmetric pre-treatment and post-treatment period, which can reduce bias in certain cases.[134]

2. IOU installation data

I used data from California Distributed Generation Statistics to create my dataset of solar installations in the IOUs' territories.

California Distributed Generation Statistics was launched by the CPUC in 2016 to provide public access to solar installation data in California's three large investor-owned utilities.[135] The California government required PGE, SCE, and SDGE to provide the California Public Utilities Commission with all of their past (pre-2016) solar installation data for publication, and now they must submit data about every system installed by their customers on a monthly basis.[136] Energy Solutions, an energy consulting firm contracted by the CPUC, cleans this data and updates the publicly available datasets at the end of every calendar month, giving users access to information about every distributed solar generation system installed in IOU territory to date.

Specifically, I used data from California Distributed Generation Statistics' "Interconnected Project Sites Data Set."[137] This data set contains all currently interconnected (it excludes pending and decommissioned) distributed generation facilities and, among other fields, includes the date a project was interconnected to the grid, the type of generation system (e.g. solar/wind/battery), the customer's business class (e.g. residential/commercial), the customer's utility, the net metering program a customer is enrolled in (e.g. NEM1/2/VNEM), the size of a customer's system in DC and AC watts, and the third-party ownership or financing structure of a system.[138]

I used the programming language R to extract each of the relevant data fields and rows and manipulate the data into a new dataset amenable to my analysis. First, I filtered the interconnected projects dataset for net-metered, residential solar installations. I then decided to remove all virtual net metering (VNEM) and net metering aggregation (NEMA) systems.

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133 Davis, Michelle, Colin Smith, Bryan White, Ravi Manghani, Xiaojing Sun, Molly Cox, Gregson Curtin, Shawn Rumery, Colin Silver, and Justin Baca. "Solar Market Insight Report 2020 Year in Review." Solar Energy Industries Association. Last modified March 16, 2021. Accessed March 22, 2023. http://Solar Market Insight Report 2020 Year in Review.

134 Chabé-Ferret, Sylvain. "To Control or Not to Control? Bias of Simple Matching vs Difference-In- Difference Matching in a Dynamic Framework." Yale University, 2010. https://www.researchgate.net/publication/228799034.

135 California Public Utilities Commission. "Proposed Decision Revising Net Energy Metering Tariff and Subtariffs." 53.

136 Energy Solutions, ed. "Download Data." California Distributed Generation Statistics. Last modified December 2022. Accessed December 2, 2022. https://www.californiadgstats.ca.gov/downloads/.

137 Energy Solutions, ed. "Download Data."

138 Energy Solutions. "Data Key." California Distributed Generation Statistics. Last modified January 31, 2023. Accessed March 21, 2023. https://www.californiadgstats.ca.gov/downloads/.

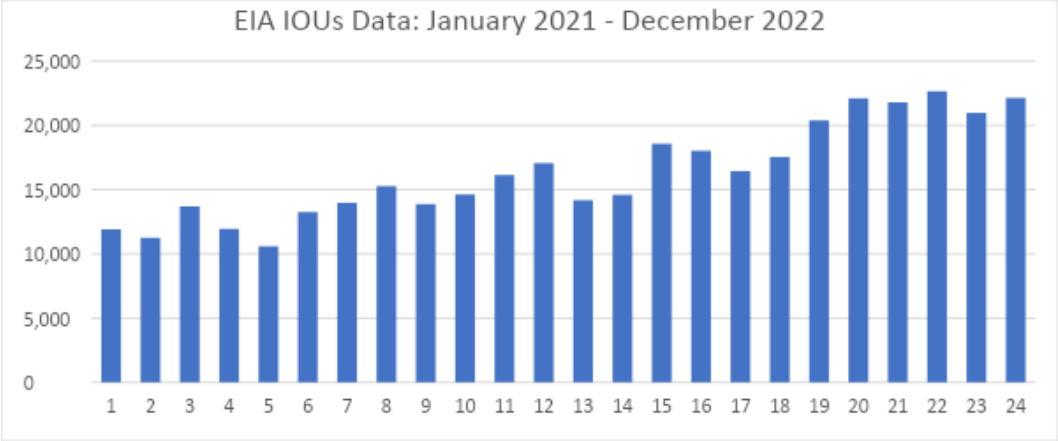

Figure 2. IOU Installations per Month, EIA Data. Underlying Data Source: Annual electric power industry report, form 861 M. (2023, March 1). US Energy Information Administration.

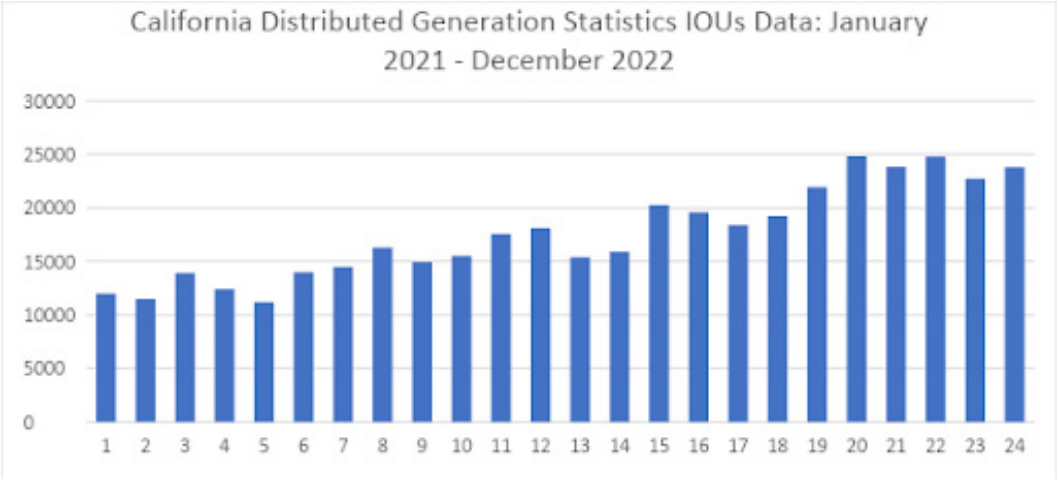

Figure 3. IOU Installations per Month, California Distributed Generation Statistics Data. Underlying Data Source: Energy Solutions (Ed.). (2022, December). "Download data." California Distributed Generation Statistics.

Under the CPUC's first NEM3 decision, NEMA and standard-income VNEM customers were treated identically to standard net metering customers; low-income VNEM customers were the only group that would have been allowed to enroll in NEM2 after NEM3 was enacted. However, under the final, enacted version of NEM3, customers with systems eligible for VNEM or NEMA tariffs are able to enroll in NEM2 indefinitely.

Customers installing systems through the end of 2022 were reacting to the CPUC's first NEM3 decision, under which new NEMA and standard income VNEM customers were treated normally. However, if any VNEM and NEMA customers followed the CPUC's deliberations closely throughout 2022, they may have foreseen the CPUC's November 2022 update. If this is the case, there are effectively untreated customers in the treated utilities dataset, which could diminish any treatment effect. I decided to err on the side of caution and eliminate this concern by removing VNEM and NEMA solar systems from my dataset.

Once I was left with non-NEMA, non-VNEM net-metered residential solar systems, I used the interconnection date field to create a new dataset with two primary fields: the number of net-metered solar systems interconnected per month in the IOUs and the total number of interconnected net-metered solar systems by the end of a month in the IOUs. The Interconnected Project Sites data set has tens of other data fields which could be included in more detailed analyses. Unfortunately, most of these additional fields are not also available in data of installations in LADWP territory, so I did not include them in the final dataset I used.

3. LADWP installation data

My data regarding the number of net-metered solar systems in LADWP territory comes from the US government's Energy Information Association (EIA).

The EIA requires the IOUs and a selection of publicly owned utilities, including LADWP, to fill out Form 861-M on a monthly basis.[139] This form asks utilities about several metrics relating to customer sales and revenue, including the count and capacity of net metered generation systems in their territory. Utilities must report this data by customer class and generation type.

Also monthly, the EIA processes information from Form 861-M and publishes a dataset of the number and capacity of net metered installations per month separated by utility, customer class, and system generation type. In my analysis, I used the EIA's "net metering customers" field from the subset of residential solar systems in LADWP as my installation metric. According to EIA documentation, this field is functionally equivalent to the number of interconnected, net-metered residential solar systems.[140]

There are two months—January and March 2021—in the EIA's dataset of LADWP installations with apparent errors: in these months, the reported number of interconnected systems is the same or lower than the month prior. To replace these errors with a more reasonable estimate of installations, I calculated the difference in installations between the month immediately preceding and following a month with erroneous data, and I added half this difference to the preceding month. I've included the edited section of my dataset in Table 2 below. The EIA's original dataset is in the penultimate column, and my edited dataset is in the last column. Orange cells represent months with originally erroneous data.

Table 2. EIA Data Edits

Utility	Year	Month	EIA Data: Residential Customers	Corrected Data: Residential Customers
LADWP	2020	12	50123	50123
LADWP	2021	1	50123	50683
LADWP	2021	2	51244	51244
LADWP	2021	3	45019	52176
LADWP	2021	4	53109	53109

Underlying Data Source: Annual electric power industry report, form 861 M. (2023, March 1). US Energy Information Administration.

The EIA has installation data for PGE, SCE, and SDGE which I could have used instead of the installation dataset from California Distributed Generation Statistics. However, California Distributed Generation Statistics' dataset included vital information about whether an installation was part of a virtual net metering (VNEM) or net metering aggregation (NEMA) program.

Additionally, the EIA's and California Distributed Generation Statistics' datasets should be almost identical. Utilities provide the EIA an estimate of how many residential solar NEM customers they have by counting the number of residential solar systems interconnected in their territory at the end of a month.[141] I create my statistic of monthly installations from California Distributed Generation Statistics' dataset the same way—I filter for the residential solar systems and then sum the total number of operative projects interconnected by the end of a month.

However, to be sure the two datasets are similar, I plotted the EIA's IOU data and my California Distributed Generation Statistics' data before removing VNEM and NEMA systems. Figures 2 and 3 show that installation levels and trends are nearly identical in both datasets.

139 U.S. Energy Information Administration. "Annual Electric Power Industry Report, Form EIA-861 Detailed Data Files."

140 U.S. Energy Information Administration. "FORM EIA-861M MONTHLY ELECTRIC POWER INDUSTRY REPORT INSTRUCTIONS," n.d. https://www.eia.gov/survey/form/eia_861m/instructions.pdf. 5.

141 U.S. Energy Information Administration. "FORM EIA-861M MONTHLY ELECTRIC POWER INDUSTRY REPORT INSTRUCTIONS," 8.

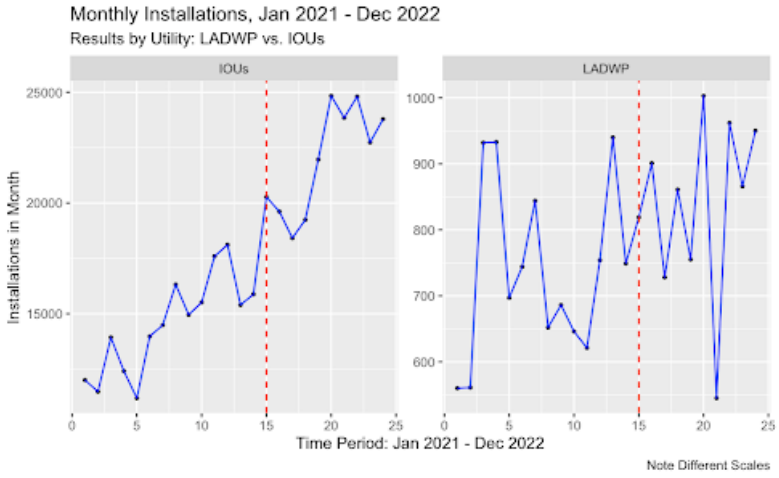

Figure 4. Monthly Installations.

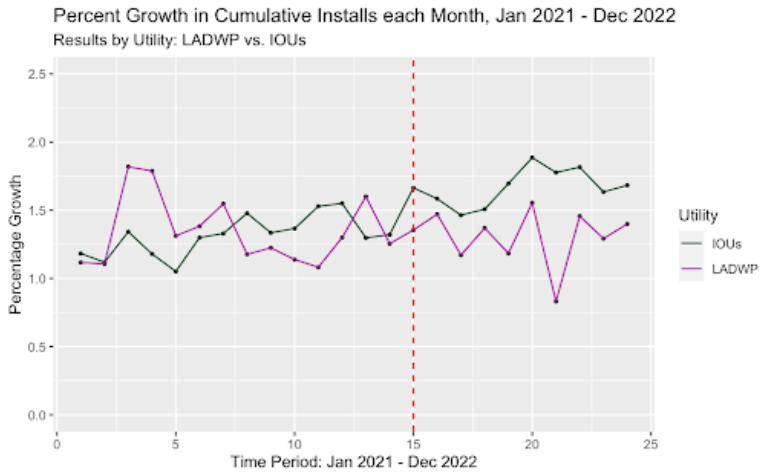

Figure 5. Month-over-Month Installation Growth.

VI. Results

A. Graphical analysis

Before running difference-in-differences regressions with my installation data, I first graphed monthly installations to elucidate general trends. In the figures below, I plot two installation metrics—monthly installations and month-over-month growth in installations—in all the IOUs combined versus LADWP.

1. Monthly installations

Figure 4 shows new monthly net-metered solar installations before and after March 2022 in all the IOUs combined and LADWP. Installations in LADWP are shown in the graph on the left, and installations in the IOUs are shown on the right. Both graphs have different y axes—installation levels are much higher in the IOUs before and after March 2022. The dashed vertical red line in each graph indicates March 2022.

In LADWP, installations do not appear to have followed a general trend before or after March 2022. In both the pre-treatment (Jan 2021–Feb 2022) and post-treatment (March 2022 onwards) periods, there were sharp fluctuations in monthly installations, with a roughly even number of months experiencing an increase versus a decrease in installations compared to the month prior.

In the IOUs, monthly installations show an increasing trend both before and after March 2022. Nonetheless, the largest monthly increase in installations occurred in March 2022, a trend that was not mimicked in LADWP.

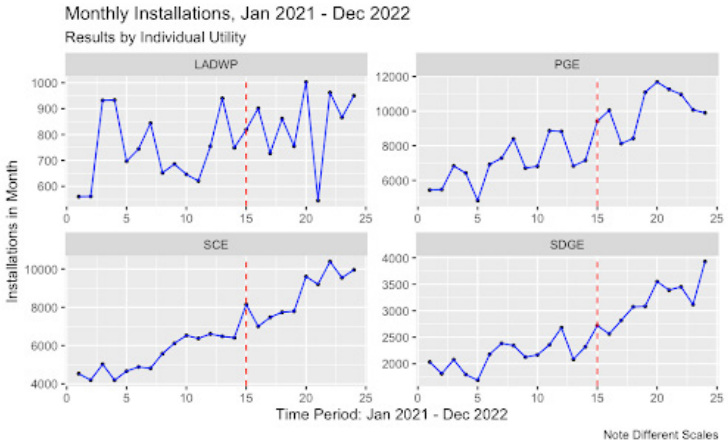

Figure 6. Monthly Installations in Each Unit

Installations in the IOUs also show the longest consecutive increase between May and August 2022 and then remained consistently high until December.

Comparing the post-treatment period in the IOUs to LADWP, these graphs highlight a clear increase in monthly installations in the IOUs around March 2022 that did not occur in LADWP. However, it is harder to discern from these graphs whether the increase in monthly installations in the IOUs broke with historical trends; this is where statistical analysis is useful.

2. Month-over-month total installation growth

In addition to monthly installations, I also graphed month-over-month growth in total installations, shown in Figure 5. The green line charts month-over-month growth in LADWP, and the purple line charts growth in all of the IOUs. The vertical dashed red line still indicates March 2022.

Month-over-month growth in total installations followed similar trends in LADWP and the IOUs before March 2022. While the level of growth differs slightly between the two groups, month-over-month growth increased and decreased during many of the same months, particularly in the first half of the pre-treatment period.

After March 2022, the two trend lines appear to diverge. Month-over-month growth increased markedly in the IOUs in March 2022, somewhat declined and plateaued through May, sharply increased through August, and then plateaued at a higher level versus the pre-treatment period through December. In contrast, month-over-month total installation growth fluctuated steeply in LADWP after March 2022. Growth increased until April and then dropped in May. From May, it continued to fluctuate month after month, with no consecutive months of decrease or increase.

Overall, this graph suggests the IOUs and LADWP followed fairly similar installation trends in the pre-treatment period. However, month-over-month installation growth increased in the IOUSs after March 2022 while growth remained roughly constant in LADWP. This suggests that the CPUC's NEM3 policy announcement did spur an increase in monthly installations in IOU territory. Whether this increase is statistically significant is the focus of my difference-in-differences regression analysis.

3. Monthly installations in all utilities

It is much harder to decipher general installation trends by plotting each of the IOUs individually versus combined. However, if one of the IOUs did not experience an increase in installations after the CPUC's NEM3 decision, it is less likely that the CPUC's proposal was driving installation trends. Therefore, to ensure the graphs of all utilities combined do not mask anomalous trends in an IOU, I also graphed installations per month for each utility separately.

As seen in Figure 6, monthly installation trends were similar in each of the IOUs. There was a large increase in monthly installations in PGE, SCE, and SDGE between February and March 2022, and installations continued to climb steeply across each IOU from May until August before plateauing through December.

B. Difference-in-differences regression analysis

1. Ordinary least squares model

A difference-in-differences regression model was employed to assess the causal effect of the CPUC's NEM3 announcement on month-over-month growth in total installations. Difference-in-differences models capture the causal effect of an event, such as a policy change, by estimating the difference in a treated and an untreated group's change in outcomes from before to after an event or treatment. The basic idea behind difference-in-differences regression is that without the event the treatment group would have followed similar trends to the control group, so any post-treatment trend divergence can be attributed to the treatment.

Specifically, I estimated the following difference-in-differences (DiD) regression model.

$$Monthly\ Installations\ Growth_{it} = \beta_0 + \beta_1(IOU_i) + \beta_2(Treated\ Period)_t + \beta_3(Treated\ Period \times IOU)_{it}$$

Equation 1.

Here, i indexes each individual utility (PGE, SCE, SDGE, or LADWP), and t indexes each time period (month).

IOU is an indicator variable for the investor-owned utilities (a treated utility). It equals 1 for each of the IOUs and 0 for LADWP. β_1 estimates the average difference in month-over-month installation growth between the IOUs and LADWP in the pre-treatment period.

Treated Period is an indicator variable for being in the treatment period (post–March 2022). It equals 1 in the treatment period and 0 in the pre-treatment period. β_2 estimates the average difference in month-over-month installation growth for LADWP in the treatment versus pretreatment period.

Finally, *Treated Period* × *IOU* is an interaction variable between *Treated Period* and *IOU*. It is equal to 1 for the IOUs during the treatment period and 0 otherwise. β_3 is the treatment effect and captures the difference in the average change in month-over-month installation growth from the pre-treatment to treatment period between the IOUs and LADWP. This estimate should capture the impact of the CPUC's NEM3 announcement on installation growth.

2. Fixed effects model

I ran two fixed effects DiD estimations in addition to the above OLS estimation. The first fixed effects DiD model includes utility fixed effects.

$$Monthly\ Installations\ Growth_{it} = \beta_0 + \beta_1(IOU_i) + \beta_2(Treated\ Period_t) + \beta_3(Treated\ Period \times IOU)_{it} + Utility_i$$

Equation 2.

The utility fixed effects, $Utility_i$, capture all unobserved, time-invariant factors within the IOUs or LADWP that affect month-over-month growth in installations.

The second fixed effects DiD model includes utility and month fixed effects.

$$Monthly\ Installations\ Growth_{it} = \beta_0 + \beta_1(IOU_i) + \beta_2(Treated\ Period_t) + \beta_3(Treated\ Period \times IOU)_{it} + Utility_i + Month_t$$

Equation 3.

The additional month fixed effects, $Month_t$, capture all unobserved factors which vary by month but are constant across utilities.

3. Difference-in-differences identifying assumption

Before running these above regressions, I checked a difference-in-differences model suits my data. A difference-in-differences regression relies on the identifying assumption that month-over-month installation growth in the IOUs and LADWP was following similar trends before the CPUC's NEM3 announcement and would have continued to follow similar trends without the announcement. If this is the case, any change in monthly installation growth in LADWP after the CPUC's announcement is essentially a "control change": an estimate of what would have happened to month-over-month installation growth in the IOUs without the CPUC's NEM3 announcement. This control change can be compared to trends in the treated group after treatment, and any difference in trends is attributable to the effect of the treatment.

To test the difference-in-differences "parallel trends" assumption, I ran each difference-in-differences model using data from the pre-treatment period only. My regressions estimate the difference between the IOUs and LADWP in the change in monthly installation growth between a base period—January to March 2021—and three pre CPUC NEM3 announcement periods—April to June 2021, July to October 2021, and November 2021 to February 2022.

Specifically, I ran the following three regressions.

OLS:

$$\textit{Monthly Installations Growth}_{it} = \beta_0 + \beta_1(IOU_i) + \beta_2(\textit{Apr} - \textit{Jun}\ 2021)_t + \beta_3(\textit{Jul} - \textit{Oct}\ 2021)_t + \beta_4(\textit{Nov}\ 2021 - \textit{Feb}\ 2022)_t + \beta_5[(\textit{Apr} - \textit{Jun}\ 2021) \times \text{IOU}]_{it} + \beta_6[(\textit{Jul} - \textit{Oct 2021)} \times \textit{IOU}]_{it} + \beta_7[(\textit{Nov}\ 2021 - \textit{Feb}\ 2022) \times \textit{IOU}]_{it}$$

Equation 4.

Utility Fixed Effects:

$$\textit{Monthly Installations Growth}_{it} = \beta_0 + \beta_1(IOU_i) + \beta_2(\textit{Apr} - \textit{Jun}\ 2021)_t + \beta_3(\textit{Jul} - \textit{Oct}\ 2021)_t + \beta_4(\textit{Nov}\ 2021 - \textit{Feb}\ 2022)_t + \beta_5[(\textit{Apr} - \textit{Jun}\ 2021) \times \text{IOU}]_{it} + \beta_6[(\textit{Jul} - \textit{Oct 2021)} \times \textit{IOU}]_{it} + \beta_7[(\textit{Nov}\ 2021 - \textit{Feb}\ 2022) \times \textit{IOU}]_{it} + \textit{Utility}_i$$

Equation 5.

Utility and Month Fixed Effects:

$$\textit{Monthly Installations Growth}_{it} = \beta_0 + \beta_1(IOU_i) + \beta_2(\textit{Apr} - \textit{Jun}\ 2021)_t + \beta_3(\textit{Jul} - \textit{Oct}\ 2021)_t + \beta_4(\textit{Nov}\ 2021 - \textit{Feb}\ 2022)_t + \beta_5[(\textit{Apr} - \textit{Jun}\ 2021) \times \text{IOU}]_{it} + \beta_6[(\textit{Jul} - \textit{Oct 2021)} \times \textit{IOU}]_{it} + \beta_7[(\textit{Nov}\ 2021 - \textit{Feb}\ 2022) \times \textit{IOU}]_{it} + \textit{Utility}_i + \textit{Month}_t$$

Equation 6.

The coefficient β_1 estimates the average difference in month-over-month installation growth between the IOUs and LADWP in the base period, similar to the full-period difference-in-differences regression models. The coefficients β_2, β_3, and β_4 estimate the average difference in month-over-month installation growth in LADWP in each respective modeled time period and the base period. The coefficients on each interaction term—β_5, β_6, and β_7—capture any difference between the IOUs and LADWP in the difference in monthly installation growth in the base period and each respective modeled time period. If the IOUs and LADWP followed similar trends before the CPUC's NEM3 announcement, each coefficient should not be statistically different than 0. Table 3 shows the results of each model.

Table 3. Parallel Trends Test Regression Results

	Response Variable: Month-over-Month Growth in Installations		
	OLS	***felm***	
	(1)	**(2)**	**(3)**
IOU	-0.160 (0.141) p = 0.261		
(Apr–Jun 2021)	0.147 (0.172) p = 0.399	0.147 (0.140) p = 0.301	
(Jul–Oct 2021)	-0.076 (0.161) p = 0.641	-0.076 (0.131) p = 0.566	
(Nov 2021–Feb 2021)	-0.038 (0.161) p = 0.813	-0.038 (0.131) p = 0.772	
IOU × (Apr–Jun 2021)	-0.193 (0.199) p = 0.337	-0.193 (0.162) p = 0.239	-0.193 (0.151) p = 0.210
IOU × (Jul–Oct 2021)	0.222 (0.186) p = 0.239	0.222 (0.151) p = 0.149	0.222 (0.142) p = 0.125
IOU × (Nov 2021–Feb 2022)	0.225 (0.186) p = 0.233	0.225 (0.151) p = 0.144	0.225 (0.142) p = 0.121
Constant	1.348 (0.122) p = 0.000		
Observations	56	56	56
R^2	0.202	0.495	0.654
Adjusted R^2	0.086	0.396	0.472
Residual Std. Error	0.211 (df = 48)	0.172 (df = 46)	0.161 (df = 36)
F Statistic	1.735 (df = 7; 48)		
Significance	*p**p***p < 0.01		

As seen, none of the coefficient estimates is statistically significant to the 5% confidence level; it is not possible to reject the null hypothesis and difference-in-differences identifying assumption that β_5, β_6, and β_7 are equal to 0. This does not prove that the parallel trends assumption holds, but it validates the use of a difference-in-differences estimation.

4. Difference-in-differences regression results

After validating the use of a difference-in-differences model, I estimated each of the three regression models. Table 4 shows the regression results.

Table 4. Difference-in-Differences Regression Results by Model

	Response Variable: Month-over-Month Growth in Installations		
	OLS	***felm***	
	(1)	**(2)**	**(3)**
IOU	-0.074 (0.071) p = 0.299		
Treated Period	-0.038 (0.095) p = 0.690	-0.038 (0.076) p = 0.620	
IOU × Treated Period	0.391*** (0.109) p = 0.001	0.391*** (0.088) p = 0.00003	0.391*** (0.082) p = 0.00001
(Constant)	1.346*** (0.061) p = 0.000		
Observations	96	96	96
R^2	0.326	0.574	0.723
Adjusted R^2	0.304	0.551	0.613
Residual Std. Error	0.229 (df = 92)	0.184 (df = 90)	0.171 (df = 68)
F Statistic	14.834*** (df = 3; 92)		
Significance Levels	*p**p***p < 0.01		

In the OLS estimate, the average month-over-month growth rate in the IOUs before the CPUC's announcement equals $\beta_0 + \beta_1$, equivalent to 1.346%–0.074%, or 1.272%. In other words, from January 2021 to February 2022, installations grew at an average rate of 1.272% in the IOUs.

However, β_1 is not statistically significant at the 1, 5, or 10% significance levels (p = 0.229), so it is not possible to say with confidence that the month-over-month growth rate in the IOUs varied from the installation growth rate in LADWP before the CPUC's announcement, which is estimated by β_0. In the OLS model, β_0 equals 1.346—installations in LADWP grew at an average rate of 1.346% per month between January 2021 and February 2022.

Variable β_3, the coefficient on the treatment variable "IOU * Treated Period," is the coefficient of interest. In the simple OLS model, β_3 is equal to 0.391. This suggests that the CPUC's announced changes to net metering policy caused a 0.391 percentage point increase in month-over-month installation growth in the IOUs versus the pre-treatment period. Given the estimate that the average month-over-month growth in installations was 1.272% in the IOUs before March 2023, this represents a 31% increase in month-over-month growth. Furthermore, with a p-value of 0.001, β_3 is statistically significant to the 0.1% level; the OLS model results offer strong evidence against the null hypothesis that the CPUC's NEM3 announcement had no effect on monthly solar installation levels.

For comparison, the model did not estimate a statistically significant difference in month-over-month installation growth in LADWP before and after the CPUC's announcement, which would be captured by β_2. β_2 is estimated at -0.038, but with a p-value of 0.690, it is not possible to reject the null hypothesis that it is equal to 0.

The first fixed effects model includes utility fixed effects, which removes potential omitted variables bias from relevant variables that are constant across time in a utility. However, the OLS estimate and first felm estimate are identical, so such omitted variables do not appear to be affecting my OLS results. Nonetheless, the treatment

effect standard error is smaller in the first felm model than the OLS model because utility fixed effects eliminate all time-invariant, between-utility variation. With a p-value less than 0.001, the utility fixed effects estimate provides very strong evidence against the null hypothesis.

The second fixed effects model also includes month fixed effects, removing any omitted variables bias from relevant variables that are constant in a month across all utilities. However, once again my estimates from this model are identical to my OLS and first felm model results, suggesting there are no relevant, unobserved utility-invariant variables confounding my OLS or utility fixed effects model results. Nonetheless, the standard error of my coefficient of interest is lowest in this model because adding time fixed effects captures all utility-invariant monthly variation. The R^2 and adjusted R^2 are also highest in this model; in eliminating certain variability, the fixed effects improved the model fit.

My statistically significant estimate of β_3 across all my models suggests the CPUC's announced plans to enact major changes to net metering policy drove customers to adopt solar at higher rates; customers rushed to install solar systems while still eligible for NEM2. Month-over-month installation growth was 31% higher on average from March to December 2022 versus the pre-treatment period, indicating net metering policy influences a customer's decision to go solar.

In the following sections, I discuss whether this result is likely indicative of customers' reaction to the CPUC's final NEM3 proposal, and I discuss the implications of my findings for California's solar industry.

VII. Discussion

A. Treatment effect: Indicative of customers' likely reaction to the CPUC's final enacted policy?

The treatment effect I estimate in this paper captures customers' reaction to the CPUC's first NEM3 proposal, not the CPUC's final, enacted decision. Given both the CPUC's NEM3 decisions proposed adopting an ACC-based export rate, my treatment effect may accurately estimate customers' reaction to the CPUC's final, enacted decision; with a roughly 80% reduction in export credits, both proposed policies provided a similarly large incentive to install and grandfather a solar system into a NEM2 program. Nonetheless, there are reasons to suspect my estimated treatment effect could underestimate or overestimate customers' reaction to the CPUC's final decision, each of which I explore below.

1. Underestimate

In September 2021, it was still unknown when the CPUC would release an updated NEM3 decision and formally begin the sunset period for installing a system under NEM2. With this initial NEM3 implementation uncertainty, customers may have felt less rushed to install a solar system during the treatment period I evaluate in my paper versus from January to April 2023. If this is the case, the treatment effect I derived may underestimate the full, later impact of the CPUC's planned changes to net metering policy on monthly solar installations.

This is not to say IOU customers going solar throughout my treatment period were likely unaffected by proposed NEM3 changes. While the CPUC did not announce a specific date that NEM3 would go into effect until November 2022, their publications and other media releases made their intentions to fulfill their outstanding statutory requirements and quickly implement a significantly altered net metering policy clear. Additionally, despite the absence of a decided sunset date, third-party media releases and advertisements still urged customers throughout the treatment period to "go solar before it's too late."[142] Nonetheless, IOU customers likely felt less compelled to install a solar system during my treatment period than they did between January and April 15, 2023.

142 SunPower. "SunPower - Act Now before Solar Savings in California Drop." go.sunpower.com. Accessed March 18, 2023. https://go.sunpower.com/net-metering-deadline/.

2. Overestimate

Conversely, the CPUC's first proposed NEM3 decision was less financially attractive than its enacted policy. Therefore, the CPUC's first NEM decision may have motivated customers to install solar systems more than the CPUC's final decision did. If this is the case, the treatment effect I found is an overestimate of the full, later impact of the CPUC's planned changes to net metering policy on monthly solar installations.

However, as I touch upon in my methodologies section, both versions of NEM3 proposed switching to a significantly reduced export compensation rate, delivering a similar, major incentive to interconnect a system under NEM2 while able. Additionally, average customers are unlikely to have read through the CPUC's hundred-page decisions; they were probably reacting to media and advertisements instead, which were similar from December 2021 until April 2023.

B. Installations after April 15: The death of California solar?

Regardless of the policy specificities customers were or were nott aware of, my regression estimates capture customers' response to major announced changes to net metering policy. This response was notable—a 0.391 percentage point increase in month-over-month installation growth—and significant at the 0.1% significance level. NEM policy does, at least partially, appear to drive a customer's decision to install solar.

Given this result, the end of retail rate net metering is likely to have a negative impact on solar installation levels across California. This is consistent with the studies included in my literature review, which examined or predicted the impact of weakening or removing net metering programs on solar installation levels. It is also the prediction of solar adoption experts who have considered the economic specificities of NEM2 and NEM3.[143]

However, it's equally unlikely that the transition to NEM3 will be the "death of California solar," as some solar activists have claimed.[144] The ACC+ Adder was designed to minimize any sudden contraction of the solar industry and provides an incentive to go solar now versus later when the adder rate drops. Additionally, with the first-year adder rate, the payback period of a system under NEM3 should be nine years, which is one year less than the supposed ten-year tipping point where customers are less inclined to purchase a solar system.[145] Net metering is also only one of many reasons customers choose to go solar; rising electricity prices, advertising, social networks, other economic benefits such as the investment tax credit, desire for energy independence, and environmental benefits, among other factors, all influence customers' decision to go solar.[146, 147, 148, 149] Full retail rate net metering is set to end in April 2023, but these incentives will remain.

It will take time for solar installation levels to recover to NEM2 levels. However, analysts expect a full recovery after a few years,[150] which is consistent with major changes to net metering made in other states, e.g.

143 Davis et al. "US Solar Market Insight Executive Summary." 2.

144 Schulze, William. "California Utilities' Brazen Plan to Kill Rooftop Solar." Utility Dive. Last modified February 1, 2022. Accessed April 6, 2023. https://www.utilitydive.com/news/california-utilities-brazen-plan-to-kill-rooftop-solar/617781/.

145 Lebbon et al. "New NEM 3.0 Provisions 'Will Cut California Solar Market in Half by 2024.'"

146 Alipour, Mohammad, Elnaz Irannezhad, Rodney A. Stewart, and Oz Sahin. "Exploring Residential Solar PV and Battery Energy Storage Adoption Motivations and Barriers in a Mature PV Market." Renewable Energy 190 (March 2022). https://doi.org/10.1016/j.renene.2022.03.040.

147 Rai, Varun, and Scott A. Robinson. "Agent-based Modeling of Energy Technology Adoption: Empirical Integration of Social, Behavioral, Economic, and Environmental Factors." Environmental Modelling & Software 70 (2015): 163-77. https://doi.org/10.1016/j.envsoft.2015.04.014.

148 Schelly, Chelsea. "Residential Solar Electricity Adoption: What Motivates, and What Matters? A Case Study of Early Adopters." Energy Research & Social Science 2 (2014): 183-91. https://doi.org/10.1016/j.erss.2014.01.001.

149 Sigrin, Ben, and Easan Drury. "Diffusion into New Markets: Economic Returns Required by Households to Adopt Rooftop Photovoltaics." N.p.: National Renewable Energy Laboratory, 2014.

150 Davis et al. "US Solar Market Insight Executive Summary." 2.

those enacted by the Hawaiian Electric Company (HECO) in 2015.[151, 152] Additionally, the costs of solar systems should continue to drop,[153] and electricity prices are projected to rise,[154] strengthening some financial incentives to go solar. The impacts of NEM3 on California solar installations will likely be notable yet temporary.

VIII. Conclusion

Since 1995, net metering policy has provided a constant incentive for IOU customers to go solar: the ability to zero out one's electricity bill with a properly sized solar system. These monthly energy savings have reduced solar system payback periods and made rooftop solar a viable investment for many.[155] However, this changed in April 2023 when the California Public Utilities Commission made a significant structural change to net metering policy, aligning energy export compensation rates with the avoided cost of energy.

Implementing NEM3 is expected to eventually result in a roughly 80% reduction in exported energy credit rates, which provided a major incentive to install a solar system before the April 14, 2023 deadline to grandfather a solar system into full retail rate net metering. As expected, installation trends appear to reflect this incentive; month-over-month installation growth increased a statistically significant 31% after the CPUC announced its new net metering policy plans in December 2021. This highlights customers' responsiveness to changes in net metering policy and likely precedes a reduction in installations over the next few years.

Future analyses could examine the impact of NEM3 implementation on solar installation levels. Such work has the potential to better elucidate the role of net metering in incentivizing solar adoption and could therefore help inform renewable energy technology adoption pathways. In 2022, 46 US states and DC took 285 solar policy actions, including 94 actions to alter distributed solar compensation policies.[156] Up-to-date studies may guide local and state governments in designing policies that are both financially sustainable and successful at promoting green technology adoption. The most recent IPCC synthesis report emphasizes the need to reduce emissions by 48% from 2019 levels by 2030 and 80% by 2040; supporting effective government climate action is of utmost and vital importance (IPCC 2012, 17).[157]

IX. Acknowledgments

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151 North Carolina Clean Energy Technology Center, ed. "A Review of Net Metering Reforms across Select U.S. Jurisdictions." California Public Utilities Commission, 2021. https://docs.cpuc.ca.gov/PublishedDocs/SupDoc/R2008020/3766/388397206.pdf. B-39.

152 Hawaiian Electric. "Quarterly Installed Solar Data." www.hawaiianelectric.com. Accessed April 6, 2023. https://www.hawaiianelectric.com/clean-energy-hawaii/our-clean-energy-portfolio/quarterly-installed-solar-data.

153 Chopra, Sagar. "Is the End of High US Solar System Prices in Sight?" Wood Mackenzie. Last modified April 13, 2022. Accessed April 6, 2023. https://www.woodmac.com/news/opinion/is-the-end-of-high-us-solar-system-prices-in-sight/.

154 Sieren-Smith, Bridget, Ankit Jain, Alireza Eshraghi, Simon Hurd, Julia Ende, Josh Honeycutt, and Andrew Ngo. "Utility Costs and Affordability of the Grid of the Future: An Evaluation of Electric Costs, Rates, and Equity Issues Pursuant to P.U. Code Section 913.1." California Public Utilities Commission, 2021. https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/energy-division/documents/en-banc/senate-bill-695-report-2021_en-banc-white-paper.pdf.

155 Lebbon et al. "New NEM 3.0 Provisions 'Will Cut California Solar Market in Half by 2024.'"

156 Apadula, Emily, Rebekah de la Mora, Justin Lindemann, Brian Lips, Vincent Potter, Autum Proudlove, and David Sarkisian. "50 States of Solar." NC Clean Energy Technology Center, 2023. https://static1.squarespace.com/static/5ac5143f9d5abb8923a86849/t/63d0a290fdbf465f8025d892/1674617494610/Q4-22-Solar-Exec-Summary-Final.pdf. 5.

157 IPCC. (2022). Summary for Policymakers. "In Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change" [P.R. Shukla, J. Skea, R. Slade, A. Al Khourdajie, R. van Diemen, D. McCollum, M. Pathak, S. Some, P. Vyas, R. Fradera, M. Belkacemi, A. Hasija, G. Lisboa, S. Luz, J. Malley, (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA. https://doi.org/10.1017/9781009157926.001. 17.

X. Bibliography

"An act to add Chapter 7.5 (commencing with Section 2830) to Part 2 of Division 1 of the Public Utilities Code, relating to energy." A. 2466, 2008 Leg. (Cal. 2008). http://www.leginfo.ca.gov/pub/07-08/bill/asm/ab_2451-2500/ab_2466_bill_20080928_chaptered.pdf.

"An act to add Section 2827 to the Public Utilities Code, relating to public utilities." S. 656, 1995 Leg. (Cal. Aug. 4, 1995). http://www.leginfo.ca.gov/pub/95-96/bill/sen/sb_0651-0700/sb_656_bill_950804_chaptered.html.

"An act to amend Sections 2827 and 2827.10 of the Public Utilities Code, relating to energy." S. 594, 2012 Leg. (Cal. Sept. 27, 2012). https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201120120SB594.

Alipour, Mohammad, Elnaz Irannezhad, Rodney A. Stewart, and Oz Sahin. "Exploring Residential Solar PV and Battery Energy Storage Adoption Motivations and Barriers in a Mature PV Market." Renewable Energy 190 (March 2022). https://doi.org/10.1016/j.renene.2022.03.040.

Apadula, Emily, Rebekah de la Mora, Justin Lindemann, Brian Lips, Vincent Potter, Autum Proudlove, and David Sarkisian. 50 States of Solar. NC Clean Energy Technology Center, 2023. https://static1.squarespace.com/static/5ac5143f9d5abb8923a86849/t/63d0a290fdbf465f8025d892/1674617494610/Q4-22-Solar-Exec-Summary-Final.pdf.

Barbose, Galen, John Miller, Ben Sigrin, Emerson Reiter, Karlynn Cory, Joyce McLaren, Joachim Seel, Andrew Mills, Naïm Darghouth, and Andrew Satchwell. (2016). On the Path to SunShot: Utility Regulatory and Business Model Reforms for Addressing the Financial Impacts of Distributed Solar on Utilities (NREL/TP-6A20-65670). National Renewable Energy Laboratory. http://www.nrel.gov/docs/fy16osti/65670.pdf.

Bill Analysis: Hearings on SB 594 Before the Assembly Committee on utilities and Commerce, 2012 Leg. (Cal. June 25, 2012) (statement of Steven Bradford). http://www.leginfo.ca.gov/pub/11-12/bill/sen/sb_0551-0600/sb_594_cfa_20120622_170511_asm_comm.html.

California Energy Commission. "Electric Load Serving Entities (IOU and Pou)." California State GeoPortal. Last modified December 16, 2021. https://gis.data.ca.gov/maps/CAEnergy::electric-load-serving-entities-iou-pou.

———. "Eligibility Criteria and Conditions for Solar Energy System Incentives - SB 1." California Energy Commission. Accessed March 13, 2023. https://www.energy.ca.gov/programs-and-topics/programs/new-solar-homes-partnership-program-nshp/eligibility-criteria-and.

Cal. Pub. Util. Code § 2827 (State of California 2019).

California Public Utilities Commission. D.16-01-044: Decision Adopting Successor to Net Energy Metering Tariff. Rulemaking 14-07-002. California Public Utilities Commission, 2016. https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M158/K181/158181678.pdf.

———. Decision Adopting Net Energy Metering Consumer Protection Measures including Solar Information Packet. California Public Utilities Commission, 2018. https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M230/K892/230892616.PDF.

———. Decision Revising Net Energy Metering Tariff and Subtariffs. California Public Utilities Commission, 2022c. https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M500/K043/500043682.PDF.

———. "Electric Rates." www.cpuc.ca.gov. Accessed March 21, 2023. https://www.cpuc.ca.gov/industries-and-topics/electrical-energy/electric-rates.

———. "Fact Sheet: Modernizing NEM to Meet California's Reliability and Climate Goals CPUC Issues Decision to Update the Net Energy Metering (NEM) Tariff to Support the Modern Grid the Decision Promotes Solar and Battery Storage, Supports Grid Reliability, and Controls Electricity Costs for All

Californians," November 10, 2022. https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/energy-division/documents/net-energy-metering-nem/nemrevisit/final-december-2022-fact-sheet-nem.pdf.

———. "Net Billing Tariff." www.cpuc.ca.gov. Accessed March 24, 2023. https://www.cpuc.ca.gov/industries-and-topics/electrical-energy/demand-side-management/customer-generation/nem-revisit/net-billing-tariff.

———. "Customer-Sited Renewable Energy Generation." www.cpuc.ca.gov. Accessed March 19, 2023. https://www.cpuc.ca.gov/industries-and-topics/electrical-energy/demand-side-management/customer-generation.

———. "Net Energy Metering NEM 2 Evaluation." www.cpuc.ca.gov. Accessed March 23, 2023. https://www.cpuc.ca.gov/nem2evaluation.

———. "Net Energy Metering Rulemaking (R.)14-07-002." www.cpuc.ca.gov. Accessed March 19, 2023. https://www.cpuc.ca.gov/industries-and-topics/electrical-energy/demand-side-management/customer-generation/net-energy-metering-rulemaking-r-14-07-002.

———. Order Extending Statutory Deadline. California Public Utilities Commission, 2022b. https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M496/K643/496643309.PDF.

———. Order Instituting Rulemaking to Develop a Successor to Existing Net Energy Metering Tariffs Pursuant to Public Utilities Code Section 2827.1, and to Address Other Issues Related to Net Energy Metering. R. 14-07-002. California Public Utilities Commission, 2014. https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M098/K303/98303355.PDF.

———. Order Instituting Rulemaking to Revisit Net Energy Metering Tariffs Pursuant to Decision D.16-01-044, and to Address Other Issues Related to Net Energy Metering. R. 20-08-020. California Public Utilities Commission, 2020. https://www.cpuc.ca.gov/nemrevisit.

———. Proposed Decision Revising Net Energy Metering Tariff and Subtariffs. California Public Utilities Commission, 2021. https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M430/K903/430903088.PDF.

———. Public Agenda 3501. California Public Utilities Commission, 2022a. https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M441/K154/441154267.pdf.

———. "R2008020 - Rulings." https://apps.cpuc.ca.gov/. Accessed March 23, 2023. https://apps.cpuc.ca.gov/apex/f?p=401:57::::::

Chabé-Ferret, Sylvain. To Control or Not to Control? Bias of Simple Matching vs Difference-In- Difference Matching in a Dynamic Framework. Yale University, 2010. https://www.researchgate.net/publication/228799034.

Chediak, Mark. "Musk, Movie Stars Join Fight to Protect California Solar Subsidy." Bloomberg. Last modified January 12, 2022. Accessed March 18, 2023. https://www.bloomberg.com/news/articles/2022-01-12/musk-ruffalo-walton-line-up-to-oppose-california-solar-plan#xj4y7vzkg?leadSource=uverify%20wall.

Chopra, Sagar. "Is the End of High US Solar System Prices in Sight?" Wood Mackenzie. Last modified April 13, 2022. Accessed April 6, 2023. https://www.woodmac.com/news/opinion/is-the-end-of-high-us-solar-system-prices-in-sight/.

Darghouth, Naïm, Galen Barbose, Ryan Wiser, and Andrew Mills. Net Metering and Market Feedback Loops: Exploring the Impact of Retail Rate Design on Distributed PV Deployment. Ernest Orlando Lawrence Berkeley National Laboratory, 2015. https://eta-publications.lbl.gov/sites/default/files/lbnl-183185_0.pdf.

Davis, Michelle, Sylvia Martinez, Zoe Gaston, Caitlin Connelly, Matthew Sahd, Max Issokson, Elissa Pierce, Chris Seiple, Shawn Rumery, Colin Silver, Tyler Thomoson, and Justin Baca. US Solar Market Insight Executive Summary. Solar Market Insight Report 2022 year in review. 2023. https://storage.pardot.com/139231/16783127725ZK2dUon/USSMI_2022_YIR_ES.pdf.

Davis, Michelle, Colin Smith, Bryan White, Ravi Manghani, Xiaojing Sun, Molly Cox, Gregson Curtin, Shawn Rumery, Colin Silver, and Justin Baca. "Solar Market Insight Report 2020 Year in Review." Solar Energy Industries Association. Last modified March 16, 2021. Accessed March 22, 2023. http://Solar Market Insight Report 2020 Year in Review.

Dong, Changgui, Benjamin Sigrin, and Gregory Brinkman. "Forecasting Residential Solar Photovoltaic Deployment in California." Technological Forecasting and Social Change 117 (2017): 251-65. https://doi.org/10.1016/j.techfore.2016.11.021.

Drury, Easan, Paul Denholm, and Robert Margolis. "Modeling the U.S. Rooftop Photovoltaics Market." 2010.

Dutzik, Tony, Bryn Huxley-Reicher, Laura Deehan, and Bronte Payne. Rooftop Solar at Risk: Cuts to Net Metering Could Threaten California's Clean Energy Progress. Environment California, 2021. https://publicinterestnetwork.org/wp-content/uploads/2021/07/Rooftop-Solar-at-risk-final.pdf.

Dyreson, Ana, Chris Hoffman, Aaron Pritchard, and Amanda Schienebeck. Effects of Salt River Project's Demand- Based Rate Change on the Rooftop Solar Market in Maricopa County, Arizona. UW-Madison, 2017. https://emp.lbl.gov/sites/default/files/uwisconsin-srp_solar_event_study_final051117.pdf.

Energy and Environmental Economics (E3). Introduction to the Net Energy Metering Cost Effectiveness Evaluation. N.p.: California Public Utilities Commission, 2010.

———. 2022 Distributed Energy Resources Avoided Cost Calculator Documentation. N.p., 2022.

———. 2020 Distributed Energy Resources Avoided Cost Calculator Documentation. N.p., 2020.

Energy Markets & Policy. "Tracking the Sun Tool." https://emp.lbl.gov, 2022. https://emp.lbl.gov/tracking-sun-tool.

EnergySage. "2023 Los Angeles Department of Water and Power (LADWP) Net Metering." EnergySage. Accessed March 21, 2023. https://www.energysage.com/local-data/net-metering/ladwp/.

Energy Solutions. "Data Key." California Distributed Generation Statistics. Last modified January 31, 2023. Accessed March 21, 2023. https://www.californiadgstats.ca.gov/downloads/.

———, ed. "Download Data." California Distributed Generation Statistics. Last modified December 2022. Accessed December 2, 2022. https://www.californiadgstats.ca.gov/downloads/.

Esfahani, Asal, Cherie Chan, Christopher Westling, Erica Petrofsky, Joshu Litwin, Narissa Jimenez-Petchumrus, and Tory Francisco. 2021 California Solar Initiative Annual Program Assessment. California Solar Initiative Annual Program Assessment june 2021. California Public Utilities Commission, 2021. https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/energy-division/documents/csi-progress-reports/2021-csi-apa.pdf.

ESRI, and U.S. Census Bureau. "Popular Demographics in the United States (2018)." ArcGIS Online. Last modified January 30, 2022. Accessed March 21, 2023. https://services.arcgis.com/P3ePLMYs2RVChkJx/arcgis/rest/services/AGOL_Base_2018_Final/FeatureServer.

Feinstein, Dianne. "Feinstein Urges Changes to Proposed CPUC Solar Energy Policy." News release. January 25, 2022. https://www.feinstein.senate.gov/public/index.cfm/press-releases?ID=31B23E67-A4BC-41A0-8DDD-42E2F72CE765.

Gong, Andrew, Christian Brown, and Samuel Adeyemo. The Financial Impact of California's Net Energy Metering 2.0 Policy: Examining the Effects of Non-Bypassable Charges with Load Profiles and Systems Designed in Aurora. 2017. http://www2.greentechmedia.com/l/264512/2017-07-18/2lfcg.

Hallock, Lindsey, and Michelle Kinman. California's Solar Success Story How the Million Solar Roofs Initiative Transformed the State's Solar Energy Landscape. 2015. Accessed December 2, 2022. https://environmentamerica.org/california/wp-content/uploads/2015/07/CA_Solar_Success_scrn_FINAL_7-7-2015.pdf.

Hawaiian Electric. “Quarterly Installed Solar Data.” www.hawaiianelectric.com. Accessed April 6, 2023. https://www.hawaiianelectric.com/clean-energy-hawaii/our-clean-energy-portfolio/quarterly-installed-solar-data.

“Hearings on SB 489 Before the Assembly Committee on Natural Resources.” 2011 Leg. (Cal. July 6, 2011).

Heavner, Brad, Julia Kantor, and Tim Lindl. “California Solar and Storage Association’s Proposal for a Successor to the Current Net Energy Metering Tariff.” Paper presented at Rulemaking 20-08-020, San Francisco, CA. https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M371/K904/371904829.PDF.

IPCC. (2022). Summary for Policymakers. In Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [P.R. Shukla, J. Skea, R. Slade, A. Al Khourdajie, R. van Diemen, D. McCollum, M. Pathak, S. Some, P. Vyas, R. Fradera, M. Belkacemi, A. Hasija, G. Lisboa, S. Luz, J. Malley, (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA. https://doi.org/10.1017/9781009157926.001

Itron. Net Energy Metering Evaluation Draft Research Plan. 2020. https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/energy-division/documents/net-energy-metering-nem/nem-evaluation/nem-20-evaluation-draft-research-plan.pdf.

Itron, Energy and Environmental Economics, and Verdant Associates. Net Energy Metering 2.0 Lookback Study. N.p., 2021.

Kennedy, Ryan. “California Set to Release Anti-rooftop Solar Net Metering Plan.” PV Magazine. Last modified November 4, 2022. Accessed March 25, 2023. https://pv-magazine-usa.com/2022/11/04/california-set-to-release-anti-rooftop-solar-net-metering-plan/.

———. “Survey Says 95% of Shoppers Would Not Buy Solar under NEM 3.0.” PV Magazine. Last modified January 13, 2022. Accessed March 24, 2023. https://pv-magazine-usa.com/2022/01/13/survey-says-95-of-shoppers-would-not-buy-solar-under-nem-3-0/.

Ladisch, Mark, and Buck Hagood. 20 Years of Net Metering in California. Scott Madden Management Consultants, 2017. https://www.scottmadden.com/content/uploads/2017/05/ScottMadden_NEM_in_California_2017_0531.pdf.

Lane, Catherine. “How Long Does a Solar Panel Installation Take?” SolarReviews. Last modified June 8, 2022. Accessed March 22, 2023. https://www.solarreviews.com/blog/solar-panel-installation-process.

Lebbon, Vivien, Mark Thomton, Sonia Kerr, Alishia Markwell, and Kevin Baxter. “New NEM 3.0 Provisions ‘Will Cut California Solar Market in Half by 2024.’” Wood Mackenzie. Last modified January 25, 2022. Accessed March 19, 2023. https://www.woodmac.com/press-releases/nem-3.0-pd-will-cut-california-solar-market-in-half-by-2024/.

Lewis, Michelle. “Elon Musk Says California Proposal to Cut Solar Incentives Is a ‘Bizarre Anti-environment Move.’” electric. Last modified January 12, 2022. Accessed March 18, 2023. https://electrek.co/2022/01/12/elon-musk-says-california-proposal-to-cut-solar-incentives-is-a-bizarre-anti-environment-move/.

Los Angeles Department of Water & Power. “EV / NEM / REO Rates | Los Angeles Department of Water and Power.” www.ladwp.com, September 1, 2008. https://www.ladwp.com/account/customer-service/electric-rates/ev-nem-reo-rates.

McCoy, Maria. “The State(s) of Distributed Solar — 2021 Update.” Institute for Local Self-Reliance, 2022. https://ilsr.org/the-states-of-distributed-solar/.

Misbrener, Kelsey. “New CPUC Proposed Decision on NEM 3.0 Expected by September 29.” Solar Power World. Last modified August 22, 2022. Accessed March 25, 2023. https://www.solarpowerworldonline.com/2022/08/cpuc-proposed-decision-on-nem-3-expected-by-sept-29/.

"Net Metering." Solar Consumer Advisor. Accessed August 25, 2022. https://www.solarconsumeradvisor.com/sce-net-metering.html.

Nikolewski, Rob. "Newsom: 'More Work to Be Done' on California Net Metering Solar Proposal." The San Diego Union-Tribune. Last modified January 11, 2022. Accessed March 18, 2023. https://www.sandiegouniontribune.com/business/story/2022-01-11/newsom-more-work-to-be-done-on-california-net-metering-solar-proposal.

North Carolina Clean Energy Technology Center, ed. A Review of Net Metering Reforms across Select U.S. Jurisdictions. California Public Utilities Commission, 2021. https://docs.cpuc.ca.gov/PublishedDocs/SupDoc/R2008020/3766/388397206.pdf.

Peevey, Michael. Proposed Decision of Commissioner Peevey. Rulemaking 10-05-004. California Public Utilities Commission, 2011.

Pacific Gas & Electric. "Net Energy Metering (NEM) Program." www.pge.com. Accessed March 20, 2023. https://www.pge.com/en/about/doing-business-with-pge/interconnections/net-energy-metering-program.html.

Rai, Varun, and Scott A. Robinson. "Agent-based Modeling of Energy Technology Adoption: Empirical Integration of Social, Behavioral, Economic, and Environmental Factors." Environmental Modelling & Software 70 (2015): 163-77. https://doi.org/10.1016/j.envsoft.2015.04.014.

Satchwell, Andrew J., Peter A. Cappers, and Galen L. Barbose. Energy Analysis and Environmental Impacts Division Lawrence Berkeley National Laboratory. Lawrence Berkeley National Laboratory, 2019. https://eta-publications.lbl.gov/sites/default/files/sein_rate_design_trends_report_final_doe_approved.pdf.

Save California Solar. "Organizations & Community Leaders in Support of Solar Net Metering.docx." Google Docs, January 17, 2022. https://docs.google.com/document/d/1eB85J3qRSeFn6dz5mPG_un34s7Q5IJ4c/edit.

———. "Save California Solar Launches Broadcast TV, Cable and Radio Ads Calling on CPUC and Governor Newsom to Reject Utility Profit Grab and Keep Rooftop Solar Growing and Affordable." PRNewswire. Last modified October 2021. Accessed March 19, 2023. https://www.prnewswire.com/news-releases/save-california-solar-launches-broadcast-tv-cable-and-radio-ads-calling-on-cpuc-and-governor-newsom-to-reject-utility-profit-grab-and-keep-rooftop-solar-growing-and-affordable-301410423.html.

Schelly, Chelsea. "Residential Solar Electricity Adoption: What Motivates, and What Matters? A Case Study of Early Adopters." Energy Research & Social Science 2 (2014): 183-91. https://doi.org/10.1016/j.erss.2014.01.001.

Schulze, William. "California Utilities' Brazen Plan to Kill Rooftop Solar." Utility Dive. Last modified February 1, 2022. Accessed April 6, 2023. https://www.utilitydive.com/news/california-utilities-brazen-plan-to-kill-rooftop-solar/617781/.

Schwarzenegger, Arnold. "Schwarzenegger: We Put Solar Panels on 1 Million Roofs in California. That Win Is Now under Threat." New York Times. Last modified January 17, 2022. Accessed March 19, 2023. https://www.nytimes.com/2022/01/17/opinion/schwarzenegger-solar-power-california.html.

Sieren-Smith, Bridget, Ankit Jain, Alireza Eshraghi, Simon Hurd, Julia Ende, Josh Honeycutt, and Andrew Ngo. Utility Costs and Affordability of the Grid of the Future: An Evaluation of Electric Costs, Rates, and Equity Issues Pursuant to P.U. Code Section 913.1. California Public Utilities Commission, 2021. https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/energy-division/documents/en-banc/senate-bill-695-report-2021_en-banc-white-paper.pdf.

Sigrin, Ben, and Easan Drury. Diffusion into New Markets: Economic Returns Required by Households to Adopt Rooftop Photovoltaics. N.p.: National Renewable Energy Laboratory, 2014.

Solar Energy Technologies Office. “Homeowner’s Guide to the Federal Tax Credit for Solar Photovoltaics.” US Department of Energy. Last modified March 2023. Accessed March 14, 2023. https://www.energy.gov/eere/solar/homeowners-guide-federal-tax-credit-solar-photovoltaics.

SolarReviews. “NEM 3.0 Survey,” 2021. https://www.solarreviews.com/content/images/blog/SolarReviews_CASurveyReport.pdf.

SunPower. “SunPower - Act Now before Solar Savings in California Drop.” go.sunpower.com. Accessed March 18, 2023. https://go.sunpower.com/net-metering-deadline/.

Thoubboron, Kerry. “NEM 3.0: What Does It Mean for You?” Energy Sage. Last modified January 17, 2023. Accessed March 14, 2023. https://news.energysage.com/net-metering-3-0/.

U.S. Census Bureau, “HI | Occupancy Status.” United States Census Bureau. Last modified 2020. https://data.census.gov/table?q=housing+units&g=0400000US06.

U.S. Energy Information Administration. “2021 Utility Bundled Retail Sales-Residential (Data from Forms EIA-861-Schedules 4A & 4D and EIA-861S).” Www.eia.gov, 2022. https://www.eia.gov/electricity/sales_revenue_price/pdf/table_6.pdf.

———. “Annual Electric Power Industry Report, Form EIA-861 Detailed Data Files.” www.eia.gov, March 1, 2023. https://www.eia.gov/electricity/data/eia861/.

———. “EIA - Electricity Data.” Eia.gov, 2023. https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=epmt_5_6_a.

———. “Form EIA-861M (Formerly EIA-826) Detailed Data.” www.eia.gov, March 1, 2023. https://www.eia.gov/electricity/data/eia861m/.

———. “FORM EIA-861M MONTHLY ELECTRIC POWER INDUSTRY REPORT INSTRUCTIONS,” n.d. https://www.eia.gov/survey/form/eia_861m/instructions.pdf.

Walker, Emily. “2021 Cost of Solar Panels in California | EnergySage.” www.energysage.com, March 15, 2023. https://www.energysage.com/local-data/solar-panel-cost/ca/.

Wigness, Sam. “LADWP Solar Incentive Program Ends Beginning of 2019.” Solar.com. Last modified November 3, 2022. Accessed March 21, 2023. https://www.solar.com/learn/ladwp-solar-incentive-program-ends-beginning-of-2019/.

Zhao, Jiayun, Esfandyar Mazhari, Nurcin Celik, and Young-jun Son. “Hybrid Agent-based Simulation for Policy Evaluation of Solar Power Generation Systems.” Simulation Modelling Practice and Theory 19, no. 10 (2011): 2189-205. https://doi.org/10.1016/j.simpat.2011.07.005.

Zientara, Ben. “LADWP Solar Programs, Incentives, and Net Metering.” SolarReviews. Last modified September 19, 2022. Accessed March 21, 2023. https://www.solarreviews.com/blog/going-solar-with-los-angeles-department-of-water-and-power.