TURN
THE UTILITY REFORM NETWORK

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Exhibit: TURN-01

PREPARED TESTIMONY OF

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TESTIMONY CONCERNING THE POLICY, COST IMPACTS AND COST RECOVERY OF SCE'S PROPOSED BUILDING ELECTRIFICATION PROGRAM

Submitted on Behalf of

THE UTILITY REFORM NETWORK

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1. INTRODUCTION AND SUMMARY OF RECOMMENDATIONS

1.1. Introduction

We are submitting this testimony on behalf of The Utility Reform Network (TURN), pursuant to the schedule established in the *Assigned Commissioner's Scoping Memo and Ruling* of April 27, 2022 (Scoping Memo), as modified by a Ruling issued on July 7, 2022 by Administrative Law Judge Scarlett Liang-Uejio. The testimony is sponsored by TURN staff Marcel Hawiger and Camille Stough, and by consultant to TURN Jalal Awan.

Marcel Hawiger has been a staff attorney with TURN since 1998, and has worked on numerous proceedings related to revenue requirements, rate design, electric and gas procurement and demand side management issues.

Camille Stough has been a staff attorney with TURN since 2020 and has been practicing before the Commission since 2016. Ms. Stough has worked on numerous proceedings related to revenue requirements, rate design, cost allocation, building decarbonization, and disadvantaged communities.

Jalal Awan is an electrical engineer and policy analyst at the RAND Corporation, pursuing his Ph.D. in policy analysis from the RAND Graduate School. Jalal has experience working on energy and climate policy issues at the state and federal levels, using both quantitative and qualitative methods.

Our statements of qualifications are included in Attachments 1-3.

As instructed in the Scoping Memo, this testimony is organized to be consistent with the questions posed in the Scoping Memo, and major headings identify the number of the question as presented in the Scoping Memo.[1]

[1] Scoping Memo, pp. 3-4, 8.

1.2. Summary of Recommendations

1.2.1. Program Authorization

TURN regretfully recommends that the Commission reject SCE's proposed subsidy program.

SCE has provided little analysis demonstrating that this subsidy program is necessary to promote market transformation, or that it would "rapidly accelerate the adoption of electric heat pumps in an equitable manner."[2] It is certainly not sufficient. It is our opinion that a massive transformation of the space and water heating appliance replacement market will require significant action either by the building industry, the appliance industry, and/or state agencies. A stand-alone utility program that targets 250,000 households will not actually "transform the market," but rather will subsidize wealthier early adopters to install electric appliances. Those individuals will benefit from subsidized appliances, but at the expense of all other ratepayers who will see their electric rates increase. The increase in electric rates will contribute to the unaffordability crisis in California and may discourage short-term electrification efforts. These issues are addressed in Section 2.4.

The "utility program" approach continues the "reverse Robin Hood" style of using regressive utility bill taxation to subsidize equipment and attempt a major market transformation, this time in the building and appliance industry. SCE claims that all electric ratepayers will benefit because increased electric sales will drive down future electric rates. We show that SCE's analysis is entirely incorrect, as it inappropriately ignores near-term rate increases. A proper analysis of the rate impacts of project costs versus the benefits of increased sales shows that over the 2024-2038 time period, rate payers will pay at least $125 million more (discounting at 3%), and more likely about $300 million more (adjusting for free ridership), on their utility bills. This issue is addressed in Section 2.1.

1.2.2. Program Design

If the Commission does authorize some variant of SCE's proposal, which TURN does not support, TURN would recommend the following modifications:

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[2] SCE-01, p. 1, lines 18-19.

- The Commission should authorize a more limited equity program, targeted towards appliance replacements for income-qualifying customers.
- The Commission should require all program participants to enroll in a demand response program so that the heat pump appliances can provide the system-level benefits that derive only from controlled load responding to prices or system conditions.

1.2.3. Cost Recovery

If the Commission does authorize some variant of SCE's proposed program, TURN recommends the following modifications concerning cost recovery:

- The Commission should reject capitalization (regulatory asset treatment) of in-home wiring and panel upgrade work. Such work will not be owned or controlled by the utility and should thus be expensed. SCE's claim that regulatory asset treatment will "benefit" ratepayers by avoiding near-term rate spikes is specious, as ratepayers will pay approximately $290 million (nominal) more over the project lifetime with the regulatory asset accounting, primarily by collecting profits and debt interest to the benefit of SCE's shareholders. The Commission could ameliorate near-term impacts of expensing by amortizing the costs over three to five years. This is addressed in Section 5.1.
- The Commission should reject SCE's attempt to evade reasonableness review by requesting that all costs up to 110% of authorized be deemed reasonable. Only the 100% of authorized costs found to be reasonable can be justified, and SCE must demonstrate the reasonableness of any costs above the reasonableness threshold. This is addressed in Section 5.2.1.
- The Commission should adopt a unit cost reasonableness threshold the utility-side electrical work associated with the program. This is addressed in Section 0.

2. PROGRAM REASONABLENESS (Question I.A)

The Scoping Memo poses the question of "[w]hether SCE's proposed Building Electrification programs are reasonable, including but not limited to program goals, design, costs, benefits, funding sources, and implementation." In the following Sections, TURN assesses the reasonableness of SCE's proposal from both a policy basis, as well as by analyzing the alleged benefits of the program for utility ratepayers. Regretfully, TURN concludes that the program is not a reasonable use of ratepayer funds.

From an analytical perspective, TURN finds that the "costs" of the program deployment significantly outweigh the "benefits" due to increased revenues, and thus result in a net negative impact on utility rates. (Section 2.1)

From a policy perspective, SCE's program is a "market-based" incentive mechanism that will lead to random adoption of heat pump technologies by wealthier early adopters. Funding electrification through regressive taxation will not transform the market, but will contribute to California's affordability crisis, and may actually impair voluntary electrification. (Section 2.4) Since such an outcome does nothing to promote the type of "managed electrification" being discussed in R.20-01-007, it will also contribute to rising utility gas rates.

2.1. SCE's Program Results in Negative Outcomes for Electric Ratepayers, and SCE's Rate Impact Analyses are Erroneous (Awan, Hawiger)

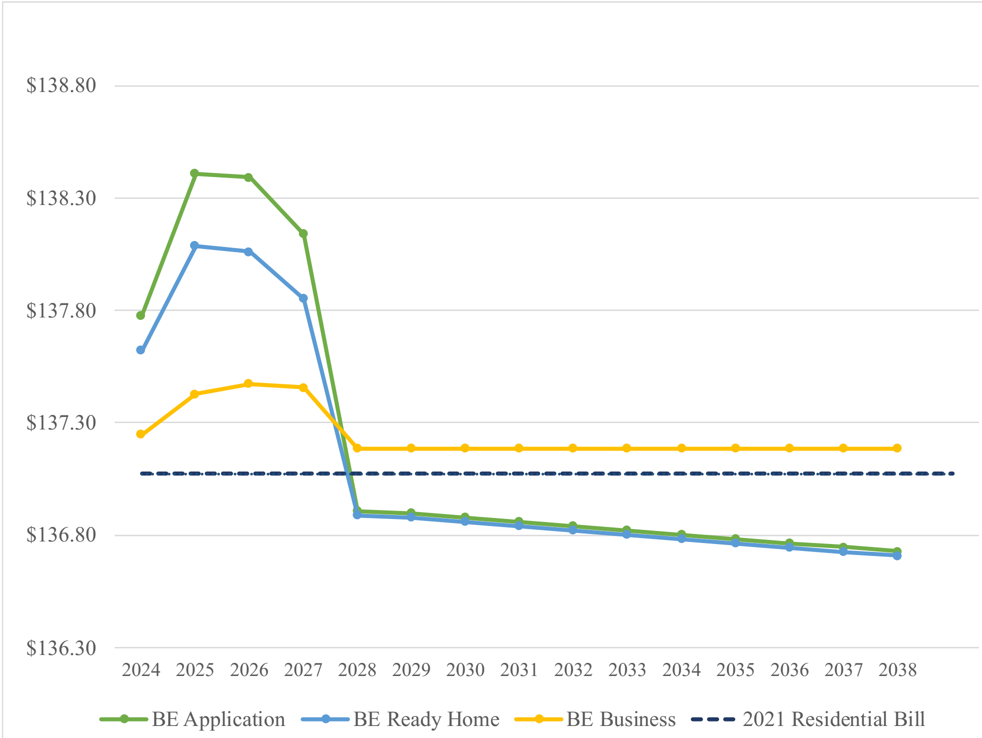
2.1.1. SCE's Rate Impact Analysis Is Flawed and Incorrect

SCE claims that the program will "provide real and lasting rate reduction benefits for customers" because the incremental load due to subsidized electric appliances will ultimately reduce utility rates.[3] SCE calculates the rate impact by dividing the annual revenue requirements associated with program costs by the "incremental electric sales" due to the electric appliances installed by the program, and shows the resulting annual electric rates.[4] SCE's fundamental contention is that the additional electric load resulting from the program will offset program costs so as to reduce rates starting in 2028, **after** the initial four years of program implementation (2024-2027), as illustrated in SCE's Figure I-2, reproduced below.

[3] FN Ex. SCE-03, p. 8, lines 5-6 and pp. 8-12.

[4] FN Ex. SCE-03, Figures I-1, I-2 and I-3.

Figure 1: SCE's Example of Rate Impacts Due to Building Electrification[5]



TURN agrees that the adoption of electric heat pump appliances to replace gas-fired appliances will increase electric consumption and could be a win for utility electric customers, potentially ameliorating the inordinate increase in utility electric rates we have seen in recent years. SCE is absolutely correct that if its customers adopted electric heat pump appliances as an alternative to gas appliances based on market economics, state of federal subsidies, and/or statutory requirements, then electric rates would go down and everyone would benefit. This is in fact exactly the scenario TURN would support. However, if electric ratepayers have to subsidize building electrification as proposed by SCE, then any resulting benefits to ratepayers would occur only if the amount of incremental revenues due to increased sales offsets the costs paid by ratepayers.

However, SCE's analysis is incomplete and incorrect, as one cannot in isolation consider future annual rate decreases without comparing them to current rate increases. The analysis should be

[5] Reproduction of SCE's Figure I-2, Ex. SCE-03, p. 11.

done over the entire term that appliances produce electricity and ratepayers pay for program costs. In its testimony, SCE presents results for the time period 2024-2038, based on the fifteen-year useful life of major appliances. However, SCE will continue to recover program costs in revenue requirements through 2052, due to the longer depreciable lives of distribution and in-home electrical upgrades and installations. Furthermore, an analysis of the impacts of streams of revenue requirements and incremental revenues over many years should be done on a net present value basis, not an "annual basis."

SCE's analysis includes other potential flaws:

- It does not appear that SCE included the future costs of power that will be necessary to serve the incremental load as an additional cost of the program (or a reduction in the future benefits of the program). Some of the "incremental revenues" will be required to purchase the additional electricity that will be consumed by increased load.
- SCE attributes increased electricity use from all incentivized appliances to the program without accounting for free ridership, which could be substantial. The incremental sales should be reduced based on a reasonable net-to-gross ratio (NTGR).

In the following sections, TURN corrects SCE's presentation, and finds that ratepayers will pay about $300 million more in revenue requirements than incremental sales revenues over the 2023-2038 time period when properly accounting for marginal generation costs and free ridership impacts, even when conservatively ignoring all of the additional revenue requirements ratepayers will pay in 2039-2052.

2.1.2. A Correct Analysis of Rate Impacts Over the Life of the Program Shows that the Program Will Harm Ratepayers

TURN first compared the nominal value of revenue requirements from 2024-2038[6] to the nominal value of incremental revenues from additional sales from 2024-2038.[7] TURN reduced

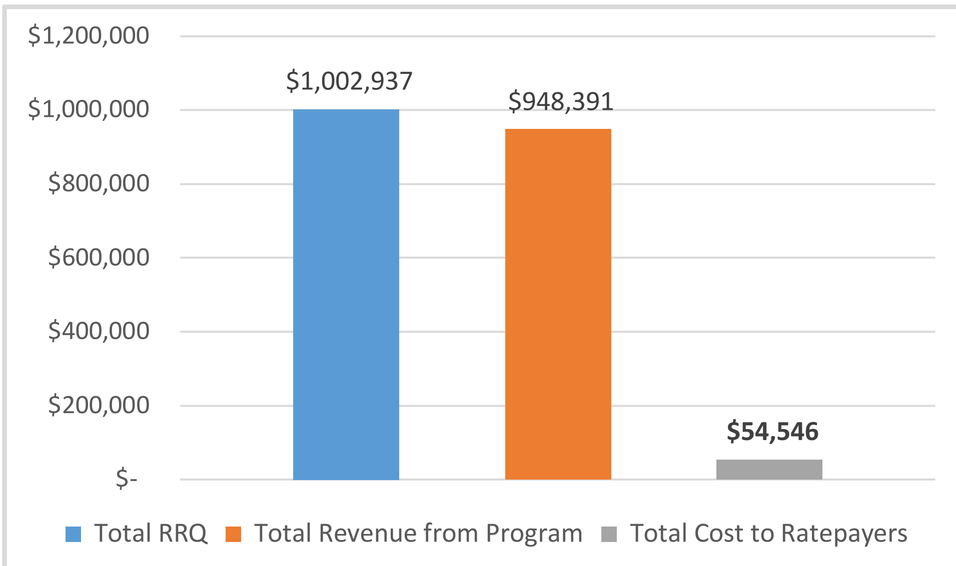
[6] Refer to "BEWP SCE-03 1.F Sheriff Rev Req by Program and Reg Asset," tab "SOE BE App Total." These are the costs using SCE's regulatory asset proposal. TURN will work with SCE to ensure relevant work papers are admitted into the record.

[7] Refer to "BEWP SCE-03 1.E.1-3 Sheriff Rate Impacts" and underlying data in the "CONFIDENTIAL A. 21-12-009 SCE BE Application Rate Design Model 2022 TURN-SCE-01." SCE used a confidential model to support calculations of rate impacts in the work papers. See, TURN DR 001-14. TURN will work with SCE to ensure any relevant work sheets are admitted into the record.

the incremental revenues by the cost of electricity that SCE would have to purchase in order to serve the incremental load (marginal generation costs).[8] TURN conservatively approximated the marginal generation costs by assuming they comprise 25% of the revenues generated by sales, based on data concerning SCE's generation rate component and generation revenue requirement.[9]

The net result of the program for the 2024-2038 time period[10] is that ratepayers will pay $54.5 million more in rates for the program, as illustrated below.

Figure 2: SCE's Program Increases Rates Over the 2024-2038 Time Period, Even Without Considering All Revenue Requirements (Nominal)



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[8] TURN's analysis includes only marginal generation costs, and assumes there are no marginal distribution costs, meaning SCE will not need to upgrade transformers or substation banks due to increased load. Such an assumption is conservative (i.e. good for SCE), since there will likely be some marginal distribution costs.

[9] SCE Responses to TURN-SCE-002-04, 06 and 07. See Attachment 4. SCE's generation rate and generation revenue requirements are approximately 30-40% of its total system average rate and revenue requirement. However, the generation rate includes some non-marginal components. TURN conservatively used 25% of total revenues as a proxy for marginal generation costs.

[10] SCE used the 2024-2038 time period apparently due to the expected fifteen-year useful life of the appliances installed by the customer. This time period ignores, however, that revenue requirements will be collected until 2052.

However, in reality SCE will continue to recover costs through 2052, due to the longer life of electrical upgrades and distribution system upgrades which are capitalized. In all, SCE will collect over $1.214 billion in revenue requirements on a nominal basis from 2024-2052, of which approximately $74 million is for debt service and about $206 million is for shareholder profit. TURN conservatively used SCE's 2024-2038 time period, thus ignoring the $211.109 million (nominal) in revenue requirements which will actually be collected from ratepayers between 2039 and 2052. The net cost to ratepayers on a nominal basis would thus more accurately be calculated as $265.655 million.

A proper analysis of future streams of costs and benefits should, however, be performed on a net present value basis. TURN compared the net present value of revenue requirements from 2024-2038 to the net present value of incremental revenues due to additional sales from 2024-2038. When properly discounted using either the utility's weighted average cost of capital of 7.68% or a societal discount rate of 3%, the outcome is even worse for ratepayers. On a net-present value basis, the total revenue requirements exceed the total additional revenues from the program (minus marginal generation costs) by between $125.2 million (at 3%) and $183.2 million (at 7.68%), as detailed in the Tables below.[11]

Table 1: SCE's Program Increases Rates on a Net Present Value Basis (at discount rate = 7.68%)

NPV Calculations	
NPV of Program Cost	$680,902.04
NPV of Incremental Revenue	$663,548.74
NPV of Marginal Costs	$165,887.19
NPV of Program Revenue	$497,661.56
NPV of Ratepayer Costs	$183,240.48

[11] The net present value analyses conservatively ignore the revenue requirements for 2039-2052. The net present value of the $211 million in revenue requirements for 2039-2052 is $49.7 million (at 7.68%) or $117.7 million (at 3%). These could be added to the "NPV of Program Cost" to more accurately reflect the actual cost of the program to ratepayers.

Table 2: SCE's Program Increases Rates on a Net Present Value Basis (at discount rate = 3%)

NPV Calculations	
NPV of Program Cost	$851,054.60
NPV of Incremental Revenue	$967,759.05
NPV of Marginal Costs	$241,939.76
NPV of Program Revenue	$725,819.29
NPV of Ratepayer Costs	$125,235.31

2.1.3. The Negative Impacts on Ratepayers Are Even Worse When Incremental Sales Are Properly Adjusted for Free Ridership

In the preceding analysis, TURN used SCE's actual forecast of incremental sales to calculate the incremental revenues due to additional appliance load. However, such an assumption overestimates the benefits of SCE's BE Program by ignoring the impact of free ridership.

At least some of the program participants will be free riders, meaning they would have installed the heat pump water heaters or heat pump HVAC systems even without the subsidies under SCE's program. Free ridership is measured during program evaluations and reported as the net-to-gross ratio (NTGR), meaning the ratio of load reductions (or increases in the case of fuel substitution) **directly caused** by the program to the total load reductions (or increases) resulting from all appliance sales. The total sales increase in the case of SCE's BE Program must be multiplied by the NTGR to properly calculate the incremental sales **caused** by the program spending.

A recent analysis of a "midstream" energy efficiency program for residential HVAC heat pumps, which provided incentives to equipment distributors, found that the NTGR for the ductless HVAC program was 0.40, and the NTGR for the central HVAC program was 0.57;[12] meaning that approximately 60% and 43% of the participants were free riders, and thus would have purchased the systems without the program incentives. While we understand that these results

[12] See, DNV, Impact Evaluation PY2020 HVAC Fuel Substitution, (CALMAC Study ID: CPU0338.01), May 20, 2022, pp. 5-6, 29-30

applied to a program targeting only HVAC technologies, a long history of Measurement, Evaluation and Verification (ME&V) studies demonstrates the existence of free riders, meaning that the NTGR is less than 1.0. Recent NTGRs for California midstream and downstream programs have ranged from about 0.6 to about 0.3.[13] A recent national evaluation of utility programs assumed an average NTGR of 0.83 based on self-reported utility data.[14]

In order to account for the reduced sales attributable to the program due to free ridership, TURN conservatively reduced the forecast sales figure by 25%, or a cumulative NTGR of 0.75. The result for the entire program is to proportionately increase net ratepayer costs as illustrated below:

Table 3: SCE's Program Hurts Ratepayers Even More When Incremental Sales Are Properly Adjusted for Free Ridership (at 7.68% discount rate)

NPV Calculations (with discount rate = 7.68% and NTGR=0.75)	
NPV of Program Cost	$680,902.04
NPV of Incremental Revenue	$497,661.56
NPV of Marginal Costs	$124,415.39
NPV of Program Revenue	$373,246.17
NPV of Ratepayer Costs	$307,655.87

Table 4: SCE's Program Hurts Ratepayers Even More When Incremental Sales Are Properly Adjusted for Free Ridership (at 3% discount rate)

NPV Calculations (with discount rate = 3 % and NTGR=0.75)	
NPV of Program Cost	$851,054.60
NPV of Incremental Revenue	$725,819.29
NPV of Marginal Costs	$181,454.82
NPV of Program Revenue	$544,364.46
NPV of Ratepayer Costs	$306,690.14

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[13] See, for example, CPUC, *Energy Efficiency Portfolio Report,* May 2018, p. 49.

[14] See, ACEEE, *2020 Utility Energy Efficiency Scorecard,* pp. 10, 115-117. We note that utility reported *ex ante* NTGRs have generally been higher than evaluated NTGRs.

Thus, it is more appropriate to conclude that on a net present value basis, SCE's electric ratepayers will be harmed by having to pay about $300 million more on their electric bills as a result of the proposed BE program.

2.1.4. Ratepayers Will Also Be Impacted by Higher Natural Gas Rates

The proposed Building Electrification program is a fuel substitution measure. The intended environmental benefits derive from reductions in natural gas combustion within residential and commercial buildings.

However, just as an increase in electric sales may reduce electric rates by spreading fixed costs over a larger volume, a decrease in gas sales will result in the opposite – increasing gas rates due to lower sales to cover fixed costs. It is precisely for this reason that the Commission is investigating methods to promote "managed electrification" in Track 2 of Rulemaking 20-01-007. A key goal is to develop policies and pilots so as to promote a managed transition that would electrify contiguous sections of the gas distribution system and allow for decommissioning of portions of the gas system concurrent with home electrification. Decommissioning portions of the distribution system would reduce costs associated with inspections, repairs and replacements of gas mains and services.

SCE's proposal does not attempt to implement a managed transition, but would partially electrify random homes based on voluntary customer participation. Individual homes are not completely electrified, and contiguous sections of the gas distribution system are not decommissioned.

If SCE is successful exactly as forecast in installing approximately 130,000 water heaters, 50,000 mini-split heat pumps, and 20,000 central HVAC systems, it would reduce gas consumption by approximately 5.25 million decatherms per year.[15] That amount represents approximately 2.34% of SoCalGas' annual residential gas consumption,[16] so that if successful, this pilot by itself would increase the gas utility's transportation rate (excluding the gas commodity) by some amount up to 2.34%. SCE has ignored this impact in any analysis of ratepayer costs and benefits.

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[15] See, BEWP.SCE-02.I.F.Carter Prescott_BE Application - Portfolio Benefits, Column P.

[16] SCE is an electric-only utility. For simplification, TURN assumes that all electrified customers are gas customers of Southern California Gas Company.

2.2. Forecast Participant Bill Savings Are Exaggerated and Will Flow to a Minority of Participants (Hawiger)

While the program as a whole will raise electric rates for all customers, SCE claims that it will reduce the bills of program participants and result in participant bill savings of $510 million over the lifetime of the equipment.[17] SCE's "analysis" relied in part on an E3 study concerning energy savings; however, SCE used only the annual bill savings from Climate Zone 10 as the basis for its calculations.[18]

Climate Zone 10 is a hot climate zone with about 900,000 customer accounts, out of a total of less than 1.5 million in SCE's hot climate zones.[19] While it has a relatively large population, it is not necessarily indicative of the impacts of HVAC installations in moderate or cool climate zones, where more than 2.8 million of SCE's customer accounts reside.[20] Using only CZ 10 for the analysis thus overestimates the average participant bill savings, since customers in moderate and cool climate zones will use less electricity and have smaller bill impacts.

Furthermore, SCE's analysis shows that for the program as a whole, about 83% of the alleged lifetime bill savings come from the installation of heat pump HVAC systems.[21] This is consistent with the findings in the E3 report, which concluded that homes with central air conditioning and heating would benefit from the installation of a central heat pump HVAC system, but found that the bill impacts of replacing just water heaters were much smaller and more variable.[22]

SCE's BE Home Ready program proposes to install about 130,000 heat pump water heaters, almost 50,000 ductless mini-split systems, and about 20,000 central HVAC systems.[23] Over 80% of the savings will flow to the 35% of customers who would get central or ductless HVAC

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[17] Ex. SCE-02, p. 3, line 19 and p. 26, lines 1-5 and fn. 51. Tellingly, SCE properly evaluates bill savings over the lifetime of the equipment, unlike its analysis of rate impacts.

[18] See, BEWP.SCE-02.I.F.Carter Prescott_BE Application - Portfolio Benefits, Column AC.

[19] D.17-09-036, Finding of Fact 11 and Conclusion of Law 2.

[20] We have used outdated numbers provided by SCE in R.12-06-013, and plan to update these numbers prior to hearings.

[21] See, BEWP.SCE-02.I.F.CarterPrescott_BE Application_Portfolio Benefits. See, Columns D and Y.

[22] E3, 2019, pp. 59-60.

[23] Central HVAC systems comprise about 14% of total equipment costs for the BE Home Ready program.

systems, and who are more likely to reside in larger single family homes that can afford to replace an entire HVAC system.

2.3. Abatement Costs for Avoided GHG Emissions are Higher for Residential Customers Compared to Commercial Customers (Awan)

Building electrification is one of many available pathways towards achieving California's aggressive GHG emissions targets and it is imperative that the benefits from reduced emissions have direct positive impacts for customers (e.g., health benefits through reduced indoor pollution exposure). Although societal benefits from avoided GHG emissions do benefit all customers, upstream emissions reductions have little direct impact on the health and well-being of residential participants of the proposed program. SCE fails to provide a rationale for residential customers to invest in a program that does not provide tangible personal health benefits, or even provides a mechanism to quantify potential health benefits from proposed appliance electrification (e.g. replacing gas stoves might provide better direct benefits from reduced particulate matter exposure, particularly for equity customers who face disproportionate negative health outcomes from indoor air pollution).

In fact, residential customers pay 1.3 to 3 times more in marginal abatement cost for avoided GHG emissions compared with commercial customers on a $/tonne avoided emissions basis as shown by SCE's own analysis below.[24]

Figure 3: SCE Program Average GHG Emissions Abatement Costs are Higher for Residential Customers

SCE BE Portfolio		
BE Program	**GHG Emissions Avoided (MMTCO2e 2024-2038)**	**Abatement Cost ($/tonne)**
Home	2.88	143
Catalina	0.03	335
Business	0.58	111

[24] Source: BEWP.SCE-02.I.B.2.Carter Prescott_BE Application - Marginal Abatement Cost, 'tab 'Abatement Calculations'

2.4. Promoting Electrification Through Utility Bill Funding is Regressive and May Be Counter Productive (Hawiger, Stough)

2.4.1. The BE Programs Would Contribute to California's Serious Electric Rate Affordability Gap

SCE's residential ratepayers, particularly those that are low and middle-income, face significant disparities in their ability to afford essential utility services. In fact, 13% of households live in areas where low-income households pay more than 15% of their disposable income on electricity serve alone.[25] California also has the highest poverty rate and population of any state in the country when accounting for both cost of living and subsidies and transfer to households.[26] These affordability pressures, coupled with rising inflation costs and the economic ramifications of the COVID-19 pandemic, have triggered an unprecedented affordability crisis. Suffice to say, ratepayers, especially low-income, have limited ability to take on more expenditures.

Given the anticipated spending in the near future for wildfire mitigation and decarbonization, the only way to ensure affordable electric rates is to limit expenditures to what is truly necessary and substantiated as providing clear benefits to ratepayers. As discussed above, SCE's proposal ignores the near-term rate increases of the program, and TURN determined that ratepayers will pay about $300 million more on their utility bills over the 2024-2038 time period.[27] TURN finds that the costs of the BE programs would contribute to the affordability gap, while benefiting only certain participating customers. This is not a reasonable and justified use of ratepayer funds.

Using utility revenues for the next twenty years to fund these BE programs would be a regressive form of taxation to advance GHG reduction goals while benefitting a few.[28]

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[25] 2019 Annual Affordability Report, CPUC, April 2021, p. 10.

[26] Bureau of Labor Statistics Supplemental Poverty Measure, Table A-5, https://www.census.gov/library/publications/2018/demo/p60-265.html .

[27] See Section 2.1.3.

[28] Borenstein, Haas School Blog, https://energyathaas.wordpress.com/2020/11/16/reinventing-fixed-charges/. (Electricity is "a tax that is substantially more regressive than a sales tax or a tax on gasoline, both of which are generally viewed as pretty regressive ways to raise revenues.")

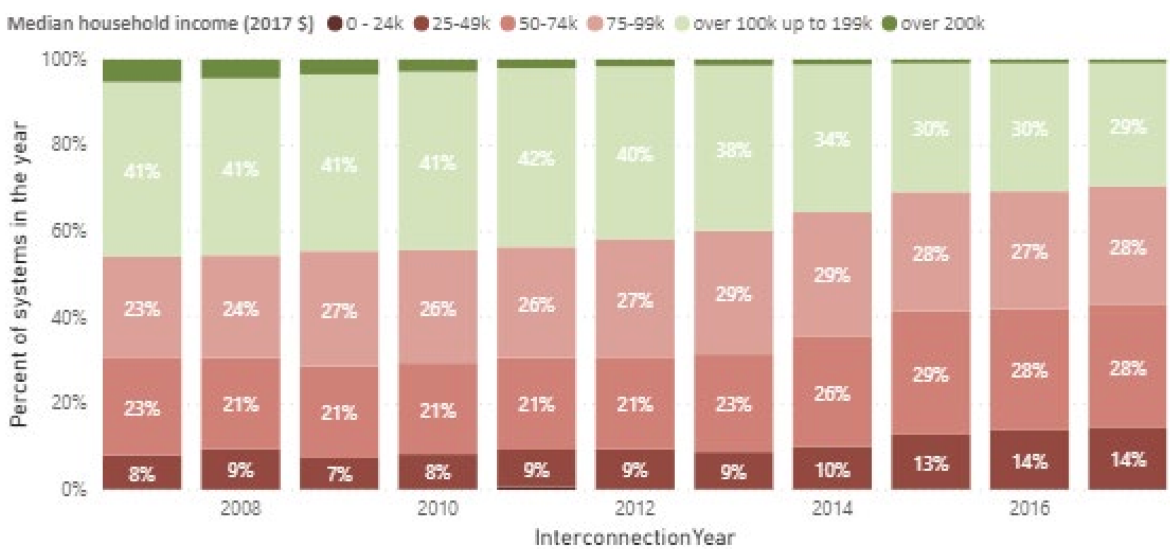
2.4.2. The BE Programs Will Subsidize Electrification Measures for Disproportionately Wealthy Early Adopters

TURN acknowledges that there are several parties in this proceeding who will focus primarily on the GHG reduction benefits of SCE's proposal, while disregarding the regressive burden of electric rates or the demographics of heat pump adopters.

The BE Ready Home program does not carve out a portion of direct technology incentives for low-income participants, but proposes at least 40% of the budget for electrical panel upgrades for those participants. But SCE makes no promises, and it may turn out that non-low-income participants may benefit from the vast majority of program spending.

Prior programs have illustrated the inequity of subsidizing expensive equipment based on participant self-selection. For example, for the CSI solar program, early adopters consisted of predominantly affluent participants. As shown below, in the first six years of the program, more than 50% of the households with a PV system had an annual income above $75,000.[29]

Figure 4: Early Adopters of Subsidized Technologies Tend to Be Higher Income



The CSI Final Impact Evaluation Report also found that it was "readily apparent that solar is being installed more often in higher income census tracts (with median incomes above $100k)

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[29] The median household statewide in 2017 was $73,555 (2017 $). California Solar Initiative Final Impact Evaluation, Final Report Submitted to CPUC, January 28, 2021, p. 33, available at https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/energy-division/documents/csi-progress-reports/csi-2/csi_evaluation-report.pdf.

than census tracts with lower incomes."[30] Research on the adoption motives between earlier and later adopters of residential solar PV systems found that recent (or later) adopters appear to install solar for different reasons than earlier ones, with recent adopters more motivated by economic reasons and less motivated by environmental reasons than early adopters.[31]

Heat pump technology for space and water heating is still relatively new in California and market-based programs such as those proposed by SCE will likely attract adopters who have non-economic motives. While it might aid in a growth of adoption of heat pumps, subsidizing that technology for wealthy participants runs counter to the Commission's ongoing work in addressing affordability and equity. Thus it would be unreasonable for ratepayers to fund SCE's proposed $1.214 billion program.

2.4.3. SCE's Proposal Could Harm Near-Term Electrification Efforts

SCE intends to promote customer adoption of electrification technologies by providing incentives to offset the high costs of purchasing and installing heat pump technology measures.[32] SCE understands that "affordable electric rates and bills also help to facilitate the electrification of buildings by enabling all customers to transition to clean electric end uses."[33]

Affordable energy rates are a critical component in building electrification policy. A recent study of U.S. households over a 70-year period, found that energy prices are the single, most important factor in households using electric heating.[34] Changes in energy prices explained over two-thirds

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[30] Id.

[31] Ben Sigrin et al., Diffusion into new markets: evolving customer segments in the solar photovoltaics market, 2015 Environ. Res. Lett. 10, p. 5, available at https://iopscience.iop.org/article/10.1088/1748-9326/10/8/084001/pdf ; See also A. Palm, Early adopters and their motives: Differences between earlier and later adopters of residential solar photovoltaics, Renewable and Sustainable Energy Reviews, Vol 133 (November 2020), available at https://www.sciencedirect.com/science/article/pii/S1364032120304330 ("[E]arliest adopters are driven mainly by environmental concern and technophilia, while later adopters are driven predominantly by economic gains.").

[32] SCE-02, p.8, lines 3-9.

[33] SCE-02, p. 7, lines 7-9.

[34] Davis, Lucas, What Matters for Electrification? Evidence from 70 Years of U.S. Home Heating Choices, May 2022, Energy Institute at Haas, pp. 2-3, available at: https://haas.berkeley.edu/wp-content/uploads/WP309.pdf

of the increase in electrification for heating.[35] An increase in electricity rates may reduce consumer interest in replacing gas-fueled appliances in their homes with electric appliances.

SCE's proposal will significantly increase rates during the four-year period of program deployment, even if it succeeds in slightly reducing rates in future years. SCE's proposal could thus discourage near-term electrification efforts by non-participants.

2.4.4. The BE Program Should Not Be Construed as a Market Transformation Program (Hawiger, Stough)

SCE touts its proposal as a market transformation program designed "to mirror market transformation initiatives that facilitate structural changes in the market."[36] In the context of the energy efficiency market, the CPUC defines "market transformation" as follows:

> "Market transformation is **long-lasting, sustainable changes in the structure or functioning of a market** achieved by reducing barriers to the adoption of energy efficiency measures to the point where continuation of the same publicly-funded intervention is no longer appropriate in that specific market. Market transformation includes promoting one set of efficient technologies, processes or building design approaches until they are adopted into codes and standards (or otherwise substantially adopted by the market), while also moving forward to bring the next generation of even more efficient technologies, processes or design solutions to the market."[37]

SCE claims that incentivizing customers will enable a mature regional market of technologies, designers, and installers to create market conditions that streamline building electrification for adoption in state and national codes.[38] However, SCE provides no clear linkage between the BE programs and these long-term targets. Instead, the programs are designed with incentive structures to address key barriers and ME&O activities with a goal to transform the market by reducing those barriers.[39] While these elements are important to promote adoption of heat pump technologies, they only play a part in the long-term goal of market transformation – specifically,

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[35] Id.

[36] Ex. SCE-02, p. 1. See, also, Ex. SCE-02, pp. 9-13.

[37] Decision 09-09-047 at 88-89 (emphasis added); *See also* Attachment A, *Adopted Market Transformation Framework*, p. 100 (D.19-12-021).

[38] Ex. SCE-01, p. 21, lines 6-11.

[39] SCE-01, p. 5, lines 5-9.

the eventual adoption of codes and standards and sustainability of the market without publicly-funded intervention.

Market transformation includes market effects that actually impact the structure of the market, as opposed to spillover, which simply increases technology purchases outside of the intervening program.[40] Indeed, "awareness" is not considered a market effect since increasing awareness itself is a short-term measure and does not strongly relate to action.[41] Examples of desired market effects could include the following:

Figure 5: Examples of Types of Desired Market Effects[42]

- A competitive market in which the efficient option battles for market share
- Reduced or eliminated price premiums for the basic technology
- New role players in the market to support and sustain the product
- Establishment of new competitors in the market who thrive on the product.
- Adoption as a voluntary standard by industry or government
- Market perceptions of the product as a status product
- End-users requesting or demanding the product
- Risks to private market actors are reduced or removed

Transformation of the space and water heating appliance market will require significant action by several market actors, including the building and appliance industry and state agencies. In a recent study on the heat pump market, industry actors observed additional significant barriers, such as installation considerations, inventory stock limits, and consumer perceptions that prevent adoption, despite existing incentives.[43]

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[40] Keating, Ken, Guidance on Designing and Implementing Energy Efficiency Market Transformation Initiatives. (2014), p. 2, *available at* https://pda.energydataweb.com/api/downloads/1206/Guidance%20on%20Designing%20and%20Implementing%20MT%20Initiatives_Dec9%202014%20Final.docx .

[41] Id., p. 14.

[42] Id., p. 14.

[43] See California Heat Pump Market Characterization and Baseline Study, April 4, 2022, https://pda.energydataweb.com/api/view/2610/OD-CPUC-Heat-Pump-Market-Study-Report-final-4-2022.pdf

While TURN understands the appeal of promoting heat pump technology adoption through an incentive structure, TURN does not believe that SCE's proposal will necessarily transform the market. SCE ignores other factors such as bill impacts, as discussed above, and how that may deter customers from participating despite the subsidies for the upfront costs.

Moreover, SCE's proposal represents only part of the solution: it addresses about 15% of the gap for electric heat pump adoption in SCE's service territory by 2030, and 6% of the gap statewide.[44] To narrow the gap, support from the legislature, regulatory agencies, and private actors is necessary in order to produce actual long-term market transformation where the market can sustainably continue on without ratepayer funding.[45] However, SCE provides no analysis as to how subsidizing 250,000 heat pump technology measures will spur the BE market, or result in any of the above market effects that are structural or institutional. SCE's BE programs provide no assurance that they would be provide beneficial long-term market transformation once the funds dry out after four years. Ratepayers should not have to fund a stand-alone program when there is a need to transform the market on a broader and statewide level.

Programs such as energy efficiency lighting incentives, the million solar roofs program, and the self-generation incentive program, have all distributed hundreds of millions of dollars in customer-specific incentives. While those programs have yielded some positive results, and some have passed applicable cost-effectiveness tests, none of them succeeded in "transforming" the market, until much more direct regulatory and business changes fundamentally "transformed" some of those markets.

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[44] SCE-01 p. 4, lines 8-8-10.

[45] Keating, Ken, Guidance on Designing and Implementing Energy Efficiency Market Transformation Initiatives. (2014), p. 16, Figure 8.

3. PROGRAM DESIGN (Question I.A)

3.1. The Commission Should Require Participants to Enroll in Supply Side Demand Response Programs (Hawiger)

TURN opposes funding for SCE's program. However, if the Commission does fund some variant of the program, it should require all participants to be enrolled in a demand response program.

SCE explains that load management of building electrification technologies can provide system benefits, including better integration of renewable energy and reduction in GHG emissions.[46] SCE apparently intends that subsidized equipment should have "the ability to interconnect" via industry standards. However, SCE does not appear to impose any conditions that subsidized technologies must actually use the connectivity capabilities to provide any load management benefits.

TURN supports ensuring technological capabilities that would allow for communication of price and system condition signals to appliances. However, merely having a port in an appliance does absolutely nothing to ensure that appliance will respond to any relevant price or condition signals. Electric appliances can provide distribution or generation system benefits if they automatically respond, or can be dispatched, based on generation or distribution capacity conditions.

The Commission has addressed similar issues regarding customer enrollment in demand response. The Commission authorized up to $22.5 million in incentives for smart thermostats, with a customer incentive of $75, in order to "achieve load reduction in hot climate zones"; and required that qualifying customers "pre-enroll in a CAISO market integrated DR program."[47] More recently, in adopting a heat pump water heater subsidy program in the Self Generation Incentive Program, the Commission required "all customers using SGIP HPWH incentives to enroll in a qualified demand response program, defined as a CAISO market-integrated supply-side demand response program that counts for resource adequacy."[48] Given that other ratepayers

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[46] Ex. SCE-01, p. 23.

[47] D.21-12-015, p. 79.

[48] D.22-04-036, p. 34.

may be subsidizing each household with several thousands of dollars in incentives in SCE's proposed program, the Commission should similarly require that any participants enroll in a demand response program.

4. STATE BUDGET IMPACT (Question I.B)

The Scoping Memo indicated that the question of "[w]hether SCE should modify its original proposal to address any relevant issue(s) or funds included within the adopted 2022-2023 State Budget as they relate to this application," should be addressed in testimony due to be submitted on August 25, 2022. TURN continues to recommend that building electrification be driven by structural mandates and/or subsidized more equitably through general revenues or cap-and-trade revenues.

5. COST RECOVERY (Question II) (Hawiger)

5.1. Capitalization of Customer-Side Infrastructure Costs Unnecessarily Increases Ratepayer Costs by Almost $300 Million (Question II.B.)

5.1.1. SCE's Regulatory Asset Proposal

As part of the BE Ready Home and the BE Ready Catalina programs, SCE proposes to spend $199.8 million on "low- and no-cost electrical upgrades (electric panel, circuit breakers, wiring, etc.) in homes with inadequate in-home electrical infrastructure."[49] The BE Ready Home program targets 63,700 electrical upgrades,[50] meaning that SCE forecasts spending an average of $3,100 per home on electrical upgrades on the customer side of the meter.[51] SCE proposes to "allocate" 40% of the electrical upgrade budget to qualifying low-income households.[52]

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[49] Ex. SCE-02, pp. 45, 78, and Table I-3, p. 32.

[50] Ex. SCE-02, p. 47, Table II-5. SCE does not identify the forecast number of electrical upgrades for the Catalina program in its testimony.

[51] SCE forecasts that electrical upgrade incentives will range from $1,411 to $3,332 for non-low-income households, and from $2,821 to $6,663 for low-income households. DR TURN-SCE-001-10. See, Attachment 4.

[52] SCE states that eligible low-income customers will receive all electrical upgrades at no cost, while non-low-income customers will receive incentives that cover approximately 50% of electrical upgrade costs. DR TURN-SCE-001-08. See, Attachment 4.

The electrical upgrades will be conducted on equipment that is owned and operated by the property owner. Such upgrades would thus not qualify as "used and useful" utility assets under normal ratemaking policies. Subsidizing customer equipment would be expensed, since traditional ratemaking only allows for capitalization of long-lived assets that are owned and operated by the utility.

SCE proposes that the Commission classify these costs as a "regulatory asset," so that SCE will capitalize these costs and earn a rate of return even without owning and operating the assets. SCE intends to depreciate the regulatory asset costs over 20 years, despite the fact that the assets may have a longer useful life, based on a balancing of "the potential life of the asset with the potential for obsolescence unrelated to function," meaning due to events under the control of the home owner and not the utility.[53]

SCE separately intends to capitalize $69.2 million in service connections and line extension costs, for equipment that will be owned and operated by SCE.[54]

5.1.2. SCE's Policy Basis for Regulatory Asset Treatment Is Flawed

From a policy perspective, TURN suggests that capitalizing behind-the-meter (BTM) electrical work is improper. SCE claims that "the customer-side infrastructure incentives proposed in SCE's BE program are analogous to the customer-side infrastructure in the Mobilehome Park Pilot program,"[55] for which the Commission authorized regulatory asset treatment of utility behind-the-meter work.[56] First, I note that when it reauthorized the Mobilehome Park program, the Commission expressly stated in that Decision that "[t]his decision's handling of BTM costs shall not be precedential,"[57] even though this is generally true of any Commission decision. This express emphasis on the non-precedential policy nature of the MHP pilot reflects certain unique characteristics associated with the MHP pilot, which make it inapposite to other voluntary incentive programs.

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[53] Ex. SCE-03, p. 6, fn. 3.

[54] Ex. SCE-02, Table II-7, p. 51.

[55] Ex. SCE-03, p. 7, lines 15-16.

[56] Ex. SCE-03, pp. 6-7, citing to D.20-04-004 and D.14-03-021.

[57] D.20-04-004, p. 124.

The mobile home program was undertaken due to the need to accelerate the conversion of old MHP distribution systems to further the goals of §§ 2791-2799.[58] The Commission found that very few mobile home parks had converted to direct utility service. The Commission was concerned regarding potential safety issues associated with legacy mobile home park electrical infrastructure.[59] The Commission recognized that park conversion required that both the "before-the-meter" and "after-the-meter" portions of legacy systems would have to be replaced.[60]

The Commission explained that "the 'beyond the meter' construction was necessary for the new distribution system to function and provide ratepayer value."[61] However, the "beyond the meter" replacement was dependent on financing by the mobile home park owner, and lack of performance by park owners jeopardized conversion projects and created the potential for stranded utility costs:

> "Beyond the meter" construction is necessary for the entire, new distribution system to function. The Joint Parties acknowledge this. Under their proposal, conversion would cease if the MHP owner was unable to establish financial wherewithal to undertake or complete construction "beyond the meter." This raises the potential for abandonment of partially constructed, replacement infrastructure, since without both halves of a new system in place, no change is possible.[62]

Due to the concerns about owner financing the Commission determined that it was valuable for utilities to capitalize the "beyond the meter" work as a regulatory asset that provides ratepayer value. Essentially, the Commission found that a drastic change was necessary to motivate mobile home park conversions:

> For more than a decade and a half, state policy has disfavored the continuation of master-meter/submeter systems, yet the majority of them continue to operate. We are persuaded this stalemate requires new strategies. We do not think the lack of actual disaster to date is a reason for further delay.[63]

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[58] See, generally, D.14-03-021, pp. 2-5.

[59] D.14-03-021, pp. 15-18.

[60] D.14-03-021, p. 22 ("The utilities uniformly anticipate that in almost all circumstances an entirely new distribution system (both "to the meter" and "beyond the meter" portions) would need to be built in parallel to the existing master-meter/submeter system.")

[61] D.14-03-021, p. 40.

[62] D.14-03-021, p. 40.

[63] D.14-03-021, p. 34.

The concerns regarding safety and compliance with statutory goals simply does not exist with SCE's BE program. The BE program would provide "incentives" for equipment, in addition to subsidies for home electrical upgrades. Such work would presumably be undertaken only if a participant was willing to purchase the equipment based on program subsidies. If a participant was unwilling to complete any beyond the meter electrical upgrade work necessary to support subsidized appliances, even with utility subsidies for the upgrades,[64] the utility would simply not allow participation in the program. There is no potential for stranded costs; and there is no inherent safety rationale for selecting one participant over another.

Indeed, this program is much more analogous to those energy efficiency programs that provide incentives for appliances as well as for work on the building structure and fixtures (e.g. insulation, showerheads, etc.), and to programs that provide incentives for electric vehicle charging infrastructure. The Commission found in D.18-05-040 that an upfront rebate that is expensed can achieve the same goals of incentivizing installation as a utility "allowance" that is capitalized by the utility.[65] The Commission balanced the benefits and costs of utility capitalization and found that "SDG&E's claimed benefits for utility ownership do not exceed the ongoing costs associated with SDG&E owning the customer-side infrastructure."[66] The same type of balancing in this case supports expensing any subsidy for customer-side electrical upgrade work.

5.1.3. SCE's Analysis of the Ratepayer Impacts of Regulatory Asset Treatment Is Flawed, as Ratepayers Pay More Under SCE's Proposal

SCE attempts to support its proposal to capitalize customer-side electrical work by arguing that capitalization 1) minimizes near-term rate spikes, and 2) promotes intertemporal equity. I address these claims in order and demonstrate that the significant disadvantages of capitalization far outweigh any potential short-term benefits.

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[64] TURN is not opposing the subsidy for electrical work, if the Commission authorizes the program, but opposing capitalization of such work.

[65] D.18-05-040, p. 28-29.

[66] D.18-05-040, p. 52.

5.1.3.1. Rate Impacts

An expense is typically recovered during the year it is spent, while a capital cost is amortized over the useful life of the asset.[67] However, the utility additionally collects a rate of return and taxes on any capitalized asset, so over the useful life of most distribution system assets (as opposed to short-lived information technology assets), the utility usually collects one-and-a-half to two times the initial investment. This is analogous to the total payments on a 30-year fixed rate home mortgage with a rate of about 7.7%.

SCE claims there are "near-term savings of $156 million" over the four years 2024-2027 due to capitalizing the customer electrical upgrade work, rather than expensing.[68] SCE's analysis neglects to mention that starting in year 5, or 2028, customers will pay more each year for the capitalized regulatory asset than without the regulatory asset. Over the entire 20-year recovery period for the regulatory asset SCE ratepayers will pay $290 million (nominal) more for the capitalized regulatory asset, as illustrated in Figure 6 below.[69] The primary reason for the higher cost is that SCE would collect almost $280 million in shareholder profits and interest costs for the regulatory asset scenario, versus only $92.6 million without the regulatory asset scenario.

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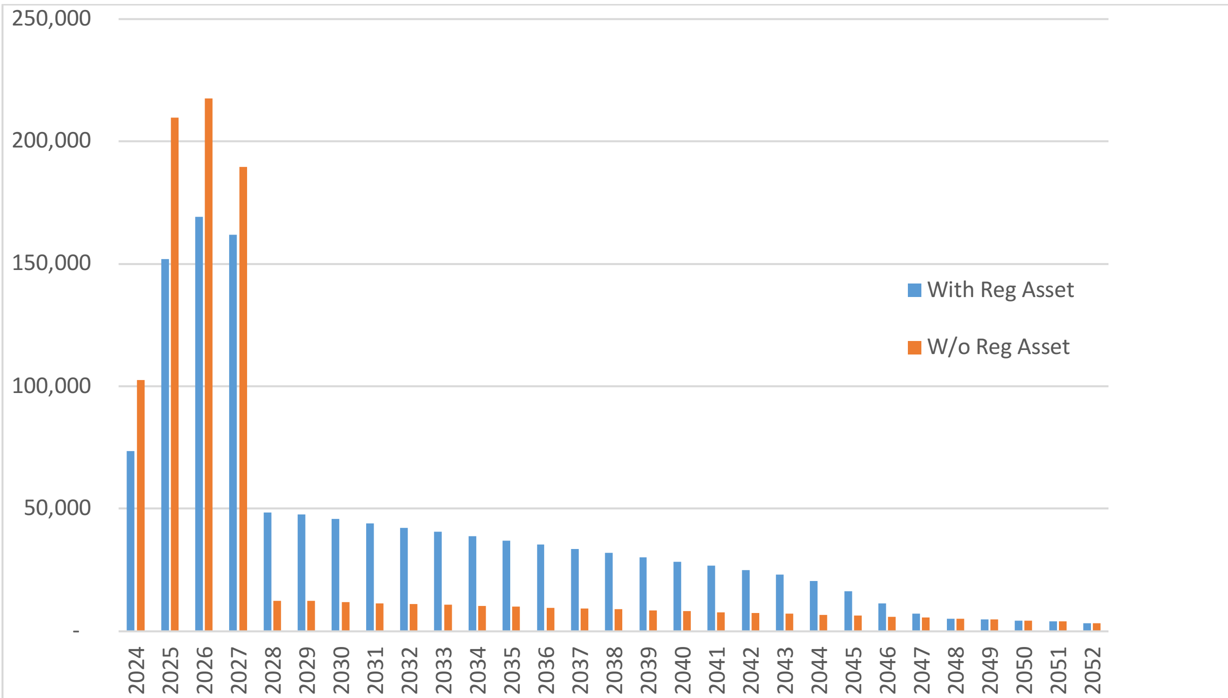
[67] In this case, SCE proposes amortization of the regulatory asset over twenty years.

[68] Ex. SCE-03, pp. 7-8 and Table I-2. Tellingly, while SCE claims there are "annual rate and revenue savings," its Table only highlights the revenue impacts for 2024-2027.

[69] In other words, from 2028 to 2048 ratepayers will pay about $446 million more, thus more than offsetting the $156 in reduced rates for 2024-2027.

Figure 6: Total Ratepayer Payments with and without Regulatory Asset[70]



Even when accounting for the time value of money, on a net present value basis customers will still pay between $61.45 million (using a 7.7% discount rate) and $168.80 million (using a 3% discount rate) more over the life of the program if the behind the meter work is capitalized as a regulatory asset.

SCE's comparisons assume full recovery of annual expenses in the year they are incurred. As discussed later in my testimony, the Commission could require that expenses for the electrical upgrade work be amortized over two to five years, thus minimizing any short-term rate increases due to expensing.

5.1.3.2. <u>Intertemporal Equity</u>

SCE claims that recovering costs over 20 years promotes intertemporal equity because "the rate impacts that customers experience are aligned with the benefits of the program and therefore,

[70] WP "BEWP SCE-03 1.F Sheriff Rev Req by Program and Reg Asset," Sheet "SOE BE App Total," summing rows 78 and 81.

current customers do not subsidize benefits enjoyed by future customers."[71] SCE's analysis would be true in the case of a large utility asset that provides service to all customers (such as a substation or power plant), or even in the case of smaller assets (such as transformers) that serve a few customers, but there are multiple such assets so that every customer is served by a transformer. In those cases, it is fair to depreciate the cost of the assets over time since multiple customers will benefit from the assets over time.

This logic does not, however, apply to SCE's program, because only program participants receive any benefits. In other words, SCE will subsidize a select group of (primarily) homeowners to receive significant upgrades to their homes' electrical systems. No other SCE customer will benefit from the particular electrical home upgrades; and no non-participating customer will receive such a benefit. The only party that benefits from regulatory asset treatment is the SCE shareholder. It is not reasonable to anticipate that this program could scale so that SCE will spend over $3,000 per home to upgrade the electrical system for every residential customer in its service territory. Funding such a program through utility bills at a 7.68% interest rate makes no sense.

Since all of the program benefits flow entirely to the participants, the issue of intertemporal equity is largely irrelevant, as there is no aligning of "costs" and "benefits." It is thus much more important to reduce total ratepayer impacts than to ensure an alignment of subsidies and rates.

5.1.3.3. Recommendation

Ratepayers would save between $61 million (7.7% discount rate) and $290 million (nominal) by recovering the costs of behind-the-meter electrical upgrade work as expenses, given that these will not be utility-owned or utility-controlled assets. It is true that rates would be somewhat higher in the early years due to expensing. However, such short-term impacts could be mitigated by amortizing the expenses over two to five years, rather than recovering them in the year incurred or forecast. The Commission has previously authorized the amortization of expenses or

[71] Ex. SCE-03, p. 6:5-16.

memorandum account balances over multiple years in order to minimize rate shock and promote equity.[72]

5.2. Balancing Account Treatment

SCE proposes to record actual revenue requirements in a new balancing account, and requests authority to collect all costs in rates without any further reasonableness review as long as total costs do not exceed 110% of the authorized costs.

TURN opposes one element of SCE's proposed ratemaking, namely the addition of a 10% "buffer" on program costs. Furthermore, TURN recommends that the Commission require a reasonableness review if unit costs exceed 100% of the forecast.

5.2.1. The Commission Should Not Authorize an Automatic 10% Reasonableness Contingency

In several recent applications the utilities have requested that the Commission authorize as reasonable a certain forecast of costs, but then further authorize no additional reasonableness review if actual costs are higher by some percentage than the authorized costs. In essence the utilities are effectively adding a cost contingency, or simply asking the Commission to authorize as reasonable a higher cost than has been justified. Such a practice does not conform to the Commission's legal obligation to find rates just and reasonable, as will be discussed in more detail in legal briefs. Here, I simply note that as a matter of fact the Commission should not authorize any such unjustified contingency.

5.2.2. The Commission Should Adopt a Unit Cost Reasonableness Threshold

Traditionally, an authorized cost was assumed to provide the just and reasonable funding for a single project. The classic examples include the construction of a power plant, an upgrade to a substation, or the repair of a compressor station. All work necessary to complete the project must be done in order for the project to be used and useful.

However, when the work involves the installation of multiple separate assets that do not depend on each other, a total cost reasonableness threshold is meaningless if not combined with a unit

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[72] As one recent example, the Commission amortized SCE's O&M expenses in various wildfire mitigation memorandum accounts over a three-year period, even though the utility sought amortization over one year. D.22-06-032, pp. 2, 6.

cost threshold. For example, if in this case the Commission authorizes the $677 million for work in approximately 250,000 homes (at an average cost of $2,708 per home), but SCE spends all of the money by completing work on 125,000 homes, the project is technically "below the reasonableness threshold," but the utility has certainly not delivered the promised work or provided the intended ratepayer benefit.

For this reason, the Commission has started requiring utilities to meet unit cost thresholds when seeking authorization for such projects. In SCE's Grid Safety and Resiliency Project, for example, the Commission approved a settlement agreement that incorporate unit cost thresholds for seven identified capital and expense costs.[73]

In this case, the need for a "unit cost" threshold is somewhat limited, given that SCE intends to provide specific rebates for equipment installation, so the cost per appliance should in theory be fixed; however, SCE apparently seeks the flexibility to modify incentive levels "to balance program efficacy and cost efficiency."[74] If the Commission does authorize this program, I recommend that the Commission establish a cap on the incentive levels for appliances, for example based on SCE's Table II-4 proposal for BE Home Ready.

The Commission should, however, adopt a unit cost reasonableness threshold for electrical upgrade work, both for the subsidized in-home work and upgrades to the utility-side electrical system. SCE forecasts of an average of $3,100 per home for electrical upgrades on the customer side of the meter .[75] For utility-side capital investments, SCE forecasts a unit cost of $314 per meter change and $6290 per service line extension upgrade.[76]

TURN recommends these unit costs be adopted as reasonableness thresholds for each type of work. If SCE's actual average unit costs exceed these thresholds, SCE must submit a reasonableness application to recover any costs in excess, even if its total costs are below the total cost threshold.

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[73] See, D.20-04-013, Appendix 1, Table C-1, p. 8-9.

[74] Ex. SCE-02, p. 44.

[75] Ex. SCE-02, p. 47, Table II-5. SCE forecasts that electrical upgrade incentives will range from $1,411 to $3,332 for non-low-income households, and from $2,821 to $6,663 for low-income households. DR TURN-SCE-001-10. TURN has not confirmed the unit cost figures from work paper data.

[76] BEWP.SCE-02.II.A.5.Thomas Littman Prescott_BE Application Budget, Cells D18 and B40.

6. ENVIRONMENTAL AND SOCIAL JUSTICE (Question III) (Stough)

6.1. The BE Programs Do Not Align with the Mitigation Goals of the ESJ Action Plan

The Commission acknowledged in the Environmental and Social Justice (ESJ) Action Plan that it must focus resources on communities that have been underserved, while recognizing that its decisions have the potential to perpetuate and exacerbate existing disparities in ESJ communities.[77] The ESJ Action Plan not only aims to address historic underinvestment and exclusionary policies and practices in these communities, but also serves as an ongoing commitment to mitigate and eliminate harms to those communities.[78] Economic harms are particularly prevalent within ESJ communities. As an example, TURN has consistently argued that the exorbitant amount of funds being used to fund transportation electrification (TE) creates a disproportionate burden on lower income communities, even if those communities benefit from reduced GHG emissions.

The Commission should not assume that installing heat pump appliances for some lower income customers in ESJ communities is consistent with the goals of the ESJ Action Plan. The affordability crisis discussed above only underscores the significance of approving a program that will only benefit some customers in ESJ communities, but increases rates and imposes additional financial burden on all lower income ratepayers.

6.2. Recommendations to Mitigate Impacts on ESJ Communities

Should the Commission consider approving some or all of SCE's proposal, TURN recommends modifying the BE programs to be a limited equity-only program. TURN believes a building electrification program that prioritizes and targets lower-income households within ESJ communities would further goals of the ESJ Action Plan by increasing access to clean energy technology for those communities, while mitigating the harms of rate increases for subsidizing a much larger program. TURN recommends the following:

- Limited equity program of $80mm for equity customers.
- Homes must have been built pre-1978 as these homes are much more difficult to convert to electrification without an electrical panel upgrade.

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[77] Environmental & Social Justice Action Plan, Version 2.0, April 7, 2022 (California Public Utilities Commission), p. 9.

[78] Id.

- Ideally, SCE should coordinate with existing pilots attempting to implement zonal electrification programs to incorporate lessons learned, so as to promote for the future possibility of zonal decommissioning of the gas system.
- Customers would need to be income-eligible to participate, using either the CARE income guidelines or a program with differentiated subsidies by income levels.

The Commission has acknowledged that increased rates place a large burden on ESJ communities who participate in clean energy programs at a lower rate than others.[79] TURN agrees and supports the Commission's commitment to prioritizing and assessing the cumulative impact of rates on households and working to mitigate these impacts on the most burdened households.[80]

This concludes our prepared direct testimony.

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[79] Id.

[80] Id.

ATTACHMENTS

ATTACHMENT 1

Statement of Qualifications: Jalal Awan

I am a doctoral candidate at the Pardee RAND Graduate School and an assistant policy analyst at RAND. Prior to joining RAND, I worked as an electrical maintenance and projects engineer with hands-on experience on industrial electrical and control systems.

My research interests broadly fall under technology policy and include autonomous transport, climate change mitigation, community science, infrastructure resilience, and the smart grid. At RAND, I am currently involved in projects under the Social and Economic Well-being division, working on datasets to disaggregate county-level environmental policy outcomes, prototyping hardware and software solutions for hyper-local air quality assessment, developing performance measures for public health emergency handling, estimating benefits of autonomous vehicles, and using gaming to understand the application of technology in food production. As a policy researcher, I have developed technical reports, presented findings to a diverse range of stakeholders, and volunteered on three panels with the U.S. National Academy of Sciences.

I completed my B.S in electrical engineering from the University of Engineering and Technology, Lahore (Pakistan) from 2006-2010, my M.S. in green technologies from the University of Southern California (Viterbi School of Engineering) in December 2015 as a Fulbright Scholar, and my M.Phil. in Policy Analysis at the Pardee RAND Graduate School in 2019. I am a member of IEEE, Six Sigma Green Belt from the American Society for Quality (ASQ) and hold the U.S. Green Building Council certification in Leadership in Energy & Environmental Design (LEED). I am currently pursuing my Ph.D. in policy analysis at the Pardee RAND Graduate School (2017-Present).

ATTACHMENT 2

Statement of Qualifications: Marcel Hawiger

My current position is Staff Attorney at TURN. I have held this position since August of 1998. I have represented TURN as the attorney of record in numerous energy proceedings since 1998, including general rate cases, electric and gas procurement cases, asset-specific applications and proceedings related to demand-side management programs and budgets. I am a member of the Procurement Review Groups for all three IOUs.

Prior to my employment with TURN, I was the Director of MidPeninsula Citizens for Fair Housing (1996-1998). I have also been employed by Evergreen Legal Services (1994-1996), the Massachusetts Department of Environmental Protection (1988-1990) and GHR Engineering, Inc. (1986-1988).

My education includes a Bachelor of Science degree in Geology from Yale University, a Master of Science degree in Civil and Environmental Engineering from Cornell University, and a law degree from New York University.

I have previously submitted the following testimonies for this Commission:

- Application 08-03-015, *Testimony Regarding Southern California Edison's Proposed Solar Photovoltaic Program,* September 12, 2008.
- Application 09-02-013, Testimony concerning proposed fuel cell projects, Sep. 14, 2009.
- Investigation 10-11-003, Testimony concerning the Rancho Cordova natural gas pipeline explosion.
- Investigation 12-01-007, Testimony concerning the San Bruno natural gas pipeline explosion.
- Rulemaking 13-09-011 concerning demand response programs, May 6, 2014.
- Application 14-04-014 regarding SDG&E's electric vehicle infrastructure program, March 16, 2015.
- Application 16-09-001, *Policy Testimony Regarding Affordability and Grid Modernization Investments*, May 2, 2017.
- A.17-10-007, *Testimony Addressing Gas Distribution O&M In Southern California Gas Company Test Year 2019 General Rate Case*, May 14, 2018.

ATTACHMENT 3

Statement of Qualifications: Camille Stough

My current position is Staff Attorney at TURN. I have held this position since September of 2020. I have represented TURN and previous clients in numerous Commission proceedings since 2016, including general rate cases, gas and decarbonization rulemakings, cost recovery applications and proceedings related to environmental justice and disadvantaged communities.

Prior to my employment with TURN, I was an Associate Attorney for the law firm Adams Broadwell Joseph and Cardozo representing utility employees before the Commission (2019-2020). I have also been employed as a Staff Attorney for Communities for a Better Environment (2018-2019) and Associate Attorney with Braun Blaising Smith and Wynne (2015-2017)

My education includes a Bachelor of Arts degree in Legal Studies from the University of California at Berkeley and a law degree from Golden Gate University School of Law.

ATTACHMENT 4

SCE Data Responses in A.21-12-009 to TURN Data Requests:

- 001-08
- 001-10
- 001-14 (Public response only)
- 002-04
- 002-06
- 002-07

Southern California Edison

A.21-12-009 – SCE Application for Approval of its Building Electrification Programs

DATA REQUEST SET T U R N - S C E - 0 0 1

To: TURN
Prepared by: Jose Buendia
Job Title: Sr. Project Manager
Received Date: 5/3/2022

Response Date: 5/17/2022

Question 08:
SCE-03, p. 4, states "Tiered incentives will provide higher coverage of heat pump installation costs for low income customers and ESJ communities." If a wealthy household is located in an "ESJ Community," could that household receive higher incentives under SCE's proposal? Please explain.

Response to Question 08:
Yes, that is correct. The proposed equipment incentives under the BE Ready Home Program are tiered to encourage participation from all households in ESJ communities by offering higher equipment incentives to those communities; that includes households that may not necessarily be wealthy, but do not meet low-income definition criteria. And qualified low-income customers will be eligible to receive in-home electrical upgrades (electric panels, circuits, wiring, etc.) at no cost; this will facilitate the immediate adoption of a space or water heater and will prepare homes to adopt additional electrification measures and Distributed Energy Resources (DERs) in the future. Non-low-income customers will be eligible to receive incentives that cover approximately 50% of electrical upgrade costs.

SCE's application proposes to increase investments in clean energy resources to improve local air quality and public health by focusing its marketing, customer recruitment efforts, and by offering higher incentives for residential and business customers located in ESJ communities. Scaling up or accelerating BE adoption through the proposed market transformation activities will result in greenhouse gas (GHG) emissions reductions and improved air quality that benefit all residents of ESJ communities that are most vulnerable to the impacts of climate change and poor air quality.

DATA REQUEST SET T U R N - S C E - 0 0 1

To: TURN
Prepared by: Jose Buendia
Job Title: Sr. Project Manager
Received Date: 5/3/2022

Response Date: 5/17/2022

Question 10:
Re the "BE Ready Home", SCE-02, p. 23 states "The program targets:
- 240,000 Digital Home Assessments
- 120,000 In-Home Assessments
- 69,000 Heat Pump HVACs
- 130,000 HPWHs
- 63,700 Customer Electrical Upgrades"

a. Please explain and quantify the number of individual households each component listed above is expected to be deployed to. For example, is it expected that each home replaces both HVAC and HPWH systems at the same time? To what extent? Please explain and provide calculations, workpapers, and assumptions in Excel.
b. If not previously provided, please provide the number of households the heat pump HVAC and HPWH subsidies will support. Please provide in Excel with supporting calculations/workpapers.
c. Please provide the unit and total cost of each element listed above, for the Full program term and separately by year if available.
d. Please provide the level of subsidy in percentage terms (e.g., 100%) that the SCE program is expected to cover for the HVAC, HPWH, and Electric Upgrade line items, separately.

Response to Question 10:
Please see responses below:

a) The table below provides estimates and assumptions for the number of individual households receiving each the program activities or offerings.

Activity	Target Qty.	Estimates & Assumptions
Digital Home Assessments	240,000	Acquisition from direct marketing (e.g., email, mail), local advertising, grassroots and community outreach activities, and other tactics detailed in application.
In-Home Assessments	120,000	• 25% or 60,000 in-home assessment will come from Digital Assessments • Remaining 60,000 in-home assessments will come from CBOs, city leadership and/or other marketing activities

Heat Pump HVAC Installations	69,000	• 36,000 or 30% of in-home assessments will result in HP HVAC installation • Remaining 33,000 units will come from other BE Ready Home intervention activities which could include direct marketing and/or coordination/layering with other customer programs.
HPWH Installations	130,000	• 39,000 or 30% of in-home assessments will result in HPWH installations • Remaining 91,000 units will come from other BE Ready Home intervention activities which could include direct marketing and/or coordination/layering with other customer programs
Customer Electrical Upgrades	63,700	• 100% of customer electric upgrades will result from in-home assessments

b) SCE expects that a small percentage of households will install more than one heat pump; for example: installing a heat pump HVAC system and a HPWH. However, it is difficult to accurately estimate how many households will actually install more than one heat pump because this is a first of its kind, wide-scale, comprehensive fuel-substitution program. At this time SCE cannot estimate the number of households that will install more than one heat pump. Therefore, the number of unique household heat pump HVAC and HPWH subsidies the BE Ready Home Program can support ranges from 130,000 households (if every participating home install both end-uses) to 193,700 households (if every participating home installs only one end-use).

c) See SCE Workpaper labeled, "BEWP.SCE-02.II.A.5.Thomas Littman Prescott_BE Application Budget.xlsx;" tab labeled "BR-Home DI Budget" for the unit and total cost of the elements listed above. The workpaper is located within the folder labeled Building Electrification Workpapers → SCE-02.

d) See tables below. Additional costing information can be found on SCE Workpaper labeled, "BEWP.SCE-02.II.A.5.Thomas Littman Prescott_BE Application Budget.xlsx." See tab labeled "Res IMC Tables" for additional equipment cost estimates and tab labeled "Electric Panel Costing" for additional electric panel and circuit cost estimates.

Equipment	Installed Cost[1]	Incentive Amount			
		ESJ/Catalina Incentive Amt	% of Installed Cost	Non-ESJ Incentive Amt	% of Installed Cost
Heat Pump Water Heater (50Gal, UEF=3.31)	$1,825	$1,500	82%	$1,000	55%
HP HVAC (3.5-Ton, Split System)	$5,798	$1,925	33%	$1,225	21%
HP HVAC (2-Ton, Ductless Mini-Split)	$4,049	$1,100	27%	$700	17%
Induction Cooktop	$1,792	$800	45%	N/A	N/A

[1] Source: CPUC Ex Ante Database Archive; available at: http://www.deeresources.net/workpapers

HP Clothes Dryer, Standard Size	$1,578	$700	44%	N/A	N/A

Electric Panel and Circuits	Installed Cost	Incentive Amount			
		Low-Income Incentive Amt	% of Installed Cost	Non-Low-Income Incentive Amt	% of Installed Cost
New Electrical Panel + 3 Circuit Runs	$6,663	$6,663	100%	$3,332	50%
3 Circuit runs to Existing 200-Amp Panel	$2,821	$2,821	100%	$1,411	50%

Southern California Edison
A.21-12-009 – SCE Application for Approval of its Building Electrification Programs

DATA REQUEST SET T U R N - S C E - 0 0 1

To: TURN
Prepared by: Matt Sheriff
Job Title: Senior Advisor
Received Date: 5/3/2022

Response Date: 5/17/2022

Question 14:
Re Excel Workpaper SCE-03, "Sheriff Rate Impacts": please provide supporting workpapers for the "Rate Impact Details" tab.

Response to Question 14:
CONFIDENTIAL
This Response And The Attachment(s) Are Marked Confidential In Accordance With D. 16-08-024 and D. 17-09-023. Basis for Confidentiality In Accompanying Confidentiality Declaration. Public Disclosure Restricted.

Please see the confidential Excel document, "CONFIDENTIAL A.21-12-009 SCE BE Application Rate Design Model TURN-SCE-01." This model is not meant to be used for any other purpose outside of the BE Application proceeding.

Southern California Edison
A.21-12-009 – SCE Application for Approval of its Building Electrification Programs

DATA REQUEST SET T U R N - S C E - 0 0 2

To: TURN
Prepared by: Matt Sheriff
Job Title: Anlys, Sr Advisor
Received Date: 6/7/2022

Response Date: 6/17/2022

Question 04:
Note: Reference to the Rate Design Model is to the spreadsheet "CONFIDENTIAL A.21-12-009 SCE BE Application Rate Design Model 2022 TURN-SCE-01" provided in DR 001-14.

Please provide SCE's total system authorized revenue requirements for 2020 and 2021 disaggregated at a minimum by fuel and purchased power, base generation, base transmission, base distribution, and any other relevant major category. [See, for example, Table VII-24 on p. 83 of SCE-07 vol. 1 submitted in Track 1 of A.19-08-013 (the 2021 GRC).]

Response to Question 04:

Year	Customers*	Sales (GWh)*	Revenue Breakout
2021	5,217,585	79,270	See attachment 'TURN-SCE-002 Q4.xlsx'
2020	5,183,295	80,119	See attachment 'TURN-SCE-002 Q4.xlsx'

- Source, 2021 ERRA Forecast November Update, A.20-07-004 Exhibit No.: SCE-04, Tables III-4 and 5

Southern California Edison
A.21-12-009 – SCE Application for Approval of its Building Electrification Programs

DATA REQUEST SET T U R N - S C E - 0 0 2

To: TURN
Prepared by: Steve Verdon
Job Title: Advisor
Received Date: 6/7/2022

Response Date: 6/21/2022

Question 06:
Note: Reference to the Rate Design Model is to the spreadsheet "CONFIDENTIAL A.21-12-009 SCE BE Application Rate Design Model 2022 TURN-SCE-01" provided in DR 001-14.

Please provide for 2020 and 2021 recorded:

a. The average bundled residential customer class rate, separately by generation and delivery;
b. The average residential bundled non-CARE rate, separately by generation and delivery; and
c. The average residential bundled CARE rate, separately by generation and delivery.

Response to Question 06: Please see the data in the attached excel file.

Southern California Edison

A.21-12-009 – SCE Application for Approval of its Building Electrification Programs

DATA REQUEST SET T U R N - S C E - 0 0 2

To: TURN
Prepared by: Steve Verdon
Job Title: Advisor
Received Date: 6/7/2022

Response Date: 6/21/2022

Question 07:
Note: Reference to the Rate Design Model is to the spreadsheet "CONFIDENTIAL A.21-12-009 SCE BE Application Rate Design Model 2022 TURN-SCE-01" provided in DR 001-14.

Please provide for 2020 and 2021 recorded, the system average rate segregated by generation and delivery;

Response to Question 07: Please see the data in the attached excel file.

SOURCE: DR TURN 002-07 (2020)

MOYRKEY	Avg_Gen_Rate	Avg_Del_Rate	TURN DERIVED - % GEN
202001	0.0524	0.0802	39.50%
202002	0.0513	0.0808	38.82%
202003	0.0516	0.0795	39.38%
202004	0.0527	0.0486	52.03%
202005	0.0533	0.0828	39.15%
202006	0.0586	0.0880	39.99%
202007	0.0701	0.0931	42.96%
202008	0.0738	0.1033	41.68%
202009	0.0717	0.1039	40.84%
202010	0.0621	0.1015	37.96%
202011	0.0506	0.0978	34.12%
202012	0.0508	0.0983	34.05%
Annual	0.0593	0.0896	39.82%

SOURCE: DR TURN 002-07 (2021)

MOYRKEY	Gen_Avg_Rate	Del_Avg_Rate	TURN Derived - Gen%
202101	0.050989	0.098677	34.07%
202102	0.046551	0.110434	29.65%
202103	0.050168	0.101865	33.00%
202104	0.057526	0.112637	33.81%
202105	0.051788	0.133525	27.95%
202106	0.052819	0.131102	28.72%
202107	0.068662	0.142537	32.51%
202108	0.067145	0.142296	32.06%
202109	0.068346	0.139339	32.91%
202110	0.061446	0.124674	33.01%
202111	0.048926	0.138283	26.13%
202112	0.050899	0.142935	26.26%
Annual	0.057363	0.128297	30.90%

ATTACHMENT 5

Other Documents Relied Upon

ENERGY INSTITUTE AT HAAS

ENERGY INSTITUTE BLOG

Reinventing Fixed Charges

Income-based monthly fees could address affordability while reducing distorted electricity rates.

California leaders tout their pathbreaking initiatives to address both the climate crisis and economic inequality. But the way we charge for one of the most basic household needs – electricity – is undermining both of those efforts. The electricity rate structures of the state's investor-owned utilities (IOUs) are discouraging building electrification and other important investments for reducing carbon emissions, while at the same time imposing a disproportionate burden on low-income customers.

Everyone knows that California IOUs, who serve over 70% of residential customers, have some of the highest electricity rates in the country. And they collect those revenues from households almost entirely through volumetric (*i.e.*, priced per kilowatt-hour) charges. Those volumetric rates, however, cover much more than the cost of providing each additional kWh.

(Source: https://www.ny-engineers.com/blog/reducing-building-emissions-with-electrification)

Why are California Electricity Rates So High?

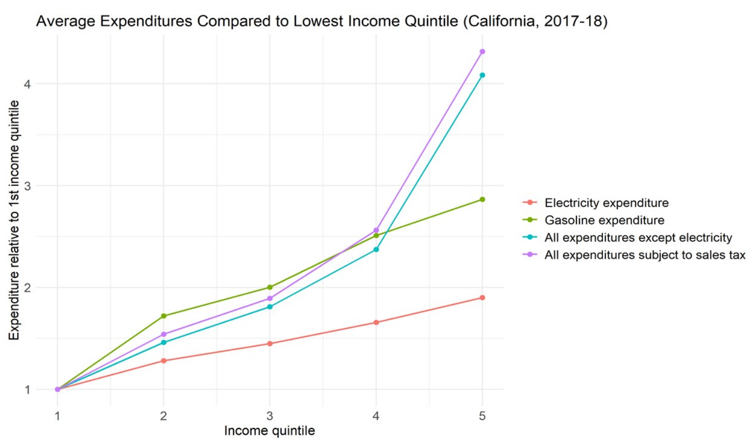
State policymakers have poured the cost of myriad public policy goals into electricity rates – subsidies for rooftop solar and EV charging stations, support for nascent high-cost renewable energy technologies, reduced rates for low-income customers, energy efficiency programs, wildfire mitigation and compensation, and **improving air and water purity in schools** **(https://www.nrdc.org/experts/max-baumhefner/california-adopts-bill-clean-air-inside-**

and-out-school), among others. Plus, many electricity system fixed costs, including most of the cost of transmission and distribution, are also covered in those volumetric rates, but don't really change with your electricity usage.

The result – as shown by research **here** (https://ei.haas.berkeley.edu/research/papers/WP294.pdf) and **here** (https://www.linkedin.com/pulse/major-update-der-avoided-costs-california-eric-cutter/?articleId=6663245546045747200) – is that volumetric rates are two or more times higher than the actual incremental cost of providing electricity. This means households have **too little incentive to switch to electricity** (https://energyathaas.wordpress.com/2018/09/17/the-electricity-price-isnt-right/) from natural gas, gasoline, or other higher-carbon fuels for household and transportation services. They also have too much incentive to install rooftop solar and outfit their basements with big batteries, when the same carbon reductions could be achieved at lower cost with large-scale renewables and storage.

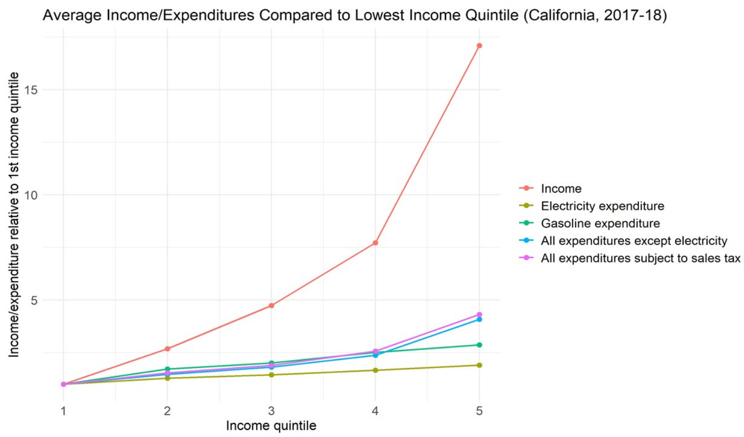
How to Cover the Revenue Gap

In ongoing research, Meredith Fowlie, Jim Sallee, and I (with the excellent assistance of our graduate student, **Marshall Blundell** (https://marshallblundell.github.io/)) are examining what causes the gap between price and the incremental cost of providing a kWh, and looking closely at who ends up paying for the gap. In essence, the rate structure imposes a volumetric tax on electricity – a surcharge on each kWh – in order to cover state energy policies and other costs that don't vary with the amount of electricity households use.



We wanted to compare the distributional implications of collecting revenue through this volumetric tax on electricity versus other sources of revenue, such as state income tax, sales tax or gasoline tax. Using government **consumption data for households** (https://www.bls.gov/cex/) in California, we compared how much customers in the lowest income bracket spend on electricity and other goods compared to consumers in higher income brackets. The figure above suggests that the highest-income quintile of households only spend about twice as much on electricity as the poorest quintile. But they spend about three times as much on gasoline, about four times as much on all goods other than electricity, and over four times as much on goods covered by the state sales tax.

In other words, we are paying for these fixed costs through a tax that is substantially more regressive than a sales tax or a tax on gasoline, both of which are generally viewed as pretty regressive ways to raise revenues. The figure below shows just why those are viewed as regressive taxes. It's the same as the figure above, but rescaled to fit in average income, which is 17 times higher for the highest quintile than for the lowest. Paying for these costs through even a flat tax on income would be far, far more progressive than through raising electricity prices.

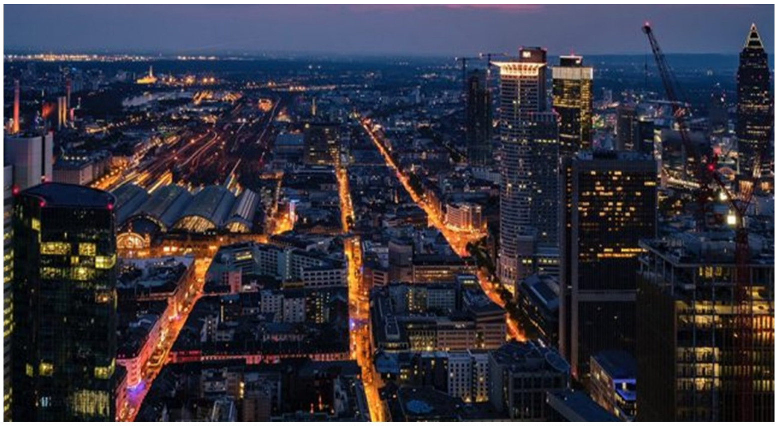


Back at the beginning of 2020 (about a decade ago), when we were starting this project, I suspected that one implication might be that it would be a good idea to move many of the public policy programs off of electricity rates and on to the state budget, financed in the general fund, *i.e.*, mostly through income taxes. Back then, California had a budget surplus. Raising that idea now just triggers laughter.

Reinventing Fixed Charges

When we have discussed this research with utility executives and with consumer advocates, there is remarkable agreement on the problem. But the agreement ends when the utilities propose their solution: **monthly fixed charges** (https://energyathaas.wordpress.com/2014/11/03/whats-so-great-about-fixed-charges/). Utility managers get all gushy over fixed charges, which bring greater revenue certainty and lower volumetric prices that encourage more usage of their product. But consumer advocates start to turn a purplish-red color (or maybe that's just Zoom) at the suggestion of increasing fixed charges, because that means charging every household the same amount (which would be a flat line at the bottom if it were on these graphs). Standard fixed charges are even more regressive than a volumetric tax on electricity.

Fixed charge advocates have countered that the charge could be reduced or waived for low-income households, such as the one-third of households on the CARE rate. But that still treats the other two-thirds of customers – from lower-middle income to extremely wealthy – the same. And, the CARE program is not exactly closely monitored. Income level is verified for only 1% of the households who sign up for the program, and there is little penalty for falsely claiming eligibility.



(Source: https://theclimatecenter.org/us-cities-see-blueprint-for-building-electrification-in-berkeley-gas-ban/)

While brainstorming alternative funding sources, we realized that fixed charges could be efficient and equitable if they were truly income-based and income-verified. Who has the information to do that? The taxman.

Broadly, here's how it would work: Households would pay a substantial monthly fixed charge, and then on their state tax return they would document the payments by submitting a utility ID that would be matched with billing information from their utility. That would automatically trigger a refund of all or part of their fixed charge payments depending on their income. The state would then collect the rebated revenue from the utility.

To implement this, some institutional barriers would need to be overcome: California's Franchise Tax Board would need additional personnel to manage this process; utilities would have to be able to exchange information and money with the FTB; not all utility customers file state income taxes (though it would be worthwhile for a rebate of many hundreds of dollars)[1]; and some low-income customers would face cash flow issues. The cash flow problem could be addressed by allowing customers to stipulate their income in advance and pay the associated lower fixed charge, subject to verification when they file taxes.

Is this approach really feasible? Yes! The federal **Earned Income Tax Credit (https://www.cbpp.org/research/federal-tax/policy-basics-the-earned-income-tax-credit)** has worked in a very similar way for decades, with households getting a refundable tax credit based on the income they demonstrate on their tax return. **California introduced its own EITC (https://www.ftb.ca.gov/file/personal/credits/california-earned-income-tax-credit.html)** in 2015, which operates the same way. And the **Affordable Care Act's subsidies for low-income households (https://blog.taxact.com/how-the-affordable-care-act-subsidies-work/)** follow this approach, including allowing households to stipulate their income and qualify for the subsidy upfront, which is then verified and potentially adjusted when they file their tax return.

Electricity rate design in California today is seriously broken, both in the distorted incentives it creates and in the regressive impact. That will only worsen as more high-income households install solar and, now, batteries. At some point soon, we need to create a system that is not just environmentally sustainable, but also financially sustainable and equitable. Income-based fixed charges could help attain all three goals.

[1] Undocumented residents **can** (https://bipartisanpolicy.org/blog/how-do-undocumented-immigrants-pay-federal-taxes-an-explainer/), and **many do** (https://itep.sfo2.digitaloceanspaces.com/immigration2016.pdf), file tax returns. The information is not supposed to be shared with immigration authorities, which it seems California could credibly commit to.

Keep up with Energy Institute blogs, research, and events on Twitter @energyathaas.

Suggested citation: Borenstein, Severin. "Reinventing Fixed Charges" *Energy Institute Blog*, UC Berkeley, November 16, 2020, **https://energyathaas.wordpress.com/2020/11/16/reinventing-fixed-charges/** (https://energyathaas.wordpress.com/2020/11/16/reinventing-fixed-charges/)

Severin Borenstein

VIEW ALL

Severin Borenstein is Professor of the Graduate School in the Economic Analysis and Policy Group at the Haas School of Business and Faculty Director of the Energy Institute at Haas. He received his A.B. from U.C. Berkeley and Ph.D. in Economics from M.I.T. His research focuses on the economics of renewable energy, economic policies for reducing greenhouse gases, and alternative models of retail electricity pricing. Borenstein is also a research associate of the National Bureau of Economic Research in Cambridge, MA. He served on the Board of Governors of the California Power Exchange from 1997 to 2003. During 1999-2000, he was a member of the California Attorney General's Gasoline Price Task Force. In 2012-13, he served on the Emissions Market Assessment Committee, which advised the California Air Resources Board on the operation of California's Cap and Trade market for greenhouse gases. In 2014, he was appointed to the California Energy Commission's Petroleum Market Advisory Committee, which he chaired from 2015 until the Committee was dissolved in 2017. From 2015-2020, he served on the Advisory Council of the Bay Area Air Quality Management District. Since 2019, he has been a member of the Governing Board of the California Independent System Operator.

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LETTER

Diffusion into new markets: evolving customer segments in the solar photovoltaics market

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Keywords: renewable energy, data analysis, technology diffusion, solar photovoltaics, distributed generation, customer acquisition

Supplementary material for this article is available online

Abstract

The US residential solar market is growing quickly, and as solar adoption diffuses into new populations, later adopters may differ significantly from earlier ones. Using a unique household-level survey dataset including 1234 adopters and 790 non-adopters from San Diego County, California, we explore differences in attitudinal and socio-economic factors for three groups: (i) adopters and non-adopters; (ii) early and more recent adopters; (iii) consumers adopting via buying or leasing. Our results suggest that adopters overall have higher incomes, are more educated, live in larger homes, and expect to stay in their homes for longer than their non-adopting peers. They also differ in their expectations of electricity retail rate changes and the impact solar could have on their home resale value. When examining differences between early and more recent adopters, we find that recent adopters are more representative of general homeowners and more politically moderate. They are also increasingly installing solar to protect against future electricity price increases and to lower electricity costs as opposed to adopting strictly for environmental reasons. Furthermore, more recent adopters differ significantly from earlier adopters in the situations that prompted them to adopt. The findings demonstrate how solar markets are evolving, reflecting changes in the underlying drivers of consumer adoption as well as innovative solar marketing strategies.

Introduction

The US residential solar photovoltaics (PV) market is expanding quickly, with installed capacity more than doubling between 2012 and 2014 (SEIA 2015). Several trends point to a maturing market—consolidation of market share among solar installers, increased access to low-cost capital (particularly from institutional funding sources), and increased competition between market players. For example, California, the largest market for solar in the US, stopped issuing state-issued rebates for residential systems in the second half of 2013 in the Southern California Edison (SCE) and Pacific Gas and Electric service territories, yet residential installations in 2014 were 50% higher than in 2013 (SEIA 2015). The US Federal Investment Tax Credit, once an irreplaceable incentive for making installations economical, is expected to decrease from 30% to 10% in 2016—and the industry will live on.

However, the solar industry is not completely in the clear. Customers still need to be recruited, and costs for acquiring customers are high, estimated at \$0.49 W^{-1} per customer, or roughly 10–20% of a system's costs (GTM 2013). In part this is because rooftop solar is an unproven commodity for many households. Trusted contacts from social networks (friends, family, coworkers, and neighbors) combined with observations of existing systems contribute significantly to convincing unsure customers. In response, the industry has experimented with a number of innovative advertising and marketing methods to either develop new leads or improve their conversion rate for existing ones. These methods range from door-to-door canvasing, to partnerships with

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established retailers, to purchasing customer leads wholesale from third-party aggregators (GTM 2013). All of these factors point to a continued need for research that can help identify new market segments, predict areas ripe for adoption, and test effectiveness of marketing tactics (Davidson *et al* 2014).

Customer behavior and preferences have been at the forefront of recent research related to solar adoption. The main framework consists of the consumer as a decision-maker, drawing on the behavioral economics, diffusion of innovations, and value-based norms frameworks (Stern *et al* 1999, Rogers 2003, Faiers and Neame 2006 and Wilson and Dowlatabadi 2007) to understand the economic, informational, social, and behavioral factors that drive adoption decision-making. Some insights from this field are that social networks can help reduce customer uncertainty (Bollinger and Gillingham 2012, Rai and Robinson 2013, Noll *et al* 2014, Graziano and Gillingham 2014) and that customers are motivated to adopt for a variety of reasons—not strictly financial or environmental concerns alone (Zhai and Williams 2011, Schelly 2014). Nonetheless, a number of barriers may inhibit adoption including high upfront costs, inadequate access to financing options, lack of awareness of available products, concerns about required system maintenance, and the perceived risk of PV negatively affecting home values (Margolis and Zuboy 2006, Hoen *et al* 2011). Compounding this complexity is price variation, which is a function of PV system characteristics but also search costs, imperfect competition, installer experience, and public policy (Gillingham *et al* 2014). In light of this, Rai and Robinson (2015) present an agent-based model of technology adoption applied to solar PV, using household-level resolution to represent demographic, attitudinal, social network, and environmental variables that impact decision-making. Accounting for financial aspects as well as agent-level attitudes and social interactions is determined to be critical in the prediction of adoption (Robinson and Rai 2015).

Furthermore, third-party ownership, or leasing, has been instrumental both in the market's expansion and in mitigating some of the barriers outlined above. Most lease contracts guarantee both production and operational and maintenance of the system, thus reducing risk and hassle to the consumer (Shih and Chou 2011). More importantly, leasing fundamentally inverts the financial proposition to the consumer by eliminating the need to take on debt or make a potentially large up-front payment. As many households do not have sufficient free cash to make these payments, leasing has helped to grow the market and attract new demographics (Drury *et al* 2012, Rai and Sigrin 2013, Davidson *et al* 2015).

To better understand what prompts solar adoption and how those underlying motivations are changing, we fielded two household-level surveys in 2013 and 2014 in the San Diego metro area to explore: (i) differences between adopters and their non-adopting peers, and (ii) demographic and attitudinal variations within adopter populations and how they have changed over time. Our analysis presents novel statistical testing results that compare adopters and non-adopters along socio-demographic dimensions, expectations of electricity rate changes, and self-reported importance of various factors in the decision to adopt. We also compare responses from early adopters and more recent ones to explore how markets may be changing; to our knowledge, this is the first study to do so using recent adoption data. While we are not able to attribute causality, our findings provide new insights into how the underlying factors that contribute to the solar adoption decision-making process at the residential level are changing.

Data

Two surveys of San Diego households were conducted in 2013 and 2014 for: (1) homeowners that had adopted PV ($n = 1234$) and (2) homeowners that had not adopted PV ($n = 790$). The surveys were designed to elicit new data exploring the factors that drive households to adopt PV, including stated motivations (e.g., wanting to save money, wanting to stabilize electricity expenditures, etc), stated barriers (e.g., upfront costs, impacts on home value, etc), personal attributes (e.g., political beliefs, demographics), social network characteristics (e.g., how many neighbors/friends have adopted), and access to information. For both surveys, the sampling was limited to homeowners since these are the households that benefit from installing PV. The sampled populations were not intended to be representative of the entire San Diego population, however controlling for homeownership allows us to understand how PV adopters differ from their peers.

Adopter survey

The PV adopter survey was administered as an online survey using SurveyGizmo in late 2013. It was in the field for three weeks, and two reminders were sent at the end of weeks one and two. Invitations to complete the survey were emailed to 10 064 PV adopters in San Diego County who had applied for California Solar Initiative incentives from January 2007 through the first quarter of 2013. Of these, participation in individual sections of the survey ranged from about 880 to 1230. The final response rate was approximately 15%, defined as the ratio of fully or partially completed surveys by the number of successfully-delivered solicitations.

To ensure representativeness of survey respondents to the population of PV owners in San Diego, we looked at two factors: (1) whether the respondent pool represented the breakdown between third-party owned PV customers and host owned PV customers;

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(2) whether respondents effectively represented adoption from early years (pre-2009) as well as more recent years (2012–2013). For (1), we find 29.7% of survey respondents leased compared to 30.6% of all PV adopters in San Diego (CSI 2014). For (2) we find a small bias towards over-representing recent installations—28.8% of survey respondents reported adopting in 2012 versus 25.3% of actual installations in 2012, and 2.3% versus 1.5%, respectively, for the first quarter of 2013.

Non-adopter survey

The survey for PV non-adopters, administered in early 2014, was fielded through Qualtrics and sent to single-family homeowners in San Diego County that had not adopted rooftop solar systems. Responses were solicited until reaching a pre-determined number of 790 completed survey responses.

The non-adopter's instrument used many of the same questions from the PV adopters survey so that responses could be compared across the populations. These include demographics, relative importance of factors in the adoption decision, and home characteristics. The non-adopter survey also included additional questions exploring any contacts that homeowners have had with solar installers to control for exposure to the solar industry.

Results

Our analysis focuses on understanding differences between adopters and non-adopters, motivations for adoption, and how the motivations and customer segments for adopters are evolving. We also briefly examine differences across adopters that decide to lease versus buy as this is another method of segmenting customers. We do not attempt to identify causal patterns; rather, we use various statistical difference tests to support our observations.

Differences in adopters versus non-adopters

We first examine the attitudinal and demographic differences between adopters and non-adopters, using Student's t-tests with the null hypothesis being the mean of adopters' responses equals that of the non-adopters, finding a number of statistically significant differences. Specifically, adopters tend to have higher incomes by $50 100 on average and are more highly educated. Adopters also differ in that they live in larger homes, potentially a proxy for higher electricity costs, and also expect to stay in their current homes by nearly 6.5 years longer than non-adopters (table 1). As the income and education variables were initially solicited as ordinal categorical measures, we convert them to numeric responses by using the midpoint of income intervals and converting education to the number of years of post-secondary instruction.

For non-ordinal categorical variables, we use a Pearson's Chi-Squared test for differences in distribution of responses. Adopters were found to be significantly more likely to have children living in the household ($\chi^2 = 30.79$, df = 1, $p < 1\text{e}{-}05$), with 32.5% of adopters reporting at least one child living in their households compared to 19.5% of non-adopters. No difference was found in the likelihood of being retired with 43.0% of adopters retired relative to 42.7% of non-adopters. Adopters were also more likely to have air-conditioning (77.1% of adopters versus 63.9% of non-adopters) ($\chi^2 = 37.58$, df = 1, $p < 1\text{e}{-}05$) or a pool (37.3% of adopters versus 18.2% of non-adopters) ($\chi^2 = 79.05$, df = 1, $p < 1\text{e}{-}05$).

Concerns over high electricity bills, in addition to concerns about future rate changes, are often highlighted as a motivation for adopting solar—particularly in California, which has some of the highest retail rates in the US. In both surveys, households were asked how they thought electricity rates would change over the next 5 years. A majority of respondents in both populations expect electricity costs to increase substantially and at a faster pace than the long-term Consumer Price Index average (BLS 2014). Expectations between groups significantly differed ($\chi^2 = 106.3$, df = 7, $p < 1\text{e}{-}05$), with 'rates about 30% higher in the next five years' the most common expectation from adopters, and '20% higher' as the most common response for non-adopters. Specifically, almost half of adopters (45.2%) expect rates to increase by at least 30% over the next five years, whereas only a quarter of non-adopters (25.2%) hold the same opinion.

Table 1 presents statistical test results for the differences in factors adopters and non-adopters considered to be important when adopting solar as well as socio-demographic factors. Lowering one's bill and protection from future rate increases were considered the two most important factors for both groups, but we do not find there to be statistically significant differences in the importance of these factors between adopters and non-adopters. This, along with the observation that adopters expect higher electricity rate increases in the future, suggests that the relative importance of this expectation is not necessarily a factor in the adoption decision, but instead, expectations of electricity rate increases among non-adopters were not high enough to spur adoption. This is reasonable considering we have already observed that non-adopters have lower incomes and smaller home sizes, which likely translates into overall lower electricity consumption. This places these households in lower electricity rate tiers, and thus the matter of electricity price increases may be less salient to non-adopters. Adopters' concerns over rate increases either could have been a prior opinion that spurred initial interest or an outcome of the adoption process itself (i.e. personal research, conversations with installers, etc).

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Table 1. Comparison of demographic and adoption factors for solar adopters and non-adopters.

H_0: $\mu_{adopt} = \mu_{nonadopt}$	Adopters	Non-Adopt			*p*-value	95% CI of difference	
Unequal var. assumed	Mean	Mean	*t*	df	2-Tailed	Lower	Upper
Edu (years post-secondary)	4.54	4.15	4.07	1666	5.0e−5***	0.13	0.67
Income ($1000)	164.9	114.8	10.4	1568	<1e−5***	40.6	59.5
Exp. remain in house (years)	21.3	14.9	13.1	1614	<1e−5***	5.39	7.30
Home size (sq. ft)	2653	2062	10.7	1834	<1e−5***	482	698
Imp. of lower elec. costs	4.56	4.59	−0.72	1684	0.472	−0.10	0.047
Imp. of protect increase in elec. prices	4.47	4.46	0.33	1816	0.745	−0.06	0.09
Imp. of protect environment	3.86	3.92	−1.05	1807	0.294	−0.164	0.050
Imp. of increasing home value	3.15	3.88	−13.39	1845	<1e−5***	−0.831	−0.619
Imp. of home easier to sell	2.50	3.64	−18.97	1780	<1e−5***	−1.26	−1.021

Significance codes: *** significant at 0.1% level or greater, ** significant at 1% level, and * significant at 5% level.

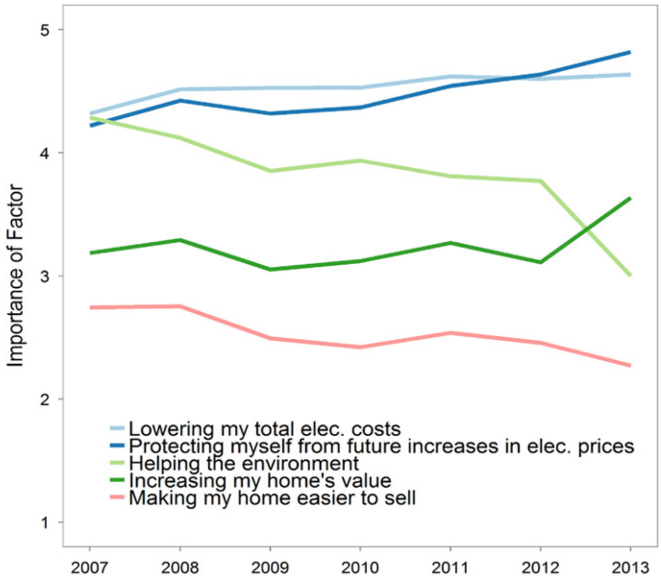

Figure 1. Evolution of important factors in adopting solar.

Non-adopters rated the importance of increasing home value and making the home easier to sell more highly than their adopting counterparts. It is logical for non-adopters to have greater concern about the impact of PV on their home's value and salability as they have indicated an intention to live in their homes for shorter periods. However, much of the current literature indicates that PV has a sizable positive impact on home resale value (Hoen *et al* 2015), which suggests non-adopters are either unaware or unconvinced of this effect. If the potential home resale value increase is enough of an incentive to motivate adoption, efforts to provide additional information could provide a low-cost opportunity to expand market size.

Motivations for adopting and how customer segments are evolving

As markets mature, they diffuse into new populations and locations to continue growing. A key prediction from the diffusion of innovations literature is that there are attitudinal and demographic differences between early-adopting individuals and the rest that follow them (Rogers 2003, Wilson and Dowlatabadi 2007). For example, while initial adopters are sometimes motivated to adopt based on the novelty of a new technology, the general populace requires a clearer degree of relative advantage between the old and new technology to consider adopting.

Figure 1 shows the relative importance of multiple factors in the decision to install solar for adopters from 2007 to 2013 (1 = 'not at all important', through 5 = 'very important'), where lowering total electricity costs and protecting one's household from future increases in prices were rated the two most important factors. Compounding this, importance of economic factors increase over time, whereas environmental concerns are decreasing in relative importance.

To further explore these observations, we tested differences between early adopters and more recent

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Table 2. Comparison of importance factors for early (2007–2010) versus recent adopters (2011–2013).

$H0: \mu_{recent} = \mu_{early}$	Recent adopter	Early adopter			*p*-value	95% CI of difference	
Unequal var. assumed	Mean	Mean	*t*	df	2-tailed	Lower	Upper
Imp. of lower elec. costs	4.61	4.52	1.87	1045	0.062 (.)	−0.005	0.191
Imp. of protect increase in elec. prices	4.6	4.35	4.455	982	9.3e−6***	0.137	0.354
Imp. of protect environment	3.77	3.94	−2.207	1046	0.028*	−0.322	−0.019
Imp. of increasing home value	3.19	3.11	1.037	1052	0.3	−0.073	0.236
Imp. of home easier to sell	2.49	2.53	−0.465	1026	0.642	−0.205	0.127

Significance codes: *** significant at 0.1% level or greater, ** significant at 1% level, * significant at 5% level, and (.) significant at 10% level

adopters by conducting a series of Student's t-tests with the null hypothesis being that the means for early adopters (2007–2010) equal those of the more recent adopters (2011–13). While our primary intent is to demonstrate market changes over time, we acknowledge there is no obvious cut-off for what defines an early adopter in the solar PV market. As such, we conducted additional sensitivities on alternative definitions of early adopters to provide robustness to our results (see supplemental materials).

The results suggest that the importance of protecting the environment is less of a motivation for recent adopters relative to early adopters ($p = 0.028$) whereas protecting against future increases in electricity prices is more important for recent adopters ($p = 0.000$) (table 2). Lowering electricity costs is also more important for recent adopters ($p = 0.062$). While the changes are relatively small in magnitude considering their scaling and categorical framework, the differences are statistically significant, suggesting some level of change. These findings highlight how homeowners are increasingly installing solar because it is an economically attractive investment opportunity—not just because of the associated environmental benefits. This could be the result of market maturation, but it also could be driven by strategic marketing strategies that focus on communicating certain benefits of adoption. When defining more recent adopters as those that adopted in 2012–2013 and early adopters as those that adopted in either 2007–2011 or 2007–2009, the results hold except that we lose significance for the importance of lowering electricity costs (tables S1 and S2). Taken together, these findings demonstrate how recent adopters appear to be installing solar for different reasons than earlier ones.

Early and recent adopters are also compared along demographic and political identification. We find that recent adopters are less educated than early adopters and more centrist on political ($p = 0.019$), social ($p = 0.033$), and economic ($p = 0.026$) issues (table 3).[5]

Examining the actual distribution of responses for political identity is instructive as well, which demonstrates large increases in the percent of respondents that self-identify as slightly conservative or conservative (24.9–30.3%) along political issues for early and recent adopters and corresponding decreases in slightly liberal or liberal respondents (30.2–22.8%). Put another way, greater numbers of early adopters identified as liberal in some way (37.6%) than conservative (33.6%), whereas affiliations have inverted for recent adopters (27.9% liberal, 40.8% conservative), with similar trends along affiliations for economic and social issues (see table S5). Overall, broad trends in political identification provide another nuanced view into how PV markets are evolving and where framing considerations could help broaden the appeal of the product to a wider set of consumers. In fact, these observations could reflect the result of existing marketing strategies that aim to appeal to different consumer segments. See tables S3 and S4 for additional detail on the sensitivity of the political inferences to 'early' and 'recent' adopter cutoffs.

It is also often the case that specific events stimulate interest in PV. The most common events that adopters cited as leading them to serious consider solar were: increasing electricity rates (32%), planning for retirement (24%), talking to friends or family members with solar (21%), direct marketing by solar companies (16%), and planning a remodeling project (11%).[6] The top two events reflect a common theme from survey respondents expressing concern over rising electricity costs or economic concerns in general; influence from social groups is also strong overall (Bollinger and Gillingham 2012, Rai and Robinson 2013, Graziano and Gillingham 2014). A surprising observation is the relative importance of retirement planning in the decision to adopt rooftop solar systems in our sample. Although we did not observe higher rates of retirees in the adopter sample as compared to non-adopters, prevalence of

[5] Note that while survey takers identify as being liberal or conservative on a scale from 1 (very liberal) to 7 (very conservative), survey takers also could identify as libertarian. We did not wish to omit these responses because of the potential bias that would be introduced, so we classify libertarians as being the most conservative (an 8 on the scale) for our analysis.

[6] Since respondents were allowed to indicate more than one event, the percentages do not sum to 100%.

Table 3. Comparison of demographics and political views of early (2007–2010) versus recent adopters (2011–2013).

$H0$: $\mu_{recent} = \mu_{early}$	Recent adopter	Early adopter			p-value	95% CI of Difference	
Unequal var. assumed	Mean	Mean	t	df	2-tailed	Lower	Upper
Age at time of adoption (years)	56.9	56.4	0.664	931	0.507	−0.932	1.884
Edu (years post secondary)	4.18	4.44	−2.015	881	0.044 *	−0.516	0.007
Income ($1000)	129.0	141.4	−1.195	627	0.233	−32.8	7.994
Married (1 = yes, 0 = no)	0.875	0.87	0.243	944	0.808	−0.037	0.048
Retired (1 = yes, 0 = no)	0.41	0.444	−1.057	960	0.291	−0.096	0.029
Politics (1 = very liberal to 8 = very conservative)	4.54	4.23	2.347	879	0.019 *	0.052	0.578
Social issues (1 = very liberal to 8 = very conservative)	3.93	3.64	2.136	866	0.033 *	0.023	0.548
Economic issues (1 = very liberal to 8 = very conservative)	4.98	4.71	2.23	871	0.026 *	0.032	0.502

Significance codes: *** significant at 0.1% level or greater, ** significant at 1% level, and * significant at 5% level.

retirement planning as a trigger indicates potential as a significant market segment.[7]

As the market is evolving, however, we were also interested in whether more recent adopters were more heavily influenced by different prompts than their early-adopting peers, since this could reflect either changing motivations for adopting or more targeted marketing by solar companies. Recent adopters were more frequently prompted by electricity rate increases relative to their early-adopting peers ($p = 0.001$), again highlighting the increasing relative importance of economic factors in decision-making. In addition, we found that advertisements ($p = 0.0008$) and direct marketing ($p = 0.049$) were more significant drivers for recent adopters (2011–2013) relative to early adopters (2007–2010), which suggests that marketing efforts may have strengthened. On the other hand, early adopters were more likely to be prompted by other solar owners as part of a home tour ($p = 0.006$) (see supplementary material table S6). The results generally hold across our sensitivity checks as well (see tables S7 and S8). We did not find there to be a statistically significant difference in being motivated by upcoming remodeling projects, retirement plans, seeing neighbors with solar, or talking to neighbors or friends about solar over time.[8]

Differences in buy versus lease samples

Momentum in PV adoption has recently been heavily skewed towards third-party ownership (leasing), as opposed to host-ownership (buying), though host-ownership has made a resurgence in 2015 due to increased access to reduced cost capital (SEIA 2015, CSI 2014). Because our survey covers adoption from 2007 to 2013, it is demonstrative of this shift towards third-party ownership—overall, 26.3% of adopters leased their system, whereas for adoption in 2012–2013 only, leasing comprises 52.2% of the sample. Therefore, it is instructive to understand differences in the third-party owned sample as compared to the host-owned. Note that we do not control for time in this comparison, so while our analysis provides some descriptive insights into how buyers and leasers differ in general across the sample, it does not account for how those differences may or may not be changing.

Customers adopting via host-ownership reported that different situations or events prompted their initial interest in installing solar panels as compared to third-party adopters (figure 2). Specifically, for leasers, ‘recent increases in prices’, ‘a conversation with a friend or family’, and ‘direct marketing by a solar company’ were the three most likely events to prompt interest. By comparison, ‘thinking about retirement planning’ and ‘conversations with friends or family’ were the second and third most likely events for buyers. In general, leasers reported being more highly influenced by installer advertising (radio, TV) and marketing, whereas buyers were more influenced by personal contacts.

In regards to demographic differences between leasers and buyers, previous research has presented contradictory findings. For example, Drury et al (2011) found demographic differences in SCE territory at the zip code level, with adoption by leasers associated with areas with lower mean incomes and educational levels. In contrast, Rai and Sigrin (2013) found no significant difference between the groups in the nascent Texas market when surveying individual households.

To test differences in our sample, we conducted a series of Student’s t-test with the null hypothesis that the mean of buyers’ responses equals that of the leasers’. We find somewhat mixed results (see supplementary table S9) with some demographic and

[7] Despite having a sunny climate, San Diego County does not have a higher rate of retirees (12.3%) than the rest of California (12.5%) (US Census 2013).

[8] Note that we are not saying that these factors are not significant determinants of adoption, but just that their relative importance hasn’t changed over time.

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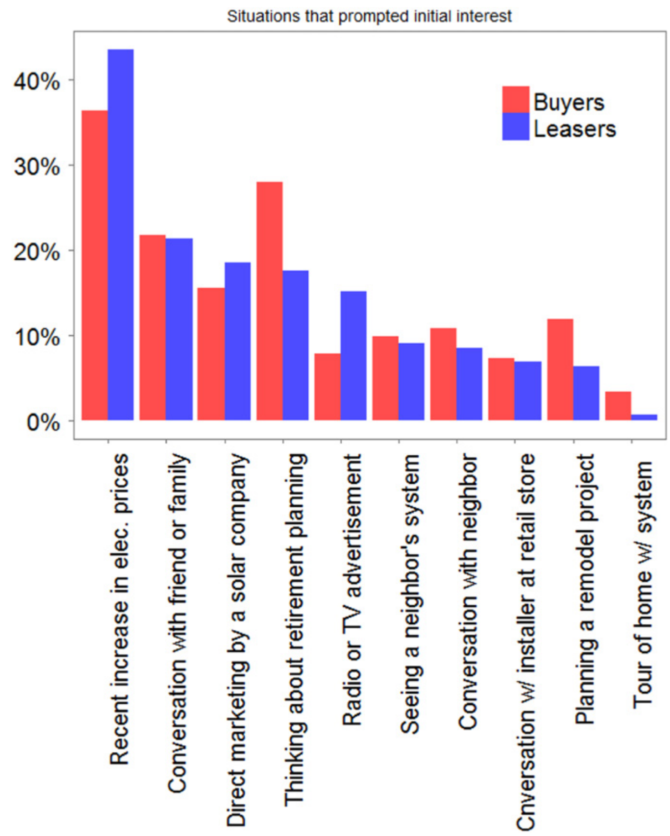

Figure 2. Buy versus lease differences in events that prompted adoption interest.

attitudinal differences between customers from the two business models. Specifically, buyers are found to have higher incomes by \$13 000 on average, though the result is not statistically significant. Buyers and leasers are roughly the same age, however buyers have nearly half a year of additional post-secondary education than leasers ($p = 4.9\text{e}{-5}$). In addition, leasers were less likely to be retired (38% of sample versus 45%) and more likely to have children living at home (37% versus 31%) though results are only significant at a 90% CI ($\chi^2 = 3.21$, df = 1, $p = 0.073$) and ($\chi^2 = 2.97$, df = 1, $p = 0.085$) respectively. For factors that adopters indicated were important in their decision to adopt PV, buyers rated 'lowering my total electricity costs' as being the most important, whereas 'protecting myself from future increases in electricity prices' was the most important factor for leasers (table S9). However, the only statistically significant difference is in the importance of protecting against future electricity prices. Aside from this difference, the two groups rated the remaining factors of decision-making with comparable magnitude of importance.

Lastly, adopters were asked how much they agreed with various statements related to their business model decision-making process (i.e., to buy or lease) with response options ranging from 1 (strongly disagree) to 5 (strongly agree). These perspectives included which business model seemed easier, would save more money in the long run, created more concern about signing a long-term contract, if selling the home would be easier, and whether those that the adopter knew had bought or leased their systems. We find there to be statistically significant differences in the importance of each of these priorities and perceptions across buyers and leasers at the 99.9% significance level (see supplementary material table S10). Specifically, buyers agree more with statements regarding the economics of the system—such as saving more money in the long run and ensuring that installing a solar system will not impede the ability to sell the home—suggesting that the long-run economics were more relevant to buyers relative to leasers than other features of the business model. Buyers are also more heavily influenced by the business model choice of their peers. In other words, they seem to be influenced by peer effects more strongly than leasers. On the other hand, leasers were more concerned with pursuing a simpler business model as they agreed more heavily with statements concerning the ease of the process and contract length.

While this analysis does not identify the causal drivers of the decision to lease or buy solar, it provides insights into how these customer segments differ. The findings have considerable implications for solar companies developing marketing campaigns and informational products that are specifically intended to motivate either leasing or buying options. Future work

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will explore the determinants of the business model decision more robustly.

Conclusion

The US residential solar market is growing quickly, and to continue growing, it must expand into new populations. In the San Diego market, motivations for adopting are evolving, with environmental concerns decreasing in priority, replaced with greater interest in economic motivations and, particularly, reducing exposure to higher future bills. In other words, adopters appear to be increasingly pursuing solar installations not just in an effort to contribute to mitigating environmental challenges, but also because it is an economically attractive investment option. Furthermore, customers leasing their systems now constitute a majority of new installations in many markets—and these customers are more representative of the general population than early adopters. Buyers and leasers appear to differ on the importance of protecting against future electricity price increases in our sample. Taken together, the findings from this research could help to inform the development of a framework for segmenting customers. On the other hand, while our analysis provides insights into how the motivations for adopting solar appear to be changing more broadly, it is unclear whether this change is associated with actual beliefs and decision-making drivers or whether this is the symptom of targeted marketing strategies that highlight specific benefits of solar adoption in their communications. Future work could use this unique household level survey data to more robustly explore the causal determinants of adoption, considering the novel attributes consistently captured in our dataset across both adopters and non-adopters.

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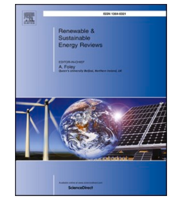

Early adopters and their motives: Differences between earlier and later adopters of residential solar photovoltaics

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ABSTRACT

To facilitate and forecast the diffusion of sustainable innovations, such as solar photovoltaics (PV), it is important to understand what motivates people to adopt them. Early adopters are known to be partly driven by other motives than late adopters, and adoption motives may thus change over time as new user segments gain interest in the technology. This paper investigates differences in adoption motives between the earliest and somewhat later adopters of residential PV systems. First, a systematic literature review is conducted, in which the findings of previous studies are mapped against the market maturity of their empirical contexts. The review reveals that the earliest PV adopters are driven mainly by environmental concern and technophilia, while later adopters are driven predominantly by economic gains. Second, an empirical investigation of Swedish adopters over a nine-year period is conducted, using Green Party voting as a proxy for environmental concern. It is found that the relationship between Green Party voting and PV adoption weakens over time, again suggesting that the earliest adopters are more driven by non-financial motives such as environmental concern than later adopters. The results can inform diffusion forecasting as well as marketing and information campaigning intended to induce PV adoptions.

1. Introduction

To mitigate climate change, it is important to understand current and future diffusion patterns of renewable energy technologies, such as solar photovoltaics (PV). Knowledge on how different factors influence diffusion can facilitate the design of policy instruments and marketing intended to increase adoption rates, and help researchers and authorities forecast future diffusion. Not least, it is important to understand the motives that different actors might have for adopting – i.e. acquiring and start using – a new technology, and how these motives develop over time as the market matures and new user segments start adopting the technology. In other words, it is desirable to grasp what differs earlier adopters from later ones.

Research on the diffusion of innovations goes back several decades [1]. A common objective of this literature has been to shed light on what distinguishes the earliest adopters (in terms of e.g. motives or personality traits) from later or non-adopters [e.g.2]. Yet, the understanding of these dynamics remains limited, with evidence being weak for many of the most cited predictors of early adoption [1].

The purpose of this paper is to investigate how adoption motives differ between earlier and later adopters of residential solar PV systems. Solar PV is a promising renewable energy technology that is suitable for both large- and small-scale applications [3]. The market for residential PV systems – i.e., PV systems adopted by households, typically as rooftop installations – has grown rapidly around the world in recent years, although this market growth has been unevenly distributed between countries [3]. Hereafter, “PV” will refer to residential PV systems if not otherwise stated. Existing studies of PV adoption motives tend to provide snapshots of motives from different contexts, while the understanding of shifts in motives over time, as PV markets develop, is limited. To facilitate and forecast PV diffusion in immature as well as more mature markets, it is useful to understand adoption motives of the earliest as well as later PV adopters. For example, public information campaigns and marketing efforts that are purposeful in an immature market may need adjustment to appeal to later adopters.

The paper employs a systematic literature review and an empirical investigation of Swedish PV adopters over a nine-year period. The systematic review maps findings regarding PV adoption motives against the level of market maturity of the studies’ empirical contexts, thus revealing general patterns of differences in motives between earlier and later adopters. The empirical study employs a – for this research area – novel approach to investigate how a non-financial adoption motive – namely environmental concern (measured though a proxy variable) –

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List of abbreviations

IEA	International Energy Agency
GHI	Global horizontal irradiance
kW	Kilowatt
m	Meter
MW	Megawatt
MWh	Megawatt hour
PV	(Solar) photovoltaics
SEK	Swedish kronor
UK	United Kingdom
US	United States (of America)
USD	United States dollar

has developed over time in Sweden. More specifically, it uses regression analysis to investigate the relationship between Green Party voting and PV adoption over time (this approach is justified in section 4). The empirical research, using fundamentally different data and methodology from previous research, corroborates the review's results through triangulation.

The rest of the paper is structured as follows. In the next section, an overview of concepts and findings of previous literature is provided, covering the following topics: differences between earlier and later adopters of innovations in general; factors known to affect PV adoption rates; and differences between earlier and later PV adopters. In section 3, a more systematised and delimited literature review is performed, in which PV adoption motives and local market maturity are mapped and compared to identify differences between earlier and later PV adopters. In section 4, the research design of the empirical study is presented, while the empirical results are presented in section 5. Conclusion and discussion are provided in section 6.

2. Frame of reference

This section provides an overview of concepts and findings of previous literature related to early adoption of innovations and to PV diffusion. This broad review contrasts to a more delimited and systematised review, mapping PV adoption motives against local market maturity, which is presented in the subsequent section.

2.1. The earliest adopters of new technology: their characteristics and what motivates them

Research on what distinguishes earlier adopters from later ones goes back to the first half of the 20th century. The most well-known work on this topic is Rogers seminal book *Diffusion of innovations* [2; first issued in 1962] in which (among several other contributions related to innovation diffusion) adopters were divided into idealised categories depending on how early they are to adopt new innovations in relation to other people in their social system. Rogers presented a set of personality traits and other characteristics that proposedly distinguished earlier adopters from later ones. He referred to the very earliest adopters as *innovators*, whom he considered to constitute about 2.5% of all potential adopters. Somewhat later to adopt were, in this framework, the *early adopters*, constituting about 14% of all potential adopters, after which, in the following order, the *early majority*, *late majority,* and *laggards* adopt the technology. According to Rogers, innovators tend to be venturesome and eager to try new ideas, and to maintain cosmopolite rather than local social relationships. Across all adopter categories, Rogers described earlier adopters as more intelligent, more accepting towards change, and more able to cope with uncertainty and risk, among various other characteristics.

As PV diffusion is still in an early stage around the world [3], existing PV adopters are, using Rogers' terminology, dominated by innovators in most markets. In the present study, however, existing adopters will also be referred to as 'earlier' versus 'later' adopters to reflect the possibility of a gradual shift in their characteristics rather than discrete categories. 'Earlier' and 'later' adopters are, thus, used as relative terms that do not necessarily follow Rogers' categories. As the present paper mainly studies innovators, 'earlier' adopters will – when this paper's results and data are discussed – refer mainly to early innovators, while 'later' adopters will include late innovators and subsequent adopters. When discussing other studies or innovation diffusion at large, however, 'earlier' and 'later' adopters – being relative terms – might correspond to other adopter categories depending on the context discussed.

The general validity of Rogers framework has, nevertheless, been disputed [e.g. 1]. Rogers' work is largely empirically based on adoption of farming equipment in the rural US, and it is unclear to what extent it generalises to other technologies and contexts. Alternative frameworks have been proposed, for example by Bass [4] who classified adopters not depending on their timing of adoption but on their degree of social influence versus imitation. Bass terms those who adopt independently of others in their social system as 'innovators' and those who are influenced by their peers as 'imitators'. Rogers' framework is, nevertheless, by far the most established one [e.g.5] and the present paper will employ his terminology.

More recently, various empirical studies have investigated predictors of early adoption. Dedehayir et al. [1], performing an extensive literature review, conclude that the characteristics of innovators and early adopters vary by product category and context. Dedehayir et al. conclude that the empirical evidence for many of the most cited variables is weak, stating that "some of the widely held notions about innovators and early adopters of innovations are not confirmed". More specifically, they find that sociodemographic variables such as age, education and gender show inconsistency, while the more consistent predictors of early adoption include technophilia, previous early adoption of other technologies, and access to resources such as knowledge, technical skills, experience, and networks [1]. Among economic variables, the review of Dedehayir et al. [1] reveals that high income as well as an orientation towards obtaining profits and savings tend to predict early adoption.

The present study investigates environmental concern as an adoption motive. Environmental concern has been found to drive early adoption in studies of technologies related to farming, transportation, food, and energy [e.g.6–13]. However, most of these studies do not compare earlier adopters to later ones, but rather rely on studying innovators or early adopters in isolation, or on comparing them to non-adopters (assuming that these represent later adopters). Thus, it remains unclear whether environmental concern is less important for later adopters of these technologies. The present study, in contrast, studies actual adopters – both earlier and later ones – to identify differences between them.

2.2. Factors driving residential solar PV diffusion

Various qualitative and quantitative studies have investigated factors affecting the diffusion of residential PV systems. Among the most reliable predictors of adoption are factors related to economic gains, such as solar insolation, subsidies, PV system prices, electricity prices, and electricity consumption [14–22]. For example, Jacksohn et al. [18], using household-level data on sociodemographic factors, housing, environmental concern, personality traits, and economic factors, found that German adopters were primarily driven by economic factors. Alipour et al. [14], performing a systematic literature review, conclude that social variables such as gender, political affiliation, age, population density, and race/ethnicity are often poor predictors of PV adoption. On the other hand, education level tends to correlate with PV adoption [14]. Attitudes and values also matter, for example regarding government policy, environmental issues, energy autonomy, novelty seeking, and

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different aspects of PV technology [14].

Predictors related to the built environment have been found important. In particular, the share of detached homes, the size of homes and households, housing/population density, home ownership, and home value tend to correlate with PV adoption [14,22,23]. Graziano and Gillingham [23] found that built environment variables were more important than “socioeconomic, demographic and political affiliation variables”. They also found that PV diffusion occurs through a wave-like, centrifugal pattern emanating from smaller and midsized population centres rather than larger urban areas. Whether a household is located in an urban or rural region is, however, a poor predictor [14].

Income tends to correlate with PV adoption, although some studies point in the opposite direction [14]. While studies using highly aggregated data (mean or median income of large numbers of households) have resulted in ambiguous findings [e.g.24,25], studies using more fine-grained data including total wealth (rather than income only) [26], or household-level data [18], reveal that financially stronger households are more likely to adopt PV. De Groote et al. [22] found that the effect of average income disappeared once variables for home ownership and household size were added. Furthermore, they found that income dispersion increased PV adoptions, which they attribute to adoptions mainly occurring in the upper tail of the income distribution. Third-party ownership business models can facilitate PV adoption among less affluent households, thus reaching new customer segments [27,28].

Information availability has been found to be important for PV adoption. Important information channels, through which homeowners learn about PV, are governments, NGOs, suppliers, peers and media [14]. Information campaigns orchestrated by public entities have been found to substantially increase PV adoption [29,30]. Case studies suggest that local actors can induce PV adoptions through various informational activities [31–33]. Knowledge about financial and technical aspects of PV are useful predictors of adoption [14].

Peer effects are an important driver of PV diffusion as existing adopters influence others (e.g. neighbours and friends) to adopt [14,23, 34,35]. The earliest PV adopters often have a desire to prove the concept and inform others about the benefits of PV [36–39]. Research suggests that peer effects in PV diffusion operate more through word-of-mouth than passive observation, and that prospective adopters experience reduced uncertainties when talking to trusted PV owners [40].

Voting behaviour has shown mixed results as a predictor of PV adoption. Democrat voters in the US have been found to be about as likely to adopt PV as Republican voters, while people voting in US general elections are substantially more likely to adopt PV than non-voters [41]. Drury et al. [27] found that voting for a Californian proposition to reduce carbon emissions was a poor predictor of PV adoption. Support for political ‘Green Parties’ has shown inconsistent results in predicting PV adoption; while van der Kam et al. [25] found Green Party voting to be a significant predictor, other studies have found no or ambiguous effects [20,42,43]. The inconsistency of Green Party voting as a predictor of PV adoption is perhaps not too surprising; Green Parties and political landscapes and discourses differ between contexts. Thus, Green Party voting may arguably show different effects in different contexts even if environmental concern has a more consistent (albeit unobserved) effect.

Studies have also investigated correlations between PV adoption and other sustainable behaviour. The adoption of electric and hybrid vehicles has proven a strong predictor of PV adoption [21,34,44]. However, as PV ownership makes the adoption of such vehicles more profitable for households [45], this relationship might be driven more by economic gains than environmental concern. Participation in a green power scheme has shown some predictive value [16], while recycling behaviour has been found insignificant [42].

Interview and survey studies have found that environmental concern, economic gains, and technophilia are common adoption motives as stated by adopters themselves [e.g.36,37,46,47]. Technophilia among PV adopters is, according to this research, not necessarily general, but often limited to domestic energy technology or similar [37]. A related motive is to demonstrate the technology’s viability [36–38]. Energy independence is another common self-stated motive [39,47–49]. Although environmental concern is often important, even the most environmentally concerned PV adopters tend to concede that other motives were necessary for them to adopt as well – that is, environmental concern is necessary but not sufficient for them [37,50,51].

However, the validity of research relying on self-stated motives is jeopardized by potential social desirability bias [cf.52]. Indeed, indications have been found that interviewees and respondents tend to overstate altruistic motives over e.g. financial ones [53,54]. This research also remains inconclusive regarding the relative importance of motives – while some studies have found environmental concern or technophilia to be most important [e.g. 36,37], other studies have found other motives – mainly economic gains – to be more important [e.g. 55, 56]. As will be demonstrated in section 3 of the present paper, this apparent inconclusiveness is largely due to different studies studying adopters in markets of different levels of maturity. Once taking the earliness of adopters into account, a pattern emerges in which the earliest adopters tend to stress environmental motives, while later adopters stress economic gains.

2.3. Previous research on differences between earlier and later residential PV adopters

Little research exists on what characteristics differ between earlier and later PV adopters. Below, previous research on this topic is accounted for. Most of these studies have other main foci than differences between earlier and later adopters, and their findings on this topic are thus rather succinct. In this subsection, only studies of actual adopters, or people presumed to adopt soon, are considered, meaning that the studied adopters (also the ones referred to as ‘later’) are all relatively early in a broader perspective (even later adopters have not been empirically studied as they do not yet exist).

Sigrin et al. [57] used a survey to study changes in PV adoption motives over time in California. They found that motives shifted gradually between 2007 and 2013, from environmental concern and economic gains being of relatively equal importance in the beginning of the period, to economic gains being substantially more important by the end of the period. Furthermore, they found that later adopters had more centrist beliefs on social, political, and economic matters, and were less educated than earlier adopters (although these differences were relatively small). While earlier adopters more often identified themselves as politically liberal than conservative, the opposite was true for the later adopters [57].

Palm [46] compared two sets of interviews performed with Swedish PV adopters in 2008–2009 and 2014–2016, respectively. She found that “there had been a shift in households’ reasons for investing in PV” as households in the first interview set were driven mainly by environmental motives and technophilia, while later adopters mainly referred to economic motives. Simpson and Clifton [55], using a survey, found that technophilia was a stronger adoption motive among earlier than later Australian PV adopters. Similarly, Rai et al. [47] found evidence that PV adopters who were first in their neighbourhood to adopt PV were more likely to report technophilic motives, while later adopters more often reported economic motives.

De Groote et al. [22] studied two time periods with different subsidy levels in Belgium. During the later period, reduced subsidies implied that PV adoption was economically less beneficial than in the earlier period even though PV prices had decreased. Overall, their results were “relatively robust over time”, although high education and income were only important among the earlier adopters, which is in line with Rogers’ framework. However, the ability of respondents to answer whether their roof was insulated was larger during the later period. This variable was used by the authors as a proxy for environmental awareness, although it

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could, according to the author of the present paper, also indicate a general interest in technical details of one's home. These results suggest that when the economic prospects of adoption are suddenly impaired, new adopters can, on some dimensions, show the characteristics of earlier adopters although they are in fact chronologically later to adopt.

Reeves et al. [58] investigated differences in information preferences between earlier and later PV adopters by comparing survey responses in one young and one more developed PV market in western US. They found that earlier adopters tended to prefer more cosmopolitan information channels (e.g. mass media) than later adopters, which they conclude is in line with Rogers' framework. However, they found no differences regarding neighbourhood-related variables, such as local peer effects.

Shirai et al. [59][1] used a survey to study Japanese PV adopters' tendencies to talk about environmental issues with their friends and family. They divided adopters into three cohorts depending on their time of adoption, finding that earlier adopters had larger tendencies to engage in such conversations.

Mildenberger et al. [41] investigated whether earlier PV adopters (in relation to later adopters in their census tract) in the US were more often registered as Democrats or Republicans, and whether they were more likely to vote in general elections. They found no such differences.

Haas et al. [38] used a survey to investigate differences in motives between Austrian adopters and non-adopters *assumed* likely to adopt relatively soon. They found that the two groups scored similarly in environmental and overall financial motives, but that that the actual adopters were more driven by the motive of demonstrating that the technology works than the assumed next adopters.

To summarise, the understanding of what distinguishes earlier PV adopters from later ones is limited. While most of the existing research suggests that the earliest PV adopters are more driven by environmental concern and technophilia than somewhat later adopters, who are more driven by economic gains, more research is needed to solidify and expand this knowledge. In particular, research relying on other data than self-stated motives is needed to triangulate the existing evidence. The present study addresses this gap.

3. PV adoption motives and local market maturity: A systematic review

As stated in the previous section, existing literature on differences between earlier and later PV adopters is scarce. However, several studies have investigated PV adoption motives without necessarily addressing differences between earlier and later adopters. In this section, a systematic review of this literature is carried out. For each reviewed study, two pieces of information are obtained (se sections 3.1.2 and 3.1.3 for details on how this was achieved):

1. The adoption motive(s) found most important
2. The *market maturity*, defined as the cumulatively installed distributed PV capacity (watts per capita) in the studied empirical setting (this information is used to represent the earliness of adopters)

The reviewed studies are then compared on these parameters, allowing for differences between earlier and later PV adopters to emerge. Importantly, this approach allows for the identification of such differences by combining studies that do not, taken by themselves, say anything about *differences* between adopters. The results of the review are, beyond providing a novel contribution in itself, used to formulate a hypothesis that is tested in the subsequent empirical sections, allowing for triangulation between the review and the empirical research.

3.1. Approach for selecting and analysing literature

3.1.1. Selection of studies

The review was limited to studies of self-stated motives for adopting PV. All included studies contain an assessment of which motives were most important. The review includes survey and interview studies from different geographical and temporal contexts. Studies using proxy variables were not included as they, due to disparities in data types and methods between the studies, were found infeasible to compare. For example, proxies for environmental concern included pro-environmental voting, recycling behaviour, and adoption of environmentally friendly vehicles. Even studies relying on similar proxies, such as Green Party voting, are difficult to compare between contexts; different Green Parties may have different characteristics, and overall political landscapes and discourses differ between countries. In contrast, studies using self-stated motives – straightforwardly asking adopters why they decided to adopt – were considered rather straightforward to compare. Although studies relying on self-stated data may have validity problems such as social desirability bias and recall problems, such biases could arguably be expected to affect the results in a similar direction across studies, thus allowing for comparison between them.

Furthermore, studies showing the following characteristics were excluded:

- Not measuring *motives* for adoption, but rather factual *perceptions.* For example, a survey item such as *"PV technology is good for the environment"* was not considered to measure motives, while the item *"Environmental concern was an important reason for me to adopt"* was.
- Relying on data obtained from non-adopters (e.g. regarding their *anticipated* adoption motives).
- Not limited to PV but including also other technologies (e.g. solar heating, micro wind), unless
  - o the PV-related results were reported separately and considered rigorous by themselves, or
  - o the non-PV data points were too few to possibly affect the relevant findings.
- Studies of 'involuntary adopters', i.e. adopters that had bought a house with an existing PV system.
- Studies using selection methods apparent to have a high risk of biasing the sample (one study was excluded for this reason, as it had recruited respondents through a website on climate change, which is arguably more likely visited by environmentally concerned people).

To identify relevant literature, searches were performed in Science Direct and Google Scholar using different combinations of terms to represent diffusion of innovations, adoption motives, and political views. For example, using the following string in Science Direct, the first 75 hits were considered for further investigation: (technology OR innovation OR PV OR renewable) AND (adopt OR adoption OR diffusion) AND (motive OR "political view"). Then, snowballing was used to identify further studies through the references of reviewed studies. This process was continued until saturation, i.e. until no further relevant studies could be identified through the references of the most recently read studies. In articles that reported results for different adopter cohorts separately depending on their time of adoption, the results for each cohort were treated as separate studies.

3.1.2. Assessment of market maturity

The earliness of the studied adopters was represented by the *market*

[1] Shirai et al. [59] is not available in English, but in Japanese only. To take part of their results, the author of the present paper relied on Google Translate and an account of their study found in Yamamoto [60].

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maturity of the respective empirical setting. Market maturity was defined as the cumulatively installed distributed[2] PV capacity in watts per capita. The *empirical setting* was defined as the country or state of data collection around the time that the interviewed or surveyed adopters had adopted. For most settings, installation data were obtained from the International Energy Agency's (IEA) yearly National Survey Reports, published through its Photovoltaic Power Systems Programme [3]. For one national setting (UK 2011), there was no such report, and data[3] were in this case obtained from the UK feed-in tariff system [61].

Regarding the US, this is a large and diverse country, and all studies from the US were empirically limited to particular states. Thus, state-level data were used for the US settings. As comprehensive state-level data for residential, small-scale or distributed installations were not available, different sources were used. For California, data were obtained from the website of California Solar Statistics,[4] covering all rooftop installations participating in the California Solar Initiative rebate program. Data for Texas were obtained by subtracting utility-scale installations (obtained from the website of Berkeley Lab[5]) from the total installations (obtained through [62]). For Wisconsin, no figure for distributed installations could be obtained, and thus the total installed capacity [62] was used (utility-scale capacity in this northern state at such an early time was assumed small). Methodologically, the estimations for California and Wisconsin are cautious. As the Californian rebate programme may not include all rooftop PV installations, these figures likely underestimate total distributed installations to some extent, while the Wisconsin data likely overestimate the distributed PV capacity. Given the findings of these respective studies (see Table 1), these biases provide cautious estimates and do thus not harm the validity of the main findings.

In the reviewed studies, adoptions had typically occurred over an extended time period. One point in time could thus not represent all adopters of a given study. However, as PV adoption rates increase rapidly in most markets, the population of adopters in a given setting can be expected to consist mainly of relatively recent adopters. Indeed, in the studies that did provide detailed information on adoption times [46,47,50,55], adoptions tended to be concentrated to the times most recent before data collection. Thus, the point in time used to represent the respective empirical setting was chosen as follows:

- For studies not specifying adoption times, the end of the year preceding data collection was used.
- For studies providing an interval or a last time of adoptions without further specification, the end of the year preceding the last adoptions was used.
- For studies providing detailed information on adoption times, the end of the year with the largest number of adoptions was used.

3.1.3. Identification of motives

Next, the importance of different adoption motives was compared between the studies. In some studies, one single motive was found to be most important, while others found more than one motive to be most important. First, the motive(s) found most important in each study were identified. Second, the relative importance between environmental concern and economic gains was identified for each study. These two motives were used for pair-wise comparison because they appeared in all included studies, and because they represent fundamentally different driving forces (altruism and self-interest, respectively), thus lending themselves well to study shifts in adoption motives over time. Using this approach, differences in motives between earlier and later adopters could be identified.

3.2. Review results

Twelve research articles were found to fulfil the criteria and were hence included in the systematic review. Three of these articles contained two studied adopter cohorts each, that had adopted during different time intervals, and these papers were considered to consist of two separate studies each. The few reviewed studies that were found to address differences between earlier and later adopters are also accounted for in more detail in section 2.3. All studied settings – 15 in total – are found in Europe, the US, or Australia.

Table 1 displays the review's results. The table reveals that studies of later adopters (in more mature markets) tend to find economic gains to be the most important adoption motive, while studies of earlier adopters (in less mature markets) tend to find other motives, primarily environmental concern and technophilia, to be more important. The pattern is very clear – economic gains is the single most important motive in all but one of the settings with more than 5 W per capita. In contrast, environmental concern and technophilia dominate almost completely in settings with less than 5 W per capita.

Technophilia is expressed somewhat differently by different adopters, including a fascination for energy technologies and a wish to demonstrate the technology to others. Another reoccurring motive is energy independence, which is present among earlier as well as later adopters.

As seen in Table 1, market maturity differs dramatically between the studied settings. The results are thus quite insensitive to inaccuracies in the measurement of this parameter. The 'adopters' column indicates to which of Rogers' adopter categories the studied adopters are roughly estimated[6] to belong. As can be seen, the shift in adoption motives observed in this review – from environmental concern and technophilia to economic gains – occurs already among the innovators (it should be emphasised, though, that the methodology is not precise enough to estimate an exact point on the adopters' curve).

Given the above results, the following hypothesis is formulated to be tested in the empirical research in the next sections: *Earlier residential PV adopters are, to a larger degree than later adopters, driven by non-financial adoption motives such as environmental concern.*

4. Research design: empirical study of Swedish adopters

The empirical research tests the hypothesis that earlier residential PV adopters are, to a larger degree than later adopters, driven by environmental concern than later adopters, thus triangulating against the results of the systematic review performed in the previous section. It does so by employing municipal-level data on Swedish PV adopters over a nine-year period, using Green Party voting as a proxy for environmental concern. One regression model was built for each year of the period

[2] *Distributed* here refers to PV systems installed to provide electricity locally, typically as roof-mounted installations [3]. It is thus the function of the PV system, not its size, that qualifies it as distributed. This contrasts to *centralised* PV, which is installed to provide bulk power for wholesale purposes, typically as ground-mounted solar parks. Data on residential PV capacity specifically was not available for all contexts, and data for distributed PV was thus used to represent the market maturity for small-scale PV, although this data includes not only household installations but also distributed installations for businesses etc.

[3] This source, as opposed to the IEA's data, classified systems by size. It was assumed that PV systems <50 kW was equivalent to the IEA's 'distributed' class. This assumption was insensitive, as the bulk of UK PV systems were <10 kW.

[4] https://www.californiasolarstatistics.ca.gov/reports/monthly_stats, accessed 9 December 2019.

[5] https://emp.lbl.gov/capacity-and-generation-state, accessed 13 February 2020.

[6] These estimations assume that all households with a suitable home will eventually adopt PV, and that about 50% of the population lives in a suitable home.

Table 1
Results of the systematic literature review. The studies are presented in falling order of market maturity. There are two columns for results: one in which the most important motive out of economic gains and environmental concern is presented, and one in which the most important motive(s) overall are presented.

Empirical setting	Market maturity		Findings: most important adoption motives		Study
	Watts per capita	Adopters (Rogers' categories)	Economic gains versus environmental concern	Overall	
Australia 2014	152	Early majority	**Economic gains**	Economic gains	Sommerfeld et al. [56] (later cohort)
Australia 2011	49.6	Early adopters	**Economic gains**	Economic gains	Sommerfeld et al. [56] (earlier cohort)
Australia 2011	49.6		**Economic gains**	Economic gains	Simpson and Clifton [55]
California 2013	34.9		**Unclear**	Environmental concern; economic gains; energy independence	Rai et al. [47]
California 2012	28.2	Innovators	**Economic gains**	Economic gains	Sigrin et al. [57] (later cohort)
Sweden 2016	16.0		**Economic gains**	Economic gains	Palm [46] (later cohort)
California 2009	8.05		**Economic gains**	Economic gains	Sigrin et al. [57] (earlier cohort)
UK 2011	7.53		**Economic gains**	Economic gains; energy independence	Balcombe et al. [50]
Finland 2016	4.90		**Environmental concern**	Environmental concern; technophilia	Karjalainen and Ahvenniemi [36]
Netherlands 2003	2.23		**Unclear**	Environmental concern; economic gains	Jager [63]
Wisconsin 2010	1.53		**Environmental concern**	Environmental concern; technophilia	Schelly [37]
Sweden 2011	0.821		**Environmental concern**	Environmental concern; technophilia	Bergek and Mignon [51]
Texas 2010	0.815		**Unclear**	Environmental concern; economic gains; technophilia	Rai and McAndrews [64]
Sweden 2009	0.343		**Environmental concern**	Environmental concern; technophilia	Palm [46] (earlier cohort)
Austria 1993	0.0389		**Environmental concern**	Technophilia ("prove that PV works")	Haas et al. [38]

2009–2017, with year-specific data for PV adoptions and control variables. The regression coefficients were then used to calculate the effects of Green Party voting on PV adoptions in terms of percent growth of per capita adoptions. Thus, it could be investigated whether earlier adopters tended to live in municipalities with more environmentally concerned voters than later adopters. During the studied time period, the Swedish market for distributed PV grew from practically non-existing to quite established, see Fig. 1. This makes Sweden a good case for studying a shift from the earliest to somewhat later adopters.

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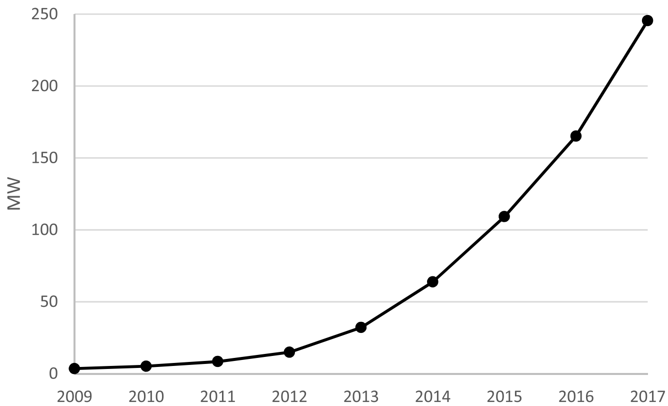

Fig. 1. Cumulatively installed distributed PV in Sweden during the studied period according to Lindahl et al. [65]. The figures include both residential and other distributed applications (e.g. PV installed on the rooftops of small businesses or multi-family buildings), but it is estimated that residential installations account for about half of this capacity in most years [65]. This graph is based on the time of installation, as opposed to the data used in the regressions which are based on the time of subsidy application.

4.1. Independent variable

The independent variable was the share of votes received by the Swedish Green Party in the national election of 2014. While support for political parties is often quite volatile depending on various short-term factors [66], ideological beliefs and issue preferences regarding political policies tend to be more stable over time [67,68]. Thus, it was decided to use Green Party support at one point in time (at around the middle of the studied time period) as a proxy for environmental concern for the whole time period.

Green Party support (particularly in the 2014 election) was considered a reasonable proxy for environmental concern for the following reasons. In general, Swedish voters traditionally perceive the Green Party as strongly associated with environmental issues [69]. Voters traditionally do not perceive the party as pronouncedly left- or right-wing, but rather as slightly left of centre [70]. Compared to most other parties, the Green Party has been perceived as quite narrowly focussed on one core issue [69], namely the environment. The party is also, as perceived by Swedish voters in general, the most trustworthy of all parties in the national parliament when it comes to promoting sound environmental policy [71]. A Google search by the author of this paper revealed that the Green Party did, in various voter opinion polls, consistently receive the by far highest trust regarding environmental issues until after the 2014 elections. A few years later, however, voters' trust regarding environmental policy was no longer as concentrated to one single party. (A likely explanation is that other parties had, by then, gotten more serious about adopting an environmental profile of their own, thus increasing the competition for environmentally concerned voters and challenging some core policy views of the Green Party, e.g. by proposing nuclear power buildout to reduce carbon emissions; the Green Party had until then faced little competition in the environmental domain.) In its election campaign of 2014, the Green Party focused strongly on, and (in the author's experience) mainly received media attention for, climate change mitigation, while other parties focused on other issues. In contrast, the overall political debate preceding the 2018 election was dominated by immigration issues in the wake of a so-called 'refugee crisis' bursting in 2015. As a consequence, in the 2018 campaign the Green Party – promoting a generous immigration policy – received much attention for its views on immigration, while its views on environmental issues received less attention than previously. Furthermore, the 2014 election results were chosen over the 2010 results because 2014 is closer to the middle of the studied time period. As a robustness check, the models were nevertheless run with data from all elections 2010–2018, providing similar results.

Data from the national election (rather than municipal or regional elections) were used because the focus, rhetoric, and perceived competence of local Green Party divisions might differ between one another. The national Green Party, on the other hand, upholds a rather uniform façade towards the whole country. Thus, national election results are more likely to measure the same thing in all municipalities.

A possible concern of the methodology could be reversed causation – that municipalities with a large share of Green Party voters could have implemented local policies (introduced by local Green Party divisions) supporting PV, thus affecting adoptions. However, the Swedish PV policy framework has been quite uniform throughout the country; for example, no sub-national subsidies have existed, and permits for grid-connection have been regulated on the national level [33]. Although some variation in building permit processes have existed, national regulations have set limits to how much municipalities can deviate on this issue, and building permit processes have typically not hindered Swedish PV installations [72].

4.2. Dependent variable

The dependent variable of each regression model was the per capita number of adoptions of residential PV systems occurring during the year in question. Data on PV adoptions were obtained from a dataset, provided by the Swedish Energy Agency, for an investment subsidy scheme that has been available for Swedish PV adopters since 2009. The number of approved subsidy applications was used to estimate the number of adoptions. During the studied time period the subsidy has, as a response to reduced PV system prices, been stepwise reduced from 60% to 20% of the PV system's price. At such high reimbursement rates, and with limited (although not insignificant) effort required to apply, few homeowners could be expected to adopt PV without applying for the subsidy. Interviews with installers have also revealed that practically all adopters apply for the subsidy [72]. Thus, the subsidy data can be expected to reflect the actual number of adoptions quite well. Only applications that were followed by an actual installation were used in the analysis (around 70% of all submitted applications have typically been followed by installation).

The point in time when the adopter submitted the subsidy application was considered the time of adoption. The process of adopting PV takes time, and it is not obvious which event in this process should be considered the adoption. Data on the time of contract signing or physical installation are not available, nor would they necessarily be the most purposeful measures of the adoption time. Asking people when they decided to adopt is neither known to be a reliable option, as adopters tend to be unable to recall this information reliably [2, pp. 126–128].

Even though the subsidy application takes place before the actual installation, the time of application is arguably purposeful for approximating the time of adoption *decision*, which is what is relevant for the present study. Due to persisting uncertainties regarding how long the funding for the subsidy would last [72], prospective adopters have been incentivised to apply early to secure being granted the subsidy. To complete the application, the applicant must however make some effort in planning and information gathering, preventing people from applying unless they have a real intention to adopt (as stated, most applications have been followed by adoption). Thus, as there are incentives not to wait unnecessarily long and not to apply unless there is a real intention to adopt, the time of application is expected to provide a reasonable estimate of the time of adoption decision.

4.3. Control variables

A set of six control variables was used, see Table 2. These were based on previous research on factors affecting PV adoption rates (see section 2.2), as well as on the experiences and intuition of the author.

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Table 2
Control variables and rationales for using them.

Variable	Unit	Rationale
Population density *(Registered inhabitants per area unit in 2016)*	persons*hectare^{-1}	Population density is a common control variable in the social sciences. It may correlate with socioeconomic factors, and might capture factors related to for example mindset, access to installers, or local peer effects.
Age *(Mean age of inhabitants in 2016)*	years	Preferences may differ depending on age.
GHI *(Global horizontal irradiance, i.e. 'the amount of sunshine')*	MWh*m^{-2}*year^{-1}	More solar insolation increases the economic gains in adopting PV.
Detached homes *(Number of detached homes* per capita *in 2016)*	detached homes*person^{-1}	Living in a detached home is typically a precondition for adopting PV.
Home price increase *(Mean price increase of detached homes during 2007-2017)*	percent (for the full ten-year period)	Increasing home prices affect homeowners' total wealth, which could affect their propensity to adopt PV.
Income *(Mean income from salaries and pensions of people aged 20 and above in 2016)*	SEK 10 000*person^{-1}*year^{-1} (~USD 1000*person^{-1}*year^{-1})	Income may affect people's will or ability adopt PV.

5. Empirical results

The results of the yearly models are shown in Fig. 2. As can be seen, the relationship between PV adoption rates and environmental concern (as estimated by Green Party voting in the national election of 2014) weakens over time. While an increase of one percentage point in Green Party support is associated with an increase in local PV adoption rates of around 30% at the beginning of the period, the corresponding figure has dropped to around 14% by the end of the period. This lends support to the hypothesis that earlier PV adopters are more driven by environmental concern than later adopters. The full results of the regressions are shown in the Appendix, Table A1.

With the exception of 2015, when the importance of environmental concern for adoption rates temporarily increases, the trend of a weakening relationship between these variables is rather consistent. A trendline (fitted through linear regression) reveals a statistically significant decreasing trend over the period. As seen in Table 3, the temporarily stronger importance of environmental concern in 2015 coincides with a temporary decrease in adoptions. This dip is likely due to a temporary dip in the perceived possibilities of receiving the subsidy. Around 2015, the subsidy scheme experienced a lack of funding and, as a result, waiting times and uncertainties regarding application approval increased dramatically [73]. This appears – as suggested by the results – to have discouraged adoption mainly among people less driven by environmental concern.

A robustness check, using data from the average of the Green Party's results of all national elections 2010–2018, provided similar results. Using this data, the trendline (corresponding to that of Fig. 2) had a slope of −0.017 and a p-value of 0.071.

The expected economic gains of PV adoption have increased during the studied period, mainly due to decreasing prices of PV systems. In Fig. 3, the estimated payback times[7] (i.e., time required for the PV system to pay for itself through electricity generation) are shown for PV systems adopted in Sweden at different times. The improved economic gains (shortened payback times) of PV adoption could potentially explain the decreasing importance of environmental concern; it should be no surprise if improved economic returns attract other adopters than those primarily driven by environmental concern. However, by the end of the period, payback times almost completely cease to decrease. Yet, the trend of decreasing importance of environmental concern continues, suggesting that the earliness of adoption in itself (disregarding economic gains) plays at least some part in explaining the decreasing importance of environmental concern over time.

The adopters studied could, using Rogers' terminology, be categorised as innovators. Summing up all adoptions in Table 3, and comparing these to the total potential Swedish adopter base,[8] it is roughly estimated that somewhere around 1% of all potential residential PV adopters had adopted PV by the end of 2017 (innovators are, according to Rogers, the first 2.5% to adopt).

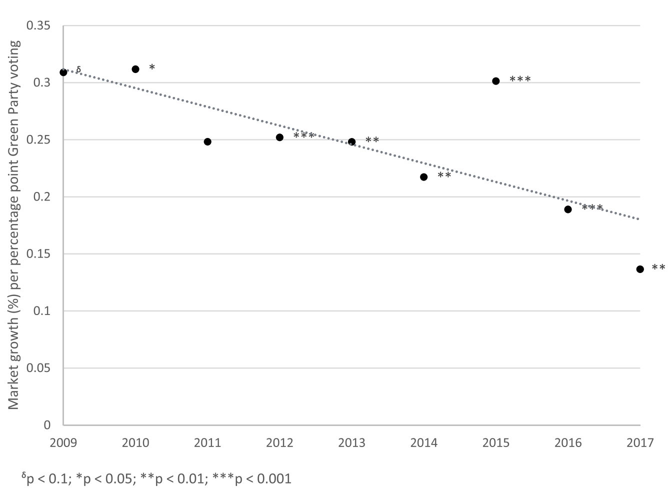

Fig. 2. Each dot represents the estimated PV market growth, in percent, per percentage point increase in Green Party support. The specification of statistical significance next to each dot refers to the regression coefficient of the independent variable. The trendline has a slope of −0.016, an R^2 of 0.59, and a p-value of 0.016.

Table 3
Yearly number of residential PV adoptions (the time of adoption is here defined as the time of subsidy application).

Year	Adoptions
2009	130
2010	200
2011	321
2012	673
2013	1234
2014	1227
2015	860
2016	1598
2017	2564

[7] Payback times were estimated using concurrent subsidies and electricity prices; 50% self-consumption; and no cost of capital (which, in the author's experience, is how Swedish installers and homeowners tend to present and think of the investment). Although these assumptions may substantially affect the calculated values, the shape of the curve (decreasing, flattening towards the end) remains similar when the assumptions are altered.

[8] Based on figures on the Swedish housing stock provided by Statistics Sweden, the number of homes with suitable rooftops in the country can be roughly estimated to 1 M, thus indicating the upper limit of the number of adoptions.

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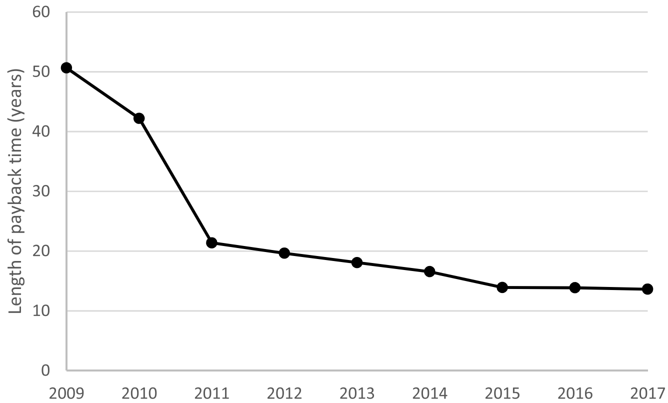

Fig. 3. Estimated payback time for a PV system purchased at different points in time. The decreasing trend is mainly due to decreasing costs of PV modules on the global market. The estimations disregard from temporary uncertainties in the subsidy scheme (applications submitted in 2015 were eventually approved, although this was not clear at that time).

6. Conclusion and discussion

This paper provides evidence that earlier adopters of residential PV systems are to a large extent driven by other adoption motives than later adopters. First and foremost, it is found that non-financial adoption motives, such as environmental concern, are more important among the earliest adopters than among later adopters. The research reveals that already among the very earliest adopters (the innovators, cf. Rogers [2]), the importance of environmental concern as an adoption motive decreases rapidly as the market matures. Later adopters (including Rogers' so-called early adopters, and even late innovators), on the other hand, are driven primarily by economic gains.

This finding is supported by both a systematic literature review of adoption motives in relation to market maturity, and an empirical study of Swedish adopters. The systematic review and the empirical study rely on fundamentally different methodologies and data; while the reviewed literature uses self-stated data, the empirical study uses revealed political preferences that are arguably intimately connected to true environmental concern. Yet, both the review and the empirical research point in the same direction, thus strengthening the validity of this finding through triangulation [cf.74]. A limitation of the paper is, however, that it is empirically limited to very early adopters. The 'later' adopters studied here are, in fact, rather early to adopt from a broader perspective, and they may not necessarily represent even later adopters.

The systematic literature review reveals that the earliest PV adopters are not only driven by environmental concern, but to a similar extent by other motives, mainly related to technophilia. Among later adopters, on the other hand, economic gains tend to dominate over all other motives. It is, thus, likely that the empirical results of the present paper reflect a shift from a broader set of non-financial motives towards economic ones. Due to data availability, the present empirical research was limited to environmental concern. However, people with high levels of environmental concern are known to have more altruistic and self-transcendent value orientations [e.g.75,76]. Thus, variables for technophilia, novelty seeking, and altruism may have shown a declining trend as well if applied to the same data set.

The findings are in line with previous research on differences between earlier and later PV adopters, while also making distinct contributions. The contribution of the systematic literature review is to reveal that dynamics that have previously been observed in a couple of settings [46,57] occur more generally throughout various geographical contexts. The contribution of the empirical research is mainly that of triangulation, employing methodology not previously applied to study differences between earlier and later PV adopters. This is important because previous studies rely on self-stated data, which could be problematic from a validity perspective due to e.g. social desirability bias (earlier adopters could, for example, be more prone to report socially desirable answers in an interview situation – an explanation that seems less likely given the present empirical results).

Given this paper's findings, research on PV diffusion should arguably pay more attention to market maturity. There are plenty of studies investigating factors affecting PV adoption rates in different contexts with different levels of PV penetration (see section 2.2). However, most of them provide snapshots without further analysis of – or even reflection upon – how the market maturity of their studied settings could affect their results. The present study demonstrates that the importance of certain variables can change dramatically over relatively short timespans as a market matures – something that may be true for other variables as well. Thus, for existing studies of later adopters some results should be expected to differ from studies of earlier adopters. Failure to take market maturity into account could thus potentially (at least partly) explain some inconsistencies in the previous research. Most notably, the previous research is highly inconsistent on the relative importance of different adoption motives when not taking market maturity into account (which most studies fail to do). However, the systematic review of the present paper demonstrates that, once taking market maturity into account, the results of previous studies are actually quite consistent. Arguably, future studies on PV diffusion should assess the market maturity of their studied settings and discuss their results in relation to it, taking the results of the present paper and other relevant studies (see section 2.3) into account. Future studies could also differentiate between adopter cohorts depending of their time of adoption.

As stated in section 2.1, previous research on early adoption of different innovations has found earlier adopters to be more oriented towards profits and savings than later adopters. Against this background, the findings of the review might seem surprising. However, it is important to keep in mind that all adopters studied in the present paper – also the 'later' ones – are relatively early to adopt. Hence, the findings are not necessarily at odds with previous research on this point, as even later adopters may prove to be driven by other motives. This is a matter for future research to be carried out as PV markets mature around the world. It is also possible that earlier PV adopters are more profits and savings oriented in their general consumption behaviour, although this orientation is overridden by other motives in their PV adoption decision.

A limitation of the present research is that the causes of the observed trends remain unclear: is the shift in adoption motives purely a consequence of the order in which people adopt, or of other factors that tend to change along with PV market growth? Sorting this out is difficult, as economic, technical, and institutional conditions for PV adoption tend to improve in parallel with growth in installed capacity [e.g. 72]. Arguably, it would not be surprising if improved economic returns from PV adoption caused people to adopt for economic reasons, regardless of how many have adopted before them. Indeed, the empirical results of the present study indicate that when the economic gains of adopting PV were suddenly impaired, the importance of environmental concern increased again. As discussed in section 2.3, the results of De Groote et al. [22] point in a similar direction. This suggests that it is not only the earliness of adoption per se that causes the observed trend. There is, however, also some evidence that the order of adoption in itself contributes to the trend. First, the empirical research revealed that the relationship between environmental concern and PV adoption rates continued to weaken even when payback times ceased to decrease. Second, the reviewed literature revealed that even with payback times shorter than 10 years (implying a good economic case for PV adoption), environmental concern remained as important a motive as economic

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gains among innovators [63,64].[9] In contrast, the later adopters studied by Palm [46] adopted for primarily economic reasons despite facing substantially longer (albeit still financially beneficial) payback times (see Table 1 and Fig. 3). This suggests – albeit the evidence is admittedly limited on this point – that later adopters tend to be less driven by environmental concern than earlier adopters *even when not facing better economic conditions from adopting PV*. Future research could pursue further evidence on this matter.

Another limitation is that the input values for the estimation of the trendline of Fig. 2 are laden with some uncertainty as the values on the vertical axis are themselves estimated through regression. Such a two-step process (using regression coefficients to construct inputs to another regression) may result in reduced internal validity as errors in the first analysis may propagate to the second one [cf.77]. This implies that the p-value calculated for the trendline is uncertain. On the other hand, the hypothesis tested is well underpinned through the systematic literature review, strengthening the overall internal validity of the paper's main result.

Another limitation is that the research is based exclusively on adopters in Europe, the US, and Australia. Future research could investigate adopters in other cultural contexts.

Another matter for further research is to investigate whether the tendency of the earliest PV adopters to be driven by environmental concern reflects some more general characteristic of innovators or early adopters. For example, these adopters may more often be driven by altruistic or idealistic motives (however perceived) across different technologies.

The present results may be useful to different actors. First, any actor interested in increasing PV adoption rates through information provision could find them useful. Research has shown that publicly organised information campaigns can substantially boost PV adoption [29,30]. Given the present results, such campaigns can arguably be adapted to appeal to the most likely adopters by e.g. focusing on environmental issues and the thrill of a new technology in the most immature markets, while focusing on economic aspects (at least if there is an economic case for PV adoption) and other practical matters in more mature markets. For similar reasons, private actors in the PV business may find the results helpful in their advertising. This said, in some cases there may be other contextual aspects that are more important, such as local discourses on climate change or a sudden introduction of generous subsidies or other policies. Another set of actors that may find the results useful are researchers forecasting PV diffusion; understanding what drives PV diffusion at different stages of market maturity may help them build more accurate models.

CRediT authorship contribution statement

A. Palm: Conceptualization, Methodology, Validation, Formal analysis, Investigation, Data curation, Writing - original draft, Writing - review & editing, Visualization.

Declaration of Competing Interest

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

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Appendix

Table A.1
Regression results for each year of the studied time period. Values are rounded to three significant figures. The coefficients in this table are presented as absolute values, and thus tend to increase over time due to the growing PV market. The decreasing importance of Green Party voting over time is observed when recalculating the coefficients to relative (percent) values (see Fig. 2).

Variable	Coefficient		Standard Error	t Stat	Lower 95%	Upper 95%
2009						
Green Party support	0.0430	δ	0.0241	1.79	−0.00435	0.0904
Population density	0.00603		0.00755	0.798	−0.00884	0.0209
Income	−0.00871		0.0132	−0.658	−0.0348	0.0173
GHI	0.000715	*	0.000350	2.04	0.0000261	0.00140
Home price increase	0.000753		0.00162	0.464	−0.00244	0.00394
Age	0.00547		0.0186	0.294	−0.0311	0.042
Detached homes	2.50	***	0.648	3.86	1.23	3.78
2010						
Green Party support	0.0662	*	0.0258	2.56	0.0153	0.117
Population density	−0.00466		0.00788	−0.591	−0.0202	0.0109
Income	0.00253		0.0135	0.187	−0.0241	0.0292
GHI	0.000870	*	0.000373	2.33	0.000135	0.00160
Home price increase	−0.000972		0.00174	−0.558	−0.00440	0.00246
Age	0.0359	δ	0.0197	1.82	−0.00283	0.0746
Detached homes	1.71	*	0.697	2.45	0.336	3.08
2011						
Green Party support	0.0840		0.0546	1.54	−0.0236	0.192
Population density	0.00514		0.0162	0.316	−0.0268	0.0371
Income	−0.0118		0.0276	−0.429	−0.0662	0.0425

(*continued on next page*)

[9] Only three of the papers included in the systematic literature review reported payback times, all of them studying very early adopters (innovators). Jager [63] stated that his studied adopters had participated in a subsidy program reducing payback times to about three years. Most adopters studied by Rai and McAndrews [64] had reported payback times of 7–10 years, while most adopters studied by Karjalainen and Ahvenniemi [36] had reported payback times of 15–25 years. As PV systems typically last for decades, payback times of <10 years clearly offer a beneficial investment.

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Table A.1 (*continued*)

Variable	Coefficient		Standard Error	t Stat	Lower 95%	Upper 95%
GHI	0.00207	**	0.000791	2.62	0.000516	0.00363
Home price increase	0.00315		0.00370	0.851	−0.00413	0.0104
Age	0.00621		0.0414	0.150	−0.0753	0.0877
Detached homes	5.49	***	1.49	3.69	2.56	8.42
2012						
Green Party support	0.177	***	0.0530	3.35	0.0732	0.282
Population density	−0.0109		0.0153	−0.716	−0.0411	0.0192
Income	−0.0126		0.0263	−0.478	−0.0644	0.0393
GHI	0.00200	**	0.000763	2.62	0.000498	0.00350
Home price increase	0.00791	*	0.00359	2.20	0.000841	0.0150
Age	0.0124		0.0402	0.309	−0.0667	0.0916
Detached homes	6.93	***	1.45	4.77	4.07	9.79
2013						
Green Party support	0.317	**	0.101	3.15	0.119	0.516
Population density	−0.00527		0.0284	−0.186	−0.0611	0.0506
Income	−0.0855	δ	0.0489	−1.75	−0.182	0.0108
GHI	0.00291	*	0.00146	1.99	0.0000367	0.00578
Home price increase	0.0133	δ	0.00689	1.94	−0.000226	0.0269
Age	−0.00227		0.0770	−0.0294	−0.154	0.149
Detached homes	14.5	***	2.79	5.20	9.01	20.0
2014						
Green Party support	0.274	**	0.0946	2.89	0.0872	0.460
Population density	−0.00664		0.0261	−0.254	−0.0581	0.0448
Income	−0.0747	δ	0.0441	−1.69	−0.162	0.0121
GHI	0.000303		0.00137	0.222	−0.00239	0.00300
Home price increase	−0.00439		0.00647	−0.679	−0.0171	0.00835
Age	−0.0419		0.0728	−0.576	−0.185	0.101
Detached homes	11.3	***	2.65	4.24	6.04	16.5
2015						
Green Party support	0.263	***	0.0616	4.27	0.142	0.384
Population density	−0.00463		0.0166	−0.279	−0.0373	0.0280
Income	−0.0598	*	0.0276	−2.17	−0.114	−0.00548
GHI	0.00186	*	0.000894	2.08	0.0000998	0.00362
Home price increase	0.00649		0.00422	1.54	−0.00182	0.0148
Age	−0.0197		0.0471	−0.419	−0.112	0.0730
Detached homes	9.96	***	1.74	5.71	6.53	13.4
2016						
Green Party support	0.302	***	0.0791	3.82	0.146	0.458
Population density	−0.0140		0.0210	−0.668	−0.0553	0.0273
Income	−0.0743	*	0.0347	−2.14	−0.143	−0.00609
GHI	0.00250	*	0.00116	2.15	0.000211	0.00479
Home price increase	0.00405		0.00546	0.742	−0.00670	0.0148
Age	−0.0373		0.0614	−0.608	−0.158	0.0836
Detached homes	11.4	***	2.24	5.10	7.02	15.8
2017						
Green Party support	0.346	**	0.120	2.87	0.109	0.583
Population density	−0.000533		0.0312	−0.0171	−0.0619	0.0609
Income	−0.127	*	0.0519	−2.44	−0.229	−0.0244
GHI	0.0122	***	0.00178	6.84	0.00866	0.0156
Home price increase	0.0232	**	0.00831	2.79	0.00682	0.0395
Age	0.0894		0.0921	0.971	−0.0918	0.271
Detached homes	22.3	***	3.42	6.52	15.6	29.1

$^{\delta}p < 0.1$; $^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$.

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Guidance on Designing and Implementing

Energy Efficiency Market Transformation Initiatives

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California policy makers have sought to create increasingly larger savings for energy efficiency programs as the State stretches to meet aggressive strategic goals. One strategic tool to make steady progress toward long-term goals is referred to as market transformation. Market transformation is both complementary to existing programs and supplements them in markets where traditional programs have had limited success. Both are necessary for a balanced statewide portfolio that pursues all cost effective energy efficiency the mandate of the investor owned utilities (IOUs) and the California Public Utilities Commission (CPUC) under Public Utilities Code 381.

To advance market transformation, the IOUs and the CPUC must build from a common definition and understanding of market transformation initiatives. In addition, they should base interventions on established guidelines for planning, designing, and carrying out market transformation initiatives in order to comply with the expectations of the Commission. The purpose of this document is to begin the dialogue that will provide a common understanding.

Defining Market Transformation

Many entities have defined market transformation and what it should accomplish. In 2009, the CPUC expanded its previous view of market transformation (changes noted in italics):

> Market transformation is long-lasting, sustainable changes in the structure or functioning of a market achieved by reducing barriers to the adoption of energy efficiency measures to the point where *continuation of the same* publicly-funded intervention is no longer appropriate in that specific market. *Market transformation includes promoting one set of efficient technologies, processes or building design approaches until they are adopted into codes and standards (or otherwise substantially adopted by the market), while also moving forward to bring the next generation of even more efficient technologies, processes or design solutions to the market."*[1]

[1] D.09-09-047 at 89

A shorter alternative might be paraphrased from several sources

> "Market transformation is designed to induce sustained increases in the adoption and penetration of energy efficient technologies and practices through structural changes in the market and in behaviors of market actors." [2]

Another option is to define market transformation as sustained market effects. Market effects in turn are defined as structural and institutional changes in a delineated market as a result of strategic intervention. Market effects differ from spillover in that the intervention impacts the structure of the market, rather than simply increasing energy efficient technology purchases by participants (participant spillover) or by nonparticipants (nonparticipant spillover). Thus market transformation successes are a subset of interventions leading to market effects that are sustainable, even if the intervention is modified, refocused, or reduced.

Market Transformation Key Concepts

A useful guide to market transformation initiatives needs to be detailed enough to provide step by step guidance, but abstracted enough to allow for the details to be modified to align with any given specific market. Key market transformation concepts include "markets-based," "barriers and opportunities," "strategic planning," "story for sustainability," and "long-term perspective."

Many authors have identified key elements in market transformation targeting, planning and design. The following are key concepts gleaned from several sources:[3]

Steps to Market Transformation Planning

1. Establish clear linkage between planned MT initiative and Strategic Goals – Since MT initiatives are expensive long-term investments, MT initiative must clearly support the Strategic Goals.

2. Establish likely <u>target markets</u> based on knowledge of the technology, the consumers, the potential savings, and the market to be addressed.

3. Have a good <u>characterization of the market</u> – actors, influences, value-added opportunities, barriers to entrance and to efficiency measures, competitors and potential partners. This should probably include a market operation diagram.

    a. Establishing a <u>baseline</u> will provide metrics to track changes in the market

[2] EPRI (2001); Sebold et al., (2001); Keating, et al., (1998); Rosenberg and Hoefgen (2009).
[3] Throughout the paper, we use as our basic resources the references found at the end of this paper. In the text we paraphrase the most germane thoughts from them for the purpose of providing guidance.

4. Strategically design the intervention in terms of the barriers and opportunities, as well as the resources and the tactics to be used. This requires overall coordination of the intervention.

    a. Lay out the program theory or logic and make sure it matches at least some parts of the market operation characterization, establishes interim and long-term metrics that can be tracked from the baseline.
    b. Prepare an explicit description of how and what program interventions will result in lasting/sustainable, and cost-effective changes across the market -- the market transformation "story."

5. If possible, use a market-based advisory group to help shape and revise the program in response to market changes.

6. Match the evaluation strategy to the program logic – always remember that the unit of analysis is the whole market, not just those touched by the program intervention.

Each of the underlined concepts is explained in more detail below.

1. Targeting

Although energy efficiency program implementers have had less experience with selecting, designing, implementing, and evaluating market transformation initiatives, logically consistent criteria for deciding when to follow a market transformation strategy do exist. Picking the best targets for market transformation interventions requires considerable thought.[4]

A composite set of guidelines would simplify to:

- There must be a clearly defined and manageable market;
- The market must represent a large enough opportunity to justify the resources and the long term commitment required to create the desired change;
- There must be a "story" that logically and defensibly links the present to the future state of the market,
- The measure or service ideally has strong non-energy benefits to help its acceptance and the sustainability in the market;
- Although the savings in aggregate may be large, they are generally small at each transaction, making market transformation the preferred strategic choice;
- The savings are able to be projected to be cost-effective over the longer time horizon.

[4] Our source materials provide significantly greater detail on what could be important attributes of a target market.

Knowing what to target is a key question in market transformation planning. Another is distinguishing between resource acquisition programs and market transformation initiatives. Because many of the attributes of a solid market transformation intervention should also be part of the best acquisition program designs – such as cost-effectiveness, knowledge of the target market, measuring savings with sufficient confidence, and the ultimate goal of achieving energy savings – the question arises about whether the distinction between the two efforts is real and important. But there are nuances that differ between resource acquisition and market transformation initiatives, such as cost-effectiveness over the long term versus the short-term, and important differences in the required depth of knowledge about the market. There are also substantive differences as well. These distinctions, if they are not made clear, can cause confusion in designing market transformation efforts. The most important and foundational aspect of the market transformation paradigm is the focus on the market, not the program. From that most of the other distinctions will follow. Table 1 synopsizes the most common distinctions.

Table1: Distinctions between Resource Acquisition and Market Transformation[5]

	Resource Acquisition	Market Transformation
Scale	Program	Entire defined market
Target	Participants	All consumers
Goal	Near-term savings	Structural changes in the market leading to long term savings
Approach	Save energy through customer participation	Save energy through mobilizing the market
Scope of Effort	Usually from a single program	Results from effects of multiple programs or interventions
Amount of Program Administrator's control	PAs can control the pace, scale, geographic location, and can identify participants in general	Markets are very dynamic, and the PAs are only one set of actors. If, how, where, and when the impacts occur are usually beyond the control of the program administrators.
What is tracked, measured, and evaluated	Energy use and savings, participants, and free-ridership	Interim and long term indicators of market penetration and structural changes, attribution to the program, and cumulative energy impacts.
Timeframe for cost-effectiveness	Usually based on 1st year or cycle savings	Is usually planned over a 5 -10 year timeframe

[5] Derived from Sebold et al., and Keating, et al. *ops cit*.

2. Characterization of the Market

Academics define a market as a system for voluntary exchanges of certain goods and services between individuals or groups, according to rules. At its simplest level, a market involves manufacturers, sellers of products or services, and consumers, but most are far more complex. They involve wholesalers, distributors, professionals who deliver the product to consumers, as well as associations of interested parties, and even regulators. Utilities are only big players in the energy market. They and their programs will generally be tangential to other markets.

Before we can develop hypotheses about how to influence a market and design programs to do so, we need a solid understanding of our market of interest. A market characterization is more than a simple description of the market. It also involves knowledge of who influences who, how profits are made, where added value occurs, how pricing is done, and where the barriers and potential leverage points might be. This often involves looking at the market from the perspectives of those who are making a living in it.

The results of market characterization research can be described in text or reflected in a market operation diagram. Two models of market diagrams are provided below. Figure 1 is a supply side market diagram for the motors market and Figure 2 diagrams the California residential new construction market[6].

As can be seen from these two examples, it can be very important in some markets -- where there is concentrated market power, for instance -- to know something about market flows and market shares. This is the case with the motors market. These types of data can be gathered from census shipment sources, interviews with knowledgeable industry experts, and distributors. In dispersed markets, like the California residential new construction market, the market information that one needs to design an intervention will need to address understanding who makes the decisions and who supplies the services needed.

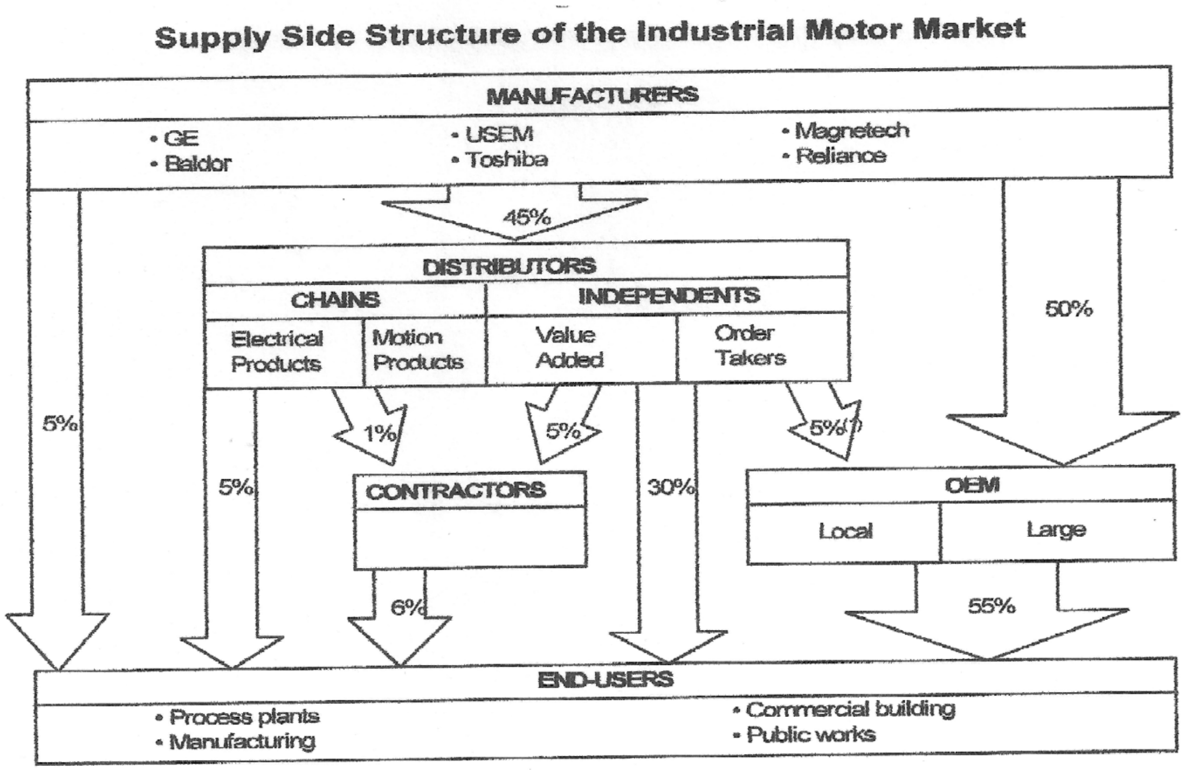
In performing a market characterization study, the approximate market must be delimited and samples taken of knowledgeable informants from each important facet of the market. This is done to avoid biases or limited perspectives that may be advanced by some market actors. Look for drivers of decisions and follow the money. Determine if there are associations that can provide leverage, or aggressive new competitors who may align with your initiative to gain market share. Look for non-energy benefits which may accompany and propel the energy efficient choices.

The market characterization should clarify the barrier to diffusion of the energy efficiency measure or practice in question, going beyond "awareness," "cost," or "consumer demand is missing." These are typical reasons given by market actors, but these aren't always the main barriers. Initial cost or incremental cost aren't barriers at all if the product is seen as having value – or no Lexuses or BMWs would be sold. A solid market characterization study,

[6] We are only including here the newly constructed residential buildings. Additions, remodels, and renovations, which are part of new construction codes, involve different market actors and dynamics.

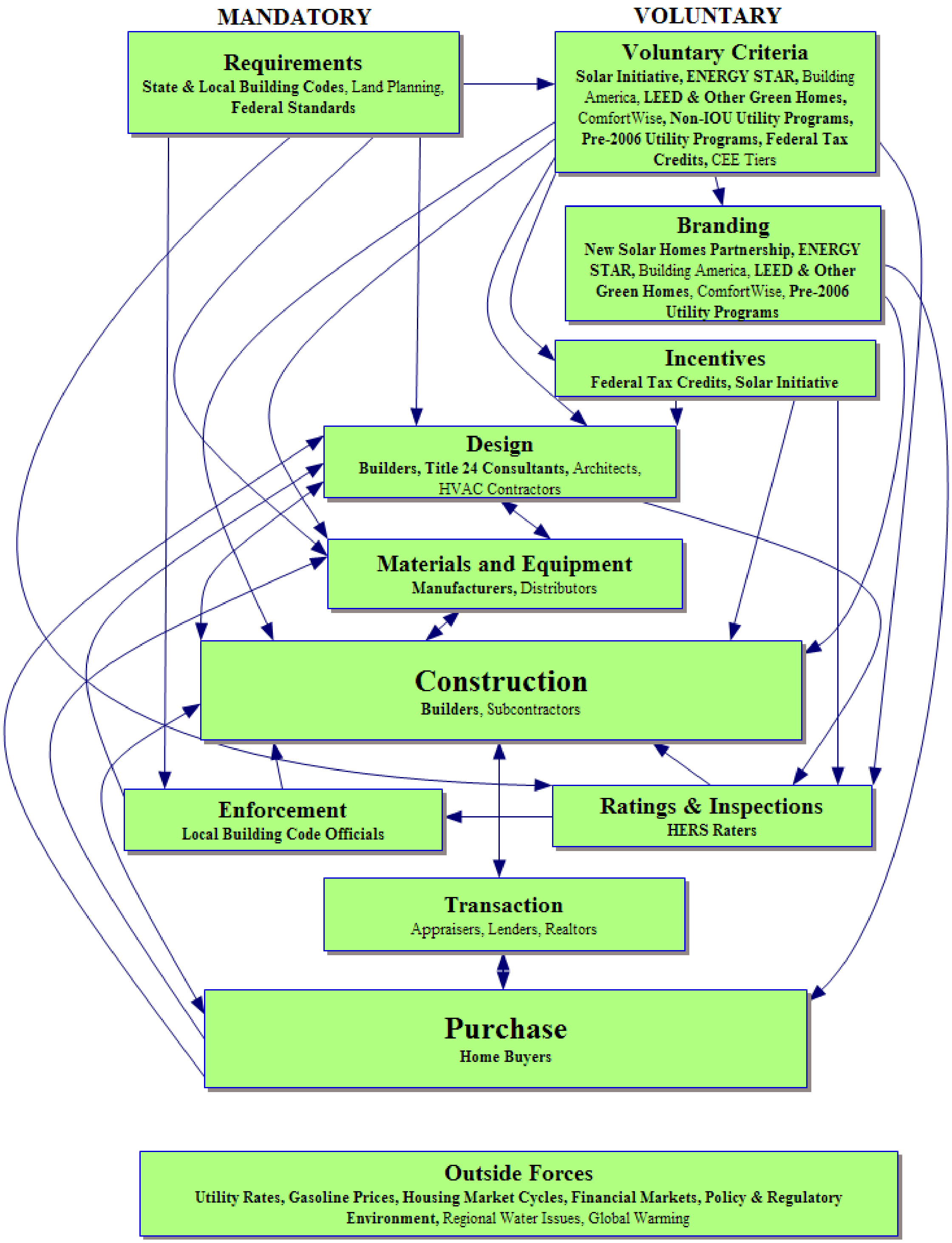
often national in scope, can lead to the identification of potential members of the intervention advisory committee (see below).

Figure 1: Supply Side Structure of the Industrial Motor Market[7]



[7] Rosenberg and Hoegen, op cit. p.47

Figure 2: California's Residential New Construction Market[8]



[8] KEMA, 2009, op.cit., p.8.

3. Baseline

At the time that the market is being characterized, it is important to gather information on baselines for potentially important efficiency indicators, such as sales, prices, availability, stocking practices, in order to be able to document change at a later time. It is important to get a market baseline, not a program baseline, since the market is the target. After each of the important baselines are captured in the market characterization, follow-up work to measure changes in the baseline metrics will need to be replicated at intervals consistent with how fast the market is changing. The baseline information is utilized within the strategic planning process to identify the appropriate metrics of progress toward the strategic goals.

4. Strategically Design the Intervention

4.1 Understanding the Market

Understanding the market that may be a target is the first area of focus for planning. The next area of focus is designing an appropriate set of activities to strategically interact with the market. As part of this, it is important to spend time understanding what appropriate program targets could be and to develop a program logic and metrics in line with this understanding.

Once the market is understood, and the target measure or behavior is determined, the design of the program – using insights from social science, marketing, and the experience of market informants – can proceed. A good market transformation program consists of a series of strategic interventions involving solid knowledge of the market and coordination with other market actors, and is pursued using well defined market tools and tactics. A well-designed market-based program will recognize and use market forces, find allies, promote competition and share risks. A market-based program approach is also frequently tied to non-energy benefits that can make the desired product or service a preference in the market. This is where having a large set of tools at the program designer's disposal is important. Well-designed market transformation programs are not about incentives, but rather are about strategic partnerships with market actors seeking similar goals for their own purpose. A good design looks for points of leverage and identifies the barriers that must be addressed.

The literature has established a list of common strategic tools for consideration.[9] Such suggestions for strategic program design include:

- Link energy efficiency to other needs that customers value highly-- new products can succeed only if they meet real customer needs.
- The market must be defined clearly enough to be targeted;
- The market must be characterized so that program administrators can understand the opportunities and barriers as well as the relationships in the market;
- Identify a baseline for the targeted measure or practice, to be tracked over time;
- Use the value-added chain to influence downstream adoption of energy efficiency.
- Seek to apply market leverage by working with natural allies.

[9] EPRI, op. cit.; Prahl and Keating (2011)

- Identify a market/product nexus that that produces large enough savings to justify the resources (in other words, ensure that large technical potential is available)
- Establish a coherent market and program theory, usually captured in a logic model, that connects the expected actions with the desired outcomes
- Focus on early adopters in opening markets for innovative products, such as products that provide both energy and non-energy benefits.
- Use different approaches to attract early adopters and achieve mainstream markets.
- Continue to measure and monitor key market indicator even after a particular market has been transformed for ongoing progress tracking; address unintended consequences or new barriers identified through this monitoring.

The type of interventions in market transformation initiatives may need to be different depending on the stage in the adoption process when the intervention occurs. Most market transformation efforts will be targeted at the innovation and early adoption phases of developing markets. We have included an example of varying the strategy with the level of penetration in the market in Appendix A.

Finally, remember that, "market transformation isn't just the product of highly structured programs. It results from focused application of specific interventions in the market – and a *certain amount of luck*." [10]

4.2 Understanding Barriers

Much of the literature on market transformation has dealt with the barriers and market failures that are seen as targets for the strategic intervention. While not all market transformation activities will address barriers – and it can be a faster and smoother phenomenon when the barriers are actually small – understanding what constitutes the key barriers to progress is an important part of the planning. Eto, Prahl and Schelgel set out 14 traditional market barriers in 1996.[11] In 2001, EPRI[12] collapsed these into just eight overarching barriers.

We believe that the fourteen original barriers are important for program planners to understand, and the original source is recommended for greater understanding, but simplicity calls for using a list similar to EPRI's for purposes of practical program planning.

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[10] EPRI (2007), p. 7-1., emphasis added.
[11] Eto, Prahl and Schlegel (1996) pp 13-16
[12] EPRI, (2001).

Figure 4: Types of Market Barriers

Eto, et al List of Market Barriers	*EPRI's List of Market Barriers*
Information search costs;	Access to information
Performance uncertainties; Asymmetric information;	Performance uncertainties – risks
Access to financing	Access to financing
Split incentives;	Split incentives – who pays is not who gains
Bounded rationality – (frustrated by old rules of thumb); Organizational practices or custom;	Decision-making – rules of thumb, habits, organizational decisions
Inability to separate product features – in particular for pricing; Inability to reverse an EE decision.	Product or service features -- can't separate efficiency features, not easily reversed
Hassle or transaction costs; Hidden costs;	Transaction costs
Externalities not visible; Mis-pricing due to regulation;	Mispricing of energy or other products in the market due to regulation and/or failure to include externalities.
Product or service unavailability;	

4.3 Intervening to Address Barriers

Market transformation interventions are selected as much by the opportunities to leverage and change markets as by the need to focus on barriers that are keeping efficiency from rising to a competitive position in a particular market. Not all markets are broken; not all markets are filled with big barriers. But making sure barriers are reduced, removed, or avoided in the future will prepare the way for sustained market transformation. Therefore knowledge and targeting of important barriers identified in the market characterization study is often a core element in planning the market intervention. One example of how barriers, interventions and metrics of success line up is derived from the EPRI handbook. [13]

Figure 5: Examples of Market-Effects Based Performance Assessment

Market Actors	Market Barriers	Intervention Activity/goal	Hypothesized Effects	Performance Indicators	Measurement Protocols
Manufacturer	Lack of Profitable market	Promotion and incentives to increase demand	Manufacturer increases production by 25%	% change in annual production	Interviews with manufacturers
	Uncertainty about product performance	Cost sharing on research to improve product	product receives increased rating from 10% of customers	% of customers satisfied with product	Interview customers about product quality
Dealers, wholesalers and volume builders	lack of profitable market	Program promotion to stimulate demand for efficient product	Sales of product increase by 18%	# of units sold	store distribution checks and interviews
	Limited product availability	product promotion to stimulate demand and increase stocking	product stocking increases by 15%	# of units in stock	Intercept surveys, stocking surveys
	Information cost	Training of sales staff to increase information flow to consumers	Sales staff increase promotion of product by 15%	% of sales staff that mention product to customer	purchaser surveys; trade ally interviews
Customers	Lack of awareness and knowledge	mass advertising	Awareness of the product increases by 40%	% of customers knowledgeable about product	customer surveys
	Uncertainty about product performance	demonstration products and customer testimonials	All demonstration customers give high ratings	percent of customers giving high rating	customer surveys
Regulators	performance uncertainty	Demonstrate technical and market feasibility	Regulators take action to remove barriers	Specific activities are taken or planned	interviews with regulators

4.4 Building a Program Theory or Logic Model

Just as it is often useful to flow chart what the operation of the underlying market looks like, program designers must also document how the program elements are intended to work together, which aspects of the market and which barriers, if any, the tactics will target. This documentation process is called a "program logic model." Building a program logic model

[13] EPRI, op. cit., p. 5-7

serves several purposes: 1) to test the reasonableness of the linkages; 2) to look for any barriers or leverage points that are inadvertently missed; 3) to see how the pieces fit together; 4) and, to establish an *a priori* version of what the intervention was designed to do for the sake of the evaluation and attribution. A logic model would typically be updated once the strategic intervention has been initiated and the program starts to come together.

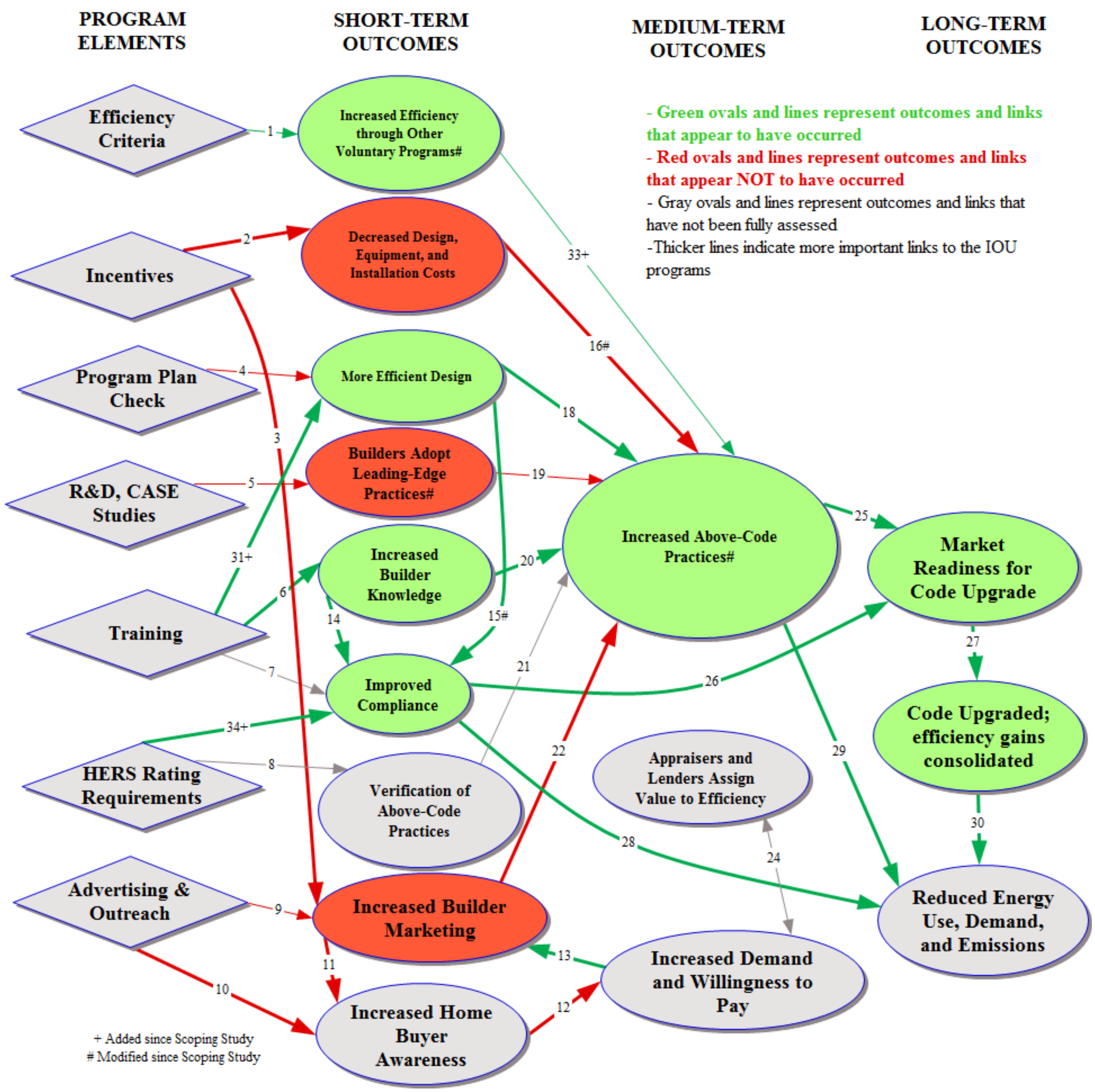
Since market transformation is planned to take place over a long period of time (as long as 2, 5, or 10 years), a good market transformation "story" will always have interim goals and expected metrics of progress that are tied to the logic of the program intervention. These metrics may change, because markets are very dynamic, and some logical links may be dropped. However, without interim metrics to look at progress and adjust the tactics used, there would be a risk of continuing investments when it should be clear that interventions need to be dropped, changed or simply abandoned.

One mistake planners should avoid is starting with what the program tactics would traditionally be, and then looking for possible results, and calling those results the goals for which we need metrics. Rather, it is important to design program intervention to aim at the outcomes that are desired for the intervention. Planners also should look at what would be interim indicators **of market progress—the desired market effects**. After these metrics have been identified, planners should decide what tactics will be needed to advance the metrics. This basic sequence of steps is sometimes ignored.

There are several models for how to lay out a logic model. One tabular approach is found in Appendix A. Additional models are offered in Rosenberg and Hoefgen[14]. Another that has been used successfully by KEMA (2009) is inserted below.

[14] Op.cit. Pp. 49 and 60.

Figure 6: Model Logic Model- Residential New Construction (CA)[15] — Desired Outcomes and Links to IOU Programs



4.5 The Market Transformation Story

A final step in designing a set of strategic interventions is building a market transformation "story[16]." A market transformation story assembles the whole picture of the

[15] KEMA (2009), op cit., p.20.

market and the planned strategy in order to justify the interventions; explain the logic of the interventions; identify the barriers, opportunities and metrics; and identify the tactics and resources to be used. The market transformation story will vary from one market intervention to the next, but it will always include the logical connections between the market effects desired and the interventions of the program. Program planning due diligence requires that the "story" of any market transformation initiative be rigorously reviewed to see where logical links may be tenuous or barriers underestimated. Getting feedback from an advisory committee can be a good reality check on linkages that are stretched too far.

A key to the "story" is to establish what market effects are expected to be accomplished by the program interventions. These **desired market effects** are the postulated goals that will help determine the program metrics, and the tactics and points of intervention in the market. They will also help decide how long to stay in the market.

Some market effects are only produced after a series of long term interventions. In addition, the relative ambition of the targeted market effects will vary from market to market, depending on the relative strength of the program in the market, the willingness to spend resources while waiting, the availability of program intervention resources, and other factors.

Examples of the types of reduced barriers and structural and institutional changes— or desired market effects— that might be targeted in the market by the program interventions include:

Figure 7: Examples of Types of Desired Market Effects

- A competitive market in which the efficient option battles for market share
- Reduced or eliminated price premiums for the basic technology
- New role players in the market to support and sustain the product
- Establishment of new competitors in the market who thrive on the product.
- Adoption as a voluntary standard by industry or government
- Market perceptions of the product as a status product
- End-users requesting or demanding the product
- Risks to private market actors are reduced or removed

Notably, "awareness" is not on this list. This is because, while most market transformation initiatives much increase awareness, awareness itself is a very short term measure and is not strongly related to action. Positive perceptions are much more important than awareness, in and of itself.

[16] The term "story" is used to distinguish the "selling of an initiative" from the dry presentation in a logic model. A story fills in the details, the interactions, and the real market details. Herman, P., Feldman, S., Samiullah, S. and Mounzih, K. (1997): "Measuring Market Transformation: First You Need a Story…" *Proceedings of the 1997 International Energy Program Evaluation Conference*, Chicago, IL

In sum, the "market transformation story" is what tells us where program planners want to go and the steps needed to get there. And as previous authors have noted, "the point here is that there is not a single criterion or set of indices to be met in determining whether and when to reduce program support to a given market. Rather, the combination of a solid program plan and timely monitoring of current market conditions provide the basis on which to make decisions regarding exit strategies and alterations of other elements of program design and delivery."[17]

5 Advisory Group

In the California program environment, transparency and openness are valued. For an optimal market transformation program planning environment, we recommend that program designers bring in individuals, stakeholders, and private sector companies to form a sounding board and an idea generator. By its nature, this type of collaboration takes time, but since market transformation efforts are long term projects, the loss of time to get the right connections made will almost always outweigh any need for urgency. Sometimes, it may not be possible to involve competitors in an open discussion, but their willingness to provide data on market structure would be enhanced if they understood how their needs might mesh (or not) with the market transformation effort. Organizations of service providers are generally more receptive, but even manufacturers have been known to come to the table for motors programs, Energy Star ® windows programs, and manufactured housing in the Pacific Northwest. Such broad collaboration occurs when a significant portion of manufacturers see synergies between their corporate goals and what the market transformers have in mind. Early feedback from involved market actors can be invaluable.

Since markets are not transformed at the same rate and speed, it is important that we resist the urge to have a one-size fits all market transformation guidance. Instead, the market transformation guidance and discussions should be specific to the markets and players in that market.

6 Evaluation Strategy

Evaluations, at their simplest, test the assumptions of the planners against in-field results. Market transformation planners have characterized a market and laid out a program theory and logic. They should have identified the interim and long term goals, or desired market effects, to measure progress in the market. They have a hypothesis of cost-effectiveness that depends on declining costs and expanding impacts from the high cost initial intervention. There are assumptions of causes and changes. The evaluation will need these assumptions to guide measurements in the field.

Just as market transformation metrics for success will be based on the whole market, the evaluation will focus on the market changes, and hopefully, the desired market effects of the program. To avoid a narrow and misleading focus on the "program" in a much larger and very

[17] Rosenberg and Hoefgen (2009, p. 53).

dynamic market, organizations across the country have even taken to calling the evaluations – Market Progress Evaluation Reports (MPERs). This **focus on the change in the market** is as important for cost-effectiveness as it is for other metrics. Because Total Resource Cost (TRC) cost-effectiveness depends not only on the cost of the intervention, but the incremental cost of the measure or service, it is important for many market transformation interventions to assume a declining cost structure for the measure over time, not just reduced per unit administrative costs. As noted above in the section on market effects, one good metric of progress is reduced unit costs over time.

The ultimate measure of market transformation success is whether the effects can be sustained over time, at least at a target level of efficiency, so that funding can either be shifted or less expensive support of the market can be substituted. Sustainability implies long lasting impacts that don't need continuous subsidization[18]. The timeline for this can be long though, so evaluators are often asked what indicators of sustainability might be used in the interim or mid-term. A review of the literature indicates that there are multiple potential metrics of sustainability.[19]These are generic, and each initiative would need to develop its specific indicators for sustainability.

Figure 8: Potential Indicators of the Probable Sustainability of Market Effects

- Is someone making money by offering it?
- Has a private market developed to continue the facilitation?
- Has the profession or trade adopted it as a standard practice?
- Would it be difficult or costly to revert to earlier equipment or practices?
- Are product performance issues resolved?
- Have more efficient codes and standards been adopted?
- Has the product achieved a dominant market share, pushing out less efficient options?
- Does customer awareness make the targeted measure the likely choice?
- Is there widespread availability of the product with the necessary infrastructure of service providers?
- Is the price of the product competitive and becoming even more competitive?

7 Conclusion

This paper can only emphasize the most important points about planning and implementing a market transformation initiative. In trying to be concise and also stay away from details that can distract from the bigger picture, we have not provided examples from the thirty years of national

[18] It is overly simple to consider total disengagement from markets. There are valid reasons for reducing, not ending support, or changing the type of support. Most market engagements continue to support increasing efficiencies over time.
[19] Hewitt (2000); Rosenberg and Hoefgen (2009).

experience with market transformation. Many of those examples can be found among the much more extensive reference material that forms the backbone of this paper. Here the emphasis has been on recognizing that market transformation is a distinct tool for achieving energy efficiency. It isn't the default strategic choice, but one that can be highly effective if used properly. It can be risky and take a long time to pay off at times; and it may be necessary to abandon initiatives that are not showing signs of being effective. The knowledge of markets and the relationships formed with market actors can pay off with unexpected opportunity and even help resource acquisition programs.

The CPUC, the CEC, non-governmental entities, private sector market actors and the IOUs will need to continue to work together to achieve some strides in market transformation. For many markets, market transformation may be the only strategic option. It will take a continual effort over several portfolio cycles and will require alignment of policy direction and appropriate metrics and rewards for the implementers. But the potential benefits of concerted market transformation initiatives make this well worth the effort.

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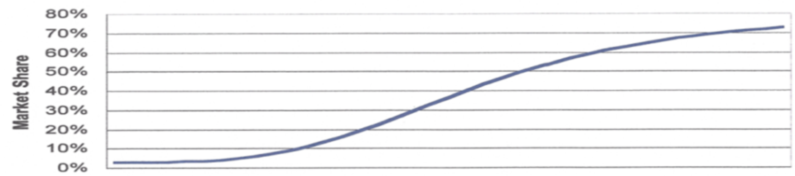
APPENDIX A: Matching Program Type to Product Life Cycle

Policy & Programs to Accelerate MT



Introduction	Early Acceptance	Take Off	Maturity
SUPPLY CHAIN ORIENTED Government lab R&D Sponsored corporate R&D Technology road mapping Mediate technology standard setting Development of performance metrics and testing protocols	Vendor technical and sal es training Co-advertising Vendor merchandising support Development & promotion of voluntary product efficiency standards Product testing	Vendor technical and sales training Co-advertising Vendor merchandising support Upstream product subsidies Initiate consideration of higher product standards Develop common service specifications	Mandatory codes and standards Promulgate higher voluntary standards
DEMAND ORIENTED Purchase of p rototypes or early models Develop and publicize case studies of applications	Bulk purchase Customer education Rebate programs General EE public relations	Customer education Rebate programs General EE pu blic relations	Continued customer education Rebate programs for higher efficiency units only

Stages in Product Life Cycle

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