Sharing the Love: “Guaranteeing” Participant Benefits from Equitable Electrification Programs

Hal T. Nelson, Ph.D, Res-Intel
Hunter Johnson, Ph.D., Res-Intel
Mike Christiansen, Res-Intel

ABSTRACT

New utility and municipal building electrification programs are multiplying around the globe. In many jurisdictions with high electricity costs and large space conditioning energy needs the electrification of energy end-uses can result in higher total utility costs following electrification. This paper presents the methodology and results of an integrated planning tool, that while applied at the utility service territory level, provides customized property and building-level analytics to identify multifamily (MF) customers that are candidates for “guaranteed” benefits from equitable electrification measures. Using redacted utility billing data for 1,143 MF properties, the paper first identifies the property and disaggregated energy attributes (heating, cooling, baseload) of MF customers that are electrification ready. Participant capital costs (after assumed incentives/rebates) and bill savings are estimated for electrification measures from California’s eTRM deemed savings database that are appropriately assigned to each property. Finally, a highly accurate rooftop solar PV mapping tool is applied to identify properties that are candidates for: 1) net-zero retrofits, or 2) to shift to net benefits with the additional bill savings of rooftop solar. The baseline results indicate that given the high cost of electricity in the study area, only about 9.5% of MF properties are electrification ready where participants receive net benefits after the annual costs of the energy retrofits are included. Only another .2% receive net benefits with added rooftop solar PV, in part due to recently lowered benefits from net energy metering in California. The results are sensitive to the cost of capital and a 4% interest rate buydown (from 7% to 3%) quadruples the amount of electrification ready MF properties. The paper presents a first-ever look at mass-scale analytics that use actual, not modeled, energy and property data for the underserved small MF property sector to scale-up equitable electrification programs.

I. Introduction

The electrification of buildings is a key strategy to reduce greenhouse gas emissions and improve resilience to extreme weather. New utility and municipal building electrification programs are multiplying around the globe. As of 2022, 131 local jurisdictions, and 11 states in the US have adopted policies that require or encourage building electrification. Electrification initiatives are occurring through building performance standards and local building codes (Prescott and Golden, 2023). In addition, the US Inflation Reduction Act (2022) has energized building electrification by giving out 30% tax credits for heat pump technologies, along with additional incentives for electrical panel upgrades and building envelope improvements. (US DOE, 2024)

These initiatives are occurring, in part, because of new electrification technologies. Induction cookstoves are winning over home and professional chefs (Clark, 2022). New cold-climate heat pump technologies are available that eliminate the need for fossil-fuel based back up heating. Heat pumps are three to five times more energy efficient than other heating technologies like electric resistance heaters. In 2022 and 2023, electric heat pumps outsold natural gas furnaces (Kempe, 2024).

Despite the programmatic movement towards building electrification, significant existing barriers remain. First, less than 15% of existing residential buildings have heat pumps, indicating a large need for retrofits (US EIA, 2024). Most of the heat pumps in the US are found in the Southeast and are not cold climate units. Second, many of the municipal and utility programs and policies are targeting residential and commercial property types that have little experience with electrification measures. To date, most heat pump technologies have been adopted by owner-occupied single-family residences (Atlas Building Hub, 2022). Finally, very few jurisdictions have included lifecycle greenhouse gas emissions (GHG) costs of natural gas which suppresses the retail price of natural gas; this makes gas less expensive relative to electricity per unit of delivered energy. The natural gas supply chain is very GHG intensive due to methane leaks (in addition to direct fuel combustion in buildings).

II. Literature

The net result of these barriers is that for many applications, building electrification will remain a niche effort: limited to higher income households who have environmental or indoor air quality justifications for the large out-of-pocket expenditures. Policymakers recognize this and have developed programs to help ensure that the benefits of electrification reach low-income households. In addition to the Inflation Reduction Act discussed below, the Biden Administration's Greenhouse Gas Reduction Fund provides $27 billion to reduce global warming pollution throughout the country (US EPA, 2024a). An example at the state level is the state of Oregon has a goal to install 500,000 heat pumps by 2030 in low-income households to help them adapt to climate change (ODOE, 2024). This paper focuses on equitable electrification defined as electrification projects that prioritize "environmental justice communities that need the benefits the most and provide the most assistance to those with the greatest need" (Greenlining Institute, 2019, p. 13). This includes utility bill savings, improvements in indoor air quality, and improved resilience against extreme weather, creating living wage jobs, and other benefits.

One of the main barriers to equitable electrification are the "soft costs" of the retrofits. This includes engineering, procurement, and contracting as well as the costs of recruiting customers into a program. The solar PV industry has done a fantastic job at identifying and mitigating customer acquisition costs as a part of solar energy's soft costs (EERE, 2024a). For electrification programs, one key element of customer acquisition costs are the identification of the costs and benefits from fuel switching at each property. This is made difficult because each property is potentially unique in its occupancy patterns, energy-use behavior, as well as the existence of different energy consuming equipment (appliances, HVAC, building envelope) and the energy efficiency of that equipment. For instance, many low-income households in the Northwest US have inefficient baseboard electric resistant heaters while others have natural gas furnaces. The cost-effectiveness of switching to heat pumps for space heating are very different given those two types of existing heating equipment. In regions like California with high electricity prices (and relatively low natural gas prices), identifying customers that are candidates for equitable electrification is even more difficult because of the added electricity consumption from fuel switching equipment including heat pumps, heat pump water heaters, and induction cookstoves.

To help reduce the customer acquisition costs associated with electrification, several types of modeling tools have been developed to help stakeholders understand costs and benefits. The first category of these tools include "one-off" retrofit evaluations that are performed one at a time and require substantial labor hours for property and building data to be manually entered. The simplest of these tools are Rewiring America's Personal Electrification Planner (Rewiring America, 2024) and RMI's Green Upgrade Calculator (RMI, 2024). These tools rely on the property owner/manager to input information about home area, heating fuel, system, water heating and clothes drying fuel, and stove/range fuel. They also include inputs about income and tax filing status to estimate IRA and local utility incentives. These one-off tools rely on physics-based building energy modeling tools like the US DOE2 engine (NREL, 2024a). Physics-based building energy modeling tools are computationally intensive and require many more data inputs. Very few physics-based modeling tools can perform simulations at scale without massive computation power (and electricity use).

Physics-based models have been applied at scale through the use of supercomputers that match energy use models to the building "stock". ORNL has utilized building data to create estimates of energy consumption for each building in the US as well as electrification measures can be adopted as part of the tool (ORNL, 2021). The massive ORNL effort links one-off tools with energy models that can be used to simulate electrification for entire cities, counties, states. The most commonly used tools in this category are the building stock models such as NREL's ResStock and ComStock (NREL, 2024b; NREL 2024c). These tools do not calibrate inputs based on actual property energy use, but rather match predicted energy use to each property based on building vintage, square footage, and water and space heating fuel types.[1]

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[1] ResStock is used for residential buildings less than 49 dwelling units see https://resstock.nrel.gov/ and excludes common area energy use for hallways, elevators, outdoor lighting and other end-uses associated with MF common

The modeling tool most similar to the one used in this analysis is the DOE's Building Efficiency Targeting Tool for Energy Retrofits (BETTER) that includes building owners and operators as the primary users (EERE, 2024b). BETTER requires stakeholders to enter property and utility bill data and then runs the ASHRAE inverse modeling toolkit to identify baseload, heating, and cooling energy use and associated energy efficiency measures (Li et al, 2019). BETTER allows users to create portfolios of properties to analyze but is labor intensive due to the manual property and utility data uploads required. One city reported this cost at $800 per property which is consistent with the authors' experience in California (ACEEE, 2022, p.9) As described in more detail below, this analysis performs the equivalent of loading property and energy data for 1,143 MF complexes into the BETTER tool. At $800 per property, the labor cost of performing the following analysis in BETTER would be ~$915,000 and wouldn't include the rooftop solar PV and participant benefits analysis. Tools like BETTER tend to be applied to larger MF properties that are required to comply with building energy benchmarking ordinances.

III. Methods and Data

This research approach allows the beneficial integration of both of the individual and building stock approaches that allows estimates of participant benefits from electrification at each property. By matching utility billing data to each property in a utility service territory, this research endeavors to make test hypotheses about participant benefits and different levels of electrification incentives. To understand electrification costs and benefits, assumes retrofit costs and benefits are passed along to MF property owners and tenants. Previous research has shown that most non high-rise properties, as well as newer properties are tenant-metered (Nelson & Johnson, 2022). Stakeholders are working to develop financing tools such as tariff on-bill financing that will hopefully rationalize investments in the MF sector (US EPA, 2024b).

Characterization Methodology

The software tool creates a technicolor "Characterization" of all properties for each building sector in a utility service territory. The Characterization develops the data shown in Figure 1.

Figure 1: Overview of the Characterization

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areas. A list of building energy modeling tools is available here: https://rmi.org/our-work/buildings/deep-retrofit-tools-resources/

This paper focuses on the *Multifamily (MF) sector*, which is the sector with the highest customer energy burden (utility bills as a share of income) and has the highest share of people of color (Drehobl et al., 2020). It also suffers from the well-known landlord-tenant market failure (Sorrell et al., 2004). The data includes property attributes such as address(es), conditioned living area (square feet), year built, number of floors, presence of a pool, and others. The authors receive data from utilities with their customer attributes includes kWh and therm consumption, income, occupancy, utility tariff type. Utility EE audit and program data is also obtained. The other data includes candidate electrification measures as well as rooftop solar PV potential. Utility and federal incentives are included in the net cost estimates.

The Characterization proceeds in the following steps:

A. **Property Data Cleaning and Aggregation**. The Characterization integrates property data from tax assessor data and commercial real estate databases to create a property inventory. About 20% of MF properties are multiparcel developments that contain multiple tax parcels purchased by the developer but that are still recorded as individual lots. The buildings and square footage of these lots are summed up based on spatial analysis in order to perform the energy analytics. Figure 2 shows a Southern California MF complex consisting of 6 tax lots on three separate street names that was correctly aggregated by the Characterization tool.

Figure 2: Property Aggregation Example

B. **LiDAR and Building Inventory.** Once MF properties have been identified, then building footprint data from counties and/or OpenStreetMaps are joined to the properties. Publicly available Light Detection and Ranging (LiDAR) layers are used to identify missing property attributes and to create a building inventory to accompany the property inventory. Figure 3 shows this for a Southern California MF complex.

Figure 3: Satellite View of MF Complex with Roof Height Estimates

C. **Matching MF Complexes to Utility Meters and Customers.** In the next step, all utility residential and commercial meter metadata are matched onto relevant properties in the utilities' service territory. Utility meter service addresses are matched to MF property street addresses using three sophisticated matching methods include text matching, geocoding of addresses, as well as spatial joins of meter locations with MF properties. One example is shown in Figure 4 below. The blue balloons represent MF service addresses, and the red dots represent the geolocation of nearby gas or electric smart meters. Typically, over 97% of utility meters were matched with at least one residential or commercial property. Once all the meter metadata had been matched to all relevant properties, daily gas and electricity consumption data for all MF properties were joined into the analysis.

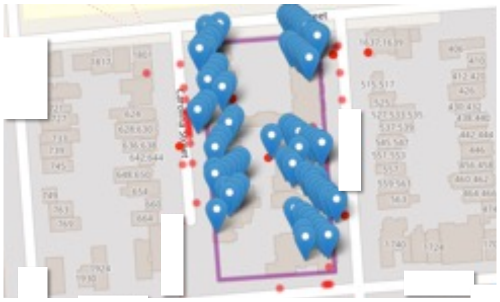

Figure 4: Meter Mapping Example

The analysis also identifies the share of low-income apartment units as a percent of total units for each MF property using enrollment in California Alternative Rates for Energy (CARE) from the utility customer metadata. CARE is a means-tested electricity and natural gas bill discount program targeting households with income less than 200% of the Federal poverty level. CARE enrollment is used an indicator of household income for each MF property.

D. **Energy Analytics and Decomposition**. Next, load disaggregation techniques are performed to identify properties with cost-effective energy efficiency (EE) and demand response supplies. Energy decomposition models use the three parameter ASHRAE inverse toolkit method that utilizes piece-wise, least-squares regression modeling (Kissock et al., 2003). This analysis identifies heating, cooling, and baseload energy use based on total energy consumption's sensitivity to daily dry-bulb temperature. This process is illustrated in Figure 5.

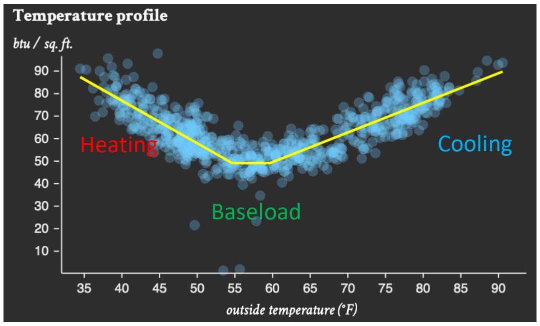

Figure 5: Energy Decomposition Model

E. **Existing Equipment Predictions.** To identify likely equipment at each property, additional data is joined into the analysis. This includes building permit data, EE audit data, and demographic data. This data was used in random forest machine learning models to predict existing equipment at each MF property. The existing equipment analysis consisted of five steps:
   1. Initial data cleaning and standardization of entries in source data.
   2. Matching of equipment data to properties.
   3. Existing equipment predictions using machine learning methods for properties without reported equipment.
   4. Evaluation and confidence assessment of final equipment results.
   5. Summary and documentation.

The following end-use equipment were predicted as shown in Table 1.

Table 1: Existing Equipment Types

Existing Equipment	**Existing Equipment**
Asbestos	Knob & Tube
Battery Storage	Pool
Battery Storage kWh	Solar PV
Central AC / Cooling / HVAC	Solar PV kW
Cooking Fuel Type	Number of Solar Panels
Dryer Fuel	Space Heat Fuel
Efficient Fridge	Transformer
Electrical Panel Baseline	Wall Insulation
Electrical Panel Upgrade	Water Heat Fuel
EV Charger	In-Unit Laundry
Heat Pump Air	In-Unit Water Heat
Heat Pump Water	Knob & Tube
In-Unit Laundry	Pool
In-Unit Water Heat	Solar PV
	Solar PV kW

Out-of-sample predictive accuracy ranged from 58%-92% depending on the equipment type and data source.

F. **Equitable Electrification and Energy Efficiency Measure Assignment.** The existing equipment data set created in the preceding step informs our energy efficiency recommendations in three ways:
   1. By indicating which energy efficiency measures are applicable at a property.
   2. By indicating whether efficient equipment is already installed.
   3. By indicating how each measure’s savings vary across properties with different equipment.

In the first case, not all measures apply to all properties. For example, properties with central laundry are not eligible for efficient in-unit laundry measures. Properties with pools are eligible for variable speed pool pumps. Second, the existing equipment data sometimes tell us that a property already has efficient equipment installed. For example, the data sometimes indicate that a property likely already has an EnergyStar efficient fridge, or the property is already well insulated. In these cases, applicable measures are not assigned to the MF property. Third, the costs and savings associated with a measure vary by heating fuel, HVAC system, and other attributes. For example, the savings associated with low-flow showerheads depend on whether the property is predicted to use gas or electric water heating.

Candidate EE measure packages from the 2023 California eTRM database (California Technical Forum, 2024) were selected based on stakeholder input. Measures were assigned to each property if it had high heating, cooling, and baseload energy use similar to Li et al. (2019). For this sample of MF properties, about 71% were candidates for heat pumps based on their heating and cooling energy use. All of the properties were assigned induction ranges, heat pump dryers, and heat pump water heaters. The number of measures assigned to each MF property were normalized using number of apartment units, estimated roof area, and other factors. For some measures, we used a generally accepted engineering rule of thumb to determine HVAC capacity/sizing of the equipment: that apartments will need 1 ton of cooling for every 500 square foot of conditioned floor area. The list of measures includes are included in Table 2.

Table 2: Eligible Electrification and Energy Efficiency Measures

- CEILING_INSULATION
- CENTRAL_HW_BOILER
- DHW_PUMP
- DUCT_SEAL
- ROOM_AC
- EFFICIENT_SHOWERHEAD
- ELECTRIC_RANGE
- EFFICIENT_CLOTHES_WASHER
- EVAP_COOLER
- HIGH_EFFICIENCY_FURNACE
- HEAT_PUMP_CLOTHES_DRYER
- HEAT_PUMP _POOL_HEATER
- HEAT_PUMP _WATER_HEATER
- EFFICIENT_HOT_WATER_BOILER
- KITCHEN_AERATOR
- LAVATORY_AERATOR
- LED_POOL
- LED_T8
- LED_WALL_PACK
- OCCUPANCY_SENSOR
- ROOM_AIR_CLEANER
- SMART_FAN_CONTROLLER
- SMART_POWER_STRIP
- SMART_THERMOSTAT
- TSV
- VARIABLE_SPEED_POOL_PUMP
- WALL_INSULATION

Using these assignments, the total labor and measure costs, peak kW demand savings, as well as annual deemed kWh and therm savings for each measure were calculated at each property for each measure.

G. **Rooftop Solar PV Estimates.** The final module in the Characterization Tool includes rooftop solar costs and benefits for all properties in a utility service territory. The Rooftop Solar PV Tool estimates annual solar PV capacity (kW) and generation (kWh) by leveraging LiDAR point clouds and digital elevation models (DEMs) for detailed solar radiation analysis, including:

- **Building code compliance:** Accounts for minimum roof edge setbacks mandated by building codes.
- **Tree canopy shading:** Integrates LiDAR data to assess and remove shading effects from trees.
- **Roof obstructions:** Considers potential obstructions on rooftops, providing a realistic assessment of usable space for solar panels.

The pink areas in Figure 6 below are an example of the rooftop solar PV generation supplies after removing the above three categories.

Figure 6: Rooftop Solar PV Example

By incorporating these factors, the Rooftop Solar PV Tool generates highly accurate annual kWh generation and kW potential for each property at the service territory scale.

H. **Participant Benefits Simulator.** Finally, the benefits simulator utilizes these detailed property, customer, energy disaggregation, and other data created above to identify properties that are "electrification-ready". These are properties that are estimated to received net benefits from adopting electrification measures based on their estimated pre-retrofit gas and electricity bills. The biggest barrier is when the cost of electrification measures (loan payments) exceeds the utility bill savings. For properties where loan payments exceed utility bill savings, rooftop solar PV is installed.

Data

The sample frame for this paper relies on the service territory of a California Investor-Owned Utility of over 30,000 5+ unit MF properties. The sample below of equitable electrification participant benefits are estimated for 1,143 5+ unit MF properties representing about 49,000 apartment units. These properties come from a single inland county with a similar climate of heating and cooling needs. MF properties were selected for this sample if they were tenant metered for electricity, which is also correlated with tenant metered configuration for natural gas. As shown in Table 3, the median size of the MF complexes is 12 units. About 56% of the apartment units are enrolled in the low-income bill assistance program (CARE) while less than 1% enrolled in the moderate-income bill assistance (FERA). The median annual electricity consumption is estimated at 59,000 kWh (~5,000 per unit year) and nearly 18,000 annual therms per property. Natural gas consumption was not available for this sample, so was estimated

NREL's ResStock building stock models MF unit energy-use based on each MF properties climate zone, year built, and square footage (NREL, 2024a). ResStock does not include common area energy usage.

Table 3: Descriptive Statistics for Sample Property Attributes and Energy Usage

	Unit Count	CARE%	FERA%	# of Elec Meters	# of Gas Meters	Annual kWh	Annual Therms
Mean	41	56	1	41	41	221681	64151
Median	12	58	0	12	12	59105	17773
Std Dev	76	24	2	79	76	463909	138776
Min	5	0	0	1	5	2199	1
Max	736	100	20	776	736	6275175	1643763

Table 4 shows the assumptions needed to estimate participant utility bills.

Table 4: Baseline Utility Bill Assumptions

Municipal Tax including System Benefit Charge %	7%
Avg kWh Tariff	$ 0.29
Avg Therm Tariff 1st baseline	$ 1.16
Avg Therm Tariff 2nd (non) baseline	$ 1.59
Electricity Basic Charge + Minimum Charge: $/Meter/Day	$ 0.37
Gas Customer Charge Therm: $/Meter/Month	$ 4.95
CARE avg. effective % discount (electric)	32.5%
CARE avg. effective % discount (gas)	20.0%
FERA % Discount (electric)	18.0%
Interest rate	7%

Table 5 displays the measure costs come from the California Electronic Technical Reference Manual (eTRM) database (California Technical Forum, 2024). These are assumed to represent the incremental cost of electrification and high efficiency measures over the assigned baseline efficiency equipment costs.

Table 5: Measure Costs

	Heat Pump Cost	HP Water Heater Cost	HP Dryer Cost	Induction Stove Cost	Insulation Cost FT^2
Measure Cost	$ 1,685	$ 2,013	$ 1,508	$ 864	$ 1.83

The assumptions for electrification and EE measure incentives include are adapted from the IRA (US DOE, 2022) but *importantly excludes the per unit caps on equipment cost which is assumed to come from incremental California incentives*.

Heat Pump Water Heater	30% of installation cost
Heat Pump (all types)	30% of installation cost

AC (all types)	30% of installation cost
Insulation	30% of installation cost
Measure life	15 years
Solar PV	30% of installation cost

Table 6 includes the assumptions for the rooftop solar costs and kWh generation. The net metering credit assumes that 50% of kWh electricity generated from rooftop solar is exported to the grid (Borenstein, 2024). Those exports are credited at 25% of the assumed retail tariff at each property. The other half of electricity that is assumed to be consumed on-site is credited at 100% of the retail tariff. This results in a weighted average percent net energy metering credit of 62.5%.

Table 6: Rooftop Solar Assumptions

Solar PV Cost/W	$ 2.95
Solar PV Life (years)	20
Solar PV Net Energy Metering Credit (% of electricity tariff)	62.5%
Building Footprint % Suitable for Solar (Max)	75%
Output per Panel (annual kWh)	1,490
Size of Solar Panel (Square Feet)	15

Solar PV sizing is based on two factors. 1) Rooftop space: the maximum kW size of rooftop PV unit at every property is 75% of the building footprint outline based on the median suitable area for kW panels for the sample. 2) Actual kW size is an approximation of California's new net energy metering rules that credits MF accounts with rooftop solar PV for their exports at 15 minute intervals (CPUC, 2023). These calculations are beyond the scope of this analysis. As a placeholder, the calculated kW size matches the annual kWh output from the solar PV system to the annual kWh consumption. This results in actual kW sizes about half of the theoretical maximum size. Actual kW is smaller than maximum rooftop kW because of the lower net energy metering rate which doesn't provide adequate incentives for property owners to export electricity to the grid without energy storage (which is beyond the scope of this analysis). More information California's virtual net billing tariff Decision 23-12-068 which is applicable to MF properties can be found on the CPUC's website (CPUC, 2023).

IV. Results

The baseline electrification readiness results show that based on the assumptions above for all 1,143MF properties: The measure packages resulted in a median 1,766 kWh increase in annual electricity consumption and median 3,950 decrease in annual therm consumption. All properties received bill savings from the electrification and EE measure packages (not shown). The median retrofit package cost nearly $200,000 with about $60,000 in incentives.

Table 7: Baseline Energy Savings and Retrofit Cost Results

	kWh Savings (Increase)	Therm Savings	Efficiency Measure Costs	Efficiency Measure Incentives
Mean	35066	11221	$655,270	$196,581
Median	-1766	3949	$200,438	$60,131
Std Dev	189196	21182	$1,219,778	$365,934
Min	-248002	80	$58,092	$17,428
Max	2186679	200021	$10,732,116	$3,219,635

However, once the payments for the retrofit measures are included, only about 9.5% of MF properties receive positive net benefits from the measure packages. These tend to be higher electricity consumers due to existing electric space heating or other factors. The median annual MF bill increased by $5,600 after including the retrofit loan package payments. This is approximately $466 per apartment unit per year based on the median of 12 units per property or $39 per month. The inclusion of heat pumps in the measure package correlates at -0.47 with positive net benefits. This means that heat pumps are more likely to reduce the likelihood of positive participant benefits. There is no substantive statistical relationship between the percent of CARE units at each MF property with positive net benefits from electrification retrofits. This indicates that the 32.5% electricity bill discount for CARE enrollees is not a primary driver of participant benefits: these households are likely to have higher initial energy use-intensity intensities defined as energy-use per square foot (Nelson and Johnson, 2022). Participant benefits correlate at 0.20 with the number of apartment units in each MF property, indicating a weak to positive relationship between larger properties and electrification readiness.

The next step in the electrification readiness assessment is the inclusion of rooftop solar PV for the ~90% of MF properties that didn't receive net participant benefits from electrification retrofits. Based on the assumptions in Table 6, the median rooftop solar PV size installed is 32 kW, with an output of approximately 47,000 kWh per year, a system cost of $65,000 after the 30% Federal tax credit, and an annual electricity bill credit of $8,500 based on the assumptions about electricity exports presented in Table 6. The rooftop solar PV installations result in uniform participant benefits, yet the percent of properties that receive net benefits from both electrification and PV increases to only 9.7%. *Combined, about 90% of MF properties are still unlikely to obtain participant benefits from electrification even with rooftop solar PV.*

Sensitivity Tests

Given these baseline results, the analysis now turns to sensitivity tests to better understand the dynamics of participant benefits. The assumed 7% interest rate in the baseline calculations could be "bought" down by a Green Bank or other dedicated financial institution or clean energy lending program. A 5% interest rate is associated with nearly 14% of MF properties receiving net participant benefits, while a 3% interest rate predicts 35% of MF properties receiving benefits from retrofits plus solar PV. The annual cumulative loan payment reductions for the 5% and 3% interest rate buydowns on the retrofit package and the rooftop PV are ~$11M and ~$21M respectively.

Limitations

There are limitations to the mass-scale analytics that should introduce some caution in the interpretation of these findings. The data includes predictions of each MF property's attributes, including aggregating of tax lots into square footage, meter matching of properties onto utility service addresses, imputations of missing data for the number of apartment units, predictions of existing equipment and other attributes. Recall that natural gas billing data was not available for the sample and was estimated from NREL's ResStock building stock models based on each MF properties climate zone, year built, and square footage. The utility bill calculator assumes the same patterns of natural gas and electricity usage per month, as well as similarity of customer bills between the domestic tariff modeled here versus under time-of-use rates that are now widespread in California. Unfortunately, utility customer bills were not available, only customer energy usage. Future iterations of the electrification readiness indicator will utilize hourly or daily kWh and therm consumption for each tenant and common area meter to faithfully reflect customer bills.

V. Conclusion and Program Implications

The MF sector is key for equitable decarbonization. It represents about 30% of the dwelling units in California and houses the largest share of low-income and people of color. Without an ability to make investment decisions about their homes, MF tenants rely on their landlords to provide thermal comfort and resilience against extreme weather. This paper analyzes potential participant benefits from equitable electrification programs. By analyzing every tenant-metered, 5+ MF property in an inland California climate zone, these ~1,200 complexes represent a wholistic Characterization of the sector including heating and cooling energy use, existing equipment, and electrification and EE measure retrofits.

There are two main findings from the baseline analysis. 1) Less than 10% of properties in this sample show participant net benefits after the annual payments for electrification retrofits are included. The implication here is that rebates and incentive levels will need to increase dramatically from the assumed 30% level. 2) Due to the reduced benefits for net metering in California, adding rooftop solar PV to MF properties is not going to be a panacea to ensure participant benefits, even in inland California with good solar resources and significant space cooling needs.

The most salient program implication is that electrification (and solar PV) incentives and tax credits need to increase from the assumed 30% level in the baseline analysis. No-cost retrofits obviously bring participant benefits. Full stop. The California Energy Commission is in the process of launching an Equitable Building Decarbonization program for low-income and underserved residential customers in the state (CEC, 2024). Also, California investor-owned utilities have had a no-cost, direct-install, low-income MF efficiency program for many years. However, only about 14% of MF properties in the sample are estimated to have more than 80% of tenant units occupied by CARE enrollees. This has been a historical low-income MF program requirement for no-cost, whole-building retrofits but will not help that much in this sample to scale equitable benefits with only 14% of properties. Since the percent of CARE units is largely uncorrelated with net benefits from electrification in this data, including the properties with higher shares of low-income tenant units is a good approach to spreading the love from electrification.

Increasing participant access to the middle-income electricity bill assistance Family Electric Rate Assistance (FERA) program that provides an 18% electricity discount can also affect participant benefits. Currently, FERA is struggling to enroll eligible participants (~10% of eligible utility customers). Each of the California investor-owned utilities is targeting increased FERA penetration (CPUC, 2021). Given the median annual payment for the baseline electrification measure package is about 40% of annual utility bill expenditures, an 18% discount on electricity could help ensure participant benefits for a considerable number of MF properties. Electrification retrofits can be used to market the FERA program discount.

While this paper focuses on tenant-metered properties, a similar analysis could be performed for MF properties with master-metered electricity. This analysis could inform the development of Tariff-on-Bill financing programs as well as the incentive design for electrification efforts.

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