ARUP

Zero-Carbon Collaboration

The Case for Los Angeles

v1.1

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Executive summary

It’s time for climate action. It’s possible to get to zero carbon, but only if we plan to act together and leave no one behind.

The City of Los Angeles’s sustainability plan — LA’s Green New Deal — established targets to achieve deep energy efficiency for buildings and electrical-grid decarbonization. These goals span a 25- to 30-year period, shaping a future in which all of the real estate within the city could be free of carbon emissions by 2050.

To support the realization of this vision, Arup analyzed the energy and cost implications of retrofitting a typical building in the commercial office and multifamily residential categories that represent 330 million square feet of the largest buildings in the city. Already regulated under the Existing Buildings Energy and Water Efficiency Program, this aggregated building stock makes up over 16% of the built construction within city limits.

This report demonstrates the relative cost to private building owners so that they can play an active role in shaping a carbon-free community. According to LA’s Green New Deal, the co-benefits of a strategic approach to citywide building decarbonization include well-paying local jobs, reductions in air pollution, and reduction in energy poverty during and after the transition.

This vision for our future requires aligned and cooperative action from the City government, its municipal utility, the citywide collective of private building owners, and their investors. Only by working together, starting this decade, can we be successful at leaving a livable city for future generations.

Summary of key findings

- It is possible to achieve zero-carbon buildings by 2050 with currently available technology.
- For aging commercial office buildings, the possible savings over a 25-year period is sufficient to cover the first cost of early electrification before 2025.
- For multifamily residential buildings that adopt early efficiency and electrification, the cumulative energy savings will cover approximately 30% of the first cost over a 25-year period. Grants or loans will likely be needed to support the conversion of this property type.
- For occupied commercial buildings and multifamily buildings older than four years, balancing electrification with energy-efficiency measures should minimize the need for citywide disruption to upsize underground electrical utilities.
- For buildings built within the last decade, alternate pathways for greenhouse gas reduction will allow these properties to align with Green New Deal intentions over the next 20 years until their equipment is ready for replacement and upgrade.

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It's time for climate action.

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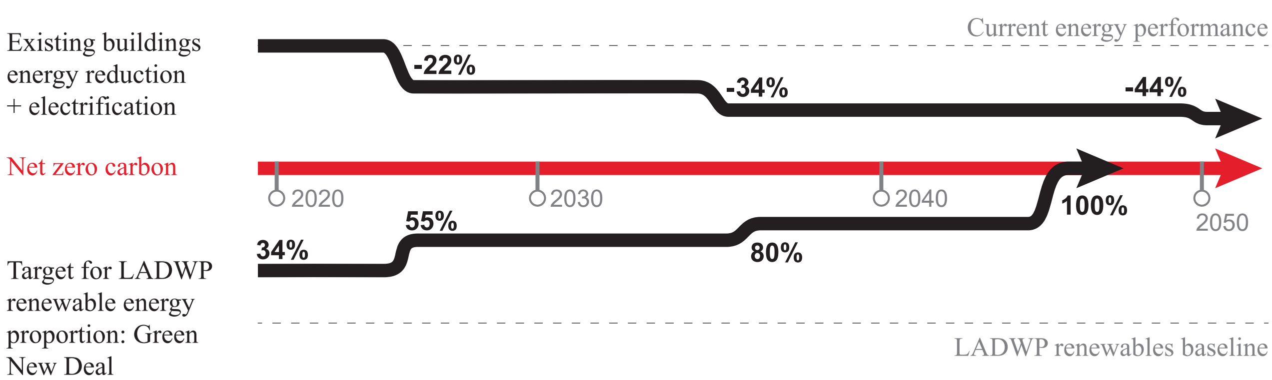
In 2015, world leaders committed themselves to two things: collective climate action and an operational ethic to end poverty, protect the planet, and improve the lives and prospects of everyone, everywhere. The first we know as the Paris Agreement for climate change, and the second as the United Nations Sustainable Development Goals (UN SDGs). Acknowledging that lofty aspirations translate into reality only at the community level, LA's Green New Deal applies the UN SDG framework to set forth recommendations and municipal targets.

Two of LA's goals inspired the research of this paper:

1. The Los Angeles Department of Water and Power (LADWP) will supply 55% renewable energy by 2025, 80% by 2036, and 100% by 2045.
2. Reduce building energy use per square foot for all types of buildings by 22% by 2025, 34% by 2035, and 44% by 2050.

Figure 1. Convergence toward net zero carbon in LA's Green New Deal



The trajectory noted in Figure 1 achieves emissions-free buildings *only* if gas appliances are converted to a zero-carbon energy source. According to UCLA's Energy Atlas, natural gas represented 61% of the total energy use of residential properties and 38% of the energy use of commercial properties for the city of Los Angeles in 2016. It is essential that gas-fired heaters, boilers, water heaters, dryers, and cooking equipment are included in the drive toward zero-emission buildings. While zero-carbon hydrogen options may be viable at scale in the future, all-electric versions of gas appliances already exist and thus are included as a key part of this analysis.

Based on 2019 emissions noted in LA's Green New Deal, the combination of efficiency upgrades, electrification, and greening of the electrical grid would avoid the release of some 9.5 million tons of carbon per year by 2050. This is the equivalent of planting 142 million trees or taking 1.9 million cars off the road per year. In total, over the 30-year transition period, LA's Green New Deal estimates 112 million tons of greenhouse gas reductions. Building energy use represented 41% of the city's 2017 energy use, making it one of the most important sectors for climate action. Furthermore, the nonprofit Architecture 2030 has identified that approximately two-thirds of the built area that exists today will still exist in 2050. It is incumbent on any greenhouse gas reduction plan to include retrofit activities related to existing buildings.

Abbreviations

DHW	domestic hot water
EBEWE	Existing Buildings Energy and Water Efficiency Program
ECMs	energy conservation measures
HVAC	heating, ventilation, air-conditioning
LADWP	Los Angeles Department of Water and Power
UN SDGs	United Nations Sustainable Development Goals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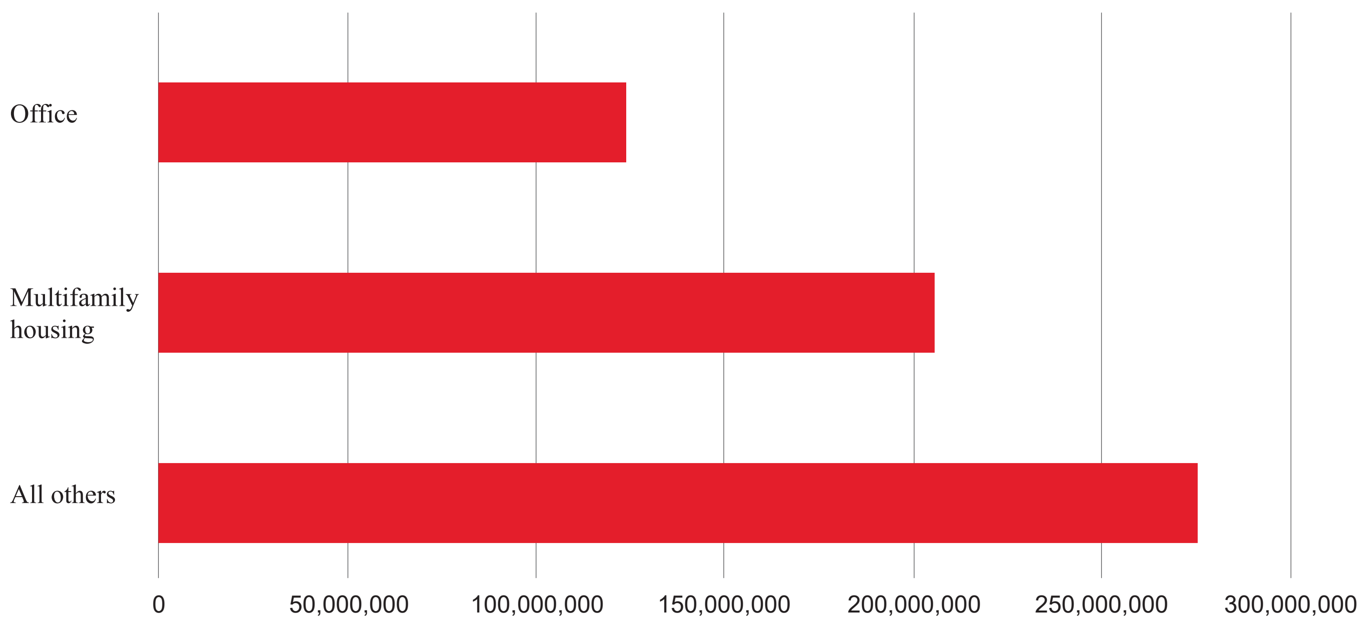
The City of Los Angeles currently mandates public reporting of energy use by buildings over 20,000ft² through the Existing Buildings Energy and Water Efficiency Program (EBEWE). A review of the EBEWE database shows that commercial office and multifamily residences dominate with almost 330 million square feet, representing 55% of the City's regulated area (Figure 2).

Figure 2. Total area (ft²) in the EBEWE database by occupancy type (2018)



Over the past few years, the City has engaged in preliminary discussions around upgrading the EBEWE ordinance to require a path toward carbon-free buildings. New York City's Local Law 97 has already followed a similar path.

Commitment to the common good of a clean energy future tends to find obstacles at the level of individual properties. A building owner facing any such carbon-neutrality ordinance will naturally want to know the following:

1. Which energy conservation measures are the best investment?
2. Which is better for electrification: heat pumps or electric resistance heating?
3. Are there benefits of early electrification?
4. Which zero-carbon path best meets the Green New Deal reduction targets?
5. What will it cost?

Arup deployed a team of cost estimators, energy modelers, embodied-energy experts, and building services engineers to answer these questions for these two largest occupancy types in Los Angeles.

Operational carbon
The indirect off-site emission of carbon dioxide associated with energy use and direct emissions from fuel-burning appliances at the property.

Embodied carbon
The indirect emissions associated with energy and the direct emissions of a variety of global-warming chemicals associated with raw material extraction, manufacturing, transportation, installation, and disposal at the end of usefulness.

1. Which energy conservation measures (ECMs) are the best investment?

Each ECM was analyzed as a stand-alone option to determine its potential.

For buildings built to the minimum energy codes before 1990, the greatest energy efficiency comes from the actions on the following pages, if taken by 2025.

Methodology

Using templates from the Department of Energy's Pacific Northwest National Lab for determining the nation's model energy codes, Arup selected two base energy models: the ~500,000ft² Large Commercial Office and the ~33,000ft² Midrise Multifamily. Arup modified the two models to be compliant with six different vintages of the California Energy Code Cycle, between 1978 and 2019. The modeling exercise applied upgrades for those items that would naturally require replacement during the next 30 years:

- Heating, ventilation, air-conditioning (HVAC) replacements due to refrigerant phase out and/or life expectancy of equipment
- LED lighting upgrades due to market shifts in technology
- Electrification of gas water heaters at the end of life cycle
- Conversion of gas-burning appliances like laundry dryers and cooking equipment
- Roof insulation upgrades to modern code
- Optional wall/window efficiency/comfort improvements for residential only

To test whether the order of action matters, for each of the building types and each of the vintage codes, four paths of electrification were analyzed to determine operational energy costs, first cost, and operational carbon per decade until zero operational carbon is achieved.

- Early electrification (in the 2020s) using electric resistance water heating
- Early electrification (in the 2020s) using heat pump water heating
- Midterm electrification (in the 2030s) using heat pump water heating
- Late electrification (in the 2040s) using heat pump water heating

For a detailed analysis methodology, see Appendix B.

Table 1. Recommended energy conservation measures for commercial office buildings built before 1990

Energy conservation measure	Decrease in energy use (%)	Simple payback period (years)
Upgrade to LED lighting	38	2
Upgrade fan motors to premium efficiency with variable frequency drives	10	2
Option 1 for electrification: Chiller replacement incorporating heat recovery for free heating hot water and domestic hot water	13	5
Option 2 for electrification: Chiller replacement and electric resistance heating for heating hot water and domestic hot water	9	16
Necessary for electrification: Appliance conversions to electrical energy source	5	4

Our analysis indicated that roof upgrades did not save energy and in fact had a negative payback period. No form of wall/window upgrade reached more than 3% energy improvement, and wall/window upgrades had simple paybacks over 30 years in length.

Figure 3. Energy savings versus simple payback for commercial office analysis

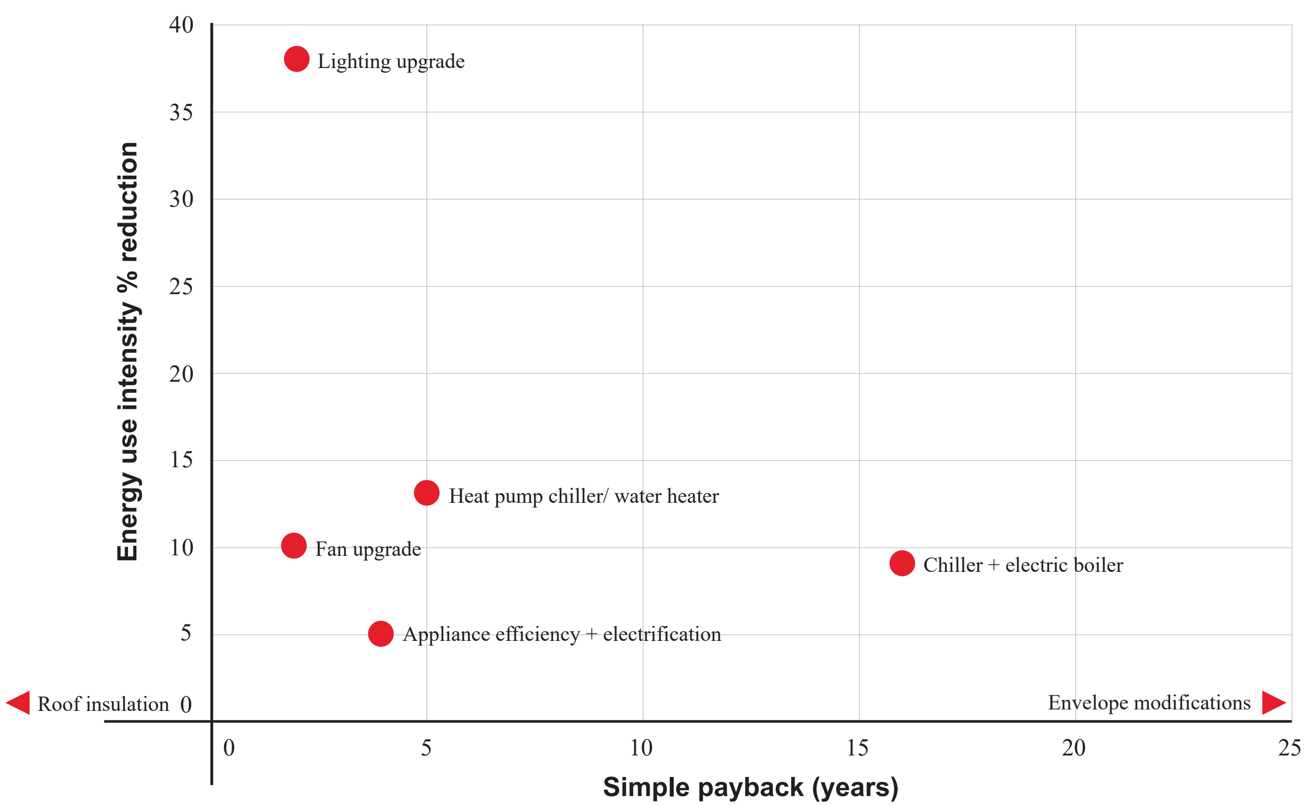
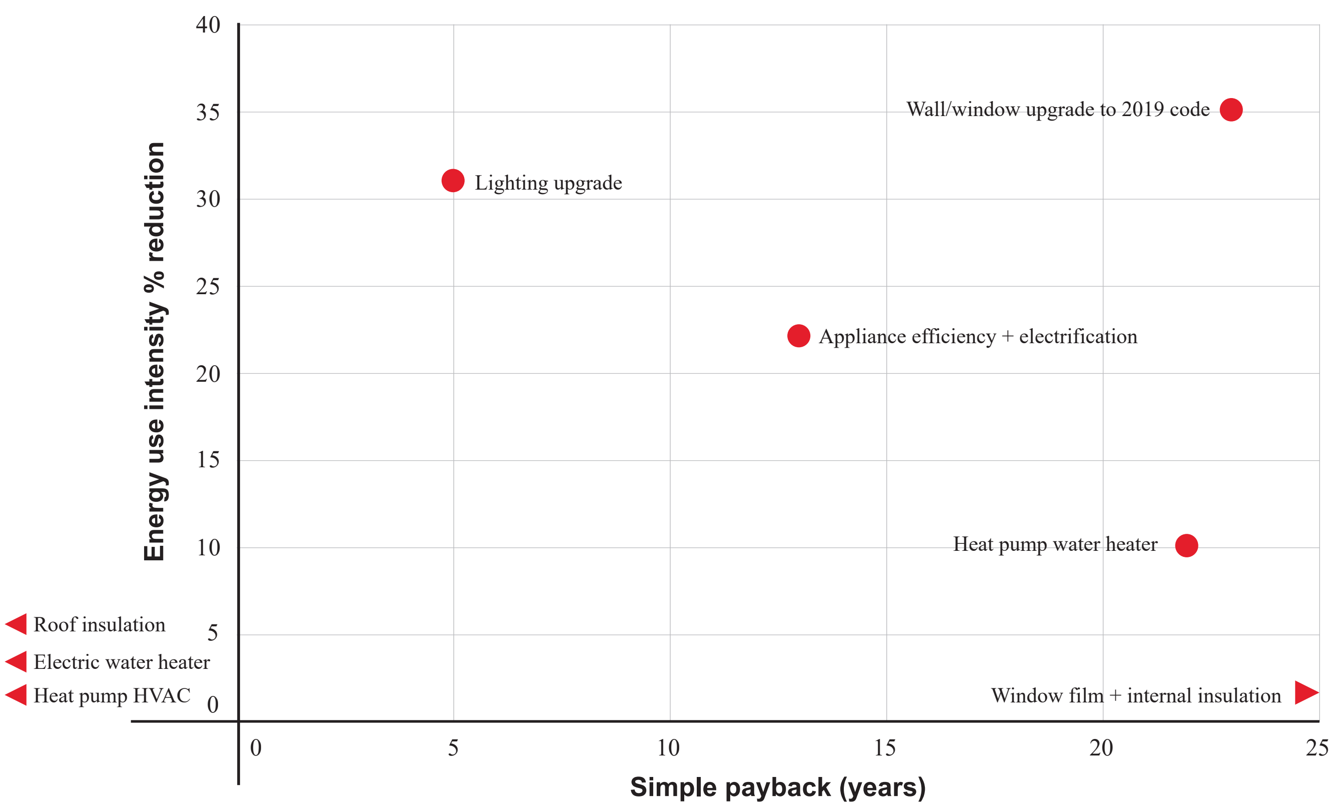


Table 2. Recommended energy conservation measures for multifamily residences built before 1990

Energy conservation measure	Decrease in energy use (%)	Simple payback period (years)
Upgrade to LED lighting	31	5
Necessary for electrification: Appliance conversions to electrical energy source	22	13
Necessary for electrification: Air-conditioning unit converted to electric heat pump	2.0% increase	negative payback as a stand-alone measure
Option 1 for electrification: Water heater converted to electric heat pump	10	22
Option 2 for electrification: Water heater converted to electric resistance	1.4% increase	negative payback as a stand-alone measure
Full wall/window upgrades to 2019 code	35	23
Window film and internal R-3 insulation retrofit	3	31

Our analysis indicated that roof upgrades did not save energy and had a negative payback period.

Figure 4. Energy savings versus simple payback for multifamily analysis



2. Which is better for electrification: heat pumps or electric resistance heating?

The results of this section are specific to the Los Angeles climate and its relatively low heating demand. The determination of whether heat pump or electric resistance heating is better is heavily determined by retrofit complexity, since both result in the required electrification goal and there are negligible operational energy cost differences. An owner may prefer a “drop in” replacement of an electric boiler in the same space a gas boiler used to occupy, but the first cost investment is significantly increased because of the required electrical infrastructure upgrade.

Heat pump
Device that absorbs heat from one fluid and releases it into another, typically using electrical power and a compressible refrigerant transfer fluid.

Electric resistance heating
Incoming electric energy is directly converted to heat by warming a surface that is exposed to the fluid to be warmed.

Table 3. Comparison of 2020 first cost and 2050 energy cost for commercial office analysis

Property vintage	Heat pumps		Electric resistance	
	Potential 25-year cumulative savings as compared to $3.7m first cost	2050 projected annual electricity cost	Potential 25-year cumulative savings as compared to $5.6m first cost	2050 projected annual electricity cost
Before 1990	$3.92m	$2.44m	$2.73m	$2.79m
1990s	$3.74m	$1.86m	$2.46m	$2.25m
2000s	$3.02m	$1.86m	$1.75m	$2.25m
Early 2010s	$1.57m	$1.43m	$0.43m	$1.79m
Late 2010s	$1.57m	$1.02m	$0.19m	$1.32m
2020s	$1.14m	$0.95m	$0.19m	$1.24m

Commercial

For commercial properties, the analysis showed a 14 to 30% difference in 2050 operational energy costs between a heat pump and electric resistance heating, and a 50% increase in initial investment (Table 3).

Multifamily residential

For multifamily properties, the analysis showed a 1 to 4% difference in 2050 operational energy costs between a heat pump and electric resistance heating, and a 12% increase ($200,000) in initial investment (Table 4).

Table 4. Comparison of 2020 first cost and 2050 energy cost for multifamily analysis

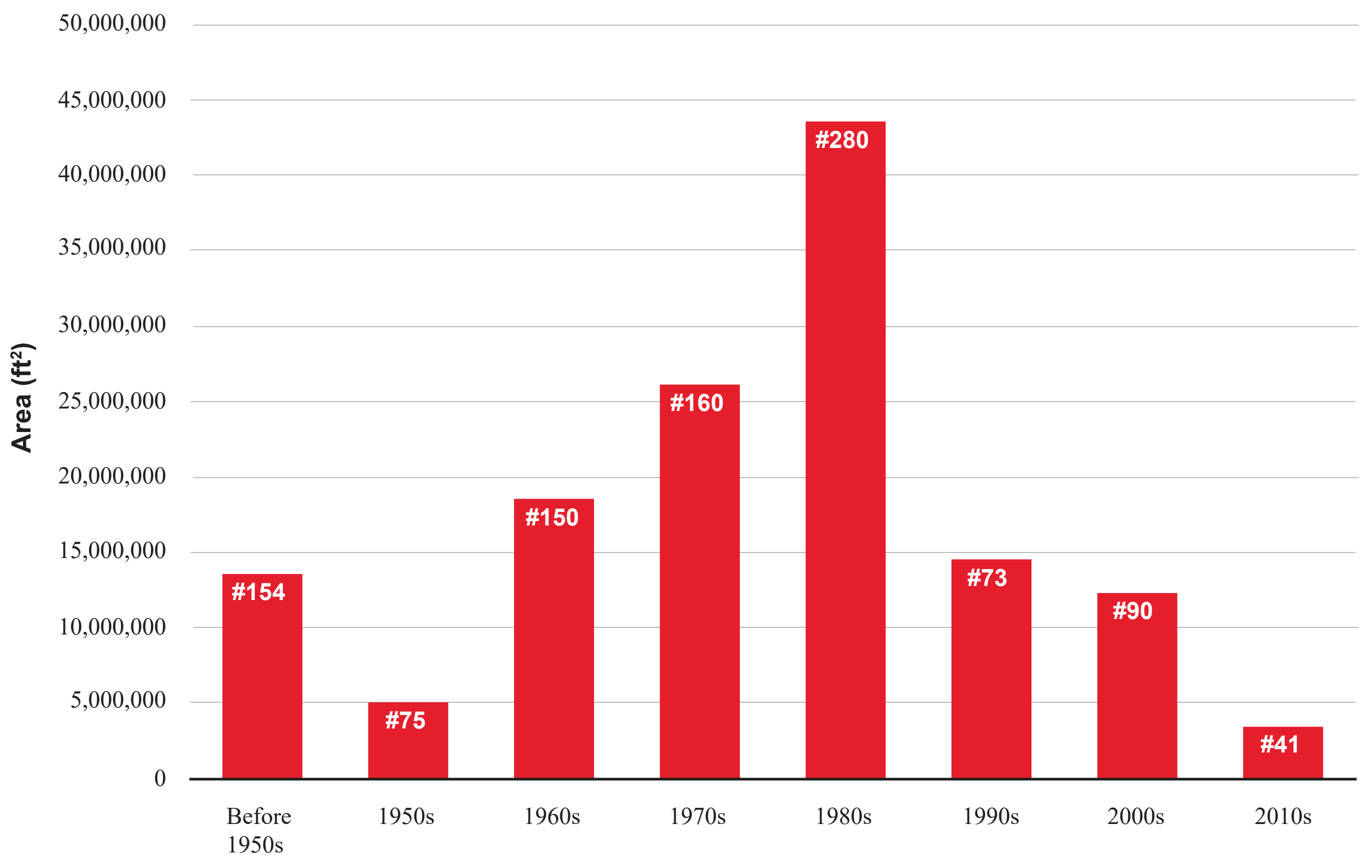
Property vintage	Heat pumps		Electric resistance	
	Potential 25-year cumulative savings as compared to $1.7m first cost	2050 projected annual electricity cost	Potential 25-year cumulative savings as compared to $1.9m first cost	2050 projected annual electricity cost
Before 1990	$0.53m	$0.14m	$0.54m	$0.14m
1990s	$0.28m	$0.09m	$0.29m	$0.09m
2000s	$0.27m	$0.09m	$0.28m	$0.09m
Early 2010s	$0.27m	$0.08m	$0.28m	$0.09m
Late 2010s	$0.26m	$0.08m	$0.26m	$0.08m
2020s	$0.25m	$0.08m	$0.27m	$0.08m

3. Are there benefits of early electrification?

In all cases, it is clear that early action is more impactful in older building stock, as the California Energy Code has enforced 45 years of progressive ECMs. In general, if changes are left until later in the 30-year transition period, owners expose themselves to risk, including:

- Greater-than-anticipated increases in electricity costs during conversion of utility source
- Likely annual increases in natural gas costs as the customer base shrinks
- Escalation of first costs
- Increased outside air temperature due to climate change if widespread mitigation measures are not engaged during this decade

Figure 5. Commercial office buildings by vintage decade in the EBEWE database



Commercial

In the commercial office built before 2000, applying early efficiency and heat pump electrification in the 2020s is estimated to yield a total 25-year operational energy cost savings of $3.7m over existing performance. This is equivalent to the first cost of the upgrade's installation. For the same vintages, the 25-year operational energy cost savings from the electric resistance package covers only 45% of the first costs.

The cumulative savings over the transition period can help offset the first cost of conversion if appropriate financing can be obtained. It is strongly recommended that older commercial buildings and those with equipment that has been in operation for more than 20 years be prioritized in the conversion cycle to take advantage of these energy savings. It is fortuitous that most of the commercial property in the EBEWE database falls into this category so that a consistent compliance regime can be established (Figure 5).

For commercial equipment installed in 2010 or later, it does not make sense to throw away an operating high-efficiency system in order to meet early electrification paths unless there are significant financial incentives from utilities or government agencies to do so. The type of equipment used in commercial properties typically has a 20- to 25-year lifespan, so it is projected that full electrification could be completed by 2050 across all vintages.

Multifamily residential

For the midrise multifamily property, there is minimal benefit to the owner for early electrification. For the multifamily buildings, the cumulative 25-year energy savings in both electrification package types can cover only ~30% of first cost. However, much of the energy savings occurs within the apartments, which may be individually metered. In older buildings where the property owner provides a centralized laundry room and domestic hot water to all of the apartments, a greater proportion of energy savings may accrue to the owner.

Since there is little direct financial benefit to the owner for early electrification, there is no significant drawback to allowing owners to start with the prerequisite upgrade to the electrical backbone, followed by a unit-by-unit conversion as they are vacated. The parsed-out cost of only the base building electrical infrastructure upgrade is $335,000, with an estimated per-unit upgrade cost of $3,000 (in 2020 dollars). The total electrical retrofit costs of $428,000 represent ~25% of the total cost of the efficiency and electrification exercise.

Because business-as-usual operation would not require this electrical upgrade, it is strongly recommended that the City consider a grant or loan program to support owners of this building type to comply with the ordinance, as the margins on residential property are already very small. The electric versions of the in-unit appliances have costs similar to those of the equivalent gas appliances. The type of equipment used within multifamily residences typically has a 12- to 15-year lifespan, so it is projected that full conversion could be completed by 2045 across all vintages, even if conversion steps are taken incrementally.

4. Which zero-carbon path best meets the Green New Deal reduction targets?

Commercial

For the commercial office vintages built earlier than 2010 to meet the City's energy-efficiency targets, early electrification with heat pumps would also need fan motor upgrades to help offset increased power use. Even with fan upgrades, the electric resistance path often just misses the 2025 threshold. Because of the citywide benefits of early electrification of large commercial properties and the financial structuring that can allow properties of this size to obtain financing based on projected energy savings, it would be advantageous for any City ordinance to allow early electrification adopters to defer the 2025 energy-efficiency target for older buildings.

All other electrification paths for older buildings can meet the energy targets. Chillers and large-scale heat pumps have already been developed using very low global-warming-potential / ozone-depletion-potential (GWP/ODP) refrigerant solutions and have been in operation for at least two years from reputable large-scale HVAC manufacturers. Incentivizing older commercial properties to complete the HVAC and DHW conversion process during the 2020s will result in the combined benefits of electrification, energy efficiency, and refrigerant replacement.

Commercial buildings that were built in the early 2010s or later tend to fail at meeting the City's targets by future compliance decade because they already have deep energy efficiency inherent to their initial design. Upgrades can be quite costly for a very small percent of energy savings and operational carbon reduction. It would be advantageous for the City to create alternate paths for meeting Green New Deal energy-efficiency targets for these younger vintages of commercial buildings. These might include on-site generation with battery storage or a utility-bill-based purchasing of LADWP community-solar-power construction equivalent to the energy reduction required.

Multifamily residential

Across all multifamily vintages, electrification of HVAC and domestic hot water in the midterm and late conversion paths will meet all City energy-efficiency targets if a lighting LED fixture upgrade is pursued during the 2020s. Applying early electrification of HVAC and domestic hot water alone during the 2020s will not meet the City's 2025 energy-efficiency targets.

Additionally, demanding early electrification of these smaller HVAC systems would be premature. The most prevalent refrigerant in the small-size air-conditioner and heat pump market in the US is R-410A, a hydrofluorocarbon (HFC) refrigerant that will be phased down in new equipment applications starting in 2024. Only recently are alternatives being introduced to the residential HVAC market, and the American Society of Heating, Refrigeration, and Air-Conditioning Engineers continues to work with the National Fire Protection Association to get a broader selection of the replacement refrigerants approved. It would be shortsighted for any policy to encourage early electrification knowing that only the last vestiges of high-global-warming-potential equipment is available.

LED lighting conversions in the first decade are the recommended first step, and they have the added benefit of not requiring the costly electrical backbone upgrade. Additionally, even though window and wall improvements were shown to have very long paybacks, if federal economic recovery funding linked to "weatherization" jobs programs becomes available (as it did during the last Recovery Act), targeted building envelope improvements to the oldest buildings would be the next logical step for the 2020s.

5. What will it cost?

When considering the cost of getting to zero-carbon emissions, it is important to remember that there is always an equipment-replacement cost embedded in the cost of ownership. For the purposes of this analysis, this business-as-usual replacement cost assumes:

- Reinstalling gas appliances and HVAC and water heater equipment when they come to the end of their lives with equivalent-sized devices meeting the minimum mandatory efficiency requirements embedded in the 2019 Energy Code
- Replacing lights with equivalent "old technology" fluorescent unless there is a significant tenant installation upgrade
- Replacing fan motors with like-for-like with no efficiency upgrade
- No envelope improvements
- No improvements in roof insulation when re-roofing for waterproofing

The differential cost increases are those associated with the following:

- Electrical infrastructure upgrades within the building and possibly at the incoming power feed
- Purchasing of more efficient devices
- The differential in cost of buying equivalent electric appliances in lieu of gas appliances
- Any modifications during installation associated with alternate points of connection or system configuration
- Whole system replacement and rewiring in the case of lighting upgrades

Commercial

Traditionally LADWP incentives and federal tax credits have covered partial replacement costs to support energy-efficiency improvements. An assessment of the differential cost of upgrade versus normal cost of a maintenance or end-of-life-cycle replacement shows that there is no projected first cost increase for the efficiency and electrification upgrades for commercial office buildings that are more than 10 years old. For more recent vintages, simple paybacks are less than 10 years for heat pump package upgrades.

Significant improvements in the energy codes around 2008 have brought mechanical and electrical performance into the realm of current codes, albeit while still favoring natural gas heating sources.

Multifamily residential

For the multifamily buildings, there is a 24 to 30% first cost increase over business-as-usual for buildings that are more than 10 years old and very long payback periods for all vintages that would not normally be commercially viable. Some form of monetary support may be necessary to help the large-scale multifamily properties convert to carbon-free fuels.

Table 5. Comparison of normal maintenance replacement cost and additional cost to achieve required efficiency and electrification, commercial office analysis (2020 dollars)

Building vintage	Package type	Normal maintenance business-as-usual replacement costs		Additional cost for efficiency and electrification upgrade		Increase in first cost	Simple payback (years)
		First cost	Annual operational energy cost	Increase in first cost	Increase in annual operational energy cost		
Before 1990	Heat pump	$4.02m	$1.26m	-$0.43m	-$0.43m	-11%	Immediate
	Electric resistance			-$0.39m	-$0.30m	-10%	Immediate
1990s	Heat pump	$4.02m	$1.04m	-$0.43m	-$0.41m	-11%	Immediate
	Electric resistance			-$0.39m	-$0.27m	-10%	Immediate
2000s	Heat pump	$3.81m	$0.96m	-$0.22m	-$0.33m	-6%	Immediate
	Electric resistance			-$0.18m	-$0.19m	-5%	Immediate
Early 2010s	Heat pump	$2.48m	$0.65m	$1.11m	-$0.17m	45%	6
	Electric resistance			$1.15m	-$0.05m	46%	24
Late 2010s	Heat pump	$2.48m	$0.47m	$1.11m	-$0.13m	45%	9
	Electric resistance			$1.15m	-$0.02m	46%	54
2020s	Heat pump	$0.23m	$0.45m	$3.36m	-$0.13m	1456%	27
	Electric resistance			$3.39m	-$0.02m	1470%	162

Table 6. Comparison of normal maintenance replacement cost and additional cost to achieve required efficiency and electrification, multifamily analysis (2020 dollars)

Building vintage	Package type	Normal maintenance business-as-usual replacement costs		Additional cost for efficiency and electrification upgrade		Increase in first cost	Simple payback (years)
		First cost	Annual operational energy cost	Increase in first cost	Increase in annual operational energy cost		
Before 1990	Heat pump	$0.81m	$0.07m	$0.20m	-$0.01m	24%	29
	Electric resistance			$0.22m	-$0.01m	27%	40
1990s	Heat pump	$0.81m	$0.05m	$0.20m	-$0.02m	24%	11
	Electric resistance			$0.22m	-$0.02m	27%	14
2000s	Heat pump	$0.81m	$0.04m	$0.20m	-$0.01m	24%	16
	Electric resistance			$0.22m	-$0.01m	27%	20
Early 2010s	Heat pump	$0.55m	$0.04m	$0.46m	-$0.01m	84%	49
	Electric resistance			$0.49m	-$0.01m	88%	60
Late 2010s	Heat pump	$0.55m	$0.03m	$0.46m	-$4k	84%	111
	Electric resistance			$0.49m	$2k	88%	None
2020s	Heat pump	$0.55m	$0.03m	$0.46m	< -$1k	84%	766
	Electric resistance			$0.49m	< $1k	88%	None

These results are based on a high-level cost assessment that takes a conservative approach to the complexities of electrical infrastructure upgrade without taking into account the business cost of disruption. This paper does not propose any particular structuring of incentive programs, but based on these findings, future policy work should consider differential cost of improvement more broadly than solely at the equipment rebate level.

Key findings

- It is possible to achieve zero-carbon buildings by 2050 with currently available technology, presuming electrification or other zero-carbon energy for gas appliances is included and the municipal utility meets its state-mandated conversion to 100% renewable energy.
- For commercial office buildings built before 2000, the savings over a 25-year period from energy efficiency and a heat recovery chiller package is sufficient to cover the first cost of early electrification before 2025, presuming financing can be obtained. It is recommended that the Green New Deal's 2025 energy-efficiency targets be waived for early electrification of commercial buildings that are 10 years or older.
- For multifamily residential buildings pursuing early efficiency and electrification during the 2020s, the cumulative energy savings over a 25-year period will cover approximately 30% of the first cost. Because most housing units are individually metered, this savings does not accrue to the owner. Approximately 25% of the cost of conversion is solely due to the upgrade of the electrical infrastructure, which would not be required under business-as-usual. Grants or loans will likely be needed to support the conversion of this property type in order to support rent stability.
- For both commercial buildings already occupied and multifamily buildings five years old or older, the proposed energy efficiency packages reduce peak electrical demand enough to absorb the new power demand required for electrification of gas appliances within the property line. This should minimize the need for citywide disruption to upsize underground electrical utilities.
- For buildings built within the last decade, original code-compliant high efficiencies make further reductions hard to achieve and early equipment replacement illogical. Alternate pathways of absolute greenhouse gas reduction through on-site renewable generation and storage, or a utility-bill-based fee to cover equivalent community solar system construction are recommended. Providing alternate pathways will allow these properties to align with Green New Deal intentions over the next 20 years until their equipment is ready for replacement and upgrade.

Arup explored the feasibility of efficiency and appliance electrification for large commercial office and multifamily residential buildings (i.e., those larger than 20,000ft^2) by examining a typical building in each category against a variety of scenarios. Our analysis focused on a subset of the portfolio of buildings already mandated for energy benchmark reporting under the Existing Buildings Energy and Water Efficiency Program. Similar analysis exercises are recommended for small-scale residential properties (80% of units in the city) and smaller offices where packaged heating, ventilation, and air-conditioning systems are common.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It's time for climate action. It's possible to get to zero carbon, but only if we act together…

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To reap the full benefits of greening the grid, the city needs aligned action that appreciates the interdependency of property-level climate action and utility-level climate action. Converting utility energy sources away from existing fuel-burning plants within the city limits and in Utah at the Intermountain Power Project requires accelerated construction of local renewable energy sources. The future cost of electricity is therefore intimately linked to the total existing and anticipated increase in electricity demand arising from building electrification and electric vehicles.

It is in the interest of the City to have its municipal utility (LADWP) spend as little as necessary on this source replacement and augmentation exercise. It is in the interest of all LA residents that the future cost of electricity is kept as low as possible during and after the grid conversion as a matter of commercial competitiveness for the business community and social equity in terms of reducing energy poverty. If a majority of property owners are slow to adopt efficiency and do not take applicable actions until 2040 to 2050, LADWP will have overinvested in building costly renewable energy sources to meet government-mandated timelines with percent-based service targets for its renewables portfolio. This would unnecessarily drive up rates during the 30-year transition period — to everyone's detriment.

Figure 6 outlines a simple representation of the challenge. If a property's fuel-burning appliances are electrified without also applying energy efficiency or on-site energy-generation solutions, a larger incoming electrical feed is necessary. If most properties follow this path, the municipal electrical supply and distribution lines would need to increase capacity to keep up, with electric vehicle loads on top of that.

The Green New Deal already anticipates a significant investment by LADWP in building distributed energy storage throughout the city to avoid the cost of significant upsizing of major distribution infrastructure. Avoiding underground work in the neighborhoods is key to keeping the overall cost of LADWP grid conversion and disruption of traffic as low as possible. If properties can manage the on-site balance of power demand, the existing infrastructure can continue to serve everyone in a cost-effective manner.

Energy poverty

Lack of access to affordable, reliable energy services. In the US, this is typically defined as more than 10% of income spent on energy bills.

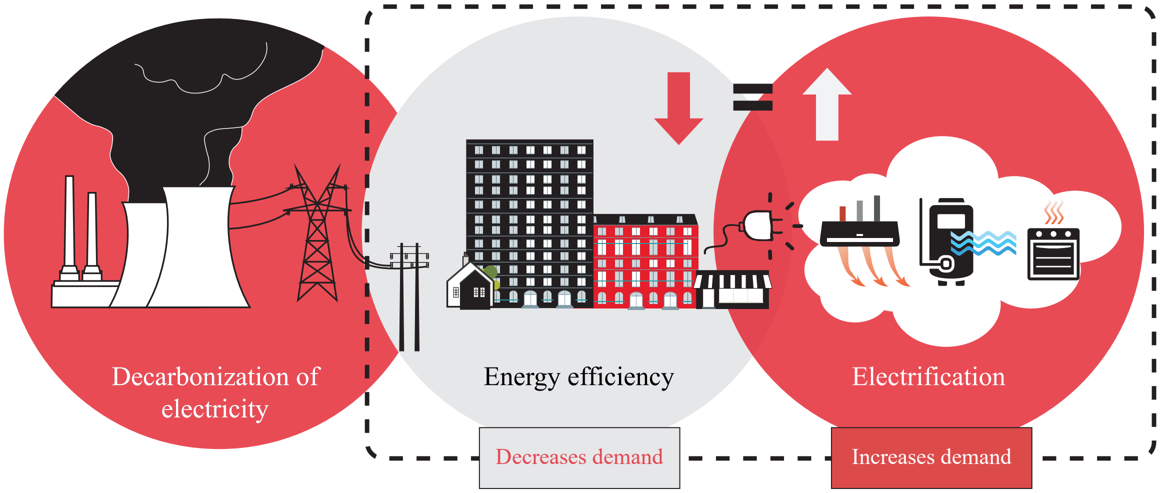
Findings from this study show that the power demand reduction that comes from deep energy efficiency is enough to cover the power demand increases that arise from the electrification of gas appliances for commercial offices until the late 2010s vintage and for the multifamily property types up to the early 2010s vintage (Table 7). For younger buildings, the baseline efficiencies embedded within the recent codes mean that there is insufficient further power reduction available from energy-efficiency of existing systems to accommodate the electrification load. These buildings are unlikely to convert gas appliances until the 2040s when the grid is nearly carbon-free, so the peak kilowatt overruns might be absorbed pending on-site metering trends, as the National Electrical Code tends to oversize capacity of electrical infrastructure.

Table 7. On-site power balance for modeled results

Building vintage	Package type	Commercial office analysis: Baseline peak (kW)	Commercial office analysis: Energy efficiency package kW reduced	Commercial office analysis: Electrification kW added*	Commercial office analysis: Net added kW	Multifamily analysis: Baseline peak (kW)	Multifamily analysis: Energy efficiency package kW reduced	Multifamily analysis: Electrification kW added	Multifamily analysis: Net added kW
Before 1990	Heat pump	6,304	3,259	562	-2,697	175	94	62	-32
	Electric resistance			35	-3,224			67	-27
1990s	Heat pump	4,591	2,184	339	-1,844	132	61	25	-37
	Electric resistance			66	-2,118			29	-32
2000s	Heat pump	3,945	1,434	231	-1,203	108	40	26	-15
	Electric resistance			-40	-1,474			29	-11
Early 2010s	Heat pump	2,478	417	315	-101	95	30	25	-5
	Electric resistance			19	-397			28	-1
Late 2010s	Heat pump	2,344	842	187	-655	73	7	21	13
	Electric resistance			52	-790			24	17
2020s	Heat pump	1,521	128	219	91	64	1	23	23
	Electric resistance			61	-67			29	29

* For commercial office, even though the high cost of electrical infrastructure is associated with the electric resistance package to accommodate winter loads, the year's peak kW demand at the property line occurs on summer afternoons when the large chiller power dominates. Heat recovery chillers are less efficient than the equivalent chillers without heating capacity, thus influencing the on-site balance.

Figure 6. On-site balance of power demand



It is beyond the scope of this study to examine the activities within LADWP related to utility-scale renewable energy and storage. However, it is appropriate to speak to the question of "urban renewable energy": the energy sources owned privately in a net-metered fashion. If on-site generation sources are available to property owners as a means to comply with their energy-efficiency targets, they should be paired with on-site battery storage to represent true greenhouse gas reduction. On-site renewable energy claiming to be equivalent to energy efficiency should not suddenly impose high ramp-up load onto the grid in the late afternoon when the sun loses intensity.

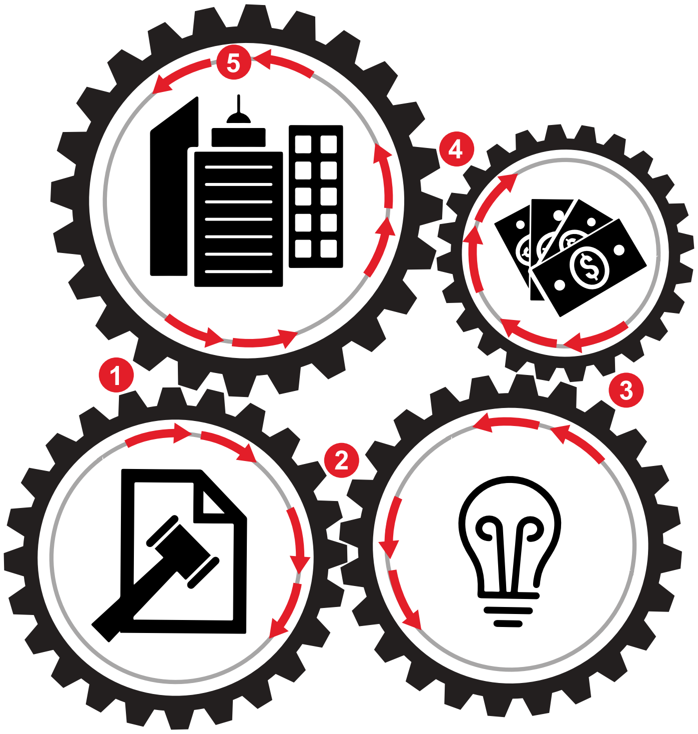
Currently, the state and city meet high ramp load with fast-start-up "peaking plants" reliant on burning fossil fuels. These peaking plants will no longer be available on the green grid, so all proposals to use photovoltaic panels for greenhouse gas reduction to meet the Green New Deal targets should also be required to control power demand fluctuations within the property line in a grid-supportive manner. The commercial office properties built after 2010 are the most likely candidates for pursuing on-site generation as the carbon offset for Green New Deal compliance due to the high cost of efficiency.

LADWP has recently released a report from the National Renewables Energy Laboratory that offers multiple paths towards carbon-free electricity over the next 25 years. Some paths assume the expansion of private photovoltaic installations without necessarily burdening them with a requirement for on-site battery storage. If the City and LADWP agree that just net-metered photovoltaic installations can be considered greenhouse gas reduction, this would make the on-property compliance significantly more affordable.

Grid decarbonization cannot be affordable without buildings being ready to go carbon-free. Coordinated action by multiple governmental agencies is necessary to normalize expectations around compliance and send the policy signals necessarily to release financing for action. We need all sectors pulling in the same direction from the area of their greatest influence to achieve the best outcomes for our community.

Figure 7 shows a simple representation of how this might work for the largest buildings in the city under review in this study.

Figure 7. Interdependency across sectors to achieve a zero-carbon community



Governments
Setting policy, incentive, and penalty structures to require carbon diets for existing buildings over 20,000ft^2

Private sector
Determining when and how to react to sustain profit and reduce risk for stakeholders

Utilities
Decarbonizing supply as State requirement, establishing rates and carbon-content trajectories

Green financing
Evaluating efficacy of loans' intent to prove carbon reduction return on investment to shareholders

Action 1

The City of Los Angeles augments the current EBEWE ordinance to require a proactive path towards decarbonization and sets in place mandates and incentives to favor electrification appropriate to the technology available. This would harden the Green New Deal targets into a compliance regime and would allow property owners to negotiate with their boards to develop strategic transition plans for their portfolio of assets.

Action 2

LADWP is already decarbonizing its supply by 2045 in conjunction with California Senate Bill 100 and the percentage of renewables set forth in LA's Green New Deal.

Action 3

Based on anticipated investment for source conversion, expansion, replacement, and maintenance of the city's electrical infrastructure, LADWP should be in a position very soon to publish its approximate rate trajectories through the transition period.

Action 4

The City's fixed policy signal paired with a predictable electricity rate trajectory allows the private sector to acquire financing to assist with the first cost of conversion. The finance sector has already signaled its preference for investments that take positive climate action into consideration, as exemplified for the second year in a row by Blackrock's 2021 Letter to CEOs from Larry Fink.

Action 5

Clarity about "the rules of the game" helps to mobilize the business community and the public to support the City by asserting peer pressure against free riders who can afford the cost of conversion. It can also assist with promoting reasonable incentive programs and modeling good carbon citizenship in alignment with the City's goals.

Any building-emissions-reduction ordinance should recognize the important role of private owners in our collective path toward a zero-emissions community. No individual sector can accomplish the complex task of citywide decarbonization alone — the only chance we have of being successful is if we all plan to act together.

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It's time for
climate action.
It's possible
to get to zero
carbon, but only
if we act together
and leave no one
behind.

…and leave no one behind.

Social equity is at the heart of many targets within LA's Green New Deal. Citywide clean energy has many co-benefits, as exemplified by a review of the UN Sustainable Development Goals.

SDG 1, No Poverty

The city has many neighborhoods with high social vulnerability, as determined by the Centers for Disease Control and Prevention. This rating aggregates a variety of socioeconomic, housing/household, and minority/language indicators to assess a community's resilience to disaster. The Resilient Cities Network highlights that the very same conditions are chronic stressors experienced by those living in these areas. To avoid exacerbating existing financial stressors or creating new ones, policy around decarbonization will need to ensure that building retrofits and renewable energy are accessible and truly affordable so that energy poverty is proactively reduced and rent protection is ensured.

SDG 3, Good Health and Well-Being

With local power plants reducing emissions, rates of asthma and respiratory disease for the vulnerable communities within their vicinity should also reduce. This community health outcome is one of the targets noted in the Green New Deal's Environmental Justice chapter.

SDG 7, Affordable and Clean Energy

The affordability of carbon-free electricity will become apparent after 2050 when free solar energy replaces purchased fossil fuels. The clean energy aim will become apparent even earlier when we no longer burn fossil fuels within city limits.

SDG 8, Decent Work and Economic Growth

The Green New Deal estimates that over 50,000 green jobs will be created immediately to support grid conversion, with an additional 175,000 created through 2050 to support building retrofits.

SDG 11, Sustainable Cities and Communities

The ultimate goal of the Green New Deal itself is SDG 11, and property owners are essential partners to make this a reality. Carbon-neutral building performance is positive climate action.

SDG 12, Responsible Consumption and Production

Wherever possible, retrofit construction should progress using low-embodied-carbon materials to avoid eroding the operational carbon savings achieved from energy efficiency.

SDG 13, Climate Action

With 41% of the city's energy supporting buildings, the full conversion of grid and buildings to zero-carbon emissions is key to the mitigation side of climate action. This SDG also reminds us that resilience of community members during the transition must also be addressed.

SDG 17, Partnership for the Goals

Only the aligned efforts of the City, the local utility, the body of private building owners, and the finance community that will make it possible to create a zero-emissions building stock.

Conclusion

It's time for climate action. It's possible to get to zero carbon, but only if we plan to act together and leave no one behind.

According to the Los Angeles Almanac, if Los Angeles County were a country, its gross national product would exceed all but 17 other countries. There is a tremendous opportunity for business leaders in this thriving economy to raise the bar for sustainable solutions for the future. Many business and community leaders supported the LA Green New Deal at its inception — now is the time to support its realization. If the city of Los Angeles can successfully model a truly public-private collaboration that accelerates our transition to a carbon-free community, we can chart a path for others to follow, first in the county and then in the world.

Changes in v1.1:

Table 3: first cost of Before 1990 Heat Pump corrected

Appendix D: cost of batteries removed

Appendix A

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Appendix A: References

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Appendix B

Analysis methodology

Appendix B: Analysis methodology

Using templates from the Department of Energy's Pacific Northwest National Lab for determining the nation's model energy codes, Arup selected two base energy models: the ~500,000ft² Large Commercial Office and the ~33,000ft² Midrise Multifamily.

Arup modified the two models to be compliant with six different vintages of the California Energy Code Cycle (noted in red in Figure A1). The modeling exercise applied upgrades for those items that would naturally require replacement during the next 30 years:

- HVAC replacements due to refrigerant phase out and/or life expectancy of equipment
- LED lighting upgrades due to market shifts in technology
- Electrification of gas water heaters at the end of life cycle
- Conversion of gas-burning appliances like laundry dryers and cooking equipment
- Roof insulation upgrades to modern code
- Optional wall/window efficiency/comfort improvements for residential only

In new-building design, common practice is to focus on energy efficiency first before applying renewable energy, as it is illogical to buy spare power at a higher premium. In the existing-building context, despite the falling costs of photovoltaic panels, this analysis focused on energy efficiency and electrification as the building-level sources of greenhouse gas reductions and its support of LADWP's conversion to a 100% renewable green grid. Pairing electrification with deep energy efficiency helps to balance operational energy costs while cutting carbon. For instance, converting a packaged air-conditioning unit to an all-electric heat pump model increases the overall annual energy use of the device when it accommodates the heating function, but makes it ready to work on carbon-free electricity. This slight energy increase can be offset by also doing an LED lighting retrofit that achieves deep energy efficiency.

To test whether the order of action matters, for each of the building types and each of the vintage codes, four paths of electrification were analyzed to determine operational energy costs, first cost, and operational carbon per decade until zero operational carbon is achieved (see Figure A2).

- Early electrification (in the 2020s) using electric resistance water heating
- Early electrification (in the 2020s) using heat pump water heating
- Midterm electrification (in the 2030s) using heat pump water heating
- Late electrification (in the 2040s) using heat pump water heating

These serve only as a sensitivity analysis to determine the impact of quick or slow action, not a planning guide for any particular building with its unique combination of equipment age profiles.

Figure B1. Timeline showing California Energy Code vintage analyzed (red) and LA Green New Deal future targets (dark green)

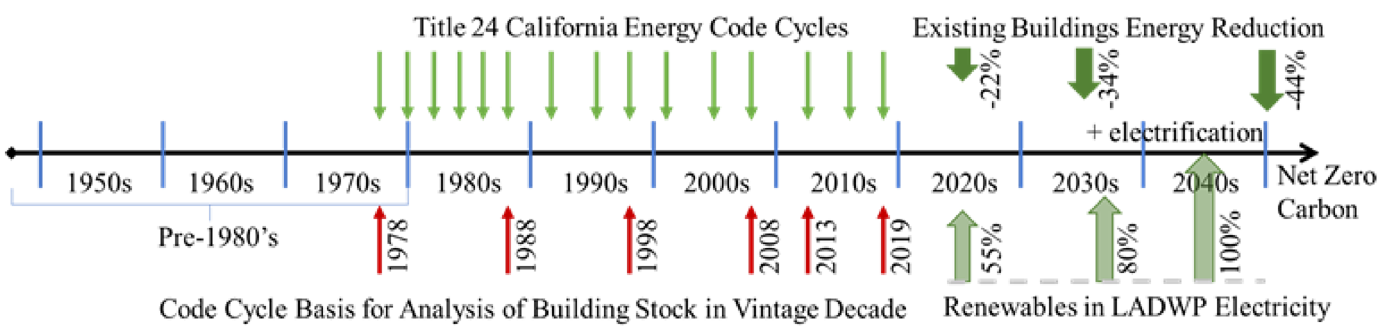


Figure B2. Representation of zero-carbon pathways for the multifamily analysis

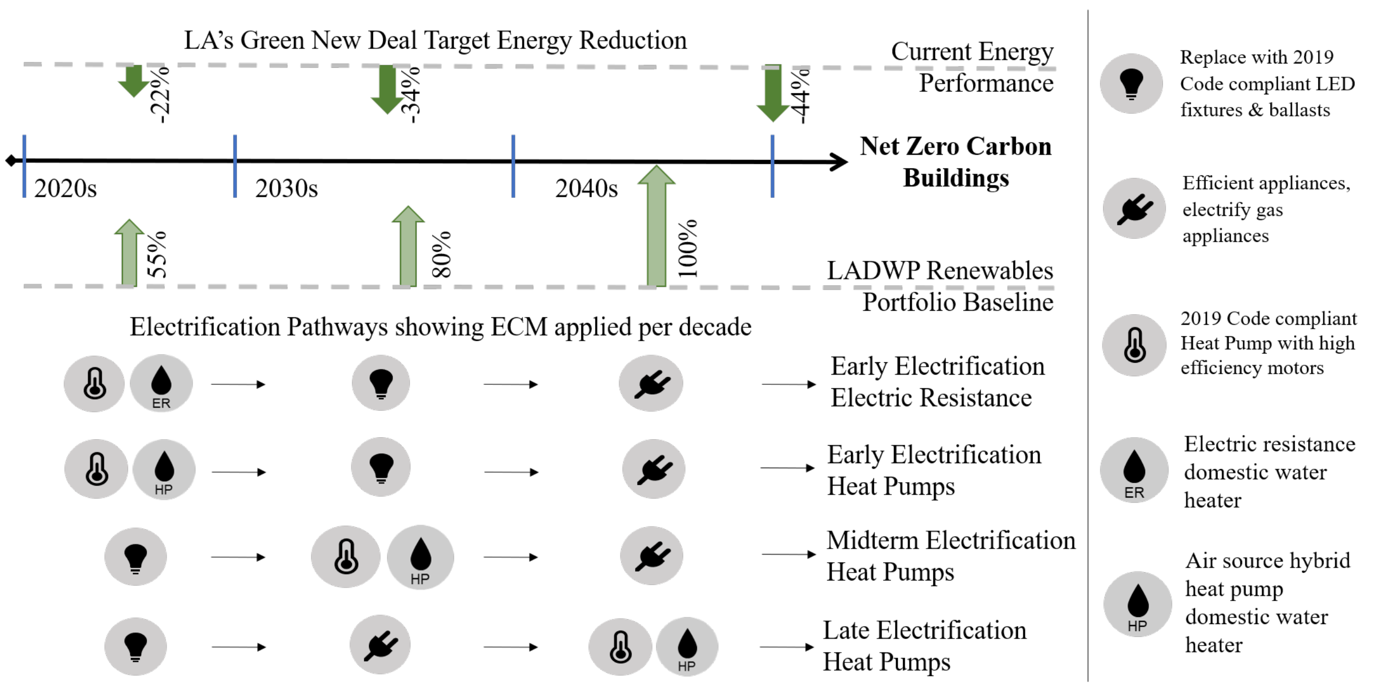
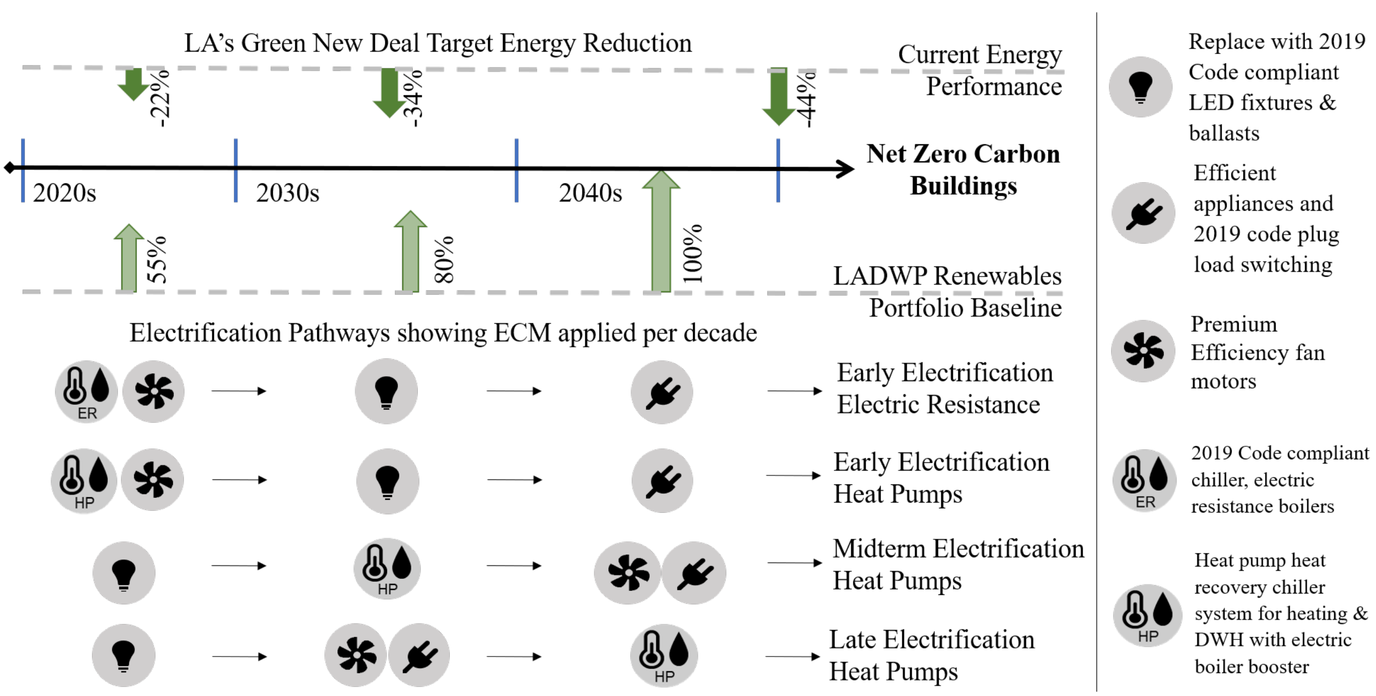


Figure B3. Representation of zero-carbon pathways for the commercial office analysis



Key assumptions

- The carbon content of electricity is based on LA's Green New Deal projected renewable portfolio and average energy cost (both electricity and gas), which is escalated at 3.86% per annum based on extrapolating trends in currently published data for LADWP and Southern California Gas Company.
- Construction cost escalation is assumed to be 2.13% per annum based on historical data from Engineering News-Record.
- In light of the pandemic, rent in 2020 is assumed to be $3/net square feet for both property types, with an escalation of +3% per annum as per the current limit within the residential Los Angeles Rent Stabilization Ordinance.
- All analysis assumes outdoor air temperature warming towards 2050, using morphed typical meteorological year files derived from WeatherShift™.
- All adopted retrofit options were found to have lower embodied-carbon payback periods than their respective financial payback periods, with embodied-carbon additions negligible as compared to operational-carbon savings over 30 years.

Smaller buildings

While this study focuses on the practical analysis of how the largest of the commercial office and multifamily residential buildings in Los Angeles could meet the City's decarbonization goals, energy and electrification retrofits will be required for buildings smaller than 20,000ft² as well.

For the commercial office typology, it would be useful to analyze a subset of the EBEWE database consisting of 31 million square feet of space that is between 20,000 and 100,000ft². These mid-size offices could be modeled using the standard Department of Energy ~53,000ft² template model more representative of buildings with rooftop packaged units instead of chiller plants. There is also an additional 29 million square feet of office space under 20,000ft² that is likely to benefit from the secondary analysis.

The current multifamily analysis is representative of just 19% of the housing units within the city. An additional analysis of the remainder of the residential market would include single-family detached and small-scale apartments, which are 49% and 30%, respectively.

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Appendix C

Energy conservation measure performance

Appendix C: Energy conservation measure performance

Appendix D: Electrification Paths

Table D1. Commercial office built before 1990	Electrification Path	Starting point	2020s	2030s	2040s
Energy use intensity (EUI, KBtu/sf/yr)	Early Electric Resistance	167	132	73	91
	Early Heat Pump	167	128	69	80
	Midterm Heat Pump	167	104	90	80
	Late Heat Pump	167	104	93	80
% energy reduction achieved	Early Electric Resistance	N/a	21%	57%	46%
	Early Heat Pump	N/a	23%	59%	52%
	Midterm Heat Pump	N/a	38%	46%	52%
	Late Heat Pump	N/a	38%	44%	52%
Green New Deal % energy reduction required	All	0%	22%	34%	44%
First Cost (in dollars escalated to midpoint of the decade of the modification)	Early Electric Resistance	N/a	$2.8m	$2.8m	$0.54m
	Early Heat Pump	N/a	$1.4m	$2.8m	$0.54m
	Midterm Heat Pump	N/a	$2.1m	$1.5m	$1.0m
	Late Heat Pump	N/a	$2.1m	$0.87m	$1.7m
Energy Cost Savings in first year	Early Electric Resistance	N/a	$0.41m	$1.2m	$0.28m
	Early Heat Pump	N/a	$0.45m	$1.2m	$0.28m
	Midterm Heat Pump	N/a	$0.74m	$0.36m	$0.86m
	Late Heat Pump	N/a	$0.74m	$0.45m	$0.65m
Simple Payback	Early Electric Resistance	N/a	7	2	2
	Early Heat Pump	N/a	3	2	2
	Midterm Heat Pump	N/a	3	4	1
	Late Heat Pump	N/a	3	2	3
Cumulative energy cost savings until 2050 due to ECM's applied in decade (mid-decade start)	Early Electric Resistance	N/a	$16m	$22m	$1.5m
	Early Heat Pump	N/a	$17m	$22m	$1.5m
	Midterm Heat Pump	N/a	$28m	$7.0m	$4.6m
	Late Heat Pump	N/a	$28m	$8.5m	$3.5m
Differential kWh per year required to be provided as renewable energy to meet Green New Deal Target	Early Electric Resistance	N/a	171,495	0	0
	Early Heat Pump	N/a	0	0	0
	Midterm Heat Pump	N/a	0	0	0
	Late Heat Pump	N/a	0	0	0
Cumulative cost until 2050 of LADWP Green Power to meet compliance target (inclusive of compounded inflation)	Early Electric Resistance	N/a	$0.20m	$0	$0
	Early Heat Pump	N/a	$0	$0	$0
	Midterm Heat Pump	N/a	$0	$0	$0
	Late Heat Pump	N/a	$0	$0	$0
Cost of onsite renewables (in dollars escalated to midpoint of the decade of the modification) PV alone based on 2020 costs	Early Electric Resistance	N/a	$0.16m	$0	$0
	Early Heat Pump	N/a	$0	$0	$0
	Midterm Heat Pump	N/a	$0	$0	$0
	Late Heat Pump	N/a	$0	$0	$0

Figure C1. Commercial office built before 1990
Energy use intensity (EUI) of electrification paths

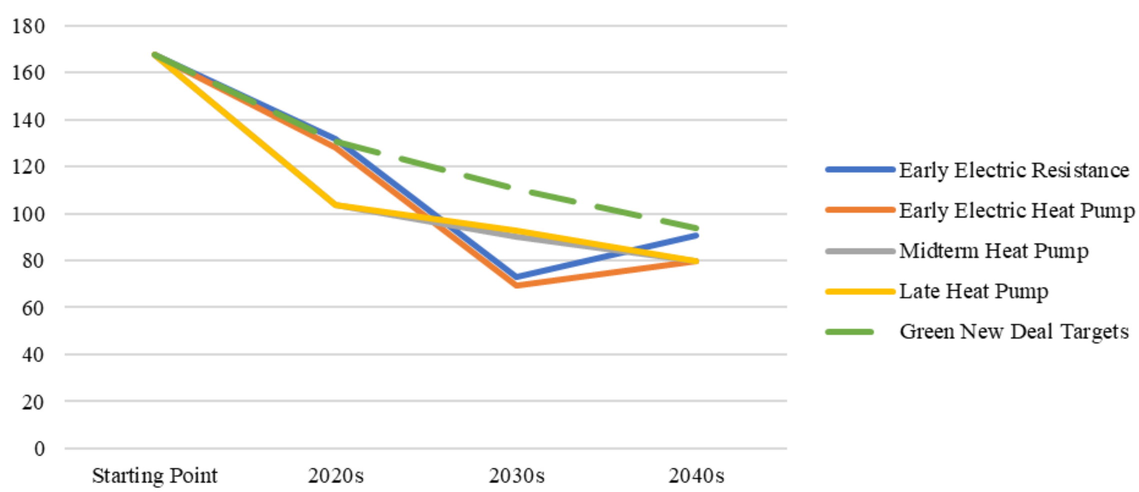
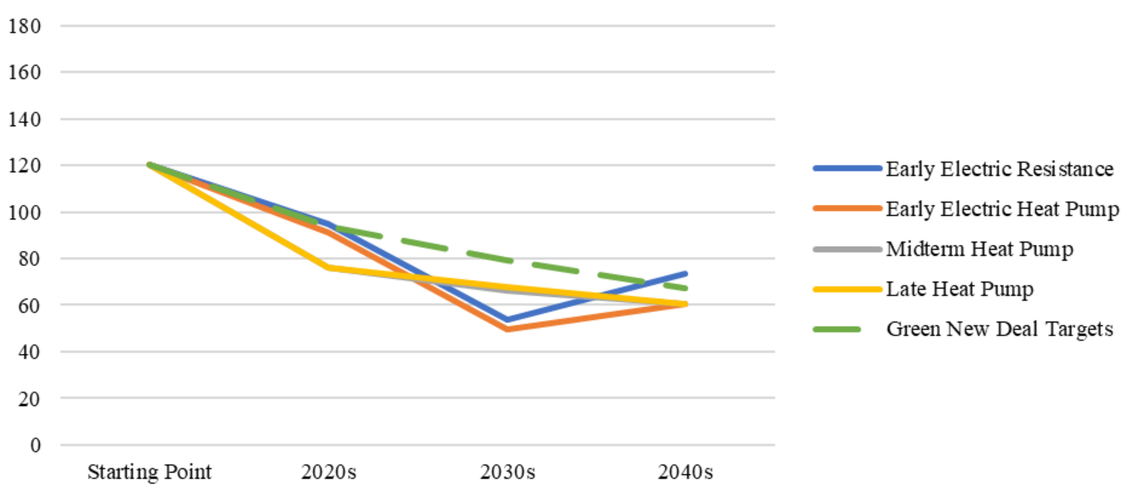


Table D2. Commercial office built during the 1990s	Electrification Path	Starting point	2020s	2030s	2040s
Energy use intensity (EUI, KBtu/sf/yr)	Early Electric Resistance	120	95	54	73
	Early Heat Pump	120	91	50	61
	Midterm Heat Pump	120	76	66	61
	Late Heat Pump	120	76	68	61
% energy reduction achieved	Early Electric Resistance	N/a	21%	56%	39%
	Early Heat Pump	N/a	24%	59%	50%
	Midterm Heat Pump	N/a	37%	45%	50%
	Late Heat Pump	N/a	37%	44%	50%
Green New Deal % energy reduction required	All	0%	22%	34%	44%
First Cost (in dollars escalated to midpoint of the decade of the modification)	Early Electric Resistance	N/a	$2.8m	$2.8m	$0.54m
	Early Heat Pump	N/a	$1.4m	$2.8m	$0.54m
	Midterm Heat Pump	N/a	$2.1m	$1.5m	$1.0m
	Late Heat Pump	N/a	$2.1m	$0.87m	$1.7m
Energy Cost Savings in first year	Early Electric Resistance	N/a	$0.29m	$0.80m	$0.19m
	Early Heat Pump	N/a	$0.34m	$0.80m	$0.19m
	Midterm Heat Pump	N/a	$0.51m	$0.25m	$0.55m
	Late Heat Pump	N/a	$0.51m	$0.31m	$0.34m
Simple Payback	Early Electric Resistance	N/a	9	4	3
	Early Heat Pump	N/a	4	4	3
	Midterm Heat Pump	N/a	4	6	2
	Late Heat Pump	N/a	4	3	5
Cumulative energy cost savings until 2050 due to ECM's applied in decade (mid-decade start)	Early Electric Resistance	N/a	$11m	$15m	$1.0m
	Early Heat Pump	N/a	$13m	$15m	$1.0m
	Midterm Heat Pump	N/a	$19m	$4.8m	$2.9m
	Late Heat Pump	N/a	$19m	$6.0m	$1.8m
Differential kWh per year required to be provided as renewable energy to meet Green New Deal Target	Early Electric Resistance	N/a	144,272	0	387,377
	Early Heat Pump	N/a	0	0	0
	Midterm Heat Pump	N/a	0	0	0
	Late Heat Pump	N/a	0	0	0
Cumulative cost until 2050 of LADWP Green Power to meet compliance target (inclusive of compounded inflation)	Early Electric Resistance	N/a	$0.16m	$0	$0.06m
	Early Heat Pump	N/a	$0	$0	$0
	Midterm Heat Pump	N/a	$0	$0	$0
	Late Heat Pump	N/a	$0	$0	$0
Cost of onsite renewables (in dollars escalated to midpoint of the decade of the modification) PV alone based on 2020 costs	Early Electric Resistance	N/a	$0.19m	$0	$0.42m
	Early Heat Pump	N/a	$0	$0	$0
	Midterm Heat Pump	N/a	$0	$0	$0
	Late Heat Pump	N/a	$0	$0	$0

Figure C2. Commercial office built during the 1990s Energy use intensity (EUI) of electrification paths



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Appendix D

Electrification paths

Appendix D: Electrification paths

Table D1. Commercial office built before 1990	Electrification Path	Starting point	2020s	2030s	2040s
Energy use intensity (EUI, KBtu/sf/yr)	Early Electric Resistance	167	132	73	91
	Early Heat Pump	167	128	69	80
	Midterm Heat Pump	167	104	90	80
	Late Heat Pump	167	104	93	80
% energy reduction achieved	Early Electric Resistance	N/a	21%	57%	46%
	Early Heat Pump	N/a	23%	59%	52%
	Midterm Heat Pump	N/a	38%	46%	52%
	Late Heat Pump	N/a	38%	44%	52%
Green New Deal % energy reduction required	All	0%	22%	34%	44%
First Cost (in dollars escalated to midpoint of the decade of the modification)	Early Electric Resistance	N/a	$2.8m	$2.8m	$0.54m
	Early Heat Pump	N/a	$1.4m	$2.8m	$0.54m
	Midterm Heat Pump	N/a	$2.1m	$1.5m	$1.0m
	Late Heat Pump	N/a	$2.1m	$0.87m	$1.7m
Energy Cost Savings in first year	Early Electric Resistance	N/a	$0.41m	$1.2m	$0.28m
	Early Heat Pump	N/a	$0.45m	$1.2m	$0.28m
	Midterm Heat Pump	N/a	$0.74m	$0.36m	$0.86m
	Late Heat Pump	N/a	$0.74m	$0.45m	$0.65m
Simple Payback	Early Electric Resistance	N/a	7	2	2
	Early Heat Pump	N/a	3	2	2
	Midterm Heat Pump	N/a	3	4	1
	Late Heat Pump	N/a	3	2	3
Cumulative energy cost savings until 2050 due to ECM's applied in decade (mid-decade start)	Early Electric Resistance	N/a	$16m	$22m	$1.5m
	Early Heat Pump	N/a	$17m	$22m	$1.5m
	Midterm Heat Pump	N/a	$28m	$7.0m	$4.6m
	Late Heat Pump	N/a	$28m	$8.5m	$3.5m
Differential kWh per year required to be provided as renewable energy to meet Green New Deal Target	Early Electric Resistance	N/a	171,495	0	0
	Early Heat Pump	N/a	0	0	0
	Midterm Heat Pump	N/a	0	0	0
	Late Heat Pump	N/a	0	0	0
Cumulative cost until 2050 of LADWP Green Power to meet compliance target (inclusive of compounded inflation)	Early Electric Resistance	N/a	$0.20m	$0	$0
	Early Heat Pump	N/a	$0	$0	$0
	Midterm Heat Pump	N/a	$0	$0	$0
	Late Heat Pump	N/a	$0	$0	$0
Cost of onsite renewables (in dollars escalated to midpoint of the decade of the modification) PV alone based on 2020 costs	Early Electric Resistance	N/a	$0.16m	$0	$0
	Early Heat Pump	N/a	$0	$0	$0
	Midterm Heat Pump	N/a	$0	$0	$0
	Late Heat Pump	N/a	$0	$0	$0

Figure D1. Commercial office built before 1990 Energy Use Intensity (EUI) of electrification paths

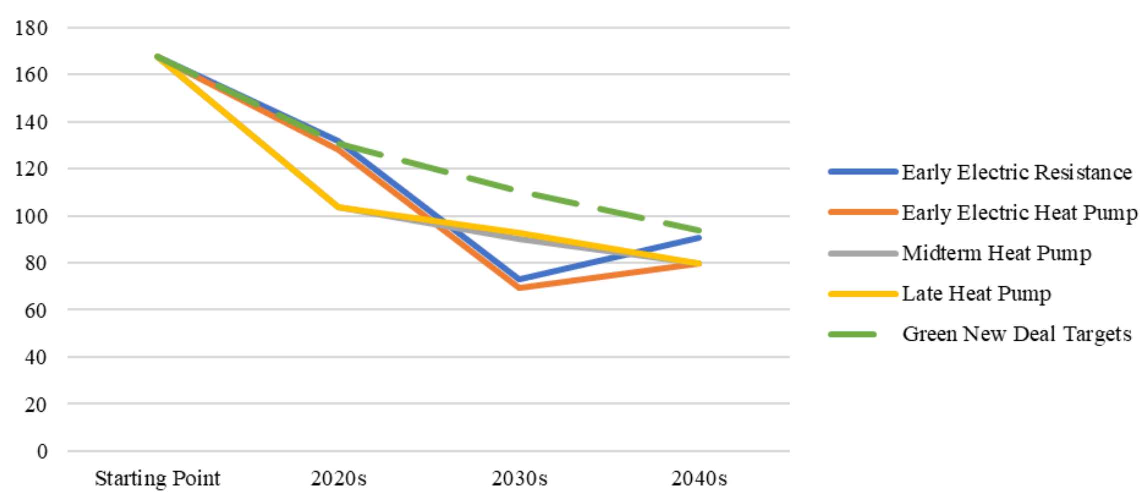


Table D2. Commercial office built during the 1990s	Electrification Path	Starting point	2020s	2030s	2040s
Energy use intensity (EUI, KBtu/sf/yr)	Early Electric Resistance	120	95	54	73
	Early Heat Pump	120	91	50	61
	Midterm Heat Pump	120	76	66	61
	Late Heat Pump	120	76	68	61
% energy reduction achieved	Early Electric Resistance	N/a	21%	56%	39%
	Early Heat Pump	N/a	24%	59%	50%
	Midterm Heat Pump	N/a	37%	45%	50%
	Late Heat Pump	N/a	37%	44%	50%
Green New Deal % energy reduction required	All	0%	22%	34%	44%
First Cost (in dollars escalated to midpoint of the decade of the modification)	Early Electric Resistance	N/a	$2.8m	$2.8m	$0.54m
	Early Heat Pump	N/a	$1.4m	$2.8m	$0.54m
	Midterm Heat Pump	N/a	$2.1m	$1.5m	$1.0m
	Late Heat Pump	N/a	$2.1m	$0.87m	$1.7m
Energy Cost Savings in first year	Early Electric Resistance	N/a	$0.29m	$0.80m	$0.19m
	Early Heat Pump	N/a	$0.34m	$0.80m	$0.19m
	Midterm Heat Pump	N/a	$0.51m	$0.25m	$0.55m
	Late Heat Pump	N/a	$0.51m	$0.31m	$0.34m
Simple Payback	Early Electric Resistance	N/a	9	4	3
	Early Heat Pump	N/a	4	4	3
	Midterm Heat Pump	N/a	4	6	2
	Late Heat Pump	N/a	4	3	5
Cumulative energy cost savings until 2050 due to ECM's applied in decade (mid-decade start)	Early Electric Resistance	N/a	$11m	$15m	$1.0m
	Early Heat Pump	N/a	$13m	$15m	$1.0m
	Midterm Heat Pump	N/a	$19m	$4.8m	$2.9m
	Late Heat Pump	N/a	$19m	$6.0m	$1.8m
Differential kWh per year required to be provided as renewable energy to meet Green New Deal Target	Early Electric Resistance	N/a	144,272	0	387,377
	Early Heat Pump	N/a	0	0	0
	Midterm Heat Pump	N/a	0	0	0
	Late Heat Pump	N/a	0	0	0
Cumulative cost until 2050 of LADWP Green Power to meet compliance target (inclusive of compounded inflation)	Early Electric Resistance	N/a	$0.16m	$0	$0.06m
	Early Heat Pump	N/a	$0	$0	$0
	Midterm Heat Pump	N/a	$0	$0	$0
	Late Heat Pump	N/a	$0	$0	$0
Cost of onsite renewables (in dollars escalated to midpoint of the decade of the modification) PV alone based on 2020 costs	Early Electric Resistance	N/a	$0.19m	$0	$0.42m
	Early Heat Pump	N/a	$0	$0	$0
	Midterm Heat Pump	N/a	$0	$0	$0
	Late Heat Pump	N/a	$0	$0	$0

Figure D2. Commercial office built during the 1990s Energy Use Intensity (EUI) of electrification paths

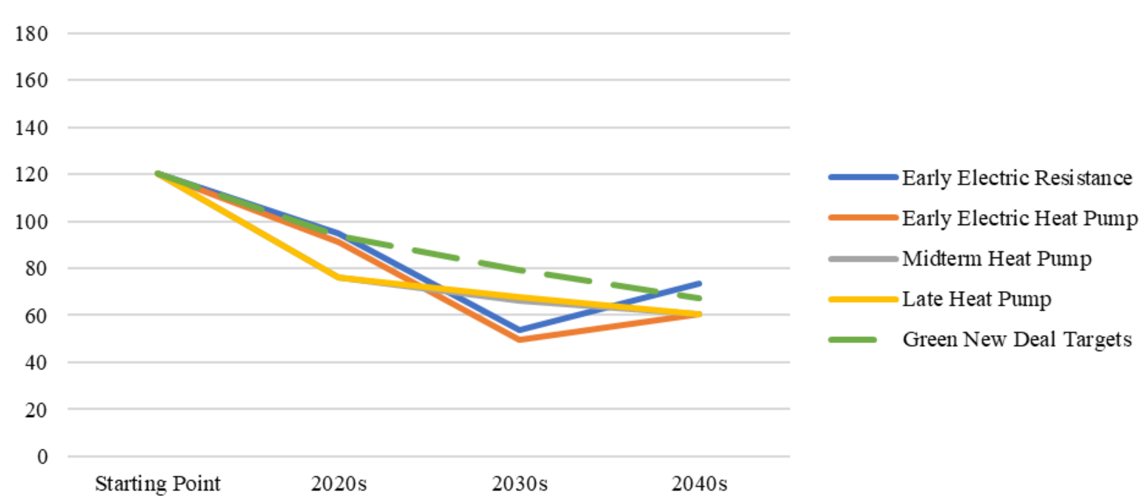


Table D3. Commercial office built during the 2000s	Electrification Path	Starting point	2020s	2030s	2040s
Energy use intensity (EUI, KBtu/sf/yr)	Early Electric Resistance	109	89	58	73
	Early Heat Pump	109	84	52	61
	Midterm Heat Pump	109	74	67	61
	Late Heat Pump	109	74	65	61
% energy reduction achieved	Early Electric Resistance	N/a	18%	47%	32%
	Early Heat Pump	N/a	23%	52%	44%
	Midterm Heat Pump	N/a	32%	38%	44%
	Late Heat Pump	N/a	32%	40%	44%
Green New Deal % energy reduction required	All	0%	22%	34%	44%
First Cost (in dollars escalated to midpoint of the decade of the modification)	Early Electric Resistance	N/a	$2.8m	$2.8m	$0.54m
	Early Heat Pump	N/a	$1.4m	$2.8m	$0.54
	Midterm Heat Pump	N/a	$2.1m	$1.5m	$1.0m
	Late Heat Pump	N/a	$2.1m	$0.87m	$1.7m
Energy Cost Savings in first year	Early Electric Resistance	N/a	$0.22m	$0.63m	$0.18m
	Early Heat Pump	N/a	$0.28m	$0.63m	$0.18m
	Midterm Heat Pump	N/a	$0.40m	$0.19m	$0.58m
	Late Heat Pump	N/a	$0.40m	$0.31m	$0.04m
Simple Payback	Early Electric Resistance	N/a	13	4	3
	Early Heat Pump	N/a	5	4	3
	Midterm Heat Pump	N/a	5	8	2
	Late Heat Pump	N/a	5	3	42
Cumulative energy cost savings until 2050 due to ECM's applied in decade (mid-decade start)	Early Electric Resistance	N/a	$8.4m	$12m	$0.97m
	Early Heat Pump	N/a	$11m	$12m	$0.97
	Midterm Heat Pump	N/a	$15m	$3.6m	$3.1m
	Late Heat Pump	N/a	$15m	$5.9m	$0.22m
Differential kWh per year required to be provided as renewable energy to meet Green New Deal Target	Early Electric Resistance	N/a	682,362	0	980,879
	Early Heat Pump	N/a	0	0	0
	Midterm Heat Pump	N/a	0	0	0
	Late Heat Pump	N/a	0	0	0
Cumulative cost until 2050 of LADWP Green Power to meet compliance target (inclusive of compounded inflation)	Early Electric Resistance	N/a	$0.77m	$0	$0.16m
	Early Heat Pump	N/a	$0	$0	$0
	Midterm Heat Pump	N/a	$0	$0	$0
	Late Heat Pump	N/a	$0	$0	$0
Cost of onsite renewables (in dollars escalated to midpoint of the decade of the modification) PV alone based on 2020 costs	Early Electric Resistance	N/a	$0.75m	$0	$1.1m
	Early Heat Pump	N/a	$0	$0	$0
	Midterm Heat Pump	N/a	$0	$0	$0
	Late Heat Pump	N/a	$0	$0	$0

Figure D3. Commercial office built during the 2000s Energy Use Intensity (EUI) of electrification paths

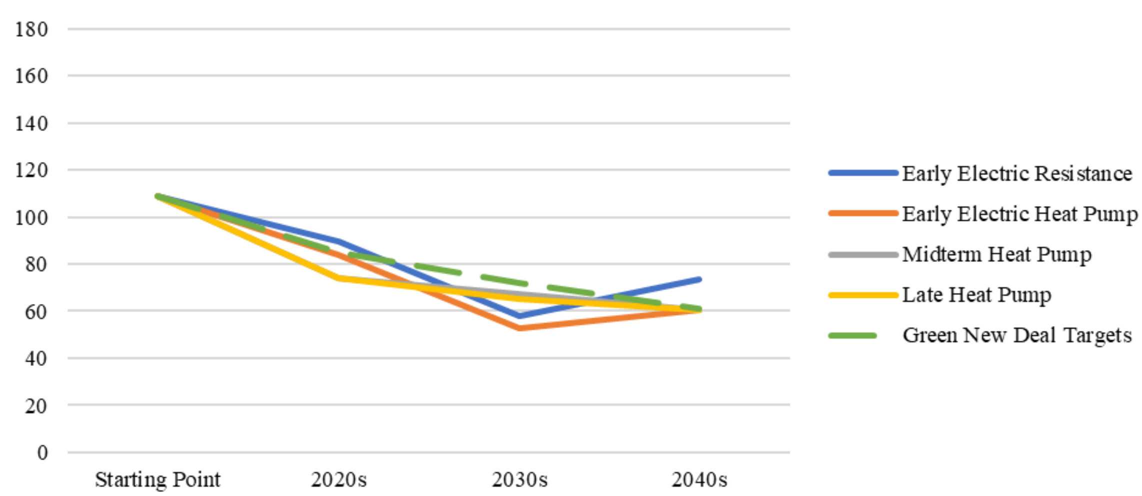


Table D4. Commercial office built during the early 2010s	Electrification Path	Starting point	2020s	2030s	2040s
Energy use intensity (EUI, KBtu/sf/yr)	Early Electric Resistance	72	60	49	58
	Early Heat Pump	72	54	43	47
	Midterm Heat Pump	72	58	53	47
	Late Heat Pump	72	58	50	47
% energy reduction achieved	Early Electric Resistance	N/a	16%	32%	19%
	Early Heat Pump	N/a	24%	40%	35%
	Midterm Heat Pump	N/a	19%	26%	35%
	Late Heat Pump	N/a	19%	30%	35%
Green New Deal % energy reduction required	All	0%	22%	34%	44%
First Cost (in dollars escalated to midpoint of the decade of the modification)	Early Electric Resistance	N/a	$2.8m	$2.8m	$0.54m
	Early Heat Pump	N/a	$1.4m	$2.8m	$0.54m
	Midterm Heat Pump	N/a	$2.1m	$1.5m	$1.0m
	Late Heat Pump	N/a	$2.1m	$0.87m	$1.7m
Energy Cost Savings in first year	Early Electric Resistance	N/a	$0.13m	$0.25m	$0.14m
	Early Heat Pump	N/a	$0.20m	$0.25m	$0.14m
	Midterm Heat Pump	N/a	$0.16m	$0.13m	$0.42m
	Late Heat Pump	N/a	$0.16m	$0.23m	$0.20m
Simple Payback	Early Electric Resistance	N/a	21	11	4
	Early Heat Pump	N/a	7	11	4
	Midterm Heat Pump	N/a	13	11	2
	Late Heat Pump	N/a	13	4	8
Cumulative energy cost savings until 2050 due to ECM's applied in decade (mid-decade start)	Early Electric Resistance	N/a	$5.0m	$4.7m	$0.73m
	Early Heat Pump	N/a	$7.6m	$4.7m	$0.73m
	Midterm Heat Pump	N/a	$6.0m	$2.4m	$2.2m
	Late Heat Pump	N/a	$6.0m	$4.3m	$1.1m
Differential kWh per year required to be provided as renewable energy to meet Green New Deal Target	Early Electric Resistance	N/a	606,000	152,871	1,789,677
	Early Heat Pump	N/a	0	0	558,463
	Midterm Heat Pump	N/a	292,783	704,236	696,435
	Late Heat Pump	N/a	292,783	370,364	659,450
Cumulative cost until 2050 of LADWP Green Power to meet compliance target (inclusive of compounded inflation)	Early Electric Resistance	N/a	$0.69m	$0.09m	$0.29m
	Early Heat Pump	N/a	$0	$0	$0.09m
	Midterm Heat Pump	N/a	$0.33m	$0.40m	$0.11m
	Late Heat Pump	N/a	$0.33m	$0.21m	$0.11m
Cost of onsite renewables (in dollars escalated to midpoint of the decade of the modification) PV alone based on 2020 costs	Early Electric Resistance	N/a	$0.66m	$0.70m	$2.0m
	Early Heat Pump	N/a	$0	$0	$0.61m
	Midterm Heat Pump	N/a	$0.32m	$0.77m	$0.76m
	Late Heat Pump	N/a	$0.32m	$0.41m	$0.72m

Figure D4. Commercial office built during the early 2010s Energy Use Intensity (EUI) of electrification paths

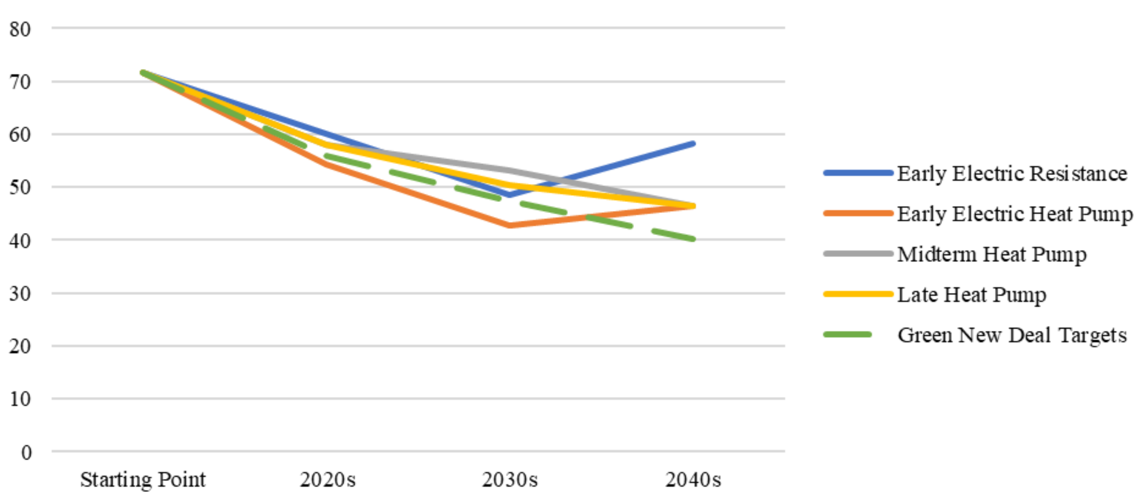


Table D5. Commercial office built during the late 2010s	Electrification Path	Starting point	2020s	2030s	2040s
Energy use intensity (EUI, KBtu/sf/yr)	Early Electric Resistance	60	51	37	43
	Early Heat Pump	60	49	35	33
	Midterm Heat Pump	60	45	44	33
	Late Heat Pump	60	45	42	33
% energy reduction achieved	Early Electric Resistance	N/a	15%	38%	29%
	Early Heat Pump	N/a	19%	41%	45%
	Midterm Heat Pump	N/a	26%	27%	45%
	Late Heat Pump	N/a	26%	29%	45%
Green New Deal % energy reduction required	All	0%	22%	34%	44%
First Cost (in dollars escalated to midpoint of the decade of the modification)	Early Electric Resistance	N/a	$2.8m	$2.8m	$0.54m
	Early Heat Pump	N/a	$1.4m	$2.8m	$0.54m
	Midterm Heat Pump	N/a	$2.1m	$1.5m	$1.0m
	Late Heat Pump	N/a	$2.1m	$0.87m	$1.7m
Energy Cost Savings in first year	Early Electric Resistance	N/a	$0.10m	$0.28m	$0
	Early Heat Pump	N/a	$0.13m	$0.28m	$0
	Midterm Heat Pump	N/a	$0.18m	$0.05m	$0.22m
	Late Heat Pump	N/a	$0.18m	$0.12m	$0.064m
Simple Payback	Early Electric Resistance	N/a	27	10	N/a
	Early Heat Pump	N/a	11	10	N/a
	Midterm Heat Pump	N/a	12	27	5
	Late Heat Pump	N/a	12	7	26
Cumulative energy cost savings until 2050 due to ECM's applied in decade (mid-decade start)	Early Electric Resistance	N/a	$3.9m	$5.3m	$0
	Early Heat Pump	N/a	$4.8m	$5.3m	$0
	Midterm Heat Pump	N/a	$6.7m	$1.0m	$1.2m
	Late Heat Pump	N/a	$6.7m	$2.2m	$0.34m
Differential kWh per year required to be provided as renewable energy to meet Green New Deal Target	Early Electric Resistance	N/a	601,303	0	841,836
	Early Heat Pump	N/a	296,964	0	0
	Midterm Heat Pump	N/a	0	444,732	0
	Late Heat Pump	N/a	0	300,230	0
Cumulative cost until 2050 of LADWP Green Power to meet compliance target (inclusive of compounded inflation)	Early Electric Resistance	N/a	$0.68m	$0	$0.13m
	Early Heat Pump	N/a	$0.34m	$0	$0
	Midterm Heat Pump	N/a	$0	$0.25m	$0
	Late Heat Pump	N/a	$0	$0.17m	$0
Cost of onsite renewables (in dollars escalated to midpoint of the decade of the modification) PV alone based on 2020 costs	Early Electric Resistance	N/a	$0.66m	$0	$0.92m
	Early Heat Pump	N/a	$0.32m	$0	$0
	Midterm Heat Pump	N/a	$0	$0.47m	$0
	Late Heat Pump	N/a	$0	$0.33m	$0

Figure D5. Commercial office built during the late 2010s Energy Use Intensity (EUI) of electrification paths

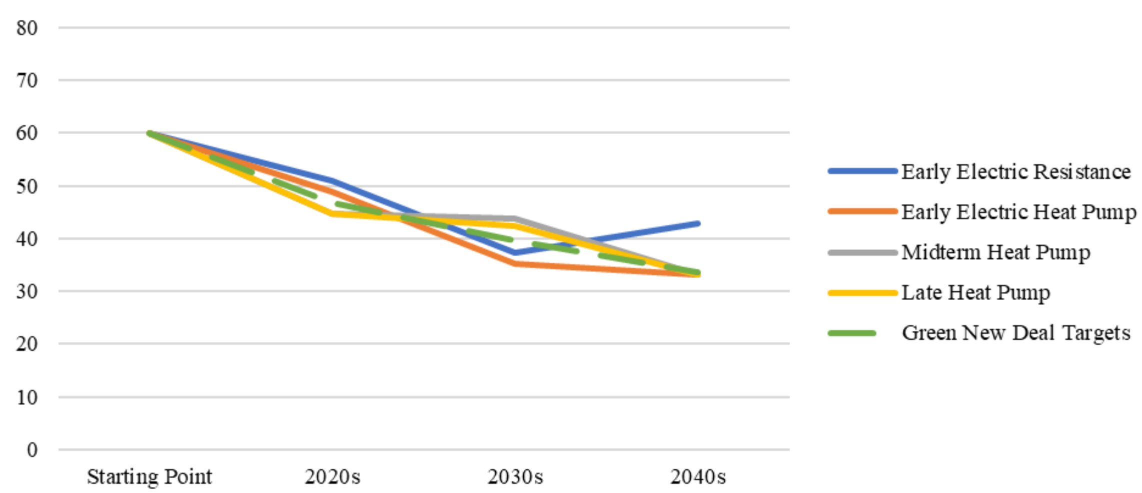


Table D6. Commercial office built during the 2020s	Electrification Path	Starting point	2020s	2030s	2040s
Energy use intensity (EUI, KBtu/sf/yr)	Early Electric Resistance	40	34	26	41
	Early Heat Pump	40	32	24	31
	Midterm Heat Pump	40	31	30	31
	Late Heat Pump	40	31	29	31
% energy reduction achieved	Early Electric Resistance	N/a	17%	37%	-1%
	Early Heat Pump	N/a	22%	42%	24%
	Midterm Heat Pump	N/a	23%	26%	24%
	Late Heat Pump	N/a	23%	28%	24%
Green New Deal % energy reduction required	All	0%	22%	34%	44%
First Cost (in dollars escalated to midpoint of the decade of the modification)	Early Electric Resistance	N/a	$2.8m	$2.8m	$0.54m
	Early Heat Pump	N/a	$1.4m	$2.8m	$0.54m
	Midterm Heat Pump	N/a	$2.1m	$1.5m	$1.0m
	Late Heat Pump	N/a	$2.1m	$0.87m	$1.7m
Energy Cost Savings in first year	Early Electric Resistance	N/a	$0.08m	$0.17m	$0
	Early Heat Pump	N/a	$0.10m	$0.17m	$0
	Midterm Heat Pump	N/a	$0.11m	$0.05m	$0.16m
	Late Heat Pump	N/a	$0.11m	$0.09m	$0.07m
Simple Payback	Early Electric Resistance	N/a	36	17	N/a
	Early Heat Pump	N/a	14	17	N/a
	Midterm Heat Pump	N/a	19	31	6
	Late Heat Pump	N/a	19	10	25
Cumulative energy cost savings until 2050 due to ECM's applied in decade (mid-decade start)	Early Electric Resistance	N/a	$2.9m	$3.2m	$0
	Early Heat Pump	N/a	$3.8m	$3.2m	$0
	Midterm Heat Pump	N/a	$4.0m	$0.91m	$0.87m
	Late Heat Pump	N/a	$4.0m	$1.7m	$0.36m
Differential kWh per year required to be provided as renewable energy to meet Green New Deal Target	Early Electric Resistance	N/a	322,363	0	1,671,470
	Early Heat Pump	N/a	12,278	0	704,080
	Midterm Heat Pump	N/a	0	366,736	895,052
	Late Heat Pump	N/a	0	284,295	873,215
Cumulative cost until 2050 of LADWP Green Power to meet compliance target (inclusive of compounded inflation)	Early Electric Resistance	N/a	$0.37m	$0	$0.23m
	Early Heat Pump	N/a	$0.01m	$0	$0.11m
	Midterm Heat Pump	N/a	$0	$0.21m	$0.14m
	Late Heat Pump	N/a	$0	$0.16m	$0.14m
Cost of onsite renewables (in dollars escalated to midpoint of the decade of the modification) PV alone based on 2020 costs	Early Electric Resistance	N/a	$0.35m	$0	$1.8m
	Early Heat Pump	N/a	$0.01m	$0	$0.77m
	Midterm Heat Pump	N/a	$0	$0.40m	$0.98m
	Late Heat Pump	N/a	$0	$0.31m	$0.31m

Figure D6. Commercial office built during the 2020s Energy Use Intensity (EUI) of electrification paths

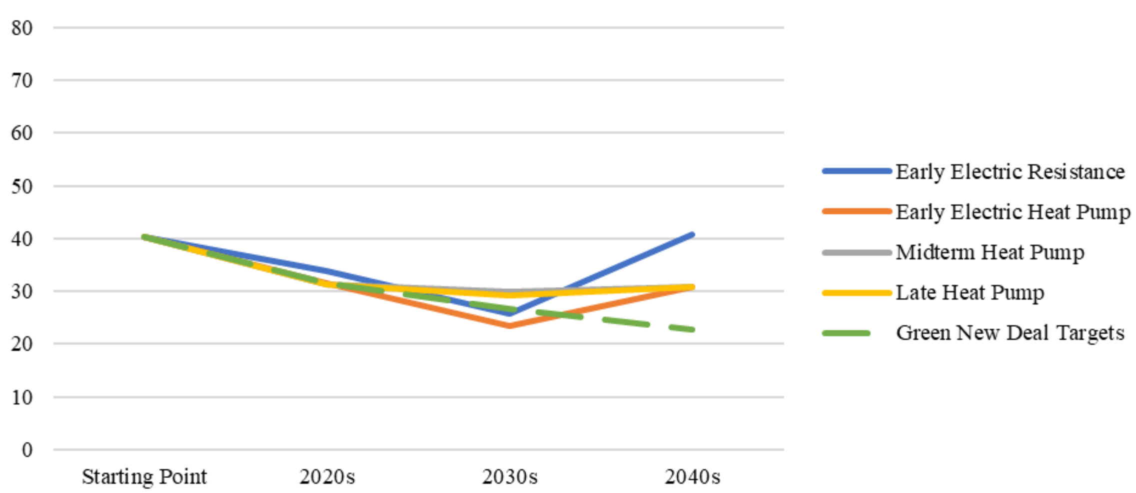


Table D7. Multifamily residential built before 1990	Electrification Path	Starting point	2020s	2030s	2040s
Energy use intensity (EUI, KBtu/sf/yr)	Early Electric Resistance	102	99	61	61
	Early Heat Pump	102	90	52	59
	Midterm Heat Pump	102	70	83	59
	Late Heat Pump	102	70	42	59
% energy reduction achieved	Early Electric Resistance	N/a	3%	41%	41%
	Early Heat Pump	N/a	12%	49%	42%
	Midterm Heat Pump	N/a	32%	19%	42%
	Late Heat Pump	N/a	32%	59%	42%
Green New Deal % energy reduction required	All	0%	22%	34%	44%
First Cost (in dollars escalated to midpoint of the decade of the modification)	Early Electric Resistance	N/a	$0.62m	$0.24m	$0.35m
	Early Heat Pump	N/a	$0.60m	$0.24m	$0.35m
	Midterm Heat Pump	N/a	$0.18m	$0.82m	$0.35m
	Late Heat Pump	N/a	$0.18m	$0.30m	$2.4m
Energy Cost Savings in first year	Early Electric Resistance	N/a	-$0.004m	-$0.007m	$0.05m
	Early Heat Pump	N/a	$0.003m	$0.05m	$0.05m
	Midterm Heat Pump	N/a	$0.03m	$0.003m	$0.05m
	Late Heat Pump	N/a	$0.03m	$0.028m	$0.02m
Simple Payback	Early Electric Resistance	N/a	-139	-32	7
	Early Heat Pump	N/a	222	5	7
	Midterm Heat Pump	N/a	6	225	7
	Late Heat Pump	N/a	6	11	124
Cumulative energy cost savings until 2050 due to ECM's applied in decade (mid-decade start)	Early Electric Resistance	N/a	-$0.17m	-$0.14m	$0.27m
	Early Heat Pump	N/a	$0.10m	$0.85m	$0.27m
	Midterm Heat Pump	N/a	$1.1m	$0.69m	$0.27m
	Late Heat Pump	N/a	$1.1m	$0.54	$0.10m
Differential kWh per year required to be provided as renewable energy to meet Green New Deal Target	Early Electric Resistance	N/a	188,283	0	19,164
	Early Heat Pump	N/a	102,410	0	8,990
	Midterm Heat Pump	N/a	0	101,178	14,312
	Late Heat Pump	N/a	0	0	7,324
Cumulative cost until 2050 of LADWP Green Power to meet compliance target (inclusive of compounded inflation)	Early Electric Resistance	N/a	$0.21m	$0	$0.003m
	Early Heat Pump	N/a	$0.12m	$0	$0.001m
	Midterm Heat Pump	N/a	$0	$0.06m	$0.002m
	Late Heat Pump	N/a	$0	$0	$0.001m
Cost of onsite renewables (in dollars escalated to midpoint of the decade of the modification) PV alone based on 2020 costs	Early Electric Resistance	N/a	$0.21m	$0	$0.02m
	Early Heat Pump	N/a	$0.11m	$0	$0.01m
	Midterm Heat Pump	N/a	$0	$0.11m	$0.02m
	Late Heat Pump	N/a	$0	$0	$0.008m

Figure D7. Multifamily residential built before 1990 Energy Use Intensity (EUI) of electrification paths

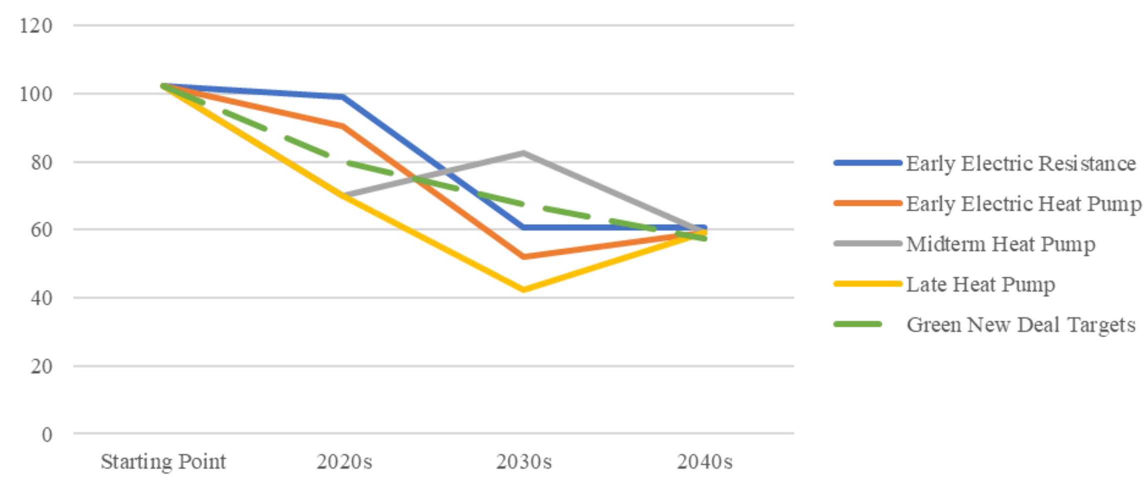


Table D8. Multifamily residential built during the 1990s	Electrification Path	Starting point	2020s	2030s	2040s
Energy use intensity (EUI, KBtu/sf/yr)	Early Electric Resistance	64	60	37	39
	Early Heat Pump	64	57	34	37
	Midterm Heat Pump	64	40	59	37
	Late Heat Pump	64	40	18	37
% energy reduction achieved	Early Electric Resistance	0%	22%	34%	44%
	Early Heat Pump	0%	11%	47%	41%
	Midterm Heat Pump	0%	38%	7%	41%
	Late Heat Pump	0%	38%	71%	41%
Green New Deal % energy reduction required	All	0%	22%	34%	44%
First Cost (in dollars escalated to midpoint of the decade of the modification)	Early Electric Resistance	N/a	$0.62m	$241,120	$350,400
	Early Heat Pump	N/a	$0.60m	$241,120	$350,400
	Midterm Heat Pump	N/a	$0.18m	$819,260	$350,400
	Late Heat Pump	N/a	$0.18m	$300,030	$2,374,060
Energy Cost Savings in first year	Early Electric Resistance	N/a	$0.0009m	$1,565	$49,704
	Early Heat Pump	N/a	$0.004m	$32,517	$49,704
	Midterm Heat Pump	N/a	$0.02m	$6,328	$49,704
	Late Heat Pump	N/a	$0.02m	$27,900	$22,729
Simple Payback	Early Electric Resistance	N/a	723	154	7
	Early Heat Pump	N/a	160	7	7
	Midterm Heat Pump	N/a	8	129	7
	Late Heat Pump	N/a	8	11	104
Cumulative energy cost savings until 2050 due to ECM's applied in decade (mid-decade start)	Early Electric Resistance	N/a	$0.03m	$29,718	$265,364
	Early Heat Pump	N/a	$0.14m	$617,347	$265,364
	Midterm Heat Pump	N/a	$0.80m	$120,135	$265,364
	Late Heat Pump	N/a	$80m	$529,699	$121,349
Differential kWh per year required to be provided as renewable energy to meet Green New Deal Target	Early Electric Resistance	N/a	100,463	0	18,564
	Early Heat Pump	N/a	67,877	0	9,082
	Midterm Heat Pump	N/a	0	104,896	15,993
	Late Heat Pump	N/a	0	0	4,988
Cumulative cost until 2050 of LADWP Green Power to meet compliance target (inclusive of compounded inflation)	Early Electric Resistance	N/a	$0.11m	$0	$2,973
	Early Heat Pump	N/a	$0.77m	$0	$1,455
	Midterm Heat Pump	N/a	$0	$59,745	$2,561
	Late Heat Pump	N/a	$0	$0	$799
Cost of onsite renewables (in dollars escalated to midpoint of the decade of the modification) PV alone based on 2020 costs	Early Electric Resistance	N/a	$0.11m	$0	$0.02m
	Early Heat Pump	N/a	$0.07m	$0	$0.01m
	Midterm Heat Pump	N/a	$0	$0.11m	$0.02m
	Late Heat Pump	N/a	$0	$0	$0.005m

Figure D8. Multifamily residential built during the 1990s Energy Use Intensity (EUI) of electrification paths

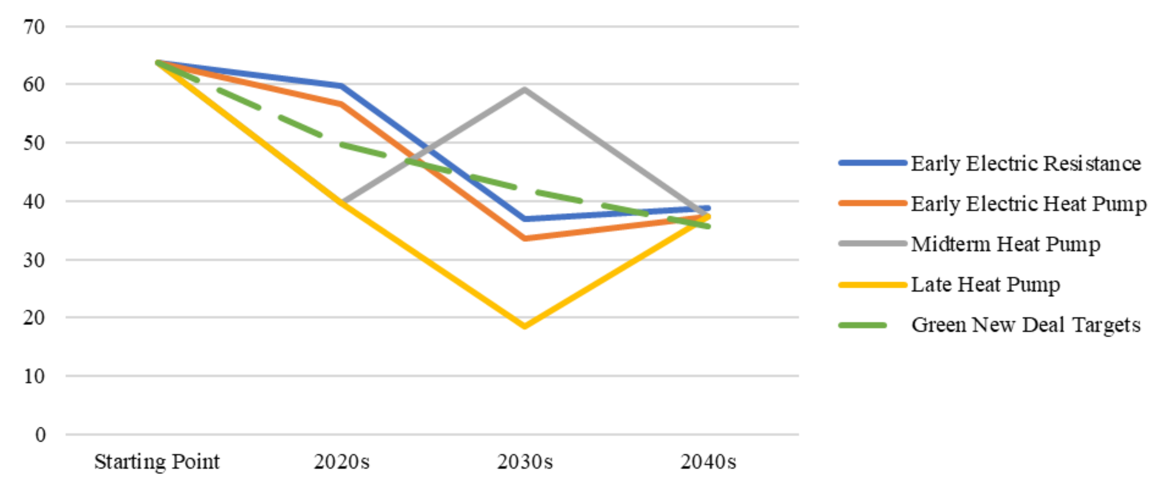


Table D9. Multifamily residential built during the 2000s	Electrification Path	Starting point	2020s	2030s	2040s
Energy use intensity (EUI, KBtu/sf/yr)	Early Electric Resistance	53	50	31	38
	Early Heat Pump	53	47	28	37
	Midterm Heat Pump	53	33	49	37
	Late Heat Pump	53	33	17	37
% energy reduction achieved	Early Electric Resistance	N/a	6%	42%	28%
	Early Heat Pump	N/a	11%	47%	31%
	Midterm Heat Pump	N/a	38%	7%	31%
	Late Heat Pump	N/a	38%	68%	31%
Green New Deal % energy reduction required	All	0%	22%	34%	44%
First Cost (in dollars escalated to midpoint of the decade of the modification)	Early Electric Resistance	N/a	$0.62m	$0.24m	$0.35m
	Early Heat Pump	N/a	$0.60m	$0.24m	$0.35m
	Midterm Heat Pump	N/a	$0.18m	$0.24m	$0.35m
	Late Heat Pump	N/a	$0.18m	$0.24m	$2.4m
Energy Cost Savings in first year	Early Electric Resistance	N/a	$0.0005m	$0.0009m	$0.04m
	Early Heat Pump	N/a	$0.003m	$0.03m	$0.04m
	Midterm Heat Pump	N/a	$0.02m	$0.005m	$0.04m
	Late Heat Pump	N/a	$0.02m	$0.02m	$0.04m
Simple Payback	Early Electric Resistance	N/a	1322	271	9
	Early Heat Pump	N/a	226	9	9
	Midterm Heat Pump	N/a	10	181	9
	Late Heat Pump	N/a	10	14	145
Cumulative energy cost savings until 2050 due to ECM's applied in decade (mid-decade start)	Early Electric Resistance	N/a	$0.02m	$0.02m	$0.20m
	Early Heat Pump	N/a	$0.10m	$0.51m	$0.20m
	Midterm Heat Pump	N/a	$0.66m	$0.09m	$0.20m
	Late Heat Pump	N/a	$0.66m	$0.41m	$0.09m
Differential kWh per year required to be provided as renewable energy to meet Green New Deal Target	Early Electric Resistance	N/a	81,661	0	47,893
	Early Heat Pump	N/a	56,875	0	36,132
	Midterm Heat Pump	N/a	0	88,359	63,333
	Late Heat Pump	N/a	0	0	21,792
Cumulative cost until 2050 of LADWP Green Power to meet compliance target (inclusive of compounded inflation)	Early Electric Resistance	N/a	$0.09m	$0	$0.008m
	Early Heat Pump	N/a	$0.06m	$0	$0.006m
	Midterm Heat Pump	N/a	$0	$0.05m	$0.01m
	Late Heat Pump	N/a	$0	$0	$0.003m
Cost of onsite renewables (in dollars escalated to midpoint of the decade of the modification) PV alone based on 2020 costs	Early Electric Resistance	N/a	$0.09m	$0	$0.05m
	Early Heat Pump	N/a	$0.06m	$0	$0.04m
	Midterm Heat Pump	N/a	$0	$0.10m	$0.07m
	Late Heat Pump	N/a	$0	$0	$0.02m

Figure D9. Multifamily residential built during the 2000s Energy Use Intensity (EUI) of electrification paths

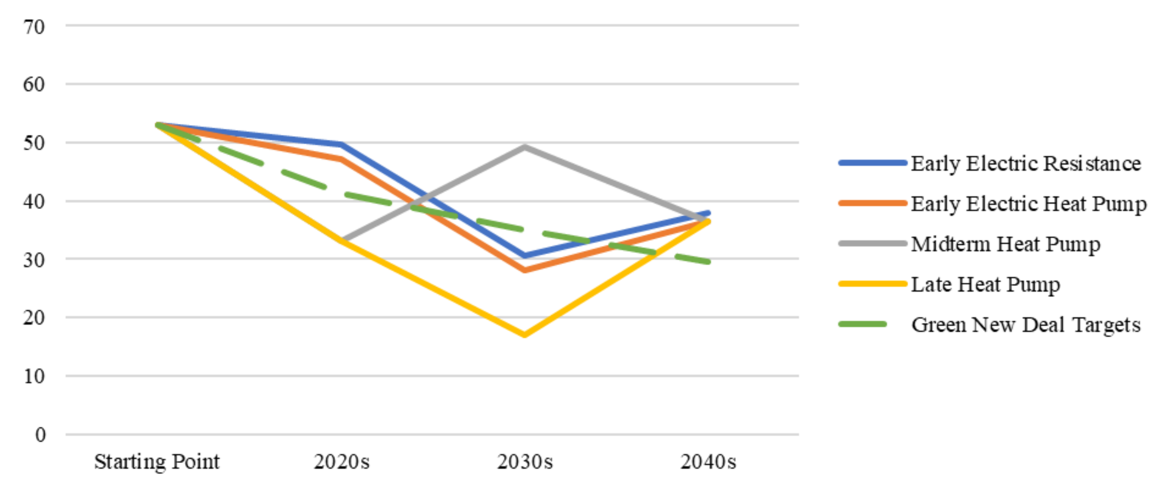


Table D10. Multifamily residential built during the early 2010s	Electrification Path	Starting point	2020s	2030s	2040s
Energy use intensity (EUI, KBtu/sf/yr)	Early Electric Resistance	48	46	27	37
	Early Heat Pump	48	45	26	35
	Midterm Heat Pump	48	28	46	35
	Late Heat Pump	48	28	15	35
% energy reduction achieved	Early Electric Resistance	N/a	4%	44%	23%
	Early Heat Pump	N/a	7%	46%	26%
	Midterm Heat Pump	N/a	41%	3%	26%
	Late Heat Pump	N/a	41%	69%	26%
Green New Deal % energy reduction required	All	0%	22%	34%	44%
First Cost (in dollars escalated to midpoint of the decade of the modification)	Early Electric Resistance	N/a	$0.62m	$0.24m	$0.35m
	Early Heat Pump	N/a	$0.60m	$0.24m	$0.35m
	Midterm Heat Pump	N/a	$0.18m	$0.82m	$0.35m
	Late Heat Pump	N/a	$0.18m	$0.30m	$2.4m
Energy Cost Savings in first year	Early Electric Resistance	N/a	-$0.0007m	-$0.001m	$0.03m
	Early Heat Pump	N/a	$0.0002m	$0.03m	$0.03m
	Midterm Heat Pump	N/a	$0.02m	$0.0005m	$0.03m
	Late Heat Pump	N/a	$0.02m	$0.02m	$0.002m
Simple Payback	Early Electric Resistance	N/a	-896	-226	11
	Early Heat Pump	N/a	2361	9	11
	Midterm Heat Pump	N/a	10	1760	11
	Late Heat Pump	N/a	10	17	1203
Cumulative energy cost savings until 2050 due to ECM's applied in decade (mid-decade start)	Early Electric Resistance	N/a	-$0.026m	-$0.02m	$0.17m
	Early Heat Pump	N/a	$0.01m	$0.49m	$0.17m
	Midterm Heat Pump	N/a	$0.64m	$0.009m	$0.17m
	Late Heat Pump	N/a	$0.64m	$0.33m	$0.01m
Differential kWh per year required to be provided as renewable energy to meet Green New Deal Target	Early Electric Resistance	N/a	83,519	0	56,857
	Early Heat Pump	N/a	72,768	0	46,537
	Midterm Heat Pump	N/a	0	86,504	83,387
	Late Heat Pump	N/a	0	0	26,751
Cumulative cost until 2050 of LADWP Green Power to meet compliance target (inclusive of compounded inflation)	Early Electric Resistance	N/a	$0.09m	$0	$0.009m
	Early Heat Pump	N/a	$0.08m	$0	$0.007m
	Midterm Heat Pump	N/a	$0	$0.05m	$0.01m
	Late Heat Pump	N/a	$0	$0	$0.004m
Cost of onsite renewables (in dollars escalated to midpoint of the decade of the modification) PV alone based on 2020 costs	Early Electric Resistance	N/a	$0.09m	$0	$0.06m
	Early Heat Pump	N/a	$0.08m	$0	$0.05m
	Midterm Heat Pump	N/a	$0	$0.09m	$0.09m
	Late Heat Pump	N/a	$0	$0	$0.03m

Figure D10. Multifamily residential built during the early 2010s Energy Use Intensity (EUI) of electrification paths

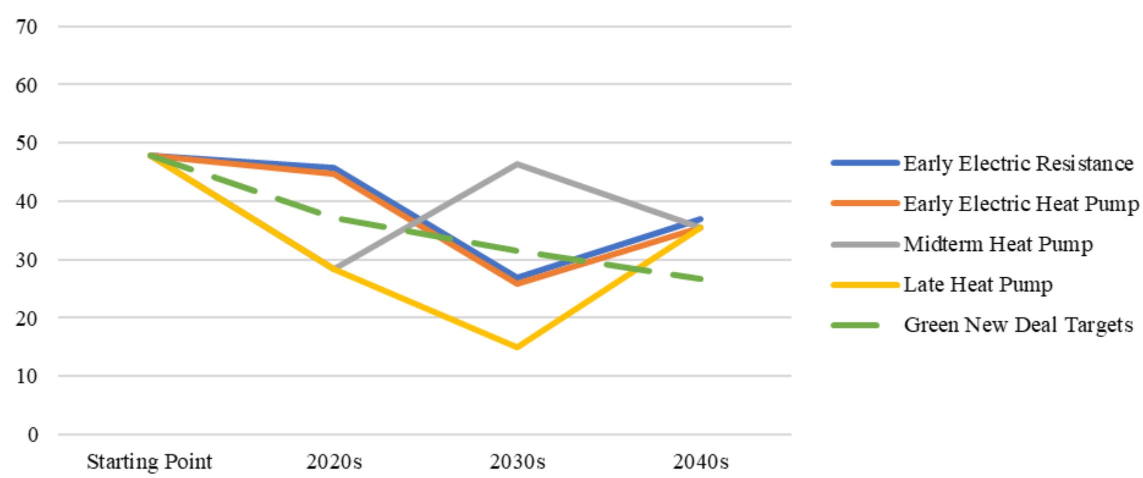


Table D11. Multifamily residential built during the late 2010s	Electrification Path	Starting point	2020s	2030s	2040s
Energy use intensity (EUI, KBtu/sf/yr)	Early Electric Resistance	38	37	26	40
	Early Heat Pump	38	37	25	33
	Midterm Heat Pump	38	26	39	33
	Late Heat Pump	38	26	13	33
% energy reduction achieved	Early Electric Resistance	N/a	3%	33%	-3%
	Early Heat Pump	N/a	4%	34%	14%
	Midterm Heat Pump	N/a	32%	0%	14%
	Late Heat Pump	N/a	32%	66%	14%
Green New Deal % energy reduction required	All	0%	22%	34%	44%
First Cost (in dollars escalated to midpoint of the decade of the modification)	Early Electric Resistance	N/a	$0.62m	$0.24m	$0.35
	Early Heat Pump	N/a	$0.60m	$0.24m	$0.35
	Midterm Heat Pump	N/a	$0.18m	$0.82m	$0.35
	Late Heat Pump	N/a	$0.18m	$0.30m	$2.4m
Energy Cost Savings in first year	Early Electric Resistance	N/a	-$0.001m	-$0.002m	$0.03m
	Early Heat Pump	N/a	-$0.001m	$0.02m	$0.03m
	Midterm Heat Pump	N/a	$0.01m	-$0.002m	$0.03m
	Late Heat Pump	N/a	$0.01m	$0.02m	-$0.006m
Simple Payback	Early Electric Resistance	N/a	-430	-104	12
	Early Heat Pump	N/a	-535	15	12
	Midterm Heat Pump	N/a	17	-450	12
	Late Heat Pump	N/a	17	18	-389
Cumulative energy cost savings until 2050 due to ECM's applied in decade (mid-decade start)	Early Electric Resistance	N/a	-$0.05m	-$0.44m	$0.16m
	Early Heat Pump	N/a	-$0.04m	$0.31m	$0.16m
	Midterm Heat Pump	N/a	$0.40m	-$0.03m	$0.16m
	Late Heat Pump	N/a	$0.40m	$0.32m	-$0.03m
Differential kWh per year required to be provided as renewable energy to meet Green New Deal Target	Early Electric Resistance	N/a	73,280	3,698	120,235
	Early Heat Pump	N/a	69,575	93	74,760
	Midterm Heat Pump	N/a	0	89,025	113,574
	Late Heat Pump	N/a	0	0	38,987
Cumulative cost until 2050 of LADWP Green Power to meet compliance target (inclusive of compounded inflation)	Early Electric Resistance	N/a	$0.08m	$0.002m	$0.02m
	Early Heat Pump	N/a	$0.08m	~$0	$0.01m
	Midterm Heat Pump	N/a	$0	$0.05m	$0.02m
	Late Heat Pump	N/a	$0	$0	$0.006m
Cost of onsite renewables (in dollars escalated to midpoint of the decade of the modification) PV alone based on 2020 costs	Early Electric Resistance	N/a	$0.08m	$0.004m	$0.13m
	Early Heat Pump	N/a	$0.08m	~$0	$0.08m
	Midterm Heat Pump	N/a	$0	$0.10m	$0.12m
	Late Heat Pump	N/a	$0	$0	$0.43m

Figure D11. Multifamily residential built during the late 2010s Energy Use Intensity (EUI) of electrification paths

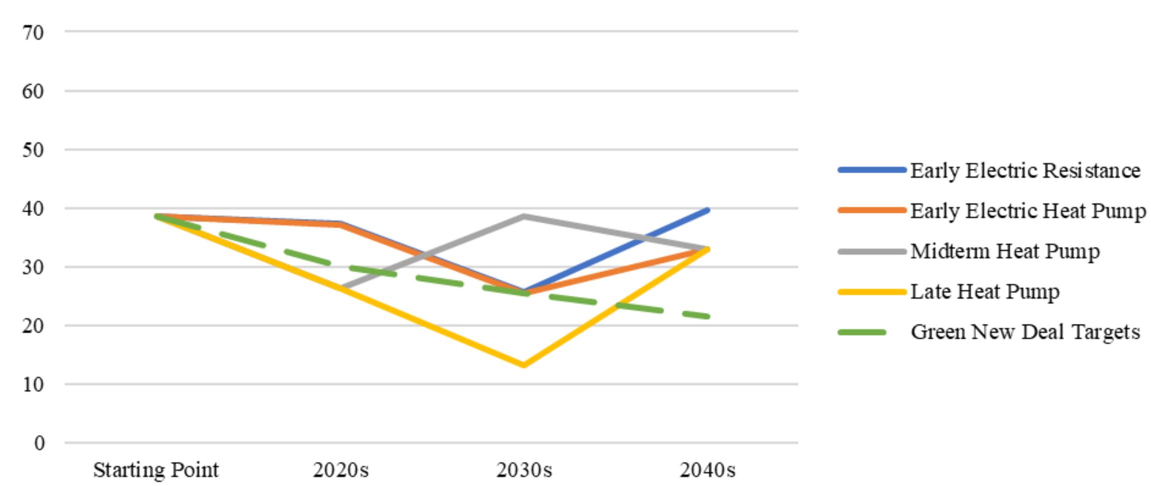
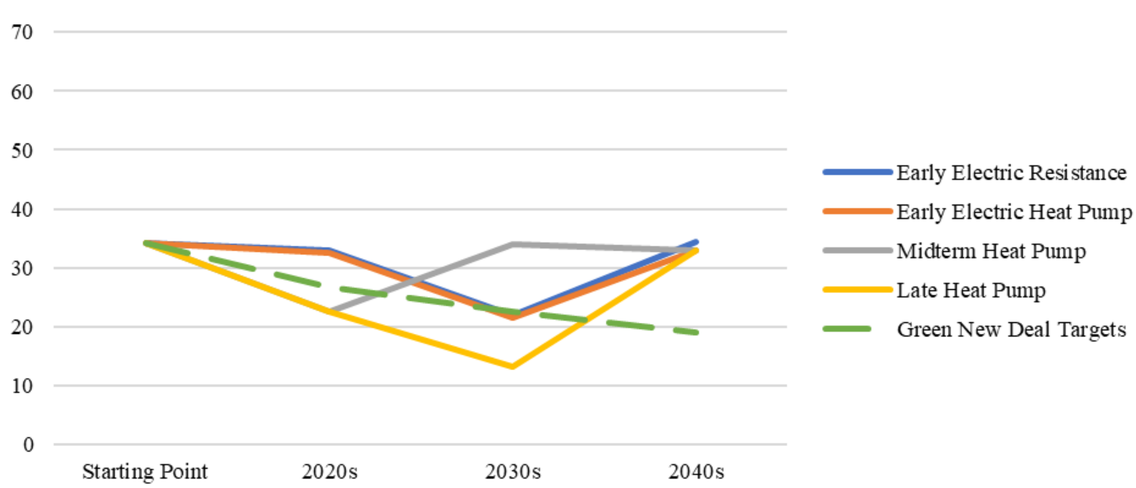


Table D12. Multifamily residential built during the late 2020s	Electrification Path	Starting point	2020s	2030s	2040s
Energy use intensity (EUI, KBtu/sf/yr)	Early Electric Resistance	34	33	22	35
	Early Heat Pump	34	33	22	33
	Midterm Heat Pump	34	23	34	33
	Late Heat Pump	34	23	13	33
% energy reduction achieved	Early Electric Resistance	N/a	4%	36%	-1%
	Early Heat Pump	N/a	5%	37%	3%
	Midterm Heat Pump	N/a	34%	0%	3%
	Late Heat Pump	N/a	34%	61%	3%
Green New Deal % energy reduction required	All	0%	22%	34%	44%
First Cost (in dollars escalated to midpoint of the decade of the modification)	Early Electric Resistance	N/a	$0.62m	$0.24m	$0.35m
	Early Heat Pump	N/a	$0.60m	$0.24m	$0.35m
	Midterm Heat Pump	N/a	$0.18m	$0.82m	$0.35m
	Late Heat Pump	N/a	$0.18m	$0.30m	$0.35
Energy Cost Savings in first year	Early Electric Resistance	N/a	-$0.001m	-$0.002m	$0.02m
	Early Heat Pump	N/a	-$0.001m	$0.02m	$0.02m
	Midterm Heat Pump	N/a	$0.01m	-$0.002m	$0.02m
	Late Heat Pump	N/a	$0.01m	$0.01m	-$0.005m
Simple Payback	Early Electric Resistance	N/a	-479	-114	16
	Early Heat Pump	N/a	-614	16	16
	Midterm Heat Pump	N/a	17	-505	16
	Late Heat Pump	N/a	17	24	-435
Cumulative energy cost savings until 2050 due to ECM's applied in decade (mid-decade start)	Early Electric Resistance	N/a	-$0.05m	-$0.04m	$0.12m
	Early Heat Pump	N/a	-$0.04m	$0.30m	$0.12m
	Midterm Heat Pump	N/a	$0.38m	-$0.03m	$0.12m
	Late Heat Pump	N/a	$0.38m	$0.23m	-$0.03m
Differential kWh per year required to be provided as renewable energy to meet Green New Deal Target	Early Electric Resistance	N/a	62,146	0	97,553
	Early Heat Pump	N/a	58,460	0	86,542
	Midterm Heat Pump	N/a	0	75,063	136,824
	Late Heat Pump	N/a	0	0	53,393
Cumulative cost until 2050 of LADWP Green Power to meet compliance target (inclusive of compounded inflation)	Early Electric Resistance	N/a	$0.07m	$0	$0.02m
	Early Heat Pump	N/a	$0.07m	$0	$0.01m
	Midterm Heat Pump	N/a	$0	$0.04m	$0.02m
	Late Heat Pump	N/a	$0	$0	$0.009m
Cost of onsite renewables (in dollars escalated to midpoint of the decade of the modification) PV alone based on 2020 costs	Early Electric Resistance	N/a	$0.07m	$0	$0.11m
	Early Heat Pump	N/a	$0.06m	$0	$0.09m
	Midterm Heat Pump	N/a	$0	$0.08m	$0.15m
	Late Heat Pump	N/a	$0	$0	$0.06m

Figure D12. Multifamily residential built during the 2020s Energy Use Intensity (EUI) of electrification paths



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