Peninsula Advanced Energy Community (PAEC)

Task 3.14: Final Economic Benefit-Cost Analysis of Energy Efficiency and Fuel Switching Measures

Prototypical Residential Multifamily Building

Prepared for
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About DNV GL

DNV GL is a global energy and climate consulting practice serving government, utility and private sector clients with 15,000 employees in more than 100 countries. DNV GL – Energy's 2,300 experts offer a broad range of energy consulting services spanning all links in the energy value chain including renewable and conventional power generation, power and natural gas transmission and distribution, smart cities and smart grids, sustainable energy use, and energy markets and regulations.

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About the Clean Coalition

The Clean Coalition is a nonprofit organization whose mission is to accelerate the transition to renewable energy and a modern grid through technical, policy, and project development expertise.

The Clean Coalition drives policy innovation to remove barriers to procurement and interconnection of distributed energy resources (DER)—such as local renewables, advanced inverters, demand response, and energy storage—and we establish market mechanisms that realize the full potential of integrating these solutions. The Clean Coalition also collaborates with utilities and municipalities to create near-term deployment opportunities that prove the technical and financial viability of local renewables and other DER.

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Legal Disclaimer

I. Introduction

DNV GL is supporting the Clean Coalition to explore combinations of emerging and proven clean-energy technologies and systems that offer the best value in terms of economic, environmental and technical performance. In this report, DNV GL presents the results of the economic analysis of specific individual energy efficiency and fuel-switching measures for a prototypical multifamily residential building in the southern portion of San Mateo County.

In summary, DNV GL completed the following analytical steps:

- Select prototypical multifamily residential building features and assumptions specific to the San Mateo area. Establish baseline energy consumption for the proposed facility and define energy usage characteristics
- Identify proposed and alternative building energy models
- Specify Energy Efficiency Measures (EEMs) which could be implemented
- Evaluate the cost-effectiveness of each measure

Table 1 summarizes the energy efficiency measures (EEMs) analyzed for a prototypical multifamily residential building, estimated annual energy savings, and economic parameters. EEM-0 is defined as the baseline model of a prototypical multifamily building, with subsequent EEMs defined and analyzed individually. EEM-9 represents a roll-up combination of all EEM measures combined into a single retrofit package.

Table 1: Summary of results

EEM	Annual Energy Use (kWh)	EUI (kBtu/sf)	Percent Reduction	Capital Cost	Payback Years
0-Baseline	106,961	64	-	-	-
1-LEDs	97,122	58	9%	$6,690	2.0
2-BMS	103,130	62	4%	$1,000	3.0
3-Phantom Loads	104,092	62	3%	$900	0.8
4-Windows	96,512	58	10%	$49,286	25.1
5-Insulation	101,958	61	5%	$4,799	11.8
6-AC	105,786	63	1%	$1,000	2.6
7-Heating	93,434	56	13%	$1,000	N/A
8-Hot Water	88,027	53	18%	$15,414	66.1
9-All EEMs	45,667	27	57%	$80,090	9.3

II. Background: Peninsula Advanced Energy Community (PAEC)

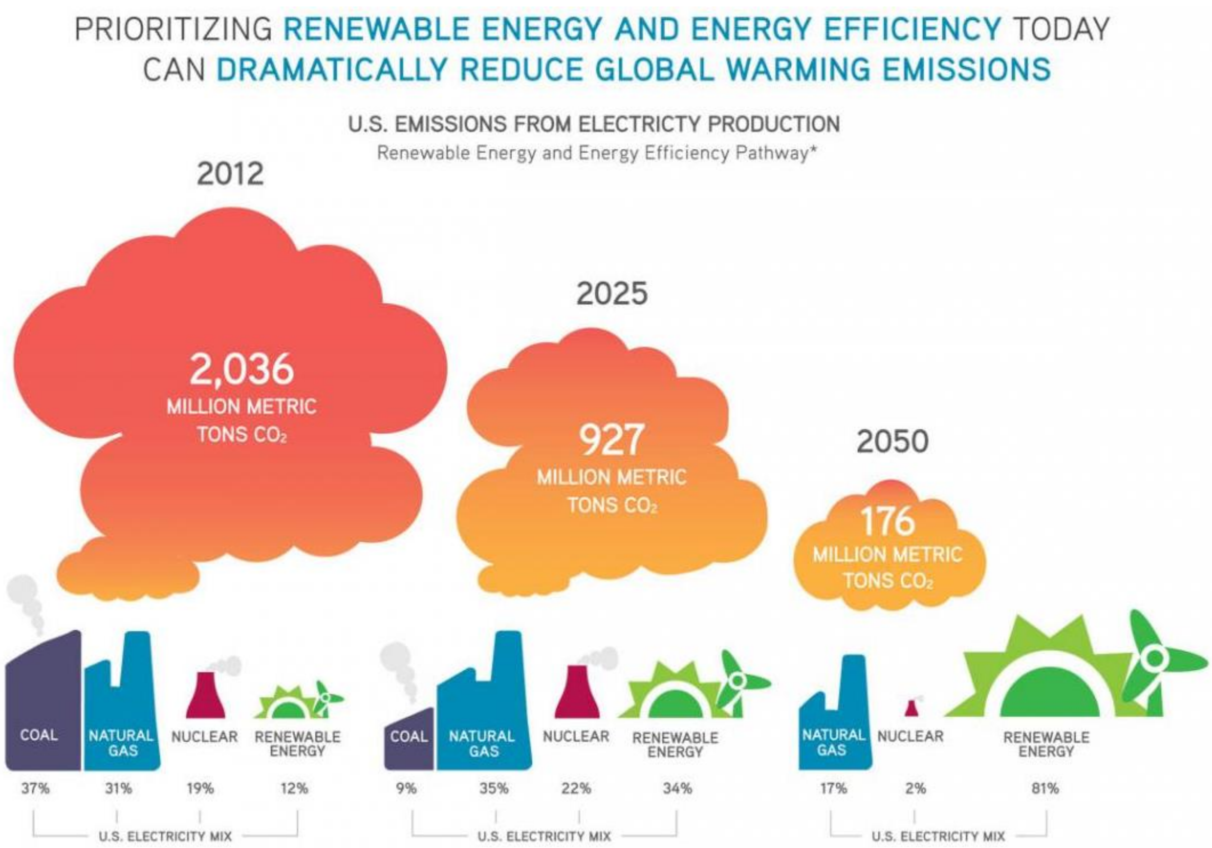
The Clean Coalition's Peninsula Advanced Energy Community (PAEC), supported by numerous local governments and PG&E, will accelerate the planning, approval, and deployment of an Advanced Energy Community (AEC) within a diverse community in the southern portion of San Mateo County. The core PAEC region encompasses the cities of Atherton, East Palo Alto, Menlo Park, and Redwood City as well as surrounding unincorporated areas. The PAEC region -largely built-out yet also experiencing enormous commercial and residential growth pressure - is representative of similar regions throughout California, ensuring that the PAEC's success can be replicated statewide. The PAEC project will include the key components necessary to define an AEC: abundant solar electricity, energy storage, and other Distributed Energy Resources (DER,) low or zero net energy (ZNE) buildings, Solar Emergency Microgrids (SEM) for power management and islanding of critical loads during outages, and charging infrastructure to support the rapid growth in electric vehicles.

AEC projects can provide significant energy, environmental, economic, and security benefits, but significant barriers too often impede their planning and deployment. Finding viable sites, securing project financing, and connecting AEC projects to the grid all represent significant challenges. The PAEC project is designed to overcome these barriers and establish a replicable model that can be used by other communities across California and beyond. The results of the PAEC will inform future action by policymakers, municipalities and other governmental agencies, utility executives, and other relevant audiences.

The goals and objectives of this project are to:

- Incentivize and accelerate the planning, approval, financing, and deployment of AECs
- Reduce the time, cost, and uncertainty associated with permitting and interconnecting commercial-scale solar and other DER
- Leverage ZNE, efficiency, local renewables, energy storage, and other DER to reduce 25 MW of peak energy across San Mateo County, which will strengthen the grid
- Reduce use of natural gas, and minimize the need for new energy infrastructure
- Create a model project and project elements that can be replicated throughout California and beyond

In addition to energy efficiency recommendations, this report also helps local governments to meet State of California climate goals by becoming all-electric, which decreases carbon emissions and minimize other risks associated with natural gas. Methane – a primary component of natural gas – leaks from drilling sites and pipelines. Over a 100-year period, it is 34 times more potent than carbon dioxide at trapping heat. According to the Union of Concerned Scientists, 1-9% of all natural gas produced escapes into the atmosphere. Therefore, it is important to shift towards renewable energy and energy efficiency and away from natural gas.



Source: Union of Concerned Scientists

Environmental risks associated with natural gas:

- Contaminated Drinking Water: from hydraulic fracturing (fracking.)
- Explosions: the deadly pipeline explosion in San Bruno, CA brought aging natural gas pipelines into focus. Since 2010, over 3,300 incidents of crude oil and liquefied natural gas leaks or ruptures have occurred on U.S. pipelines. These incidents have killed 80 people, injured 389 more, and cost $2.8 billion in damages. They also released toxic, polluting chemicals in local soil, waterways, and air.

- Land Impact: erosion, loss of soil productivity, flooding, increased runoffs, and landslides due to drilling and exploration
- Hazardous Emissions: carbon dioxide, carbon monoxide, nitrogen oxides, sulfur dioxides, particulates, and mercury

DNV GL is supporting the Clean Coalition to explore combinations of emerging and proven clean-energy technologies and systems that offer the best value in terms of economic, environmental and technical performance. Below, we detail the results of DNV GL's economic analysis of specific individual energy efficiency and fuel-switching measures.

a. Methodology

Our team utilized IES Virtual Environment software to create a baseline energy model for prototypes of each of the following five building types: large office, large municipal, school, multifamily residential, and retail. The model used for the residential building in this report reflects the average size, orientation, vintage, construction type, and occupancy profile as it relates to the southern portion of San Mateo County. DNV GL used demographic data, Global Information System (GIS) data, and planning data to ascertain the characteristics of the typical office, municipal, school, multifamily residential, and retail buildings in the area. California's Commercial End Use Survey (CEUS) and Residential Appliance Saturation Survey (RASS) data has been used along with DNV GL's previously collected data and building project experience to determine typical energy use and calibrate the energy model.

After creating the baseline buildings, DNV GL focused on conducting economic analysis of the following eight (8) energy efficiency and fuel switching measures:

1. LED lighting conversion
2. Building Management System (BMS)/advanced controls
3. Reduction in phantom loads
4. Higher efficiency windows
5. Improved insulation quality
6. Replacement of obsolete AC systems with higher efficiency
7. Convert to heat pump from natural gas space heating
8. Alternative water heating systems

The economic analysis examines the following parameters for the above 8 measures:

- Upfront costs
- Incentives available
- Operations and maintenance compared with baseline equipment

- A set of "self-funded" and “financed” economic metrics such as payback, internal rate of return and revenues/savings

The energy efficiency and fuel switching measures have been entered into the energy simulation software to run parametric analysis and determined associated energy use and energy costs savings for each associated measure and bundle of measures for each prototypical building type. RSMeans data along with data procured from manufacturers informed the capital cost as well as lifecycle maintenance costs components of the economic analysis. The results of the economic analysis are based on predicted costs of technologies and energy over the next 15-20 years which evaluates the cost effectiveness of each measure on each facility type.

III. Model assumptions

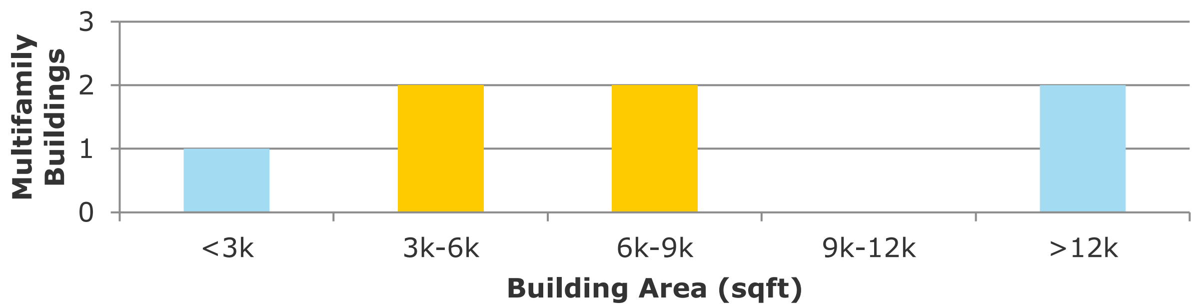
a. Prototypical multifamily residential building selection

The DNV GL team selected the prototypical multifamily building based on extensive research of the building type in the South San Mateo County area (including East Palo Alto, Menlo Park and Redwood City). Based on building vintage data from LoopNet, DNV GL assumes that the prototypical multifamily building was constructed pre-building code with minimal upgrades to envelope, and mostly 22-year-old mechanical equipment in place.

Figure 1 below provides a summary of existing multifamily building stock analysis conducted for southern San Mateo County to determine the appropriate assumptions for prototypical multifamily buildings. Main data sources consulted include LoopNet, CBECS, RECS, CEUS, extensive research and professional experience. The median multifamily residential building size among the analyzed dataset is roughly 5,000 square feet. Building system types on this size range of multifamily spaces are typical from 3,000 – 9,000 square feet which will ensure “lessons learned” can also be shared with smaller/larger buildings. The typical height is two stories.

Figure 1. Summary of prototypical multifamily building analysis for southern San Mateo County (Data source: LoopNet)

Most Common Range	Average Area	Median Area
3k-9k sqft	10,000 sqft	5,000 sqft



b. Energy efficiency measures (EEMs)

For the purposes of this study, IES Virtual Environment (IES VE) energy modeling software was used to analyze the EEMs effect on annual energy use for the multifamily residential building. Energy equipment efficiencies, plug load estimations, and modeling schedules were based off the American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) and California Title 24 requirements for building energy modeling. Additionally, the weather file used for analysis was (TMY3) San Francisco International Airport, California. Energy consumption in this report is in reference to site energy, not source.

Table 2 provides a brief description of each measure and Figure 2 is a screenshot of the prototypical building in IES VE. Each measure is run individually with the final model (9-All EEMs) including all the measures together. Although we are assuming a packaged baseline HVAC system with combined heating and cooling, for the purposes of this report we have analyzed the heating and cooling upgrades separately in order to identify the individual savings associated with each. However, it is most likely that the HVAC upgrades would occur concurrently.

Table 2: Energy use per measure

EEM	Description of Measure
0-Baseline	Based on a 1995 vintage multifamily building (22 years old)
1-LEDs	LED Lighting and Occupancy Controls
2-BMS	Building Management System/advanced HVAC controls
3-Phantom Loads	Reduction in phantom loads with smart strips and training
4-Windows	Improved window thermal properties
5-Insulation	Improved wall thermal properties
6-AC	Replacement of obsolete AC systems with higher efficiency
7-Heating	Convert to heat pump from natural gas space heating
8-Hot Water	Upgrade to a solar hot water heater with an electric heat pump
9-All EEMs	All measures 1-8

Figure 2: IES VE screenshot

Table 3 summarizes the specific assumptions associated with existing (baseline) conditions associated with the prototypical multifamily residential building, along with the set of proposed EEM measures. The existing conditions assume a multifamily building from 1995 with minimal upgrades based on typical replacement schedules for lighting and mechanical (HVAC) equipment. The existing conditions assume no changes to original building envelope, such as windows and insulation on exterior walls/roof. The proposed EEMs assume reasonable retrofit efficiencies that go beyond Title 24, and together as a retrofit package, support zero net energy (ZNE) retrofit energy goals. The efficiencies associated with the proposed measures are based on DNV GL's experience with ZNE retrofit projects.

Table 3: Model assumptions

EEM	Building Component	Age of Existing Component	Existing Conditions (Title 24 1995)	Proposed Measures
1-LED	**Interior Lights**	22 years	0.8 W/ft^2 Fluorescent Lights	0.25 W/ft^2 (100% LED, occupancy & daylight sensors)
	Exterior Lights	22 years	Entrance: 33 W/lin. ft Facade: 0.25 W/ ft^2	Entrance: 15 W Facade: 0.18 W/ ft^2
2-BMS	**Building Management System**	n/a	-	10% savings to HVAC
3-Phantom Loads	**Phantom Loads**	n/a	1.50 W/sf Equipment	1.25 W/sf Equipment (Smart strips & training)
4-Windows	**Windows**	22 years	U-Factor = 0.75 (single pane windows)	U-Factor = 0.32 (dual pane, energy efficient)
5-Insulation	**Insulation - Exterior Walls**	22 years	U-Factor = 0.10 (wood frame walls with R13 insulation)	U-Factor = 0.05 (add 2" rigid insulation)
	Insulation - Roof	22 years	U-Factor = 0.03 (R30)	U-Factor = 0.03 (R30)
6-AC	**AC Systems**	22 years	9.7 SEER Packaged Rooftop Unit	3.2 COP Rooftop Heat Pump
7-Heating	**Heating Systems**	22 years	78% efficiency Natural Gas Boiler	3.4 COP Rooftop Heat Pump
8-Hot Water	**Hot Water Heater**	22 years	78% efficiency Natural Gas Boiler	Solar hot water heater (60% of annual use) & electric heat pump (3 EF)

IV. Results for prototypical multifamily residential building

a. Energy savings per EEM

Table 4 summarizes the energy consumption, energy use intensity (EUI), and percent reduction associated with each energy efficiency measure (EEM). Energy models 1-8 incorporate each EEM individually and model 9-All EEMs includes them altogether. It is noted that the savings associated with each measure individually do not add to equal the cumulative savings seen in model 9. This is because the measures affect one another and as the overall building load decreases the percent savings yields less kWhs. The baseline model begins with an EUI of 64 kBtu/sf/yr and decreases down to 27 kBtu/sf/yr if all EEMs are implemented. An upgrade to the hot water heating system has the largest individual impact on the energy consumption (18% reduction). Three other measures that have large impacts are upgrading the heating system (13% reduction), upgrading the existing windows (10% reduction), and upgrading to LEDs (9% reduction). If all eight measures are implemented at the assumed levels, DNV GL estimates a 57% reduction in energy consumption on an annual basis for the prototypical multifamily building.

Table 4: Prototypical multifamily energy-use per measure

EEM	Annual Energy Use (kWh)	EUI (kBtu/sf)	Percent Reduction
0-Baseline	106,961	64	-
1-LEDs	97,122	58	9%
2-BMS	103,130	62	4%
3-Phantom Loads	104,092	62	3%
4-Windows	96,512	58	10%
5-Insulation	101,958	61	5%
6-AC	105,786	63	1%
7-Heating	93,434	56	13%
8-Hot Water	88,027	53	18%
9-All EEMs	45,667	27	57%

Figure 3 shows the annual energy consumption calculated for each measure broken down by end use. Table 5 on the next page provides the detailed data points for the graph. As you can see, each measure can affect multiple end uses. For example, EEMs that reduce lighting and plug loads also affect HVAC (increase in heating and a decrease in cooling), because the equipment and lights emit heat into the space.

Figure 3: Annual energy consumption per model

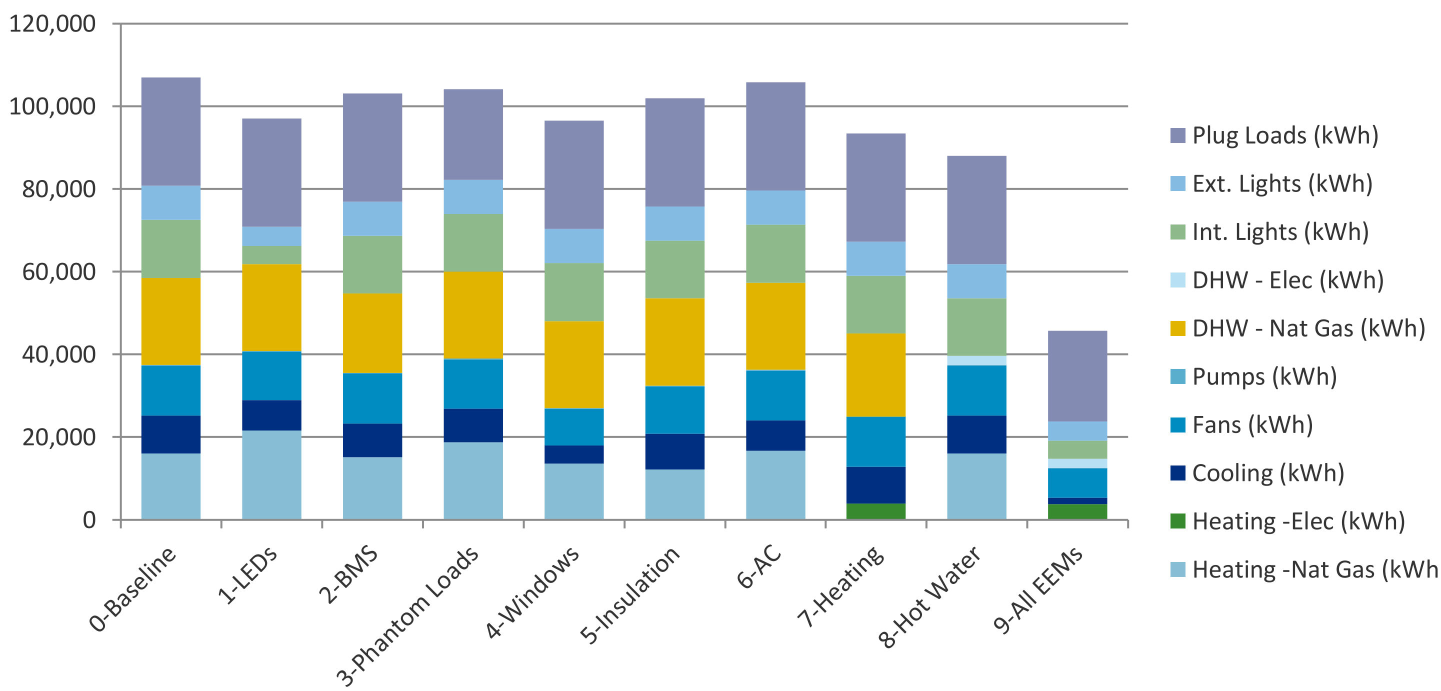


Table 5: Energy consumption by end use

EEM	Heating -Nat Gas (kWh)	Heating -Elec (kWh)	Cooling (kWh)	Fans (kWh)	Pumps (kWh)	Hot Water - Nat Gas (kWh)	Hot Water - Elec (kWh)	Int. Lights (kWh)	Ext. Lights (kWh)	Plug Loads (kWh)	Annual Energy Use (kWh)
0-Baseline	16,099	0	9,095	12,066	166	21,132	0	13,964	8,256	26,183	**106,961**
1-LEDs	21,564	0	7,389	11,719	185	21,007	0	4,364	4,712	26,183	**97,122**
2-BMS	15,151	0	8,131	12,068	168	19,208	0	13,964	8,256	26,183	**103,130**
3-Phantom Loads	18,781	0	8,120	11,898	176	21,078	0	13,964	8,256	21,819	**104,092**
4-Windows	13,632	0	4,328	8,967	157	21,024	0	13,964	8,256	26,183	**96,512**
5-Insulation	12,243	0	8,535	11,561	149	21,067	0	13,964	8,256	26,183	**101,958**
6-AC	16,667	0	7,351	12,068	168	21,129	0	13,964	8,256	26,183	**105,786**
7-Heating	0	3,926	8,945	12,068	61	20,031	0	13,964	8,256	26,183	**93,434**
8-Hot Water	16,099	0	9,095	12,066	166	0	2,198	13,964	8,256	26,183	**88,027**
9-All EEMs	0	3,750	1,657	7,107	61	0	2,198	4,364	4,712	21,819	**45,667**

b. Economic analysis

Table 6 and Table 7 summarize the economic analysis for each measure based on payback, internal rate of return (IRR) for ten years, IRR over the life of the measure, levelized cost of energy (LCOE), and the revenue/savings over the life of the measure. The capital costs, incentives, incremental operations and maintenance costs, and system lifespan values are based on research utilizing RSMeans, quotes from industry professionals, incentive programs, and professional experience.

Table 6: Economic analysis – EEM analysis

Energy Efficiency Measures (EEMs)	EEM Analysis				
	Capital Cost	Incentives Available	Incremental Operations & Maintenance	Annual Energy Cost Savings ($/yr)	System Life (years)
1-LEDs	$6,690	-		$3,383	13
2-BMS	$1,000	-	$0	$337	15
3-Phantom Loads	$900	-	$0	$1,199	15
4-Windows	$49,286	-	$0	$1,960	30
5-Insulation	$4,799	-	$0	$406	30
6-AC	$1,000	-	$0	$390	20
7-Heating	$1,000	-	$0	-$210	20
8-Hot Water	$15,414	$2,885	$100	$290	20
9-All EEMs	$80,090	$15,000*	$100	$7,113	20.4

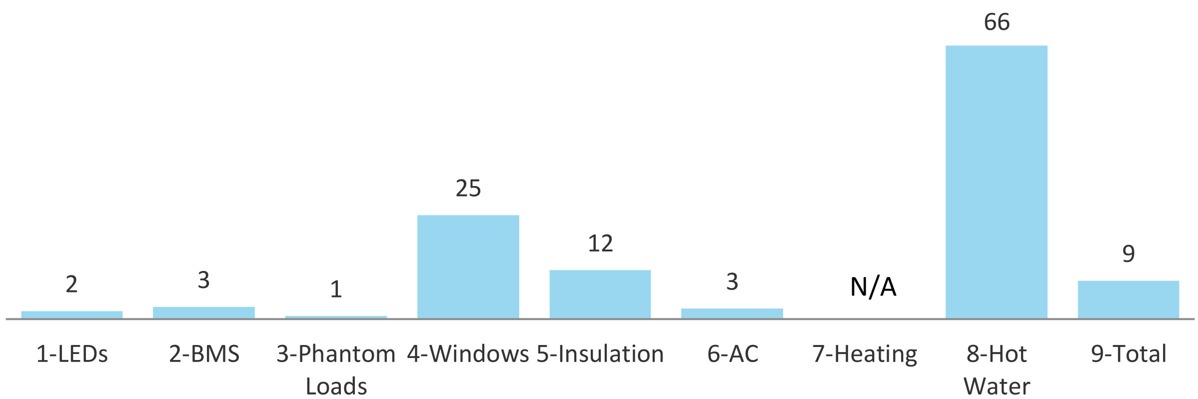
*The incentives available for the All EEMs calculation is based off a whole building reduction in annual energy consumption through PG&E's Multifamily Upgrade program, which offers $3,000/unit ($15,000 for 5 units).

Table 7: Economic analysis – economic metrics

Energy Efficiency Measures (EEMs)	Self-funded Economic Metrics				
	Payback	IRR (10 yrs)	IRR (system life)	LCOE	Revenue/ Savings
1-LEDs	2.0	50%	50%	$0.05	$37,291
2-BMS	3.0	31%	33%	$0.02	$4,050
3-Phantom Loads	0.8	133%	133%	$0.02	$17,082
4-Windows	25.1	-14%	1%	$0.16	$9,508
5-Insulation	11.8	-3%	7%	$0.03	$7,375
6-AC	2.6	37%	39%	$0.04	$6,790
7-Heating	N/A	N/A	N/A	$0.00	-$5,193
8- Hot Water	66.1	-20%	-11%	$0.04	-$8,738
9-All EEMs	9.3	2%	9%	$0.05	$77,797

The payback for each measure considers the incremental capital costs, available incentives, incremental operation and maintenance costs, and annual energy cost savings. This financial metric indicates that the following EEMs have quick paybacks of less than five years: LEDs, BMSs, Phantom Loads, and AC. Insulation and window upgrades have longer paybacks, but they are still within the lifespan of the installed systems. The upgrade to the heating system does not have a payback since the fuel switching results in a negative annual energy cost savings despite the 13% savings in overall energy use. Lastly, the solar hot water heater combined with a heat pump hot water heater has a very long payback of 66 years despite saving the most energy of all the EEMs. This is due to the high upfront costs. Although there are not many multifamily incentives available for the individual measures, the combined measures are eligible for a large performance-based incentive through PG&E's Multifamily Upgrade program, which offers $3,000 per unit (total of $15,000 for a 5-unit building). Therefore, when all the measures are implemented together the total payback with this incentive becomes a reasonable nine years.

Figure 4: Payback analysis (years)



A variety of state and federal financing opportunities are available. Specifically, PG&E provides a 0% interest rate for 5 years on energy efficiency upgrades up to $100,000. Although there are few rebates available for individual measures, there are multiple whole building rebate incentives through programs such as PG&E's Multifamily Upgrade, Energy Upgrade California's Bay Area Multifamily Building Enhancements, and the City of Palo Alto's Multi-Family Plus Program, as well as tax incentives through the Residential Energy Conservation Subsidy Exclusion. A list of details by EEM is provided on the next page.

c. LED lighting retrofit assumptions

i. Energy cost savings

LED lighting reduces lighting energy use, as well as cooling and fan energy by reducing the cooling load on the space. However, buildings will see an increase in heating energy due to the decreased heat output of the lamps.

ii. Capital costs

It is estimated that the LED retrofit would cost $15/tube for material and take two people approximately 30 min per fixture (15 min per tube). According to RS Means, average labor rate for the area is $90 per hour. Therefore, we estimated the cost to be $60 per tube (or $120 per fixture) for the retrofit.

iii. Operations and maintenance costs

LED lights have a typical rated life of 50,000 hours (13 years) versus the typical 20,000 hours for a fluorescent tube lamp. As such, bulb replacements occur half as often as with current T8 fluorescent tube lighting. LED costs have dropped substantially over the past 5 years, however, are still higher than a typical fluorescent tube. We expect these prices to equal out over the coming years, but cannot predict the future. As such, we have held operations and maintenance costs as equal to the baseline for this measure.

iv. State, Federal, and local incentives and rebates

There do not appear to be incentives available for this EEM.

d. BMS system assumptions

i. Energy cost savings

BMS systems help reduce energy costs by ensuring systems are running at peak efficiency or off when they are not in use.

ii. Capital costs

Capital cost of the BMS system (such as a Nest thermostat) for the small multifamily residential prototype has been assumed to be $200 per unit ($1000 for the 5-unit building), but this will vary widely based on the system selected.

iii. Operations and maintenance costs

There are no operations and maintenance costs associated with this measure.

iv. State, federal, and local incentives and rebates

There do not appear to be incentives available for this EEM.

v. Reduction in phantom loads assumptions

Energy Cost Savings

Phantom loads result in energy usage while an item is off. The energy required for a television to consistently be searching for a remote signal is a common example. Stereo equipment, computers on sleep mode, phone systems, coffee machines, and other miscellaneous residential equipment tends to draw energy when the occupants are not there. Occupant behavior is the simplest and most cost effective way to reduce vampire loads, especially paired with the use of smart strips. Smart strips are advanced power strips that allow you to plug an appliance into a master outlet, which controls the other outlets. For example, you can plug your computer into the master outlet, and plug speakers, printers and monitors into "automatic" outlets on the strip. When you turn off your computer, all the appliances plugged into the "automatic" outlets will turn off as well. Smart strips usually also have one or two "constant" outlets, which allow for appliances plugged into those to always stay on unless manually turned off. It is assumed that smart strips and occupant behavior training will reduce annual plug load usage by 16%.

vi. Capital costs

Capital costs of $900 for this measure include one training from an energy efficiency consultant with an approximate cost of $500 and $400 for smart strips (assumed 4 strips per household in a 5-unit building at $20 per strip).

vii. Operations and maintenance costs

There are no operations and maintenance costs associated with this measure.

viii. State, federal, and local incentives and rebates

There do not appear to be incentives available for this EEM.

e. Higher-efficiency windows assumptions

i. Energy cost savings

High efficiency windows reduce energy usage for heating, cooling, and fan systems by reducing conduction heat loss to the outdoors and solar heat gain from the outdoors. The prototype building has single pane windows, which would be replaced with dual pane, low-e, high performance glass units. These have the added benefit of reducing noise, increasing comfort, and reducing draft.

ii. Capital costs

Capital costs held for this measure were estimated to be $58.66 per square foot of glazing based on RS Means.

iii. Operations and maintenance costs

The operations and maintenance costs may decrease with the installation of new windows; however, the savings has not been included in our economic analysis.

iv. State, federal, and local incentives and rebates

There do not appear to be incentives available for this EEM.

f. Improved insulation quality assumptions

i. Energy cost savings

Insulation requirements for roofs have not grown substantially over the past two decades. Since our assumed baseline roof has R30 insulation (per Title 24 1995), we do not have any additional recommendations for adding roof insulation. However, we are recommending adding a minimum of 2" rigid insulation on the exterior walls. This will reduce HVAC loads and increase comfort in the building.

ii. Capital costs

Capital costs held for this measure were estimated to be $1.04 per square foot of exterior walls based on RS Means.

iii. Operations and maintenance costs

The operations and maintenance will not be affected by this measure.

iv. State, federal, and local incentives and rebates

There do not appear to be incentives available for this EEM.

g. Replacement of obsolete AC systems with higher efficiency assumptions

i. Energy cost savings

HVAC systems are typically replaced every 15-20 years due to component failure, rust, and other issues. When replacing an HVAC system, it pays back to use high efficiency models. Air conditioning equipment has vastly improved since the turn of the century, and is capable of higher efficiency than before. For our analysis, we have assumed the prototypical building utilizes gas-fired, packaged, rooftop systems. We have assumed these will be replaced with high efficiency heat pump systems (see heat pump space heating,) but that ductwork and layout will remain unchanged.

ii. Capital costs

Capital costs held for this measure are based on the assumption that the equipment has reached the end of its useful life and will need to be replaced. The incremental cost difference of $200 per unit at the 1-3 ton size has been held to account for the higher efficiency selection ($1000 for the 5-unit building).

iii. Operations and maintenance costs

The operations and maintenance will not be affected by this measure.

iv. State, federal, and local incentives and rebates

There do not appear to be incentives available for this EEM.

h. Heat pump space-heating assumptions

i. Energy cost savings

HVAC systems are typically replaced every 15-20 years due to component failure, rust, and other issues. When replacing an HVAC system, it pays back to use high efficiency models. Heating equipment has vastly improved since the turn of the century, and is capable of higher efficiency than before. For our analysis, we have assumed the prototypical building utilizes gas-fired, packaged, rooftop systems. We have assumed these will be replaced with high efficiency heat pump systems, but that ductwork and layout will remain unchanged.

ii. Capital costs

Capital costs held for this measure are based on the assumption that the equipment has reached the end of its useful life and will need to be replaced. The incremental cost difference of $200 per unit at the 1-3 ton size has been held to account for the higher efficiency selection ($1000 for the 5-unit building).

iii. Operations and maintenance costs

The operations and maintenance will not be affected by this measure.

iv. State, federal, and local incentives and rebates

There do not appear to be incentives available for this EEM.

i. Solar hot-water heater and heat pump hot-water assumptions

i. Energy cost savings

Hot water heaters are replaced every 10-20 years on average. This measure switches out the aged, existing natural gas hot water heating system with a solar hot water heater combined with an electric heat pump hot water heater. This fuel switching measure results in approximately 90% energy savings of the hot water load, but does not result in an economical payback due to the high upfront costs and artificially low price of fracked and subsidized natural gas. However, the annual cost of running a hot water heater is relatively low, and switching to an electrically-powered unit with solar hot water offsets will decrease cost of photovoltaics to go Zero Net Energy.

ii. Capital costs

The incremental cost difference for solar hot water heater system with an electric heat pump hot water heater is $15,414 installed for the whole building (per the City of Palo Alto Residential Electrification Analysis).

iii. Operations and maintenance costs

The operations and maintenance costs will be a total of $100 per year (per the City of Palo Alto Residential Electrification Analysis).

iv. State, federal, and local incentives and rebates

Heat pump hot water systems are eligible for a $300 rebate per unit from PG&E. The solar hot water heaters are eligible for $0.42/kWh saved from PG&E.

V. Conclusion

In this report, DNV GL has conducted an economic analysis of specific individual energy efficiency and fuel-switching measures for a prototypical multifamily building reflecting the average size, orientation, vintage, construction type, and occupancy profile as it relates to the southern portion of San Mateo County. DNV GL used demographic data, Global Information System (GIS) data, and planning data to ascertain the characteristics of the typical office, municipal, school, multifamily residential, and retail buildings in the area. California's Commercial End Use Survey (CEUS) and Residential Appliance Saturation Survey (RASS) data has been used along with DNV GL's previously collected data and building project experience to determine typical energy use and calibrate the energy model. Our team utilized IES Virtual Environment software to create a baseline energy model and the following eight (8) energy efficiency and fuel switching measures:

1. LED lighting conversion
2. Building Management System (BMS)/advanced controls
3. Reduction in phantom loads
4. Higher efficiency windows
5. Improved insulation quality
6. Replacement of obsolete AC systems with higher efficiency
7. Convert to heat pump from natural gas space heating
8. Alternative water heating systems

The baseline multifamily residential model begins with an energy use intensity (EUI) of 64 kBtu/sf/yr and decreases down to 27 kBtu/sf/yr if all EEMs are implemented. An upgrade to the hot water heating system has the largest individual impact on the energy use (18% reduction). Three other measures that have large impacts are upgrading heating systems (13% reduction), upgrading the existing windows (10% reduction), and upgrading to LEDs (9% reduction). If all measures are implemented, DNV GL estimates a 57% reduction in energy consumption on an annual basis for the prototypical multifamily building. The energy efficiency measures with less than 5 year paybacks are LED upgrades, BMS, phantom load reduction, and AC upgrades. Insulation and window upgrades have longer paybacks, but they are still within the lifespan of the installed systems. The upgrade to the heating system does not have a payback since the fuel switching results in a negative annual energy cost savings despite the 13% savings in overall energy use. Lastly, the solar hot water heater combined with a heat pump hot water heater has a very long payback of 66 years despite saving the most energy of all the EEMs. This is due to the high upfront costs. Although there are not many multifamily incentives available for the individual measures, the combined measures are eligible for a large performance-based incentive through PG&E's Multifamily Upgrade program, which offers $3,000 per unit (total of $15,000 for a 5-unit building). Therefore, when all the measures are implemented together the total payback with this incentive becomes a reasonable nine years.

VI. References

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