Economics of Energy Efficiency and Fuel Switching for Commercial-Scale Buildings

Wednesday, January 31, 2018

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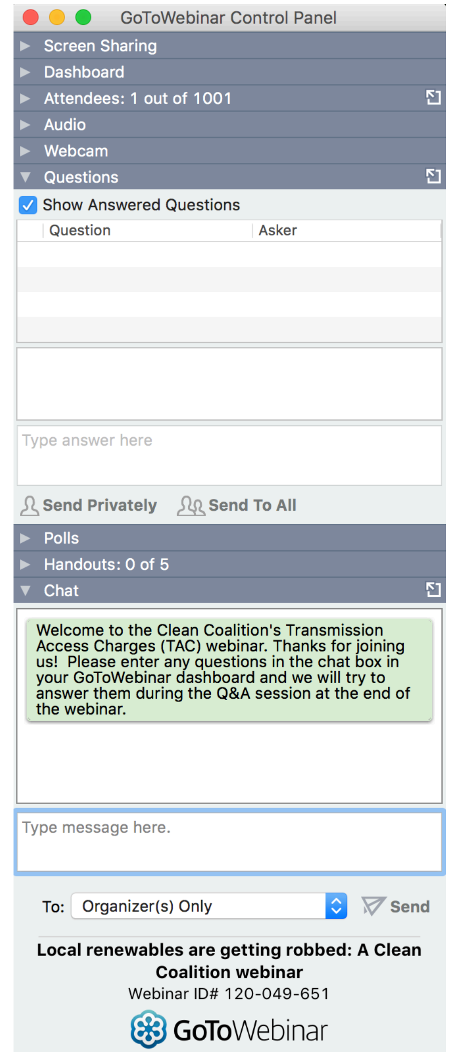

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Presenters

- **Betty Seto, Head of Department, Sustainable Buildings & Communities, DNV GL** leads a team of sustainability consultants with a passion for clean energy and demand-side solutions at the building, district, and citywide scales with technical competencies across energy modeling, passive strategies, natural ventilation, daylighting analysis, solar, storage, and microgrid feasibility analysis.

- **Blake Herrschaft, Senior Engineer, Sustainable Buildings & Communities, DNV GL** is a professional engineer (PE) who provides passive and innovative design assistance for net zero and net zero capable buildings, portfolios, and communities.

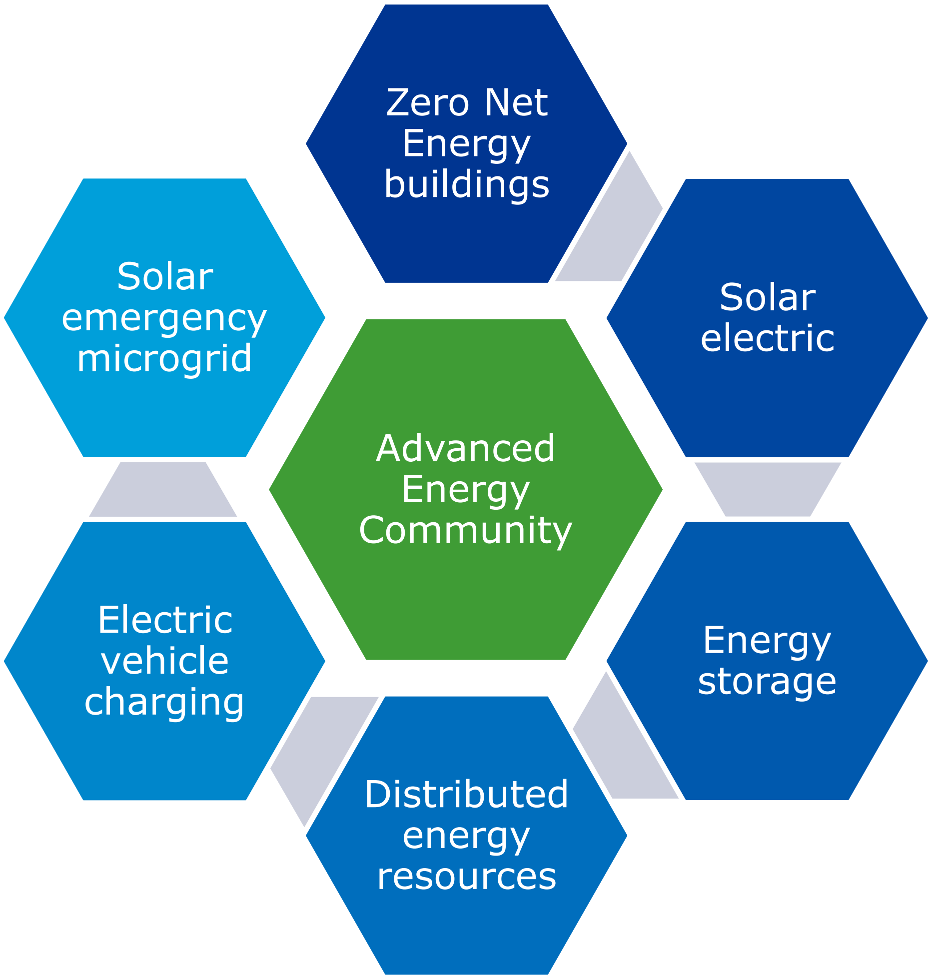
The **Clean Coalition's Peninsula Advanced Energy Community (PAEC),** supported by Pacific Gas & Electric and numerous local governments, will accelerate the planning, approval, and deployment of an Advanced Energy Community (AEC).

Project Funding

PAEC is made possible from a grant through the **CEC's Electric Program Investment Charge (EPIC) program**, which offered "The EPIC Challenge: Accelerating the Deployment of Advanced Energy Communities."

PAEC region: southern San Mateo County (highlighted)

Key Components of an Advanced Energy Community



PAEC Project Goals

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- Accelerate deployment of AECs
- Reduce cost and uncertainty in permitting and interconnection
- Reduce 25 MW of peak energy across southern San Mateo County
- Reduce natural gas and minimize need for expensive utility upgrades
- Create model project with scalable project elements

Why reduce use of natural gas?

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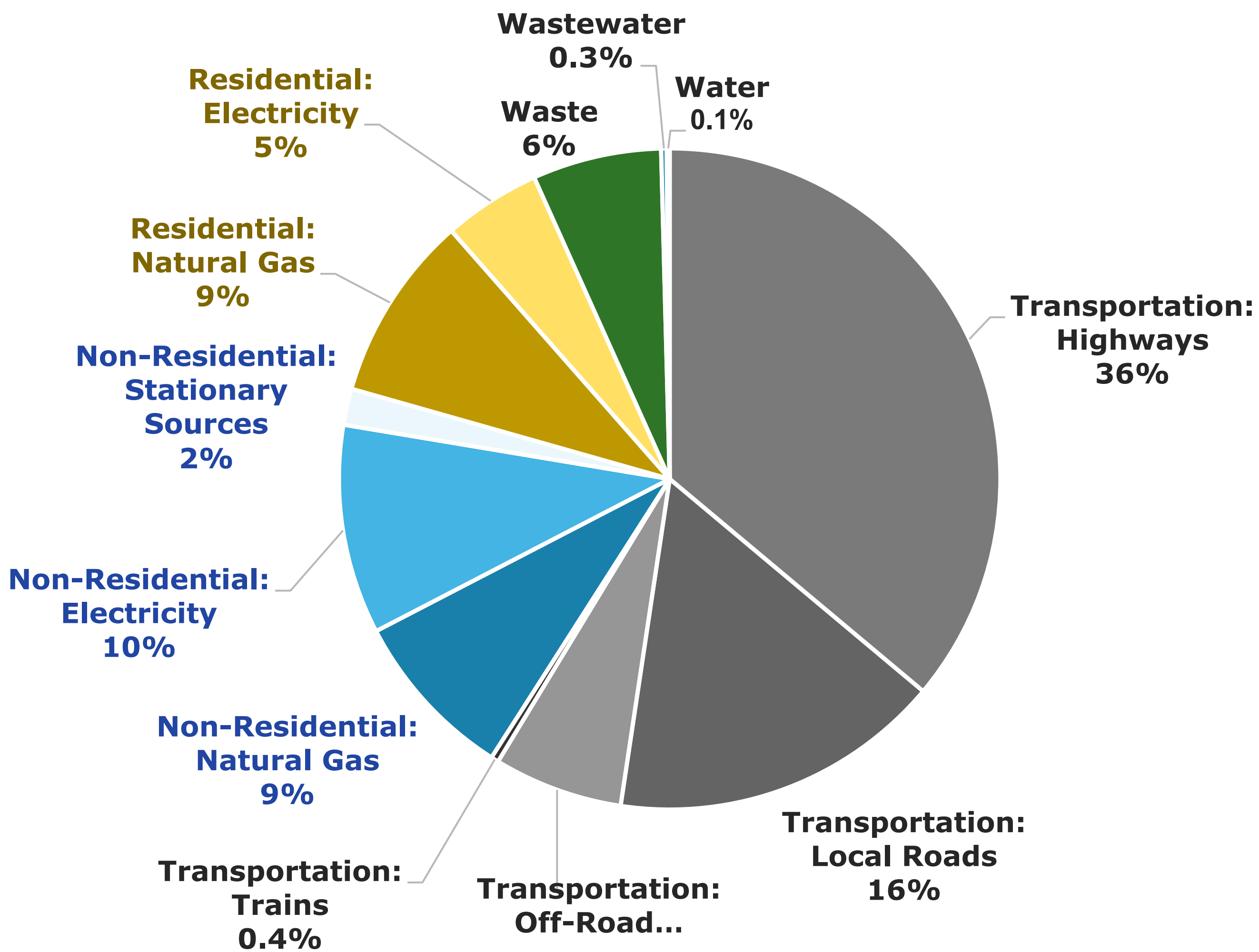
San Mateo County: 2014 Greenhouse Gas Emissions (MT CO2e)



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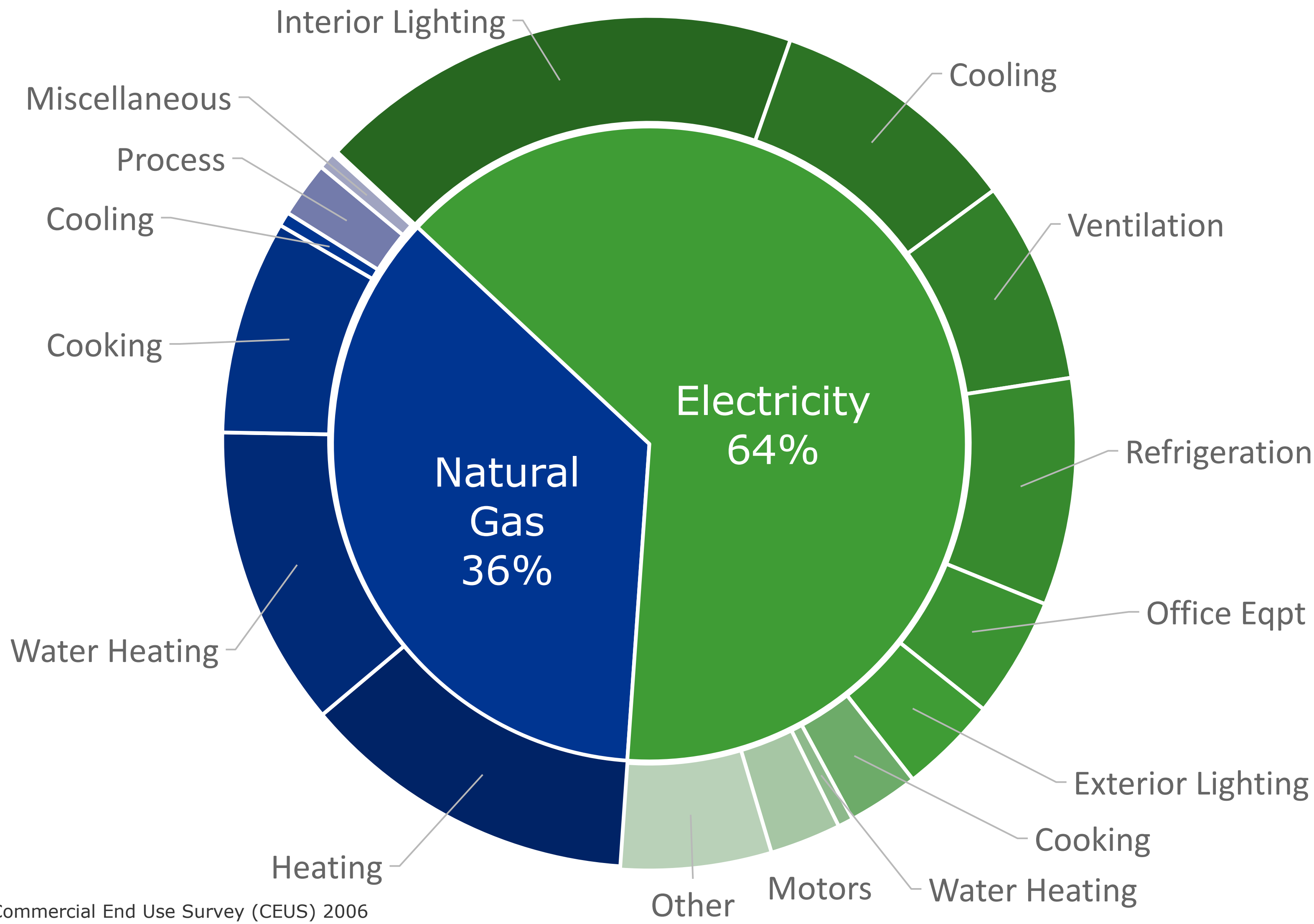
Role of Buildings in Achieving the Advanced Energy Community Vision

Economic Benefit-Cost Analysis of Energy Efficiency and Fuel Switching Measures for Commercial Buildings

Energy Use Breakdown – San Mateo County (CEC Climate Zone 3)



Source: Commercial End Use Survey (CEUS) 2006

Electrification & Zero Carbon Heating Concepts

Some considerations:

In high renewable penetration, natural gas is biggest building-related emitter

25% of US homes are all-electric

Norway has been all-electric, all-renewable for years

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Electrification – The Hazards of Natural Gas

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What about renewable natural gas/biogas?

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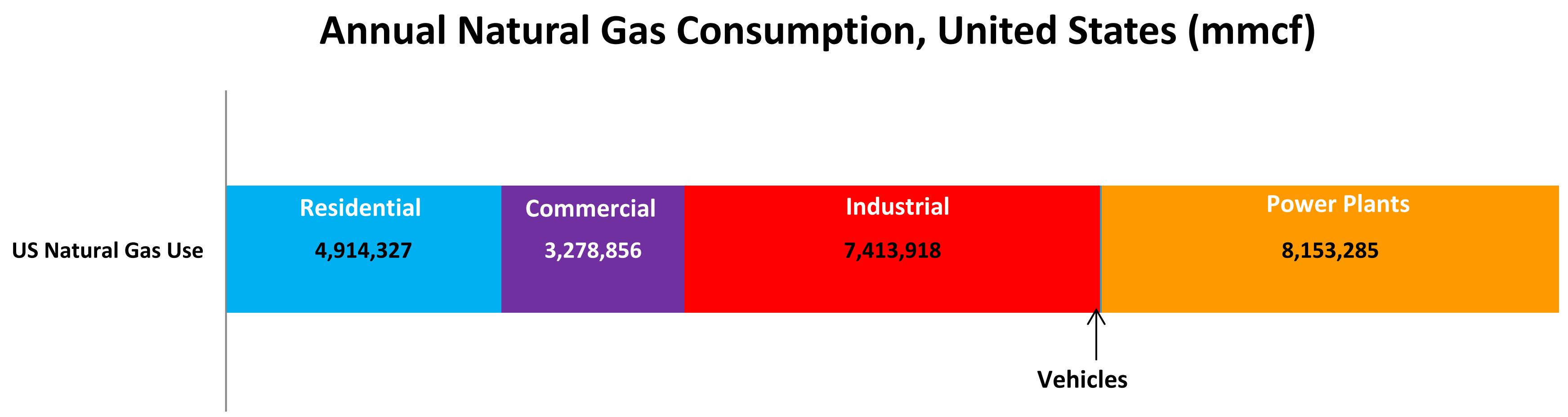

Sources
NREL, Biogas Potential in the United States
EIA Natural Gas Use, 2013

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What about renewable natural gas/biogas?

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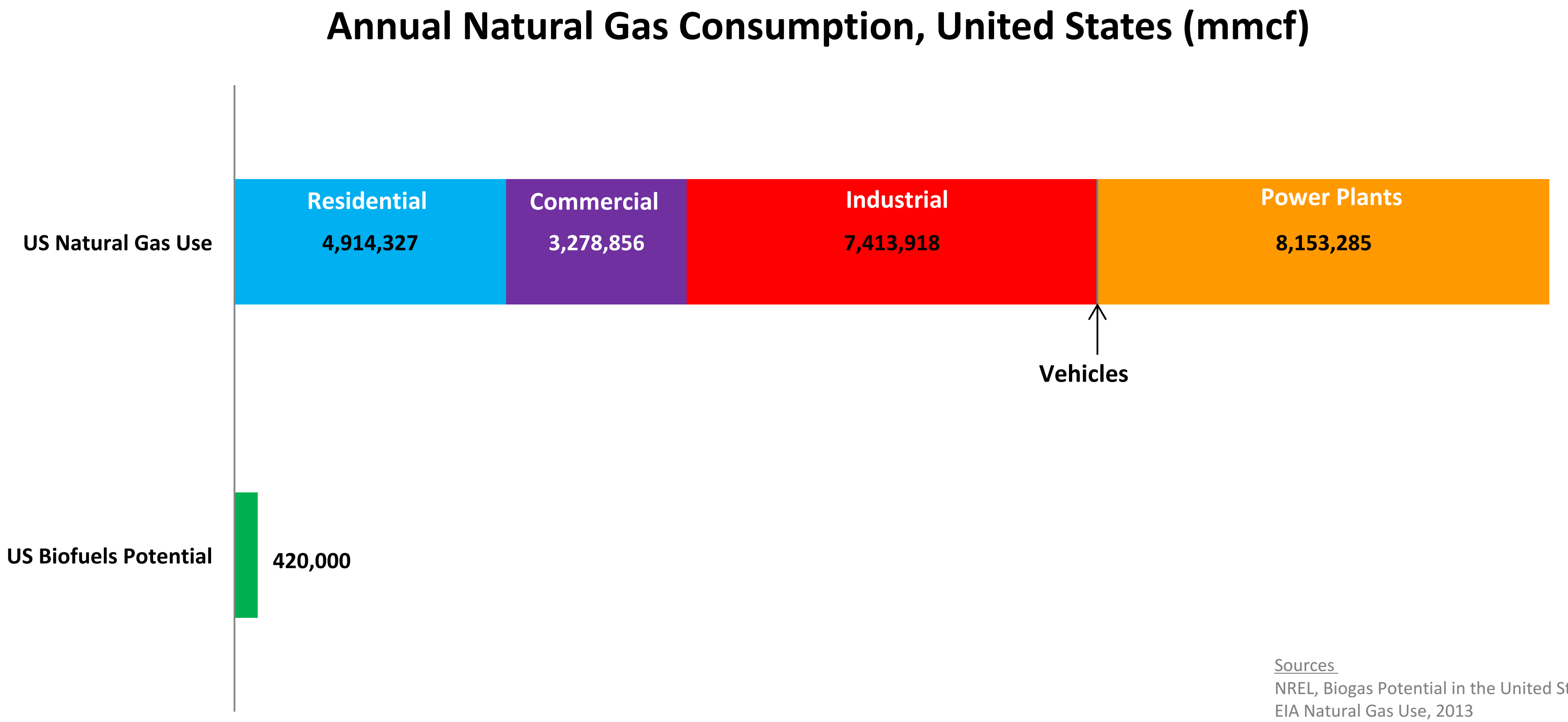

Sources
NREL, Biogas Potential in the United States
EIA Natural Gas Use, 2013

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Utilities Start to Recommend Electrification

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SOUTHERN CALIFORNIA EDISON
Energy for What's Ahead℠

THE CLEAN POWER AND ELECTRIFICATION PATHWAY

Realizing California's Environmental Goals

November 2017

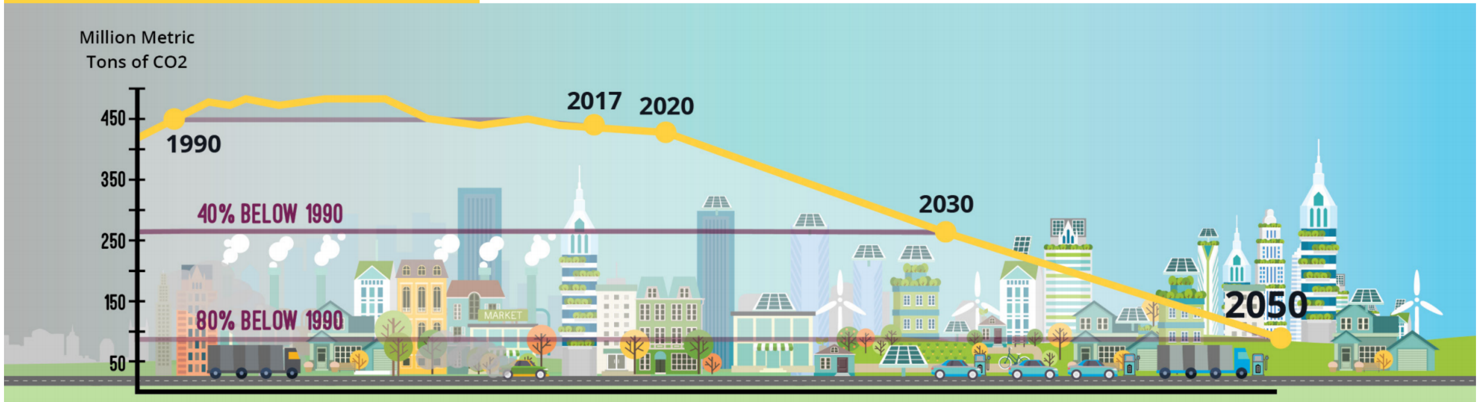
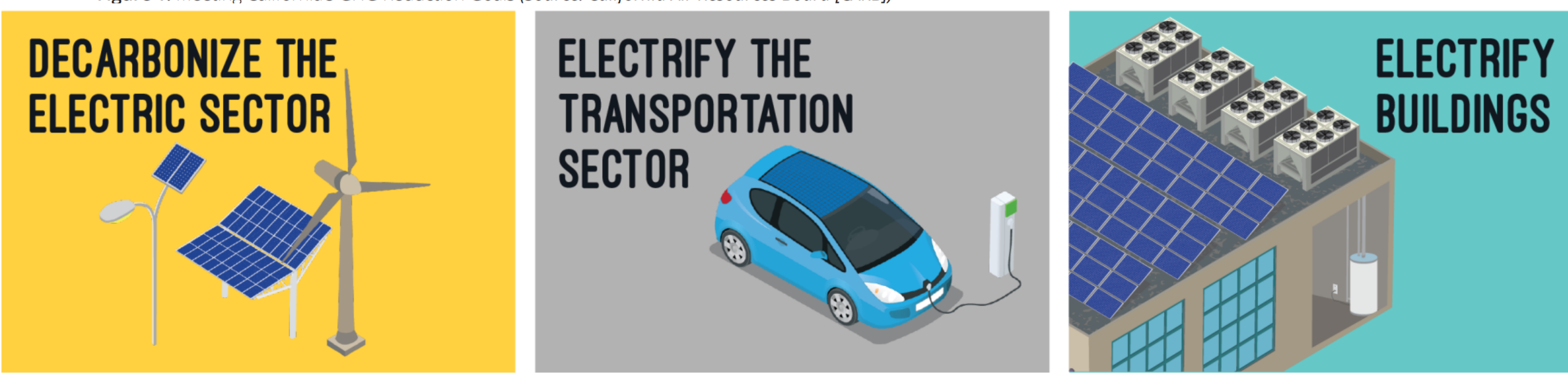


Figure 1: Meeting California's GHG Reduction Goals *(Source: California Air Resources Board [CARB])*



Zero Carbon Heating Concepts, Technologies, and Benefits

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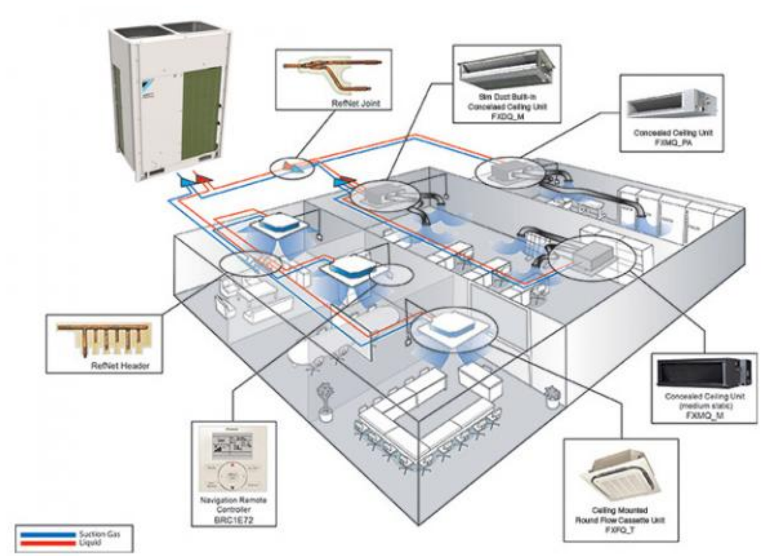
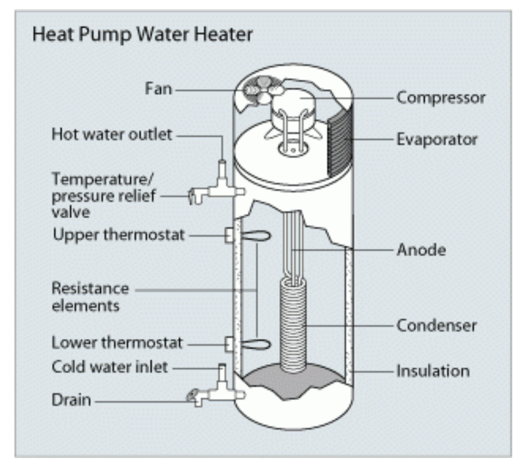
Heating, Ventilation, and Air Conditioning (HVAC) system is one of the major end use consumptions. A variable refrigerant flow (VRF) system with heat recovery is typically a three pipe system that have the ability to simultaneously heating certain zones and while cooling others, yielding the efficiency up to 14 EER.

Typical **domestic hot water systems** include electric water heater or natural gas water heater, including an expansion tank, which incur standby loss. Heat Pump Water Heater (HPWH) is an emerging technology that extracts heat from air to heat the water. Due to its high efficiency, it is recommended instead of electric tank-less water heater. Even federal regulation requires heat pump water heater where electric heaters are to be installed in commercial facilities where the rated storage volume are above 55 gallons.



Variable Refrigerant Flow System Diagram



Heat Pump Hot Water Heater

Energy Efficiency and Electrification Analysis

Archetype Methodology for the Core PAEC Region

- **Building type selections**
  - Identifying appropriate financial and business models for building owners requires consideration of ***building types that should be targeted for zero net energy and deep energy efficiency retrofits***.
- **Baseline building vintage**
  - Based on discussions with Clean Coalition, the analysis focused on prototypical buildings constructed around ***1995***, as the ideal candidates for retrofits. Based on professional experience, older vintage buildings are likely to be torn-down and rebuilt, rather than new investments in energy efficiency.
- **Baseline and proposed efficiencies**
  - The model assumption deliverables provides a professional assessment of likely ***baseline equipment efficiencies*** and appropriate ***higher efficiency upgrades*** for achieving AECs.

The 5 Prototypical Buildings

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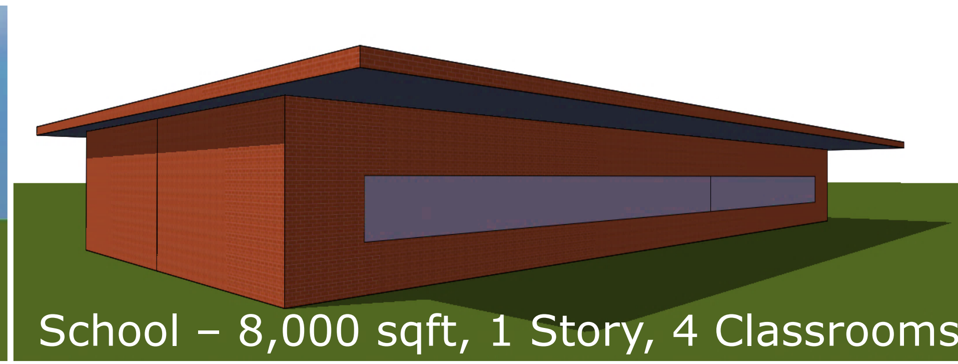
Office – 10,000 sqft, 2 Stories

Multi-Family – 5,000 sqft, 2 Stories, 5 Units

Retail – 5,000 sqft, 1 Story



School – 8,000 sqft, 1 Story, 4 Classrooms

Municipal – 7,000 Fire Station

Based on: LoopNet, CBECS, RECS, Menlo Park and Redwood City Fire Departments, and Department of Education/School District websites.

Introduction to Economic Analysis – Why is this useful?

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- **The economic analysis examines the following parameters for each EEMs:**
  - Incremental **capital costs** (RS Means & manufacturer data)
  - **Incentives** available
  - Incremental **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
  - Annual **energy cost savings** (energy model results)

The Energy Efficiency Measures (EEMs)

EEM	Description of Measure	Capital Cost Range**
Baseline	Based on a 1995 vintage office building (22 years old)	-
LEDs	LED Lighting and Occupancy Controls	$7k - $27k
BMS	Building Management System (BMS)/advanced HVAC controls	$1k - $4k
Phantom Loads	Reduction in phantom loads with smart strips training	$1k - $2k
Windows	Improved window thermal properties	$23k - $70k
Insulation	Improved wall and roof thermal properties	$5k - $8k
AC	Replacement of obsolete Air Conditioning systems with higher efficiency	$1k - $2k
7-Heating	Convert to heat pump from natural gas space heating	$1k - $2k
8-Hot Water*	Upgrade to a solar hot water heater and/or an electric heat pump hot water heater	$4k - $15k

** The retail and school prototypical buildings do not have hot water heating in their buildings. The multi-family building is the only one to include solar hot water heaters.*

*** Capital cost range is dependant upon prototypical building size and type, as well as system selection.*

Assumptions

EEM	Building Component	Age of Existing Component	Existing Conditions (Title 24 1995)	Proposed Measures
1-LED	Interior Lights	22 years	1.5 W/ft^2 Fluorescent Lights	0.4 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 = 1.23 (single pane windows)	U-Factor = 0.32 (dual pane, energy efficient)
5-Insulation	Insulation - Exterior Walls	22 years	U-Factor = 0.43 (mass walls)	U-Factor = 0.10 (add 2” rigid insulation)
	Insulation - Roof	22 years	U-Factor = 0.05 (R19)	U-Factor = 0.036 (add 2” rigid insulation)
6-AC	AC Systems	22 years	8.9 EER 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	80% efficiency Natural Gas Boiler	3 EF Electric Heat Pump

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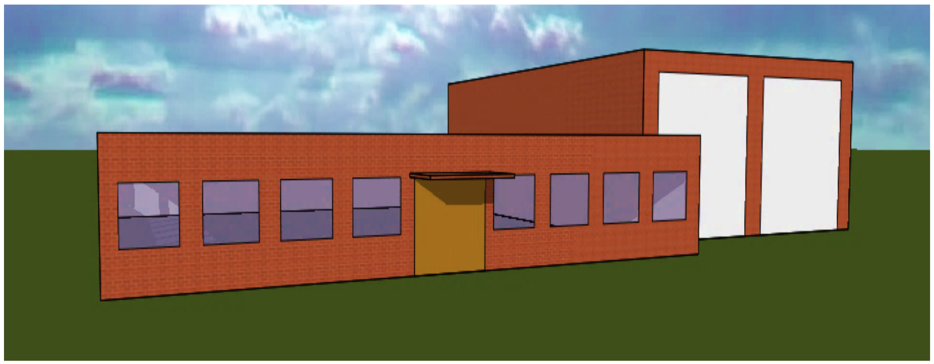
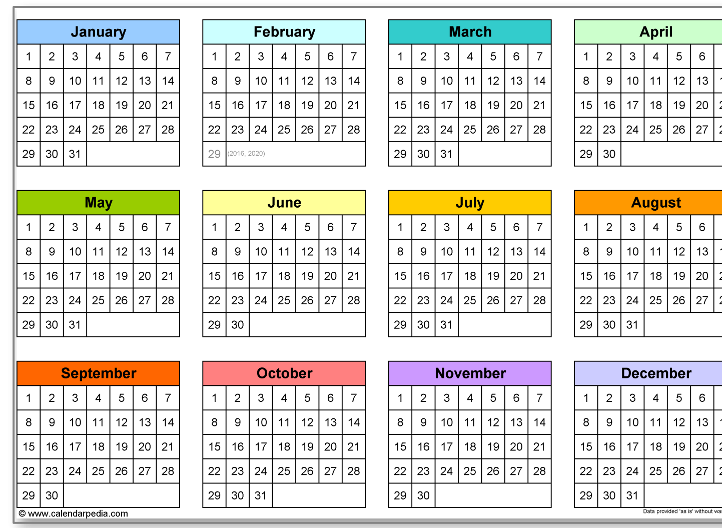
The Right Tool for Each Job



Energy Simulation – IES Virtual Environment

- Insulation
- Windows
- Air Conditioning
- Heating
- Building Management System



8,760 “Hand” Calculation

- Interior Lighting
- Exterior Lighting
- Hot Water

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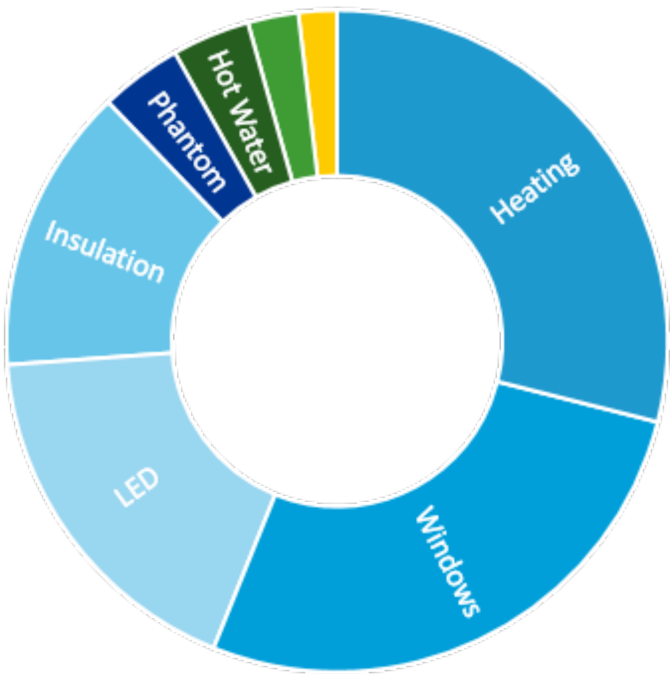
Office Results

Baseline Use 59 kBtu/sf/yr → **Proposed Use** 22 kBtu/sf/yr

63% energy reduction & 5 year payback

Top Energy Savings by EEM



< 5 year payback
- **LEDs**
- Phantom Loads
- **Insulation**
- AC
- **Heating**

Longer payback
- BMS
- **Windows**

No payback (fuel switching)
- Hot water heater

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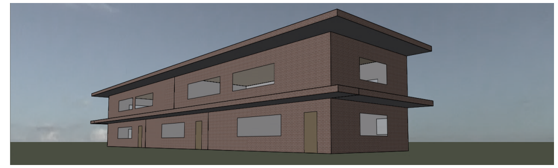
Multi-Family Results



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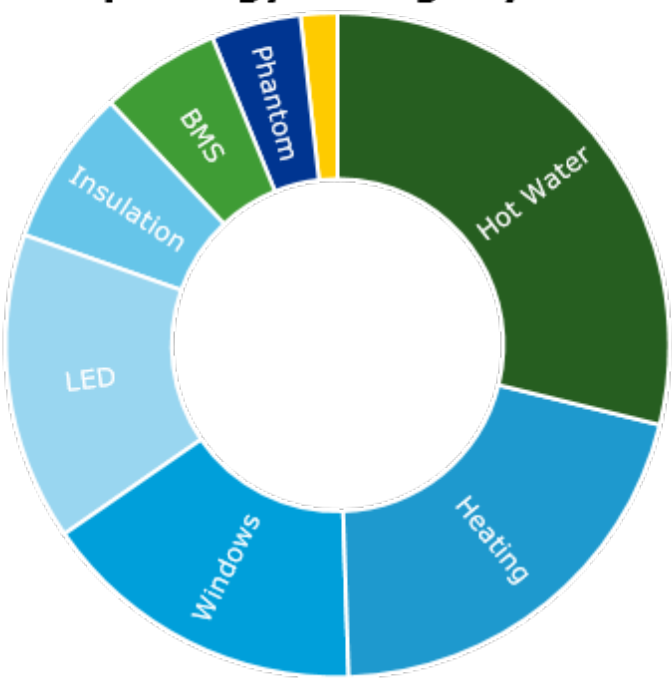
Baseline Use → **Proposed Use**

64 kBtu/sf/yr → 27 kBtu/sf/yr

57% energy reduction & 9 year payback

Top Energy Savings by EEM



< 5 year payback
- **LEDs**
- BMS
- Phantom Loads
- AC

Longer payback
- Insulation
- **Windows**
- **Hot water heater**

No payback (fuel switching)
- **Heating**

Not economical due to high upfront costs of solar hot water heaters (66-year payback) but saves the most energy of all EEMs

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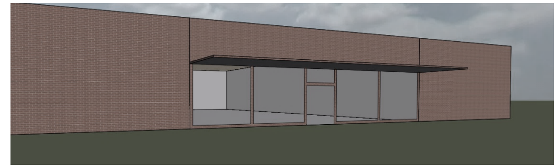

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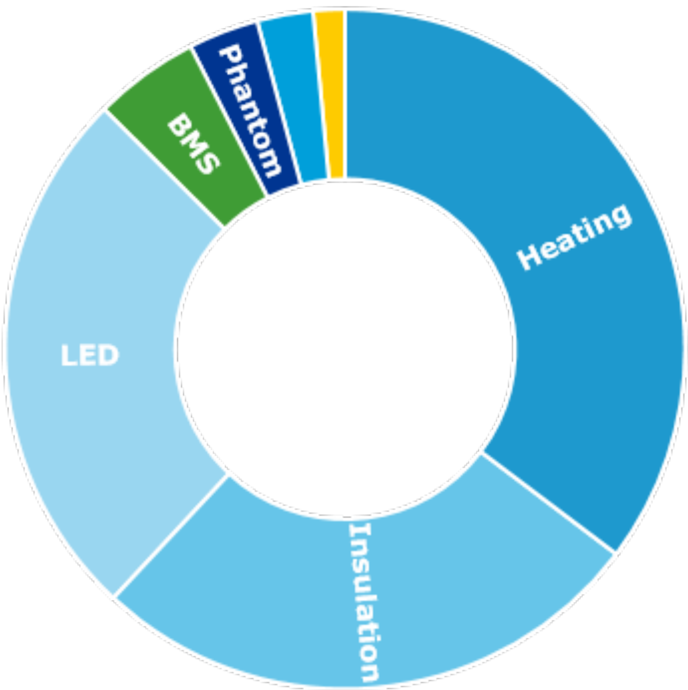
Retail Results

Baseline Use
64 kBtu/sf/yr

Proposed Use
21 kBtu/sf/yr

66% energy reduction & 7 year payback

Top Energy Savings by EEM



< 5 year payback
- **LEDs**
- Phantom Loads
- AC

Longer payback
- **Insulation**
- BMS – Not economical (56-year payback)

No payback (fuel switching)
- **Heating**
- Windows – No payback due to high upfront costs

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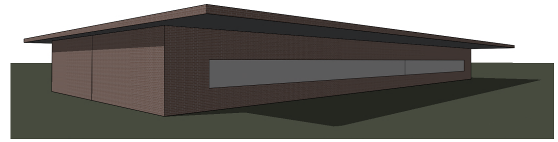

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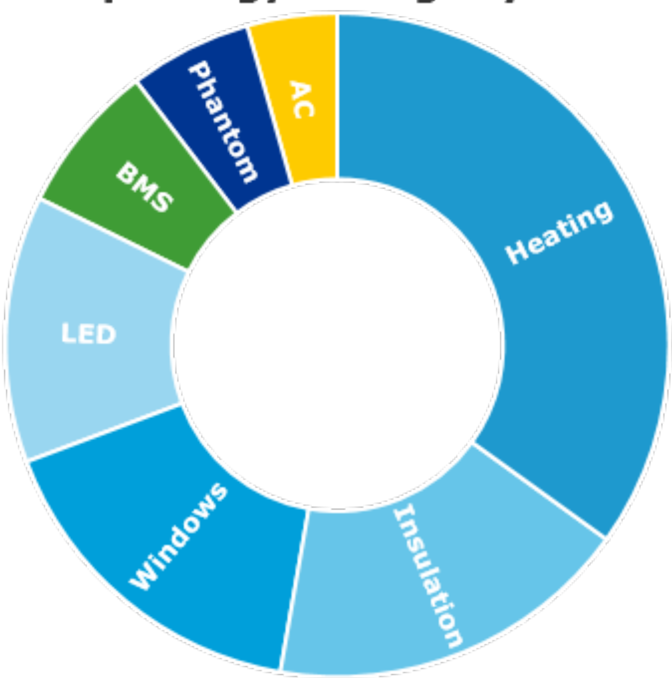
School Results

Baseline Use 60 kBtu/sf/yr → **Proposed Use** 26 kBtu/sf/yr

57% energy reduction & 11 year payback

Top Energy Savings by EEM



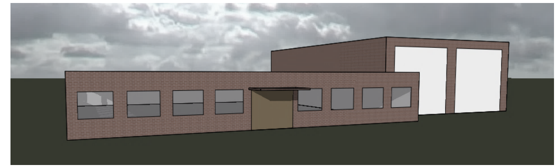
< 5 year payback
- **LEDs**
- Phantom Loads
- AC

Longer payback
- BMS
- **Insulation**
- **Windows**

Not economical but saves a lot of energy (43 yrs)

No payback (fuel switching)
- **Heating**

Municipal Results



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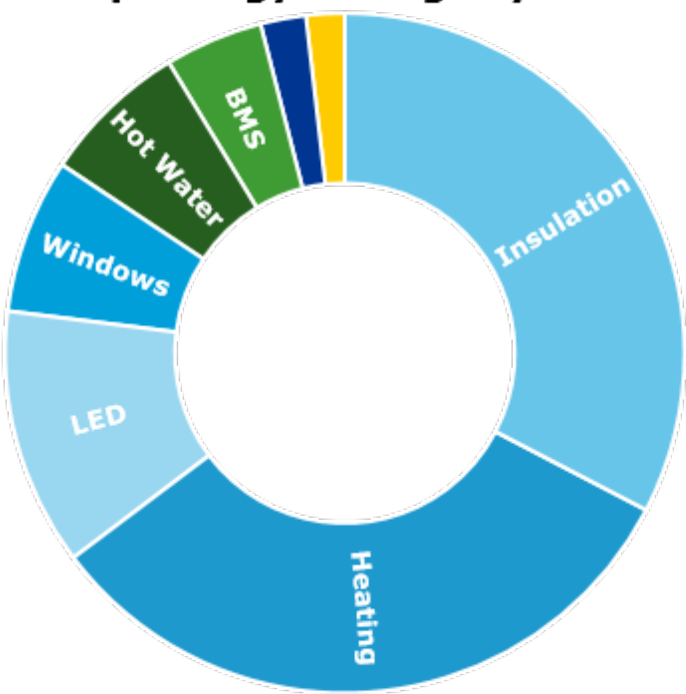
Baseline Use
84 kBtu/sf/yr

Proposed Use
39 kBtu/sf/yr

54% energy reduction & 5 year payback

Top Energy Savings by EEM



< 5 year payback
- **LEDs**
- Phantom Loads
- AC

Longer payback
- BMS
- **Insulation**
- Windows

No payback (fuel switching)
- **Heating**
- Hot water heater

Savings Comparison by Building Type

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Building	EUI before Upgrades (kBTU/sf-yr)	EUI after upgrades (kBTU/sf-yr)	Average payback (years)
Office	59	22	5.4
Municipal (fire station)	84	39	4.6
Retail	64	21	9.3
Multifamily	64	27	6.9
School	60	26	10.7

Energy efficiency before and after: Five modeled types of buildings
Source: PAEC report, Final Economic Benefit-Cost Analysis of Energy Efficiency and Fuel Switching Measures

Economic Deep Dive (Bundling)

Top Half

100 Avos

2 Hours

$100/hr

Bottom Half

100 Avos

1 Hour

$200/hr

Whole Tree

200 Avos

3 Hours

$133/hr

Economic Deep Dive (Bundling)

Top Half

Fuel Switching

BMS

Windows

Whole Tree

Whole Building Energy Efficiency

Bottom Half

Lights

Pumps/Motors

Phantom Loads

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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	2.5	38%	40%	$0.06	$96,332
2-BMS	9.2	2%	7%	$0.12	-$176
3-Phantom Loads	0.8	131%	131%	$0.02	$28,048
4-Windows	11.8	-3%	7%	$0.06	$108,385
5-Insulation	3.8	23%	26%	$0.02	$69,577
6-AC	2.9	33%	34%	$0.03	$11,877
7-Heating	0.4	271%	271%	$0.00	$106,324
8- Hot Water	NA	NA	NA	$0.03	NA
9-All EEMs	5.4	13%	18%	$0.05	$320,640

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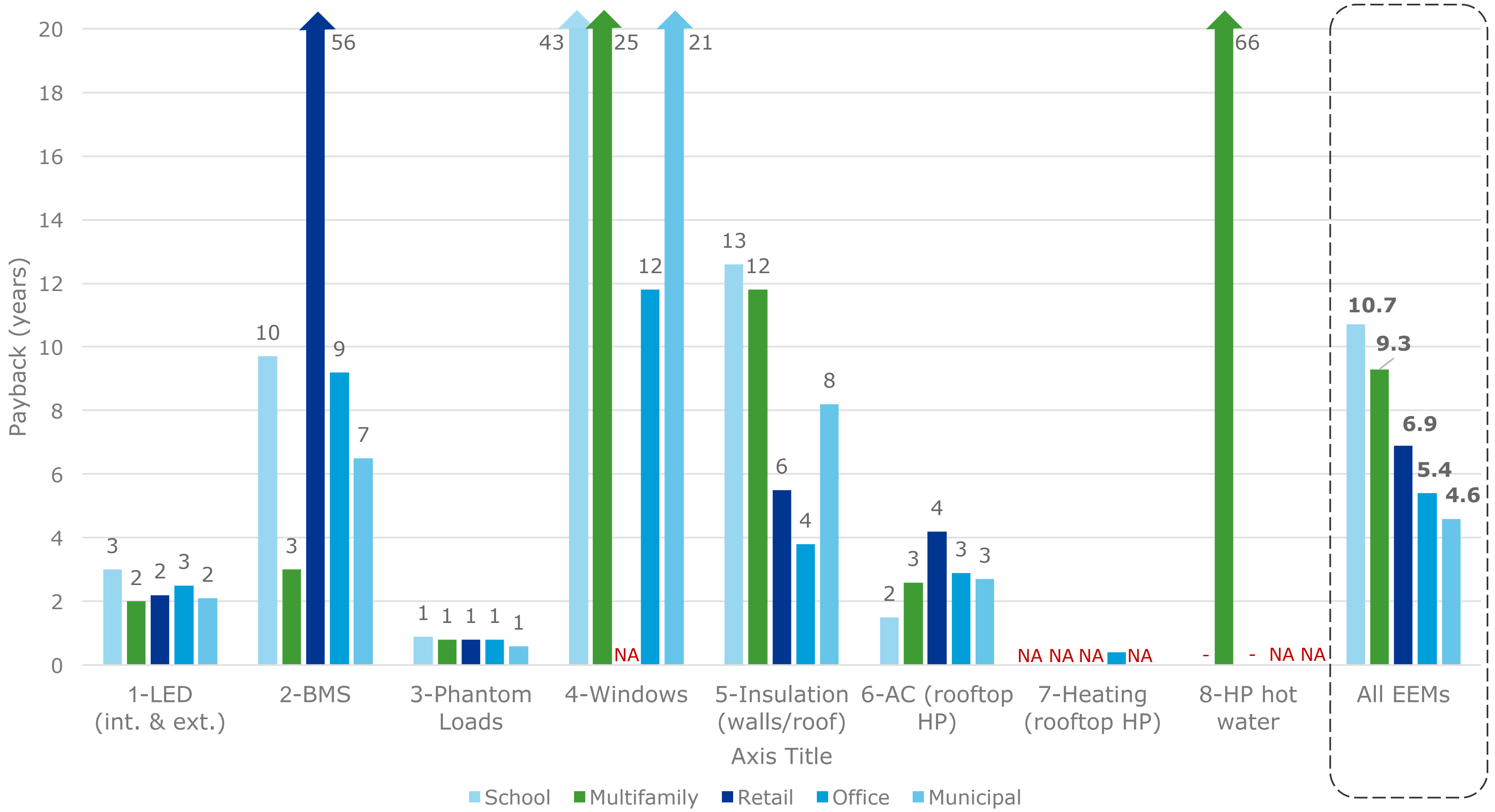
Table 6: Economic analysis – EEM analysis

Energy Efficiency Measures (EEMs)	EEM Analysis				
	Capital Cost	Incentives Available	Incremental Operations & Maintenance	Annual Energy Cost Savings ($/yr)	System Life (years)
1-LEDs	$26,760	$3,853	$0	$9,172	13
2-BMS	$4,000		$180	$435	15
3-Phantom Loads	$1,500		$0	$1,970	15
4-Windows	$70,392		$0	$5,959	30
5-Insulation	$10,213		$0	$2,660	30
6-AC	$2,000		$0	$694	20
7-Heating	$2,000		$0	$5,416	20
8-Hot Water	$4,000	$300	$0	-$187	20
9-All EEMs	$120,865	$4,153	$180	$21,645	20.4

Summary of Findings – Payback



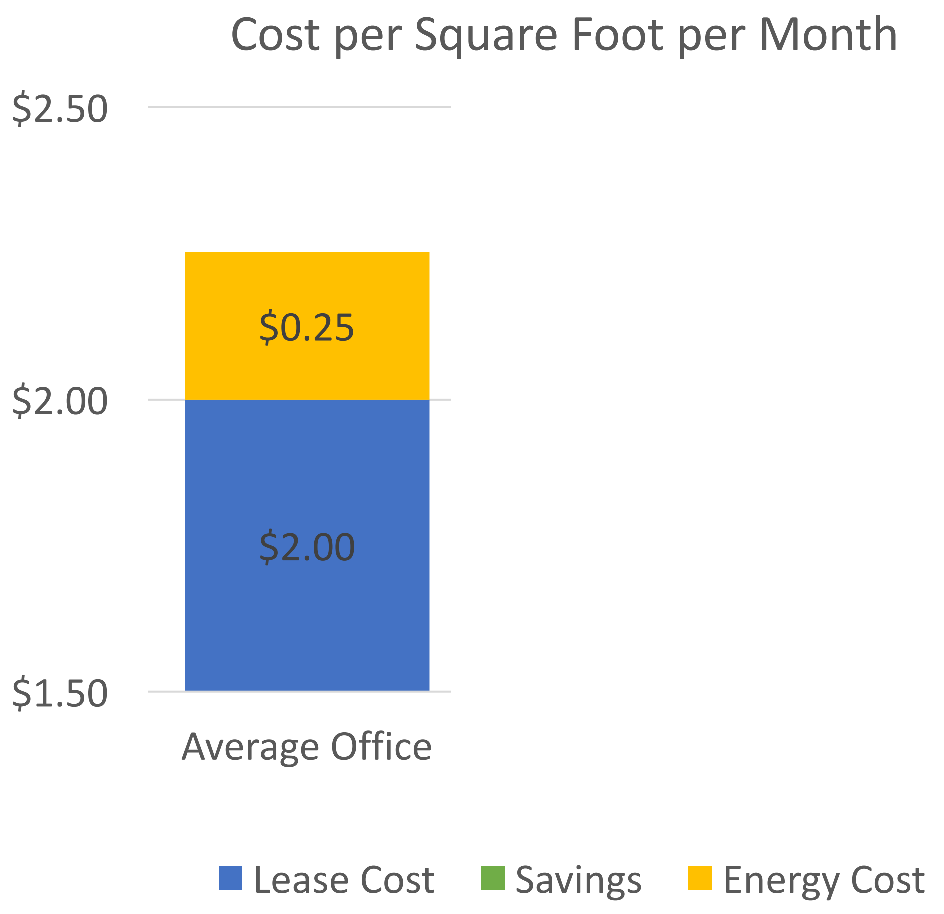
\- *The retail and school prototypical buildings do not have hot water heating in their buildings.*

NA *These measures have no payback, typically due to fuel switching.*

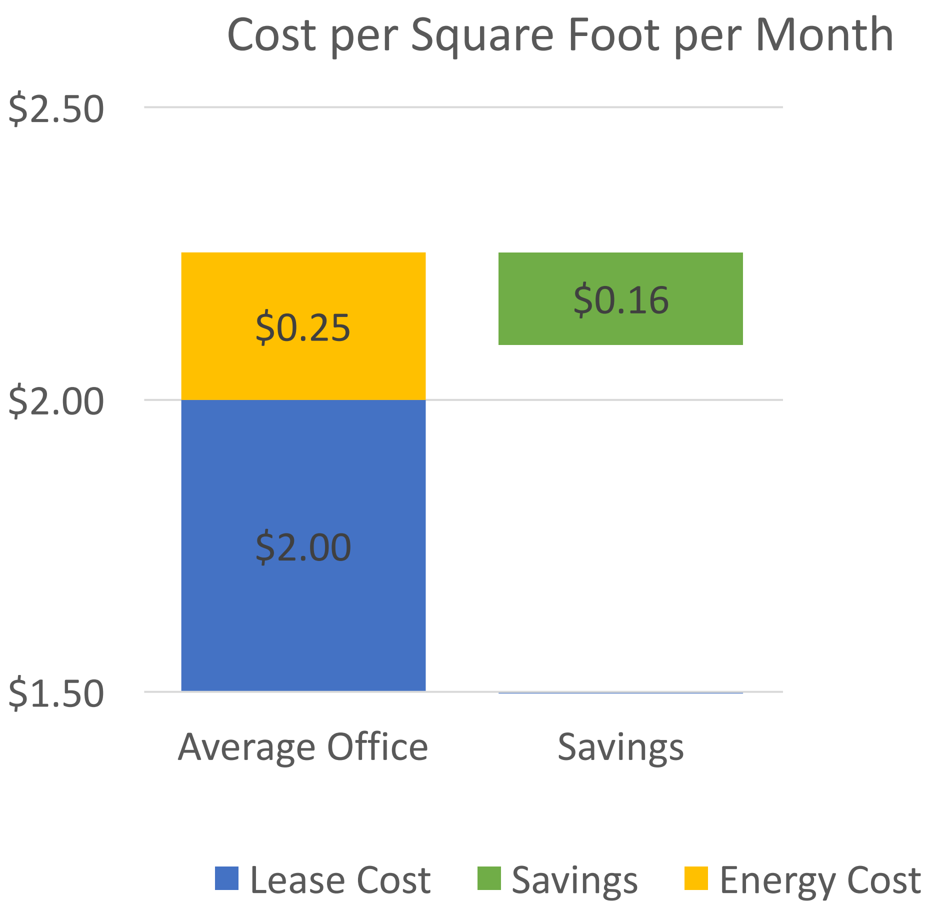
Summary of Findings

- **Most cost-effective measures**
  - The analysis found that the most cost-effective measures were generally addressing ***phantom loads*** and ***LED lighting***, followed by investments in ***rooftop heat pumps for air-conditioning***.
- **Economics of fuel switching**
  - While strategies related to electric heat pumps for water heating are of interest to cities for reducing natural gas consumption, this measure was not found to be cost-effective at this time. ***Due to the low cost of natural gas, the heat pump water heaters result in higher energy costs for water heating.***
- **How it ties into overall task goal/objectives**
  - Identifying appropriate financial and business models to make AEC financially attractive will require identifying ***how to bring down the upfront costs of electrification***, including ways to better internalize the environmental costs of fossil fuel usage (e.g., carbon tax on natural gas) and also consideration of costs associated with natural gas infrastructure.

Benefits for Owners and Property Managers



Benefits for Owners and Property Managers



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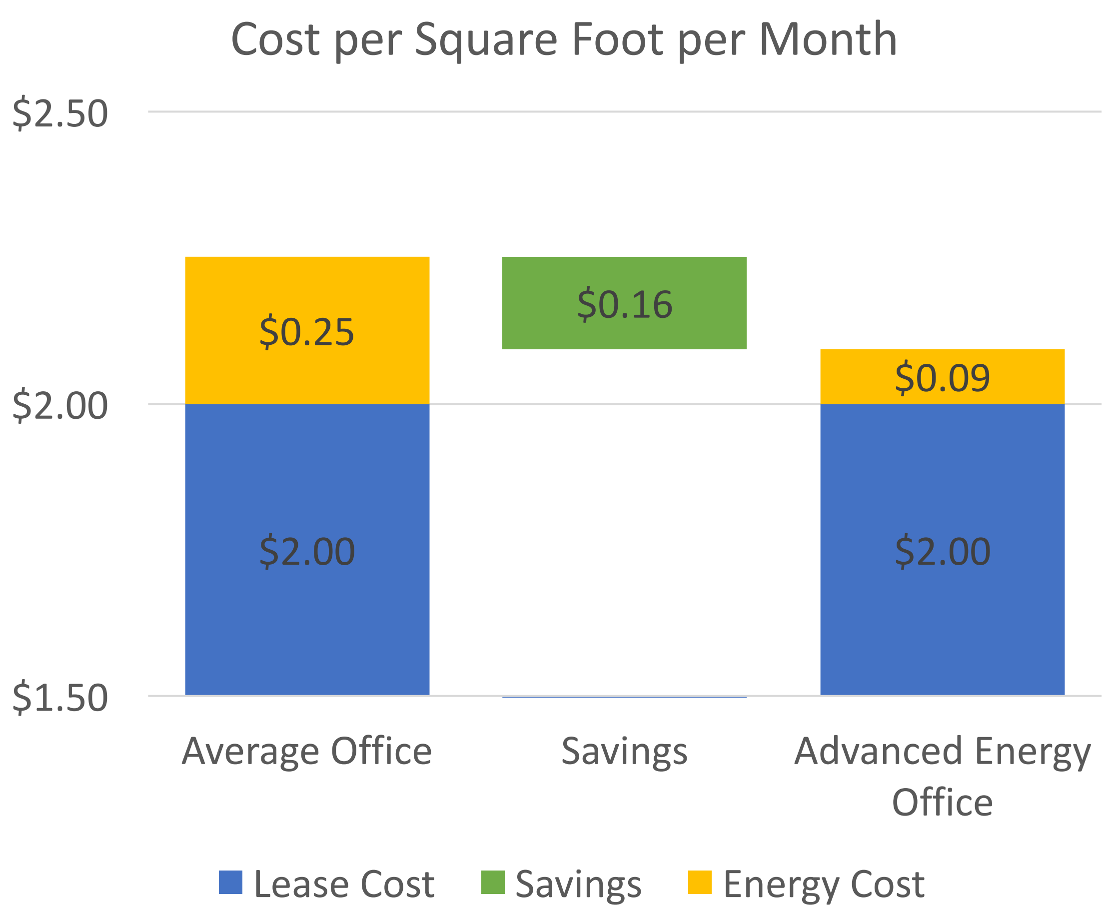
Benefits for Owners and Property Managers



Benefits for Owners and Property Managers

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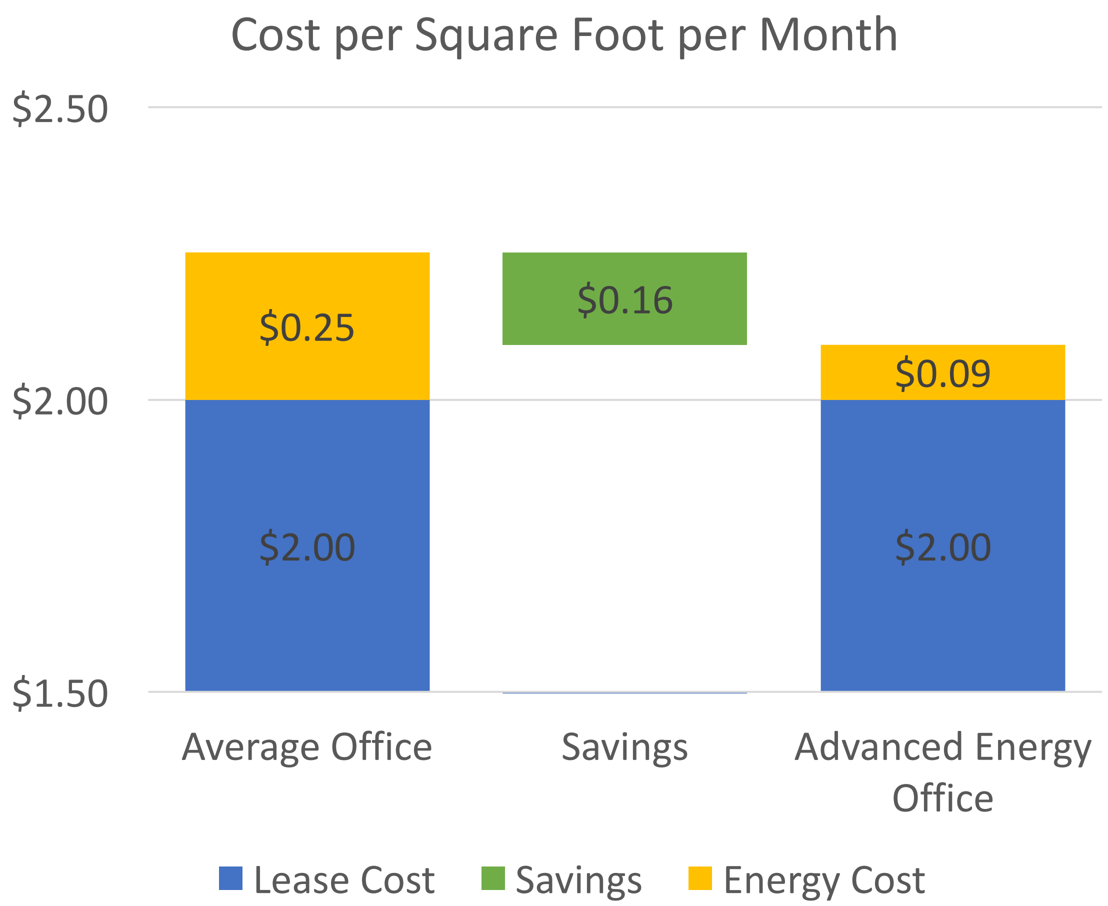

Charge an extra

$1,280

per month

Entice tenants with

$1,000

per month lower utility bills

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Benefits for Owners and Property Managers

Benefits for Owners and Property Managers

$800k

$1.85M

Property value of DPR Phoenix Before and After Deep Energy Retrofit

Benefits for Owners and Property Managers

- New Equipment that Pays for Itself
- Less Complaints Due to Old Equipment
- Increased Safety from Natural Gas Leaks and Carbon Monoxide Poisoning
- Leasing and Sales Marketability
- Energy Price Stability
- Decreased Opex and Capex Costs

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Questions?

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