scout

U.S. DEPARTMENT OF ENERGY

Developing prospective technology targets for BTO Sensors and Controls: Methods and assumptions

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U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

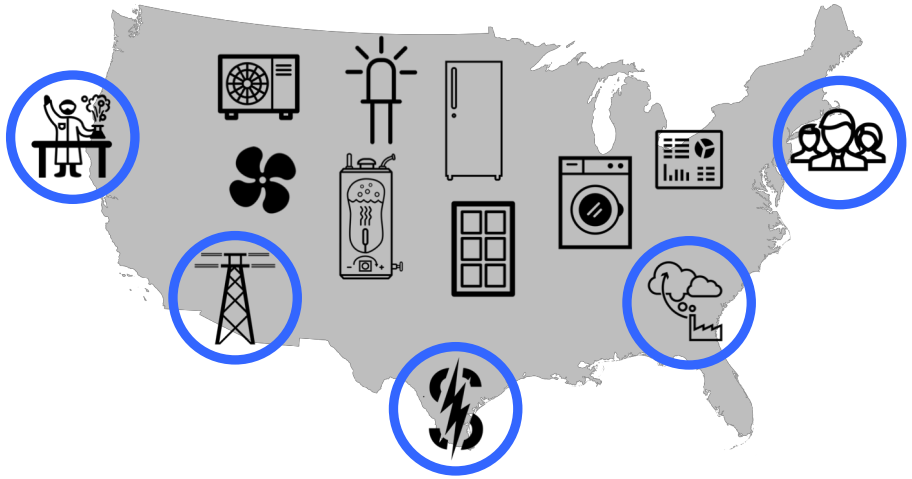
Four technology areas and the need for prospective targets

Multi-function wireless sensor networks
- Low cost, low power, plug-and-play
- Measure multiple parameters
- Enabling technology for other areas

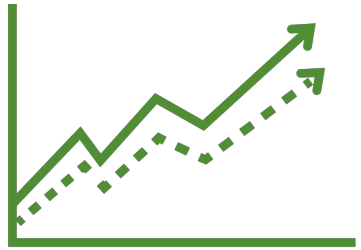
Adaptive and autonomous controls
- Integrated at the whole building level
- Predictive, prescriptive, able to learn
- Longer-term response capabilities

Advanced sub-metering and analytics
- Low cost, high identification accuracy
- Disaggregate equipment state and usage patterns

Occupant-centric controls
- Accurate, real-time local presence and comfort estimation for individual, group
- Control algorithms that maximize comfort while minimizing energy use



Targets establish **common points of reference** for the sensors and controls (S&C) research community, allow comparison of S&C with other technology areas



Targets encourage a **forward-looking, strategic outlook** on how S&C R&D contributes to longer-term objectives for reductions in U.S. building energy use

Target technologies are defined as Scout measures (ECMs)

Inputs

EIA Annual Energy Outlook (AEO)

Baseline definition

DOE Building Technologies Office

Energy Conservation Measure (ECM) definition

Defined for Specific Building Type(s), Climate Zone(s), End Use(s), and Fuel Type(s)

Building Stock Data

Buildings, Floor Area

Technology Stock Data

Units, Energy Use

Cost, Performance, and Lifetime

Adoption Parameters

Cost
Performance
Lifetime
Market Entry Year

Engine

For each year, determine adoption of all available ECMs (those that have entered the market) subject to stock and flow dynamics and ECM competition

Stock and flow dynamics

New stock and stock up for replacement or retrofit (baseline and ECM)

ECM Competition

Determine which technologies will be adopted by different types of consumers based on technology CAPEX and OPEX

Outputs

ECM/Portfolio Impacts

Primary energy use savings (quads)

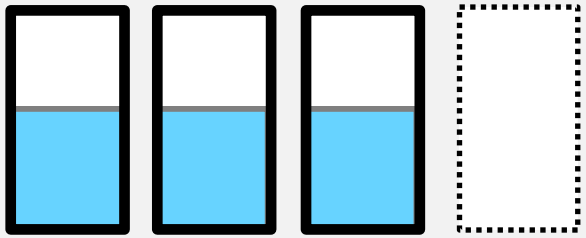
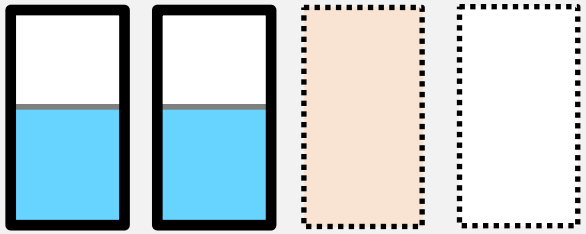
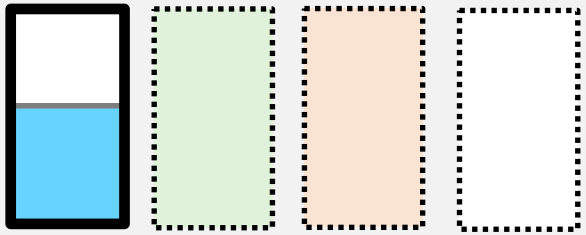
Avoided CO_2 emissions (Mt)

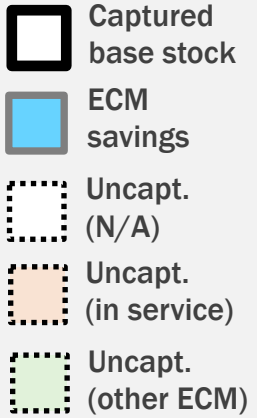
Avoided energy costs ($)

ECM/Portfolio Cost Effectiveness

IRR (%)
Simple Payback (years)
Cost of Conserved Energy ($/MMBtu saved),
Carbon ($/Mt avoided)

Scout measures (ECMs) are simulated on the national stage

Calculation Step	High-Level Equations	Annual Savings Outcome
Set baseline, estimate technical impact potential	$\Delta M_y = \sum_{c=1}^{C} \sum_{b=1}^{B} \sum_{f=1}^{F_b} \sum_{u=1}^{U_{b,f}} \sum_{t=1}^{T_{b,f,u}} \sum_{v=1}^{V} (M_{base})_{X,y} - (M_{ecm})_{X,y}$ Where $\Delta \boldsymbol{M}$= Tech. potential ECM impact on metric $\boldsymbol{M}$(energy, CO_2, cost); $\boldsymbol{M_{base}}$=Total AEO baseline value for metric $\boldsymbol{M}$; $\boldsymbol{M_{ecm}}$ = total value for metric $\boldsymbol{M}$after application of ECM; $\boldsymbol{c, b, f, u, t, v, y}$=AEO climate zone, building type, fuel type, end use, tech. type, bldg. vintage, and year, respectively; $\boldsymbol{X}$=c, b, f, u, t, v	
Add stock and flow dynamics	$(\Delta M_{sf})_{X,y} = (\Delta M)_{X,y} * (\lambda_n + \lambda_r + \lambda_{re})_{X,y}$ Where $(\Delta \boldsymbol{M_{sf}})_{X,y}$= Potential ECM impact on metric $\boldsymbol{M}$ (energy, CO_2, cost) in baseline segment $\boldsymbol{X}$and year $\boldsymbol{y}$after technology stock and flow adjustment; $\boldsymbol{\lambda_n, \lambda_r, \lambda_{re}}$ = tech. stock addition rate (from AEO), stock replacement rate (1/base life) and retrofit rate (0.01) for AEO baseline segment $\boldsymbol{X}$	
Add ECM competition	$(\Delta M_{sf,c})_{X,y} = (\Delta M_{sf})_{X,y} * a_{X,y,C}$, $a_{X,y,C} = f((c_{cap})_y, (c_{op})_y, b)$ Where $(\Delta \boldsymbol{M_{sf,c}})_{X,y}$= Potential impact on metric $\boldsymbol{M}$ (energy, CO_2, cost) in baseline segment $\boldsymbol{X}$and year $\boldsymbol{y}$after technology stock/flow AND competition adjustment; $\boldsymbol{a_{X,C}}$= competition adj. fraction for baseline segment $\boldsymbol{X}$, year $\boldsymbol{y}$, and competing ECM set $\boldsymbol{C}$	



Target costs are estimated given performance, payback ranges

Set market entry year

Near-term (2020) and longer-term (2025) market entry years depending on measure

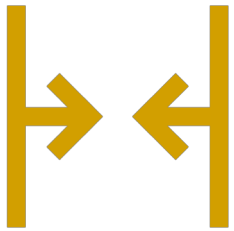
Set applicable baseline market, measure lifetime

Define separately for residential/commercial sectors at market entry and in 2030

Set target measure performance

Feasible low, medium, and high levels based on literature

Set cost effectiveness threshold



1-3 years simple payback based on typical customer/ organization requirements

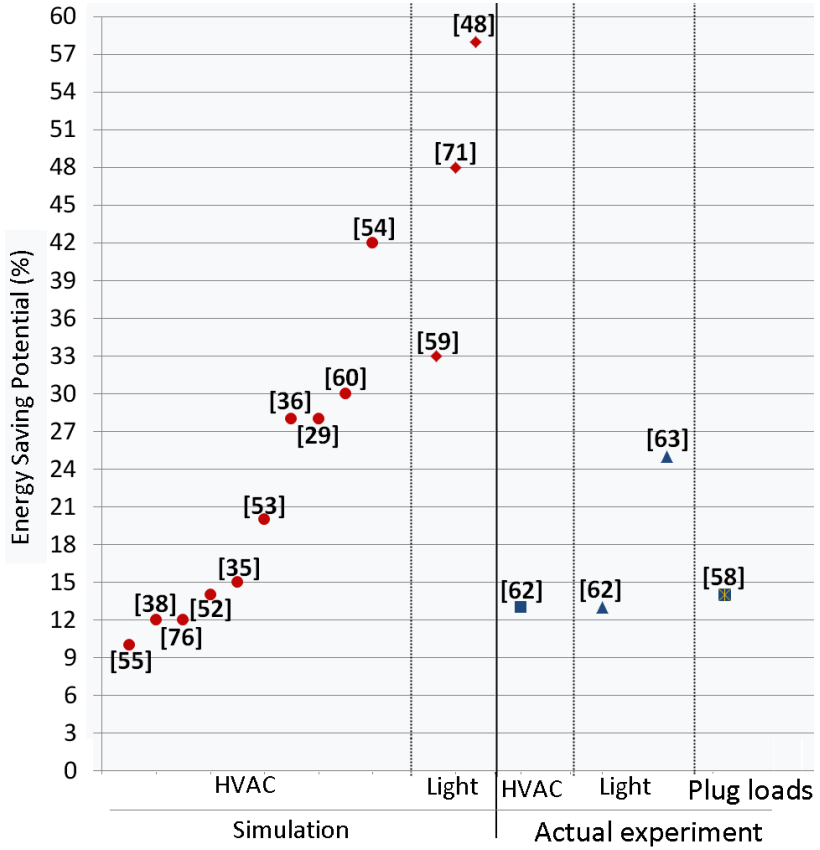
Find measure cost that meets threshold

Measure-specific cost units ($/ft^2 floor, $/node, $/occupant)

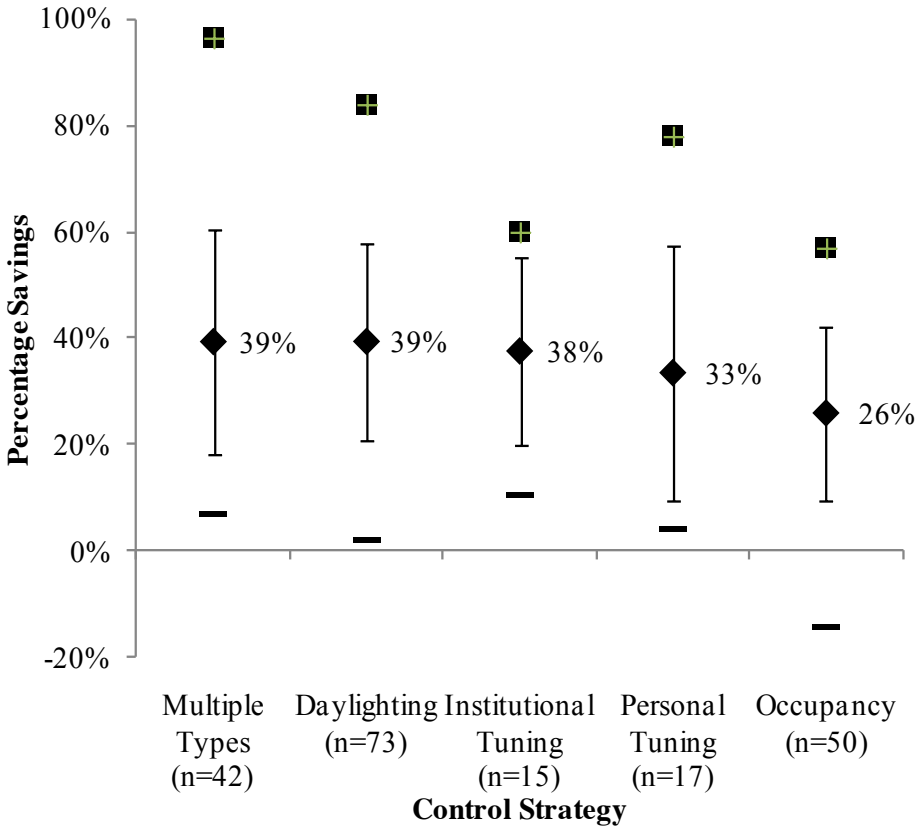
A timeline for market entry and target evolution is assumed

	2020	2025	2030
 Multi-Functional Wireless Sensor Networks	Enter market in **single family homes, large offices** with **mid-level performance**		Extend to **all residential/commercial buildings** while meeting **1 year payback** *(extend market, reduce cost)*
 Autonomous Controls with Sub-metering	Enter market in **all commercial buildings** with **mid-level performance**		Enter market with **high-level performance** *(improve performance)*
 Occupant-Centric Controls (Occupancy, Comfort-Driven)	Enter market in **single family homes, large offices** with **mid-level performance** (**occupancy-driven** controls only)	Add **comfort-driven** control capabilities with **mid-level performance** *(improve performance)*	Extend to **small office, lodging, assembly, education, and health care** with **high-level performance** *(extend market, improve performance)*

Performance ranges are based on literature meta-analyses



From Nguyen et al, "Energy intelligent buildings based on user activity: A survey," 2013



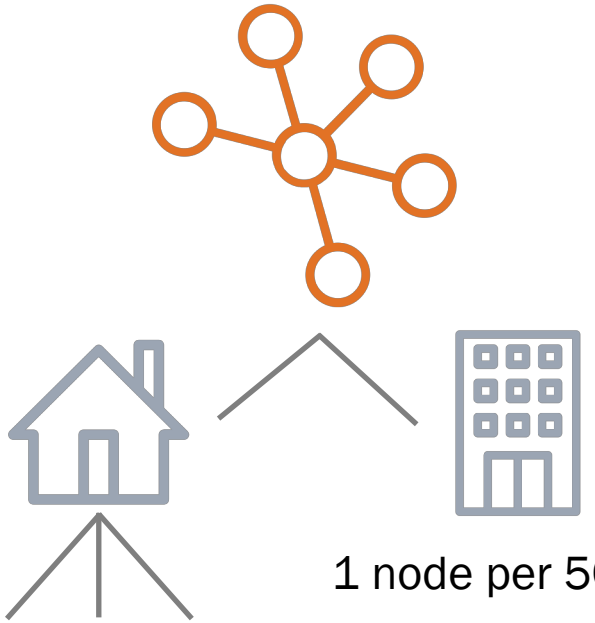
From Williams et al, "Quantifying National Energy Savings Potential of Lighting Controls in Commercial Buildings," 2012

Full sourcing information is available in the Prospective S&C ECM definitions posted on GitHub:
https://github.com/trynthink/scout/tree/master/ecm_definitions

Standard cost unit conversions are developed and applied

$/node

(assume: nodes/ft^2 floor)



1 node per 240-370 ft^2

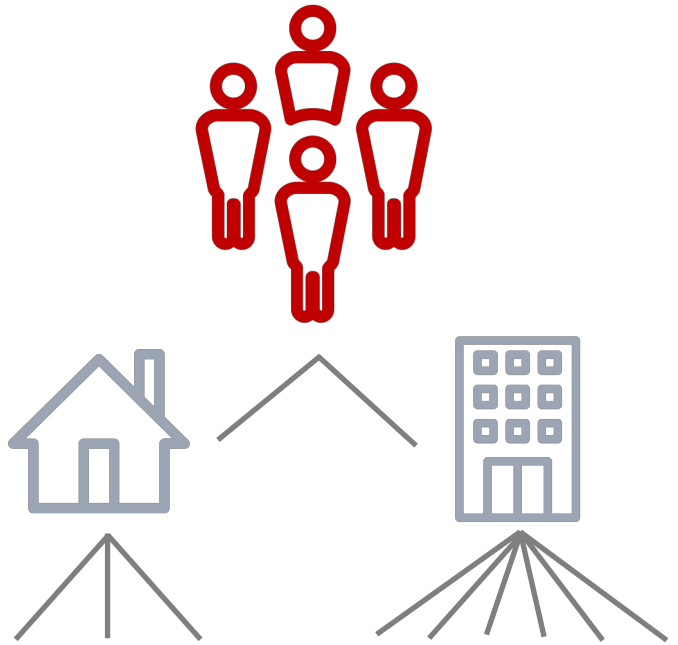
Source: RECS 2015

1 node per 500 ft^2

Source: Kinter-Meyer et al, "Opportunities of Wireless Sensors and Controls for Building Operation," 2005

$/occupant

(assume: occupants/ft^2 floor)



1 occupant per 340-965 ft^2

Source: 2010 U.S. Census and RECS 2015

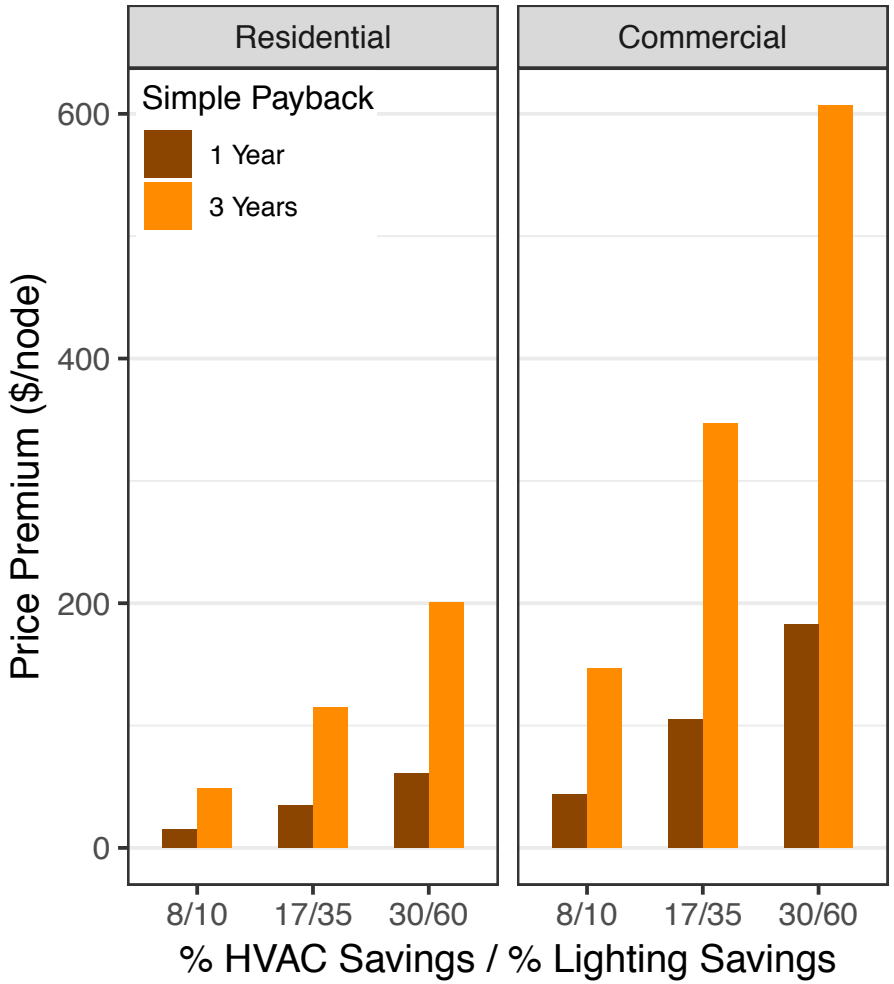
1 occupant per 50-200 feet ft^2

Source: Deru et al, "U.S. Department of Energy Commercial Reference Building Models of the National Building Stock," 2011

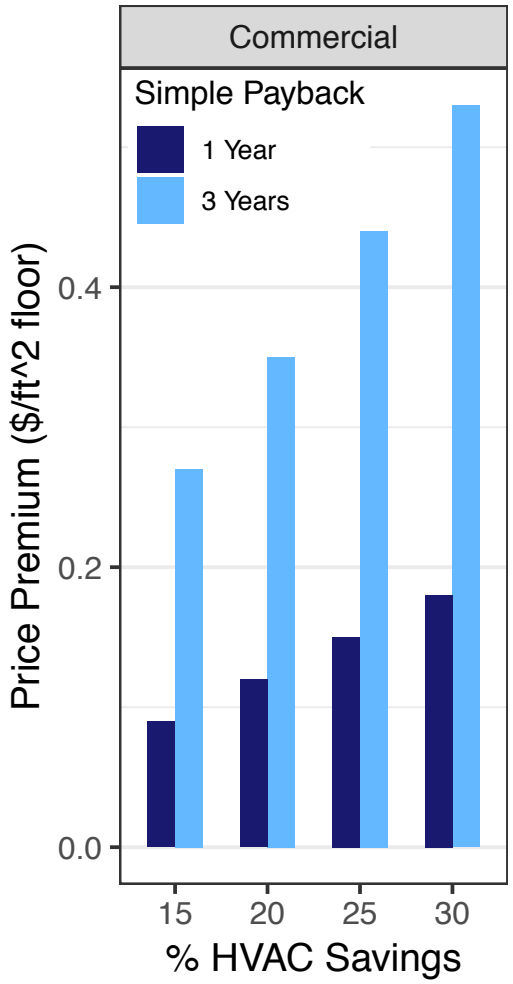
Full set of cost conversion assumptions and notes available via GitHub:
https://github.com/trynthink/scout/blob/master/supporting_data/convert_data/ecm_cost_convert.json

Sector-specific cost and performance targets are produced

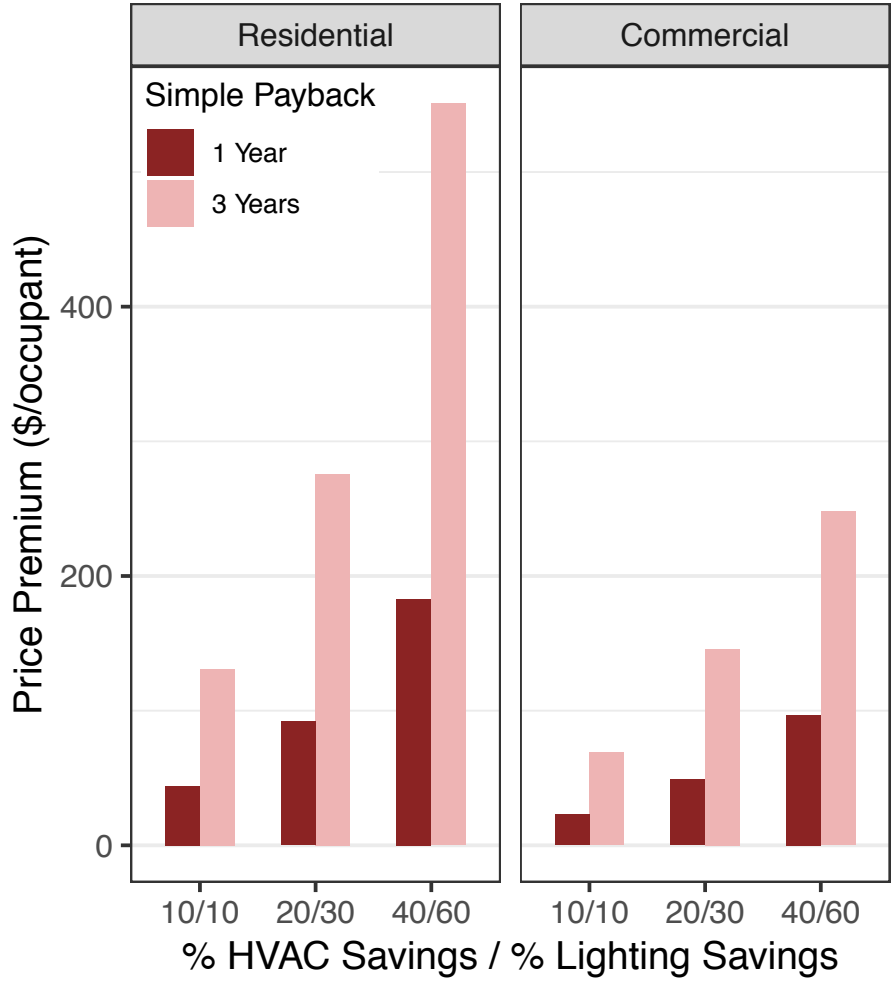
Multi-functional Wireless Sensor Networks (2020)



Autonomous Controls with Sub-metering (2020)



Occupant-Centric Controls (2020 - Occ. / 2025 - Comf.)



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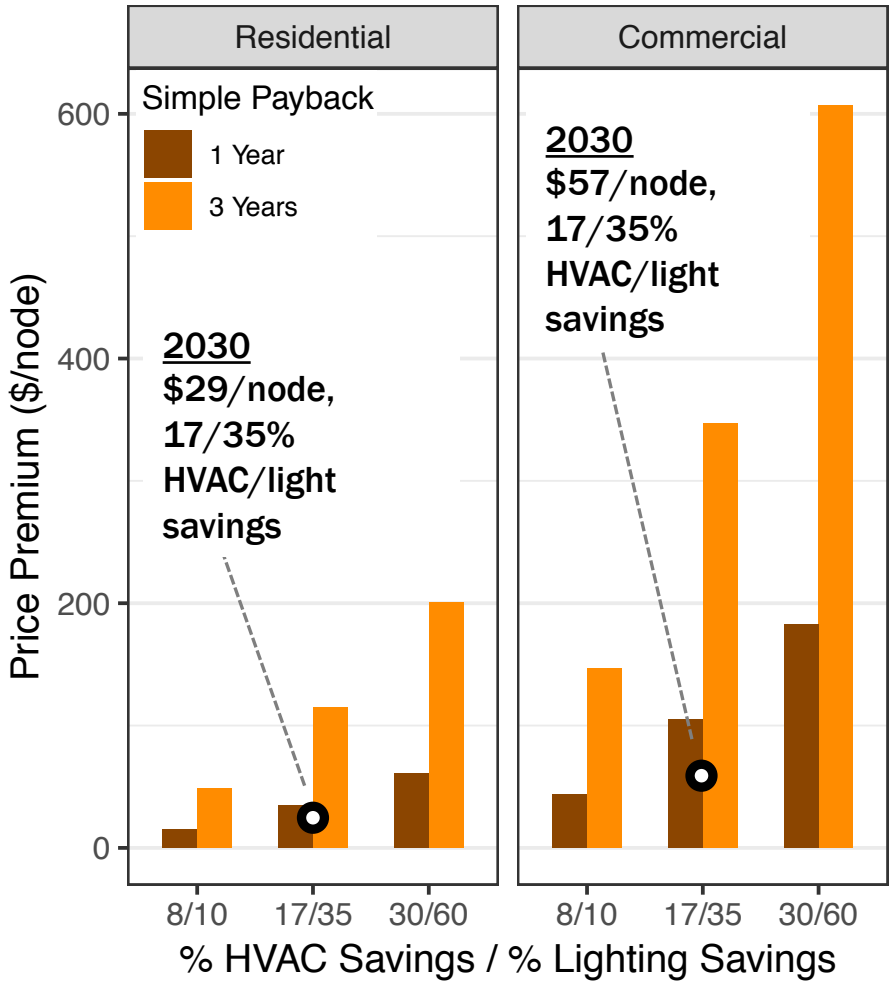

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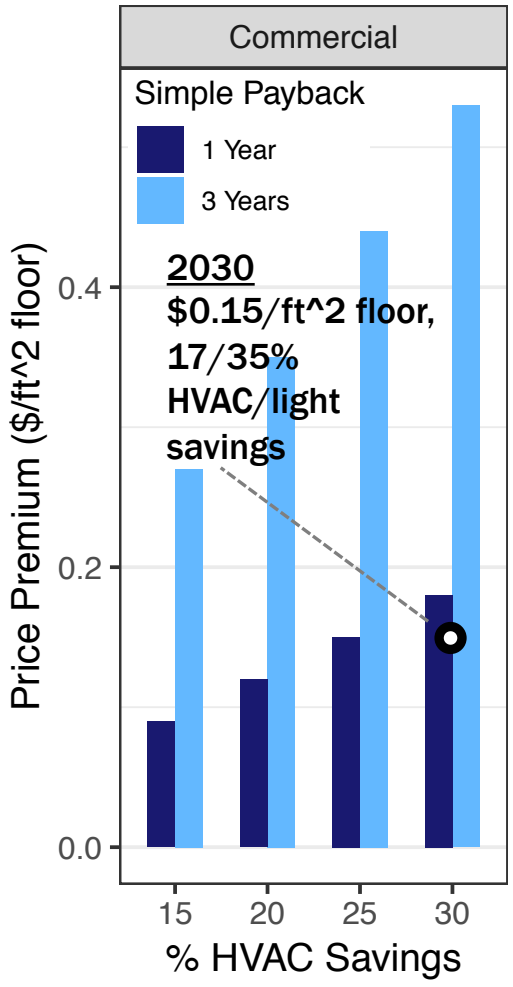

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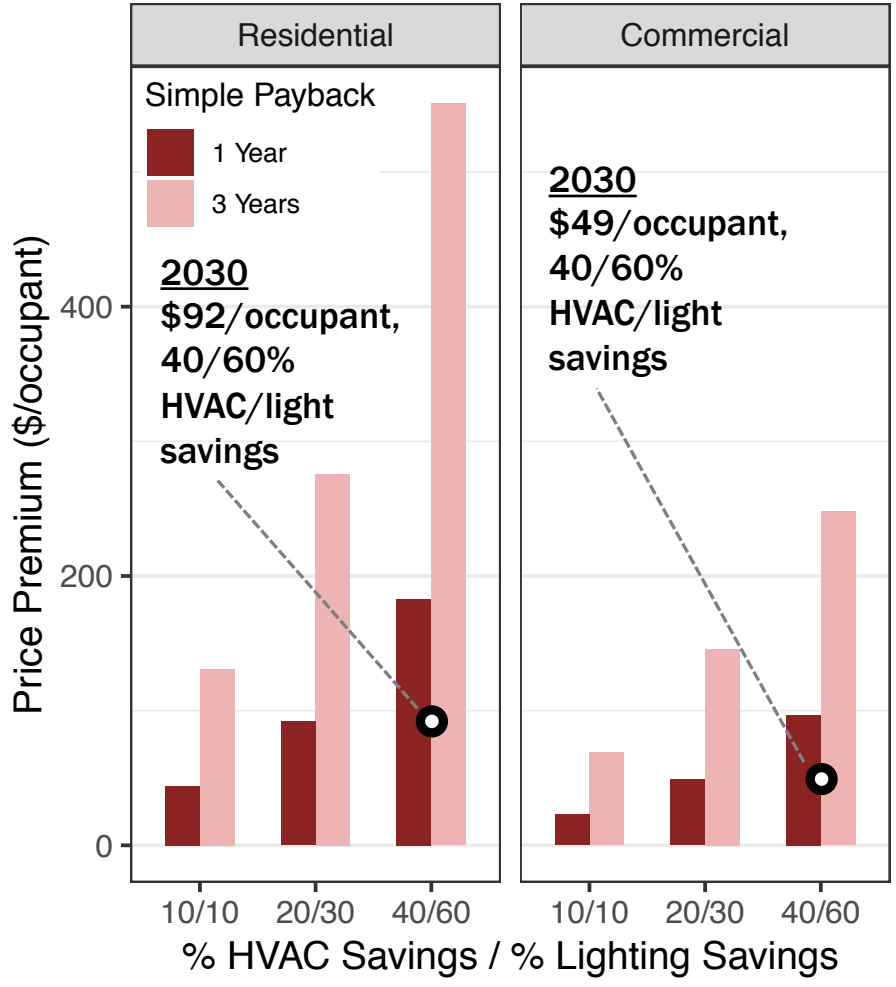

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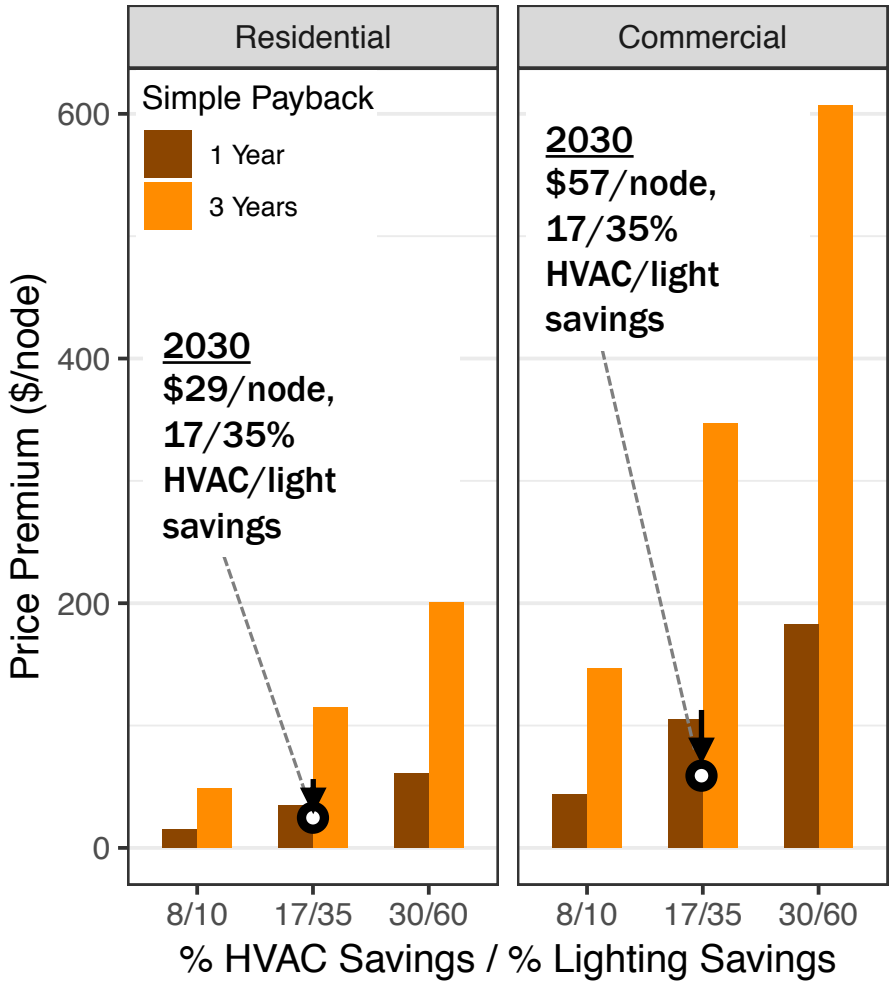

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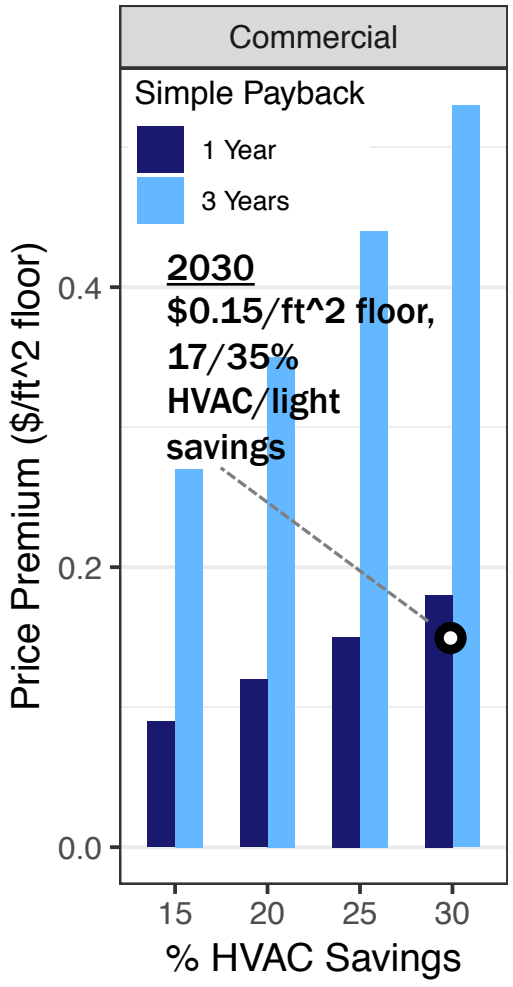

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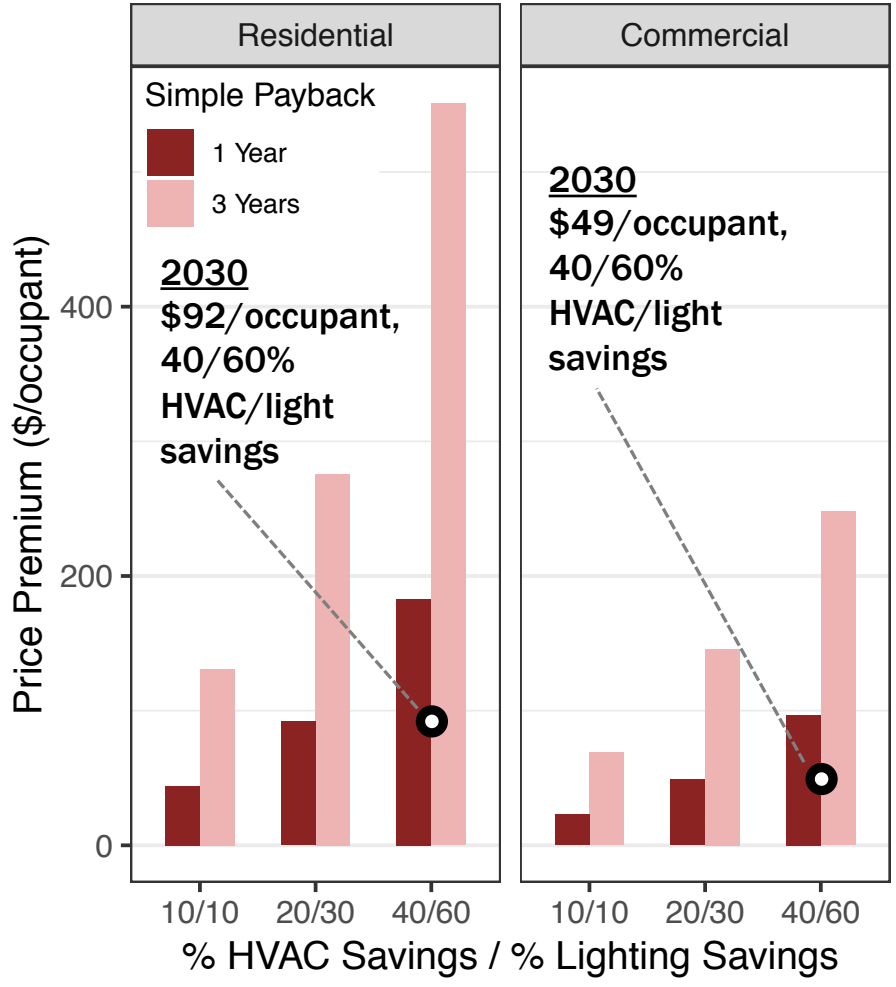

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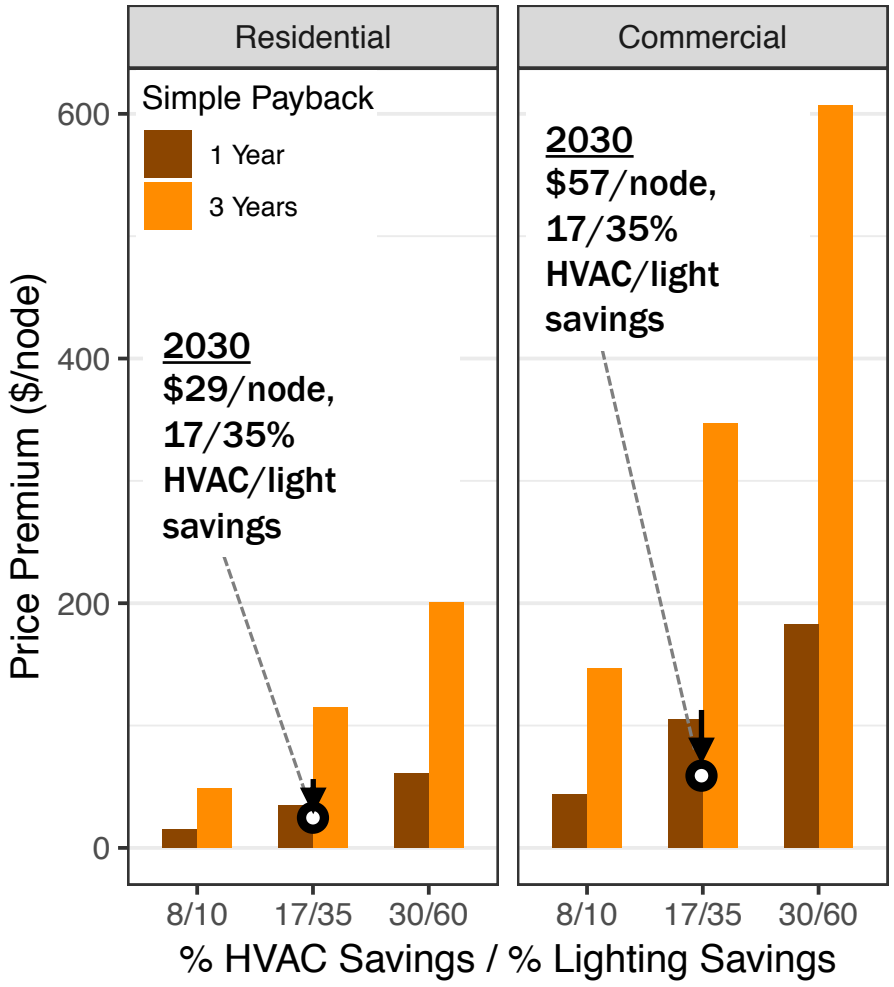

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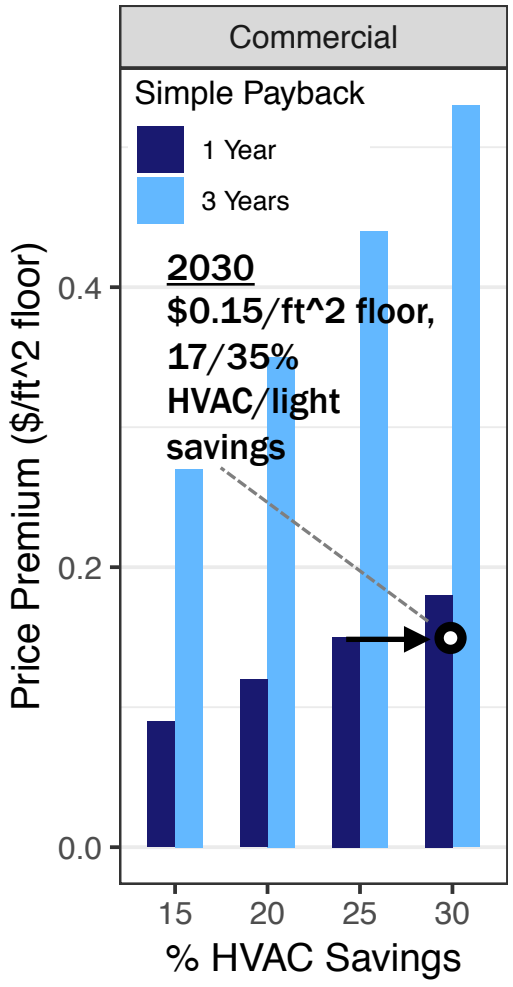

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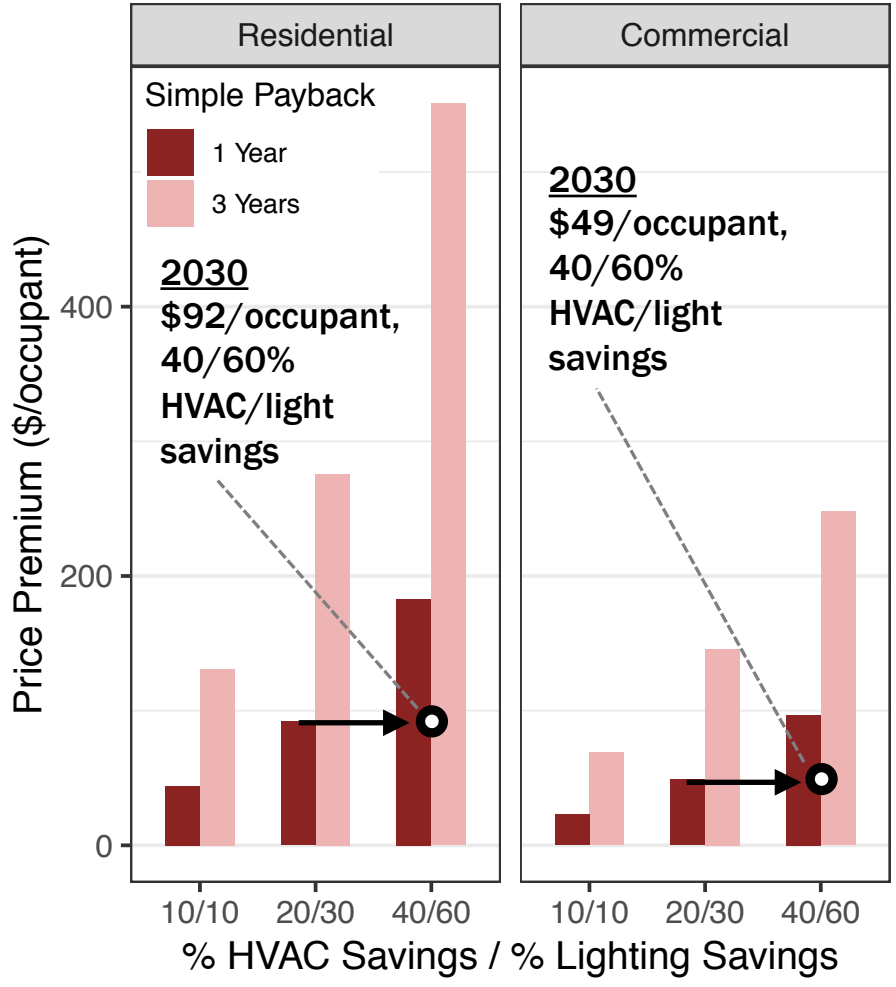
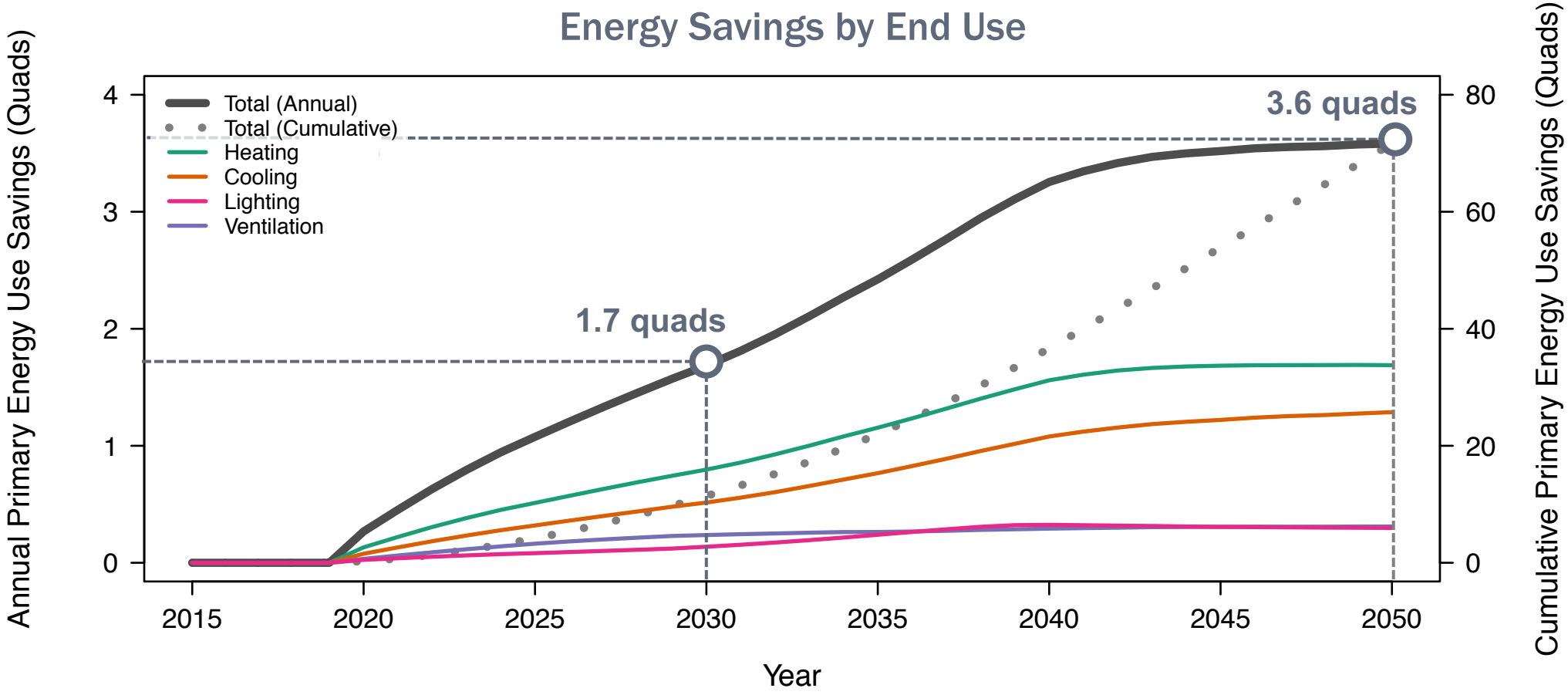
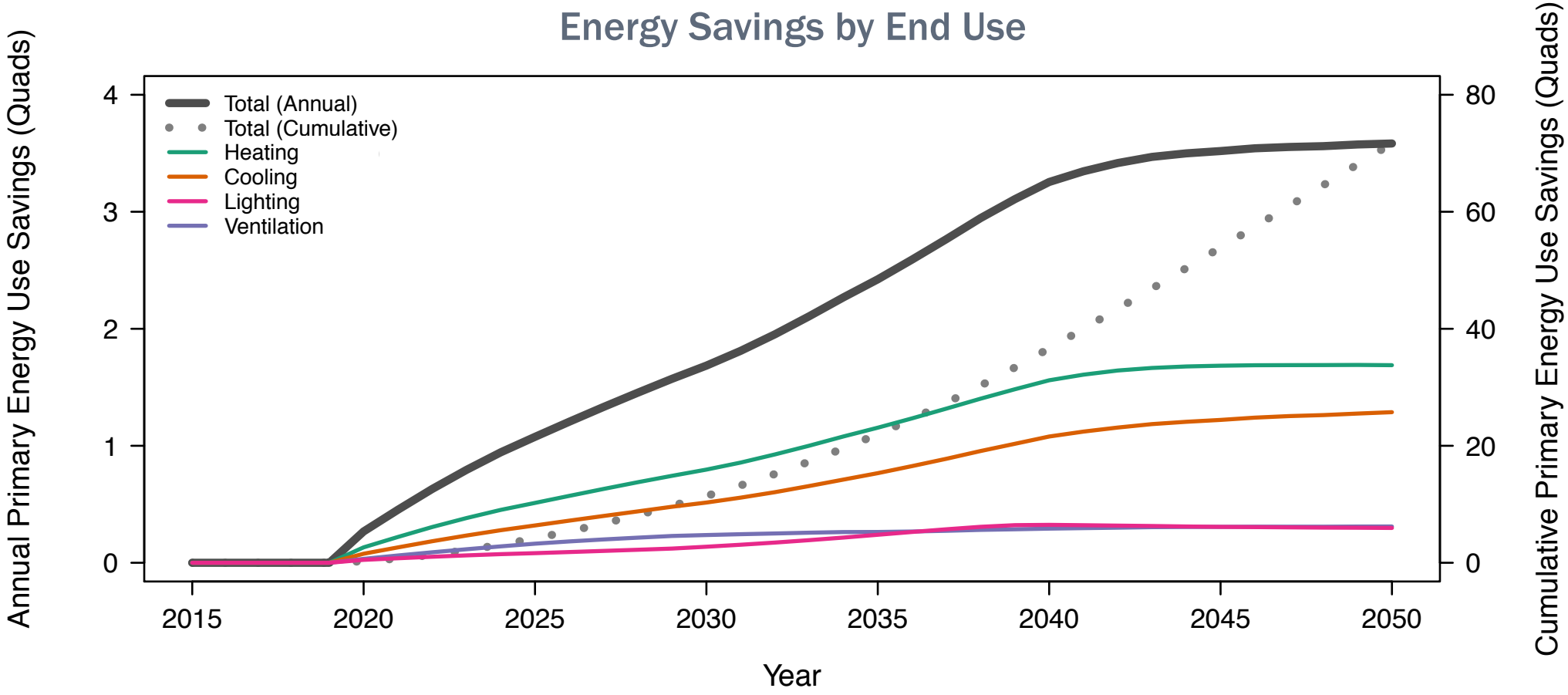


Target S&C measure impacts can be assessed as a portfolio



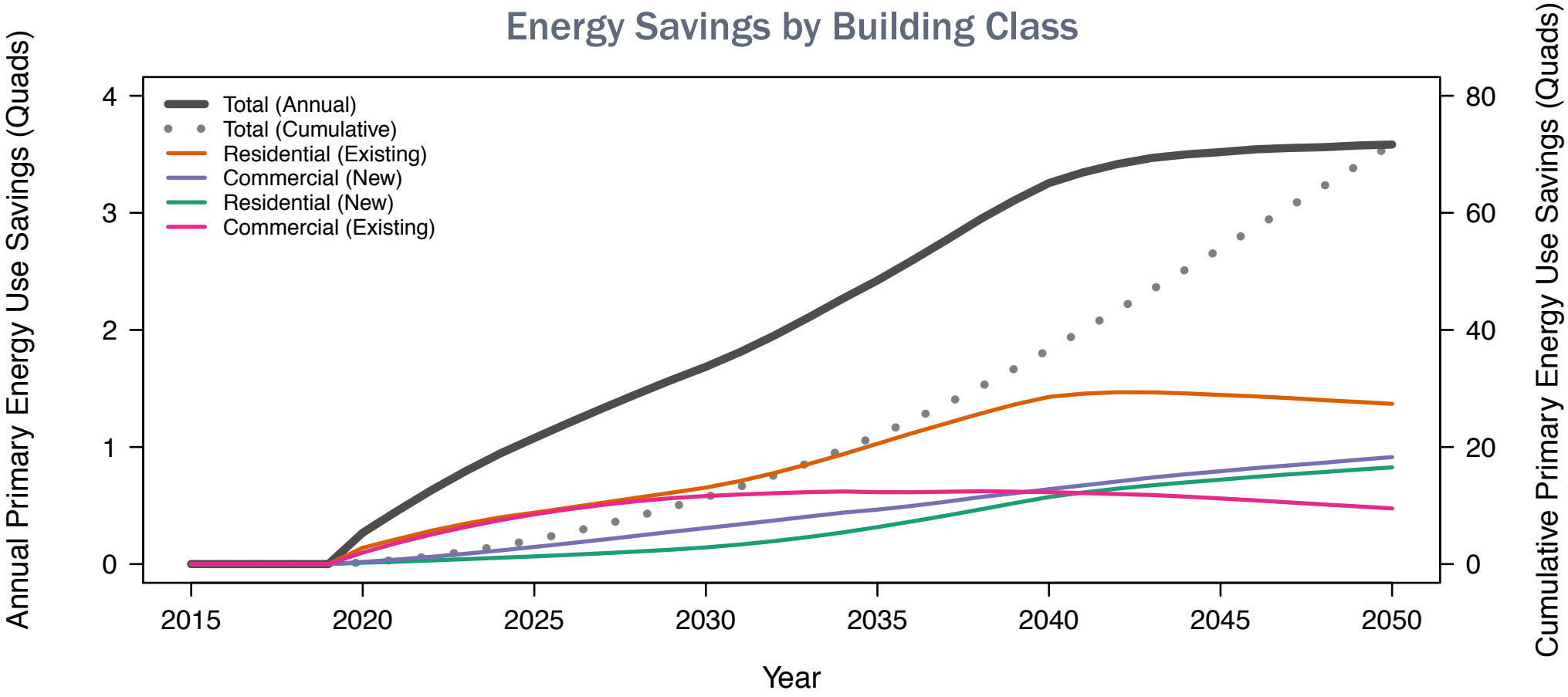
- Considered in isolation, the **S&C target portfolio can avoid 3.6 quads of primary energy use by 2050**
- *Note: Based on AEO 2018 data, excludes wireless sensor network measure (considered enabling)*

Target S&C measure impacts can be assessed as a portfolio



- By 2050, most energy savings are attributable to **heating** (1.7 quads/47%) and **cooling** (1.3 quads/36%) end uses

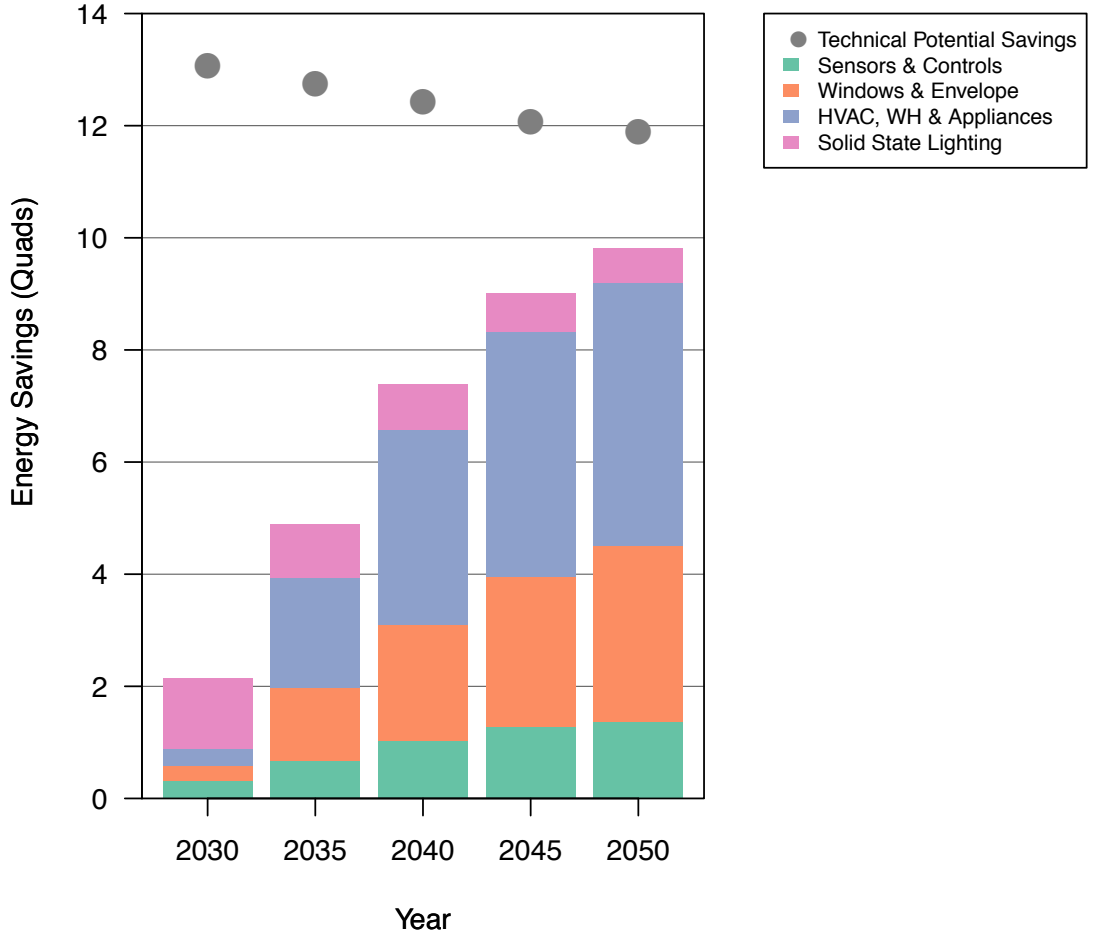
Target S&C measure impacts can be assessed as a portfolio



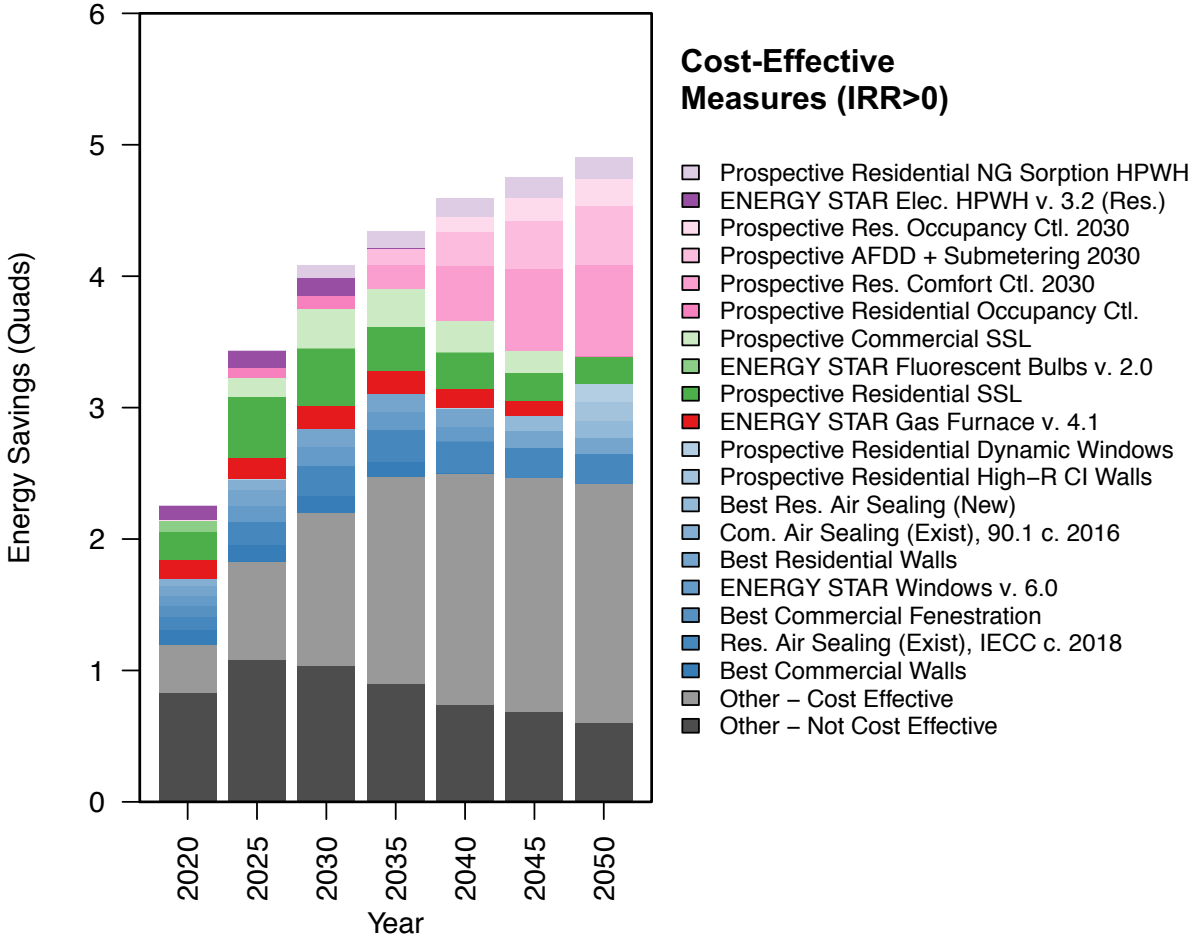
- By 2050, most energy savings are attributable to **existing residential buildings** (1.4 quads/38%) and **new commercial buildings** (0.9 quads/25%)

S&C target measures can be competed with other measures

Competing S&C target measures as part of the BTO ET target portfolio



Establishing the cost-effective energy savings contributions of S&C targets



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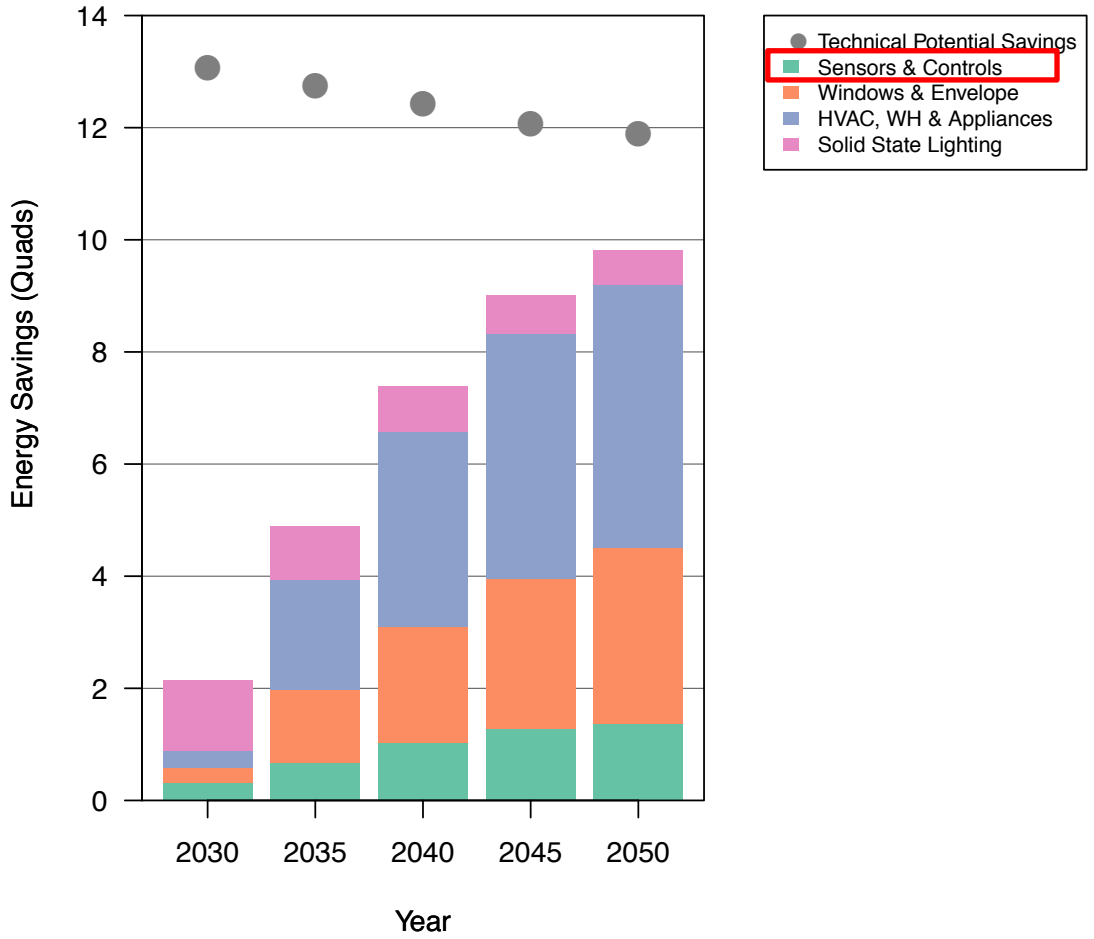

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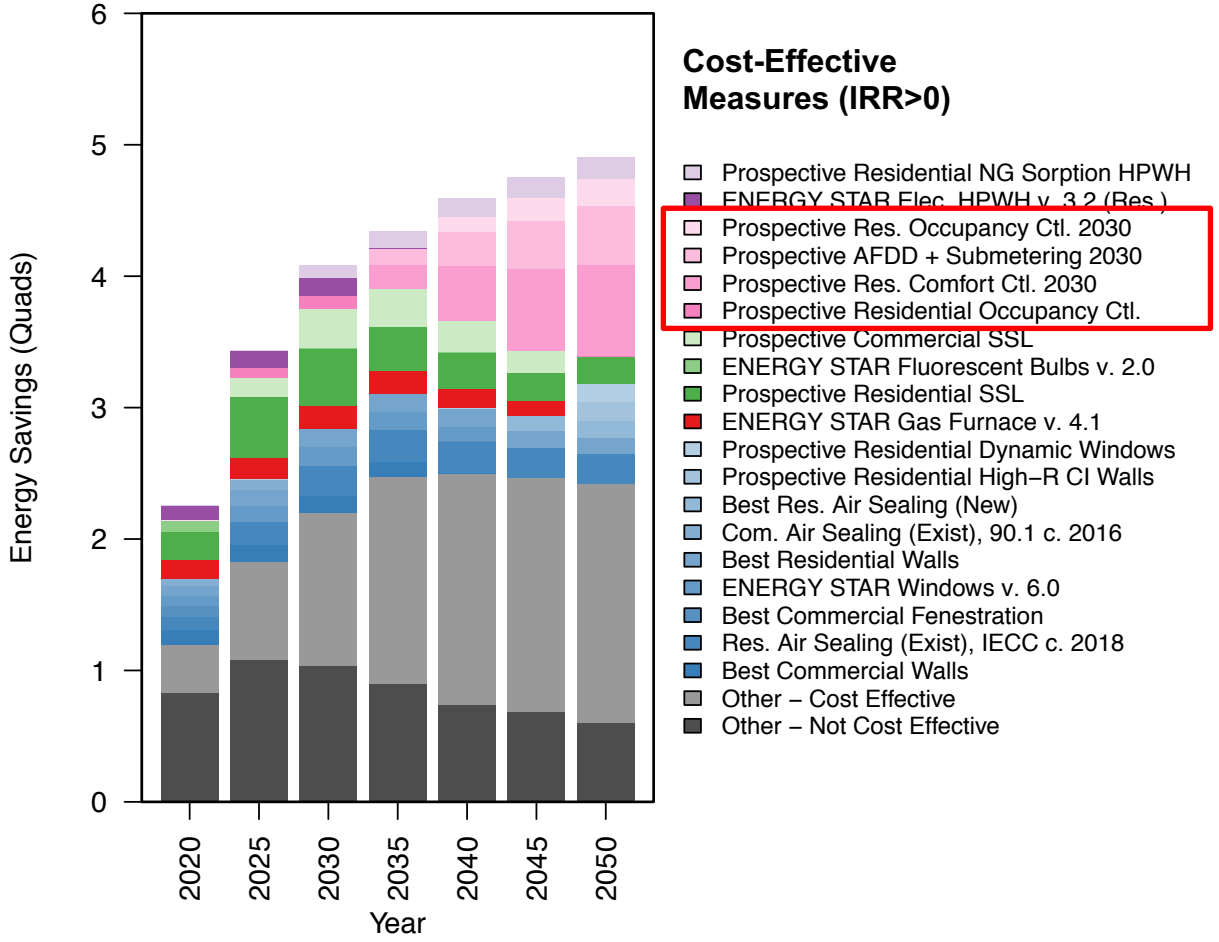
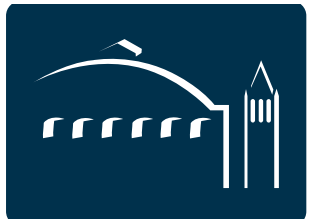


The limitations of technology targets and how to improve them

- **Opportunities for improvement**
  - Represent plug loads, 'other' miscellaneous loads
    - ~44% of total U.S. building energy use by 2050 (2019 EIA Annual Energy Outlook (AEO))
    - FY18-19 S&C-funded effort has improved our ability to characterize these loads
  - Improve range of performance estimates given updated literature
    - Particularly important for the residential sector, where few studies exist
  - Quantify non-energy benefits in terms of cost
    - Comfort/productivity gains, ease of installation/maintenance

- **S&C target impacts will be periodically reassessed**
  - Annual updates to Scout's baseline data with new AEO version - update to S&C impacts
  - The latest data on S&C target definitions and their impacts are available on scout.energy/gov/ecms.html



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Visit scout.energy.gov

A default set of annually updated ECM portfolios

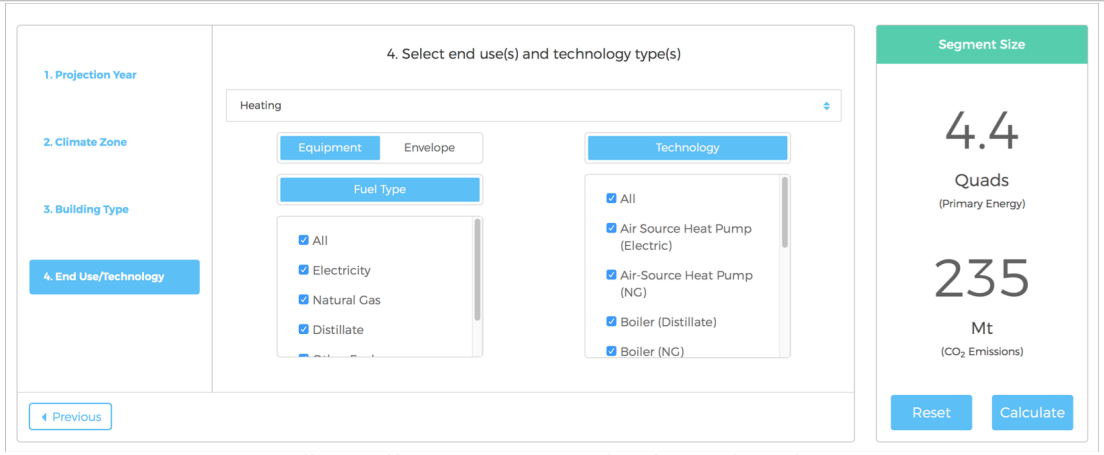
Focus Area	Relevant ECM	Sector	Installed Cost		Energy Performance (HVAC, Lighting)		2030 Energy Savings Technical Potential
			Market Entry	2030 Target	Market Entry	2030 Target	
Wireless Sensor Networks	Plug-and-play sensors	Residential	$35/ node	$29/ node	17%, 35%		1.14 quads
		Commercial	$115/ node	$57/ node			0.99 quads
Advanced Controls	AFDD	Commercial	$0.12/ ft^2 floor	$0.15/ ft^2 floor	20%, N/A	30%, N/A	1.18 quads
Granular Equipment Sub-metering	AFDD and sub-metering	Commercial	$0.14/ ft^2 floor		25%, N/A	30%, N/A	1.18 quads
Occupant-centric Sensors and Controls*	Occupancy-Driven Controls	Residential	$70/ occupant		15%, 15%	30%, 40%	2.31 quads
		Commercial	$36/ occupant				1.10 quads
	Comfort-Driven Controls	Residential	$92/ occupant		20%, 30%	40%, 60%	3.14 quads
		Commercial	$49/ occupant				1.49 quads

A default set of annually updated ECM portfolios

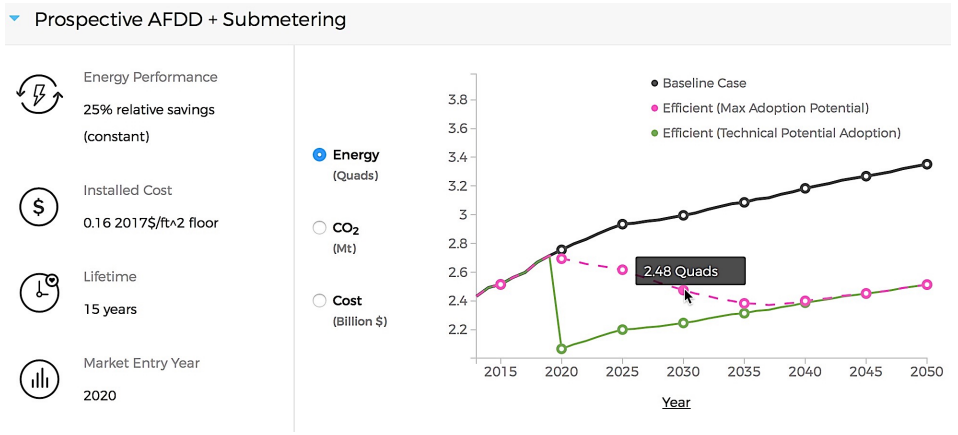
ECM Portfolio Name	ECM Portfolio Description	Data Sources
Performance Guidelines (40 ECMs)	• Current ENERGY STAR standards for major equipment • 90.1-2016 (res.) and IECC 2018 (com.) for envelope and other equipment not covered by ENERGY STAR	ENERGY STAR, ASHRAE 90.1-2016, IECC 2018
Best Currently Available (39 ECMs)	• Best performing tech. available on the market today • Generally drawn from the "2017 Best" column of EIA's "Updated Equipment Costs and Efficiency" document	EIA Equipment Costs and Performance (2018), NREL Res. Eff. DB, AEDG (50%)
Target ECMs (50 ECMs)	• Early-stage technologies with prospective cost and performance targets (for market entry between 2020-2030) drawn mostly from the U.S. Department of Energy (DOE) Building Technologies Office (BTO) 2016 Multi-Year Program Plan (MYPP)	U.S. DOE BTO MYPP, BTO Windows & Envelope, Sensors & Controls roadmaps (unpublished)
Fuel Switching ECMs (30 ECMs)	• ECM definitions from all portfolios (Performance, Best, and Target) adapted to allow/incentivize fuel switching	N/A

Most of these ECM definitions now come standard with a Scout download:
https://github.com/trynthink/scout/tree/master/ecm_definitions

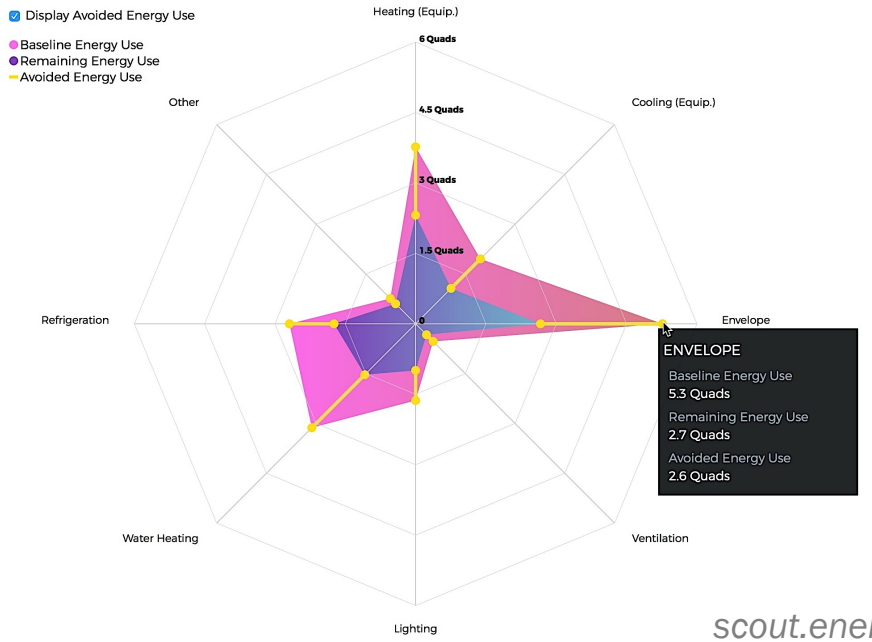
Visit scout.energy.gov to explore your own efficiency measures

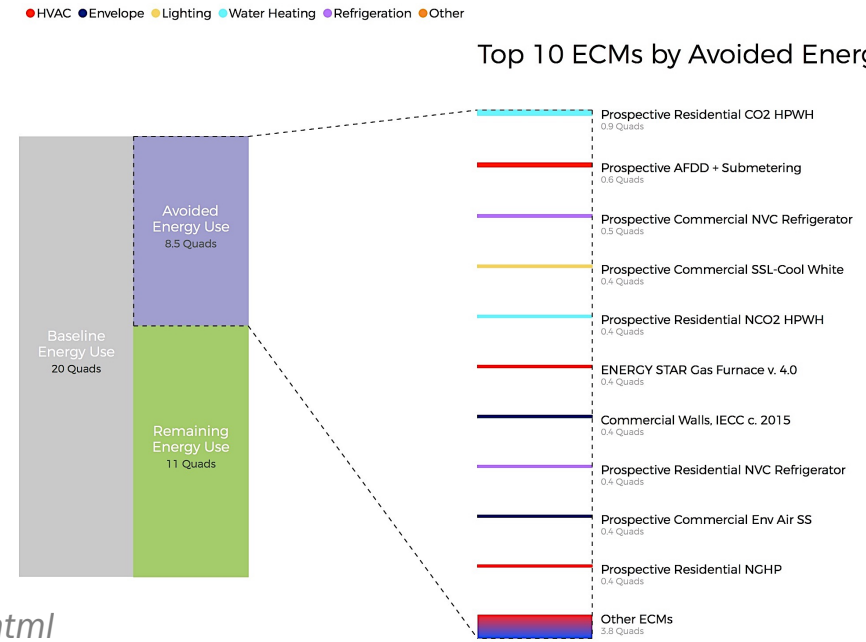


scout.energy.gov/baseline-energy-calculator.html



scout.energy.gov/ecms.html





scout.energy.gov/energy.html