Valuing Residential Energy Efficiency: Analysis for a Prototypical Southeastern Utility

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Disclaimer

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A Technical Appendix describing key modeling inputs, assumptions, and methodology is available at: https://emp.lbl.gov/publications/valuing-residential-energy-efficiency

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Study Purpose

In the context of an evolving U.S. power system, it is important to develop a more nuanced understanding of the value of energy efficiency (EE) as a system resource.

The purpose of this study is to identify how much cost-effective residential EE remains, which new program and policy initiatives could access it, and the value it would bring to the power system.

The benefits of residential EE to the power system are estimated in a forward-looking system planning and valuation analysis.

The analysis focuses on a variety of residential EE measures that could be deployed by a prototypical summer-peaking utility in the Southeastern U.S.

Findings are based on NREL's hourly ResStock EE savings profiles and Berkeley Lab's Cost of Saving Electricity database. The modeling was done using Brattle's GridSIM capacity expansion platform.

Key study boundaries

THIS ANALYSIS DOES…

- Identify the amount of each EE measure that is cost-effective from the **utility's** perspective.
- Assess a range of common standalone residential EE measures and a packaged grouping that may be offered by utilities.
- Characterize a vertically-integrated utility intended to be *generally representative* of Southeastern loads and resources.

THIS ANALYSIS DOES NOT…

- Identify cost-effective EE from the participating or non-participating **customer** perspective.
- Model numerous EE measures with different performance assumptions and grouped into many possible packages for program delivery.
- Evaluate specific Southeastern utilities, alternative future grid scenarios, and uncertainty in EE assumptions.

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Analysis framework

The analysis uses a capacity expansion model (Brattle's GridSIM model) to quantify the prototypical Southeastern **utility's total cost of serving electricity demand** for a 20-year planning horizon (i.e., 2021-2040).

We analyze the impact of EE additions under business-as-usual (BAU) conditions, and then quantify the extent to which cost-effective residential EE deployment would increase under various program and policy initiatives.

Note: See Technical Appendix for EE measure assumptions and modeling methodology.

The modeling simulation selects the **cost-effective EE portfolio** by allowing it to "compete" with supply side resources.

- **EE benefits** are represented by avoided system resource costs (i.e., avoided capacity, energy, and ancillary services).
- **EE costs** are represented by participation incentives (i.e., share of incremental equipment & installation cost), administrative costs, and marketing costs.

Energy savings from the EE measures (except smart thermostats, which are modeled as demand flexibility) are modeled as **hourly-interval annual shapes.**

Scenarios

The analysis quantifies achievable, cost-effective EE potential under several scenarios, to explore how new policy initiatives can unlock greater EE value.

Modeling scenarios:

- **Business-As-Usual (BAU) Achievable Potential:** Utility cost-effective, achievable EE potential under average assumptions about measure costs, customer adoption, and grid characteristics.
- **EE Cost Reduction:** Relative to the BAU assumptions, EE measure costs are reduced by 40% (e.g., through technological advancements).
- **Grid Cost Increase:** Relative to the BAU assumptions, power system costs are higher (e.g., due to higher-than-anticipated fuel prices or labor costs, or materials shortages).
- **Higher EE Adoption:** Relative to the BAU assumptions, maximum customer adoption of EE measures is higher (e.g., due to improved marketing/awareness campaigns).
- **Clean Energy Standard:** A clean energy standard is introduced that ramps up to 40% of generation from carbon-free sources by 2040.
- **Packaged Measures:** Measures are offered to customers as a package rather than a la carte.
- **Technical Potential:** Provided only for context of upper-bound EE potential, assumes eventual 100% participation among eligible customers in all measures modeled.

Note: Further detail about each scenario is provided in the discussion of findings.

The GridSIM model is used to simulate long-term power system operations and the impact of energy efficiency

INPUTS

Supply

- Existing resources
- Fuel prices
- Investment/fixed costs
- Variable costs
- New resources (incl. EE)

Demand

- Representative day hourly demand
- Capacity needs
- Operational reserves requirements

Energy Efficiency

- Hourly load reduction parameters
- Measure interactions

Regulations, Policies, Market Design

- State energy policies and renewable generation procurement mandates

GridSIM OPTIMIZATION ENGINE

Objective Function

- Minimize NPV of investment & operational costs

gridSIM

With *dynamic* selection of cost-effective EE measures

Constraints

- Market design and co-optimized operations
  - Capacity
  - Energy
  - Ancillary services
- Regulatory & policy constraints
- Resource operational constraints
- EE adoption constraints

OUTPUTS

Annual Investments and Retirements (incl. EE)

Hourly Operations

Supplier Revenues

System and Customer Costs

Prices

Emissions and Clean Energy Additions

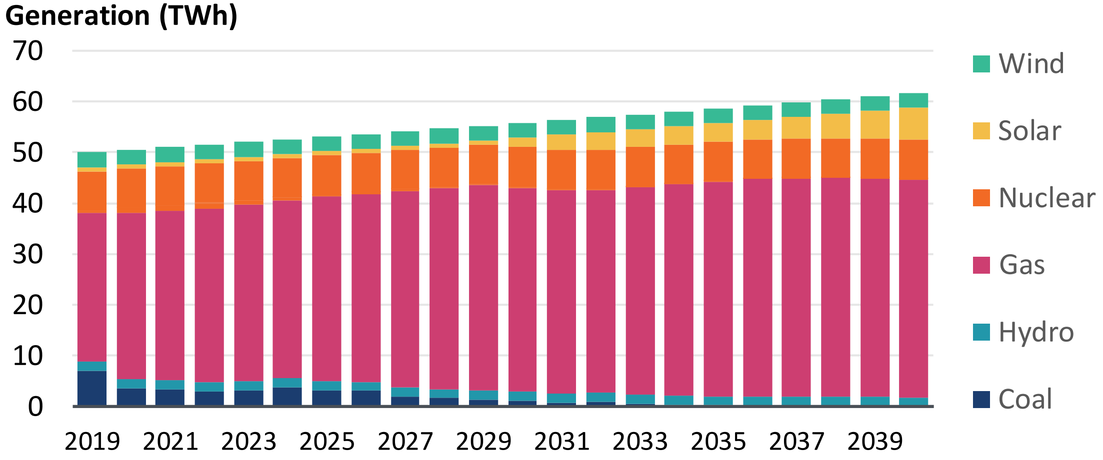
Note: Further detail about the GridSIM platform and the optimization formulation is provided in the Technical Appendix.

Characterizing the prototypical Southeastern utility

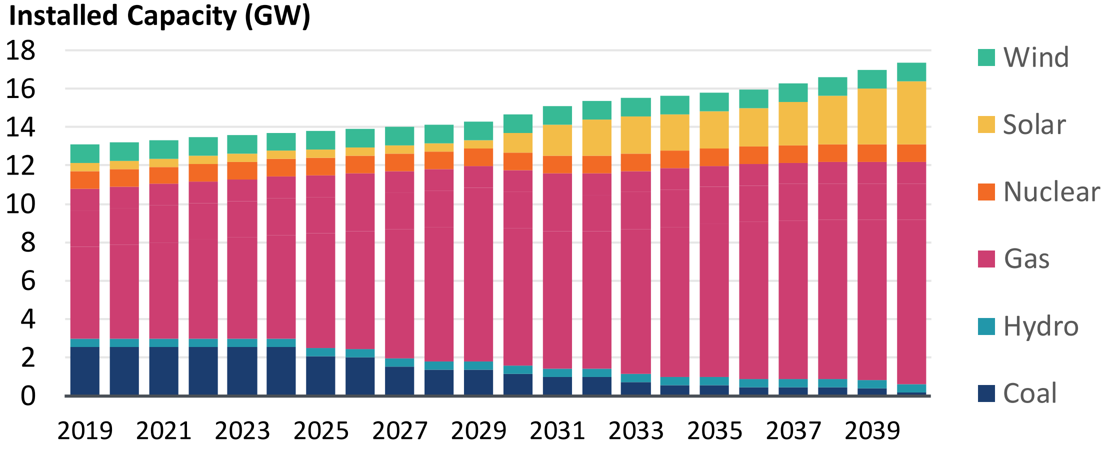
The analysis uses a prototypical Southeastern utility to illustrate the power system value of energy efficiency.

- The prototypical utility is defined using the characteristics of a variety of Southeastern utilities.
- Gas generation accounts for most of the system generation and capacity expansion.
- Some solar capacity is added as solar costs decline by 2030 and beyond.

MODELED GENERATION MIX EVOLUTION WITHOUT EE



MODELED CAPACITY MIX EVOLUTION WITHOUT EE



Note: See the Technical Appendix for details on assumed utility system conditions.

Energy efficiency measures analyzed

EE measure savings shapes are based on Duke Energy Carolinas weather locations inResStock to ensure consistency in the weather driving utility loads and EE shapes.

Smart thermostats are included as DR measures in the analysis.

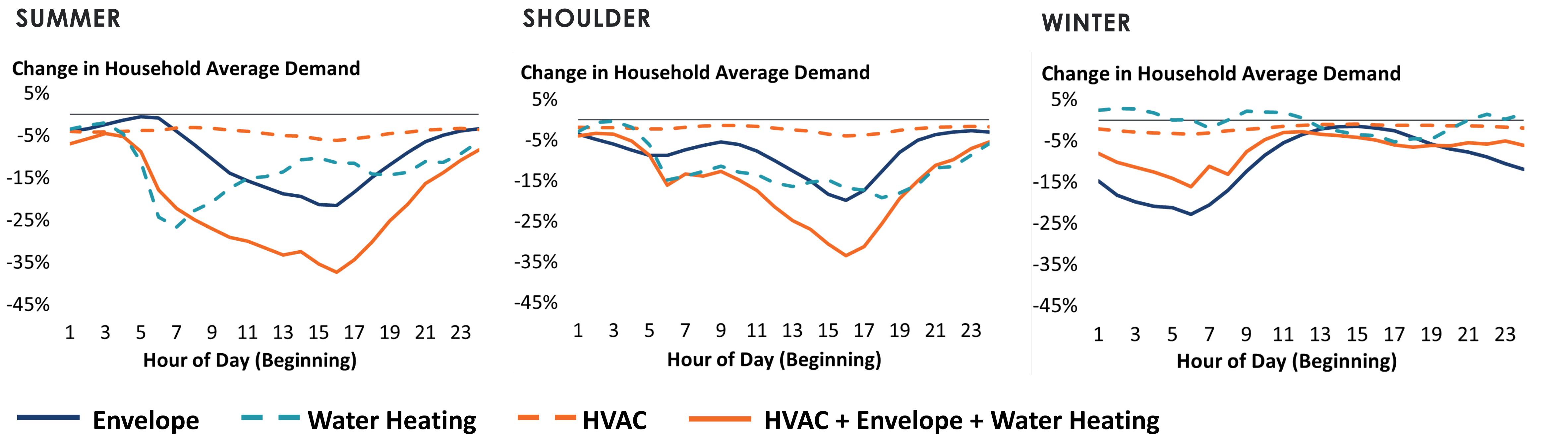
		EE Measures						
		Air Sealing	Attic Insulation	Windows	EE Heat Pump Water Heaters	DR Thermostat	EE CAC & ASHP*	Cool Roofs
EE Packages	Envelope	✓	✓	✓				✓
	Water Heating				✓			
	Thermostat DR					✓		
	HVAC						✓	
	HVAC + Envelope + Water Heating + Tstat	✓	✓	✓	✓	✓	✓	✓

* CAC = Central air conditioning, ASHP = air-source heat pumps

Note: See the Technical Appendix for additional EE measure detail, performance assumptions, discussion on EE measure selection and package definition, and a description of the NREL ResStock tool.

EE energy impacts

EE savings profiles are represented on an hourly basis. In some hours, the EE packages increase consumption relative to the baseline (though all packages decrease usage over the year).



Note: Energy savings profiles shown are a per-household average for all days of the season. Summer is June through August, winter is December through February, and shoulder is all other months.

Thermostat hourly modifiers not shown because the measure is modeled as a dispatchable DR resource.

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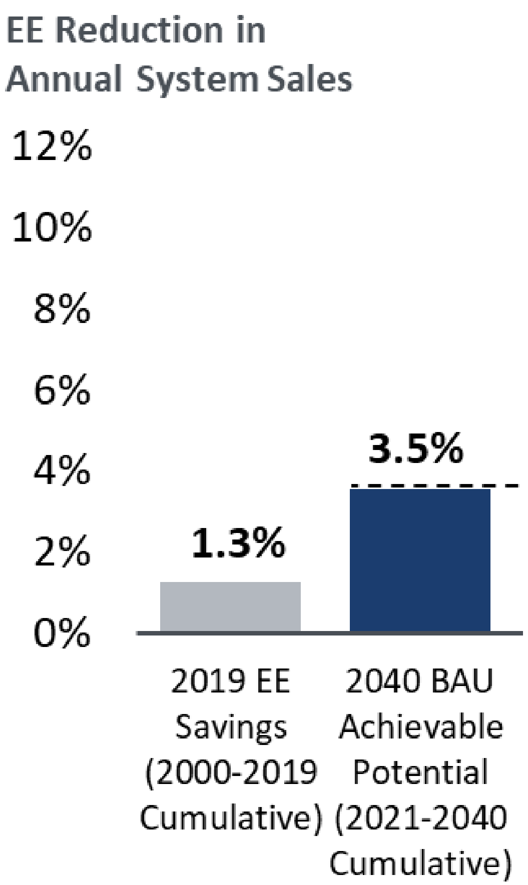
Business-as-usual achievable potential

ACHIEVABLE REDUCTION IN ANNUAL SYSTEM ENERGY SALES



Historical Savings

- In 2019, Southeastern utility energy efficiency programs deployed over the prior 20 years provided total annual system energy savings of 1.3%.
- This calculation is based on EIA-861 data. It sums incremental EE savings over 20 years, and expresses this sum as a portion of total 2019 Southeastern utility sales.

Business-as-usual savings potential

- Under business-as-usual (BAU) conditions, EE potential that could be achieved through utility programs is almost 3x higher than what has been achieved historically. As discussed previously in this report, this savings potential reflects a forward-looking estimate of cost-effective levels of EE development in a utility resource planning framework under typical system conditions.

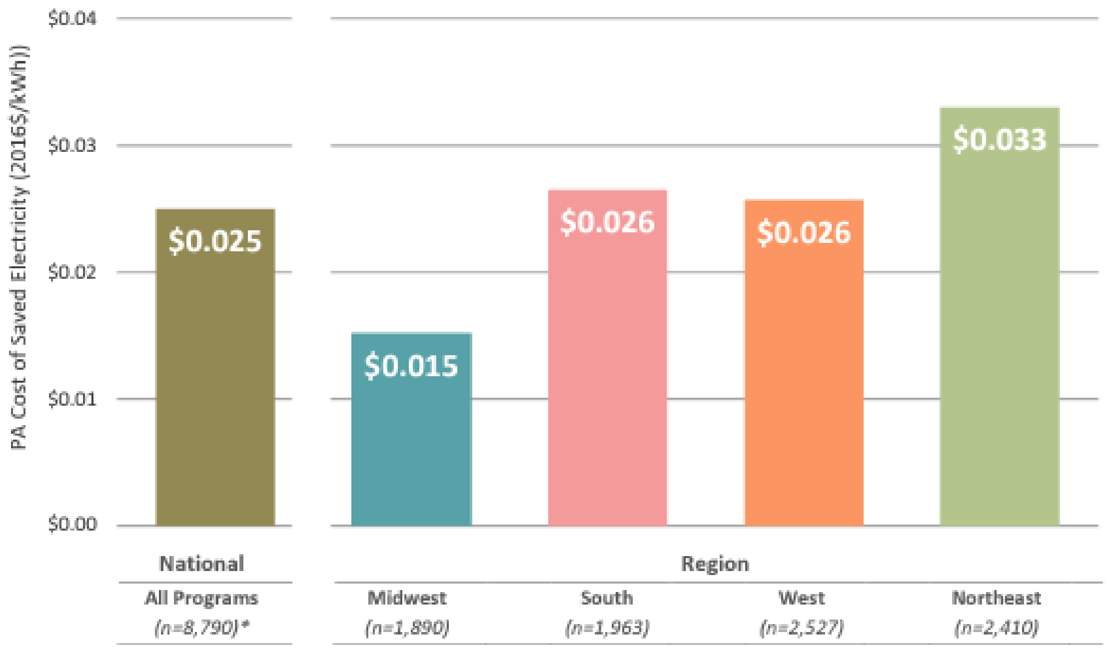
Defining the **EE Cost Reduction** scenario

The "EE Cost Reduction" scenario captures the impact of a reduction in EE program costs that could be attributed to developments such as technological breakthroughs, economies of scale, or initiatives such as increased research and development activity.

We assume a 40% reduction in EE program costs, based on a review of Berkeley Lab's analysis of energy efficiency program costs.

- The cost of saving electricity (CSE) varied significantly among U.S. Census regions ranging from a low of $0.015/kWh in the Midwest to $0.033/kWh in the Northeast.
- We assumed a 40% reduction in costs representing the approximate regional difference from the South (our region of focus) to the Midwest (lowest).
- While regional differences in EE costs could be driven in part by a different mix of adopted measures across the regions, we use this comparison as general support for the magnitude of cost reduction assumed in this scenario.

AVERAGE EE PROGRAM COST, BY REGION, 2009-2015

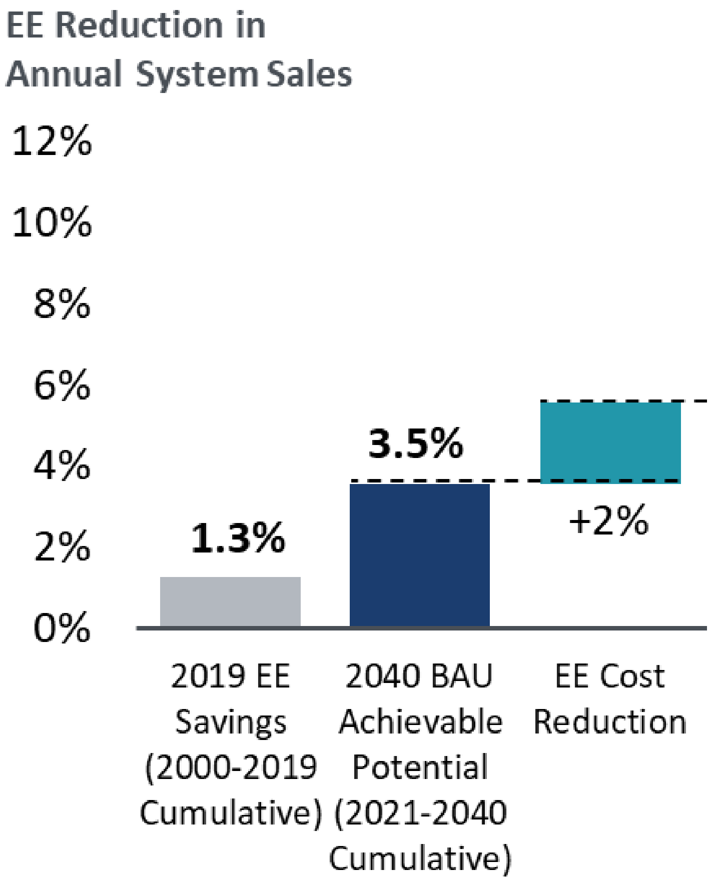


** The sample size for the full portfolio includes programs for which savings are not claimed but which support the efficiency activities of the program administrator (e.g., planning, research, evaluation and measurement). Costs for these programs are included in our calculation of PA CSE at the portfolio and market sector level.*

Source: Hoffman, I., Goldman, C., Murphy, S., Frick, N., Leventis, G., Schwartz, L. The Cost of Saving Electricity Through Energy Efficiency Programs Funded by Utility Customers: 2009–2015. 2018. https://emp.lbl.gov/publications/cost-saving-electricity-through

Impact of the **EE Cost Reduction** scenario

ACHIEVABLE REDUCTION IN ANNUAL SYSTEM ENERGY SALES



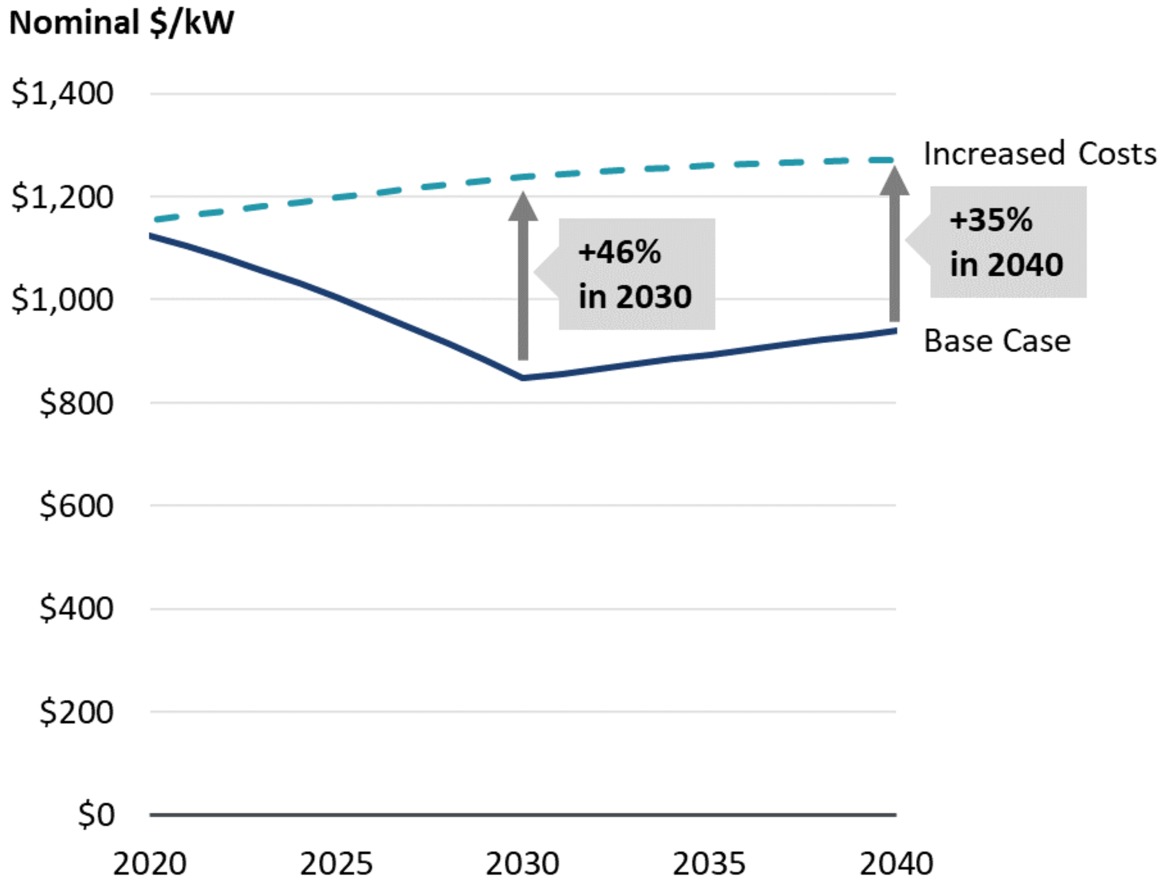
The 40% reduction in EE program costs results in EE becoming a more cost-competitive resource. Annual cost-effective energy savings potential increases to 5.5% as a result.

Defining the **Grid Cost Increase** scenario

The "Grid Cost Increase" scenario captures the impact of an increase in power system costs, which could be due to factors such as higher-than-anticipated fuel prices or labor costs, or materials shortages.

- **Wind and solar capital cost:** Increased costs consistent with the NREL Annual Technology Baseline (ATB) "Conservative" case assumptions (see figure at right).
- **Fossil generation capital cost:** Capital cost of new fossil generation is increased by 10%.
- **Fixed O&M cost:** Increased by 10% for all generation.
- **Natural gas price:** Natural gas fuel costs are increased by 20%.

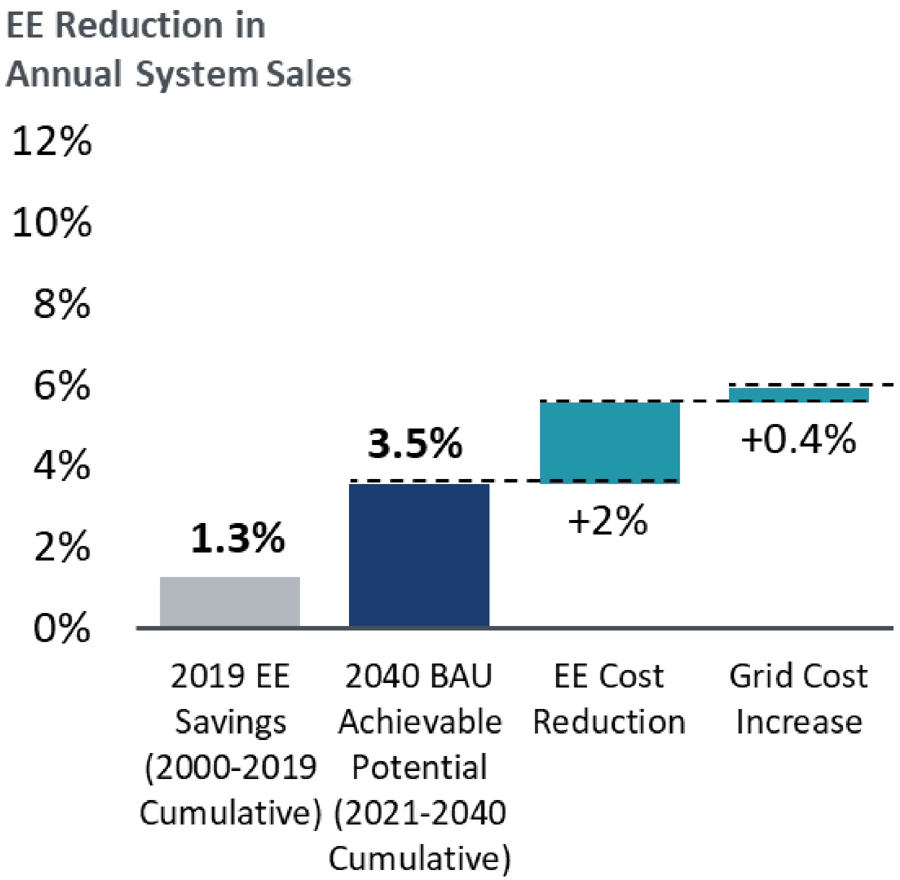
NREL ATB SOLAR CAPITAL COST PROJECTIONS, BY CASE



FINDINGS

Impact of the **Grid Cost Increase** scenario

ACHIEVABLE REDUCTION IN ANNUAL SYSTEM ENERGY SALES



Energy efficiency becomes more economically competitive due to the increased cost of generation resources. The increase in cost-effective EE is smaller than in the EE Cost Reduction scenario, primarily because the modeled EE cost reduction is larger than the modeled generation cost increase.

Defining the **Higher EE Adoption** scenario

The "Higher EE Adoption" scenario captures the impact of increased EE adoption at a given participation incentive level, which could be due to initiatives such as improved marketing and awareness campaigns.

- This scenario assumes that, all else equal, an increased share of eligible customers will adopt the EE measures.
- For example, whereas up to 30% of customers were assumed to adopt the envelope package at the highest available incentive level* in the BAU scenario, 50% would adopt the envelope package at that highest incentive level in the Higher EE Adoption scenario.
- The assumed increase in participation is derived from assumptions developed for DOE's *A National Roadmap for Grid-Interactive Efficient Buildings*, based on a review of various market research studies and EE potential studies.

** Refer to the Technical Appendix for more information on incentive assumptions.*

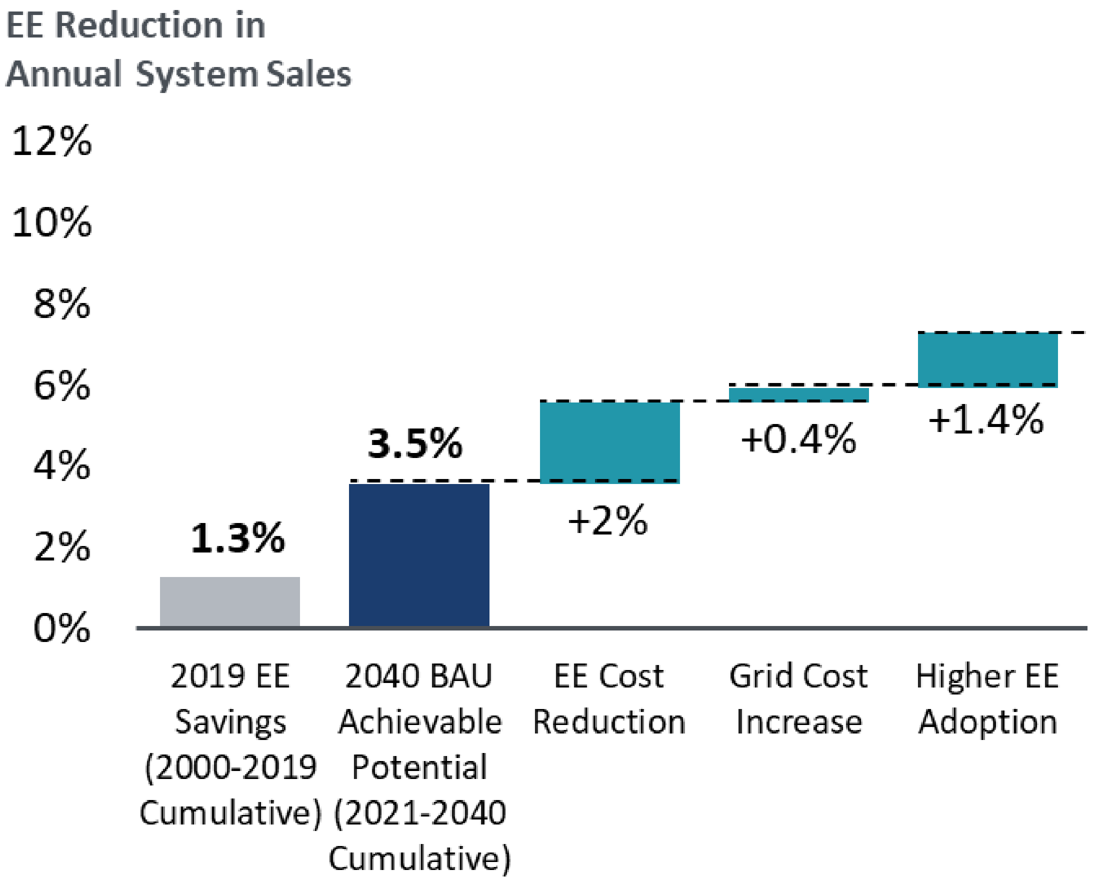
MAXIMUM ADOPTION RATES, BY EE PACKAGE

	BAU	Higher EE Adoption
Envelope	30%	50%
Water Heating	60%	80%
Thermostat DR	30%	50%
HVAC	50%	70%
Envelope + HVAC + Water Heating	60%	80%

Source: U.S. Department of Energy, A National Roadmap for Grid-Interactive Efficient Buildings, prepared by Berkeley Lab, The Brattle Group, Energy Solutions, and Wedgemere Group, May 2021.

Impact of the **Higher EE Adoption** scenario

ACHIEVABLE REDUCTION IN ANNUAL SYSTEM ENERGY SALES



Expanding the base of engaged customers through innovative means other than financial incentives (e.g., awareness campaigns, targeted marketing) can significantly increase overall EE impacts.

Defining the **Clean Energy Standard** scenario

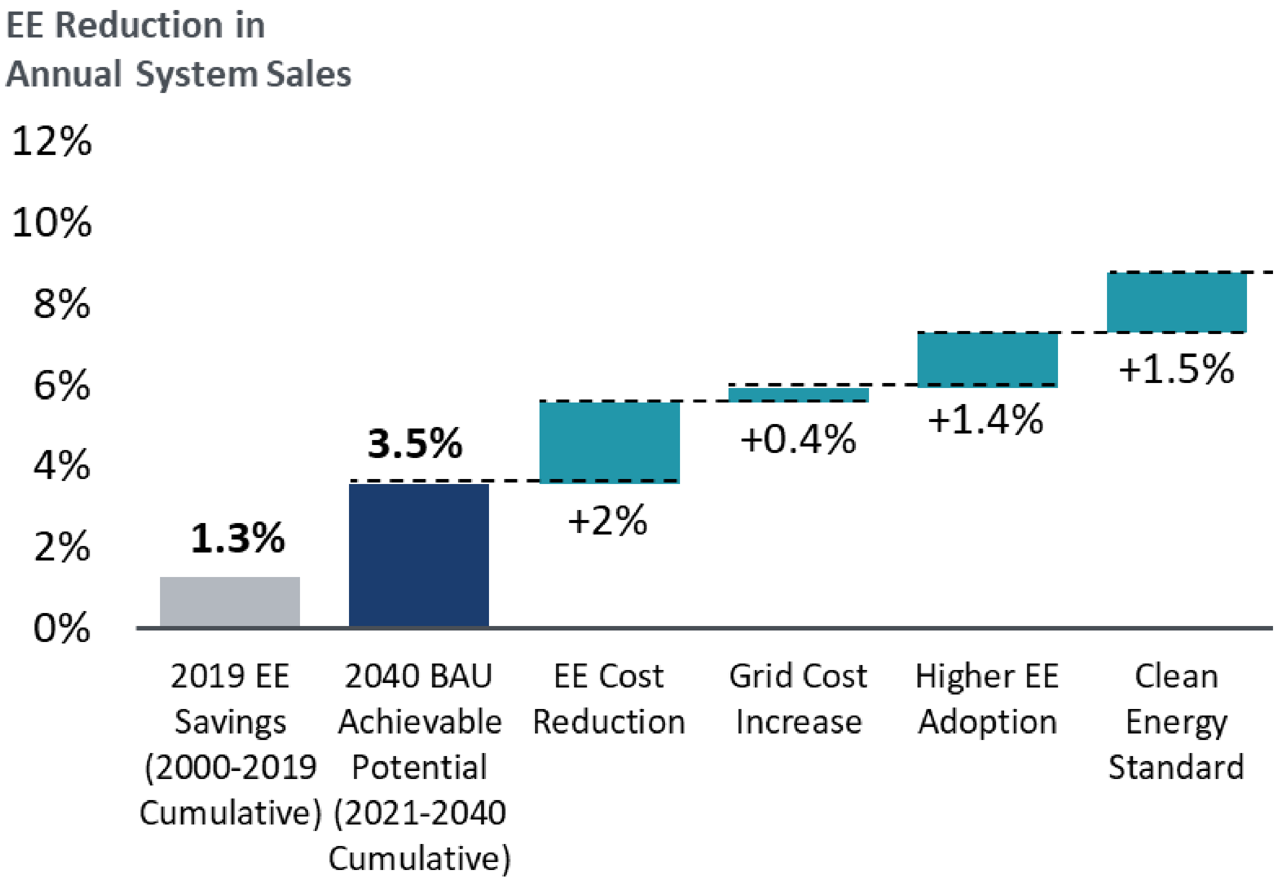
The "Clean Energy Standard" scenario captures the role that EE can play in satisfying a policy requirement for clean energy resources.

- We assume that a new clean energy standard is introduced, ramping up to 40% of generation from carbon-free sources by 2040 (which is consistent with the requirements of clean energy standards in some other U.S. states). EE savings count directly toward satisfying the requirement.
- While state-level RPS requirements are uncommon in the Southeastern U.S., many Southeastern utilities have announced deep decarbonization goals.

Southeast State	RPS Policy	Is EE Eligible?	Example Utility or State Decarbonization Goals
Alabama	None	-	Southern Company net-zero GHG emissions by 2050
Florida	None	-	NextEra 67% reduction in CO_2 emissions from 2005 levels by 2025
Georgia	None	-	Southern Company net-zero GHG emissions by 2050
Louisiana	None	-	Entergy net-zero carbon emissions by 2050
Mississippi	None	-	Southern Company net-zero GHG emissions by 2050
North Carolina	11.88% by 2021 (weighted-averaged of IOU and POU obligations)	Yes	Duke Energy net-zero CO_2 emissions by 2050
South Carolina	None	-	Dominion net-zero carbon emissions by 2050
Tennessee	None	-	TVA net-zero carbon emissions by 2050
Texas	MW requirement amounting to ~5% of electricity sales.	No	AEP, Entergy, Xcel net-zero carbon emissions by 2050
Virginia	100% by 2050	No	Dominion net-zero carbon emissions by 2050

Impact of the **Clean Energy Standard** scenario

ACHIEVABLE REDUCTION IN ANNUAL SYSTEM ENERGY SALES



Allowing EE savings to count directly toward the clean energy standard's requirements is a key driver of the significant impact of this scenario.

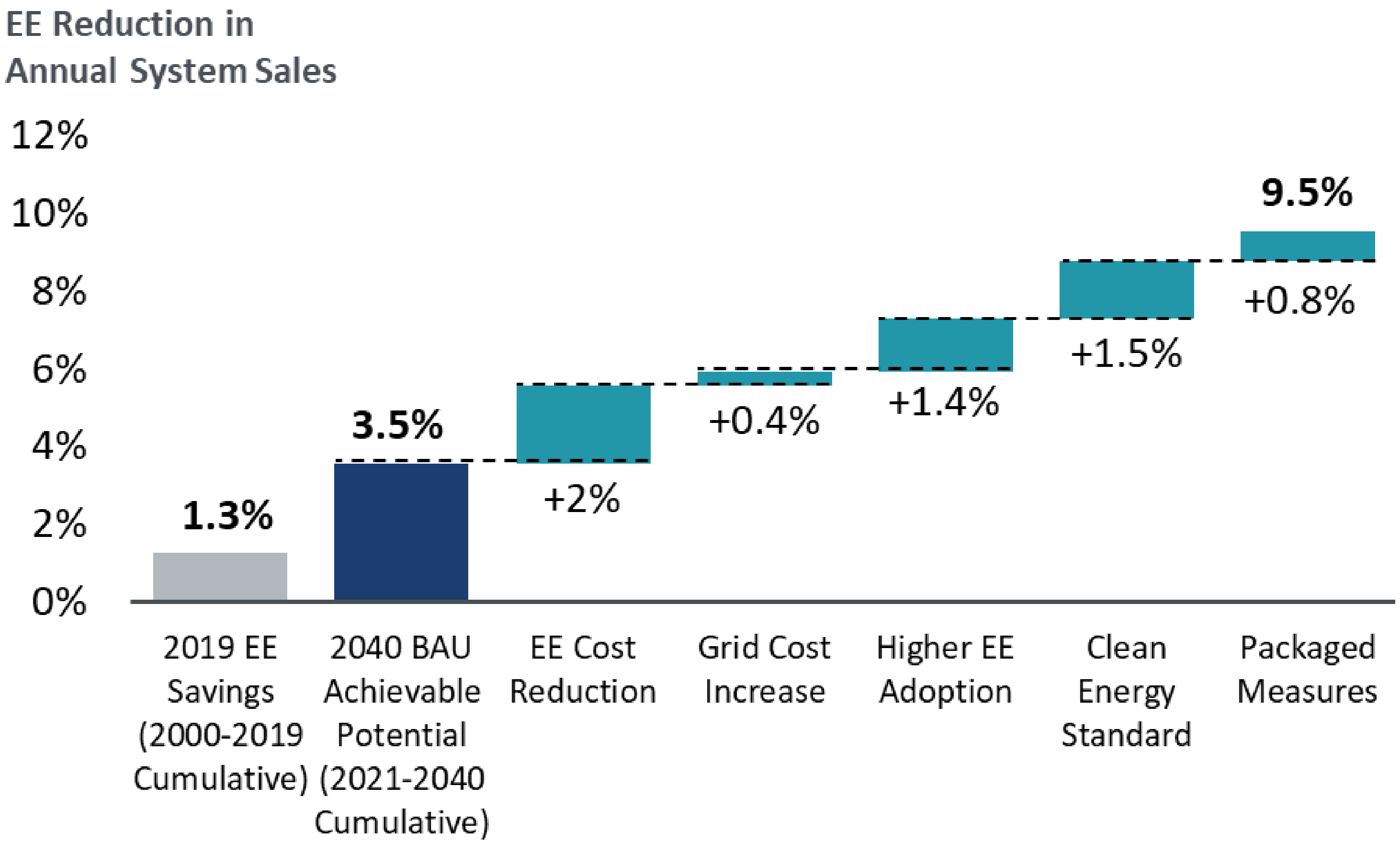
Defining the **Packaged Measures** scenario

The "Packaged Measures" scenario captures the potential for bundling and discounting EE packages to boost program participation and capture installation efficiencies.

- We used ResStock data to account for the energy savings interactions between HVAC, envelope, and water heating measures when combined into a package (e.g., envelope measures improve thermal efficiency and reduce the incremental impacts of HVAC measures when considered in combination).
- To capture the maximum potential benefit of measure packaging, we assumed that the package would be adopted at the highest achievable participation assumed for any of the individual measures.
- We assumed that the levelized cost of saved electricity for the package is equal to the lowest of any individual measure, to account for the cost savings associated with installing the measures together.
- In general, there is limited empirical information available on the costs, benefits, and customer interest in EE packages; this area needs further research.

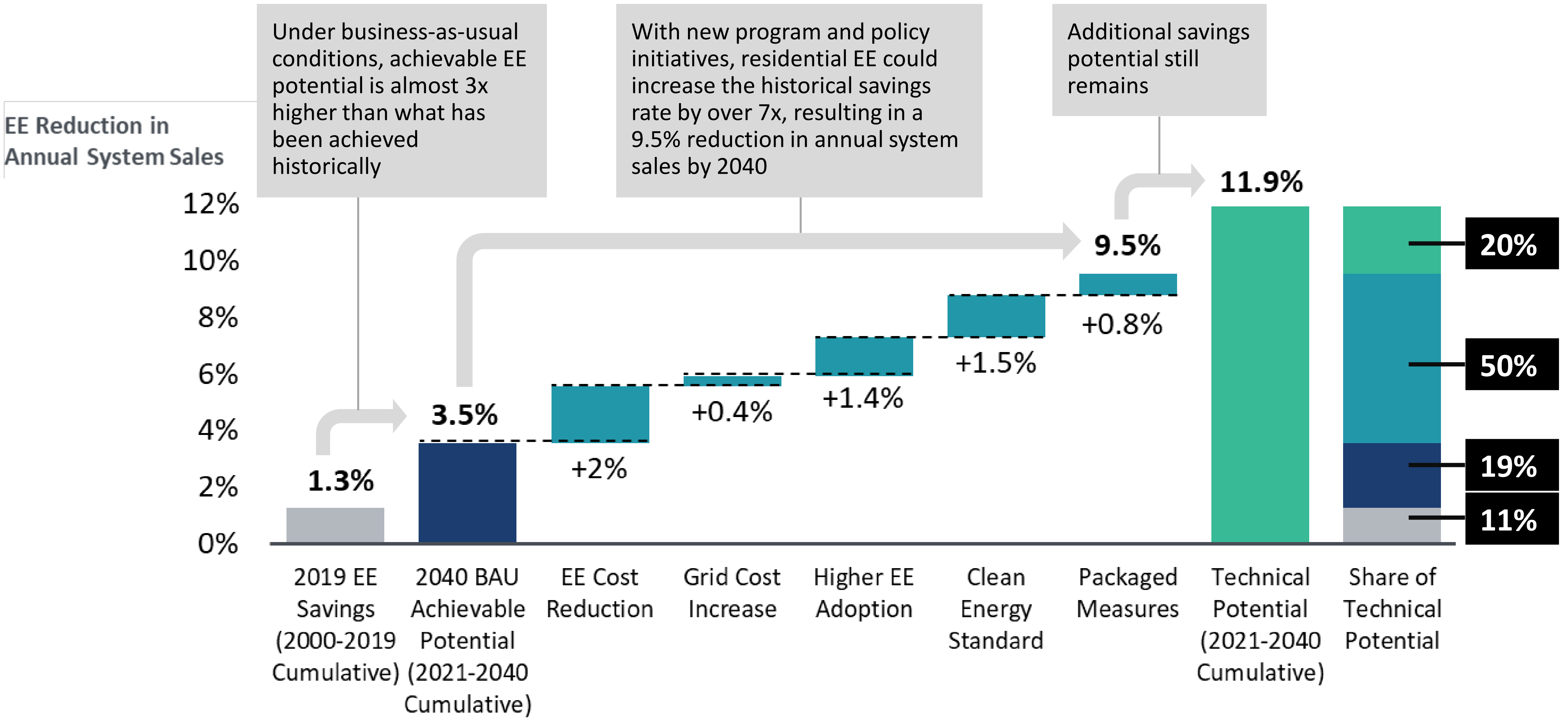
Impact of the **Packaged Measures** scenario

ACHIEVABLE REDUCTION IN ANNUAL SYSTEM ENERGY SALES



While interactions can decrease the energy savings contributions of individual measures in a package, cost savings and/or increased adoption potentially could more than offset this effect, resulting in a net increase in system energy savings.

Achievable reduction in annual system energy sales
For a prototypical Southeastern utility, residential EE only



Four-fifths of technical potential could be captured if all new program and policy initiatives were implemented

Note: Cumulative EE reduction in system annual sales may be different from component values due to rounding.

Energy efficiency “scorecard”

MODELED RESIDENTIAL ENERGY EFFICIENCY IMPACTS, 2021-2040

	Business-as-Usual Scenario	With All Policy Initiatives
Energy savings	3.8% reduction in total system sales (11.3% of residential sales)	10.4% reduction in total system sales (30.6% of residential sales)
Avoided CO_2 emissions	17 million tons (4.9% of total power sector emissions)	86 million tons* (24.9% of total power sector emissions)
Retired coal capacity	2,532 MW (About five medium-sized coal plants)	2,532 MW* (About five medium-sized coal plants)
Power generation cost savings	$1,025 million, NPV (4.8% of total power system cost)	$4,759 million, NPV† (17.7% of total power system cost)

* Effects attributable to combined impact of energy efficiency and renewable generation required by clean energy standard. All coal capacity is retired in BAU scenario, so there are no further increases in coal retirements associated with additional policy initiatives.

† Reference generation cost includes grid cost increases and clean energy standard.

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Key insights

EE is a cost-effective resource

- For the prototypical Southeastern utility analyzed in this study, a limited portfolio of residential EE measures could reduce system energy consumption by 3.8% per year, and save roughly $1 billion (NPV) in resource costs under BAU cost and participation assumptions by 2040.
- Implementing all the program and policy initiatives considered would increase annual energy savings 2.7x and deliver ~$3.7 billion (NPV) in additional power system cost savings.

Reducing utility EE program costs and/or higher program participation are among the most impactful initiatives

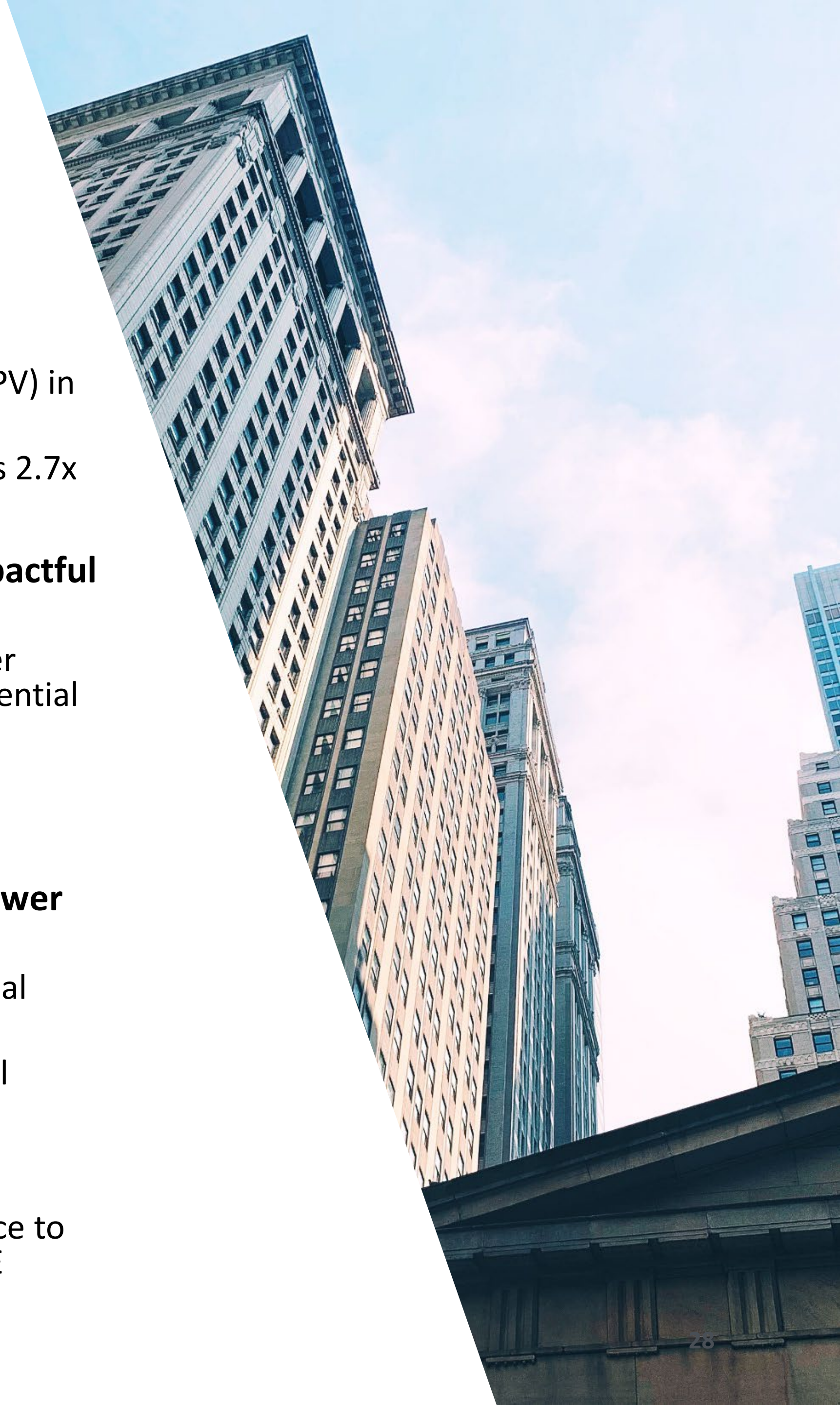
- Initiatives that lower EE costs (e.g., R&D activities) and increase program participation (e.g., customer education, more effective contractor channels) resulted in the largest increase in cost-effective residential EE.
- The two initiatives may complement each other as lower EE costs are likely to drive greater program participation.

Utility resource planning tools can be used to assess the value of residential EE to the utility power system

- Publicly available tools, like Berkeley Lab's Time-Sensitive Value (TSV) Calculator, can be used for initial screening of high value EE measures that are then modeled within resource planning tools.
- Additional analysis outside of the traditional resource planning framework can account for additional incremental EE benefits such as deferred investment in distribution system upgrades

Packaging EE measures is under-explored

- While many of the interactions with energy savings can be estimated, there is little empirical evidence to inform whether measure packages are cheaper and/or more likely to be adopted than standalone EE measures.



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