Increasing the Economic Potential of Residential Energy Efficiency as a Utility Grid Resource

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Motivation and scope

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 and what new program and policy initiatives could access it

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

The analysis focuses specifically 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 LBNL's Cost of Saving Electricity database

Key study boundaries

This analysis does…	***This analysis does NOT…***
Identify the amount of each EE measure that is cost-effective from the **utility's** perspective	Identify cost-effective EE from the participating or non-participating **customer** perspective
Assess a range of common standalone residential EE measures and a packaged grouping that may be offered by utilities	Model numerous EE measures with different performance assumptions and grouped into many possible packages for program delivery
Characterize a vertically-integrated utility generally representative of Southeastern loads and resources	Evaluate a broad range of utilities, alternative future grid scenarios, and uncertainty in EE assumptions

GridSIM model framework

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

Transmission

- Zonal and intertie limits

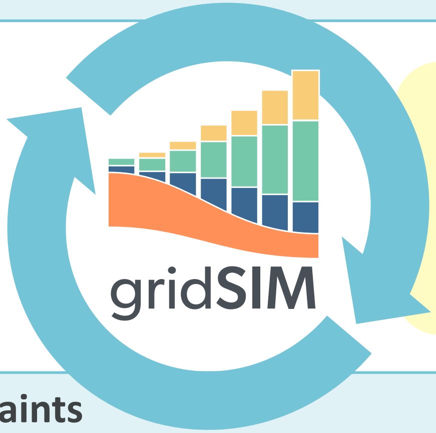
Regulations, Policies, Market Design

- Carbon pricing
- State energy policies and procurement mandates

GridSIM OPTIMIZATION ENGINE

Objective Function

- Minimize NPV of Investment & Operational Costs



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
- Transmission Constraints

OUTPUTS

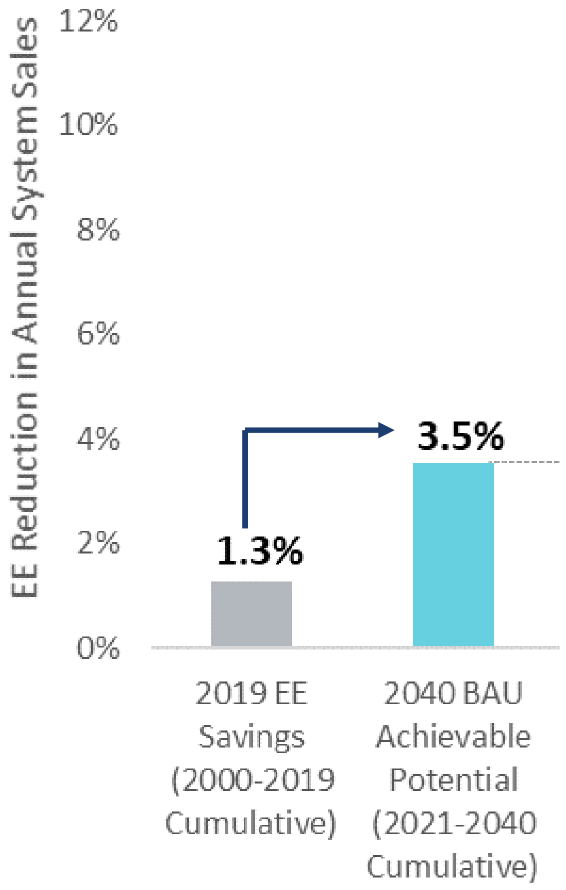
- **Annual Investments and Retirements (incl. EE)**
- **Hourly Operations**
- **Supplier Revenues**
- **System and Customer Costs**
- **Prices**
- **Emissions and Clean Energy Additions**

Energy efficiency measures analyzed

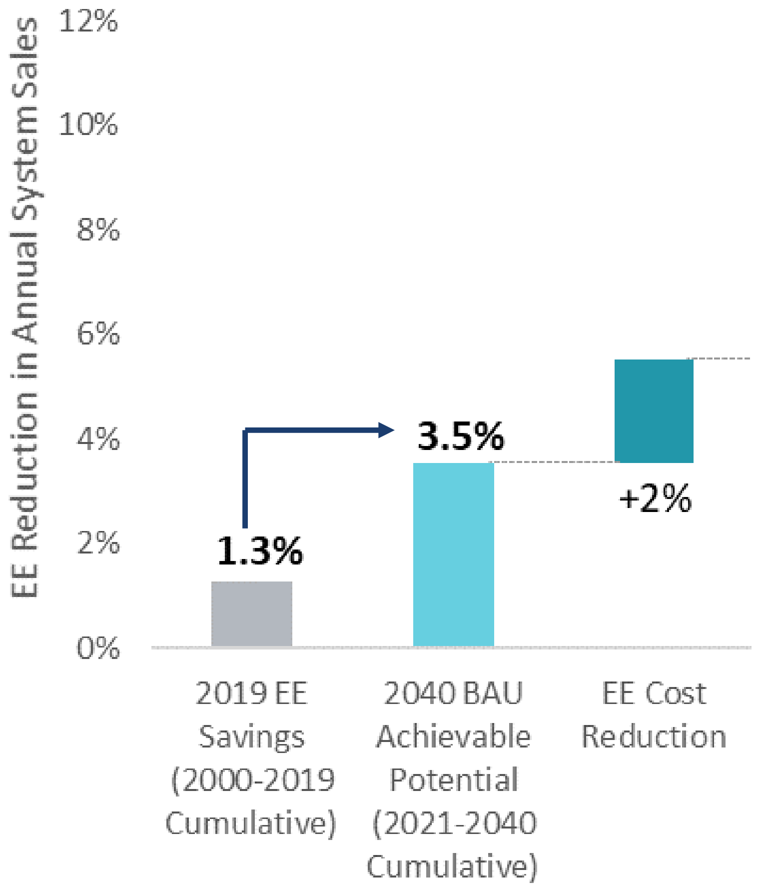
- EE measure shapes based on Duke Energy Carolinas weather locations in ResStock to ensure consistency between weather driving utility loads and EE shapes
- Smart thermostats are included as DR measures in the analysis

		EE Measures						
		Air Sealing	Attic Insulation	Windows	EE HPWH	DR Thermostat	EE CAC & ASHP	Cool Roofs
EE Packages	Envelope	X	X	X				X
	Water Heating				X			
	DR Thermostat					X		
	HVAC						X	
	Comprehensive	X	X	X	X	X	X	X

Under business-as-usual (BAU) conditions, achievable EE potential is almost 3x higher than what has been achieved historically



Relative to BAU, EE measure costs are reduced by 40% (e.g., through technological advancements, R&D activities)



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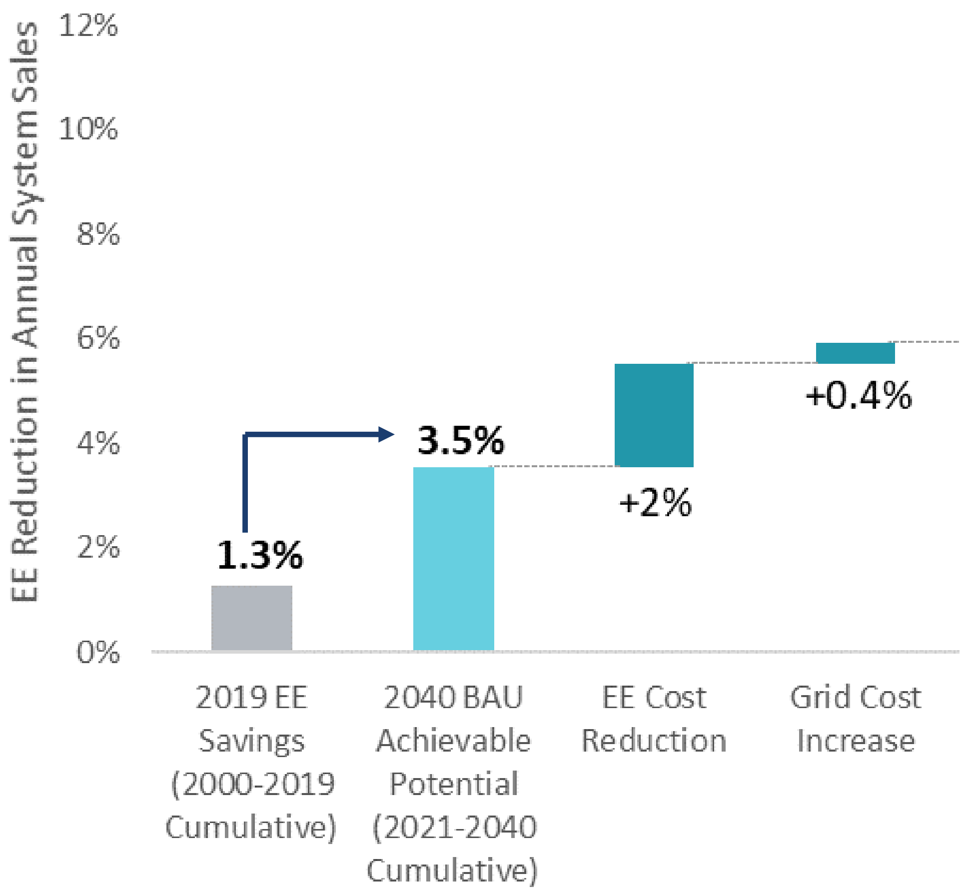
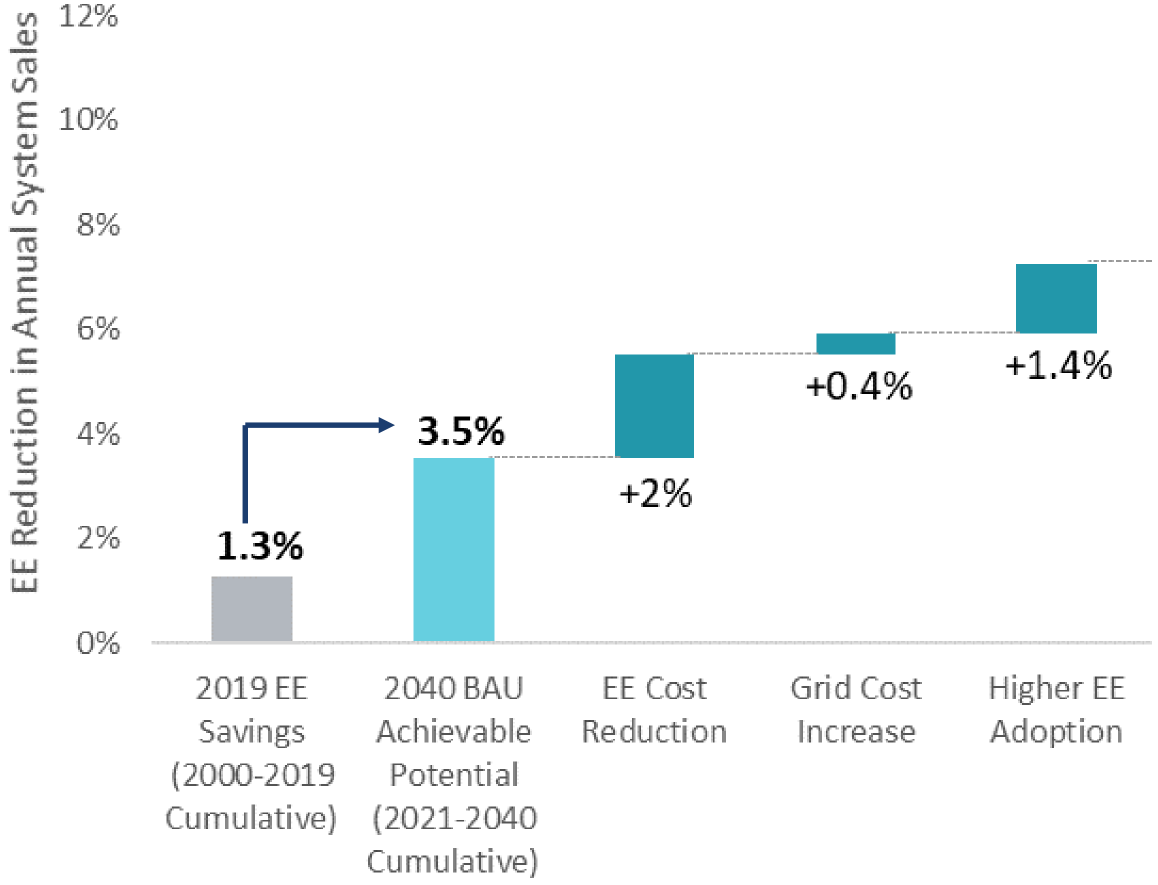
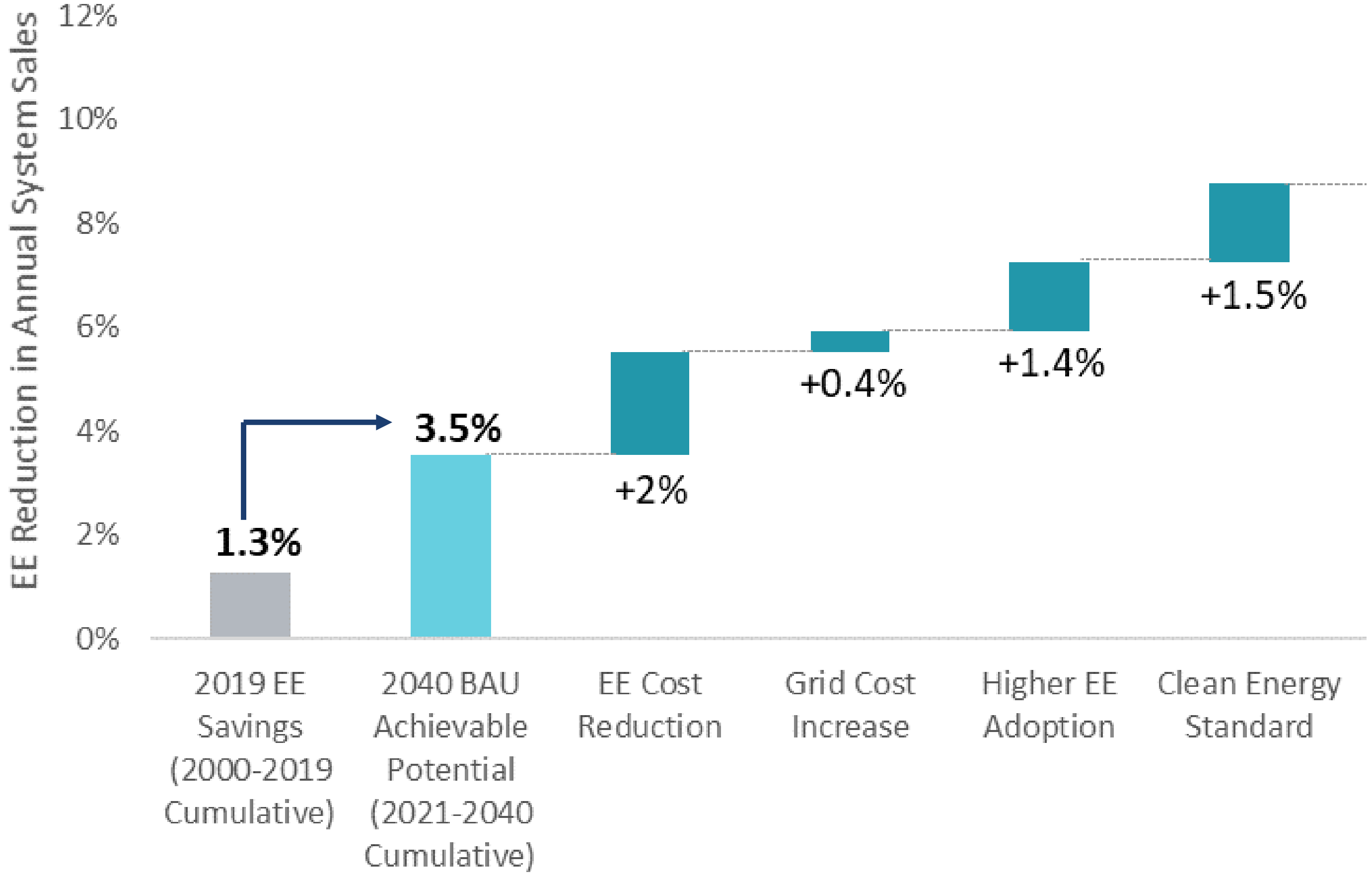
Relative to BAU, power system costs are higher (e.g., due to higher-than-anticipated fuel prices or labor costs, or materials shortages)



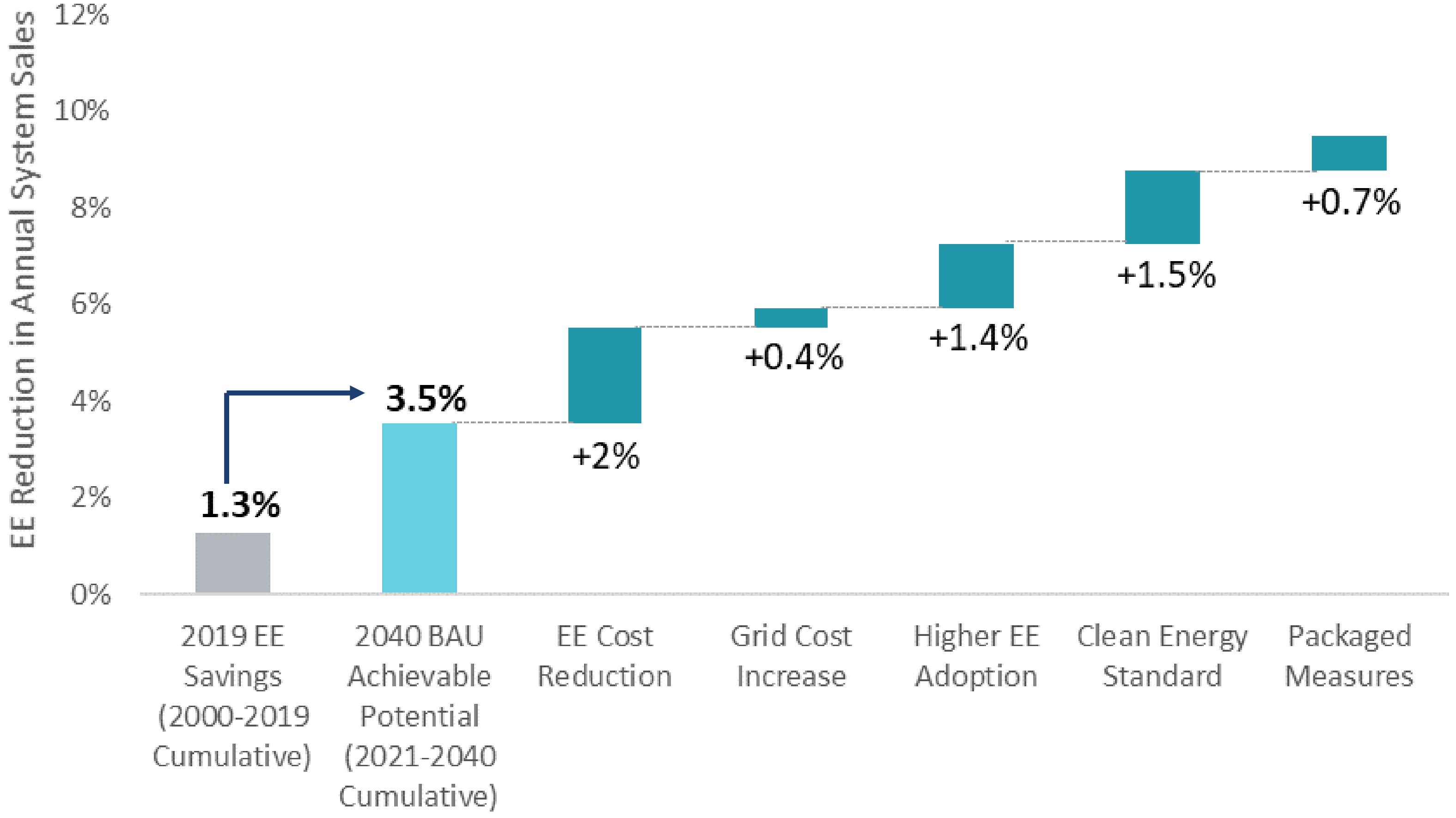
Relative to BAU, customer adoption of EE measures is higher (e.g., due to improved marketing/awareness campaigns)



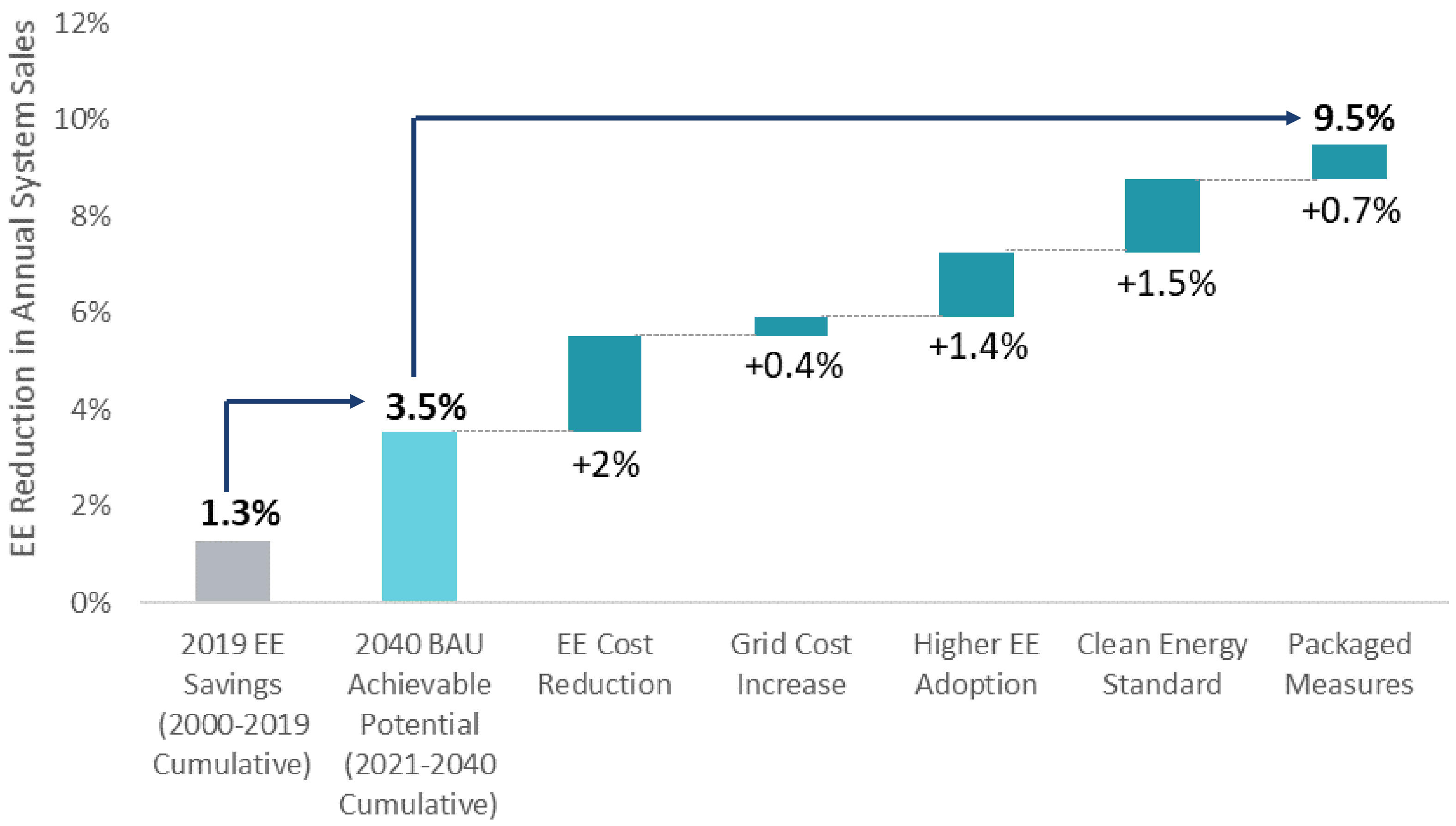
A clean energy standard is introduced, ramping up to 40% of generation from carbon-free sources by 2040



Measures are offered to customers as a package rather than a la carte



With new program and policy initiatives, residential EE could increase the historical savings rate by over 7x, resulting in a 9.5% reduction in annual system sales by 2040



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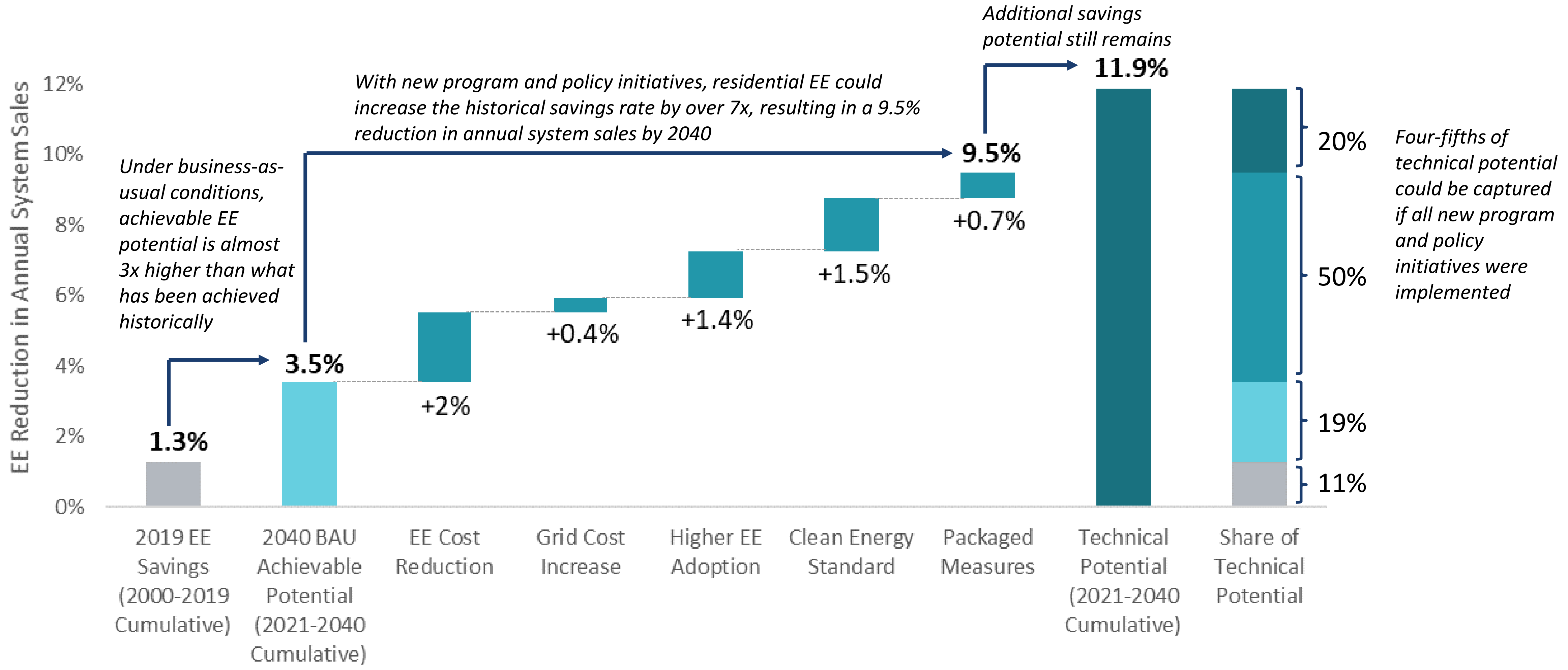
Achievable reduction in annual system energy sales

For a prototypical Southeastern utility, residential EE only



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)	84 million tons* (24.3% 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)	$4,458 million, NPV† (16.6% 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.

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 3.5% 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 ~$3.4 billion (NPV) in additional power system cost savings.

Reducing utility EE costs and/or higher program participation are 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.

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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The analysis quantifies achievable, cost-effective EE potential under several scenarios

Scenario	Description	Assumptions/sources
Historical residential EE savings	Provided only for context, represents the historical annual residential energy savings achieved by utility EE programs in the Southeastern U.S.	Cumulative residential annual savings for all utilities in Southeastern states for 2000-2019, divided by total 2019 residential sales for those utilities, according to EIA-861
BAU achievable potential	Utility cost-effective, achievable EE potential under average assumptions about measure costs, customer adoption, and grid characteristics	Brattle's GridSIM model is used to project cost-effective levels of EE development in a utility resource planning framework.
EE Cost Reduction	Relative to BAU, EE measure costs are reduced by 40% (e.g., through technological advancements)	Based on literature review and ranges of observed EE measure costs from LBNL Cost of Saving Electricity database
Grid Cost Increase	Relative to BAU, power system costs are higher (e.g., due to higher-than-anticipated fuel prices or labor costs, or materials shortages)	Renewables capital costs are increased to costs in the NREL ATB "Conservative" case; capital cost of new fossil generation is increased by 10%; fixed O&M cost of all generation is increased by 10%; natural gas fuel costs are increased by 20%
Higher EE Adoption	Relative to BAU, customer adoption of EE measures is higher (e.g., due to improved marketing/awareness campaigns)	EE adoption rates based on GEB Roadmap "high adoption" case: - Envelope: 30% --> 50% - HVAC: 50% --> 70% - Thermostat: 45% --> 60% - Water Heating: 60% --> 80%
Clean Energy Standard	A clean energy standard is introduced, ramping up to 40% of generation from carbon-free sources by 2040.	Assumption based on national review of RPS requirements. EE qualifies as clean resource; savings count directly toward requirement
Packaged Measures	Measures are offered to customers as a package rather than a la carte	Measure interactions from ResStock. Package cost per unit of saved energy assumed equal to lowest cost standalone measure. Adoption of package can reach highest rate of adoption from standalone measures
Technical Potential	Provided only for context, assumes 100% participation among eligible customers in all measures modeled	N/A

Residential EE Measure Performance Levels

Air Sealing	• 25% air leakage reduction applied from current ACH50 levels
Attic Insulation	• Insulate vented attics to R-49, reduce duct leakage to 10%, and all ducts located in attic insulated to R-8
Windows	• Windows with U-factor 0.27 and SHGC 0.2
EE HPWH	• ENERGY STAR Heat Pump Water Heater (EF 2.4, 80 gallon)
Thermostat	• Simulate dispatch to curtail load during limited number of events per year. All curtailed load assumed to be offset with pre-cooling
EE CAC and ASHP	▫ Central AC CEE Tier 2 (SEER 16, 1 stage) ▫ ASHP CEE Tier 2 (SEER 16 HSPF 9.0)
Cool Roofs	▫ Properties derived from BEopt database using “light” materials, by roofing type (data originally sourced from FSEC publication) and all roofing material types are ENERGY STAR qualified

Source: LBNL summary of NREL modeling assumptions.

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