U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Quadrennial Technology Review: Appliances and Equipment

U.S. Department of Energy

Executive Summary

The DOE deploys energy efficiency using three strategies that build a self-reinforcing efficiency ecosystem

- Research and develop new technologies
- Prime the market for technology adoption
- Use codes and standards to “clean up”

Buildings account for over 40% of energy consumption with meaningful opportunities for reduction through enduse-specific and cross-cutting opportunities; we present these opportunities viewed on four horizons

- Deploy today’s technology
- Research emerging technologies
- Advance cross-cutting components
- Explore not-in-kind advances

Deploying today’s technology can save 20-45% of our energy use

Researching emerging technologies offers considerable benefits in major end-uses (HVAC, misc. electric loads, lighting, and water heating) and minor end-uses

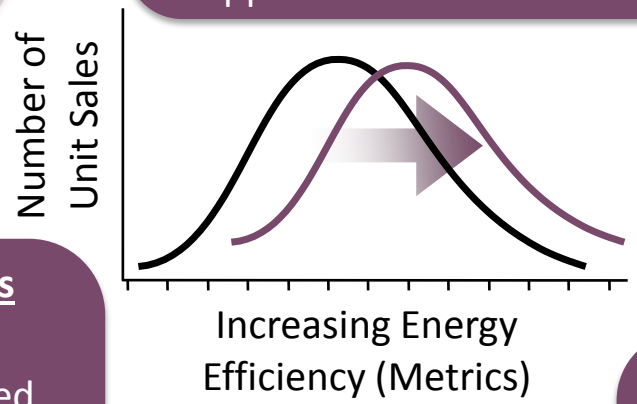
Advancing cross-cutting components provides savings in many end-uses through insulation, heat exchangers, motors, DC electronics, and working fluids

Exploring not-in-kind advances can provide dramatic changes in cooling, lighting, refrigeration, displays, and other areas

DOE deploys energy efficiency using three strategies that build a self-reinforcing efficiency ecosystem

R&D

- Advance innovative technologies for appliances, equipment, and products
- Integrated buildings approaches



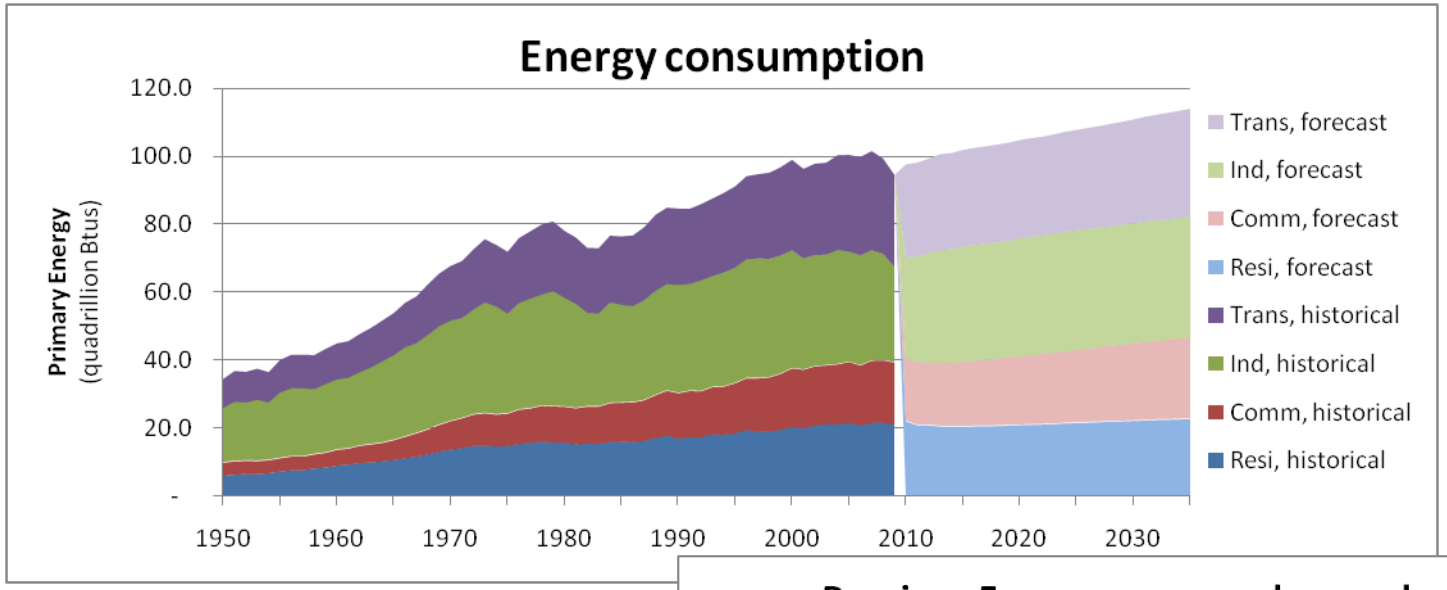
Codes & Standards

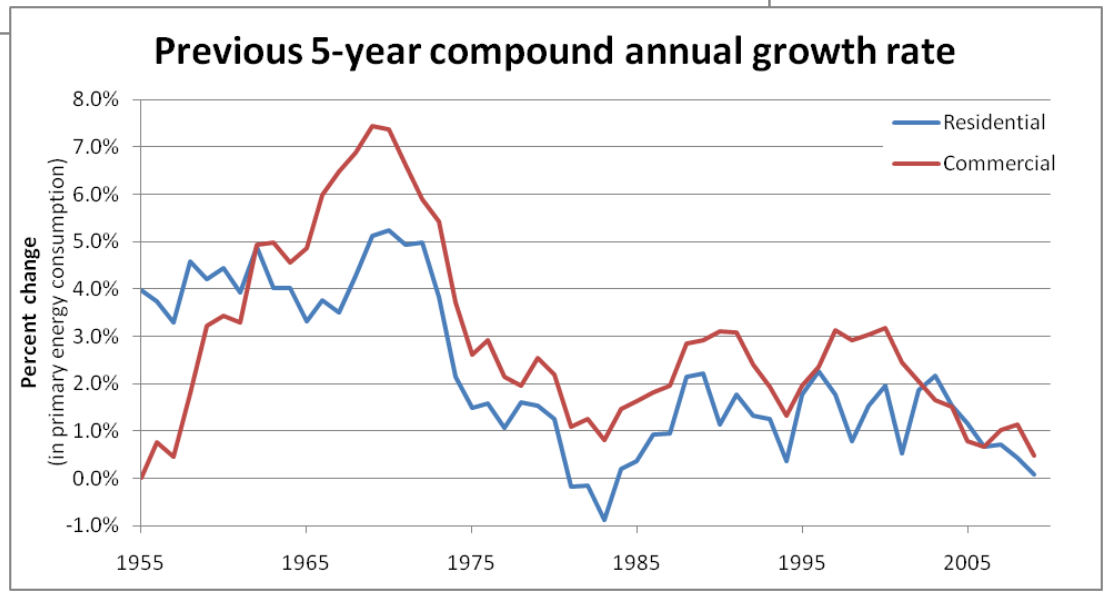
- Leverage market priming and advanced technologies
- Broaden coverage and update frequently to capture savings opportunities

Market Priming

- Pull new products, practices and services into market faster at scale
- Technical support to ENERGY STAR / new higher tier

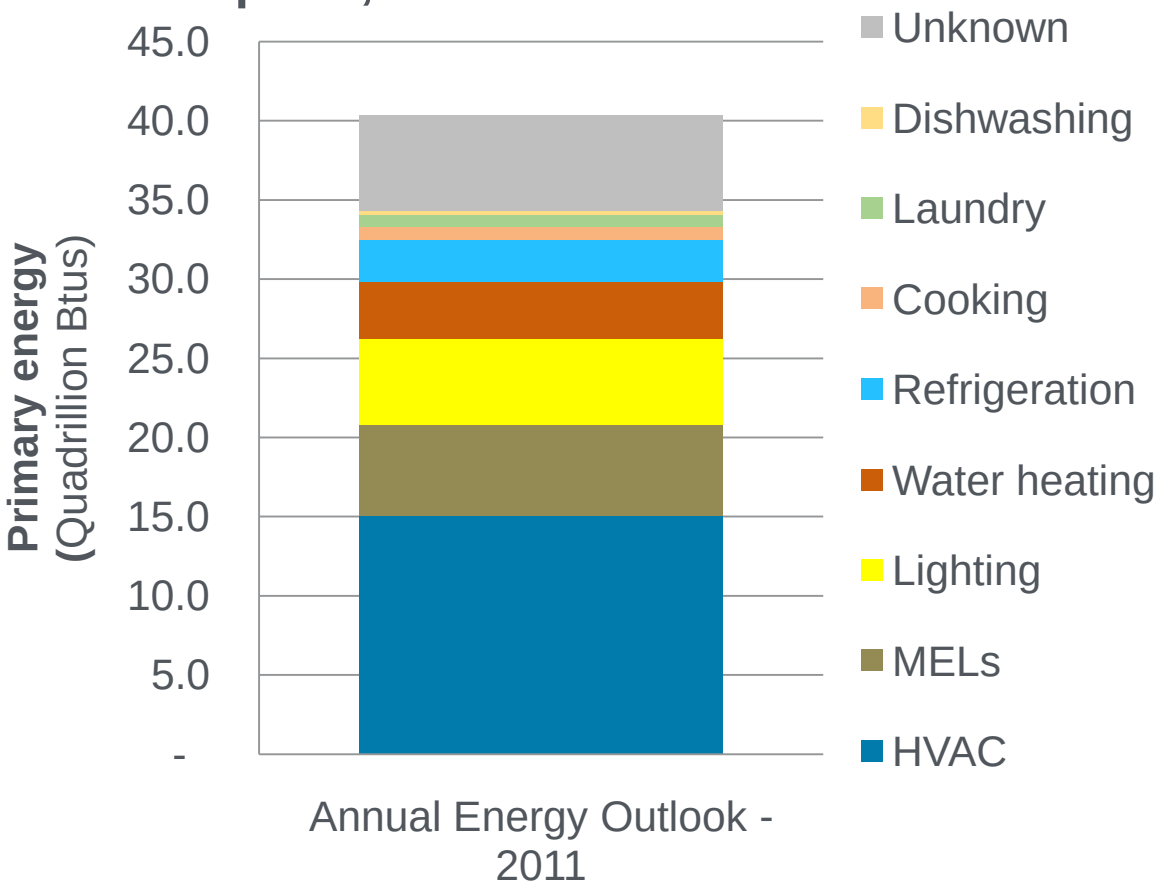
…this energy use has grown overtime, but that growth is slowing





75% of today's energy consumption comprises four major end-uses with minor/unknown uses composing the balance

Residential and commercial building energy consumption, 2010

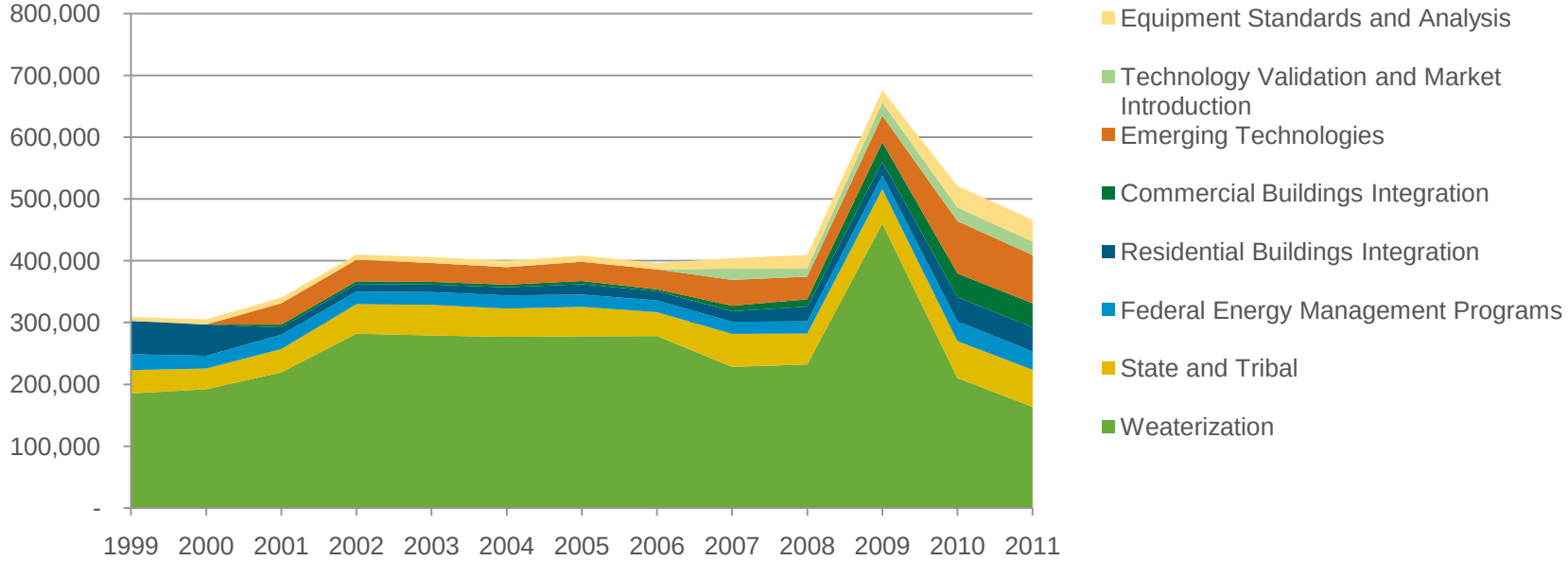


Minor or unknown end-uses: Offer energy savings opportunity but widely considered lower priority than major end-uses

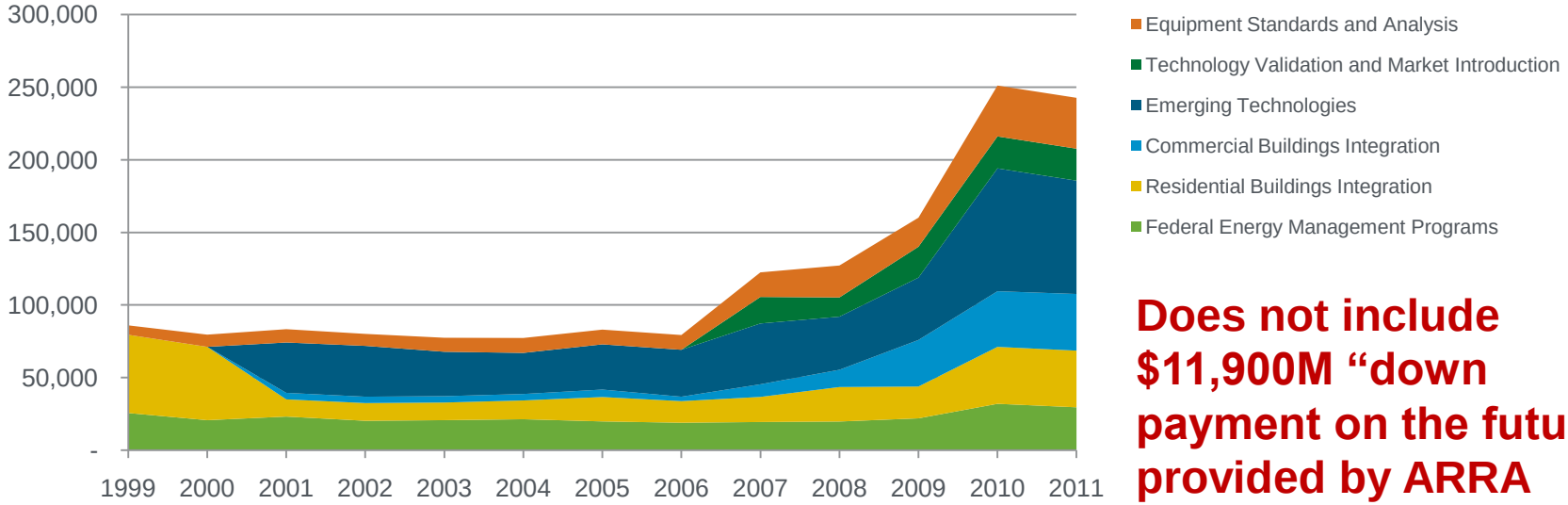
HVAC (Heating, ventilation, and air-conditioning), misc. electric loads (MELs), lighting, and water heating: the major end-uses representing 75% of today's building energy use

Building related funding has grown considerably over the past five years

Weatherization funding has traditionally dominated

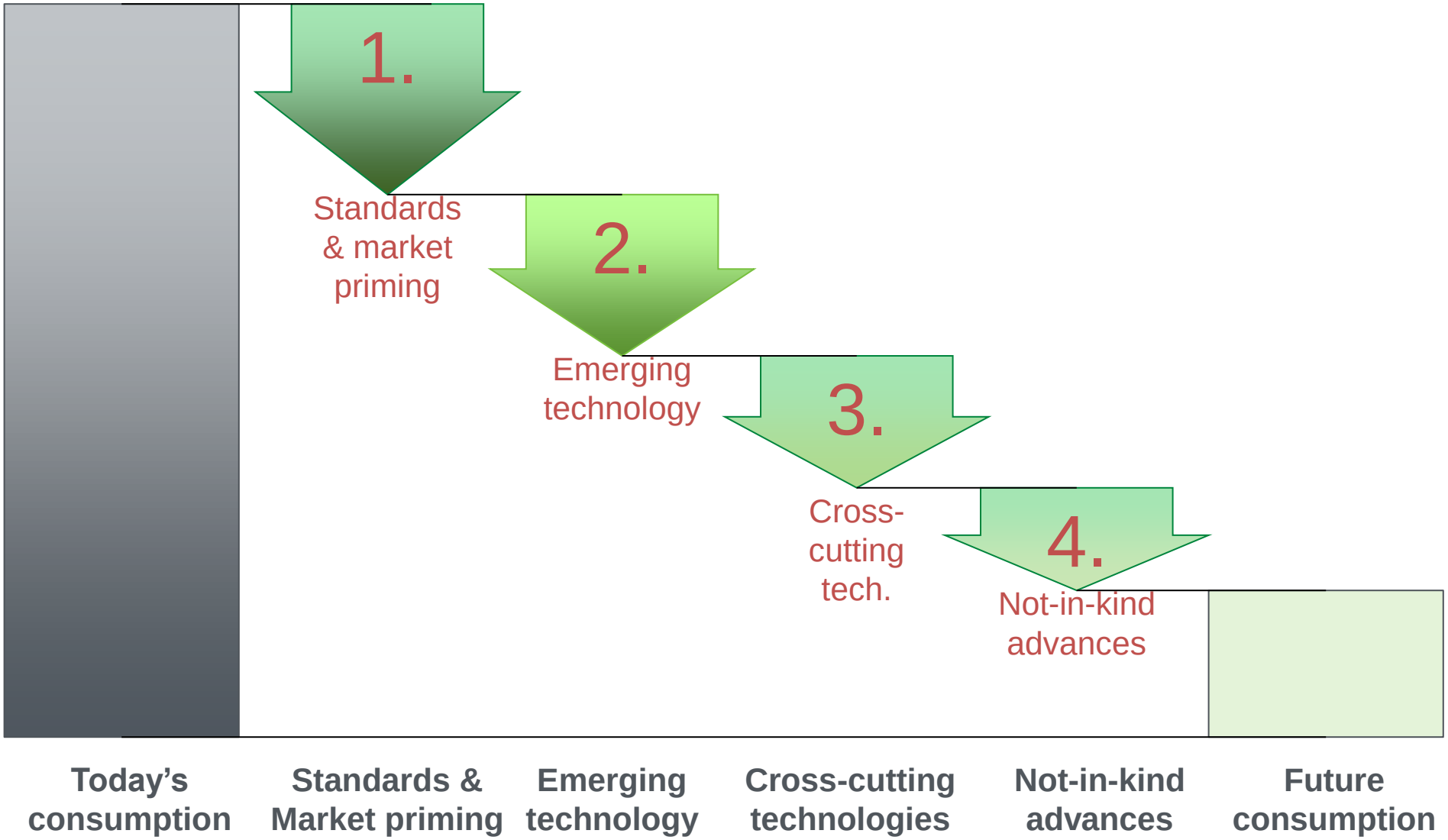


BTP funding has more than doubled in the past five years



Does not include $11,900M "down payment on the future" provided by ARRA

Four horizons exist and require unique technology approaches to reduce energy consumption (1 of 2)



Four horizons exist and require unique technology approaches to reduce energy consumption (2 of 2)

1. Deploy today's technology
- Includes market priming, appliance standards, and building codes
- Includes OWIP, FEMP, and BTP activities
- Presents significant benefits today

2. Research emerging technologies
- Represents the majority of BTP emerging technology spending
- Develops next generation of technology to deploy and standardize
- Provides benefits in near-term*

3. Advance cross-cutting component technologies
- Includes ARPA-E and to a lesser extent BTP research
- Provides benefits to multiple technologies
- Requires alignment to technology and use-specific research as research advances
- Can provide benefits in near- to mid-term

4. Explore not-in-kind advances
- Includes research topics in the purview of ARPA-E and the Department of Science
- Represents higher-risk opportunities
- Requires high potential reward to justify risk
- Provide benefits mostly in the mid- to long-term

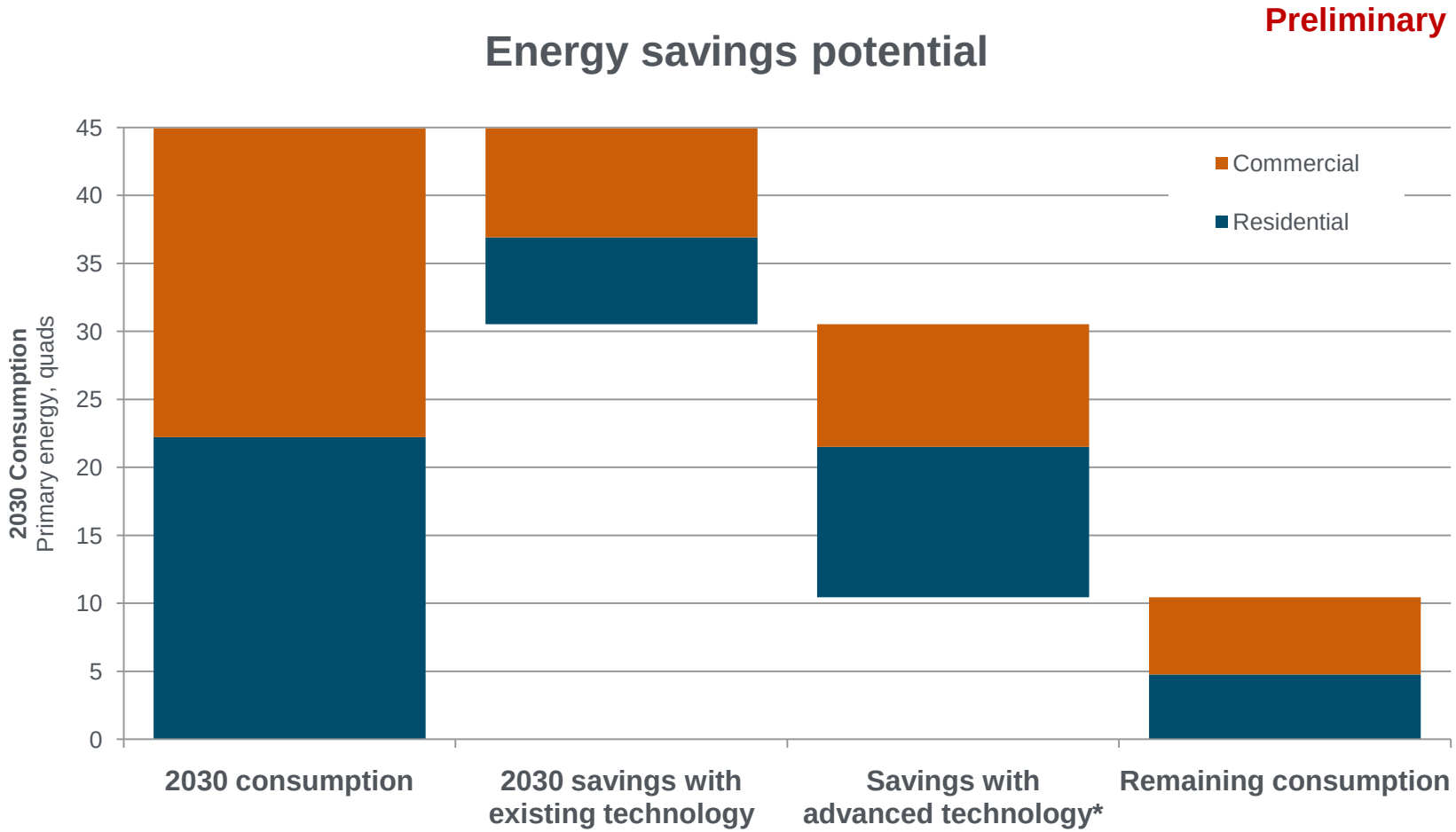
*** As per the QTR Framing document near-term is 0-10 years (i.e., impact in 2020) and mid term 10-20 years (i.e. impact in 2030)**

Multiple opportunities exist across these levers…

		Enduses to address							
		HVAC	**Water heating**	**Lighting**	**Refrigeration**	**MELs**	**Laundry**	**Cooking**	**Dishwashing**
1. Standards & market priming		Vapor-compression	• Electric HP • Solar	• CFLs • Electronic ballasts	Vapor-compression	Active-power	Possible standards activity	Possible standards activity	Possible standards activity
2. Near-term Emerging technology		• Cold-climate heat pump • Integrated HP	• "CO2" HP • Gas absorption heat pump	Solid state (i.e., LEDs)	• Linear & variable speed compressors • System improvements		Various	Various	Various
3. Cross-cutting technologies	**Heat exchangers**	X	X	X	X	X		*	
	Motors	X	X		X	X	X	*	X
	Working fluids	X	X		X		*		
	DC equipment	*	*	X	*	X	*	*	*
	Cascading & storage	X	X		X		X		
	Insulation	X	X		X	X	X	X	X
4. Not-in-kind research and development		• Moisture transport membranes • Indirect evaporative • Liquid desiccants		Multi-photon phosphors	• Thermo-accoustic and magnetic • Solid state technology • Sterling cycle • Absorption & adsorption	OLED displays		Non-thermal cooking	

"X" indicates are where cross-cutting technology can save energy
"*" Indicates where cross-cutting technology applies to a limited extent
Gray boxes indicated limited opportunities

…to provide considerable savings over time



All estimates assume 100% market adoption of efficient technology
*Timing of availability of advanced technology is highly uncertain
Source: National Academies, BTP roadmaps

1. Deployment assistance: Standards and Market Priming (1 of 2)

Appliance standards:

- Legislation and Standard rulemakings completed between 1987 and 2010 currently provide annual energy savings of 1.8 quads in 2011
- Rulemakings underway should save another 1.8 quads/year in 2030 and save consumers $264B cumulatively from 2010 to 2030

Market priming:

- **Existing residential buildings**: The Weatherization and Intergovernmental Program and the Better Buildings deploy commercially available energy efficiency measures including air sealing, insulation, and efficient HVAC equipment; DOE aims to support retrofitting 1 million homes between 2010 and 2013.

1. Deployment assistance: Standards and Market Priming (2 of 2)

Market priming:

- **Existing commercial buildings:** “Better Buildings Initiative” seeks to reduce commercial building consumption by 20% by 2020

- **New buildings:** The building codes program, Building America, and Advanced Energy Design Guides improve new buildings. Goals include:
  - Approving a 50% savings in model building codes by 2015*
  - Enabling zero net energy new buildings by 2030

***50% goal for commercial buildings is 2014, for residential is 2015**

2. Emerging Technologies offer 50-90% savings in major end-uses

HVAC:
- Combustion heating
- Cold-climate heat pumps
- Integrated heat pumps
- Ground source heat pumps

15 quads primary consumption
10-60% reduction possible

Lighting:
- Solid State: LED to 211 Lm/W by 2020
- Outdoor lighting advances
- Sensors and controls

5.4 quads primary consumption
70-90% reduction possible

Water heating:
- Electric heat pump water heaters (HPWH)
- Gas absorption HPWH
- Solar water heating
- Demand reduction

3.7 quads primary consumption
50-75% reduction possible

Misc. Electric Loads:
- Energy management controls
- Standby power reduction
- Component improvements

5.7 quads primary consumption
Significant reduction possible

2. Emerging Technologies offer additional savings through minor end uses

Refrigeration:

- "Max tech" appliance would yield approximately 40% energy savings
- Roughly half is required for new Federal energy standards:

2.6 quads primary consumption
20-40+% reduction possible

Laundry:

- CEE-tier 2 washers provide 43% energy savings
- Over 50% additional savings with:
  - Reduced hot water use
  - Improved machine efficiency
  - Reduced drying need

0.74 quads primary consumption
40-70+% reduction possible

Cooking:

- Induction cook tops
- Dual cavity ovens
- Low emissivity heating elements
- Increasing microwave oven use
- Develop combined infra-red (IR)-microwave technology

0.83 quads primary consumption
10-50+% reduction possible

Dishwashing:

- Advanced hydraulics
- Sorption assisted drying
- Improved food filters
- Efficient motors
- Advanced controls

0.28 quads primary consumption
35-50+% reduction possible

3. Some cross-cutting opportunities can impact more than 50% of building related energy consumption

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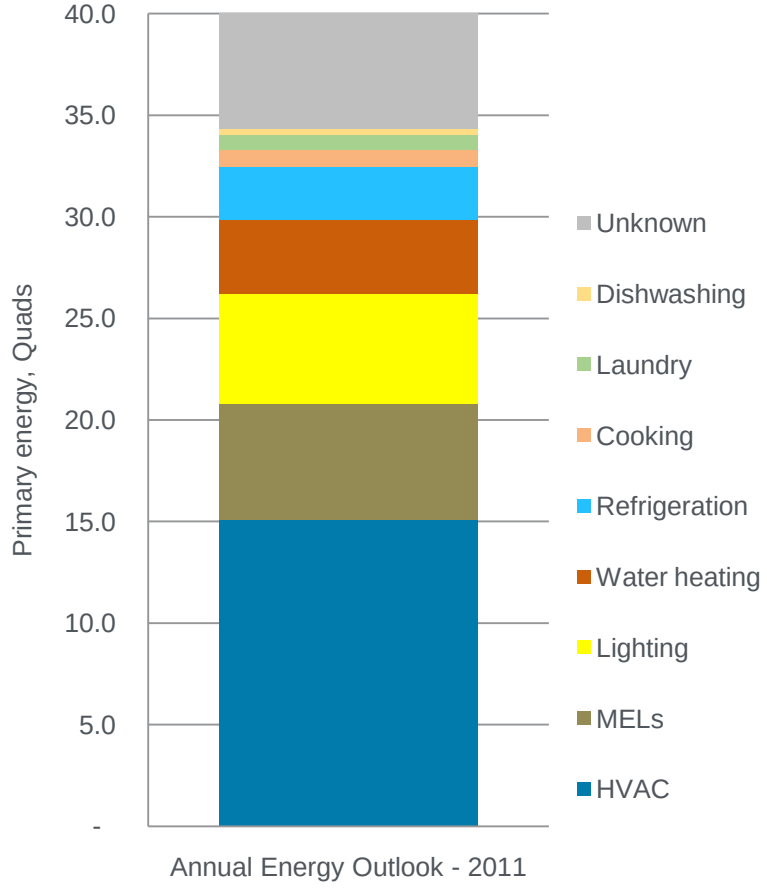
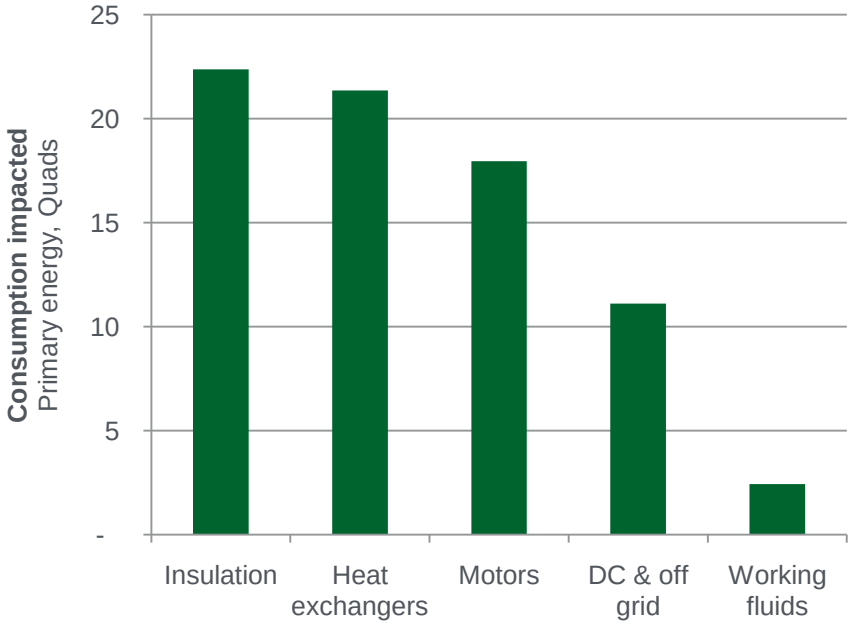


Cross-cutting opportunties



4. Not-in-kind technologies offer the potential for dramatic break-throughs in some areas

Improved dehumidification, latent, and sensible cooling:

- 50-90% savings for specific climates
- Moisture transport membranes (dynamically controlled)
- Liquid desiccants

Non-vapor compression (VC) cycle refrigeration:

- Thermoaccoustic and magnetic cooling
- Other candidates include:
  - **Solid state technology:** Magnetocalorics, thermoelectrics, thermoelastic, thermoioinic, thermotunneling.
  - **Gas-based cycles** Stirling cycle.
  - **Alternative cycles:** Absorption, adsorption, and Vuilleumier cycles

Multi-photon phosphors: A possible alternative to solid state lighting

OLED technology: Reduce costs to expand to large displays

Broadly applicable nanotechnology benefits through advanced materials such as high-k dielectrics, high energy density storage, or superconducting materials

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