Energy Savings from Honeywell Connected Thermostats

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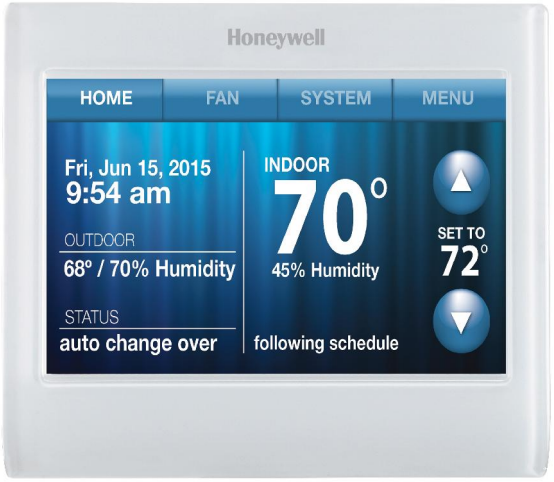
INTRODUCTION

Study Background

- Study conducted for Honeywell
- Total Connect Comfort (TCC) thermostats
  - Wi-Fi and mobile capability
  - Reduces control costs
  - Sold through select retailers, home heating and cooling contractors, and utility programs
- Principal research question:
  - What are the energy and cost savings from TCC thermostats?



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Study Requirements and Data Sources

- Requirements
  - National study
  - Annual space heating and cooling savings
  - Estimates by climate zone
- Data sources
  - Connected Thermostat User-Interface (UI) Data
    - 1,769 TCC thermostats
    - Date and time, location, display (interior) temperature, thermostat set points
    - January 2012-December 2012
  - InfoGroup household demographic and housing data
  - No energy use meter data

Study Design

- Honeywell TCC thermostat UI data
  - Space heating and cooling behavior in homes with connected thermostats
- 2009 Residential Energy Consumption Survey (RECS)
  - Establishes baseline for TCC t-stat homes
  - Preceded widespread adoption of connected thermostats
- Coarsened Exact Matching (CEM) of TCC t-stat homes to RECS homes
  - Controls for differences of TCC thermostat adopters
- Estimation of models of home heating and cooling energy use as a function of average thermostat set points
  - Yields energy savings per degree of temp setback

ANALYSIS STEPS

Analysis Steps

- Step 1: Develop models of energy use for home space heating and cooling
- Step 2: Match TCC homes to RECS homes
- Step 3: Estimate models of cooling and heating energy use models with matched RECS data
- Step 4: Determine average thermostat set points for TCC and RECS homes
- Step 5: Estimate energy savings as a function of difference in set points

Step 1: Develop Energy Use Estimating Equations

- Model annual energy use for home heating and cooling as a function of
  - Areas of home envelope (ceiling and wall)
  - Difference between avg. t-stat set point and avg. outdoor temperature
  - Equipment type
- Derived directly from a thermodynamic model of home heating and cooling
- Model coefficients
  - indicate average kBTu/sq. ft/hr for each degree of difference between t-stat set point and outdoor temp
  - Can be interpreted as home thermal efficiency: inverse = envelope *R* value x efficiency of space conditioning equipment

Step 2: Match TCC Homes to RECS Homes

- Coarsened Exact Matching (CEM) procedure used to estimate causal effects
  - Reduces imbalances between treatment and control groups
- Matching was performed using the following variables:
  - Household income
  - Home square footage
  - Reportable domain
  - Building America climate zone
- Resulted in the following analysis sample:
  - 653 homes with Honeywell devices
  - 2,578 RECS homes
- Tested validity of matching by comparing matched TCC and RECS homes on non-matching variables

Step 3: Estimate Heating and Cooling Energy Use Models

- Heating and cooling energy-use models estimated for each climate zone

  Energy use per hour = g(ceiling area x ΔT , wall area x ΔT, equipment type)

- Data sources
  - Matched RECS (2009) household-level survey
  - 2009 NOAA weather
- Models estimated by weighted least squares

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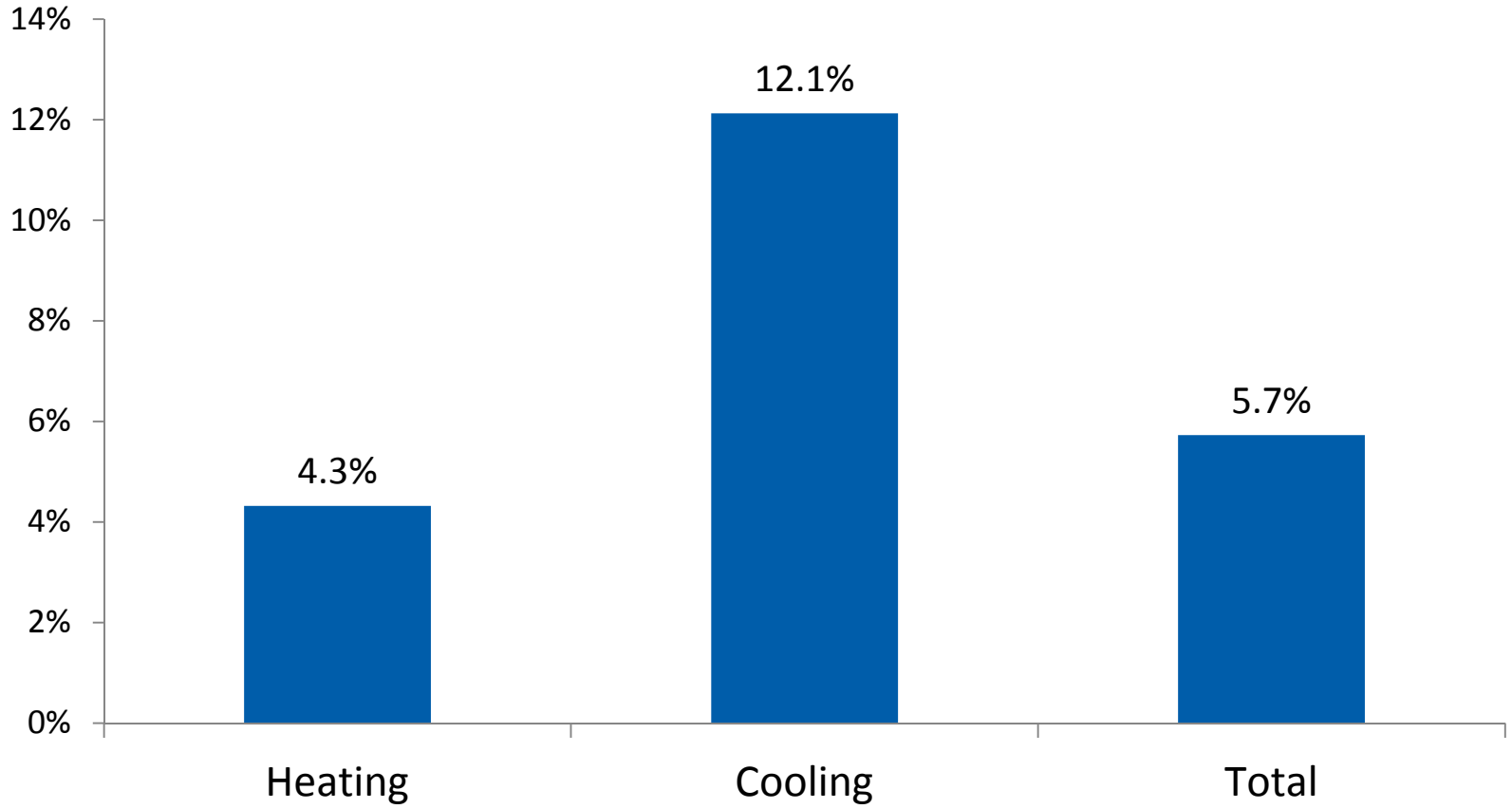
Predicted Percent Space Conditioning Energy Savings (from adjusting thermostat set point by 1°F) Normal Weather



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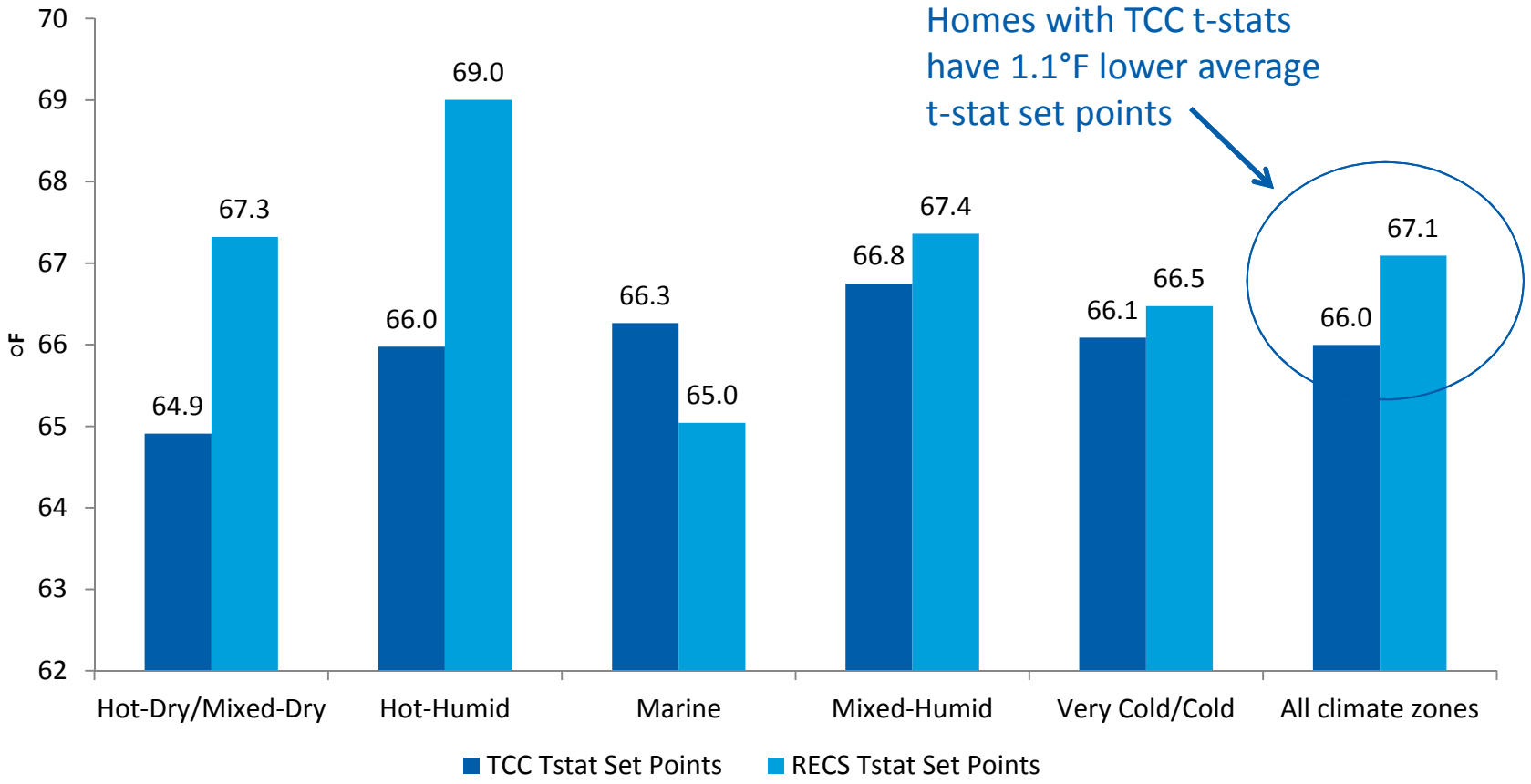
STEP 4: DETERMINE TCC AND BASELINE (RECS) THERMOSTAT SET POINTS

Matched TCC and RECS Thermostat Set Points (°F) - Heating Season



Note: TCC thermostat set points estimated for hours when heating system switched to on between December and March. All differences are statistically significant at the 5% level except in the Very Cold/Cold region.

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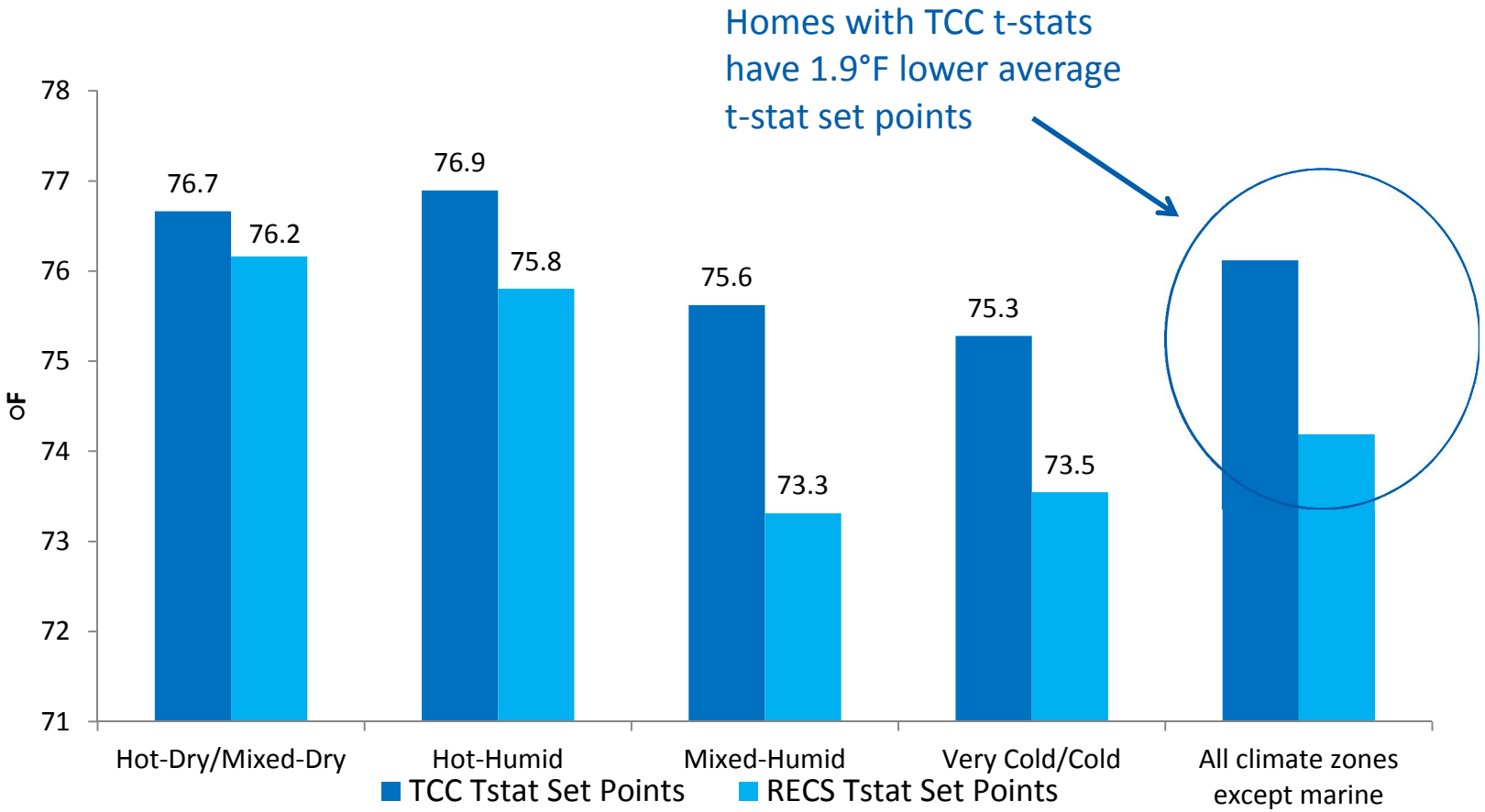
Matched TCC and RECS Thermostat Set Points (°F) - Cooling Season



Note: TCC thermostat set points estimated for hours when cooling system switched to on between June and September. All differences are statistically significant except in Hot-Dry/Mixed-Dry climate zone.

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Step 5: Connected Thermostat Savings Estimation

- TCC thermostat savings for heating and cooling estimated for each climate zone

$$\text{TCC t-stat savings} = \Delta F \times s \times h$$

where:

ΔF = difference between matched TCC home and RECS home t-stat set points

s = regression-based estimate of energy savings per hour per degree of setback for average home

h = hours in normal heating or cooling season

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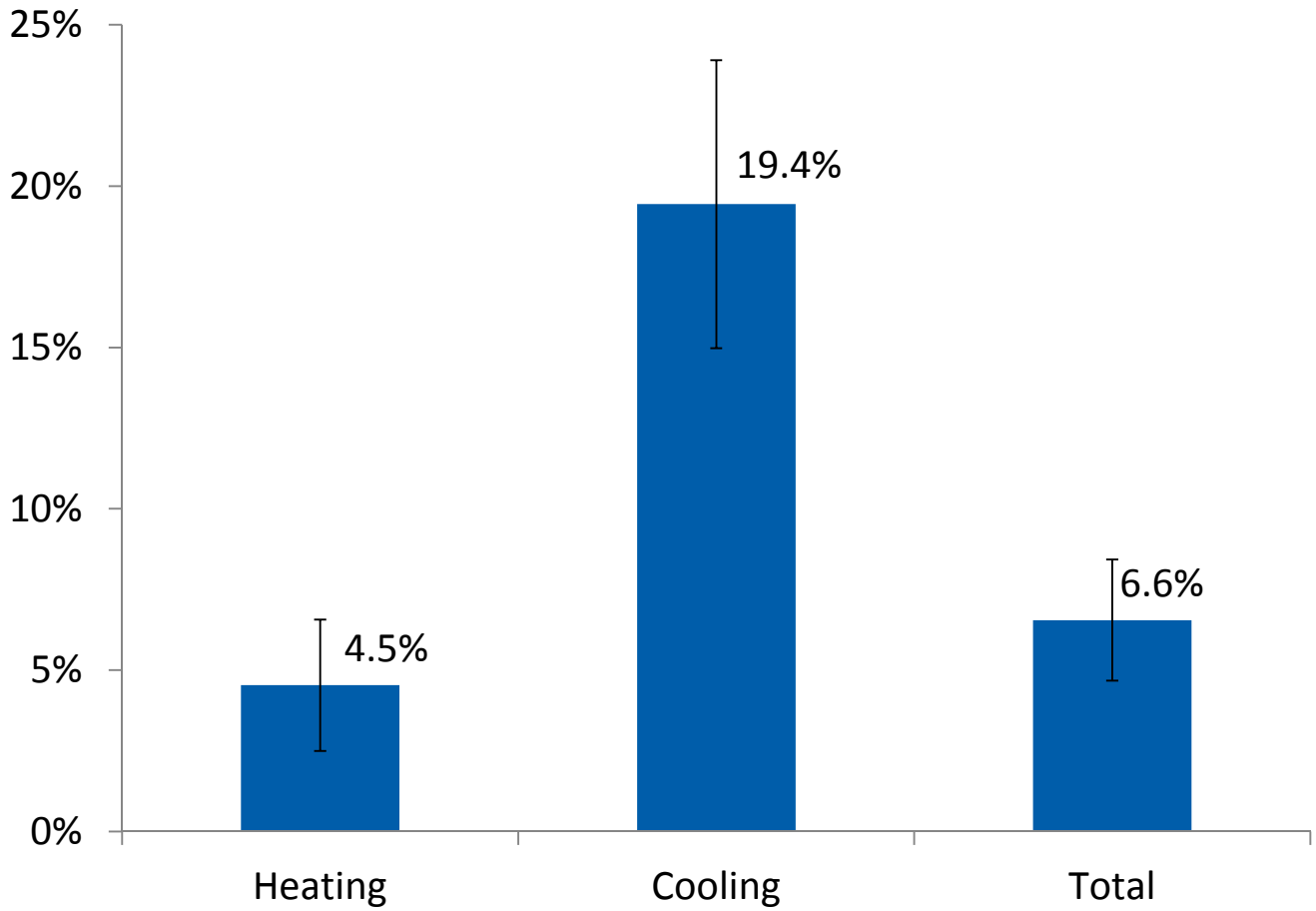
RESULTS

TCC Thermostat
Percent Space Conditioning Energy Savings for U.S. Normal Weather



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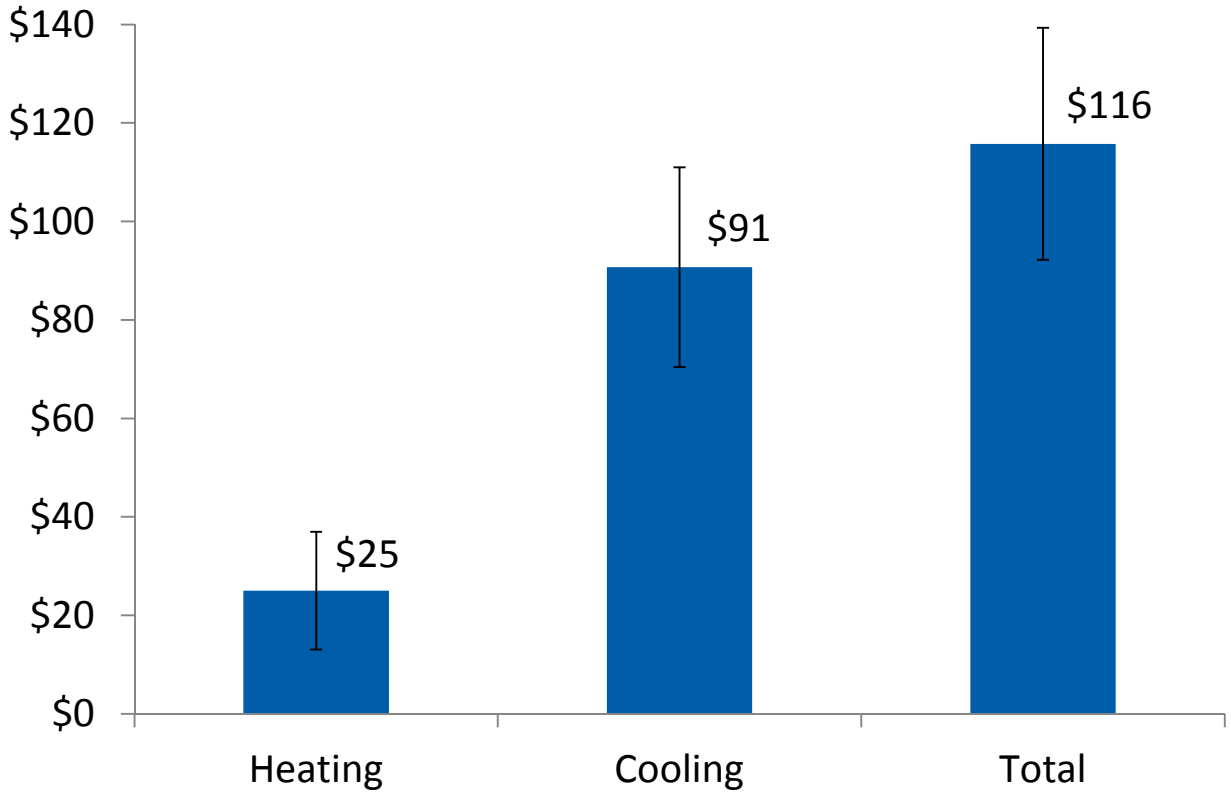
TCC Thermostat
Annual Cost Savings per Home for U.S. Normal Weather



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Heating Season
TCC Thermostat Energy and Cost Savings by Climate Zone

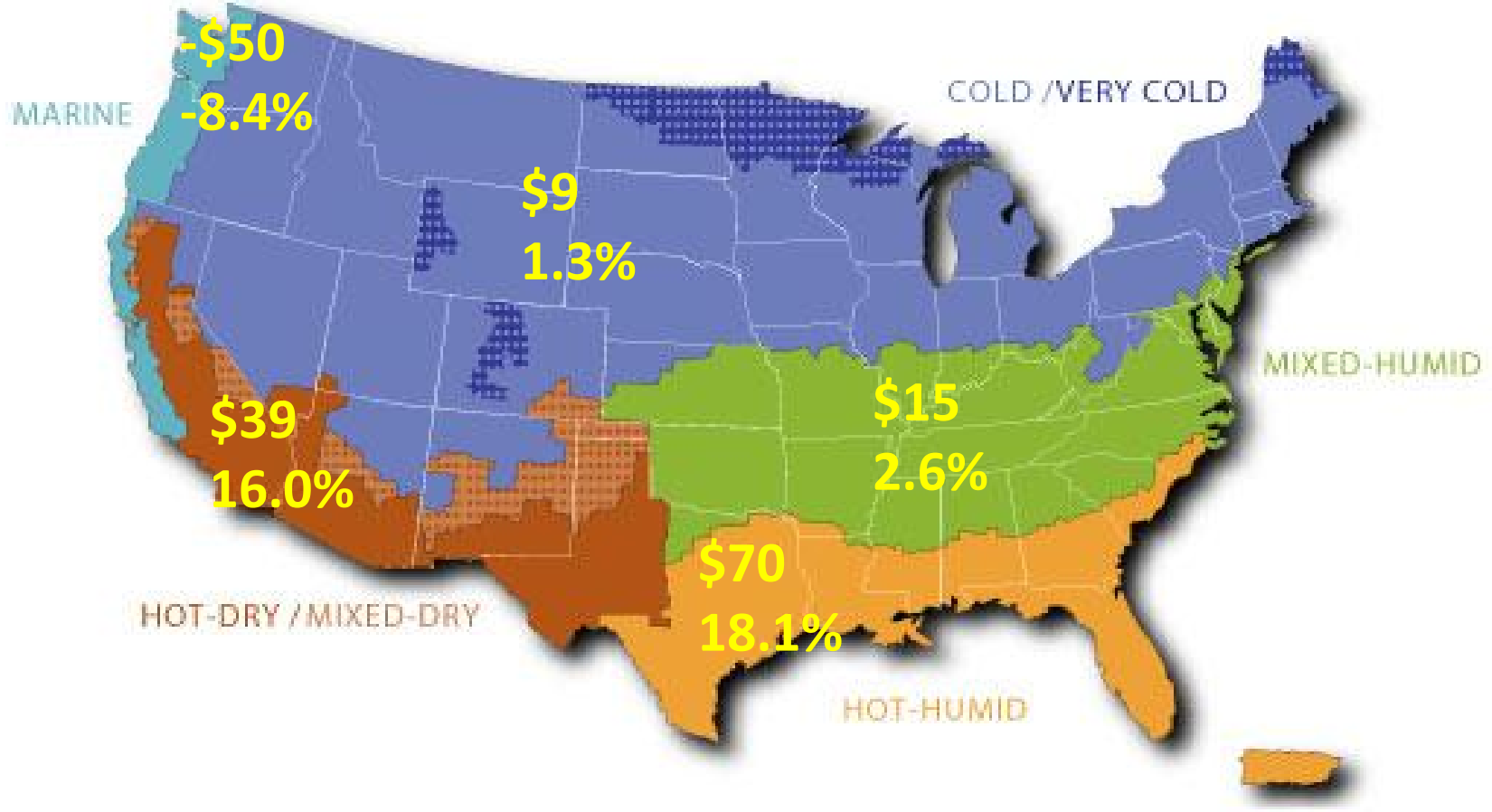

Figure shows the dollar and percent energy savings for each climate zone for normal weather and 2013 energy costs.

Cooling Season
TCC Thermostat Energy and Cost Savings by Climate Zone

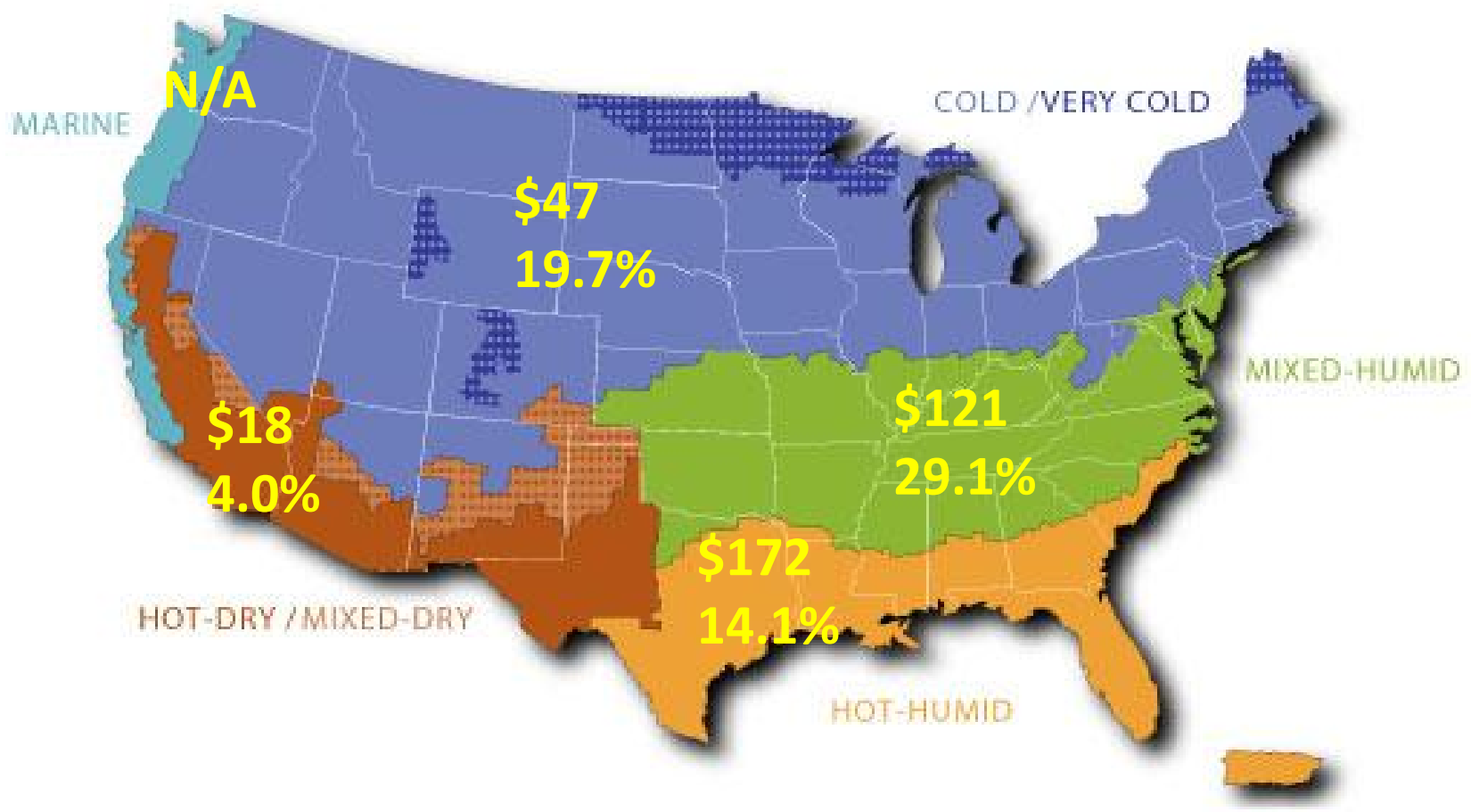

Figure shows the dollar and percent energy savings for each climate zone for normal weather and 2013 energy costs.

Honeywell TCC Thermostat Payback Period

Climate Zone	Annual energy cost savings per home	Approximate Payback Period
Hot-Dry/Mixed-Dry	$57	<2 years
Hot-Humid	$242	<1 year
Mixed-Humid	$135	<1 year
Very Cold/Cold	$57	<2 years
All climate zones except marine	$116	<2 years

Notes: Analysis assumes the discount rate equals 8%, the incremental cost of connected thermostat equals $100, and that future energy prices do not change from 2013 levels.

Summary of Key Findings

- Connected thermostat homes had lower average temperature set points during winter and higher average set points during summer
- TCC t-stats save about 6.6% in space conditioning energy use (2-3% of home energy use) and $116 in energy costs per home with normal weather
- Energy and cost savings from connected thermostats vary by region
- Connected thermostat will be cost-effective for many utility customers

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Final Thoughts

- Policymakers should consider connected thermostats for achieving EE and GHG emissions objectives
- Need impact studies of connected thermostats that employ energy use meter data
- Cadmus is expanding study to include much larger number of Honeywell connected thermostats
  - More in-depth analysis of thermostat user-interface data to understand user behaviors

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