TRC Reach Code Research and M&V

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Outline

1. Reach Codes

- Cost Effectiveness Methodologies
- Results

2. Electrification of Space Heating and Water Heating in Palo Alto

- Goals
- Results

3. Heat Pump Space Heating in Single Family Alterations

- Goals
- Preliminary Results

4. So You Think You're ZNE? Prove it! (Parts 1 & 2)

- My best Abhijeet impression

Reach Codes

What is a reach code?

Mandates that buildings achieve energy performance better than Title 24 minimum requirements

- "Prescriptive"
  - Exactly 3 measures **or** 3 measures from 10 listed
  - Detailed guidance
  - Restrictive
- "Performance"
  - 15% better than Title 24 **or** 9 kBtu/ft^2/year **or** EDR Target
  - Flexible
  - Often achieved with higher performance equipment

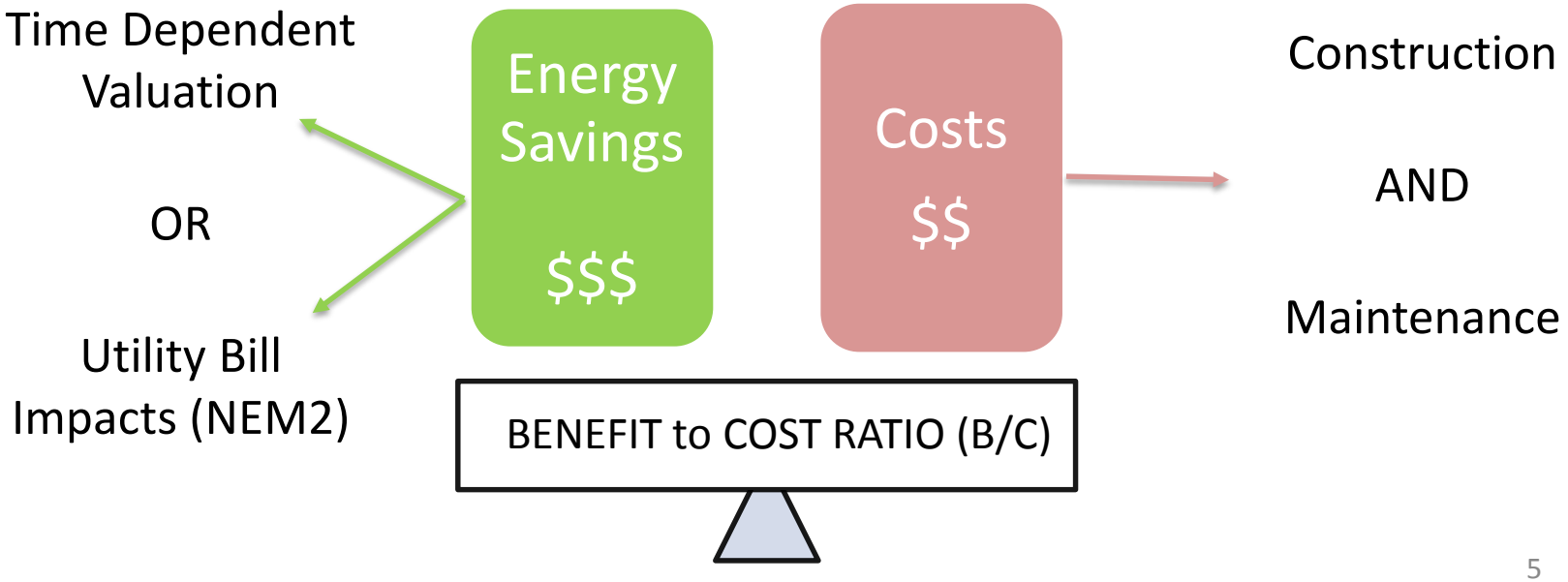
Cost effectiveness analysis necessary for CEC approval

Cost effectiveness methodologies

Our typical approach

- Title 24 Rx Prototypes
- Apply EE measures and PV in CBECC
  - Constraints: Pre-emption, Title 20, lighting, prototypes, modeling software
- 30-year or 15-year NPV

Goal: B/C > 1.0



Recent work

Implemented 2016 T24 reach codes

- Palo Alto: 10% better than code for all new construction, solar-ready
  - OR 0% plus a PV system
  - OR all-electric design

  } Residential alternates
- San Mateo: Cool roof and PV mandates
- Santa Monica: ZNE for low-rise residential
  - CALGreen Tier 3 ZNE Definition → 15% better than code + PV
  - Also 10% for nonresidential

Statewide reach code analysis in progress (SCE)

- Residential Zero Net Electricity (ZNe)
  - Coordinating with CEC
  - Battery storage analysis pending
- Nonresidential 10% / 15%
  - Mostly lighting measures

Single family ZNe measures

Measure			Climate Zone															
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Envelope	Quality Insulation Installation (HERS)		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	Cool Roof	(ASR-0.28 / TE-0.85)								x								
		(ASR-0.32 / TE-0.85)									x	x	x	x	x	x	x	
	Improved Fenestration	(U-0.30 / SHGC-0.23)		x		x		x		x	x	x	x	x	x	x	x	x
		(U-0.30 / SHGC-0.50)	x		x		x											
	Insulated Door (U-0.20)		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	High Performance Walls (U-0.043)		x	x							x	x	x	x	x	x	x	x
	High Performance Attics (R19 below deck)		x	x						x	x	x	x	x	x	x	x	x
	Reduced Infiltration (3 ACH50)		x	x	x	x	x			x	x	x	x	x	x	x	x	x
DHW	Hot Water Piping Insulation, All Lines (HERS)		x	x	x	x	x			x	x	x	x	x	x	x	x	x
	Compact Hot Water Distribution (HERS)		x			x				x	x	x	x	x	x	x	x	x
	Drain Water Heat Recovery (2700 ft² only)		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
HVAC	AHU Reduced Fan Watt Draw (0.3 W/CFM)		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	Verified Refrigerant Charge (HERS)		x		x	x	x	x	x									x
	Increased Duct Insulation (R8)				x		x											

Single family cost effectiveness

CZ	Compliance Margin	ENERGY EFFICIENCY ONLY PACKAGE (TDV)			ZNE PACKAGE (ON-BILL)				
		Present Value of Savings (TDV)	Present Value of Costs	B/C Ratio	PV Size (kW)	2016 Energy Design Rating	Present Value of Savings (On-Bill)	Present Value of Costs	B/C Ratio
1	30%	$5,053	$3,889	1.3	3.0	17	$38,710	$11,099	3.5
2	25%	$3,467	$3,041	1.1	2.6	15	$34,145	$9,268	3.7
3	23%	$2,198	$1,967	1.1	2.5	11	$31,809	$8,065	3.9
4	24%	$2,747	$2,334	1.2	2.5	14	$32,890	$8,385	3.9
5	26%	$2,187	$1,967	1.1	2.4	9	$32,050	$7,679	4.2
6	17%	$1,322	$1,131	1.2	2.6	12	$20,108	$7,241	2.8
7	16%	$799	$1,213	0.7	2.5	10	$26,519	$7,087	3.7
8	29%	$2,421	$1,996	1.2	2.7	10	$21,554	$8,305	2.6
9	32%	$4,320	$3,691	1.2	2.7	12	$23,373	$10,070	2.3
10	30%	$4,234	$2,507	1.7	2.8	11	$33,588	$9,064	3.7
11	29%	$7,850	$3,838	2.0	3.2	16	$49,972	$11,551	4.3
12	31%	$5,480	$3,838	1.4	2.7	15	$36,542	$10,393	3.5
13	29%	$7,788	$3,838	2.0	3.4	17	$50,808	$11,995	4.2
14	28%	$7,185	$4,241	1.7	2.9	18	$31,605	$11,018	2.9
15	26%	$10,250	$4,241	2.4	4.8	14	$54,295	$15,626	3.5
16	22%	$5,303	$3,011	1.8	2.5	23	$39,889	$8,922	4.5

Preliminary reach code rec's

CZ	Single Family		Low-rise Multifamily	
	Efficiency-Only Compliance Margin	2016 Energy Design Rating	Efficiency-Only Compliance Margin	2016 Energy Design Rating
1	30%	20	20%	15
2	25%	15	25%	15
3	20%	15	10%	10
4	20%	15	20%	15
5	25%	10	10%	10
6	15%	15	15%	10
7	0%	10	10%	15
8	25%	10	20%	15
9	30%	15	20%	15
10	30%	15	20%	15
11	25%	20	25%	15
12	30%	15	20%	20
13	25%	20	25%	15
14	25%	20	20%	20
15	25%	15	25%	15
16	20%	25	20%	20

Electrification of Space Heating and Water Heating in Palo Alto

Overview

New and Existing Residential and Nonresidential in CZ4 (CPAU)

Goal: Is electrification of space heating and water heating cost effective?

- Palo Alto procures carbon neutral electricity

Methodology

- Both TDV and Utility Bill cost effectiveness
- Individual measure and infrastructure costs (electrical upgrades and gas piping savings)

Scope and Limitations

- Prototypes: Single family, LR multifamily, small office, medium office
- Existing conditions variable
- Excluded other appliances and grid impacts
- Sean has a list of 15+ more

Measure details

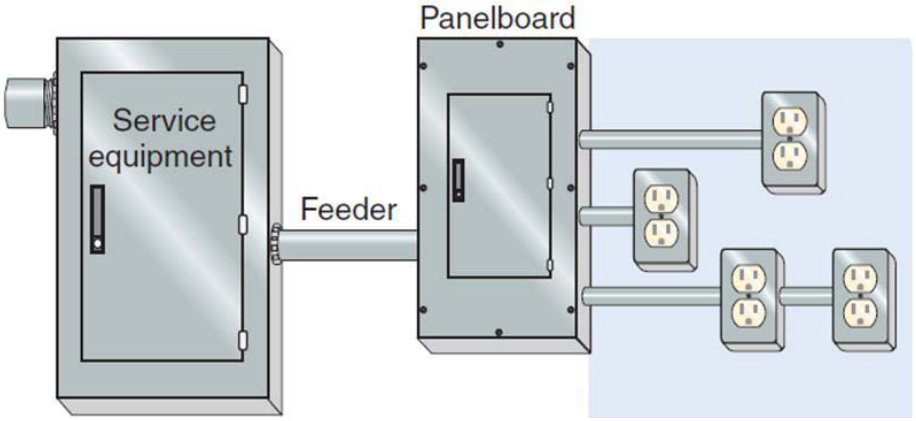
Proposed equipment

- Must be readily available in Palo Alto, likely to be cost-effective
- HPWHs: NEEA-Rated
- HPSHs:

Residential	Small Office	Medium Office
Central Split HP	Packaged Heat Pump	Heat Pump Boiler

Infrastructure (single family example)

- Electrical upgrades
  - New: $50
  - Altered: $4,600
- Plumbing
  - New: -$6,412
  - Altered: -$2,000
  - ~~Condensate drain: $1,000~~



Source: 2011 NEC Handbook

Cost effectiveness results

TDV and On-Bill analyses have same result 61/64 scenarios

- Heat pump measures push residential electricity to Tier 2 consumption
- HPWHs cost more than conventional gas, not enough savings
- HPSHs cost less than baseline split ACs with furnaces, no savings
  - Negative costs outweigh negative savings → cost effective
  - No electrical resistance element necessary in Palo Alto

All-electric new construction packages avoid gas infrastructure costs

Building Type	Construction Type	Heat Pump Water Heater	Heat Pump Space Heater	Heat Pump Package (Gas Connection Remains)	All-Electric Package (No Gas Connection)
Single Family	New	$(2,459)	$5,180	$2,639[ii]	$9,051
	Alteration	$(8,424)	$3,866	$(3,737)	$(5,170)
Low-rise Multifamily	New	$(21,982)	$18,023	$(5,665)	$12,041
	Alteration	$(54,324)	$16,537	$(36,627)	$(38,060)
Small Office	New	$(777)	$(5,620)	$(6,397)	$5,941
	Alteration	$(3,187)	$(9,844)	$(12,904)	$(14,337)
Medium Office	New	$(777)	$(169,234)	$(170,011)	$(159,533)
	Alteration[i]	$(3,344)	-	-	-

Conclusions + recommendations

Code, technical, and operational barriers

- Title 24 compliance modeling
  - HPWHs impacted by natural gas availability
  - HPSH alterations uncertainty
- Lack of experience from contractors, building departments, and owners
- High temperature, high capacity heat pump systems not yet widely available in commercial sector
- Barriers will diminish through increased penetration

Future analysis

- Adjust residential electric rate thresholds or charging schemes
- Expand scope
  - PV, battery storage, electric vehicles, demand response
  - Other efficiency measures
  - Future cost reductions due to increased penetration

Heat Pump Space Heating in Single Family Alterations

Overview

Single Family Alterations in CZ4 and CZ12 (CPAU and SMUD)

Goal: What heat pump efficiency and/or measure package = new gas furnace performance?

- Utilities want to avoid requiring energy models from program applicants
- CEC previously developed prescriptive equivalency for HP water heater EFs, but has balked for HP space heating because of electrical resistance runtime concerns

Existing building assumptions

- Sizes: 1500 ft^2, 2100 ft^2, 2700 ft^2 (1 zone), 2700 ft^2 (2 zone)
- Vintages: Pre-1978, 1978-1992, 1992-2001, and Post-2001
  - Residential ACM Appendix B
  - Further research into ECO, RASS, contractor interviews, and AHRI database

Automation saves time

Climate Zone	Prototype	Vintage	HP Efficiency (HSPF)	HP Capacity @ 47F (Btu/h)	Ceiling Insulation	Duct Leakage
4	1500	Pre-1978	8.2	18,000	R-11	15%
12	2100	1978-92	8.5	24,000	R-19	5%
	2700-1	1992-2001	9	30,000	R-30	
	2700-2	Post-2001	9.5	36,000	R-38	
			10	48,000	R-49	
			10.5			
			11			
			11.5			
			12			

14,400 permutations

Preliminary Results – 1500 ft²

With Cooling

Pre-1978

	HEATING CAPACITY (CAP47)				
HSPF	18000	24000	30000	36000	48000
8.2	-	ducts+R 38	ducts+R 11	R 30attic	R 30attic
8.5	-	ducts+R 30	R 30attic	R 19attic	R 19attic
9	-	R 38attic			
9.5	-	R 30attic			
10	ducts+R 38				
10.5	ducts+R 30				
11	ducts+R 21				
11.5	ducts+R 19				
12	R 49attic				

1978-92

	HEATING CAPACITY (CAP47)				
HSPF	18000	24000	30000	36000	48000
8.2	-	R 38attic	R 30attic	R 21attic	R 19attic
8.5	-	R 30attic	R 21attic	R 19attic	
9	ducts+R 19				
9.5	ducts+R 11				
10	R 21attic				
10.5					
11					
11.5					
12					

No Cooling

Pre-1978

	HEATING CAPACITY (CAP47)				
HSPF	18000	24000	30000	36000	48000
8.2	-	-	-	ducts+R 19	R 19attic
8.5	-	-	ducts+R 38	R 49attic	
9	-	-	ducts+R 11	R 19attic	
9.5	-	-	R 21attic		
10	-	R 38attic			
10.5	-	R 19attic			
11	-				
11.5	-				
12	-				

1978-92

	HEATING CAPACITY (CAP47)				
HSPF	18000	24000	30000	36000	48000
8.2	-	-	ducts+R 11	R 30attic	
8.5	-	-	R 38attic		
9	-	ducts+R 11			
9.5	-	R 30attic			
10	-				
10.5	ducts+R 21				
11	ducts+R 21				
11.5	ducts+R 19				
12	R 49attic				

Preliminary Results – 1500 ft²

With Cooling

1992-2001

HSPF	HEATING CAPACITY (CAP47) 18000	24000	30000	36000	48000
8.2	ducts+R 19	R 21attic	R 21attic	R 19attic	
8.5	ducts+R 11	R 21attic			
9	R 21attic				
9.5					
10					
10.5					
11					
11.5					
12					

2001 and After

HSPF	HEATING CAPACITY (CAP47) 18000	24000	30000	36000	48000
8.2	ducts+R 11	R 21attic	R 19attic		
8.5	R 30attic	R 19attic			
9					
9.5					
10					
10.5					
11					
11.5					

No Cooling

HSPF	HEATING CAPACITY (CAP47) 18000	24000	30000	36000	48000
8.2	-	R 49attic	R 21attic	R 19attic	
8.5	-	R 30attic			
9	ducts+R 19				
9.5	R 49attic				
10					
10.5					
11					
11.5					
12					

HSPF	HEATING CAPACITY (CAP47) 18000	24000	30000	36000	48000
8.2	-	R 38attic	R 21attic	R 19attic	
8.5	ducts+R 21	R 21attic			
9	ducts+R 11				
9.5	R 30attic				
10					
10.5					
11					
11.5					
12					

Questions or Comments (please)

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