Public Webinar

Draft Report: The Technical Feasibility of Zero Net Energy Buildings in California

Derek Jones
Evaluation Measurement & Verification
PG&E

December 3, 2012

Overview

Research Team

- Study Team Lead: Dan Suyeyasu, Arup
- Team Members: Davis Energy Group, Sun Light & Power, Engineering 350, Sustainable Design & Behavior, New Buildings Institute

Description

- Model exemplar residential and commercial buildings as best projected to exist in 2020 and
- Use those models to estimate the technical potential for ZNE buildings in CA in 2020.
- Produce a “scenario analysis tool” for IOUs to test sensitivities of various measure combinations based on EnergyPlus and Beopt outputs.

Overview

Collaborative Research

- Co-funded by four investor owned utilities (IOUs)
- Planning coordinated with Energy Division

Unique Research

- Program deliverables for PG&E's ZNE Pilot Program
- Funded from IOU EM&V budget; led by IOU EM&V staff
- Example of IOU contributions to pursuit of ZNE goals

Timely Research

- Residential Roadmap to ZNE (CPUC/CEC)
- 2016 Title 24 update (CEC)
- C&S Planning and Coordination Subprogram (IOUs)
- Emerging Technologies Program roadmaps (IOUs)

Draft Report: Public Review

Draft report posted on Energy Data Web (PDA) for public review

- Use the comment feature on the PDA website
- Comments due December 6th, 2012
- Details on comment process are included in public notice for this meeting

Study team will consider all comments submitted by December 6th

- Will not provide responses to comments
- May not incorporate all comments in the report
- See “Key Questions” for consideration in public notice

Webinar Ground Rules

- **Due to high attendance all callers are on mute**
- **If you would like to ask questions:**
  - 1) Use the “Emoticons” function in the “File Menu” to signal that you have a “Question” (moderator will unmute your line)

  OR

  - 2) Type your question into the Chat window and identify yourself
    - We will try to record and review any chat questions that we are not able to address.
- **In the interest of time, please limit yourself to only one follow-up question**
- **We may not be able to answer all questions. The study lead welcomes clarifying questions offline via email:**

  Dan Suyeyasu - dan.suyeyasu@arup.com

The Technical Feasibility of Zero Net Energy Buildings in California

December 3, 2012

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2. ZNE Design Strategies
3. Research Parameters
4. Renewable Energy
5. Results: Residential
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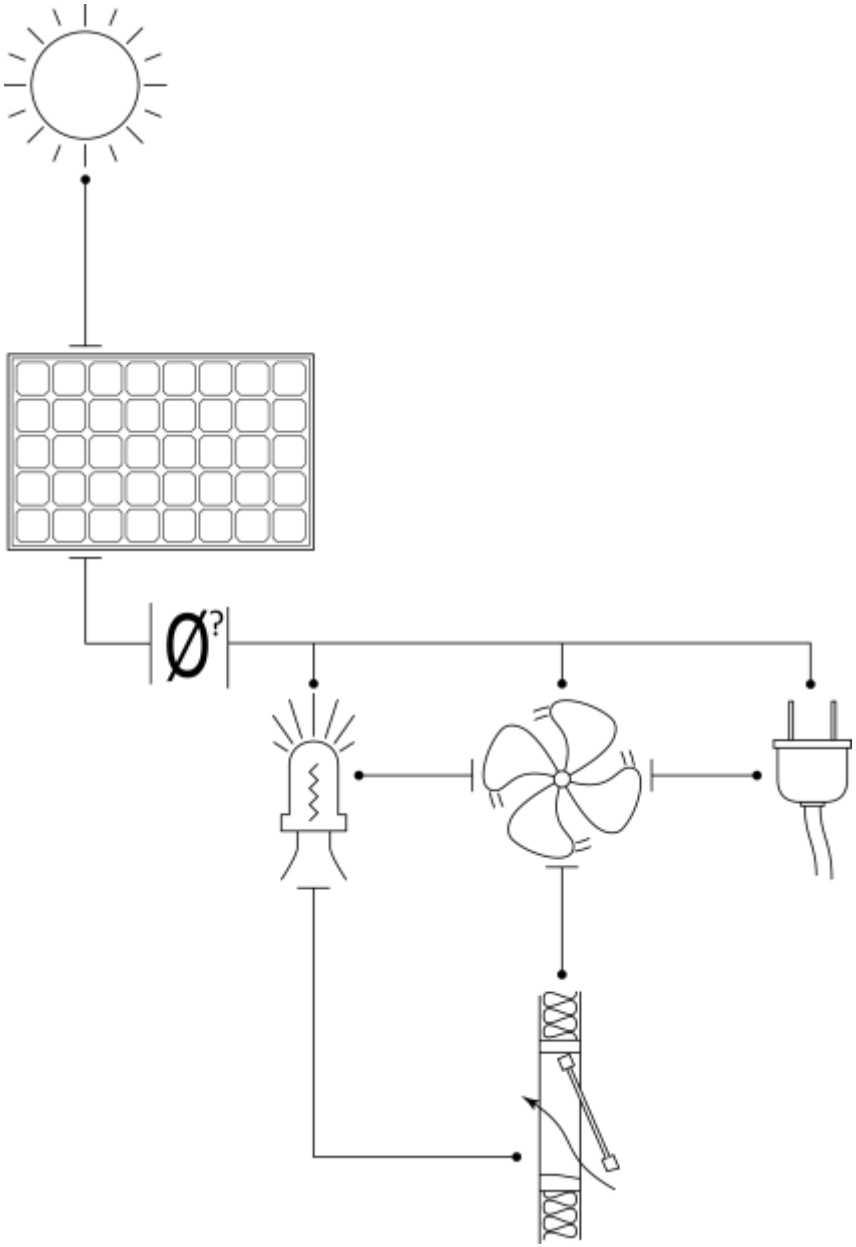
7. Broad Trends
8. (Scenario Analysis Tools)



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Technical Feasibility - Research Team

Davis Energy Group	- Residential Design
Sun Light & Power	- Solar Production
New Buildings Institute	- ZNE Reference Data - Plug Load Calculations
Engineering 350	- Design Assistance
Sustainable Design + Behavior	- Behavior Related Efficiency
Arup	Lead Investigator

Technical Feasibility - Primary Oversight

Peter Turnbull	PG&E
Derek Jones	PG&E
Lonnie Mansi	SDG&E
Dan Hopper	SCE
Rob Rubin	SoCal Gas
Anna LaRue	Resource Refocus (for PG&E)
Cathy Fogel	CPUC
Jordana Cammarata	CPUC

Objectives

- Estimate lowest possible EUI of **12 Building Types**
- Repeat analysis in **5-7 California Climate Zones**
- Define resulting building characteristics
- Model **solar** production
- **Assess ZNE Feasibility**

- Identify primary barriers and opportunities
- Develop a tool for the analysis of design variants

Results:

Percent of 2020 New Build:		TDV$/ft^2 (30 yr)								
		15: Palm Springs			**12:** Sacramento			**16:** (Sierras)		
		Load:	*Solar:*	*Net:*	*Load:*	*Solar:*	*Net:*	*Load:*	*Solar:*	*Net:*
Single Family Home	52%	**11.9**	-11.9	**0.0**	**9.8**	-9.8	**0.0**	**10.3**	-10.3	**0.0**
Multifamily Lowrise	5%	**19.4**	-19.4	**0.0**	**14.6**	-14.6	**0.0**	**15.2**	-15.2	**0.0**
Multifamily Highrise	3%									
Medium Office	2%	**23.4**	-23.4	**0.0**	**18.5**	-18.5	**0.0**	**17.0**	-17.0	**0.0**
Large Office	7%	**22.7**	-7.9	**14.7**	**18.9**	-7.7	**10.2**	**21.1**	-8.5	**12.6**
w/ parking PV			-22.7	**0.0**		-18.9	**0.0**		-21.1	**0.0**
Strip Mall	7%									
School	3%	**31.9**	-31.9	**0.0**	**26.0**	-26.0	**0.0**	**21.9**	-21.9	**0.0**
Large Hotel	2%									
Grocery	2%									
Sit-down Restaurant	1%									
Hospital	2%	**70.2**	-19.0	**50.1**	**67.0**	-18.6	**48.9**	**65.5**	-20.4	**45.1**
w/ parking PV			-31.8	**38.4**		-30.4	**36.6**		-33.8	**31.7**
Warehouse	6%	**13.1**	-13.1	**0.0**	**10.1**	-10.1	**0.0**	**10.1**	-10.1	**0.0**

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ZNE Design Strategies

Cole Roberts

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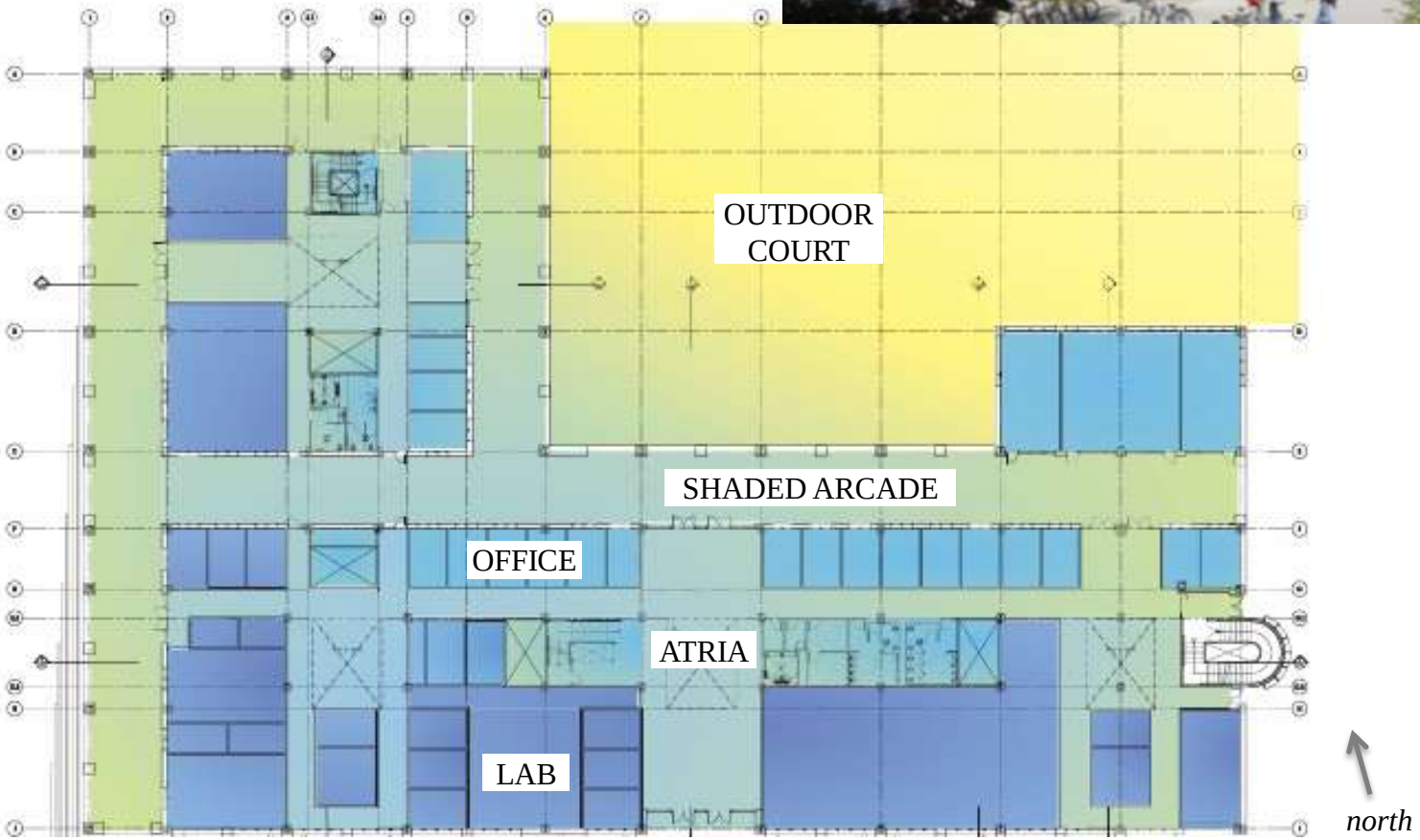
Team Design Experience

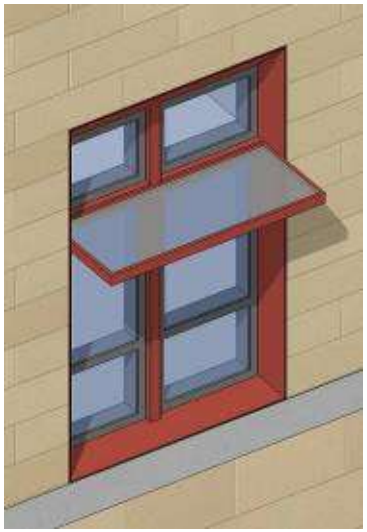
Integrated Design

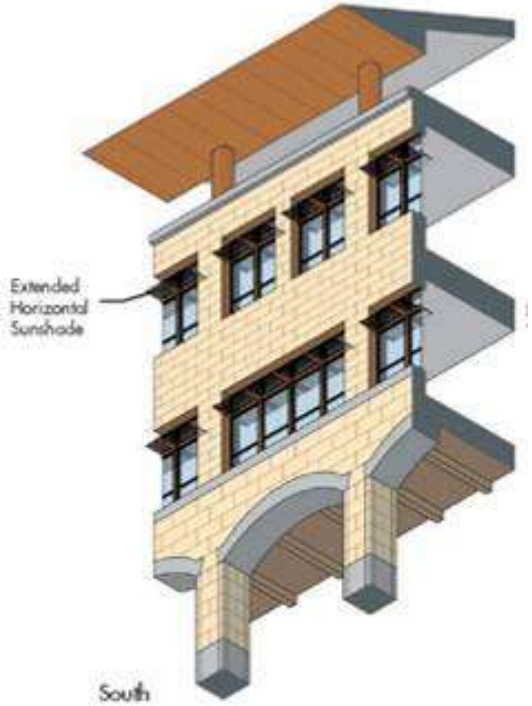
- Blurring discipline boundaries
- Blurring interior and exterior



Step 1 -Reduce Loads

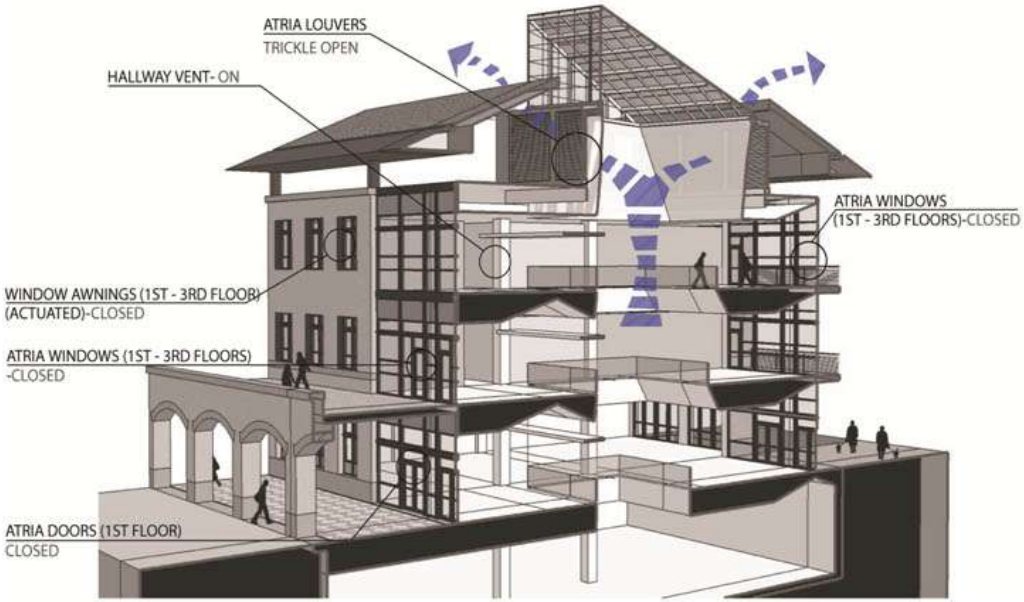
- Volume
- Envelope
- Plug Loads
- Lighting Levels
- Infiltration
- And…
  - Kitchen Loads
  - Lab Air Changes
  - Vertical Circulation
  - ICT/Server Rooms
  - Transformer Losses



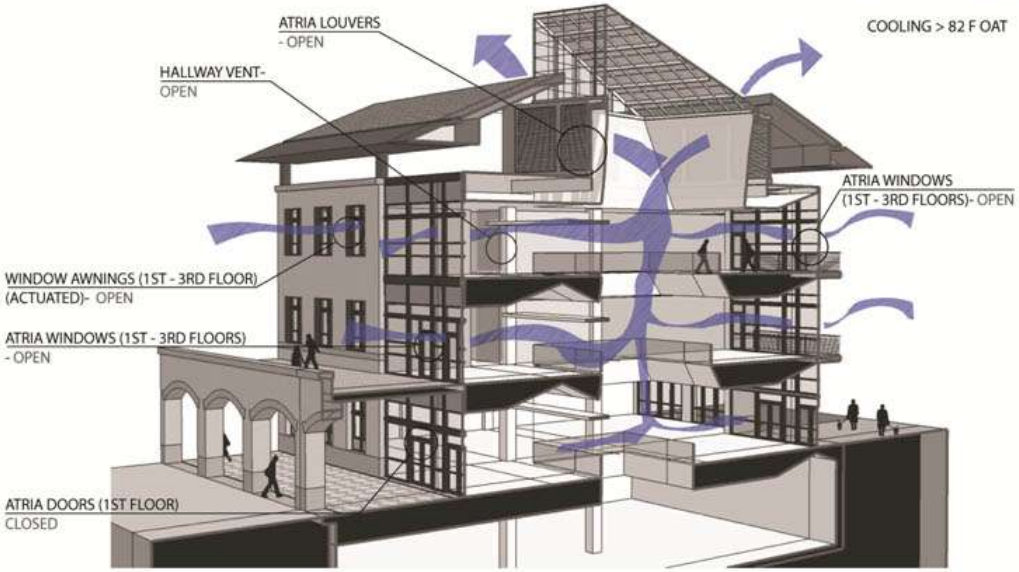


Step 2 – Passive Design

Much of California is well suited for *natural ventilation* and *daylighting*



COOLING > 82 F OAT

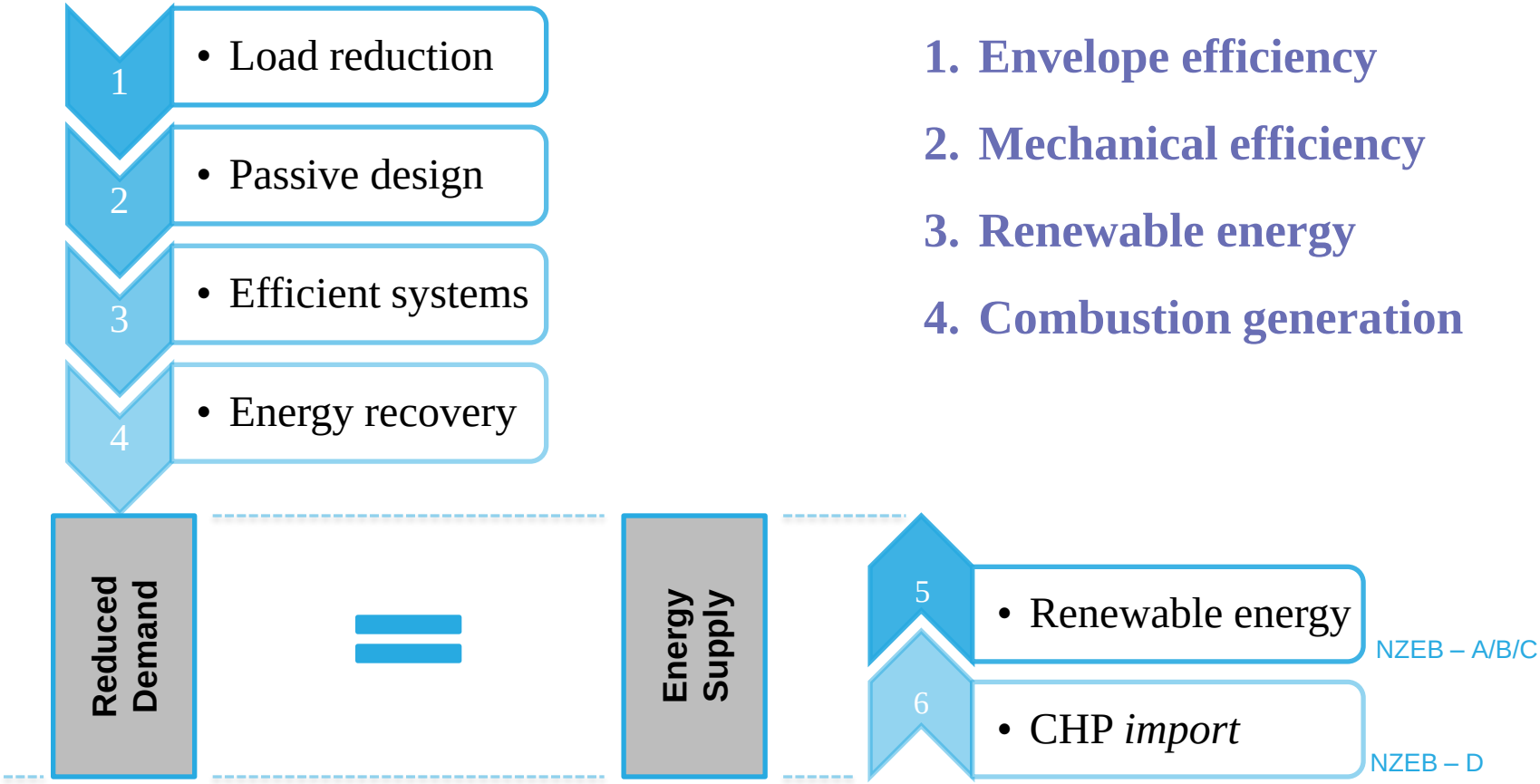


COOLING < 82 F OAT

ZNE Comprehensive Prioritized STRATEGY

Synchronized with State loading order:

1. **Envelope efficiency**
2. **Mechanical efficiency**
3. **Renewable energy**
4. **Combustion generation**



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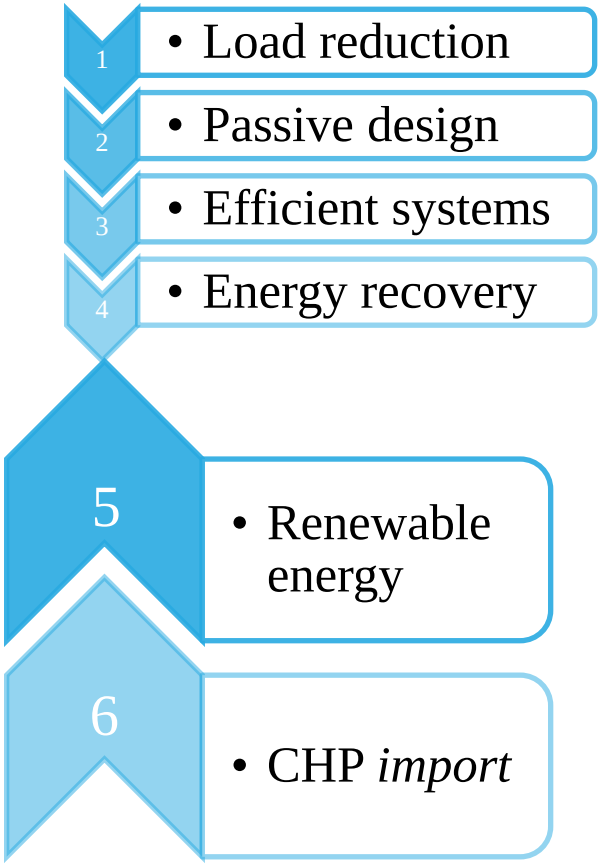
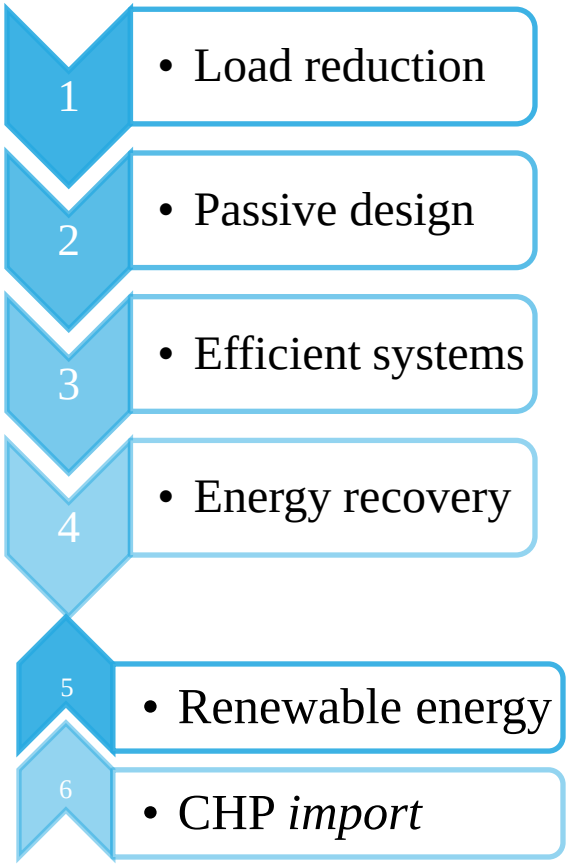
ZNE Comprehensive Prioritized STRATEGY



LARGE GENERATION



DEEP EFFICIENCY

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And Renewables Balance the Efficiency

- **But:** Difficult logistics with rooftop mechanical and daylighting systems

Consensus and Correlation

- **Our results match well with:**
  - Other ZNE modeled data
  - Other ZNE metered data
  - Our design project experience

  (taking account of the unique parameters of this research)

- **Our strategies match those used by many others**
  - Most of what we recommend is being implemented today
  - A challenge is bringing together all strategies at a single site

Research Parameters

Dan Suyeyasu

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Climate Zones for Study

CZ 15: Palm Springs

CZ 13: Fresno

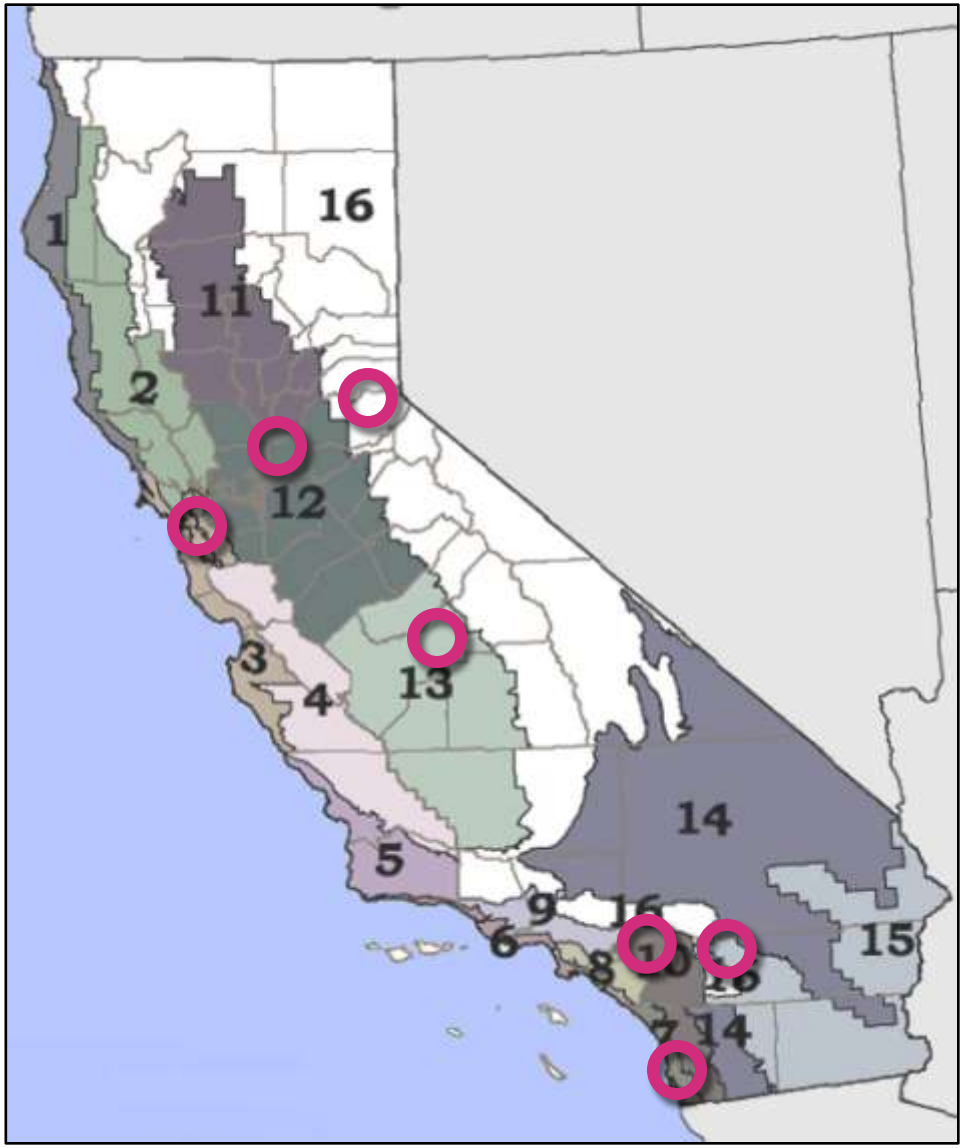
CZ 12: Sacramento

CZ 10: Riverside

CZ 7: San Diego

CZ 3: Oakland

CZ 16: Blue Canyon



Wide climate range:

Targets growth areas:

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Building Types:

		Percent of 2020 New Build:	TDV$/ft^2 (30 yr)								
			15: Palm Springs			**12:** Sacramento			**16:** (Sierras)		
			Load:	*Solar:*	*Net:*	*Load:*	*Solar:*	*Net:*	*Load:*	*Solar:*	*Net:*
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12	Warehouse	6%	**13.1**	-13.1	**0.0**	**10.1**	-10.1	**0.0**	**10.1**	-10.1	**0.0**
	College (composite)	2%									
	Other (composite)	8%									

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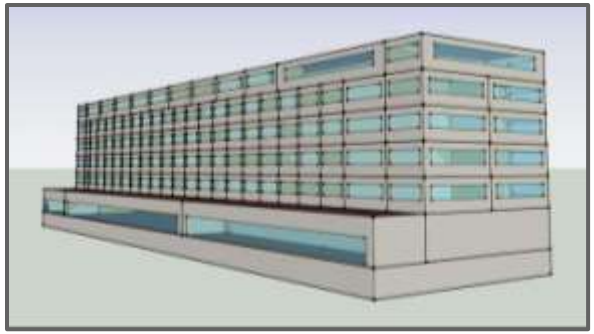
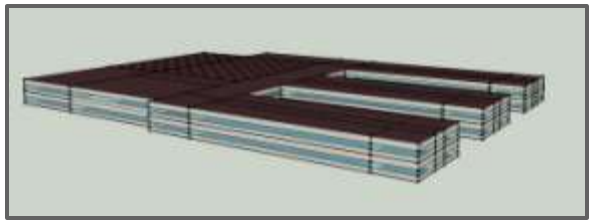
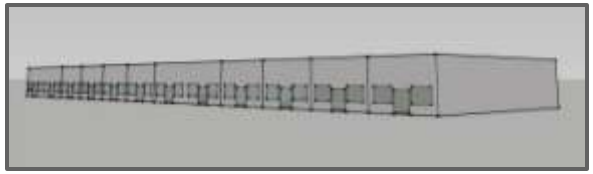
Research Prototypes and EnergyPlus

- **DOE Commercial Research EnergyPlus Prototypes**
  - Invaluable in establishing starting design parameters
  - Operational characteristics especially valuable
  - Anchor point for comparison to other research efforts
    - CEC, ASHRAE, DOE, etc.
  - (Thank you Department of Energy!)



- **EnergyPlus models the broadest range of strategies**
  - Advanced HVAC
  - Natural ventilation
  - Daylighting
  - Radiant cooling





- **EnergyPlus prototype developed to match CEC Single Family Residential research prototype**

2020 is reference year for research

- Allows for forward planning
- 2020 is target for residential ZNE

Capped at 2020 due to projection challenges beyond 8 years

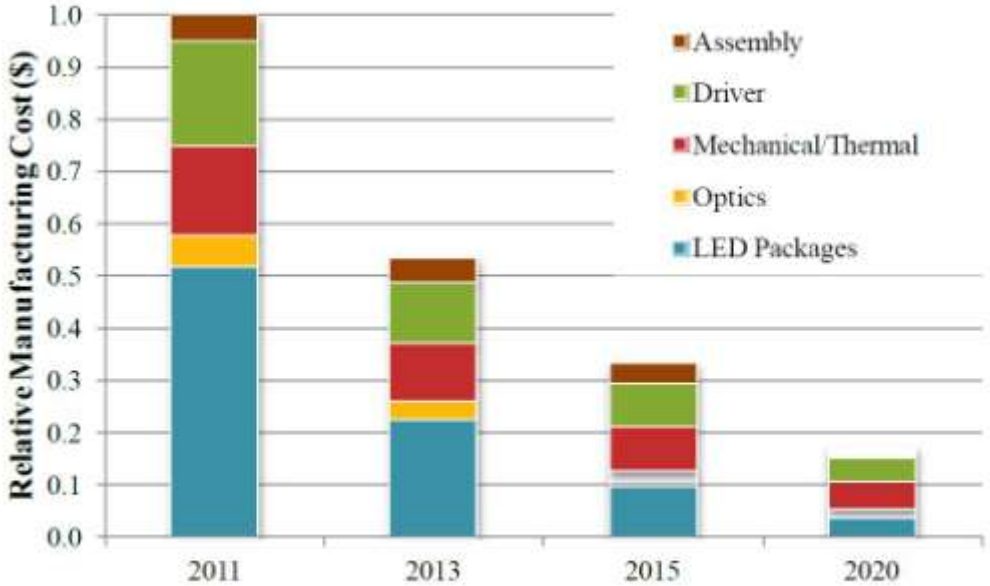


Figure 1-1. Projected cost track for an LED-based A19 60W replacement lamp
Source: data provided by the 2011 Manufacturing Roundtable attendees

"Solid-State Lighting Research and Development: Manufacturing Roadmap." Bardsley Consulting, 2012. Prepared for the Department of Energy.

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Technical (yes) vs. Behavioral (no) Feasibility

- **Best possible systems**
  - Envelope, Lighting, HVAC
  - Plug loads
    - Assumed improvements in offices and homes
    - Assumed status quo in hospitals and schools
    - Determined on a case-by-case basis
    - High overall uncertainty
  - Ubiquitous controls
- **But average occupants**

Minimizing Energy Use, Unrestrained by Cost

- Not constrained by cost effectiveness
- But all technologies and strategies are:
  - Employed today, or
  - Reasonable projections based on those employed today

Units – Site-kBtu, TDV and . . . ?

Two leading metrics for ZNE:

Site-kBtu	Time Dependent Valuation (TDV)
Most-commonly used metric	Basis for comparing energy use under Title 24
Prioritizes electricity over natural gas	Source metric - including carbon, grid capacity, escalators, RPS, etc.
	A monetary metric, representing the net present value of energy over 30 yrs
	Hybrid societal cost and participant cost
	Designed as a consumption metric. Likely needs modification to properly measure renewable exports.
Electricity and natural gas can be "traded" under both metrics	

- **The study optimized efficiency to minimize TDV**
- **The study reports both to compare metric impacts**

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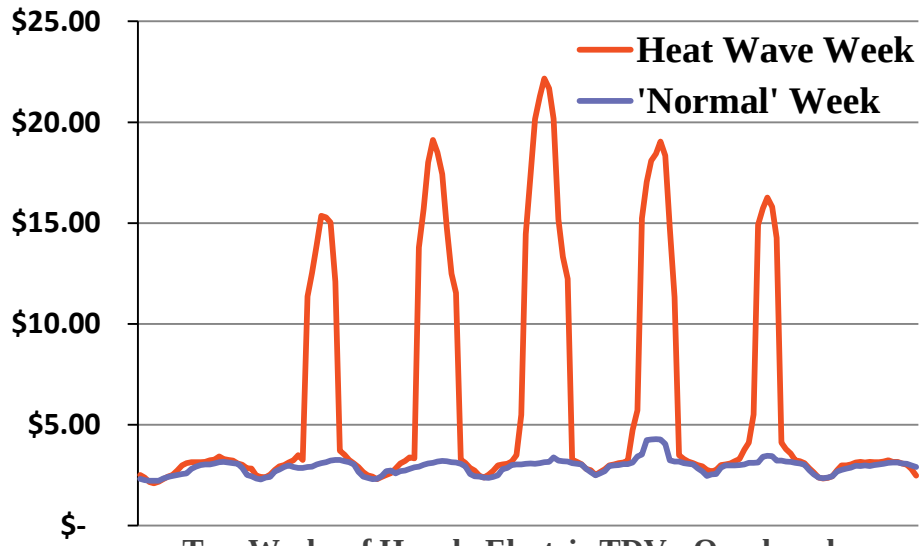
Units – Site-kBtu, TDV and . . . ?

- **Implications:**
  - TDV necessitates **far less PV** to reach **Zero**
    - Difference greatest on residences
    - Less impact on commercial buildings (9-5, Mon-Fri usage)
  - TDV ZNE usually closer to Zero Net kWh (site-kBtu is net exporter)
  - Site-kBtu ZNE building reduces more carbon



Two Weeks of Hourly Electric TDV - Overlayed
(Consecutive weeks in September)

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Matched values: Site-kBtu to TDV

- If TDV expressed in 30 year dollar values, values can be compared as if site-kBtu.
  (But TDV values are not fixed long-term like site-kBtu; they increase in response to resource markets.)

Metric:	Bldg 1	Bldg 2	Bldg 3	Bldg 4	Bldg 5	Bldg 6	Avg.
Site-kBtu	*13.0*	*17.0*	*73.8*	*18.3*	*19.7*	*36.8*	***29.8***
TDV$	*$11.9*	*$18.9*	*$66.7*	*$21.1*	*$10.3*	*$40.2*	***$28.2***

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Renewable Energy

Dan Suyeyasu

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PV Production – Density is critical for ZNE

- Assume 80% maximum roof coverage
- Projected max production levels by 2020:

Attribute:	Value:	
Base Panel Efficiency	20%	(33% over standard 15% panels)
Efficiency by 2020	24%	(20% above current performance)
Module Optimizer	26%	(+10% performance improvement)
Average Degradation	24%	(-10% lifetime average from degradation)
Total	**24%**	(60% improvement/ft^2 compared to 15%)

- Parking lots will be critical for some buildings
  - Tracker units to improve evening production
  - 35% coverage of parking area assumed

NREL RSF Parking Canopy
Credit: Dennis Schroeder / NREL

Design Team Creativity - Critical to Density

Credit all: Sun Light and Power

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Residential Results

Bill Dakin - Davis Energy Group

Alea German - Davis Energy Group

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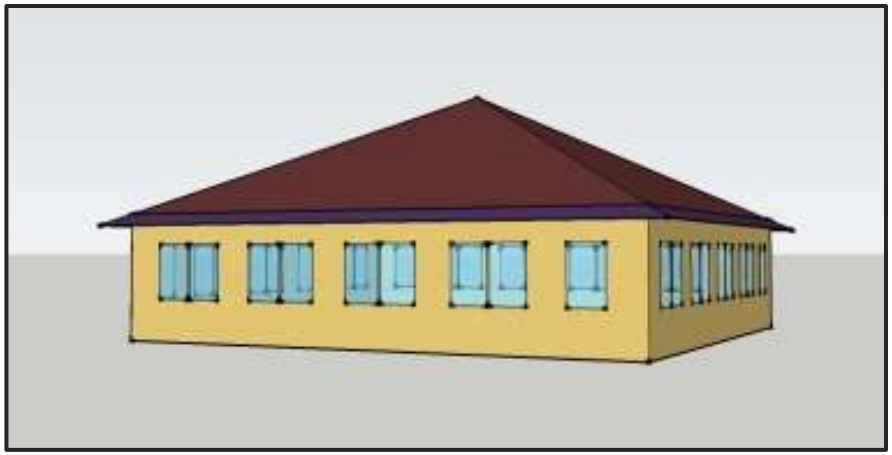
Path to ZNE…Single Family Home

Baseline Model Assumptions

- Prototype C from the Title 24 2008 Residential ACM Manual
  - 2100 sqft, 1-story, 20% win area to CFA, 3 beds, 2 bath
- Based on 2013 Title 24 Package A prescriptive measures
  - Includes whole house fan in CZ 8–14
- Thermostat set points / schedules based on Title 24
- Lighting, appliance, MEL assumptions based on T-24 & DOE Building America profiles and correlated with RASS



What Makes a ZNE Home

- *Integrated Design, Planning & Quality Control*
- *Aggressive Envelope Features*
- *Substantial Internal Load Reductions*
- *High Performance HVAC & Nighttime Ventilation Cooling (Some Climates)*
- *High Performance Water Heating*

ZNE Techniques – Advanced Walls

- Advanced Framing: 2x6 24”oc, insulated headers
  - Improved performance of wall assembly
  - Lower material & labor costs
- 1” Exterior Foam
  - Minimize thermal bridging

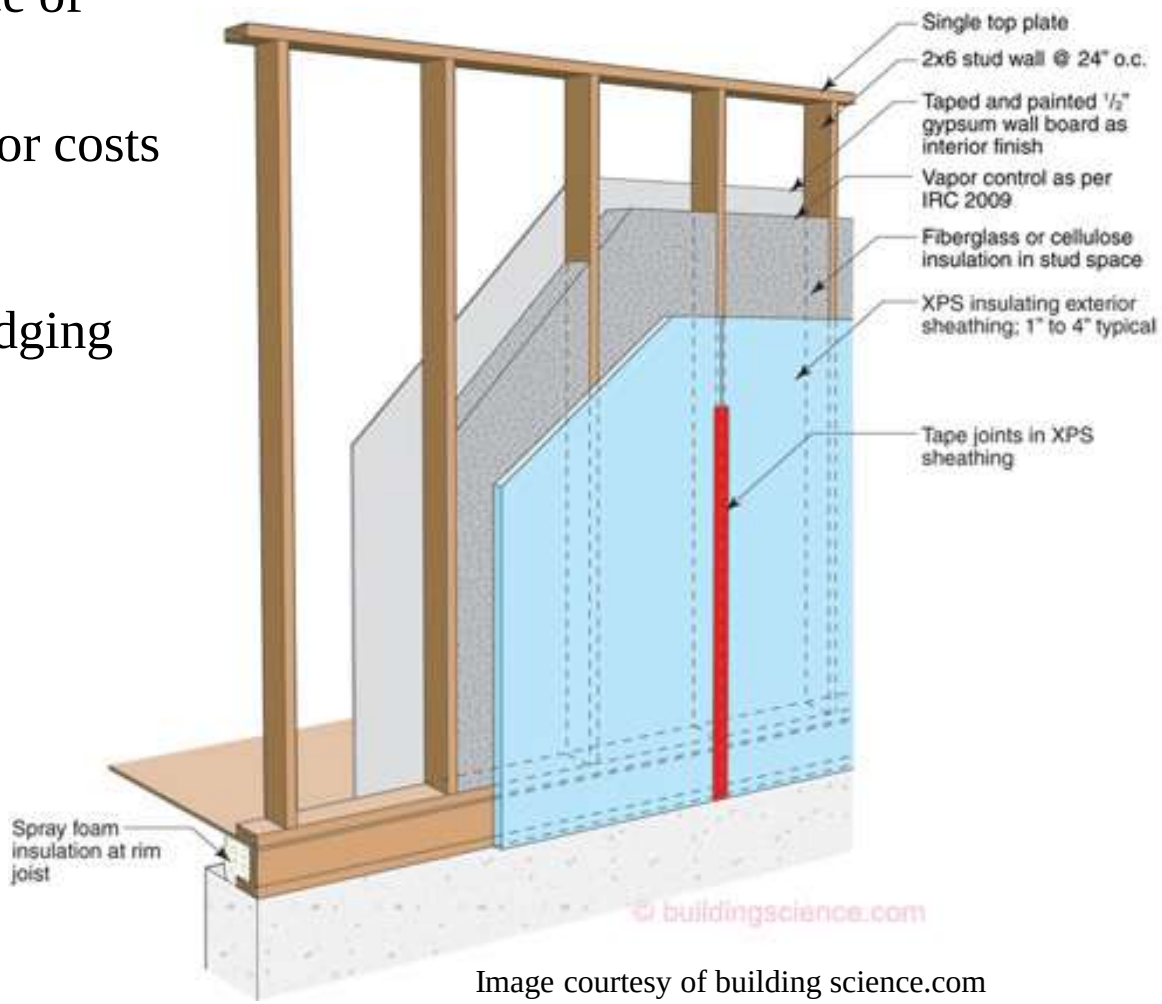
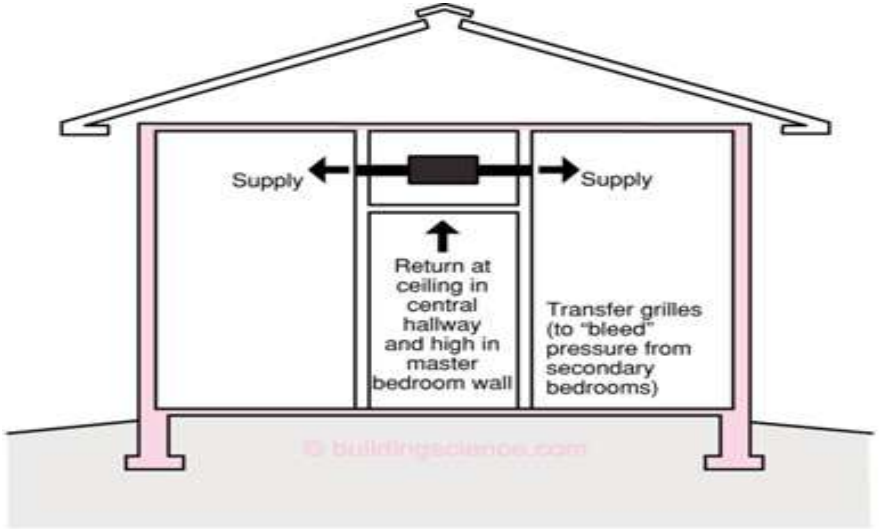


Image courtesy of building science.com

ZNE Techniques – Ducts in Conditioned Space

- Eliminate attic heat gains and air leakage to outside
- Allow for equipment downsizing
- Several strategies: Revised truss, dropped ceiling, unvented attic, fully buried ductwork

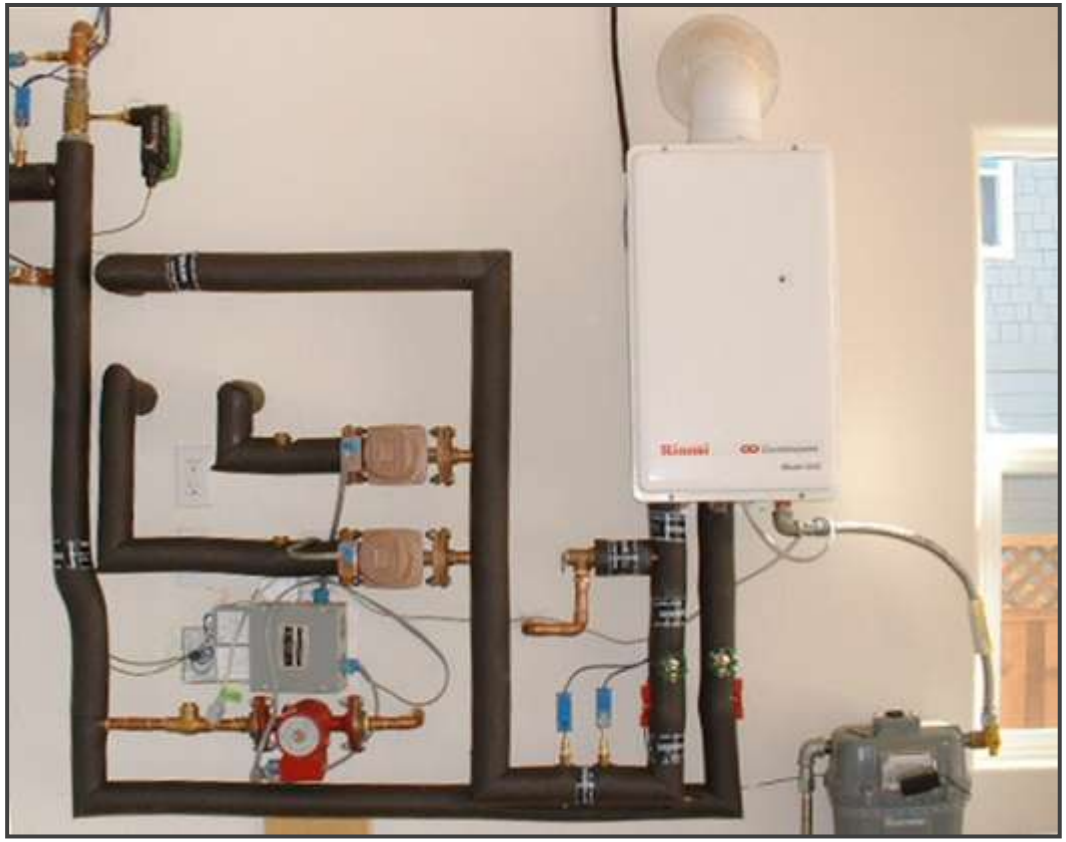


Note: Colored shading depicts the building's thermal barrier and pressure boundary. The thermal barrier and pressure boundary enclose the conditioned space.

- OR ductless options.

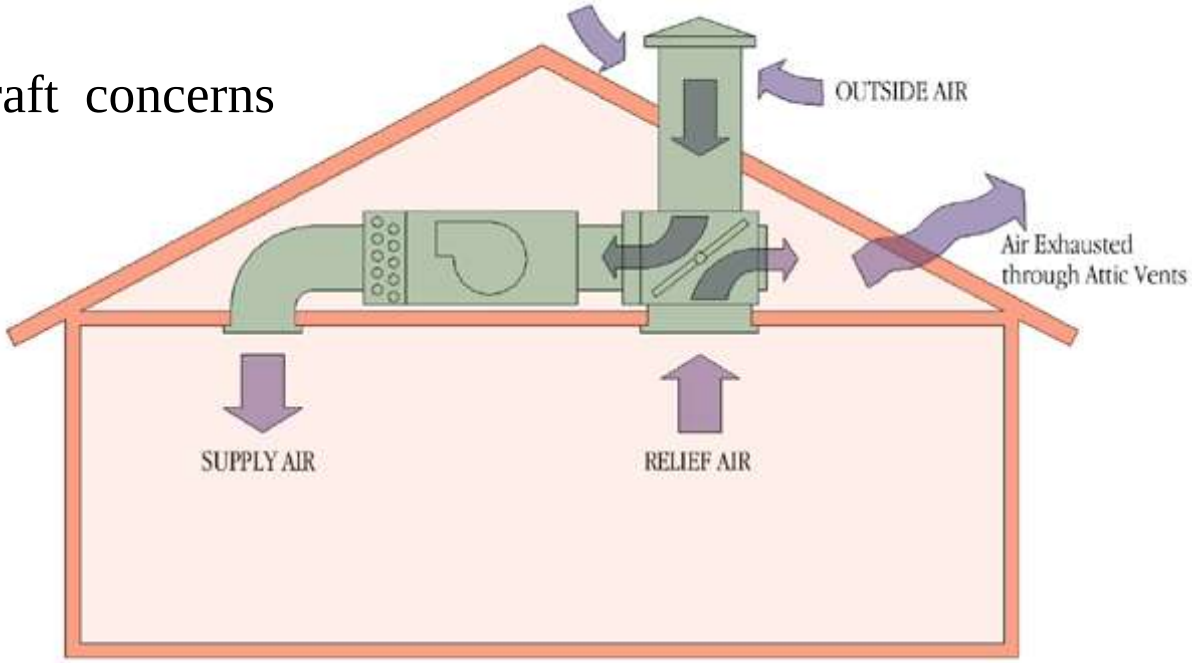
ZNE Techniques – Space Heating

- Gas furnace not well suited for low load homes
- Alternative Strategies:
  - Combined hydronic w/ condensing water heater
  - Heat pumps (central or mini-split)



ZNE Techniques – Nighttime Ventilation Cooling

- Introduce cool nighttime air – removing heat & charging thermal mass
- Assumed in Package A for Climate Zones 8 – 14 in 2013 Standards
- Integrated systems have advantages over manual systems
  - An automated system ensures ideal initiation and cessation of operation
  - Control algorithms & variable speed fans minimize overcooling on milder days
  - Eliminates back draft concerns



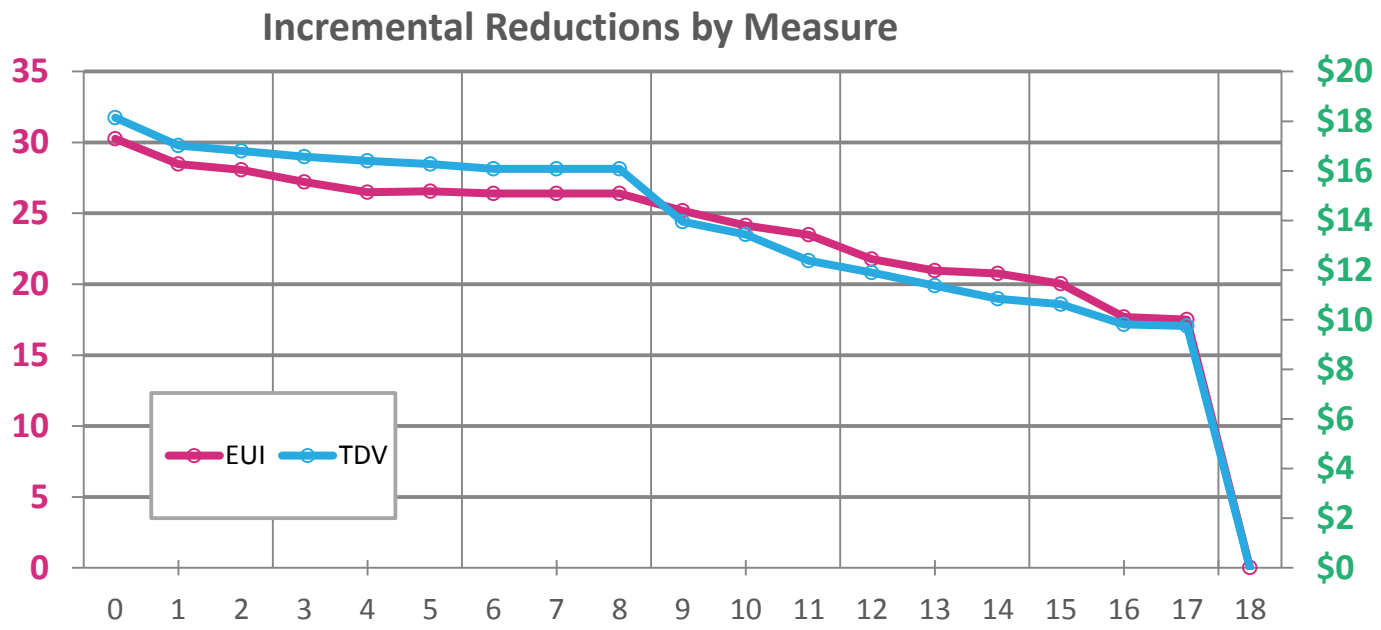
Ventilating

Single Family Residential

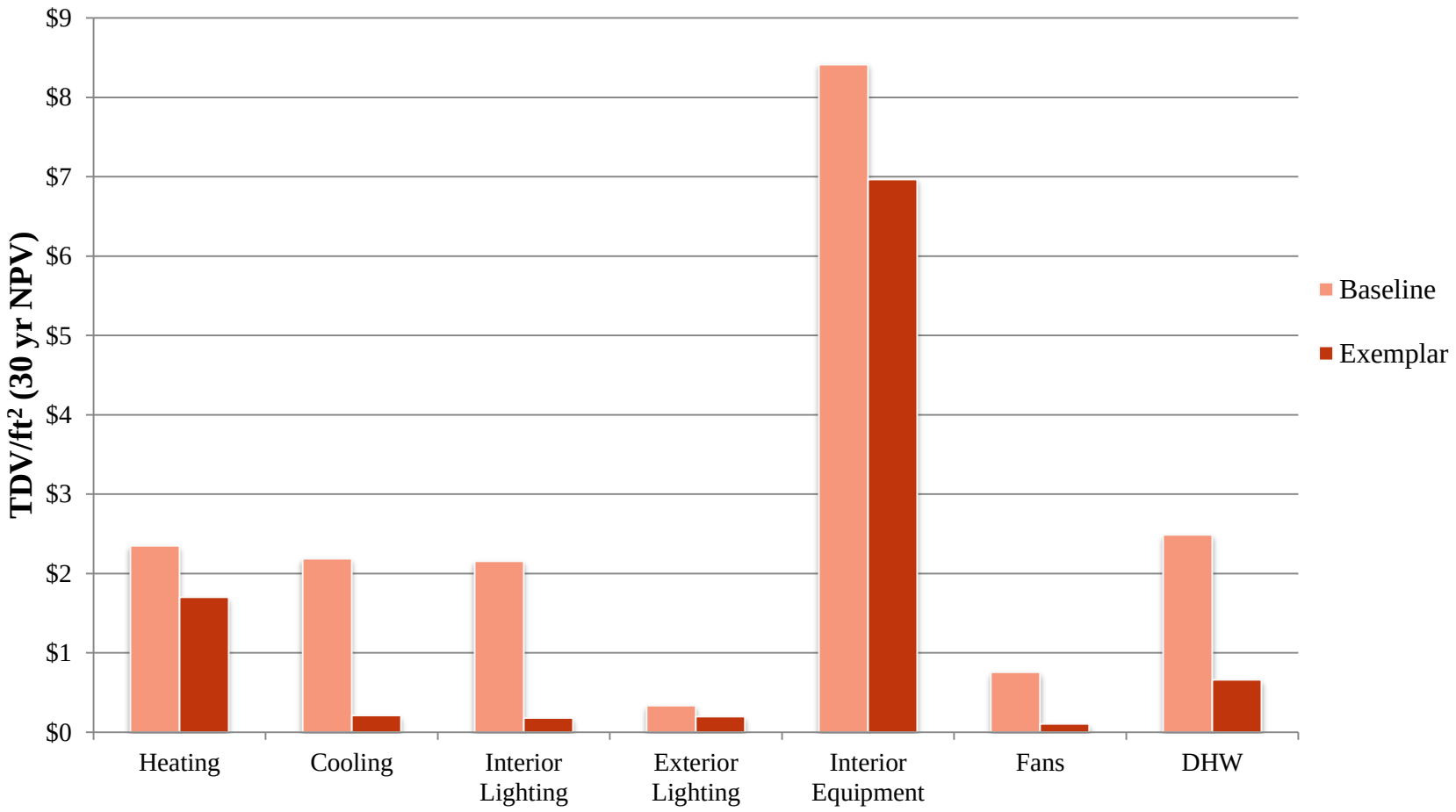
CZ12
Sacramento

	Strategy	kBtu/ft2/yr incremental savings	TDV/ft2 (30 yr) incremental savings	TDV cumulative percent reduction
	Starting EUI:	30.4	$18.68	0%
1	Improved Wall Construction: 2x6 walls, R-21 w/ R-4 rigid ext. sheathing. Advanced framing, 24" o.c.	-1.94	-$1.15	6%
2	Ceiling Insulation: R-60 blown-in insulation w/ raised heel trusses	-0.43	-$0.23	7%
3	Reduced Building Infiltration: 1.8 SLA / 3.15 ACH50	-0.91	-$0.24	9%
4	Improved Windows: U-Factor=0.25 / SHGC=0.20	-0.78	-$0.16	10%
5	Cool Roof: Reflectivity=0.40 / Emissivity=0.85	0.06	-$0.14	10%
6	Additional Thermal Mass	-0.15	-$0.20	11%
7	N/A			11%
8	N/A			11%
9	Improved Lighting: High efficacy LED lighting and vacancy controls	-1.32	-$2.20	23%
10	High Efficiency Appliances: Clothes washer, Dishwasher, Refrigerator	-1.12	-$0.52	26%
11	Reduced Plug Loads from Improved Equipment Efficiency and Controls	-0.71	-$1.09	32%
12	Low-Flow Shower & Sinks	-1.84	-$0.49	34%

13	Ducts in Conditioned Space	-0.86	-$0.54	37%
14	High Efficiency 2-speed AC, SEER 21 w/ Integrated Ventilation Cooling	-0.23	-$0.55	40%
15	Condensing Gas Space Heating	-0.78	-$0.22	42%
16	Condensing Gas Water Heater	-2.53	-$0.85	46%
17	Improved HW Distribution: Compact Design, Insulated HW Pipes	-0.18	-$0.06	46%
18	Rooftop photovoltaic	-16.66	-$10.02	100%
	Ending EUI:	**0.0**	**$0.00**	



Annual TDV Energy Use: Single Family CZ12



Single Family Residential

Single Family Residential

Size: **2,100** ft^2

Number of Floors: **1** floors

Climate Zones

		15	13	12	10	7	3	16
kBtu/ft²/yr	Load:	12.89	16.37	16.66	12.94	11.55	12.73	17.28
	Solar:	-12.89	-16.37	-16.66	-12.94	11.55	-12.73	-17.28
	Net:	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
TDV/ft² (30yr NPV)	Load:	$11.96	$10.95	$10.02	$8.71	$8.18	$8.24	$10.23
	Solar:	-$11.96	-$10.95	-$10.02	-$8.71	-$8.18	-$8.24	-$10.23
	Net:	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**

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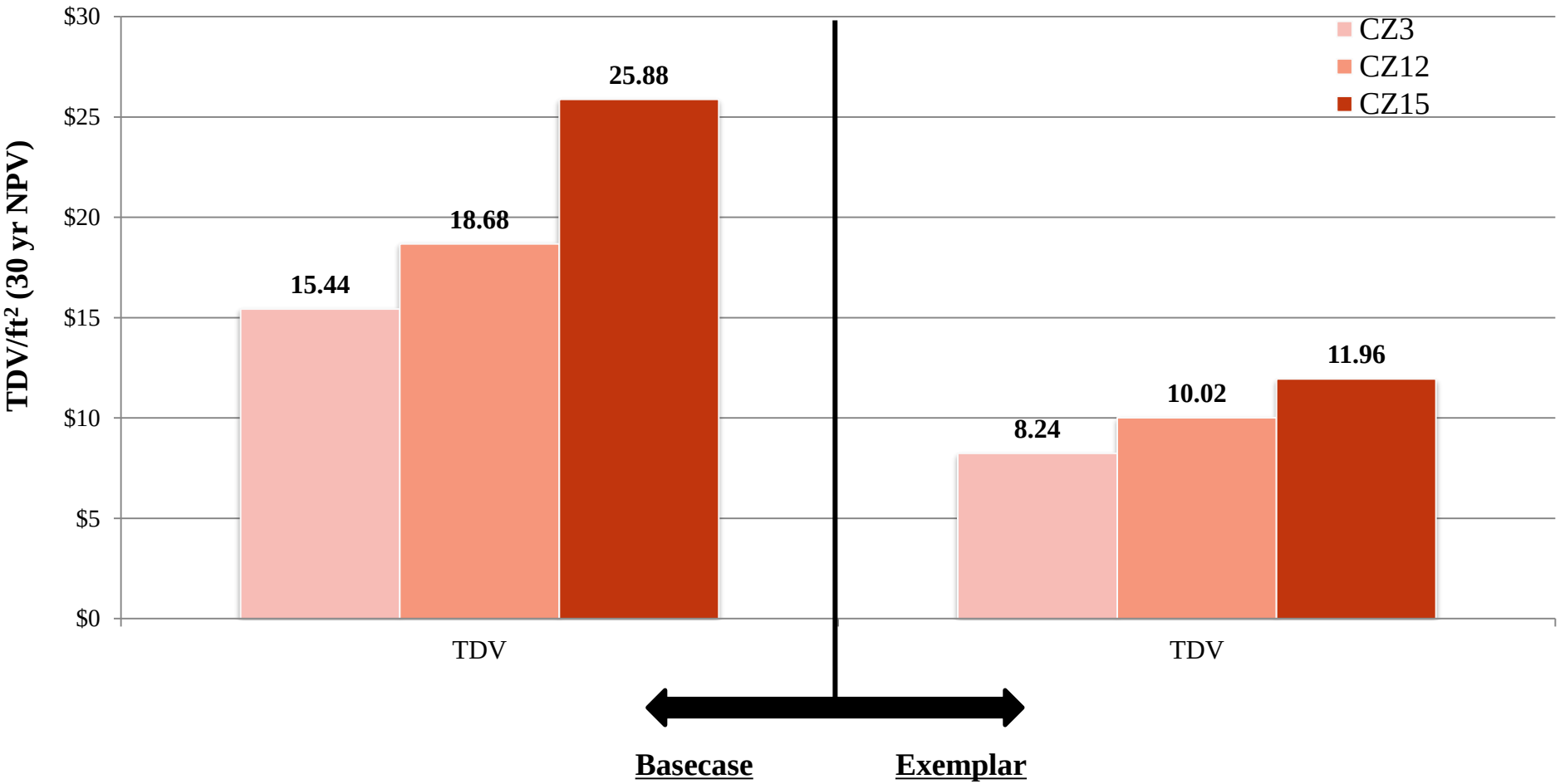
PV Sizing: Single Family

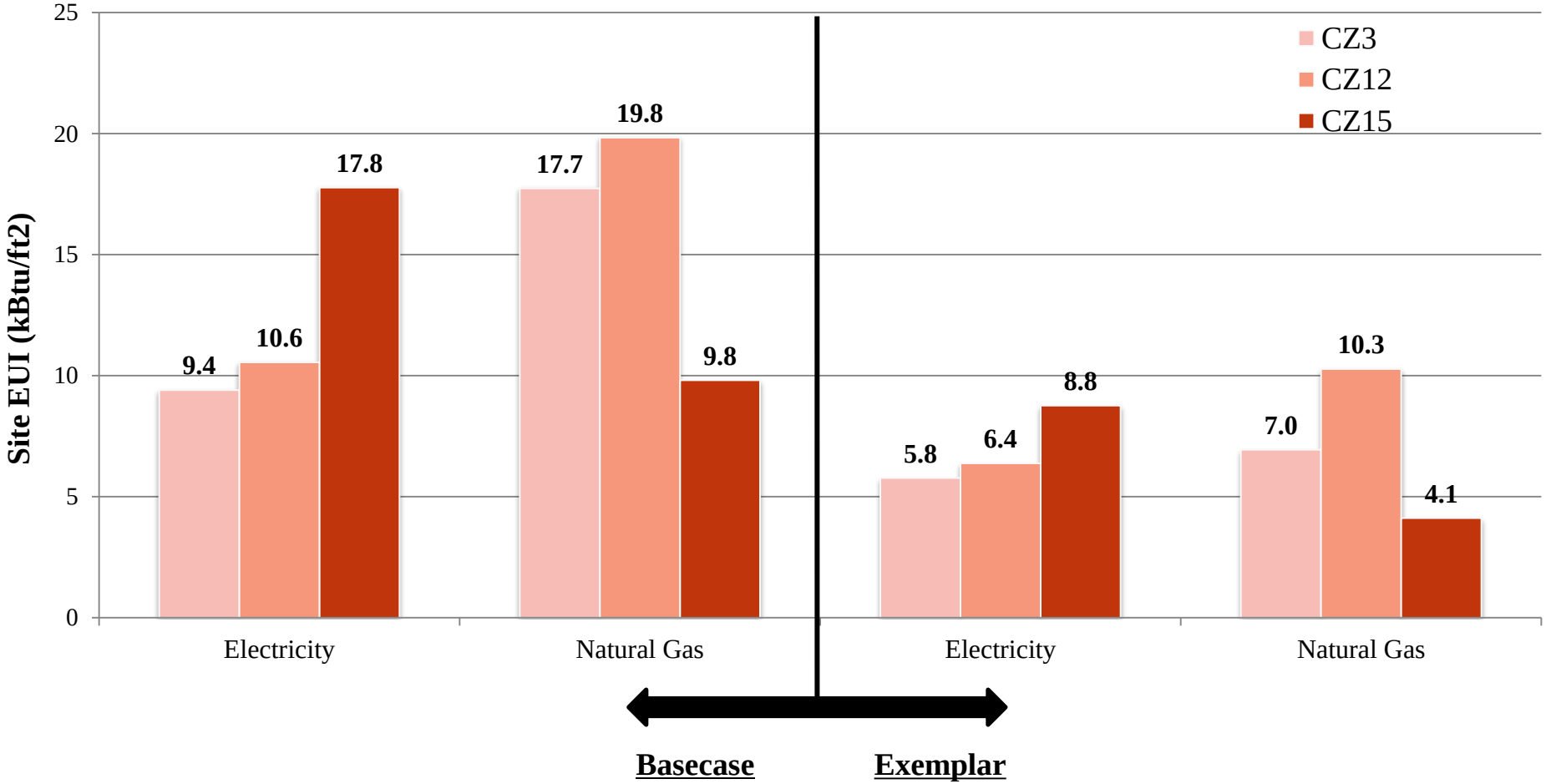
Building Performance Data		Climate Zones		
		15	12	3
Total Building Energy Metrics				
Peak Import 250hr Method (kW – bldg)	Total Load	1.6	0.5	0.4
	Minimized Site-kBtu	0.2	-1.9	-2.1
	Minimized TDV	0.5	-0.7	-0.2
Solar Capacity				
Solar PV (kWDC)	Minimized Site-kBtu	4.8	6.6	5.0
	Minimized TDV	3.9	3.2	2.5
Peak Export (kW - bldg)	Minimized Site-kBtu	-3.7	-5.1	-3.9
	Minimized TDV	-3.0	-2.3	-1.8
Empty Avail. Roof (ft^2)[1]	Minimized Site-kBtu	820	736	809
	Minimized TDV	859	891	925

[1]Based on available south facing roof, total available roof area = 1,040ft^2

Annual TDV EUI Comparison: Single Family



Annual Site EUI Comparison: Single Family



Commercial Results

Wyatt Kennedy

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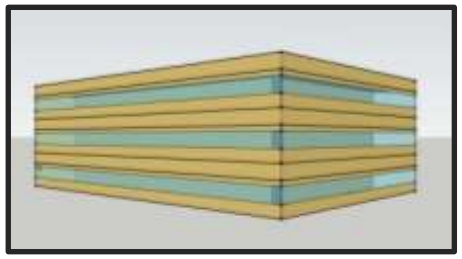
Medium Office

Medium Office



Size: **53,600** ft^2

Number of Floors: **3** floors

		Climate Zones						
		15	**13**	**12**	**10**	**7**	**3**	**16**
kBtu/ft^2/yr	**Load:**	20.3	18.4	17.5	17.3	15.5	15.4	18.5
	Solar:	-20.3	-18.4	-17.5	-17.3	-15.5	-15.4	-18.5
	Net:	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
TDV/ft^2 (30yr NPV)	**Load:**	$23.39	$19.77	$18.54	$19.08	$16.14	$15.37	$17.01
	Solar:	-$23.39	-$19.77	-$18.54	-$19.08	-$16.14	-$15.37	-$17.01
	Net:	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**

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Medium Office

CZ12
Sacramento

	Strategy	kBtu/ft2/yr incremental savings	TDV/ft2 (30 yr) incremental savings	TDV cumulative percent reduction
	Starting EUI:	32.6	$31.43	0%
1	Reduce Lighting Power Density (LPD) by 60%	-2.67	-$2.44	8%
2	Reduce nighttime plug load schedule to 0.10, with use of night turn-off software	-2.32	-$1.69	13%
3	Reduce plug load level from 1.0 W/sf to 0.5 W/sf	-4.10	-$4.10	26%
4	Reduced exterior lighting wattage level by 50%	-0.72	-$0.52	28%
5	Adjusted WWR from 33% to 30% by reducing the height of the windows	-0.29	-$0.24	29%
6	Added 2 foot overhangs to all facades	-0.29	-$0.25	29%
7	Changed exterior wall insulation from R-9.73 to R-12.16, 25% over 90.1	-0.15	-$0.12	30%
8	Increased R-value of roof insulation from 19.7 to 24.6 (25% increase)	-0.09	-$0.10	30%
9	Changed windows to Window_U_0.43_SHGC_0.29	-0.45	-$0.32	31%
10	Added PV panel shading on roof	-0.07	-$0.21	32%
11	Additional thermal mass (2 inches of concrete)	-0.10	-$0.04	32%
12	Implemented natural ventilation	-0.87	-$1.02	35%
13	Cooling setpoint from 75.2 F to 77 F occupied hours	-0.50	-$0.57	37%
14	Remove electric reheat	0.13	-$0.37	38%

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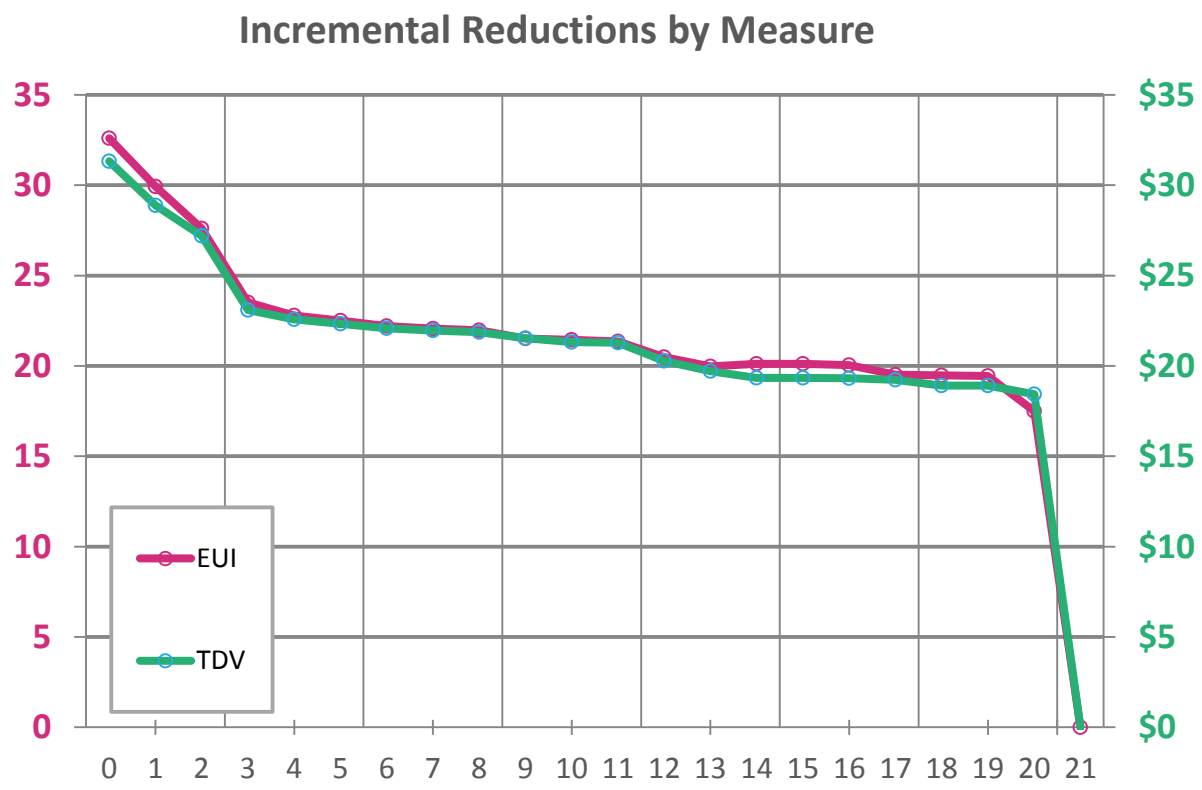
15	Changed fan efficiency from 0.6045 to 0.7	0.00	$0.00	38%
16	Changed boiler efficiency to 0.98 (condensing boiler)	-0.07	-$0.01	38%
17	Improved water heater efficiency to 0.97 from 0.8	-0.53	-$0.09	38%
18	2.07" pressure drop for air distribution	-0.04	-$0.31	39%
19	3.5 COP on DX coils (from 3.4)	-0.02	-$0.01	40%
20	**Reduced minimum turndown on VAV boxes to 10%**	**-1.95**	**-$0.47**	41%
21	Rooftop PV	-17.5	-$18.54	100%
	Ending EUI:	**0.0**	**$0.00**	



For office building, almost no difference: Site-kBtu or TDV

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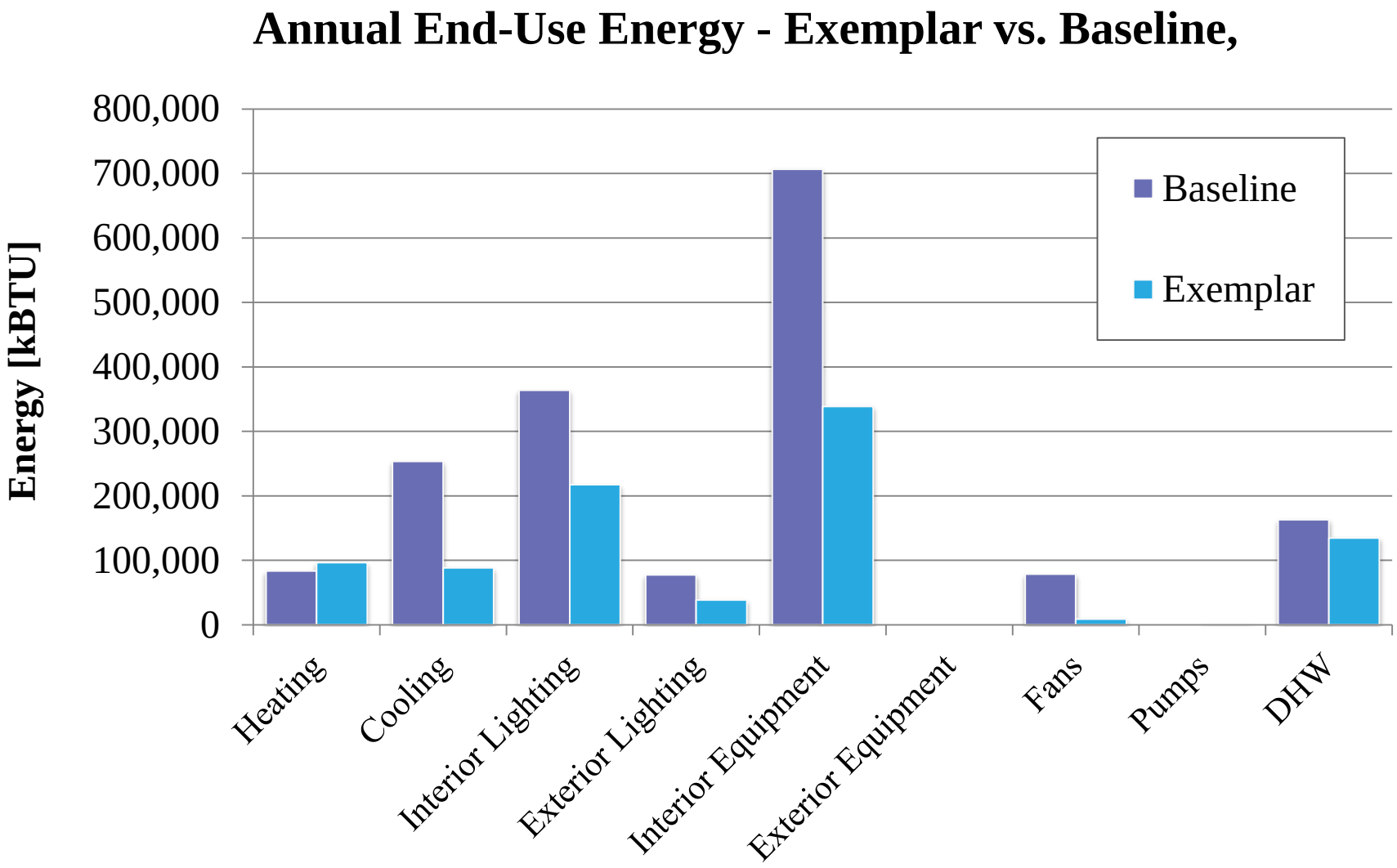
Path to ZNE: Medium Office, CZ 12



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Hospital

Hospital

Size: **241,410** ft^2

Number of Floors: **5** floors *+basement*

		Climate Zones						
		15	**13**	**12**	**10**	**7**	**3**	**16**
kBtu/ft²/yr	**Load:**	76.3		73.8				72.5
	Solar:	-17.4		-16.3				-17.4
	Net:	58.9		57.5				55.1
TDV/ft² (30yr NPV)	**Load:**	$69.59		$66.65				$64.86
	Solar:	-$19.03		-$18.56				-$20.39
	Net:	$50.56		$48.08				$44.47

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Hospital

CZ12
Sacramento

	Strategy	**kBtu**/ft2/yr incremental savings	**TDV**/ft2 (30 yr) incremental savings	**TDV** cumulative percent reduction
	Starting EUI:	**108.8**	**$82.87**	**0%**
1	**220 lm/W LED lighting, this results in a 60% reduction**	**-4.11**	**-$4.94**	**6%**
2	Use occ sensors in Office, Lobby, Clinic, OR	-0.39	-$0.38	**6%**
3	Window shades on all facades, 2'	0.42	-$0.01	**6%**
4	PV shading on roof	0.03	$0.05	**6%**
5	Reduce exterior lights by 50% - LEDs	-0.42	-$0.22	**7%**
6	**Reduced elevator design loads**	**-1.89**	**-$1.61**	**9%**
7	Changed windows to 'Window_U_0.35_SHGC_0.35'	-0.83	-$0.11	**9%**
8	Reduced infiltration rate by 40%	-0.05	-$0.01	**9%**
9	Increased wall insulation by 25%	-0.12	-$0.02	**9%**
10	**Patient room VAV box minimum to 0.2 from 0.5**	**-4.27**	**-$1.18**	**10%**
11	Changed boiler efficiency to 0.97 (condensing boiler)	-3.14	-$0.53	**11%**
12	Changed fan efficiency from 0.6045 to 0.7	-0.85	-$0.77	**12%**
13	Improved water heater thermal efficiency to 0.97 from 0.8 to reflect high efficiency technology currently on market	-0.17	-$0.03	**12%**
14	**Improved COP of chillers from 5.5 to 6.5**	**-1.46**	**-$1.26**	**13%**

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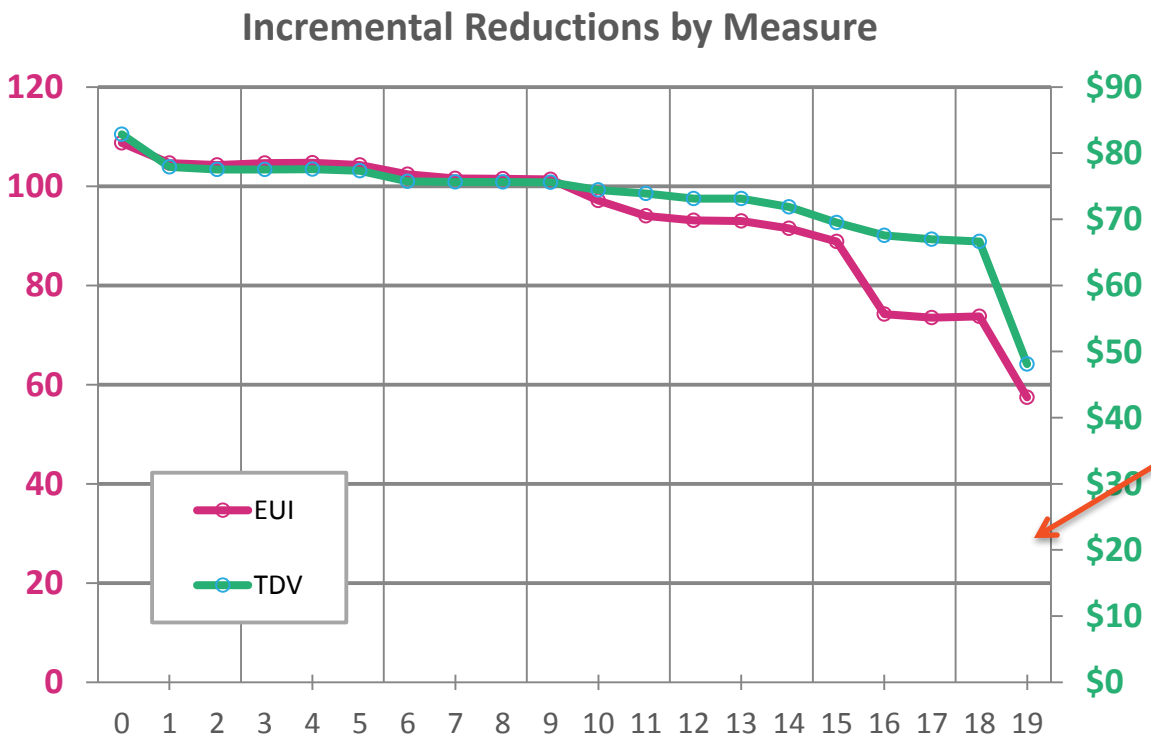
15	**Reduced fan pressure drop from 5.58” to 3.0” wc (through use of low-pressure design, therma-fusers)**	**-2.63**	**-$2.35**	**16%**
16	**Creted new HVAC system: chilled beams, convective baseboard heaters, DOAS with heat recovery**	**-14.64**	**-$1.96**	**18%**
17	Fixed the chilled water temperature to be 59 F	-0.72	-$0.57	**19%**
18	Changed supply air temp from 60 F to 55 F that serves active chilled beams	0.25	-$0.32	**20%**
19	Rooftop PV	-16.3	-$18.56	**42%**
	Ending EUI:	**57.5**	**$48.08**	



CHP w/ Parking PV	15	12
CHP system size (kW)	332	332
Site-kBtu/ft^2	84.5	83.5
TDV/ft^2 (30yr NPV)	**$26.1**	**$25.1**

Parking lot PV and CHP can take TDV down to $26, but Site-kBtu rises with CHP

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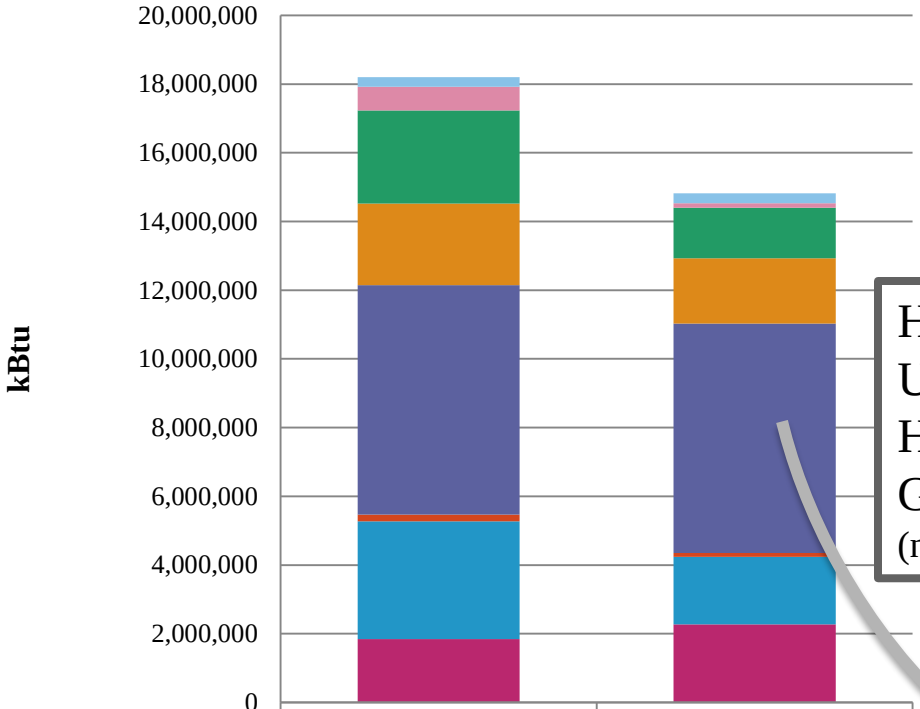
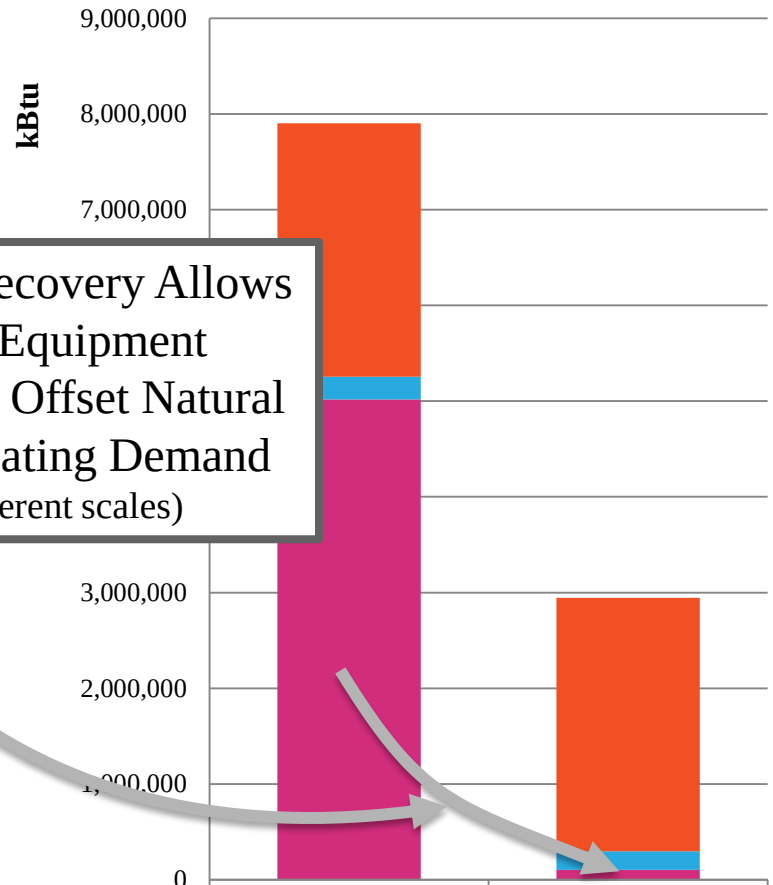
Path to ZNE: Hospital, CZ 12

Electricity Consumption (Annual kBtu)



	Baseline	Exemplar
Heat Rejection	280126.63	291891.31
Pumps	692965.73	130469.45
Fans	2702711.07	1467305.79
Exterior Equipment	2383294.97	1904096.65
Interior Equipment	6673670.82	6673670.82
Exterior Lighting	195219.22	117134.51
Interior Lighting	3433966.4	1959362.71
Cooling	1840078.38	2277120.81

Natural Gas Consumption (Annual kBtu)



Heat Recovery Allows Use of Equipment Heat to Offset Natural Gas Heating Demand
(note different scales)

	Baseline	Exemplar
Interior Equipment	2648047.11	2648047.11
Water Systems	235341.91	194201.49
Heating	5018478.29	102785.91

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Building Performance Data

Hospital

		Climate Zones						
Square feet:	**241,410**							
Avail. Roof:	**38,626**	**15**	**13**	**12**	**10**	**7**	**3**	**16**
Total Building Energy Metrics								
kWh/ft^2	Load	18.8		17.8				17.4
	Minimized Site-kBtu	13.7		13.0				12.3
kW/bldg (250 hr method)	Load	666.5		628.3				611.3
	Minimized Site-kBtu	455.4		364.0				332.2
Therms/ft^2	Load	0.12		0.13				0.13
Solar Capacity								
Solar PV (kW)	Minimized Site-kBtu	739		739				739
Peak Export (kW)	Minimized Site-kBtu	-198.0		-178.4				-240.4
Building Height Analysis								
Max Floors at ZNE	w/ TDV Metric	1.4		1.4				1.5
Floors with Parking PV	w/ TDV Metric	2.5		2.5				2.8
	Park. PV Size (kW)	463		463				463

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Broad Trends

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Nothing is Better than Nothing

Sensors and Controls

Software

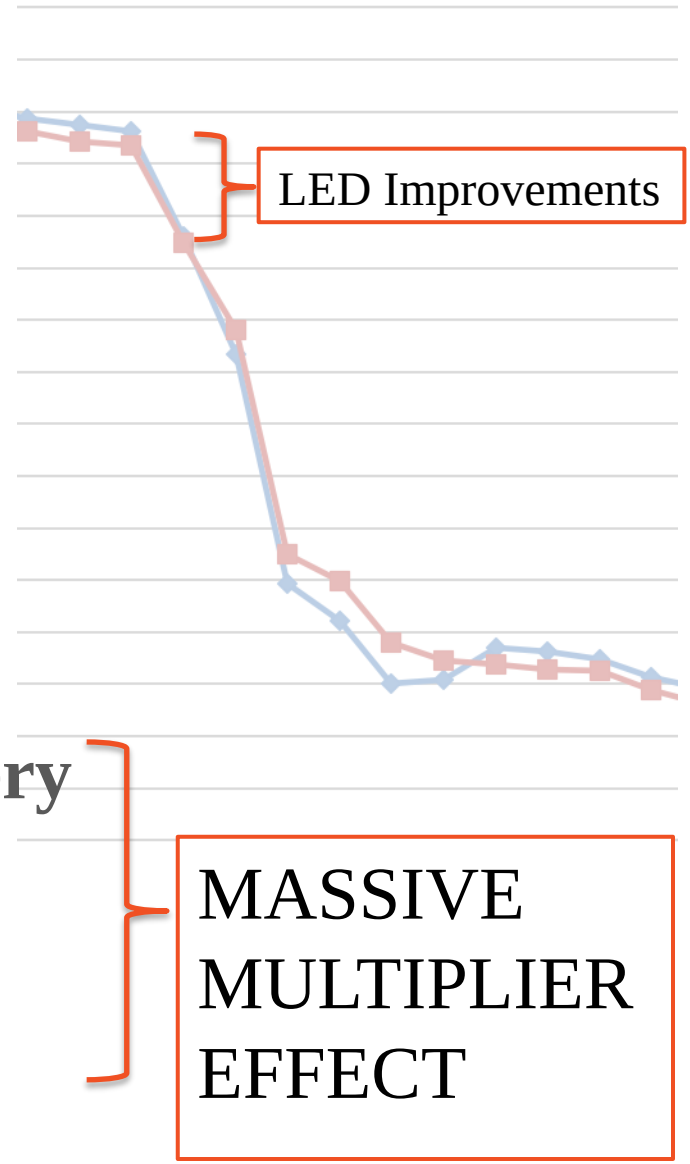
Embedded Intelligence

From: "You never know" operations
To: "We know what's happening" operations

"Free" Cooling & Heating

LEDs are a Bright Spot

- **Significant potential to further increase performance (220 lm/W)**
  - (Other building systems nearing limits)
- **Ability to put photons where you need them, not where you don't**
  - Efficiency greater than fluorescent
  - Precision equal to halogens
- **Creates savings for essentially every square foot of new construction**
  - Equal or larger retrofit opportunities
  - Extending to roads and parking lots



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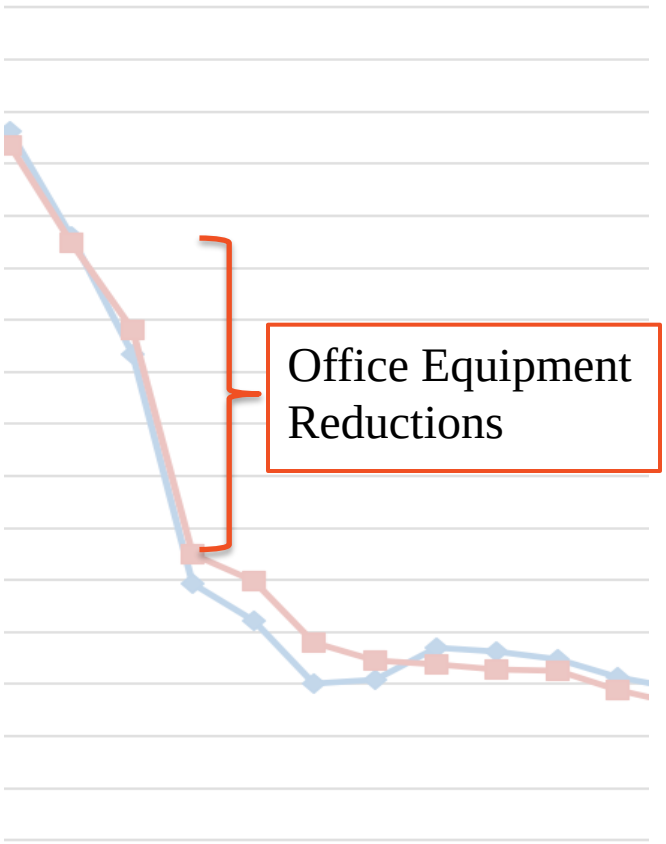
Plug Loads

- **Must be addressed to reach ZNE**
  - Equipment level trends are good
  - Overall volume is problematic
- **Software and controls will improve auto-off functions**
- **Monitors and T.V.s are a big part**
  - LED improvements should help here



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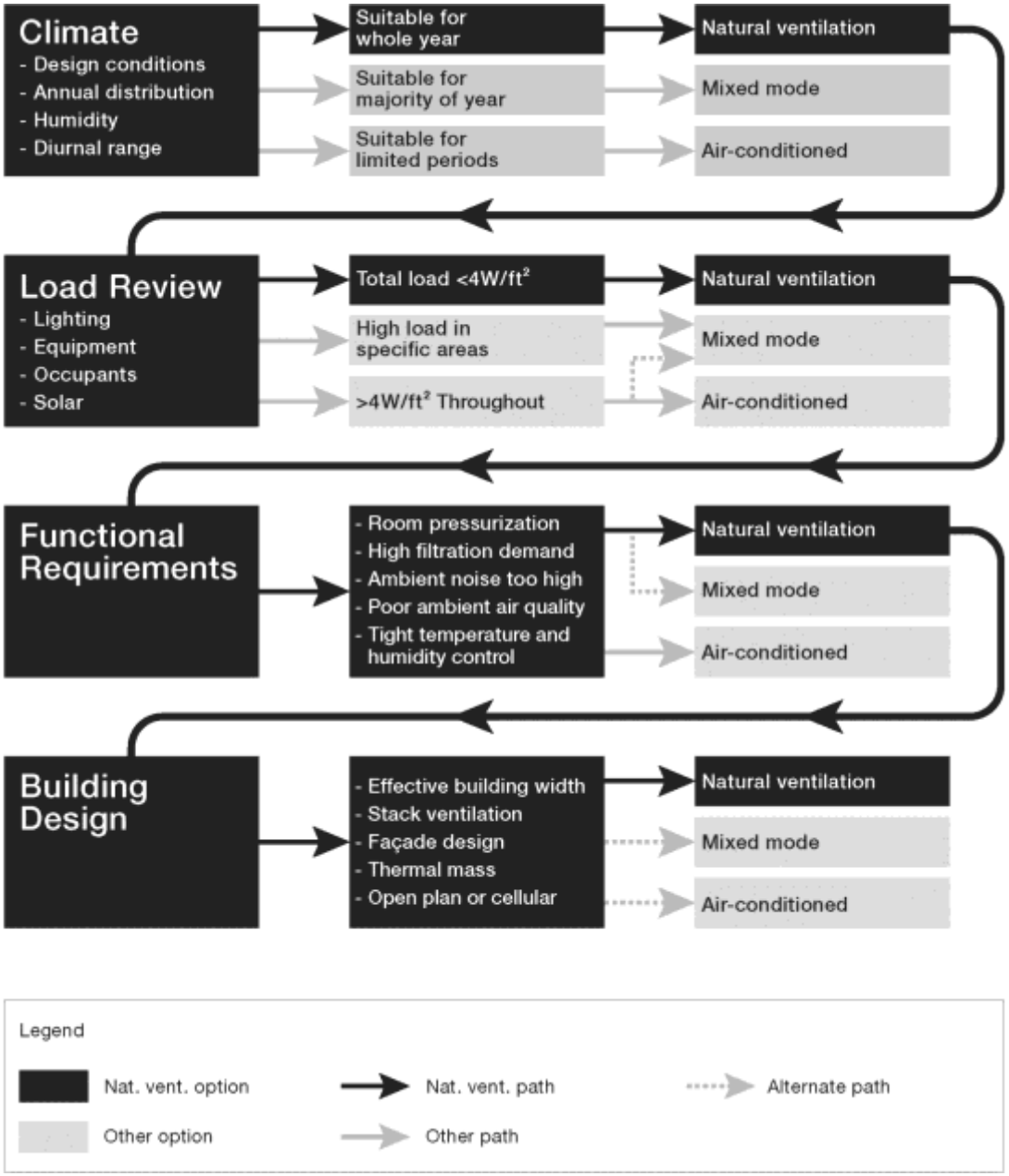
Will Natural Ventilation Work?



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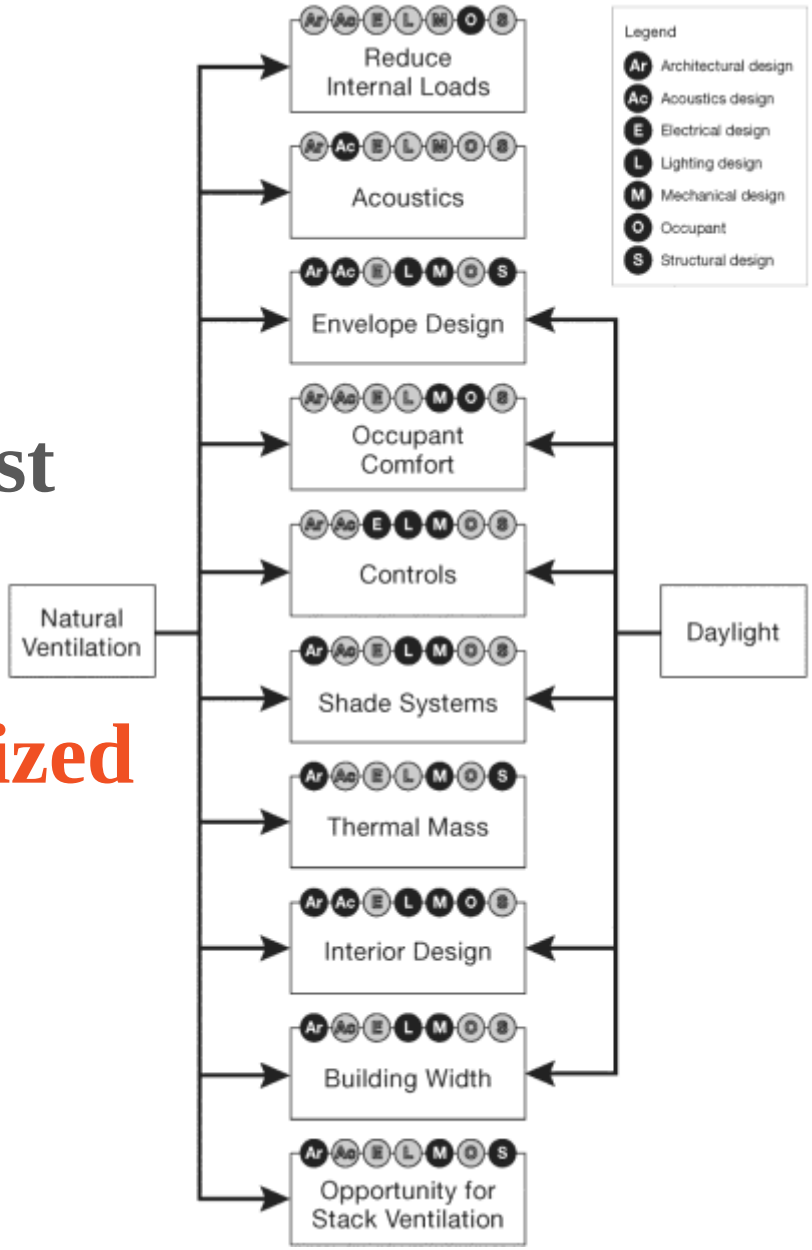
Natural Ventilation

- **Often impeded by *N O I S E***
- **A pleasant convergence:**
  - **Car, bus, and truck efficiency will reduce this problem.**
- **Also impeded by necessary control connections between HVAC and building envelope**
  - **Creates many potential points of failure. Need to nail the details.**

Integrated Design Essential to ZNE

- Interactions between different disciplines must be optimized
- "Standard practice" enables compartmentalized engineering of systems
  - Easier
  - But limits savings



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Conflict Avoidance

- **Move residential ducts out of the attic**
  - Running an A/C system in a 140° + environment will never be efficient
- **Design commercial HVAC systems to minimize reheat**
  - e.g. VAV boxes with low-turndown
- **Capture and reuse waste heat from A/C systems or through cogeneration (CHP)**

Questions?

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ZNE Scenario Analysis Tool

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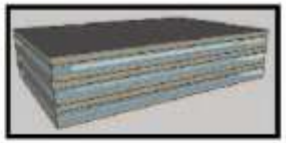
building specific technical potential to achieve Zero Net Energy

building type: medium office | climate zone: 10 - riverside | ft² = 53,700



plement energy reduction strategies, but it is by no means the only order or universal best order

load reduction

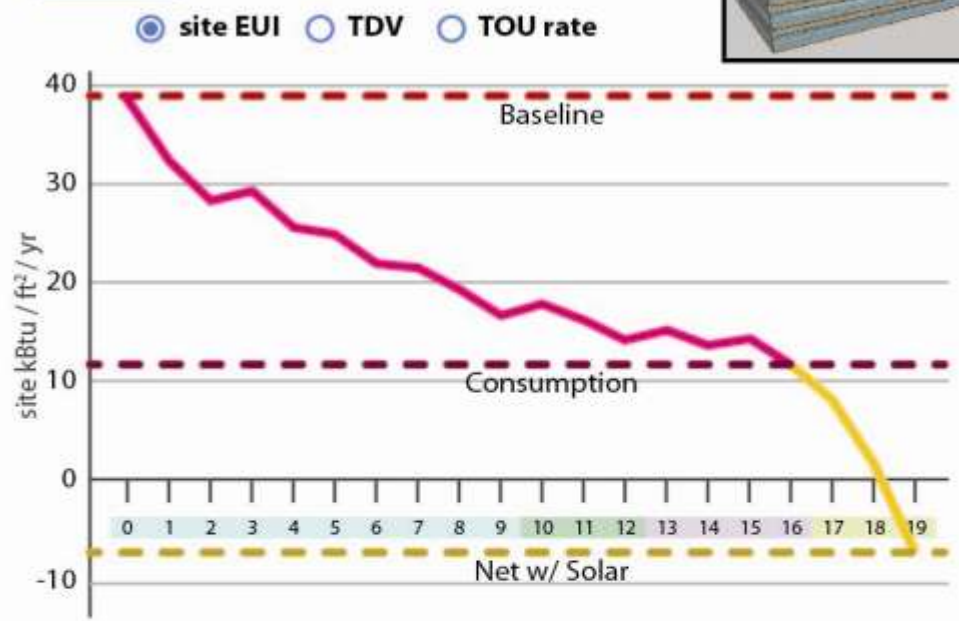
1. **lumens per watt** (used to derive LPD in relation to 90 l/w fixture) — baseline: 150, current: 115 — 90 / 180
2. **occupied hours schedule peak** (% of full, w/o daylighting) — baseline: 80, current: 65 — 80 / 50
3. **equipment power density** (W/ft²/yr) — baseline: 1.0, current: 0.8 — 3.0 / 0.3
4. **occupied hours schedule peak** (% of full) — baseline: 80, current: 68 — 80 / 50
5. **unoccupied hours schedule minimum** (% of full) — baseline: 50, current: 45 — 60 / 10
6. **solar heat gain coefficient** (SHGC) — baseline: 0.25, current: 0.30 — 0.5 / 0.2
7. **window conduction** (U-factor) — baseline: 0.40, current: 0.35 — 0.45 / 0.10
8. **window/wall ratio** (wwr %) — baseline: 30, current: 35 — 50 / 20
9. **wall conduction** (assembly R-value) — baseline: 13, current: 20 — 10 / 25

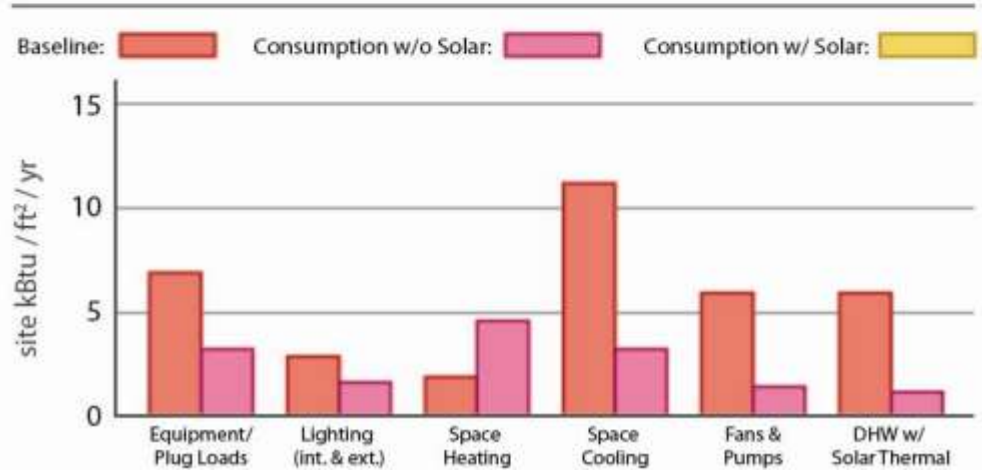
passive systems

10. **window overhang** (length / height-above-sill ratio) — baseline: 0.0, current: 1.0 — 0.0 / 1.0
11. **natural ventilation** — yes / no (baseline: yes / no)
12. **thermal mass** — yes / no (baseline: yes / no)

ems

13. **HVAC system** — VAV / UFAD / radiant (HVAC baseline: VAV / UFAD / radiant)
14. **chiller COP**





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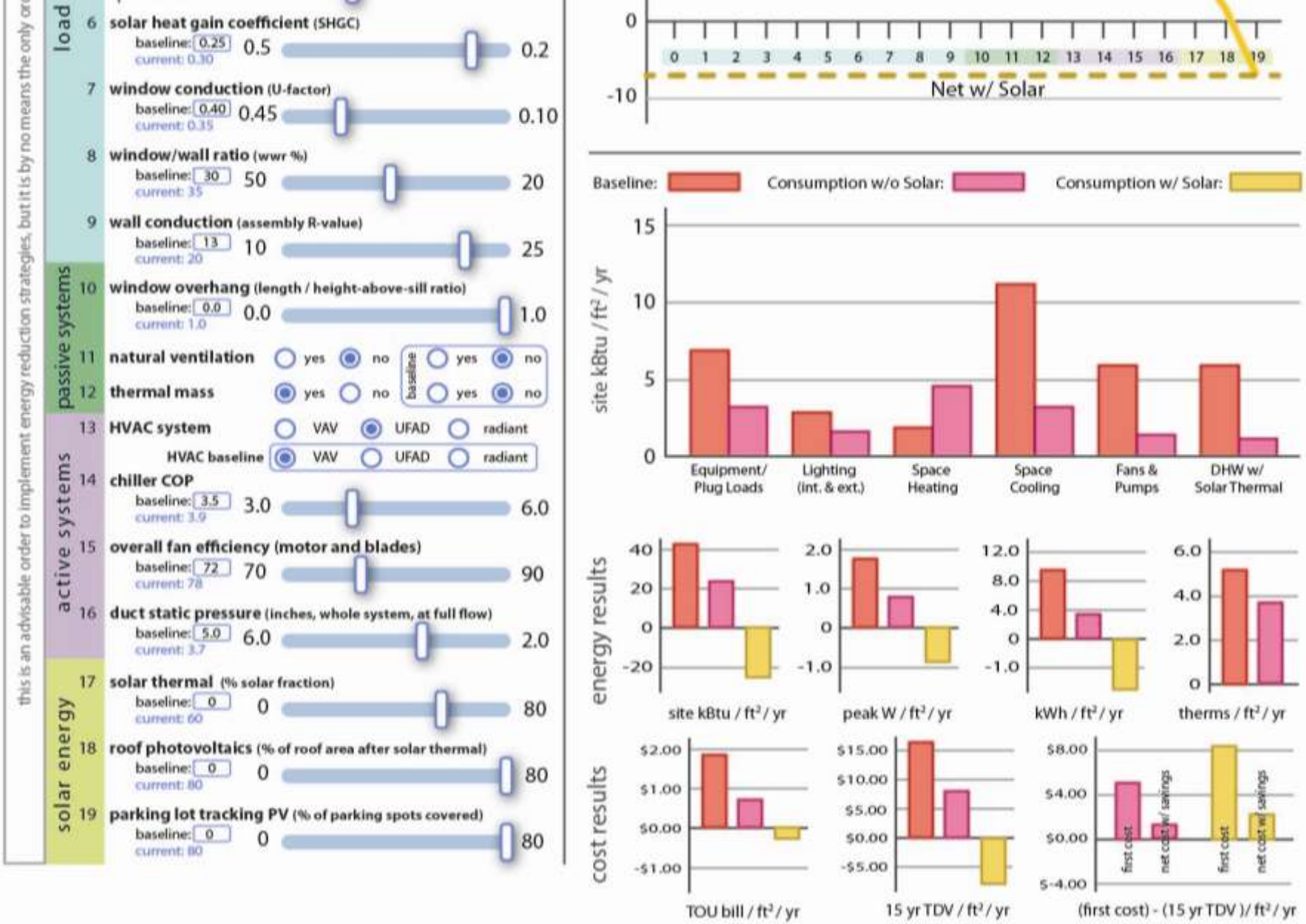
this is an advisable order to implement energy reduction strategies, but it is by no means the only order
load
passive systems
active systems
solar energy
6 solar heat gain coefficient (SHGC)
baseline: 0.25 current: 0.30 0.5 0.2
7 window conduction (U-factor)
baseline: 0.40 current: 0.35 0.45 0.10
8 window/wall ratio (wwr %)
baseline: 30 current: 35 50 20
9 wall conduction (assembly R-value)
baseline: 13 current: 20 10 25
10 window overhang (length / height-above-sill ratio)
baseline: 0.0 current: 1.0 0.0 1.0
11 natural ventilation yes no baseline yes no
12 thermal mass yes no baseline yes no
13 HVAC system VAV UFAD radiant
HVAC baseline VAV UFAD radiant
14 chiller COP
baseline: 3.5 current: 3.9 3.0 6.0
15 overall fan efficiency (motor and blades)
baseline: 72 current: 78 70 90
16 duct static pressure (inches, whole system, at full flow)
baseline: 5.0 current: 3.7 6.0 2.0
17 solar thermal (% solar fraction)
baseline: 0 current: 60 0 80
18 roof photovoltaics (% of roof area after solar thermal)
baseline: 0 current: 80 0 80
19 parking lot tracking PV (% of parking spots covered)
baseline: 0 current: 80 0 80
0
-10
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
Net w/ Solar
Baseline:
Consumption w/o Solar:
Consumption w/ Solar:
site kBtu / ft² / yr
15
10
5
0
Equipment/ Plug Loads
Lighting (int. & ext.)
Space Heating
Space Cooling
Fans & Pumps
DHW w/ Solar Thermal
energy results
site kBtu / ft² / yr
peak W / ft² / yr
kWh / ft² / yr
therms / ft² / yr
cost results
TOU bill / ft² / yr
15 yr TDV / ft² / yr
(first cost) - (15 yr TDV)/ ft² / yr
first cost
net cost w/ savings

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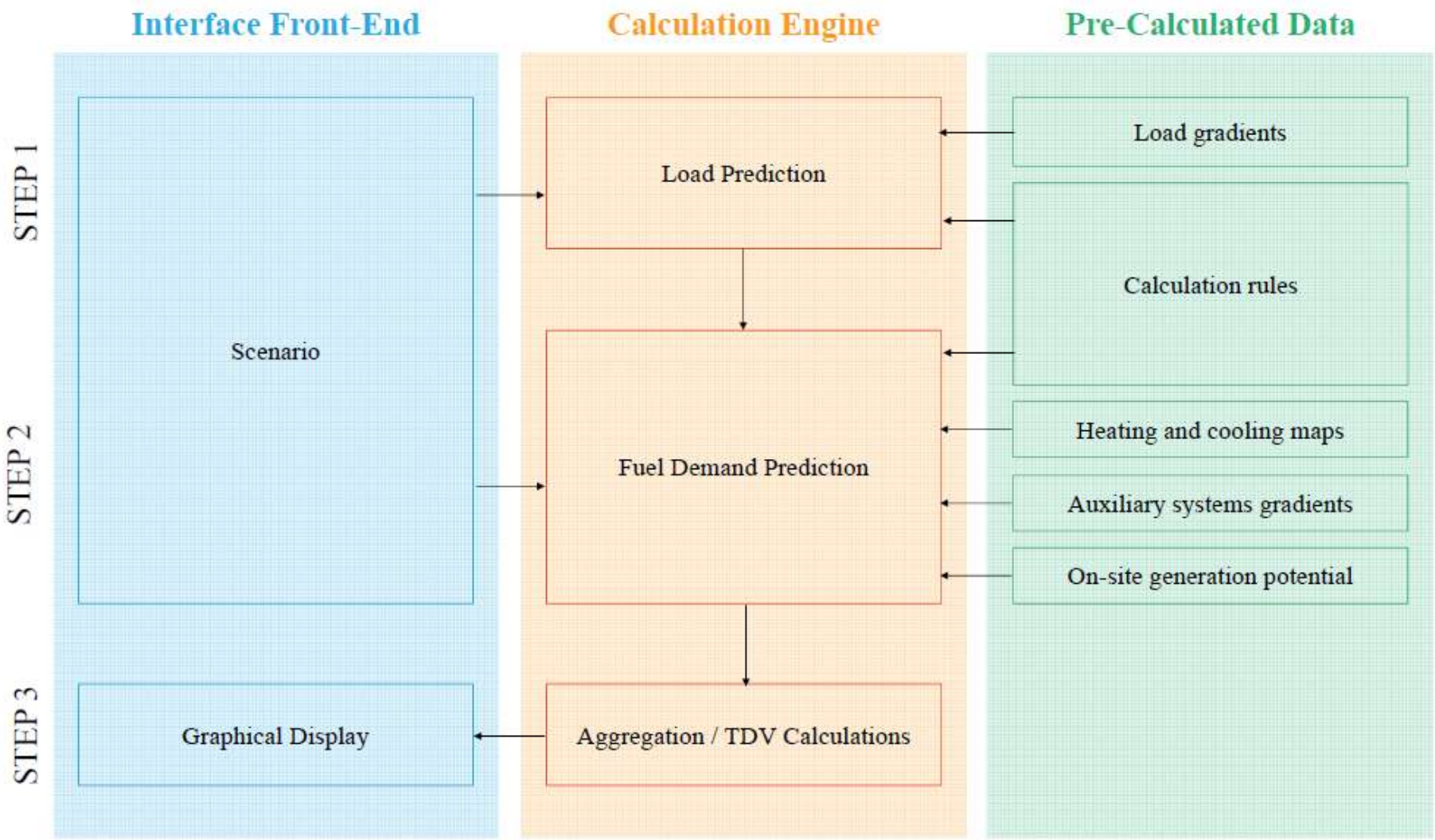
Interface Front-End
Calculation Engine
Pre-Calculated Data
STEP 1
STEP 2
STEP 3
Scenario
Graphical Display
Load Prediction
Fuel Demand Prediction
Aggregation / TDV Calculations
Load gradients
Calculation rules
Heating and cooling maps
Auxiliary systems gradients
On-site generation potential

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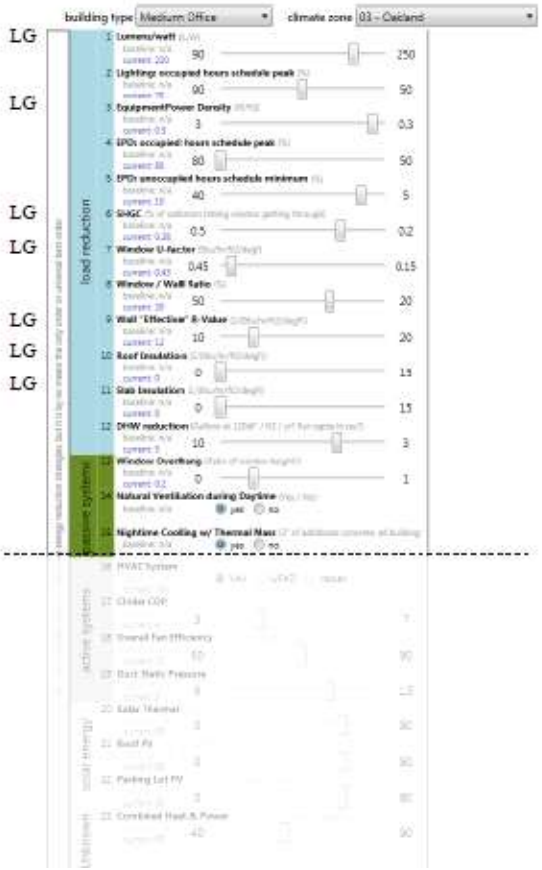
Scenario

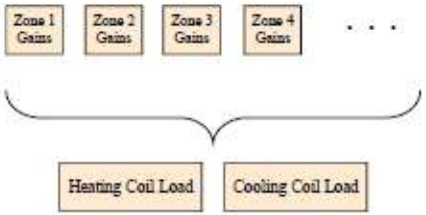
Users select a 'scenario' by using sliders, radio buttons and drop-down menus. For energy efficiency measures (EEMs) that have slider inputs, users select a value between high and low bookends. The EEMs that relate to this calculation step are shown below.



Load Prediction

The first calculation is a prediction of loads at the heating and cooling coils of the building, using EEM settings that relate to load reduction and passive systems. There are two types of calculations - those that employ 'load gradients', and those that employ 'calculation rules'.

The pre-calculated **load gradients** are used to calculate the heating and cooling loads on an **hourly basis by zone**, interpolating between the EEM bookends. The EEMs that employ this methodology are marked 'LG' on the diagram to the left.



Calculation rules are used to predict the effect of the remaining EEMs.

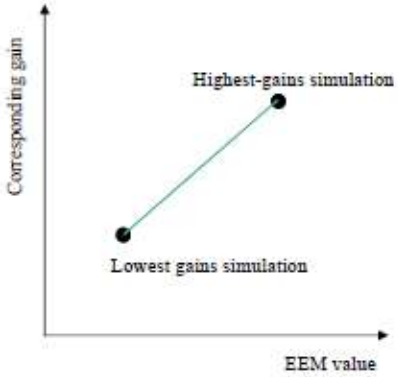
Load gradients

Thermal gains include internal gains (lighting and equipment) and envelope gains (window and wall) with each EEM having an influence on one or more of the thermal gains. A linear relationship between the EEM setting and its related thermal gains is established by running two simulations that represent the extreme high and low cases. These cases are as follows.

1) All EEMs set to highest gain settings

2) All EEMs set to lowest gain settings

This process is performed on an hourly, per zone, per gain basis.



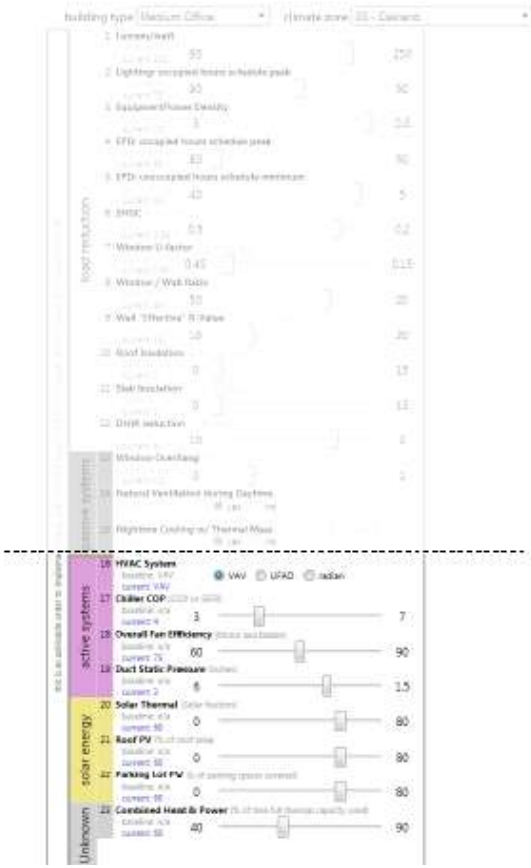
Calculation rules

These rules do not use interpolation to predict the effect of EEMs. EEMs that require calculation rules each have a mathematical function that relates their position in the scenario to their effect on thermal loads or fuel demand. For example, the "window overhang" EEM has an associated calculation rule that determines how much solar radiation is blocked out on an hourly basis depending on the altitude of the sun.

ARUP

Scenario

The EEMs that relate to this calculation step are shown below.



Fuel Demand Prediction

The second calculation is a prediction of fuel demand, using calculated loads and EEM settings that relate to active systems.

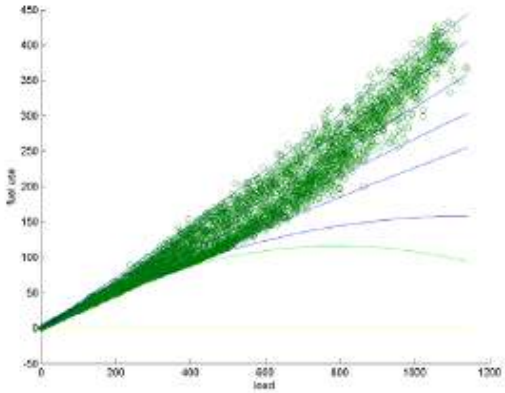
Heating and cooling maps are used to calculate fuel demand, as a function of coil load, due to heating and cooling systems. Further calculations are required when rule-based EEMs affect these systems.

Auxiliary systems gradients are used to calculate fan, pump and heat rejection fuel demand. Further calculations are required where rule-based EEMs affect these systems.

On-site generation potential, along with EEM settings relating to solar energy, are used to determine how much energy can be offset using on-site sources.

Heating and cooling maps

These maps correlate coil loads to fuel demand and are generated using hourly simulation data and normalized against peak load. A separate map is generated for different dry-bulb temperature bands.



Auxiliary systems gradients

These are generated in the same way as the 'load gradients', and are used to describe relationships between total coil load and auxiliary system energy due to fans, pumps and heat rejection equipment.

On-site generation potential

This pre-calculated data relates to a particular climate zone's potential for harnessing solar energy for solar thermal and photovoltaic strategies. These sources will be "netted out" on a yearly, daily, or hourly basis depending on the system type

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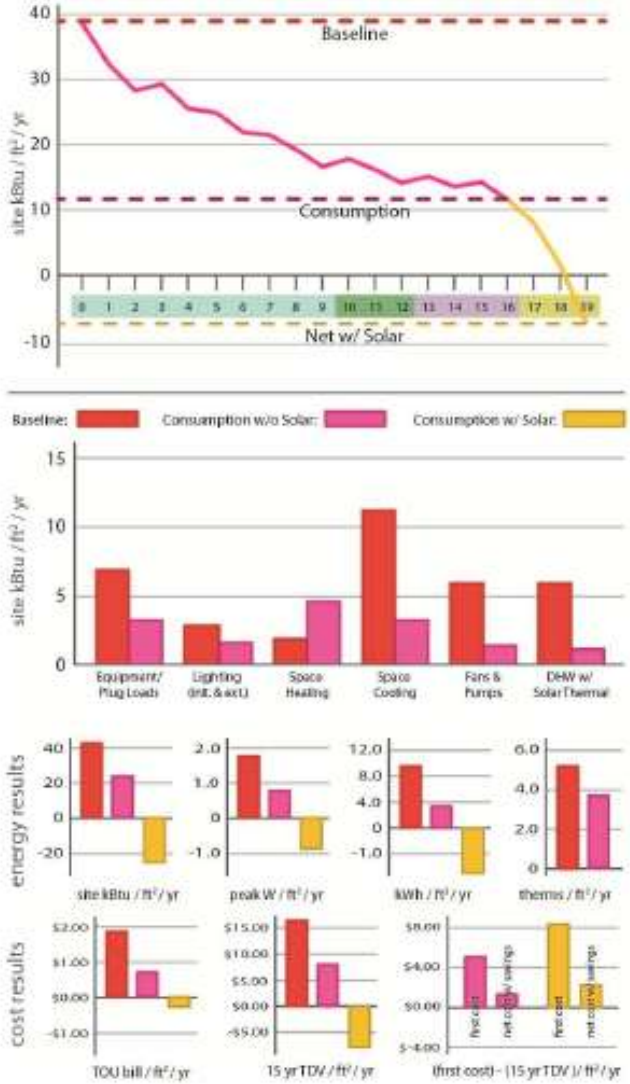
Graphical Display

Aggregation / TDV Calculations

Hourly fuel demand values are used to calculate hourly TDV. These values are aggregated and sent back to the interface front-end.



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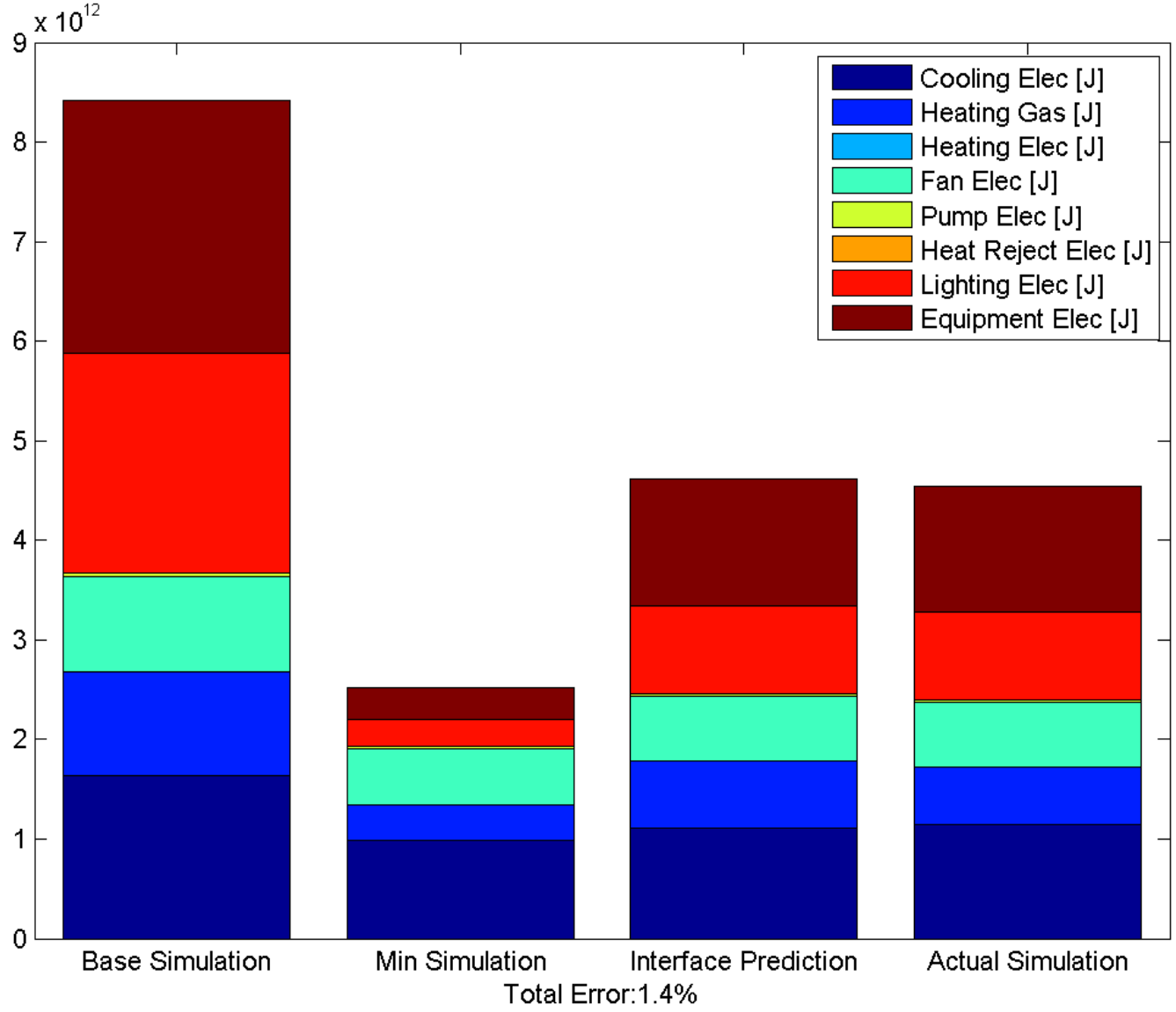
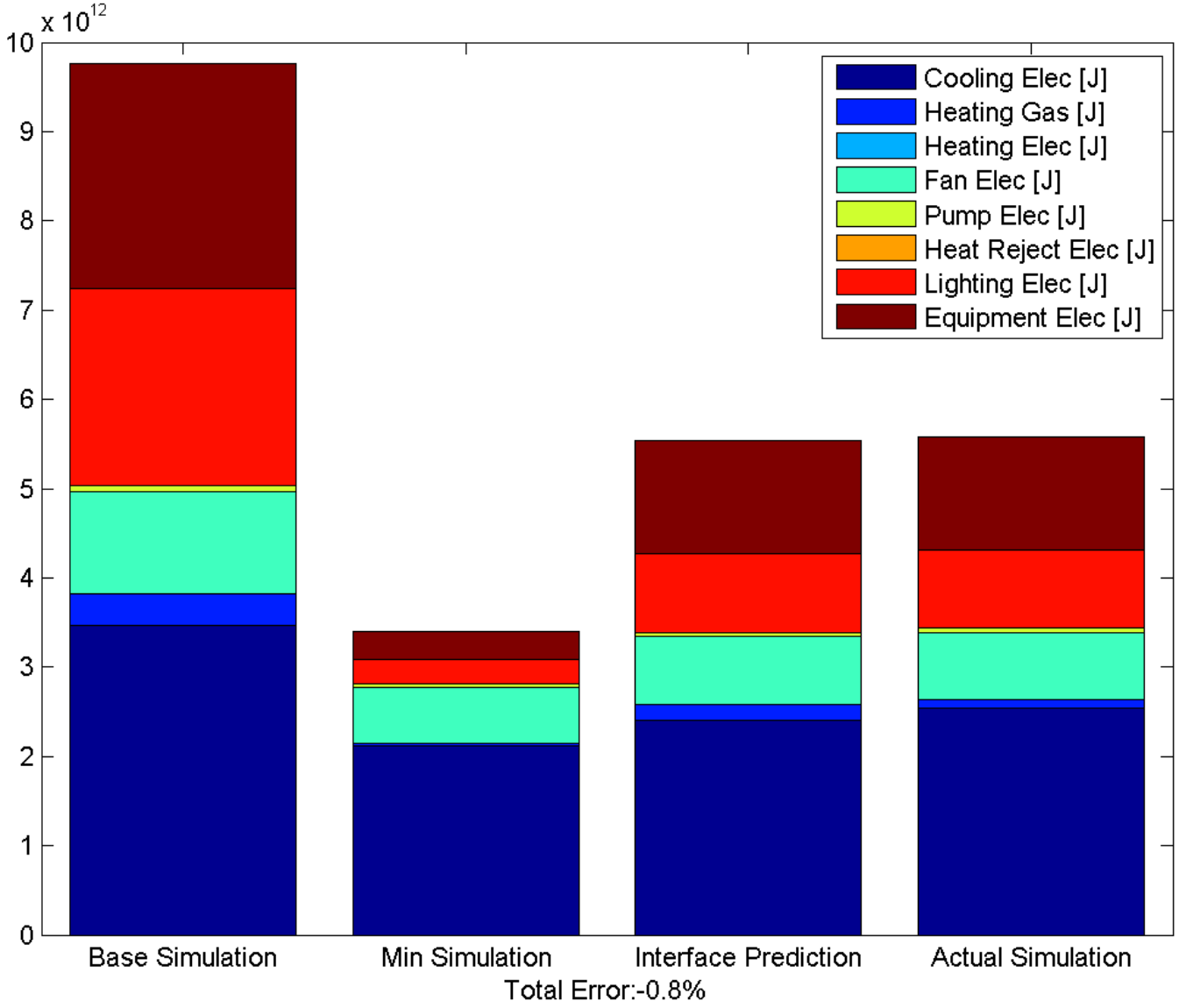
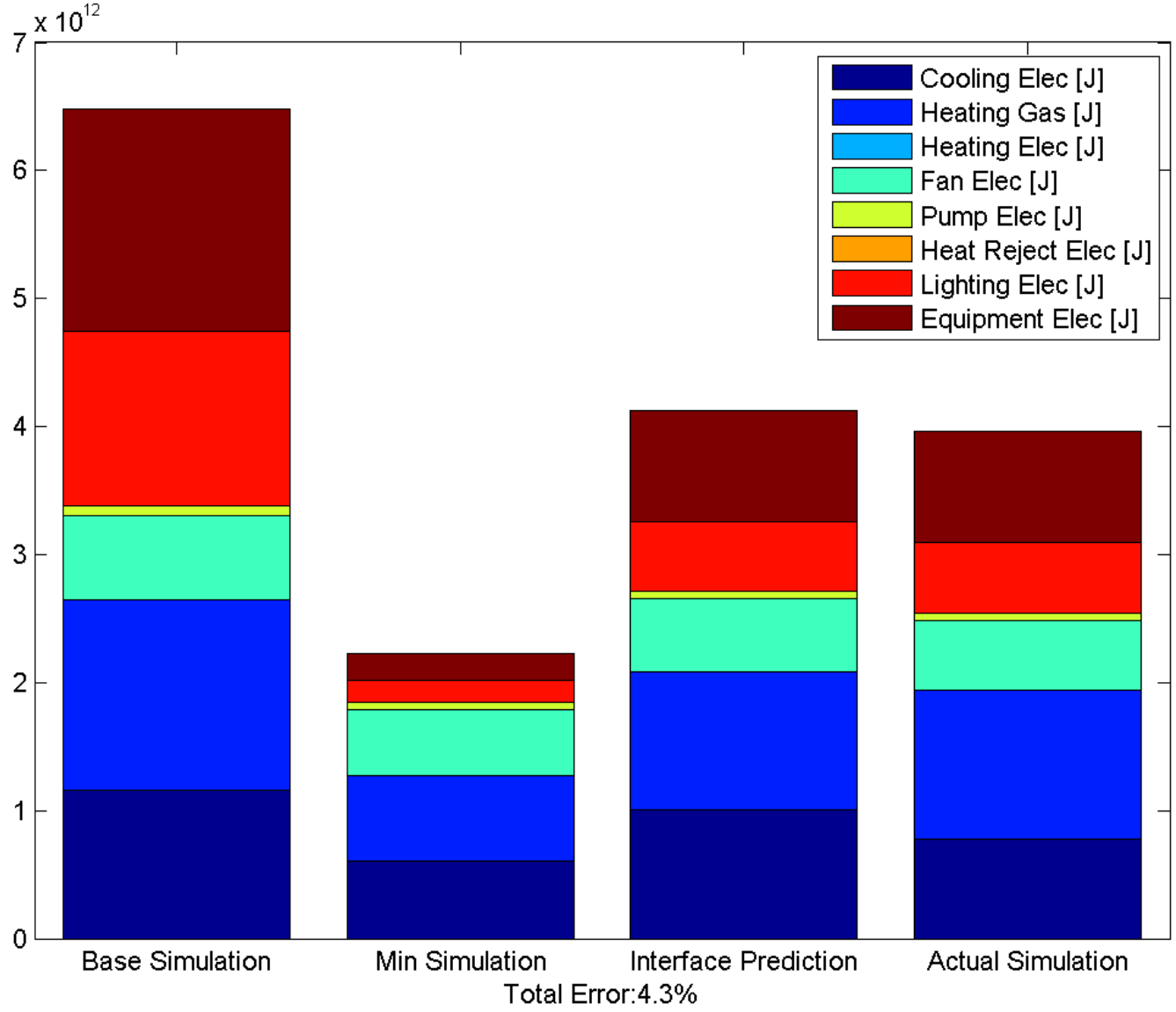

x 10^12
9
8
7
6
5
4
3
2
1
0
Cooling Elec [J]
Heating Gas [J]
Heating Elec [J]
Fan Elec [J]
Pump Elec [J]
Heat Reject Elec [J]
Lighting Elec [J]
Equipment Elec [J]
Base Simulation
Min Simulation
Interface Prediction
Actual Simulation
Total Error:1.4%

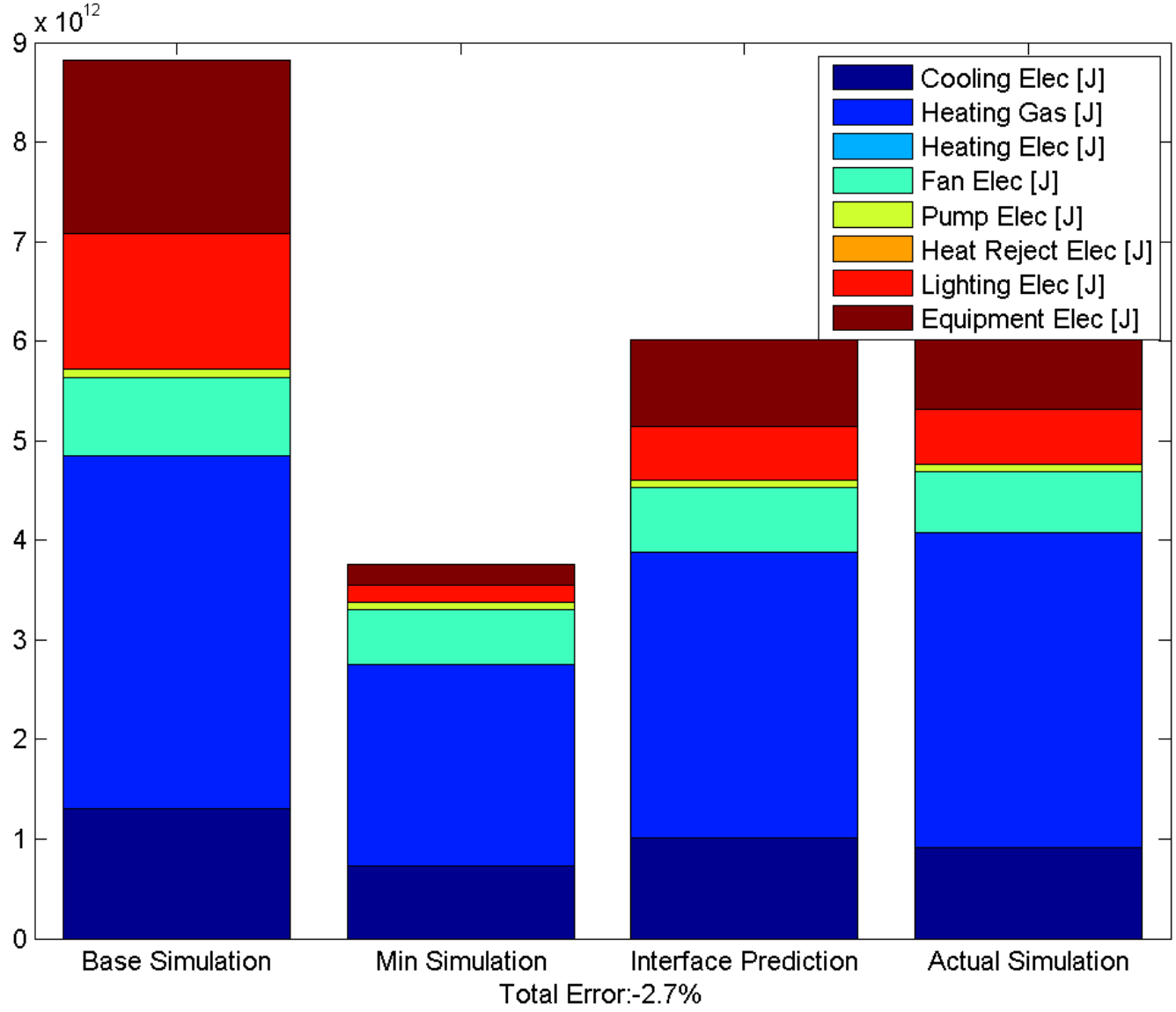
ARUP


x 10^12
10
9
8
7
6
5
4
3
2
1
0
Cooling Elec [J]
Heating Gas [J]
Heating Elec [J]
Fan Elec [J]
Pump Elec [J]
Heat Reject Elec [J]
Lighting Elec [J]
Equipment Elec [J]
Base Simulation
Min Simulation
Interface Prediction
Actual Simulation
Total Error:-0.8%

ARUP


x 10^12
7
6
5
4
3
2
1
0
Cooling Elec [J]
Heating Gas [J]
Heating Elec [J]
Fan Elec [J]
Pump Elec [J]
Heat Reject Elec [J]
Lighting Elec [J]
Equipment Elec [J]
Base Simulation
Min Simulation
Interface Prediction
Actual Simulation
Total Error:4.3%

ARUP


x 10^12
9
8
7
6
5
4
3
2
1
0
Cooling Elec [J]
Heating Gas [J]
Heating Elec [J]
Fan Elec [J]
Pump Elec [J]
Heat Reject Elec [J]
Lighting Elec [J]
Equipment Elec [J]
Base Simulation
Min Simulation
Interface Prediction
Actual Simulation
Total Error:-2.7%

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