

Opt, Opt and Away: Cost-Optimal* HERS Indices

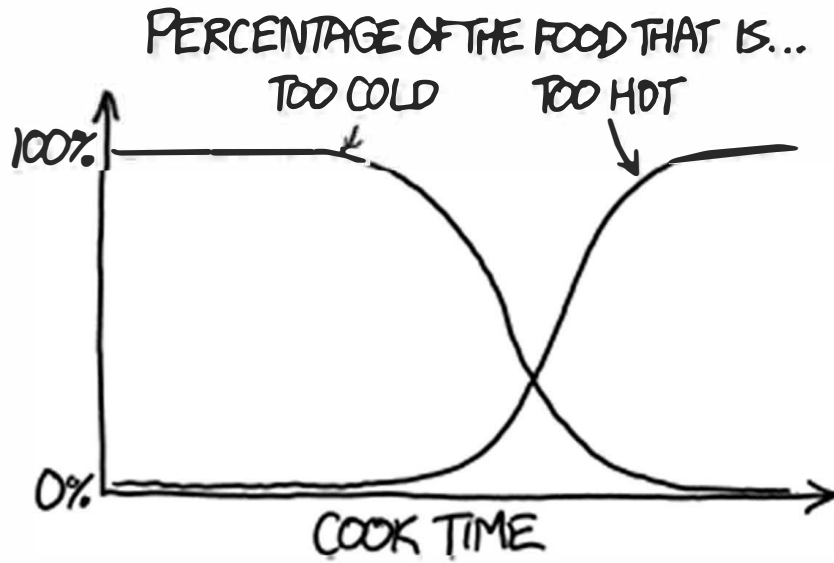


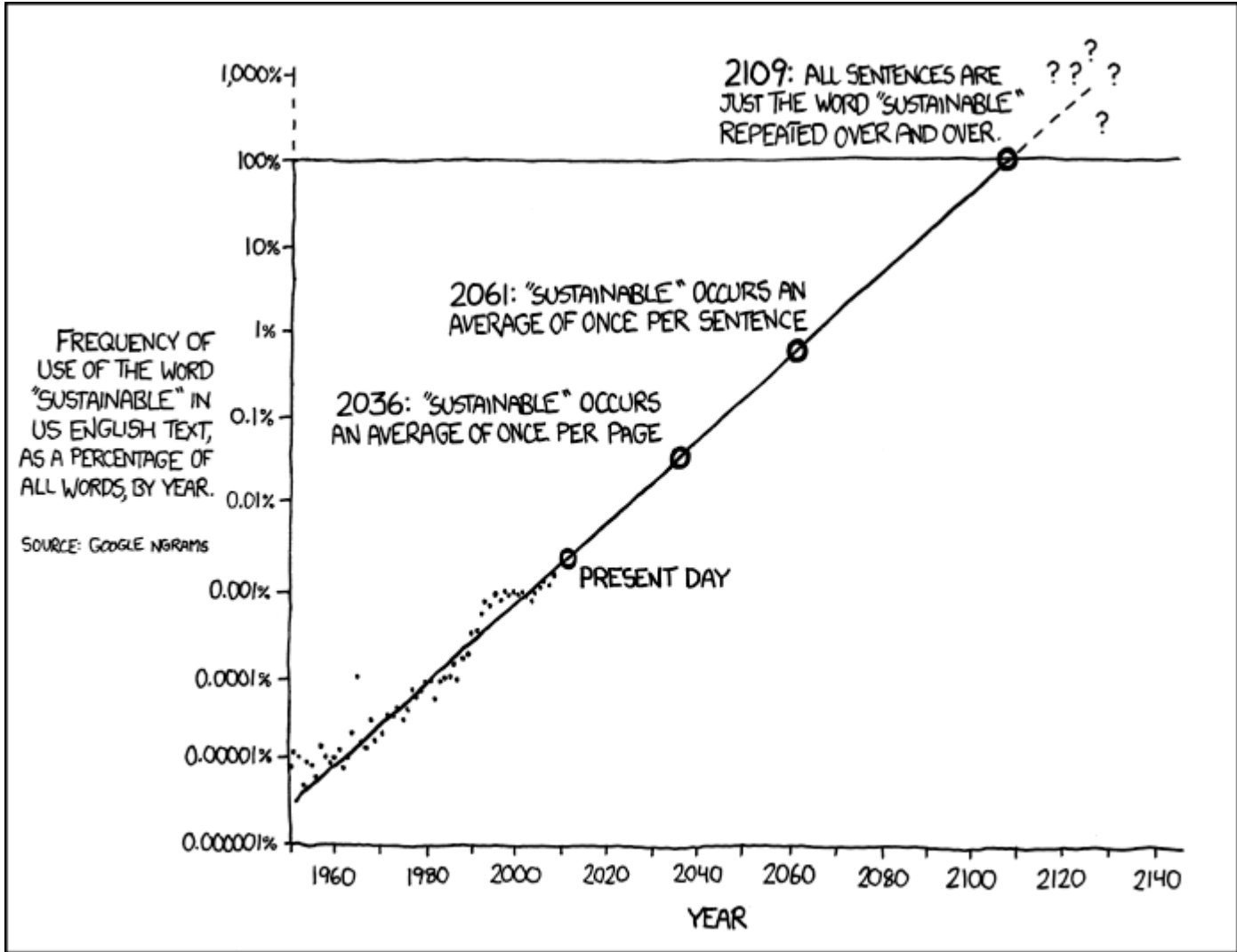
Dave Roberts

2016 RESNET Building Performance Conference
March 1, 2016

NREL/PR-5500-71703

*Cost-optimal from the perspective of the home owner.

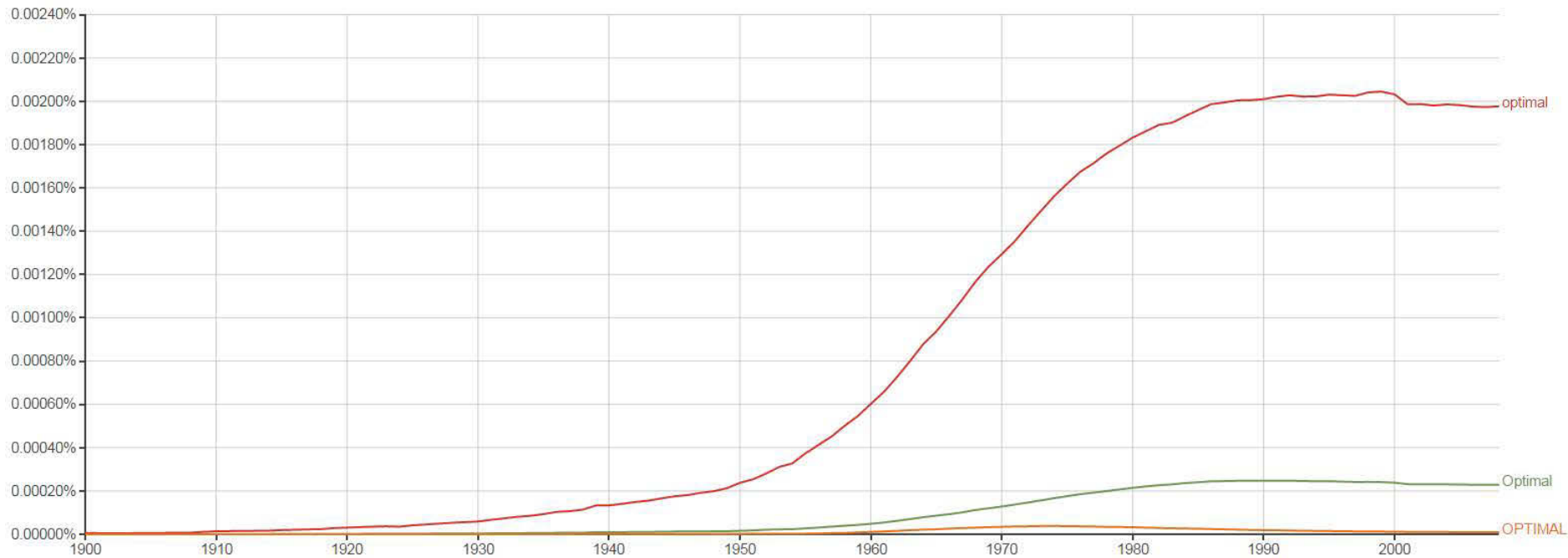




THE WORD "SUSTAINABLE" IS UNSUSTAINABLE.

op·ti·mal
/äptəməl/
adjective

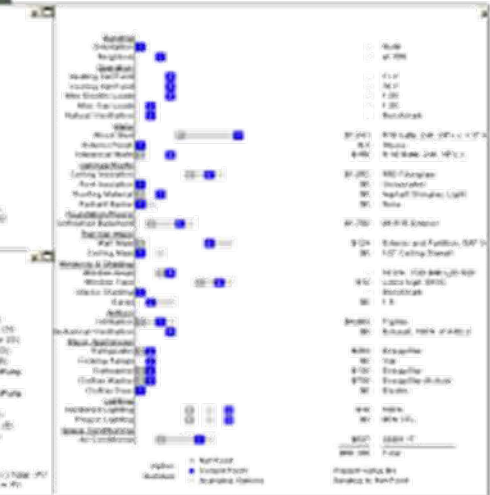
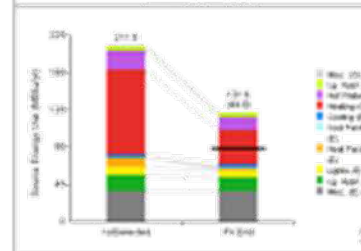
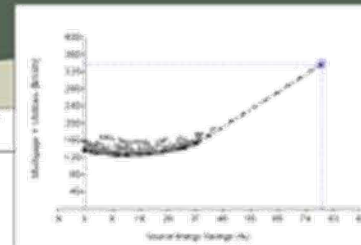
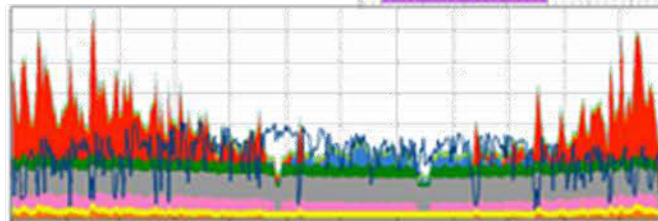
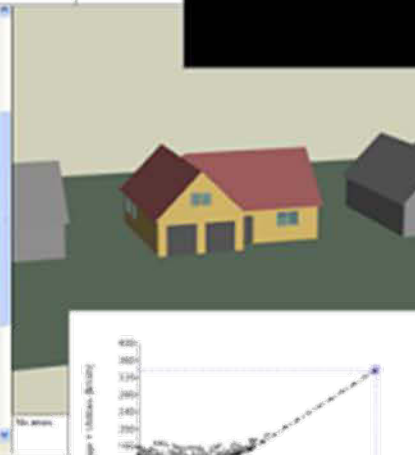
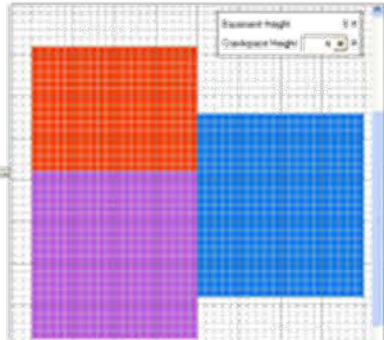
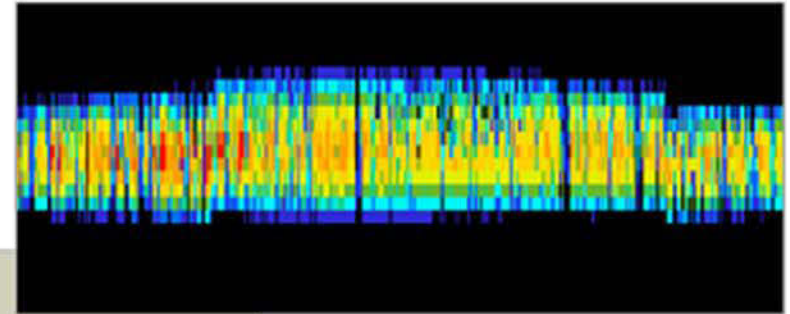
best or most favorable; optimum.
"seeking the optimal solution"



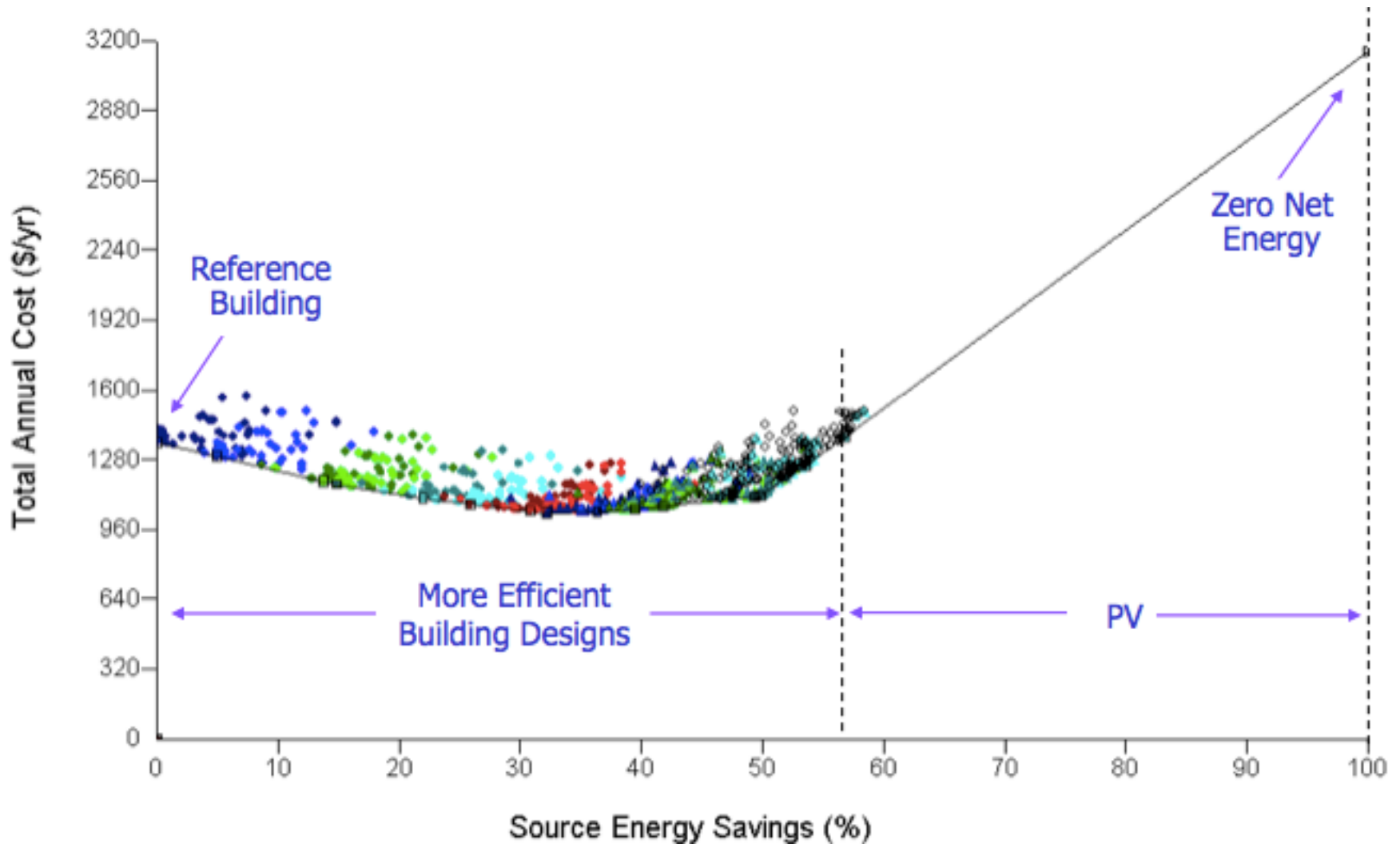
BEopt Building Energy Optimization with Hour-by-Hour Simulations

The screenshot displays the 'Simulation options' window in BEopt. On the left, there are several expandable categories: Building, Operations, Walls, Ceilings/Floors, Fenestration, Windows & Shading, and Airflow. Each category contains a grid of checkboxes for enabling or disabling specific simulation components. On the right, a table lists simulation parameters:

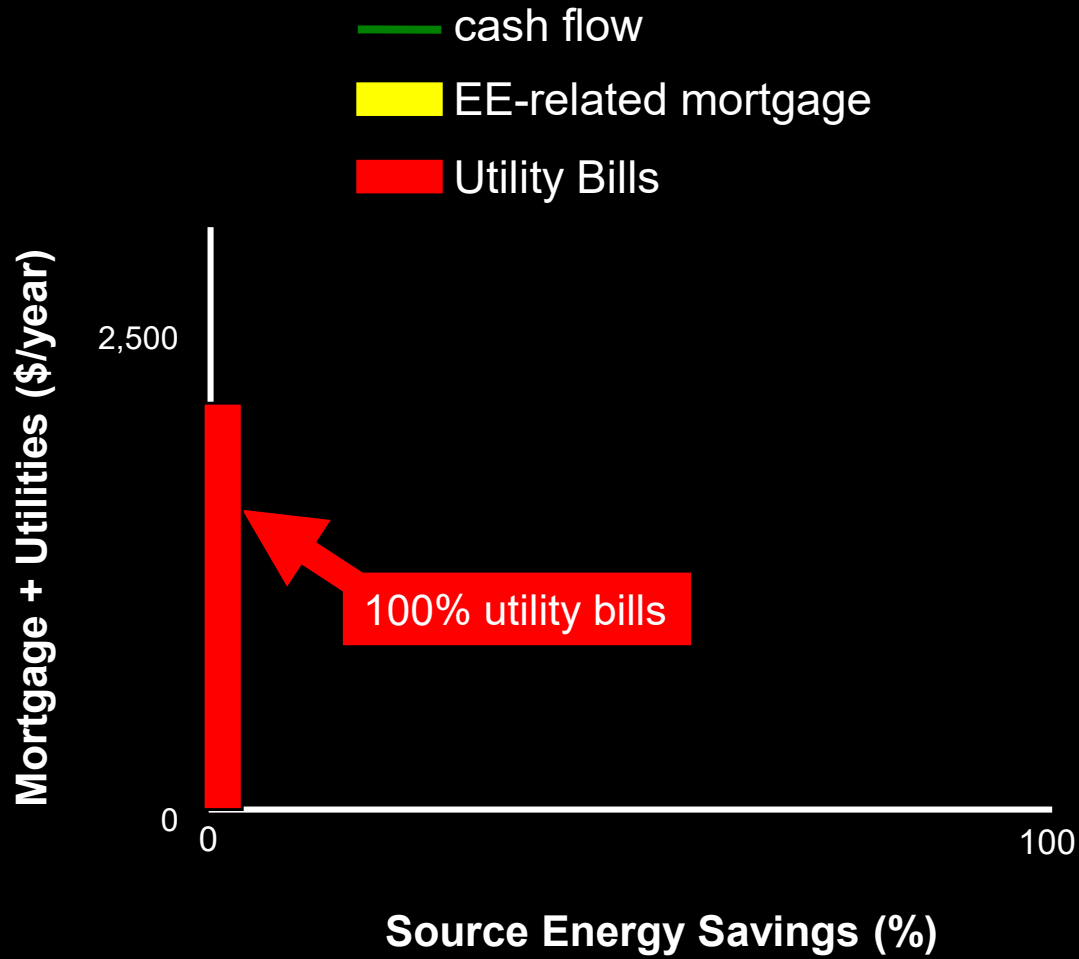
Parameter	Value	Units	Default
W1 Area	212.7	m ²	0
W1 U-factor	2.04	W/m ² K	0
W1 SHGC	0.75	-	0
W1 Solar	240.0	W/m ²	0
W1 Southwall	194	W/m ² K	0
W1 Top	0.17	W/m ² K	0
W1 South	0	W/m ² K	0
W1 North	0	W/m ² K	0
W1 Eastwall	48	W/m ² K	0
W1 West	0.17	W/m ² K	0
W1 Wind	0	W/m ² K	0
W1 South	136	W/m ² K	0
W1 North	137.3	W/m ² K	0



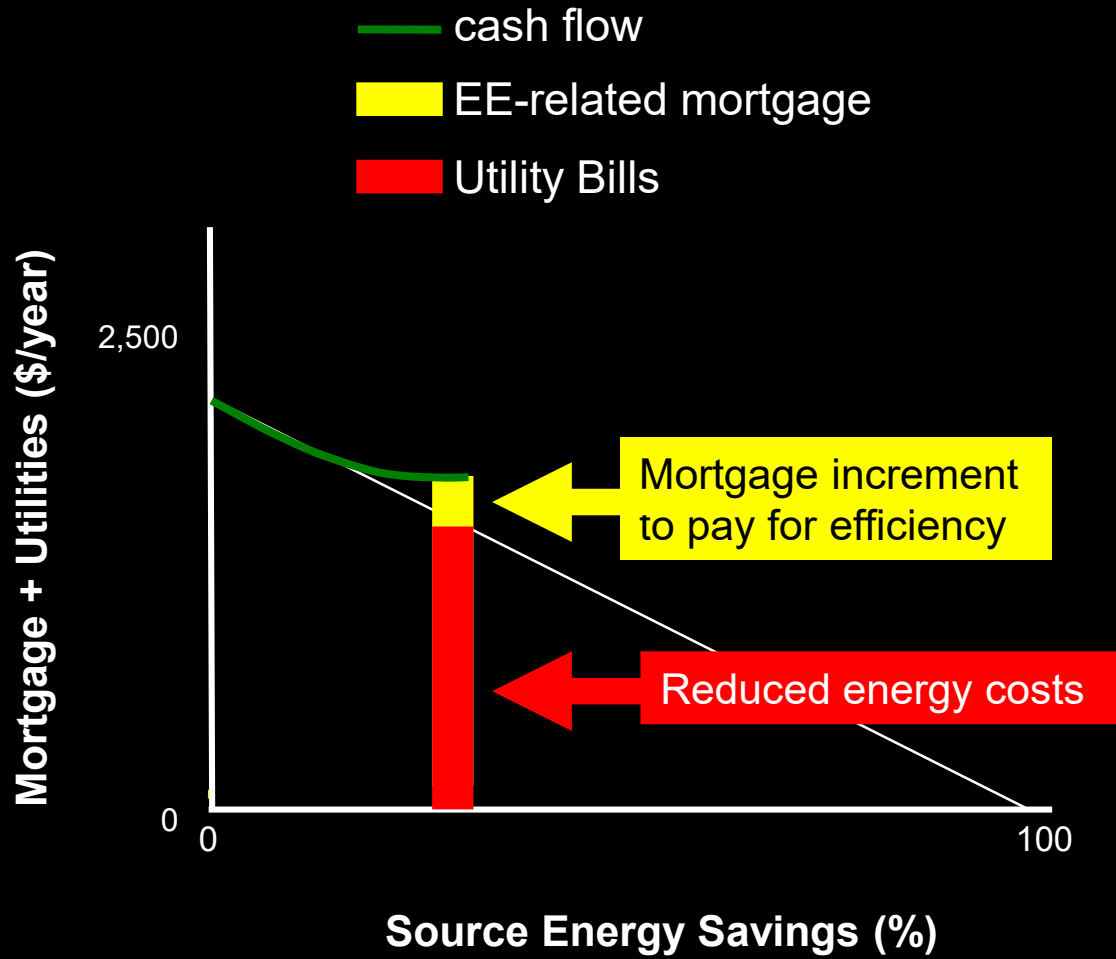
The Optimal Path



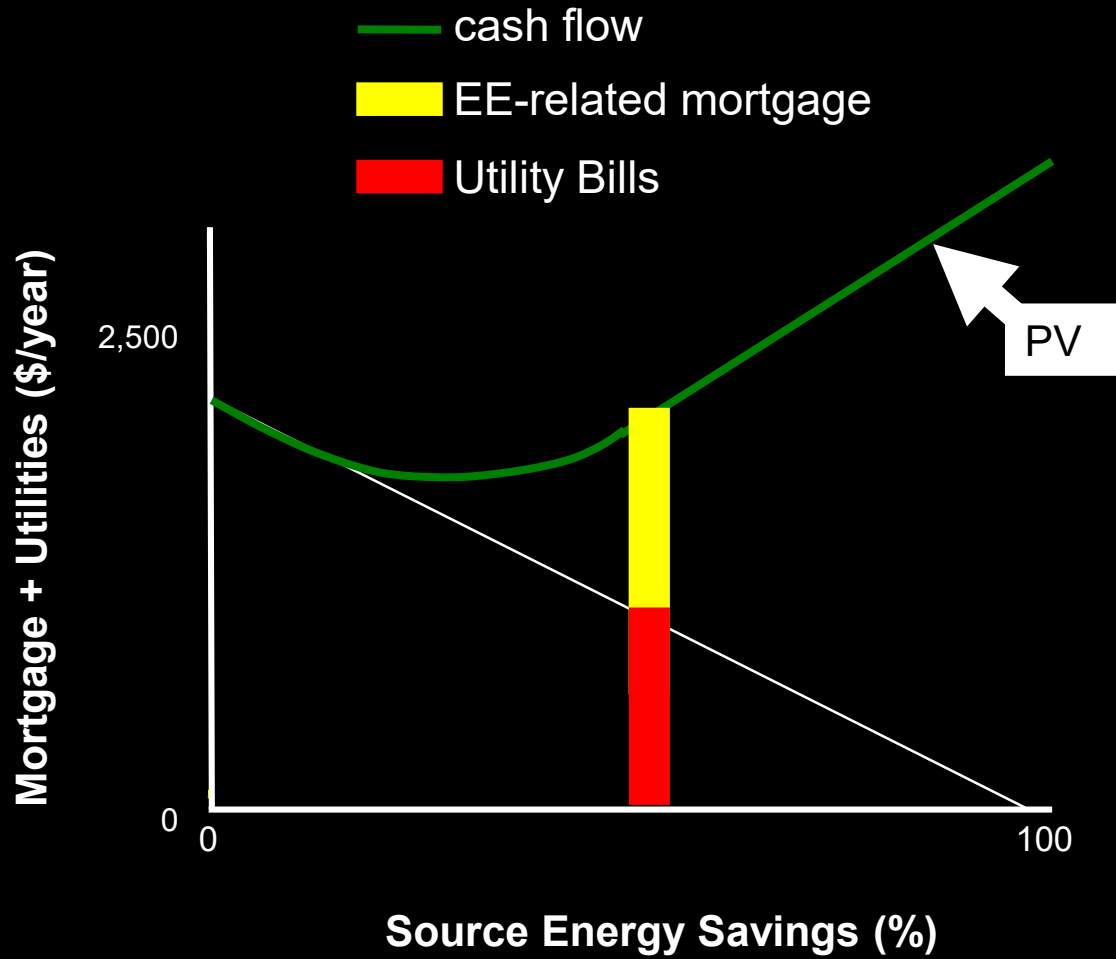
The Path to Zero Net Energy



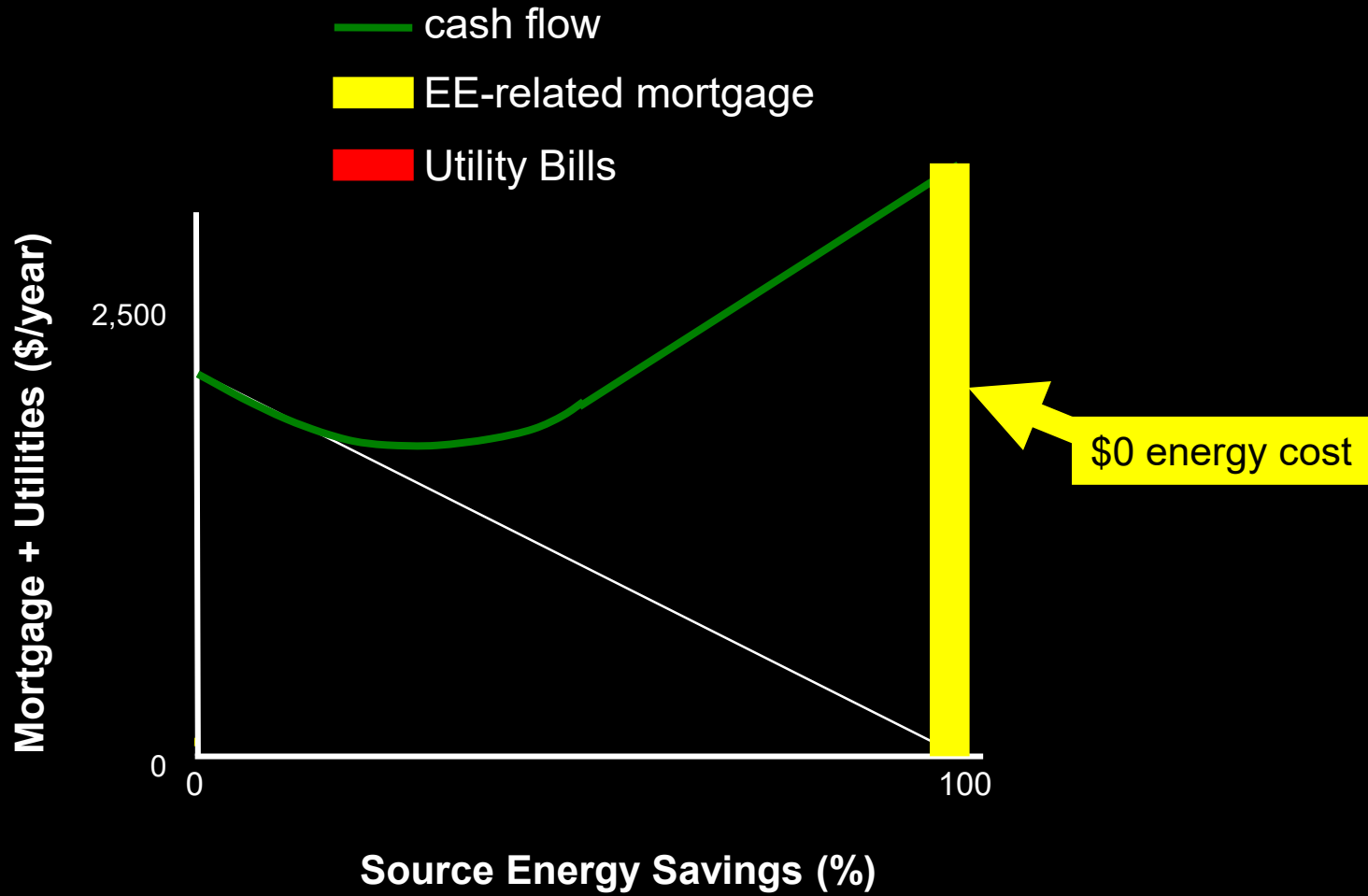
The Path to Zero Net Energy



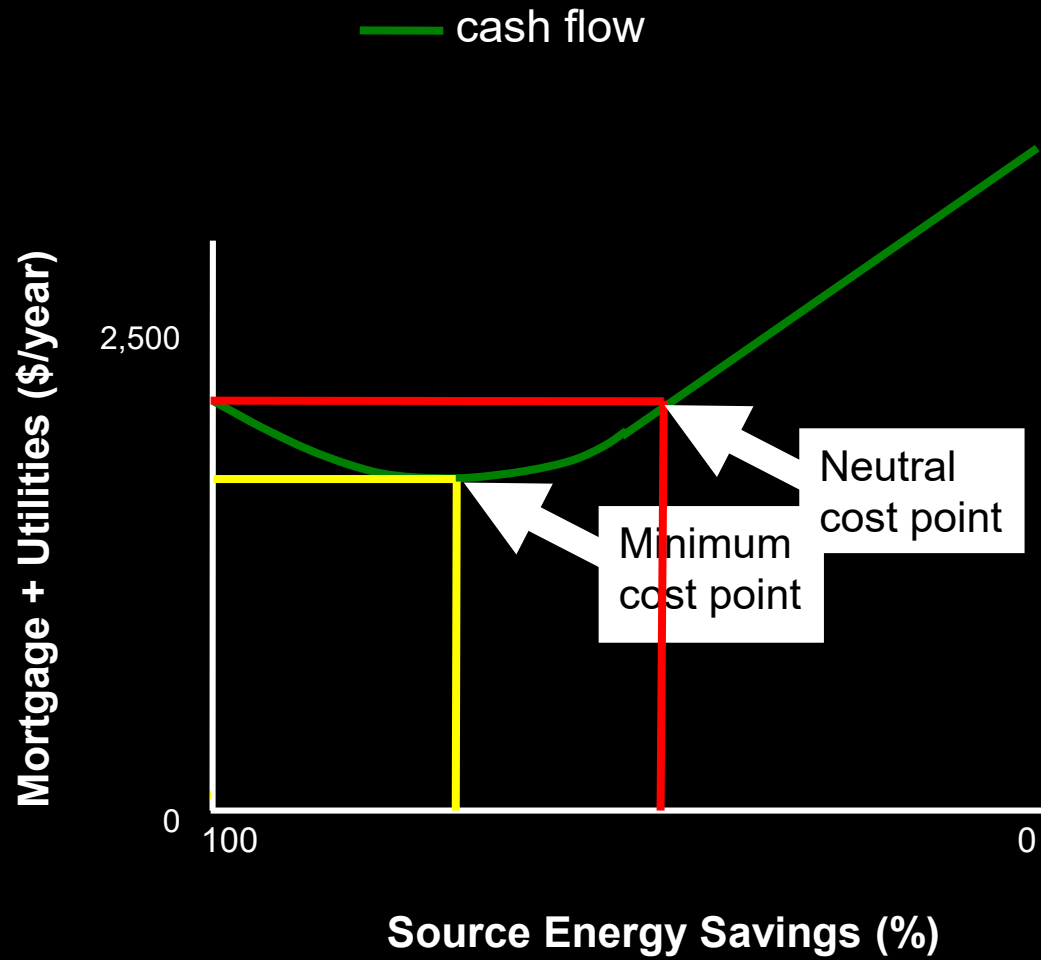
The Path to Zero Net Energy



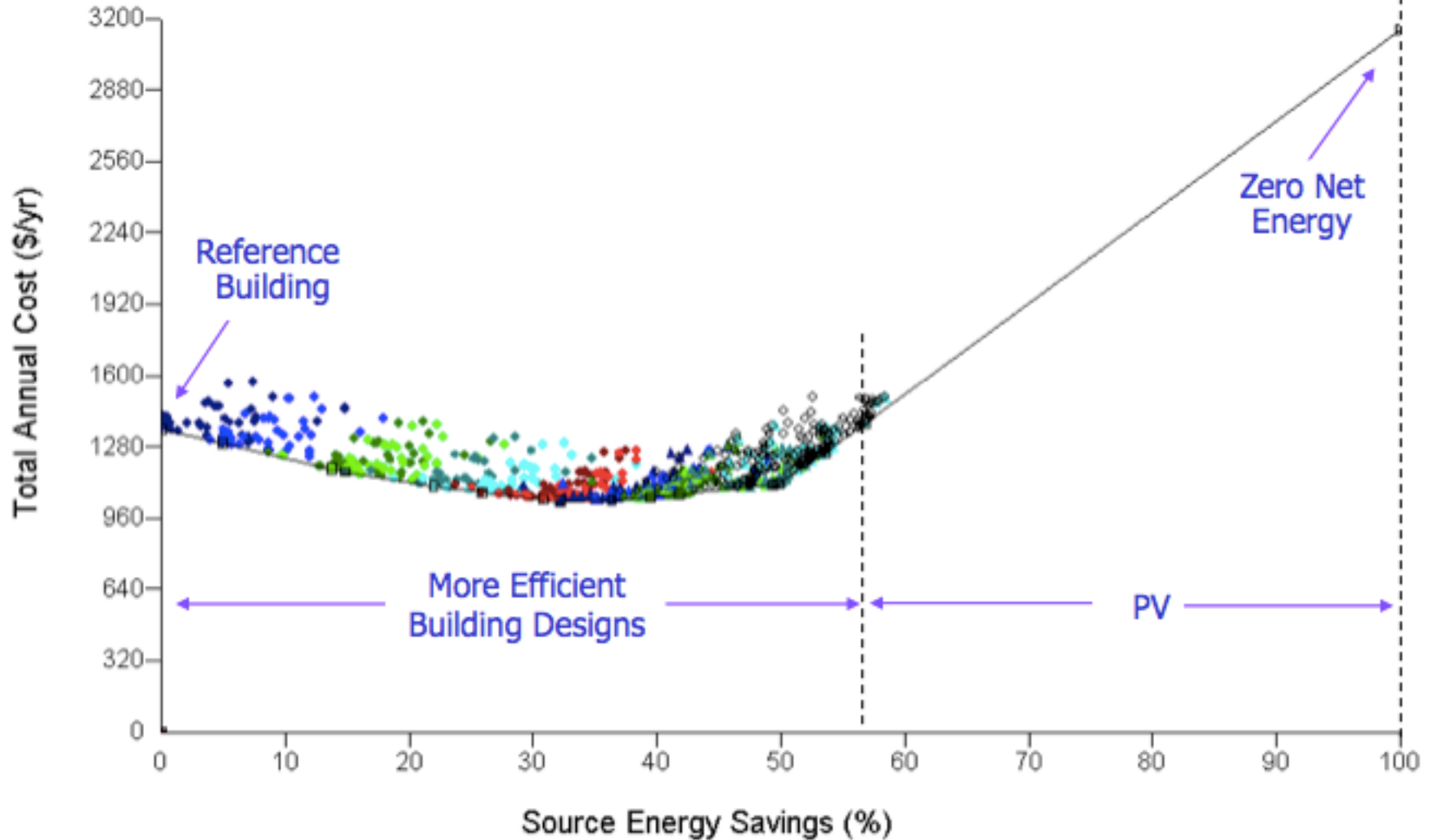
The Path to Zero Net Energy



The Path to Zero Net Energy



The Optimal Path

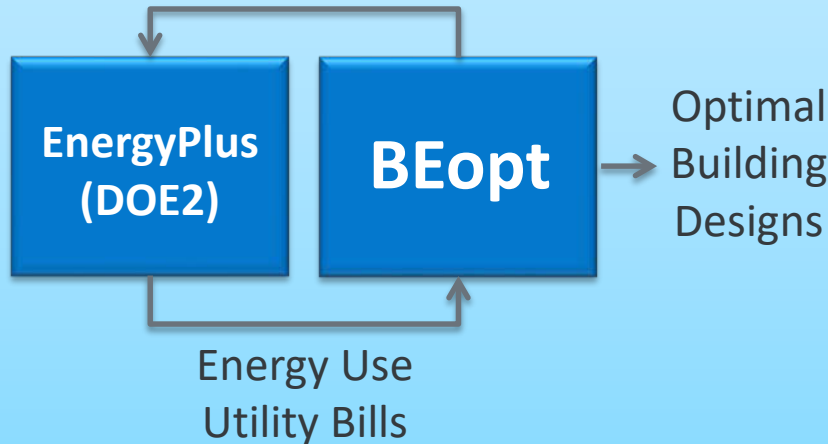


What is BEopt?

(beopt.nrel.gov)

Plug-and-Play Optimization Software

Heating
Cooling
Lighting
Appliances
Other Efficiency
PV/SHW



Features:

- Design, parametric, optimization
- New construction and retrofit
- Detailed cost database
- Rapid building drawing tool
- Detailed utility rates (tiered, time-of-use, real-time pricing)
- PV compensation (net-metering, feed-in tariffs)
- Utility cost effectiveness tests
- PV/efficiency incentives
- Demand response
- HPXML export
- Schedule wizard
- Output visualization
- Metrics: LCC, NPV, SPP, LCOE, CO2
- Batch simulations
- Library manager
- ...



Schedule



Partner Contributions

CEC (FY08-FY09)
BEopt w/Micropas

ARRA (FY10-11)
Updated platform,
batch simulations

CPUC (FY11-14)
Retrofit analysis, utility
cost effectiveness tests,
incentives, etc.

CPS Energy (FY12)
San Antonio
analysis

BPA (FY13-14)
EnergyPlus vs.
SEEM validation

BPA (FY14)
BEopt follow-on

CPUC (FY14-15)
Multifamily

CEC (FY15)
CSE tool



NREL National Renewable Energy Laboratory

Innovation for Our Energy Future

A national laboratory of the U.S. Department of Energy
Office of Energy Efficiency & Renewable Energy

Searching for the Optimal Mix of Solar and Efficiency in Zero Net Energy Buildings

Preprint

S. Horowitz, C. Christensen, and R. Anderson
National Renewable Energy Laboratory

*Presented at Solar 2008
San Diego, California
May 3–8, 2008*

Conference Paper
NREL/CP-550-42956
August 2008

House

event of time



pared to various

D

all J and ACCA

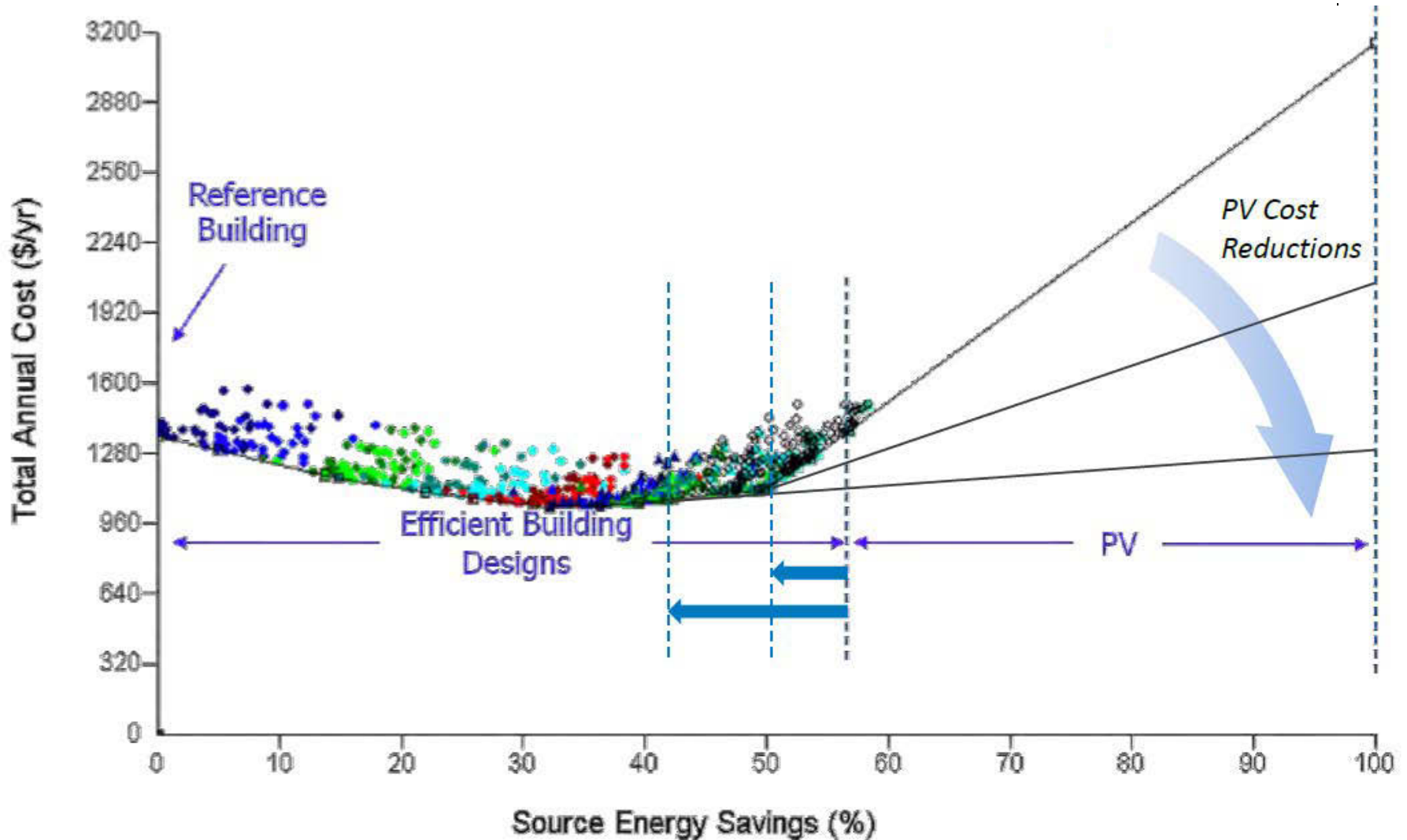
gs the HVAC

Latent were

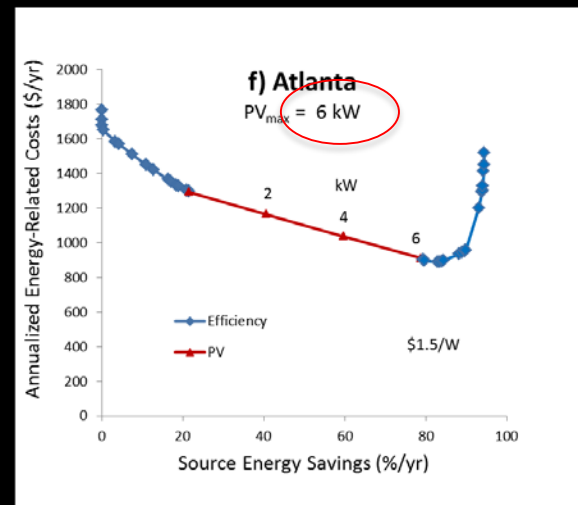
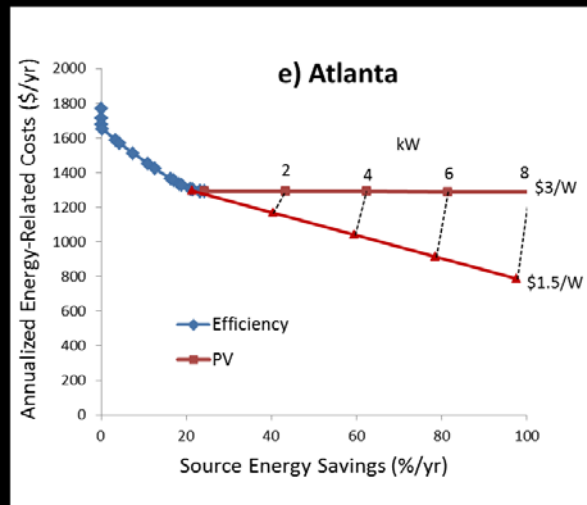
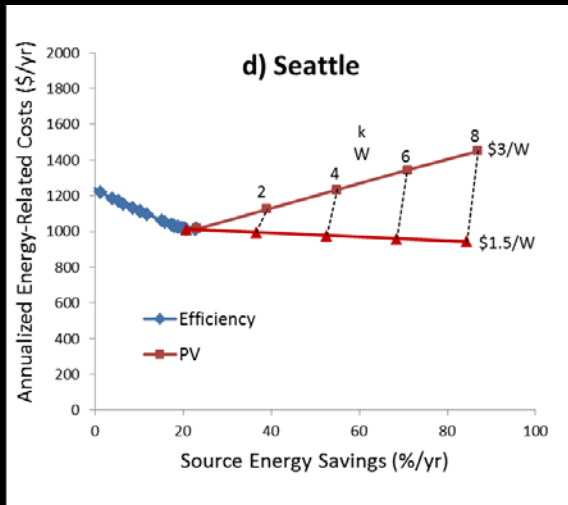
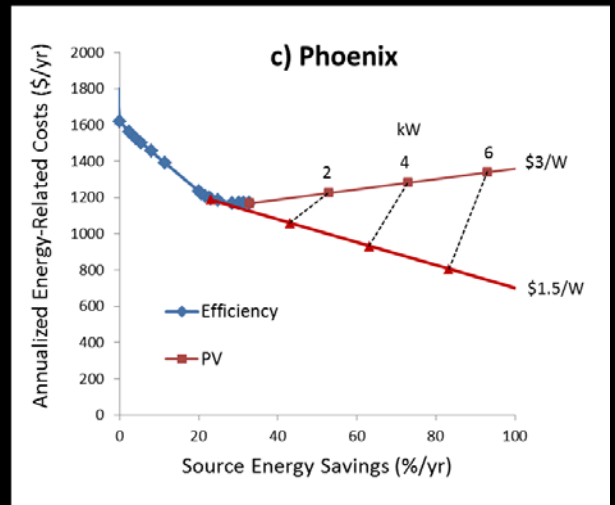
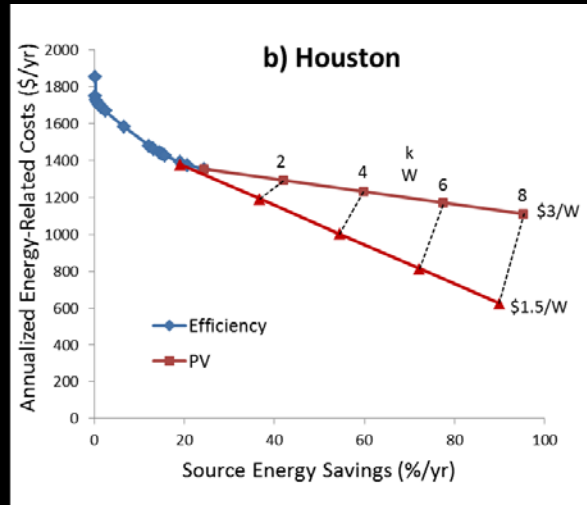
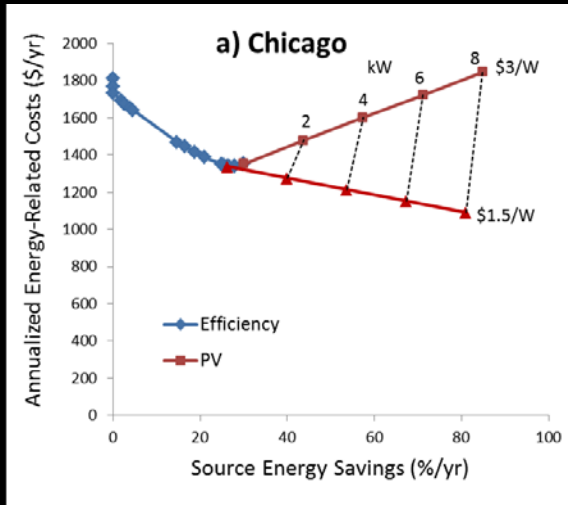
area of 2,421 ft²

usually

The Optimal Path



The Optimal Path

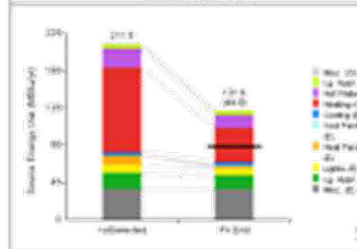
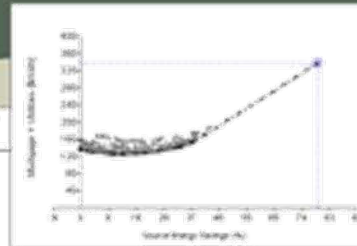
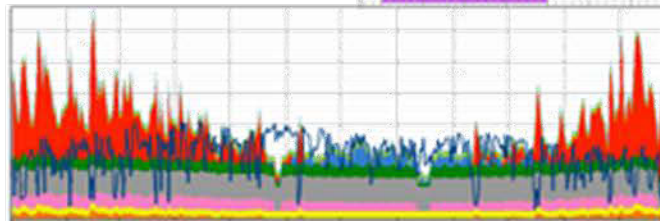
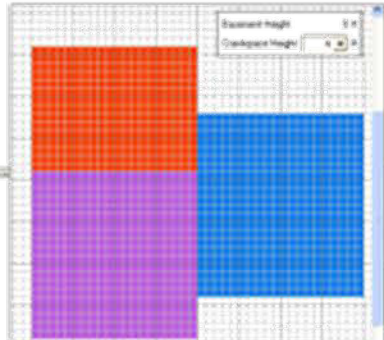
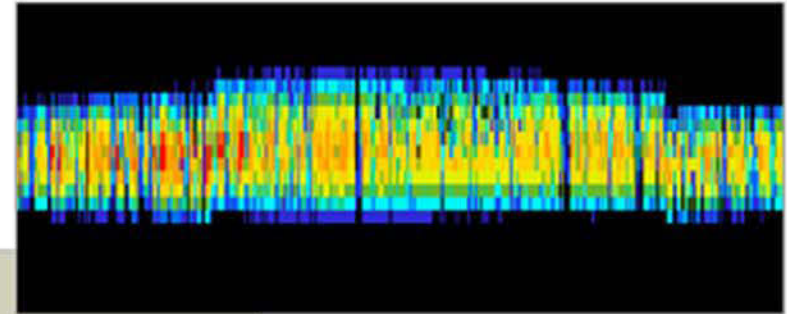


BEopt Building Energy Optimization with Hour-by-Hour Simulations

The screenshot shows the BEopt software interface with several panels:

- Building:** A tree view on the left showing categories like Temperature, Operations, Walls, Ceilings/Floors, Fenestration, and Airflow.
- Simulation options:** A central panel with various input fields and checkboxes for simulation parameters.
- Results Table:** A table on the right with columns for Name, Amount, and Lifetime Energy. It lists various building components and their associated energy values.

Name	Amount	Lifetime Energy
1. WWR	212.7	0
2. WWR	212.7	0
3. WWR	212.7	0
4. WWR	212.7	0
5. WWR	212.7	0
6. WWR	212.7	0
7. WWR	212.7	0
8. WWR	212.7	0
9. WWR	212.7	0
10. WWR	212.7	0
11. WWR	212.7	0
12. WWR	212.7	0
13. WWR	212.7	0
14. WWR	212.7	0
15. WWR	212.7	0
16. WWR	212.7	0
17. WWR	212.7	0
18. WWR	212.7	0
19. WWR	212.7	0
20. WWR	212.7	0
21. WWR	212.7	0
22. WWR	212.7	0
23. WWR	212.7	0
24. WWR	212.7	0
25. WWR	212.7	0
26. WWR	212.7	0
27. WWR	212.7	0
28. WWR	212.7	0
29. WWR	212.7	0
30. WWR	212.7	0



The screenshot shows the BEopt software interface with a detailed energy usage breakdown. It includes a list of energy sources and components, along with their respective energy usage values. The interface is color-coded to match the energy usage patterns shown in the other figures.

BEopt

BEopt 2.0.0.6 - Sample - new construction optimizations [Standard, New Construction]

File Screen Case Run Reports Tools Graphs Help

Input: Output:

Chicago, E+ Phoenix, E+ Chicago, DOE2 Phoenix, DOE2

Analysis: Optimization Reference: B10 Benchmark Cost Group: Default Sim Engine: EnergyPlus

This case contains output associated with these inputs and therefore inputs are disabled. To modify inputs, either [clear](#) the existing output or create a [new case](#).

Levels: **1st** Fnd 2nd 3rd 4th Roof

Beds 3 Baths 2 Total Finished 2496 sqft

Spaces

- Living
- Garage
- Erase

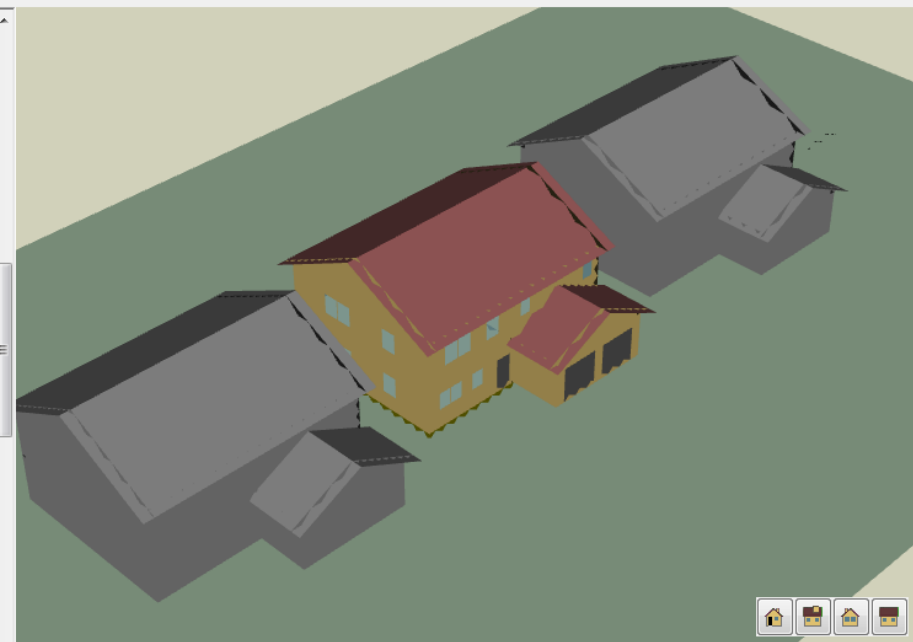
Attached Walls

- Left-Facing
- Right-Facing
- Back-Facing



Scale: 1 cell = 1 ft

Front



No errors.



BEopt

BEopt 2.0.0.6 - New Project [Standard, New Construction]

File Screen Case Run Reports Tools Help

Input: Output: Run:

Analysis: Design Reference: My Design Cost Group: Default

My Design

- [-] +
- Building
- Operation
- Walls
 - Wood Stud 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
 - Double Wood Stud 1 2 3 4 5 6 7
 - CMU 1 2 3 4 5 6
 - SIP 1 2 3 4 5 6 7 8 9
 - ICF 1 2 3 4
 - Other 1 2 3 4
 - Wall Sheathing 1 2 3 4 5 6 7 8 9 10 11 12
 - Exterior Finish 1 2 3 4 5 6 7 8 9 10 11
- Ceilings/Roofs
- Foundation/Floors
- Thermal Mass
- Windows & Doors
 - Window Areas 1 2 3 4 5 6 7 8 9 10
 - Windows 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
 - Eaves 1 2 3 4
 - Overhangs 1 2 3 4 5 6 7
- Airflow
 - Air Leakage 1 2 3 4 5 6 7 8 9 10 11 12 13 14
 - Mechanical Ventilation 1 2 3 4 5 6 7
- Major Appliances
- Lighting
- Space Conditioning
 - Central Air Conditioner 1 2 3 4 5 6 7 8 9 10
 - Furnace 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
 - Boiler 1 2 3 4 5 6 7 8 9 10 11 12 13
 - Electric Baseboard 1 2
 - Air Source Heat Pump 1 2 3 4 5 6 7 8 9
 - Ground Source Heat Pump 1 2 3 4 5 6 7 8 9 10 11 12 13
 - Ducts 1 2 3 4 5 6 7 8 9 10 11 12
 - Ceiling Fan 1 2 3 4 5 6 7 8 9 10 11 12 13
- Water Heating
- Power Generation

Option	R-Assembly [h-ft ² -R/Btu]	Framing Factor [frac]	Install Grade	Cost [\$ /ft ² Exterior Wall]
1) None				
2) Uninsulated, 2x4, 16 in o.c.	3.6	0.25	NA	\$1.84
3) Uninsulated, 2x6, 24 in o.c.	3.7	0.22	NA	\$1.76
4) R-7 Fiberglass Batt, Gr-3, 2x4, 16 in o.c.	8.3	0.25	3	\$2.41
5) R-7 Fiberglass Batt, Gr-2, 2x4, 16 in o.c.	8.7	0.25	2	\$2.43
6) R-7 Fiberglass Batt, Gr-1, 2x4, 16 in o.c.	8.9	0.25	1	\$2.46
7) R-11 Fiberglass Batt, Gr-3, 2x4, 16 in o.c.	9.6	0.25	3	\$2.49
8) R-11 Fiberglass Batt, Gr-2, 2x4, 16 in o.c.	10.1	0.25	2	\$2.51
9) R-11 Fiberglass Batt, Gr-1, 2x4, 16 in o.c.	10.5	0.25	1	\$2.54
10) R-13 Fiberglass Batt, Gr-3, 2x4, 16 in o.c.	10.3	0.25	3	\$2.53
11) R-13 Fiberglass Batt, Gr-2, 2x4, 16 in o.c.	10.9	0.25	2	\$2.55
12) R-13 Fiberglass Batt, Gr-1, 2x4, 16 in o.c.	11.4	0.25	1	\$2.58
13) R-15 Fiberglass Batt, Gr-3, 2x4, 16 in o.c.	10.9	0.25	3	\$2.57
14) R-15 Fiberglass Batt, Gr-2, 2x4, 16 in o.c.	11.7	0.25	2	\$2.59
15) R-15 Fiberglass Batt, Gr-1, 2x4, 16 in o.c.	12.2	0.25	1	\$2.62
16) R-19 Fiberglass Batt, Gr-3, 2x6, 24 in o.c.	13.4	0.22	3	\$2.58
17) R-19 Fiberglass Batt, Gr-2, 2x6, 24 in o.c.	14.6	0.22	2	\$2.60
18) R-19 Fiberglass Batt, Gr-1, 2x6, 24 in o.c.	15.5	0.22	1	\$2.62
19) R-21 Fiberglass Batt, Gr-3, 2x6, 24 in o.c.	14.6	0.22	3	\$2.61
20) R-21 Fiberglass Batt, Gr-2, 2x6, 24 in o.c.	16.1	0.22	2	\$2.64
21) R-21 Fiberglass Batt, Gr-1, 2x6, 24 in o.c.	17.2	0.22	1	\$2.66
22) R-13 Cellulose, Gr-3, 2x4, 16 in o.c.	10.3	0.25	3	\$2.55
23) R-13 Cellulose, Gr-2, 2x4, 16 in o.c.	10.9	0.25	2	\$2.57
24) R-13 Cellulose, Gr-1, 2x4, 16 in o.c.	11.4	0.25	1	\$2.60
25) R-19 Cellulose, Gr-3, 2x6, 24 in o.c.	14.0	0.22	3	\$2.64
26) R-19 Cellulose, Gr-2, 2x6, 24 in o.c.	15.3	0.22	2	\$2.66
27) R-19 Cellulose, Gr-1, 2x6, 24 in o.c.	16.4	0.22	1	\$2.69
28) R-13 Fiberglass, Gr-3, 2x4, 16 in o.c.	10.3	0.25	3	\$2.36
29) R-13 Fiberglass, Gr-2, 2x4, 16 in o.c.	10.9	0.25	2	\$2.39
30) R-13 Fiberglass, Gr-1, 2x4, 16 in o.c.	11.4	0.25	1	\$2.41
31) R-19 Fiberglass, Gr-3, 2x6, 24 in o.c.	14.0	0.22	3	\$2.49
32) R-19 Fiberglass, Gr-2, 2x6, 24 in o.c.	15.3	0.22	2	\$2.51
33) R-19 Fiberglass, Gr-1, 2x6, 24 in o.c.	16.4	0.22	1	\$2.54

Standard wood stud framed walls with cavity insulation. When batt insulation must be compressed to fit within the cavity (e.g. R19 in a 5.5' 2x6 cavity). R-values refer

Gr = Grade of batt installation quality (1, 2, or 3) as described in RESNET's "2006 Mortgage Industry National Home Energy Rating Systems Standards."

BEopt

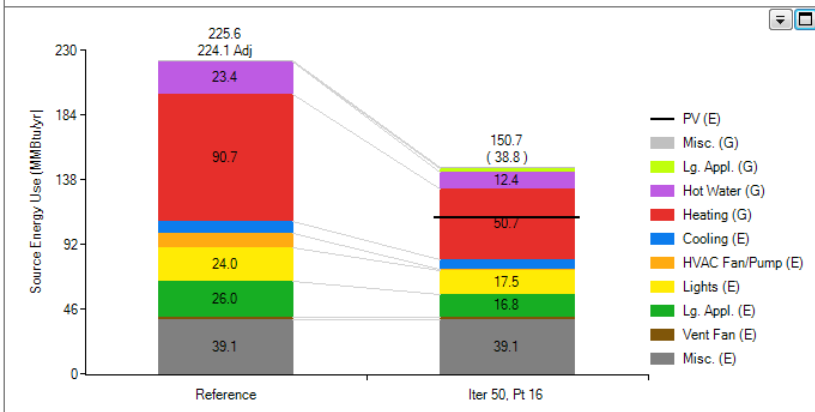
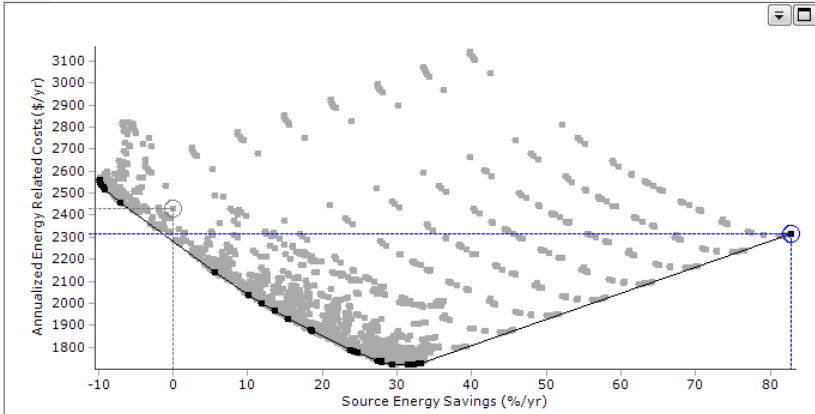
BEopt 2.0.0.6 - Sample - new construction optimizations [Standard, New Construction]

File Screen Case Run Reports Tools Graphs Help

Input: Output:

Chicago, E+ Phoenix, E+ Chicago, DOE2 Phoenix, DOE2

Select: Max Savings Reference: B10 Benchmark Tools:

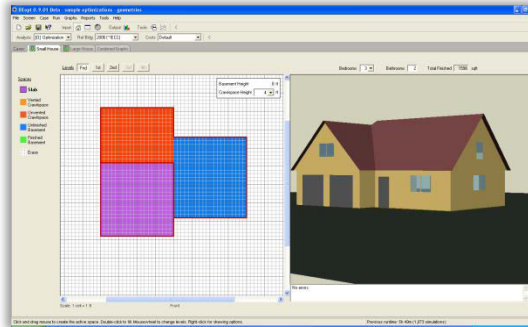


Building	Option Number	Cost	Description
Orientation	1	\$0	East
Neighbors	1	\$0	at 15ft
Operation			
Heating Set Point	4	\$0	71 F
Cooling Set Point	4	\$0	76 F
Humidity Set Point	4	\$0	60% RH
Misc Electric Loads	4	\$0	1.00
Misc Gas Loads	2	\$0	1.00
Misc Hot Water Loads	2	\$0	1.00
Natural Ventilation	2	\$0	Benchmark
Interior Shading	2	\$0	Benchmark
Walls			
Wood Stud	12	\$3,560	R-19 Fiberglass Batt, Gr-1, 2x6, 24 in o.c.
Double Wood Stud	18	\$0	None
CMU	1	\$0	None
SIP	1	\$0	None
ICF	1	\$0	None
Other	1	\$0	None
Wall Sheathing	2	\$3,190	OSB, R-10 XPS
Exterior Finish	1	\$15,973	Stucco, Medium/Dark
Interzonal Walls	11	\$759	R-19 Fiberglass Batt, Gr 1, 2x6, 24 in o.c., R-5 XPS
Ceilings/Roofs			
Unfinished Attic	5	\$959	Ceiling R-60 Fiberglass, Vented
Roof Material	1	\$3,911	Asphalt Shingles, Dark
Radiant Barrier	1	\$0	None
Foundation/Floors			
Unfinished Basement	1	\$1,852	Whole Wall R-10 XPS
Interzonal Floor	2	\$146	R-38 Fiberglass Batt
Carpet	5	\$0	80% Carpet
Thermal Mass			
Floor Mass	2	\$2,583	Wood Surface
Exterior Wall Mass	2	\$2,193	1/2 in. Drywall
Partition Wall Mass	2	\$1,962	1/2 in. Drywall
Ceiling Mass	2	\$2,025	1/2 in. Drywall
Windows & Doors			
Window Areas	4	\$0	15.0% F20 B40 L20 R20
Windows	5	\$7,851	Double-Pane, Medium-Gain Low-E, Non-metal Frame, Argon
	8	\$0	
	13	\$0	
	14	\$0	
	15	\$0	
	16	\$0	
	17	\$0	
	18	\$0	
	19	\$0	
	20	\$0	
	21	\$0	
	22	\$0	
	23	\$0	
	24	\$0	
	25	\$0	
	26	\$0	
	27	\$0	
	28	\$0	
	29	\$0	
	30	\$0	
	31	\$0	
	32	\$0	
	33	\$0	
	34	\$0	
	35	\$0	
	36	\$0	
	37	\$0	
	38	\$0	
	39	\$0	
	40	\$0	
	41	\$0	
	42	\$0	
	43	\$0	
	44	\$0	
	45	\$0	
	46	\$0	
	47	\$0	
	48	\$0	
	49	\$0	
	50	\$0	
	51	\$0	
	52	\$0	
	53	\$0	
	54	\$0	
	55	\$0	
	56	\$0	
	57	\$0	
	58	\$0	
	59	\$0	
	60	\$0	
	61	\$0	
	62	\$0	
	63	\$0	
	64	\$0	
	65	\$0	
	66	\$0	
	67	\$0	
	68	\$0	
	69	\$0	
	70	\$0	
	71	\$0	
	72	\$0	
	73	\$0	
	74	\$0	
	75	\$0	
	76	\$0	
	77	\$0	
	78	\$0	
	79	\$0	
	80	\$0	
	81	\$0	
	82	\$0	
	83	\$0	
	84	\$0	
	85	\$0	
	86	\$0	
	87	\$0	
	88	\$0	
	89	\$0	
	90	\$0	
	91	\$0	
	92	\$0	
	93	\$0	
	94	\$0	
	95	\$0	
	96	\$0	
	97	\$0	
	98	\$0	
	99	\$0	
	100	\$0	
	101	\$0	
	102	\$0	
	103	\$0	
	104	\$0	
	105	\$0	
	106	\$0	
	107	\$0	
	108	\$0	
	109	\$0	
	110	\$0	
	111	\$0	
	112	\$0	
	113	\$0	
	114	\$0	
	115	\$0	
	116	\$0	
	117	\$0	
	118	\$0	
	119	\$0	
	120	\$0	
	121	\$0	
	122	\$0	
	123	\$0	
	124	\$0	
	125	\$0	
	126	\$0	
	127	\$0	
	128	\$0	
	129	\$0	
	130	\$0	
	131	\$0	
	132	\$0	
	133	\$0	
	134	\$0	
	135	\$0	
	136	\$0	
	137	\$0	
	138	\$0	
	139	\$0	
	140	\$0	
	141	\$0	
	142	\$0	
	143	\$0	
	144	\$0	
	145	\$0	
	146	\$0	
	147	\$0	
	148	\$0	
	149	\$0	
	150	\$0	
	151	\$0	
	152	\$0	
	153	\$0	
	154	\$0	
	155	\$0	
	156	\$0	
	157	\$0	
	158	\$0	
	159	\$0	
	160	\$0	
	161	\$0	
	162	\$0	
	163	\$0	
	164	\$0	
	165	\$0	
	166	\$0	
	167	\$0	
	168	\$0	
	169	\$0	
	170	\$0	
	171	\$0	
	172	\$0	
	173	\$0	
	174	\$0	
	175	\$0	
	176	\$0	
	177	\$0	
	178	\$0	
	179	\$0	
	180	\$0	
	181	\$0	
	182	\$0	
	183	\$0	
	184	\$0	
	185	\$0	
	186	\$0	
	187	\$0	
	188	\$0	
	189	\$0	
	190	\$0	
	191	\$0	
	192	\$0	
	193	\$0	
	194	\$0	
	195	\$0	
	196	\$0	
	197	\$0	
	198	\$0	
	199	\$0	
	200	\$0	
	201	\$0	
	202	\$0	
	203	\$0	
	204	\$0	
	205	\$0	
	206	\$0	
	207	\$0	
	208	\$0	
	209	\$0	
	210	\$0	
	211	\$0	
	212	\$0	
	213	\$0	
	214	\$0	
	215	\$0	
	216	\$0	
	217	\$0	
	218	\$0	
	219	\$0	
	220	\$0	
	221	\$0	
	222	\$0	
	223	\$0	
	224	\$0	
	225	\$0	
	226	\$0	
	227	\$0	
	228	\$0	
	229	\$0	
	230	\$0	
	231	\$0	
	232	\$0	
	233	\$0	
	234	\$0	
	235	\$0	
	236	\$0	
	237	\$0	
	238	\$0	
	239	\$0	
	240	\$0	
	241	\$0	
	242	\$0	
	243	\$0	
	244	\$0	
	245	\$0	
	246	\$0	
	247	\$0	
	248	\$0	
	249	\$0	
	250	\$0	
	251	\$0	
	252	\$0	
	253	\$0	
	254	\$0	
	255	\$0	
	256	\$0	
	257	\$0	
	258	\$0	
	259	\$0	
	260	\$0	
	261	\$0	
	262	\$0	
	263	\$0	
	264	\$0	
	265	\$0	
	266	\$0	
	267	\$0	
	268	\$0	
	269	\$0	
	270	\$0	
	271	\$0	
	272	\$0	
	273	\$0	
	274	\$0	
	275	\$0	
	276	\$0	
	277	\$0	
	278	\$0	
	279	\$0	
	280	\$0	
	281	\$0	
	282	\$0	
	283	\$0	
	284	\$0	
	285	\$0	
	286	\$0	
	287	\$0	
	288	\$0	
	289	\$0	
	290	\$0	
	291	\$0	
	292	\$0	
	293	\$0	
	294	\$0	
	295	\$0	
	296	\$0	
	297	\$0	
	298	\$0	
	299	\$0	
	300	\$0	
	301	\$0	
	302	\$0	
	303	\$0	
	304	\$0	
	305	\$0	
	306	\$0	
	307	\$0	
	308	\$0	
	309	\$0	
	310	\$0	

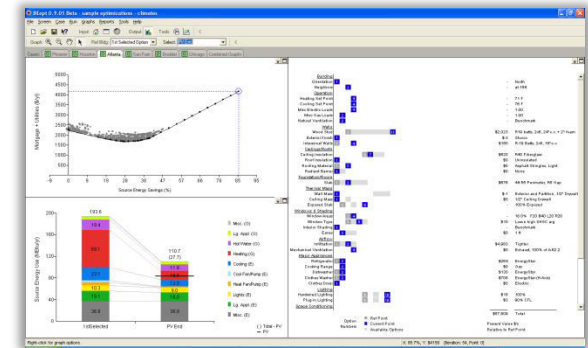
BEopt GUI

Input

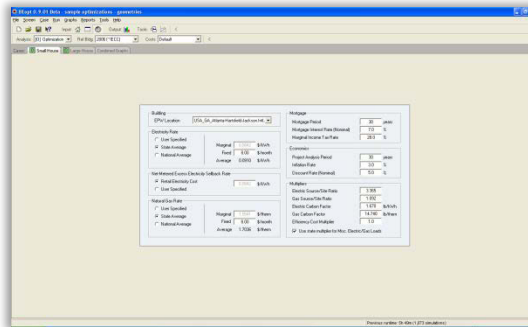
Geometry



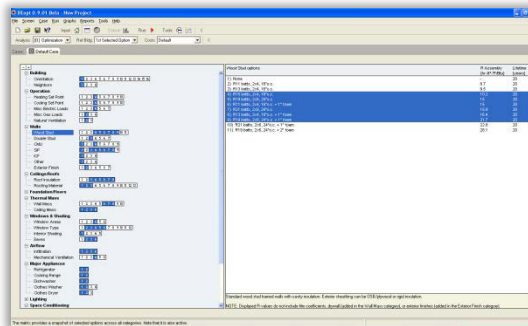
Output



Run



Site



Options



Live Demo

Prototype Analysis



2-Story

2500 sf

Climate-specific foundations



Basements

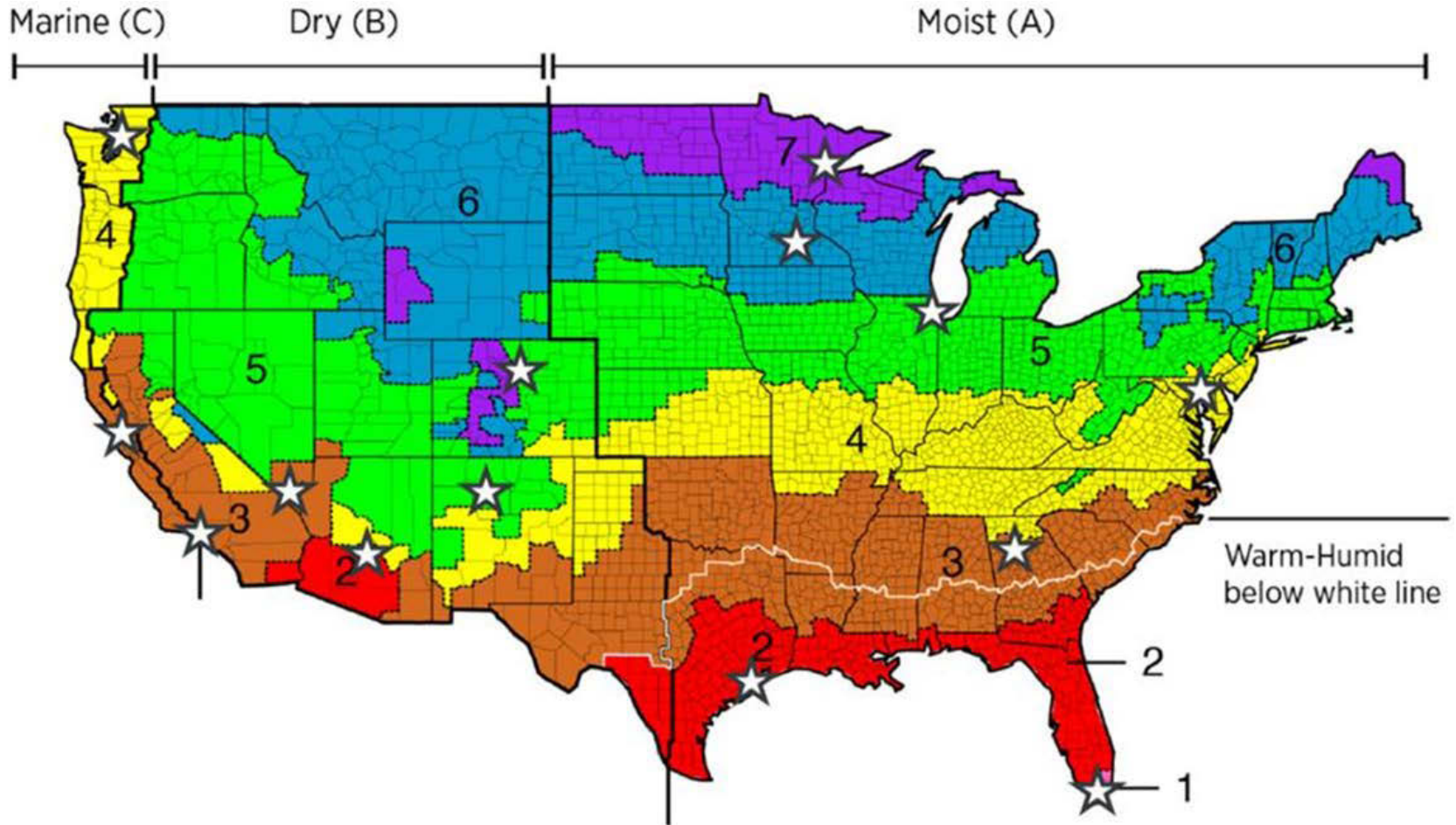


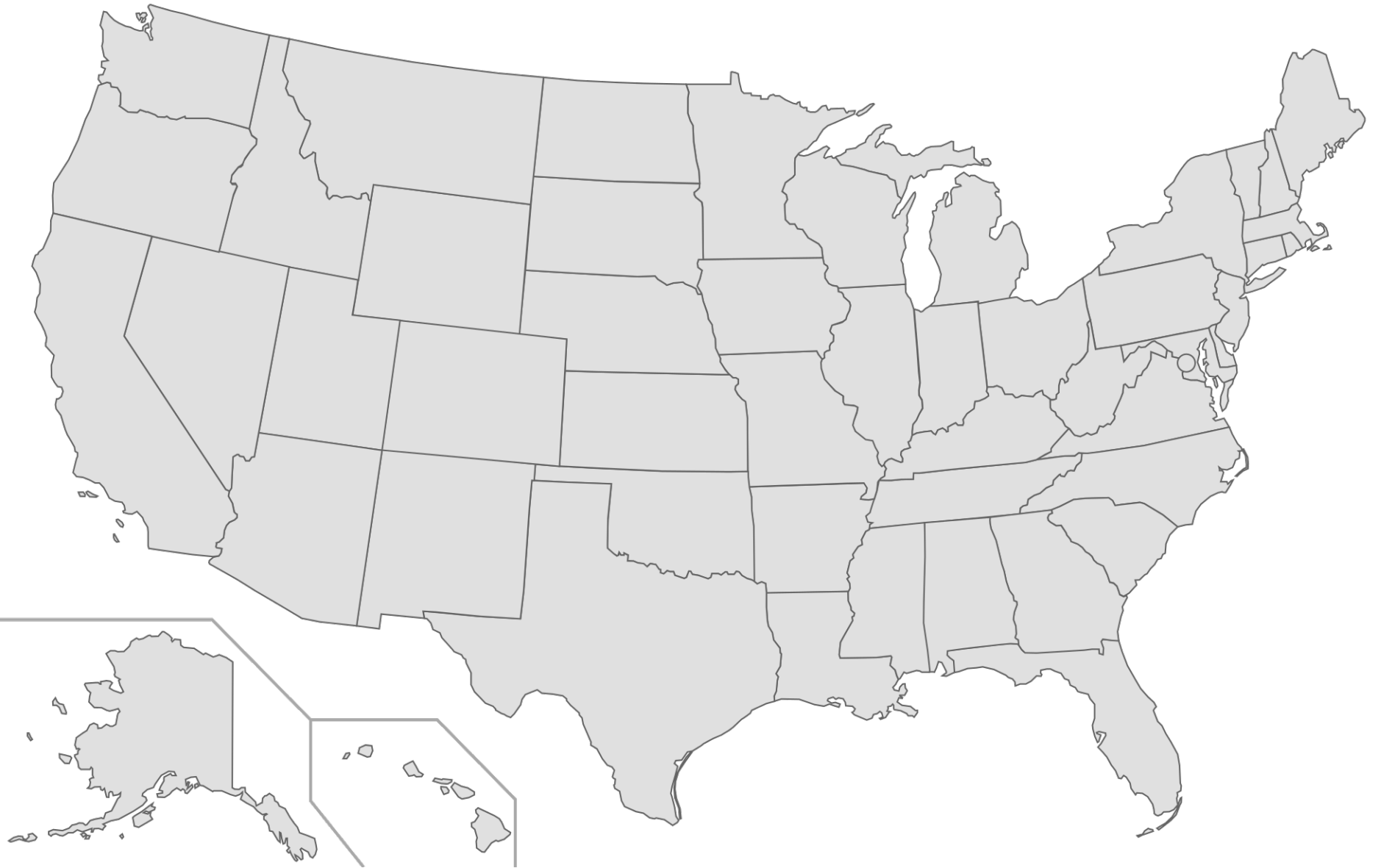
Crawlspace

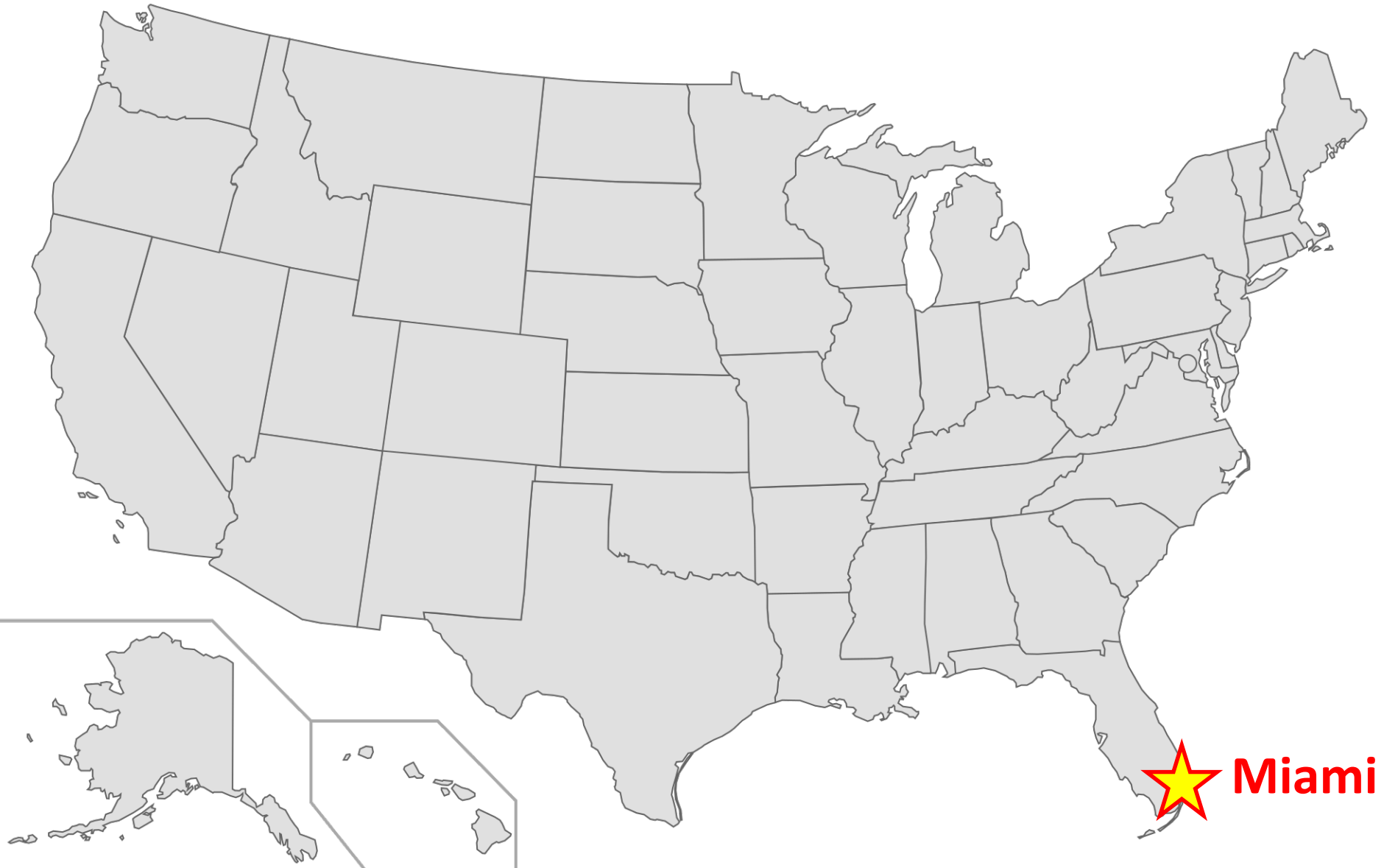


Slabs

Selected cities









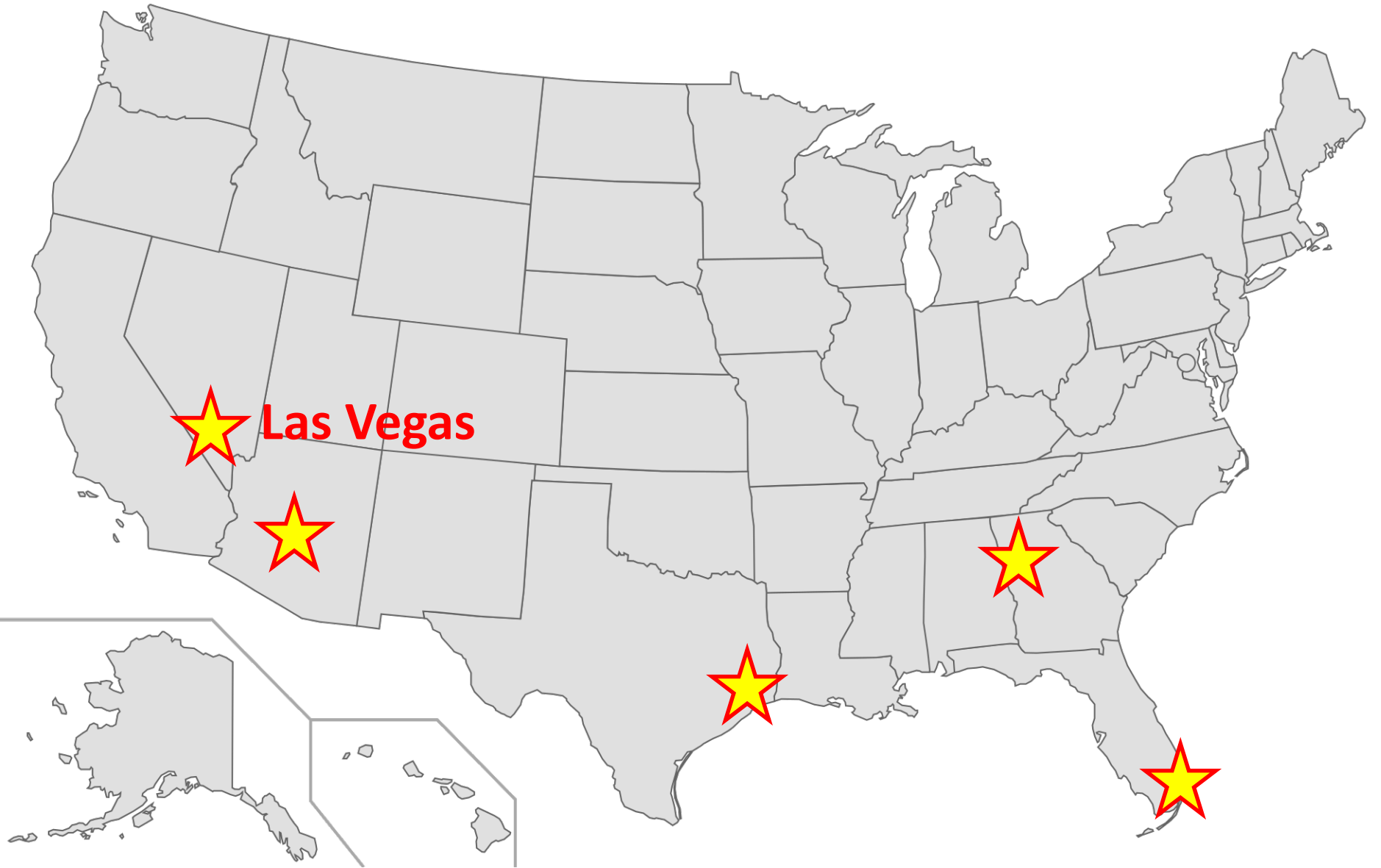
Houston



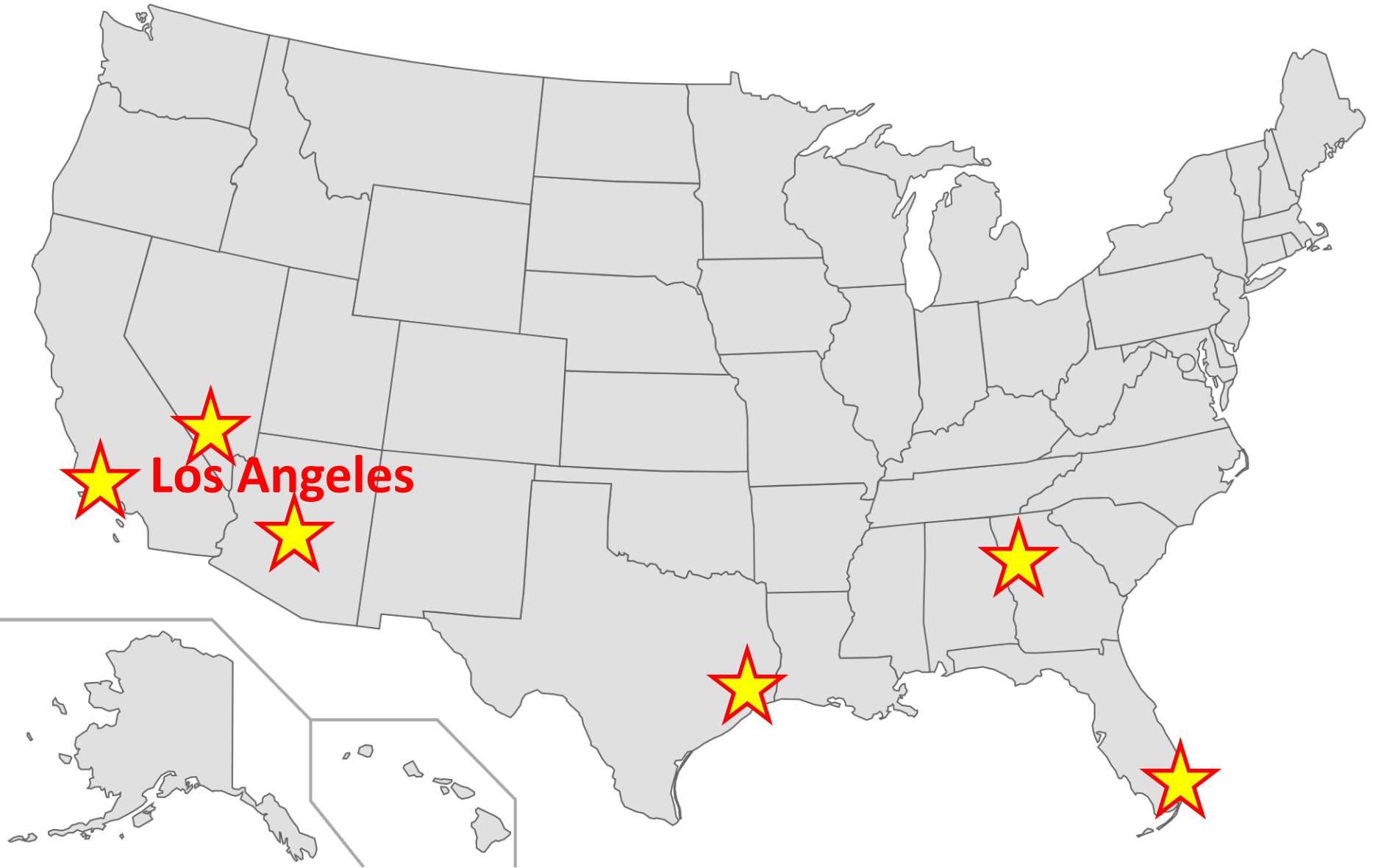
★ Phoenix



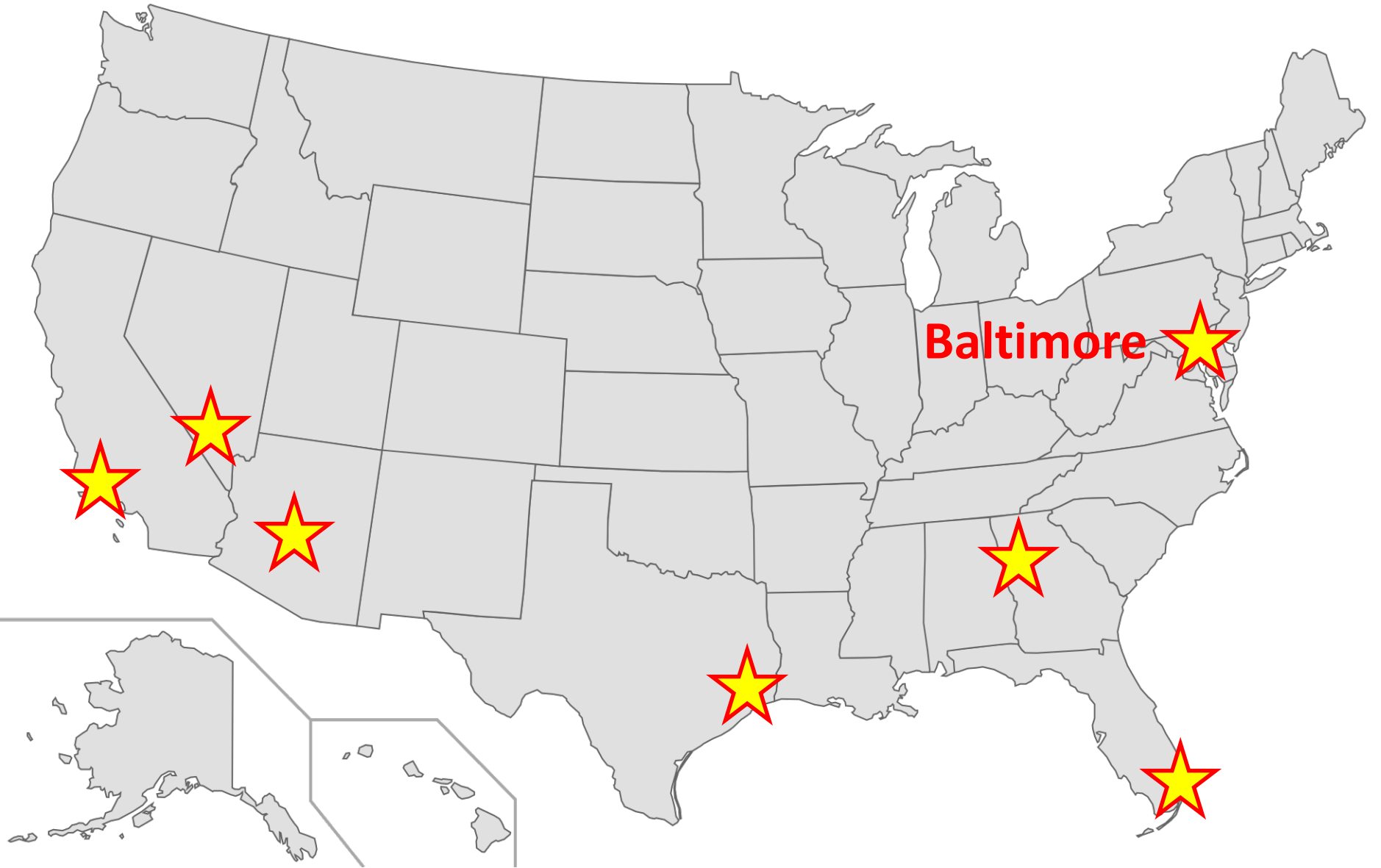
Atlanta



Las Vegas

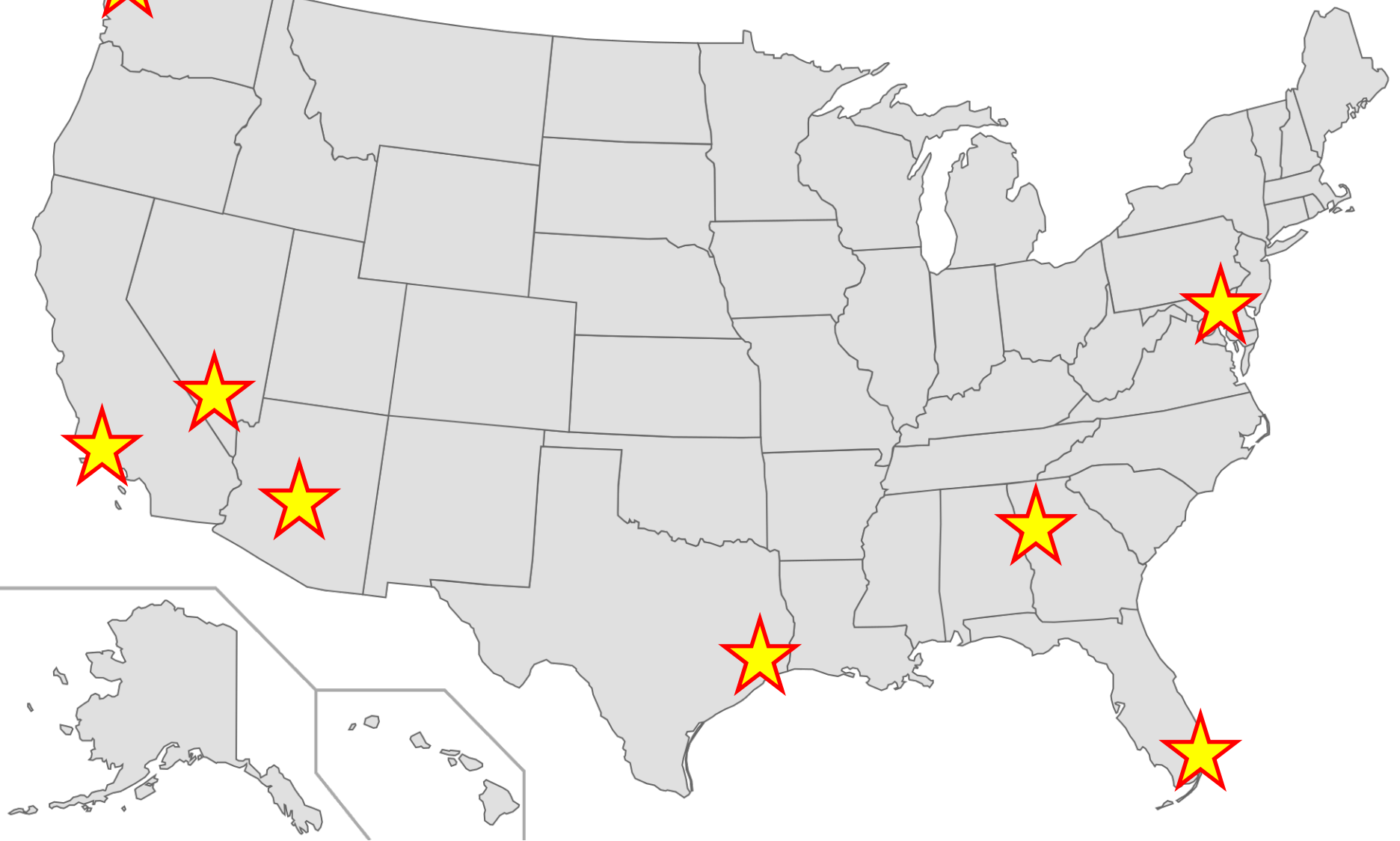


Los Angeles



Baltimore

 **Seattle**



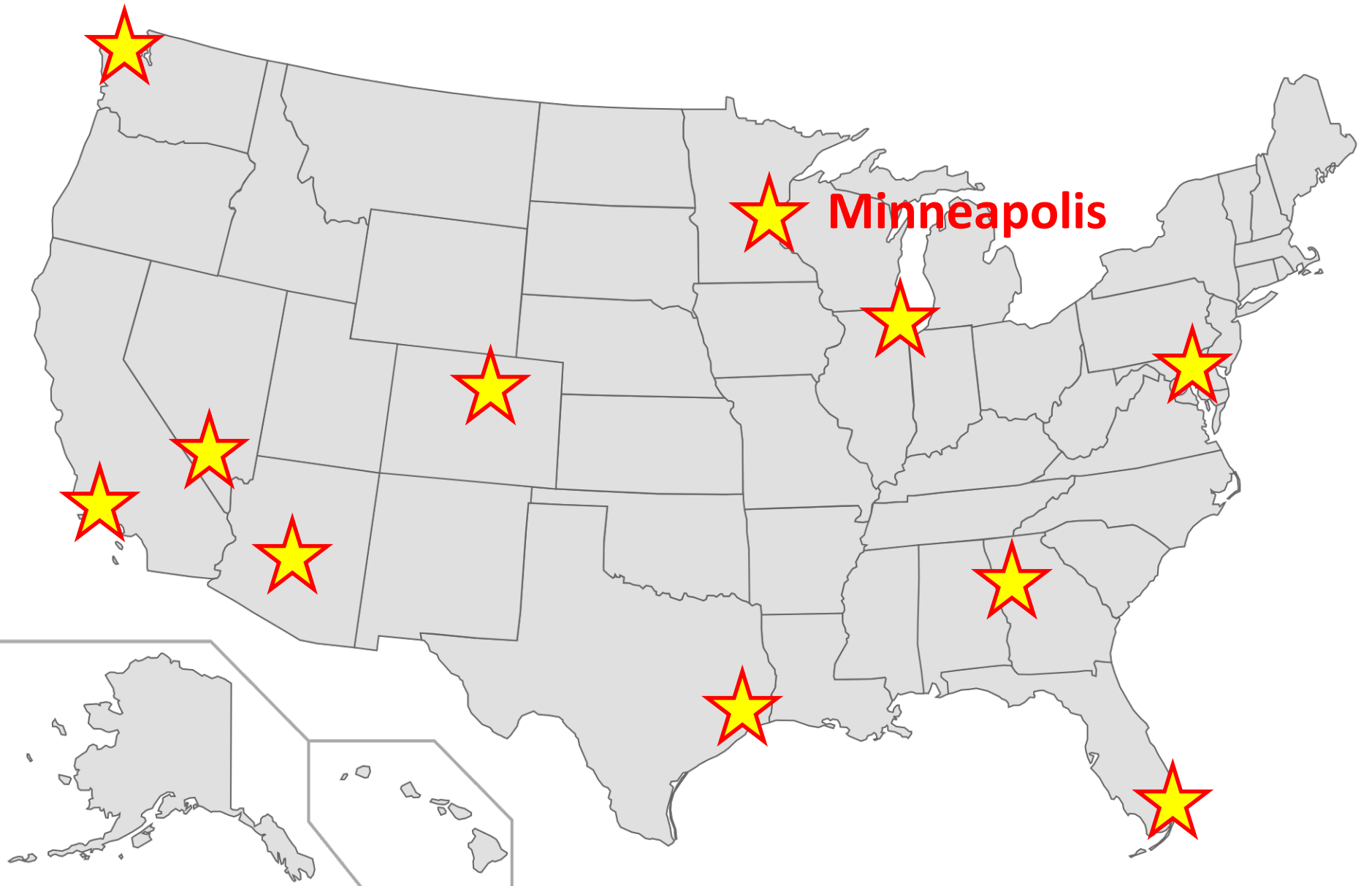


Chicago



Denver

Chicago



Minneapolis

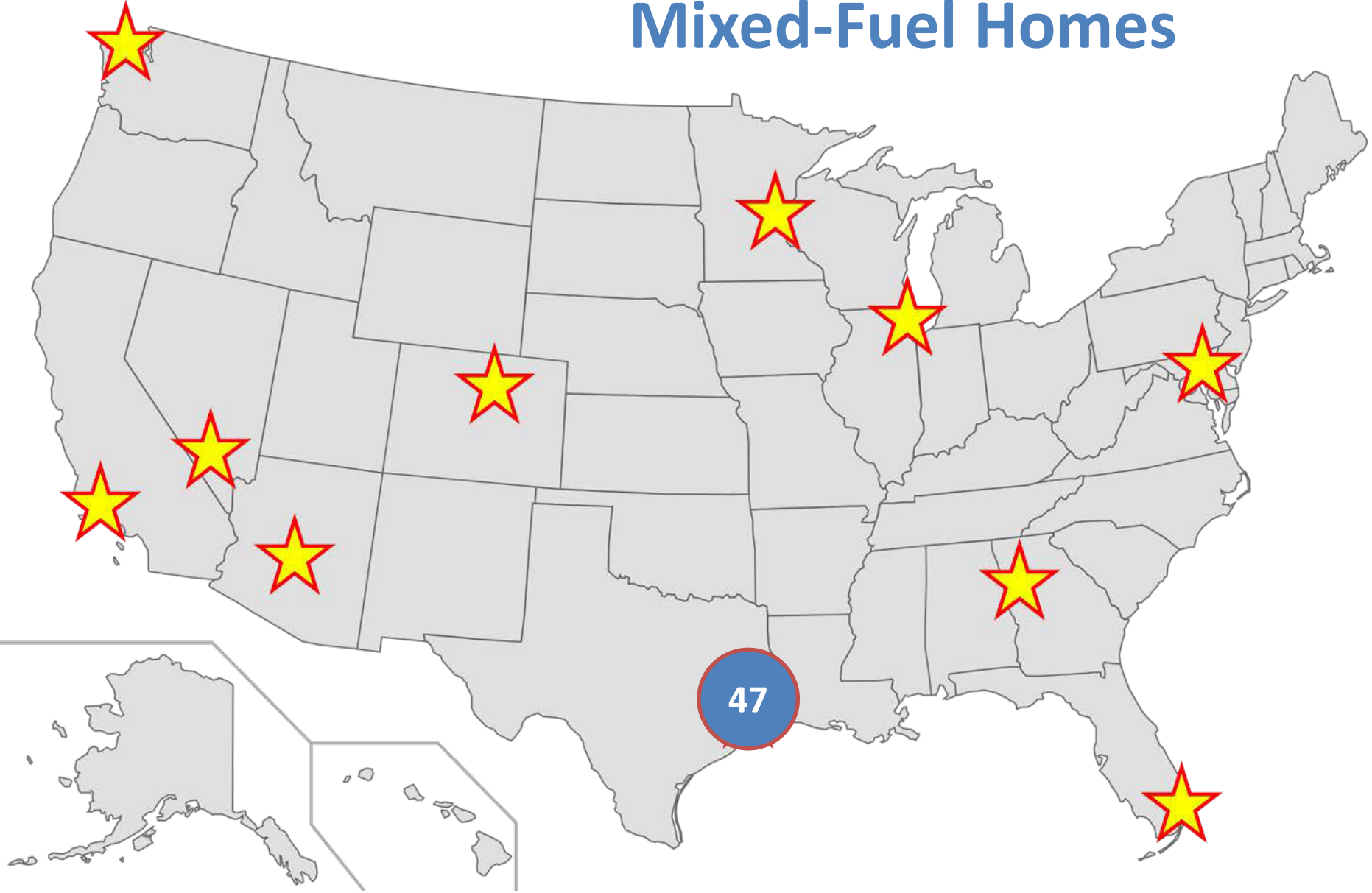
A map of the United States with several yellow stars with red outlines placed on various states, including Washington, Oregon, California, Nevada, Arizona, Texas, Louisiana, Mississippi, Alabama, Georgia, Florida, New York, and Maryland. A large light blue box with a dark blue border is centered over the map, containing text.

Average HERS Index in 2015

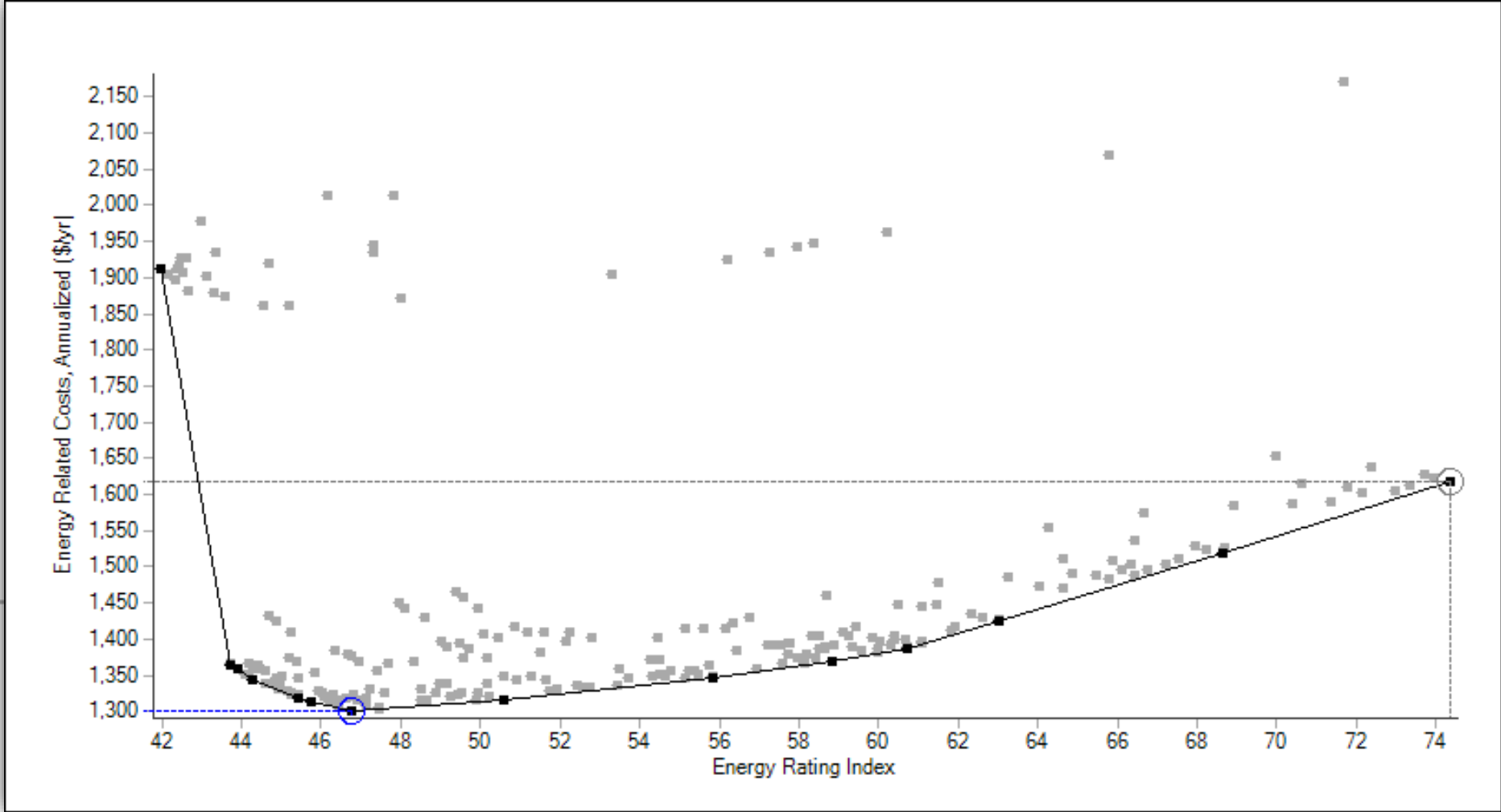
62

National average for 190,180 homes rated in 2015.

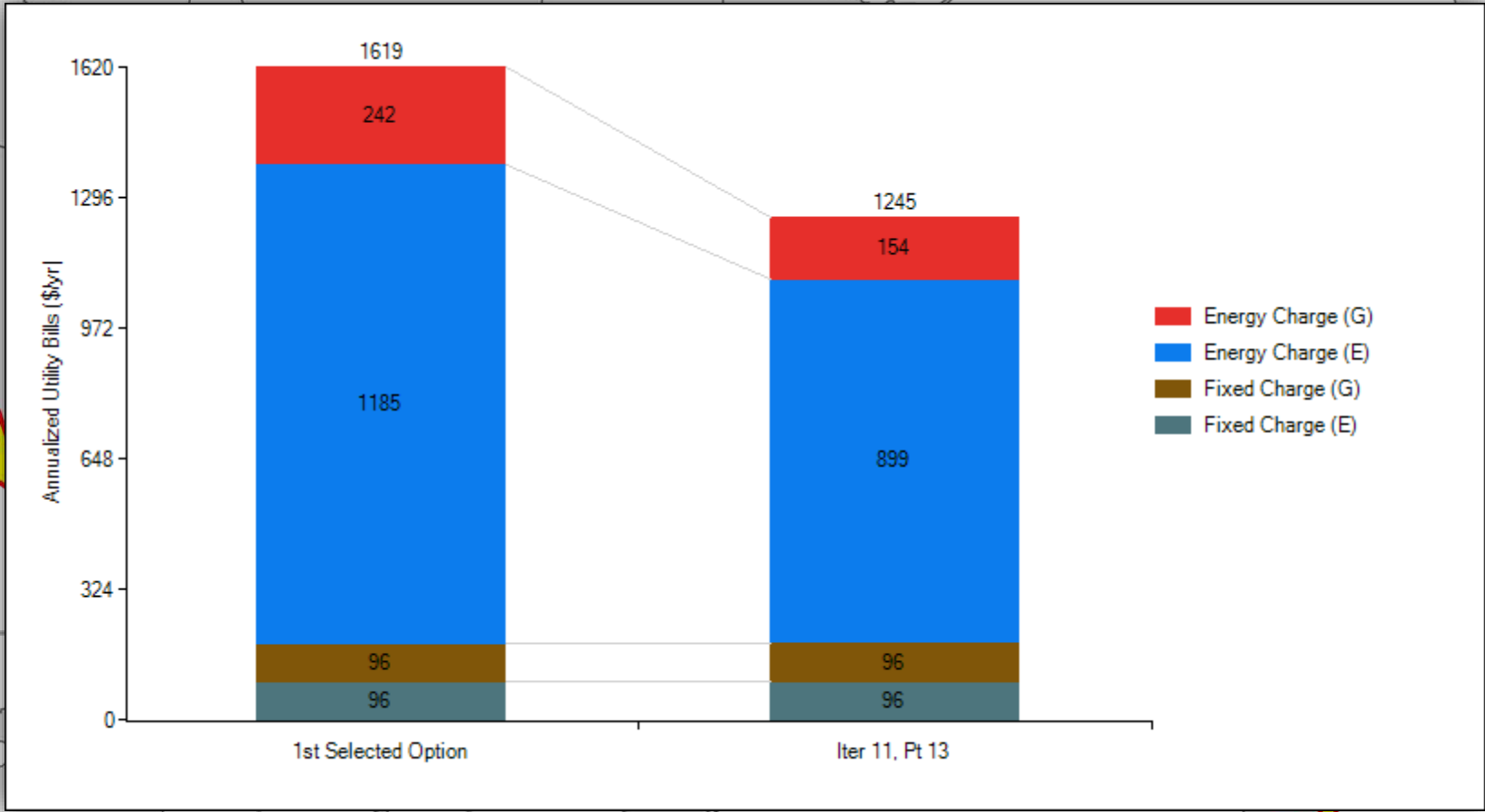
Mixed-Fuel Homes



Mixed-Fuel Homes



Mixed-Fuel Homes

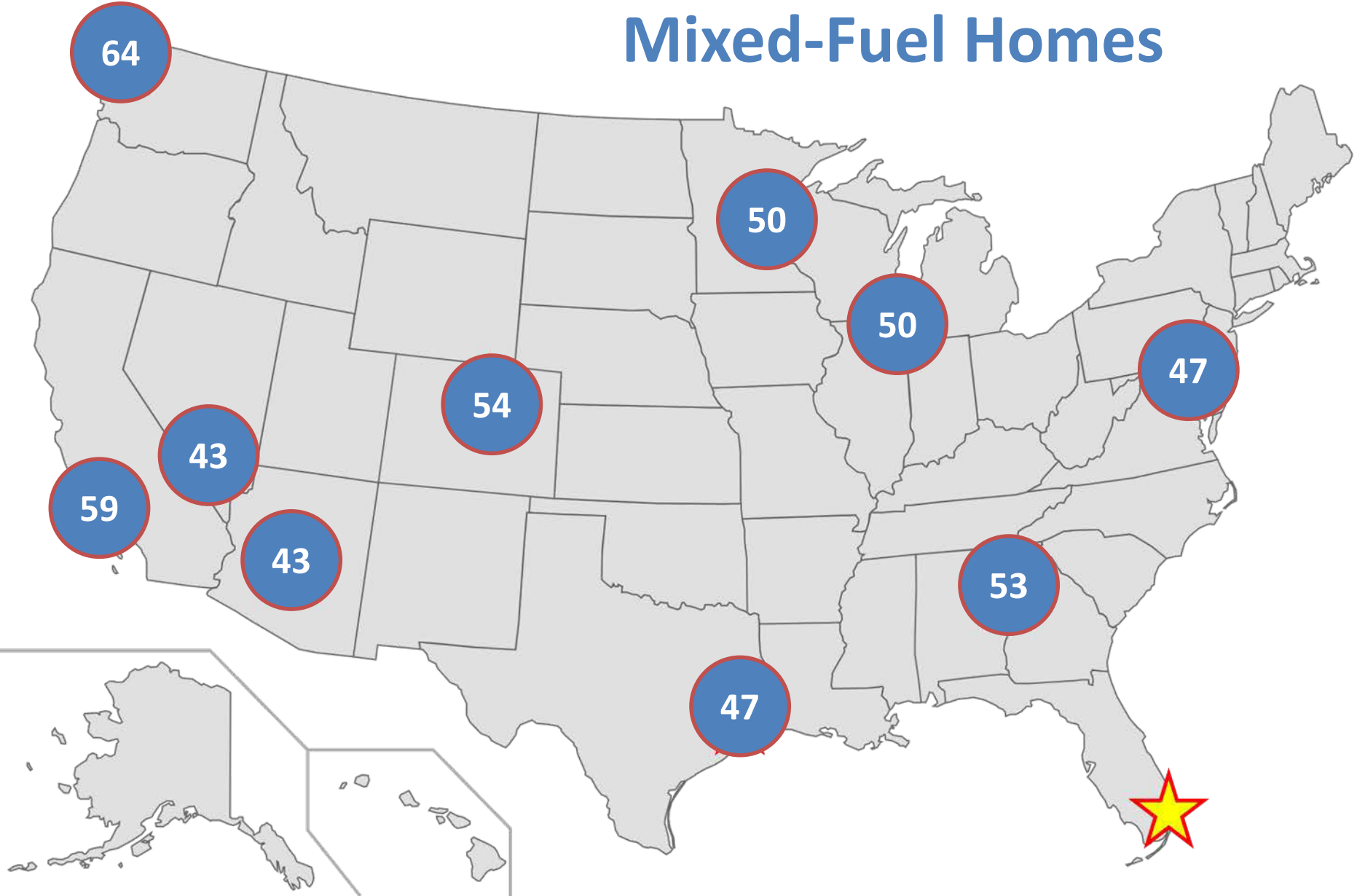


<u>Building</u> ⊕	
<u>Walls</u> ⊖	
Wood Stud	5 7 9
Wall Sheathing	2 8 9
Exterior Finish	8
<u>Ceilings/Roofs</u> ⊖	
Unfinished Attic	7 8 9
Roof Material	2
Radiant Barrier	1
<u>Foundation/Floors</u> ⊖	
Slab	2
Carpet	1
<u>Thermal Mass</u> ⊕	
<u>Windows & Doors</u> ⊖	
Window Areas	2
Windows	8 23
Interior Shading	2
Door Area	4
Doors	3
Eaves	3
Overhangs	1
<u>Airflow</u> ⊖	
Air Leakage	10 12 14
Mechanical Ventilation	3
Natural Ventilation	1
<u>Space Conditioning</u> ⊖	
Central Air Conditioner	4 6 10
Furnace	9 12
Ducts	17 30
Ceiling Fan	2
Dehumidifier	1
<u>Space Conditioning Schedules</u> ⊕	
<u>Water Heating</u> ⊖	
Water Heater	7 9 11
Distribution	2
Solar Water Heating	1
Solar Water Heating Azimuth	1
Solar Water Heating Tilt	1
<u>Lighting</u> ⊖	
Lighting	3 18 23
<u>Appliances & Fixtures</u> ⊕	
<u>Appliances & Fixtures Schedules</u> ⊕	
<u>Miscellaneous</u> ⊕	
<u>Miscellaneous Schedules</u> ⊕	
<u>Power Generation</u> ⊕	

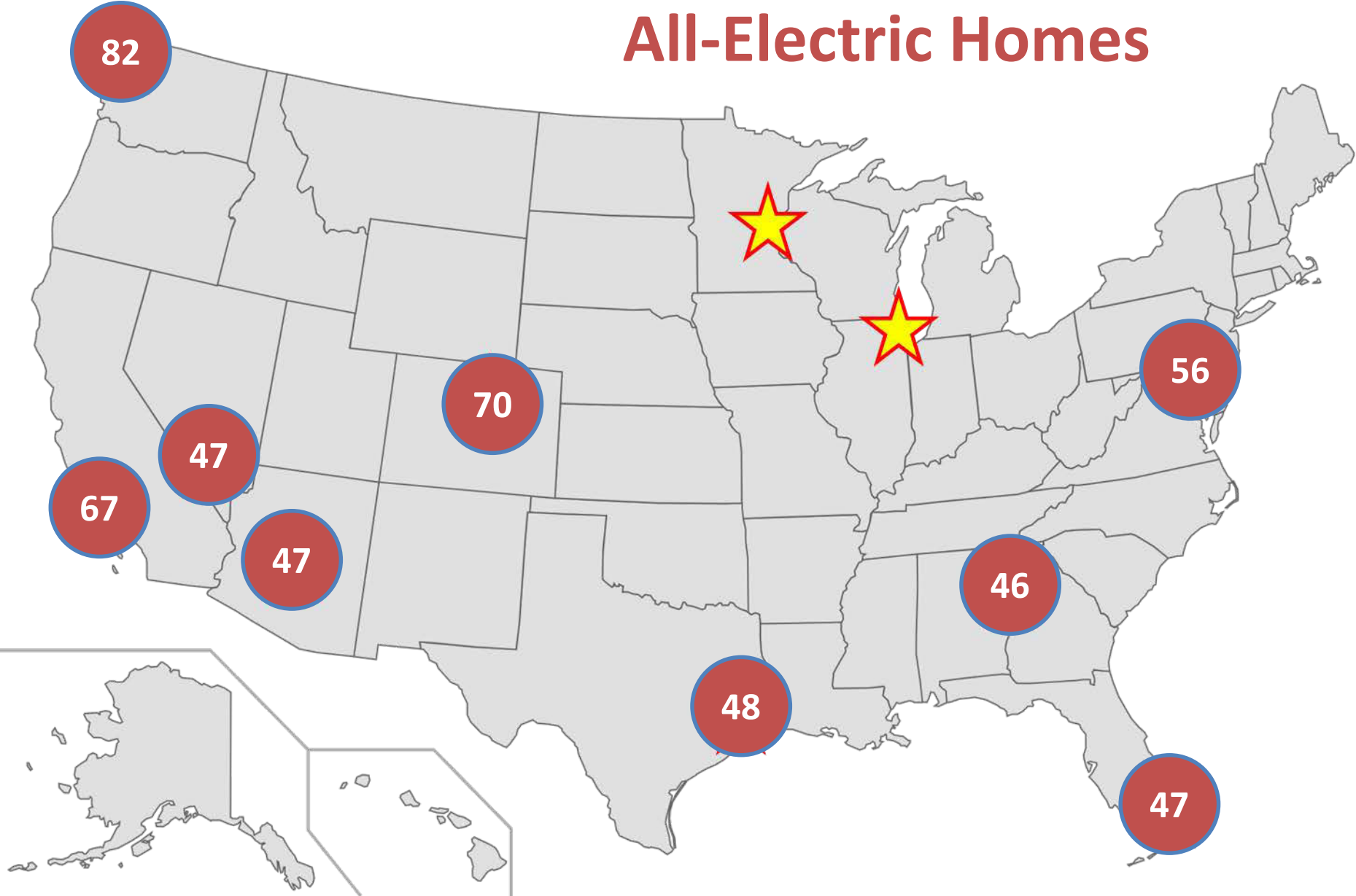
\$595	R-21 Fiberglass Batt, 2x6, 24 in o.c.
\$0	OSB
\$0	Vinyl, Light
\$0	Ceiling R-38 Fiberglass, Gr-1, Vented
\$0	Asphalt Shingles, Medium
\$0	None
\$0	Uninsulated
\$0	0% Carpet
\$0	F18 B18 L18 R18
\$0	Low-E, Double, Non-metal, Air, L-Gain
\$0	Summer = 0.7, Winter = 0.7
\$0	40 ft ²
\$0	Fiberglass
\$0	2 ft
\$0	None
\$831	1 ACH50
\$0	Exhaust, 2013 ASHRAE 62.2
\$0	None
-\$140	SEER 18
-\$54	Gas, 80% AFUE
-\$30	In Finished Space
\$0	National Average
\$0	None
\$902	Gas Tankless, Condensing
\$0	Uninsulated, TrunkBranch, Copper
\$0	None
\$0	Back Roof
\$0	Roof Pitch
\$958	100% LED
<hr/>	
\$3,062	Total Incremental Initial Cost

Option Numbers ■ Ref Point
 ■ Current Point
 ■ Available Options
 — Higher Option Number
 — Lower Option Number

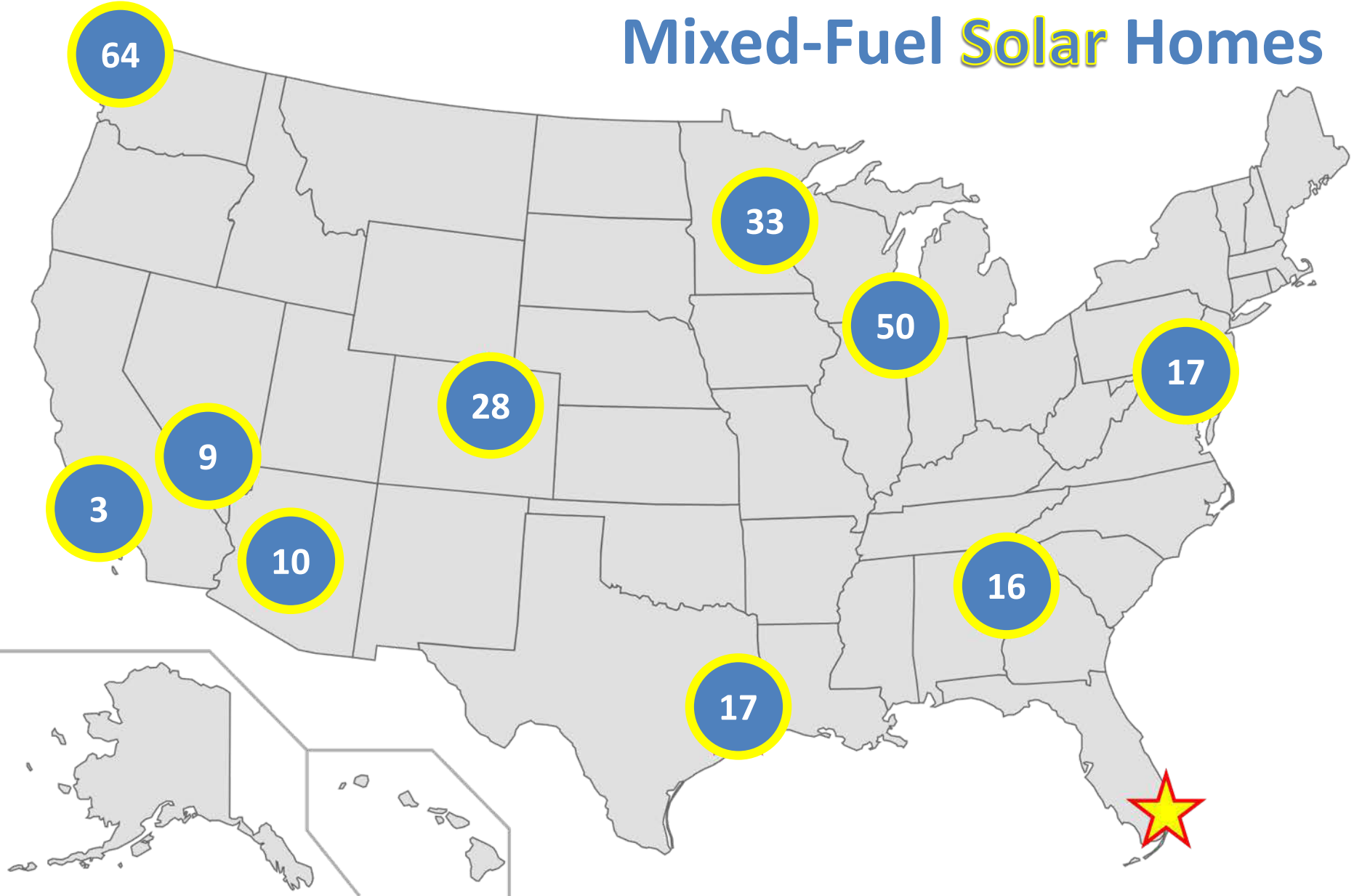
Mixed-Fuel Homes



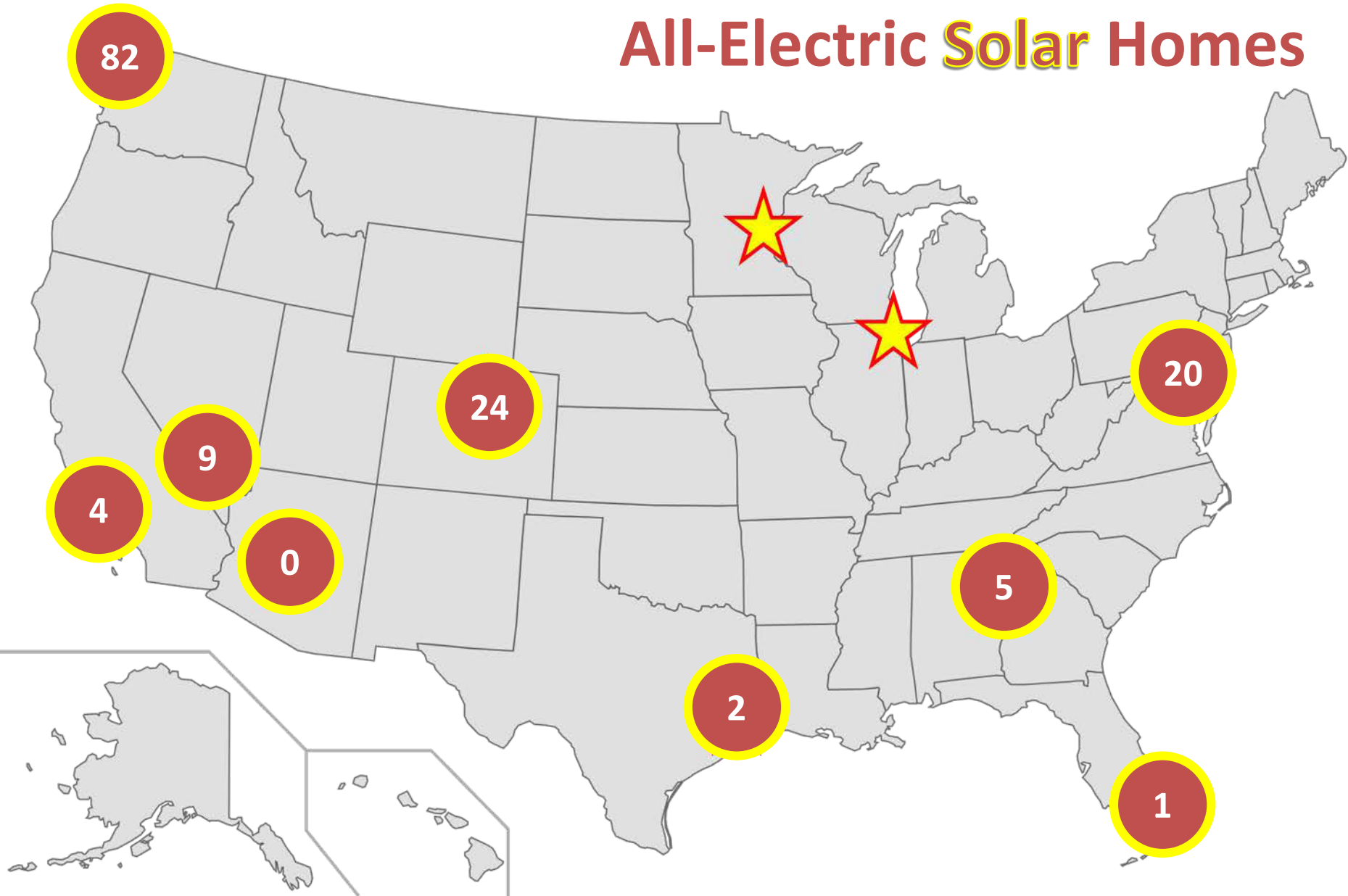
All-Electric Homes



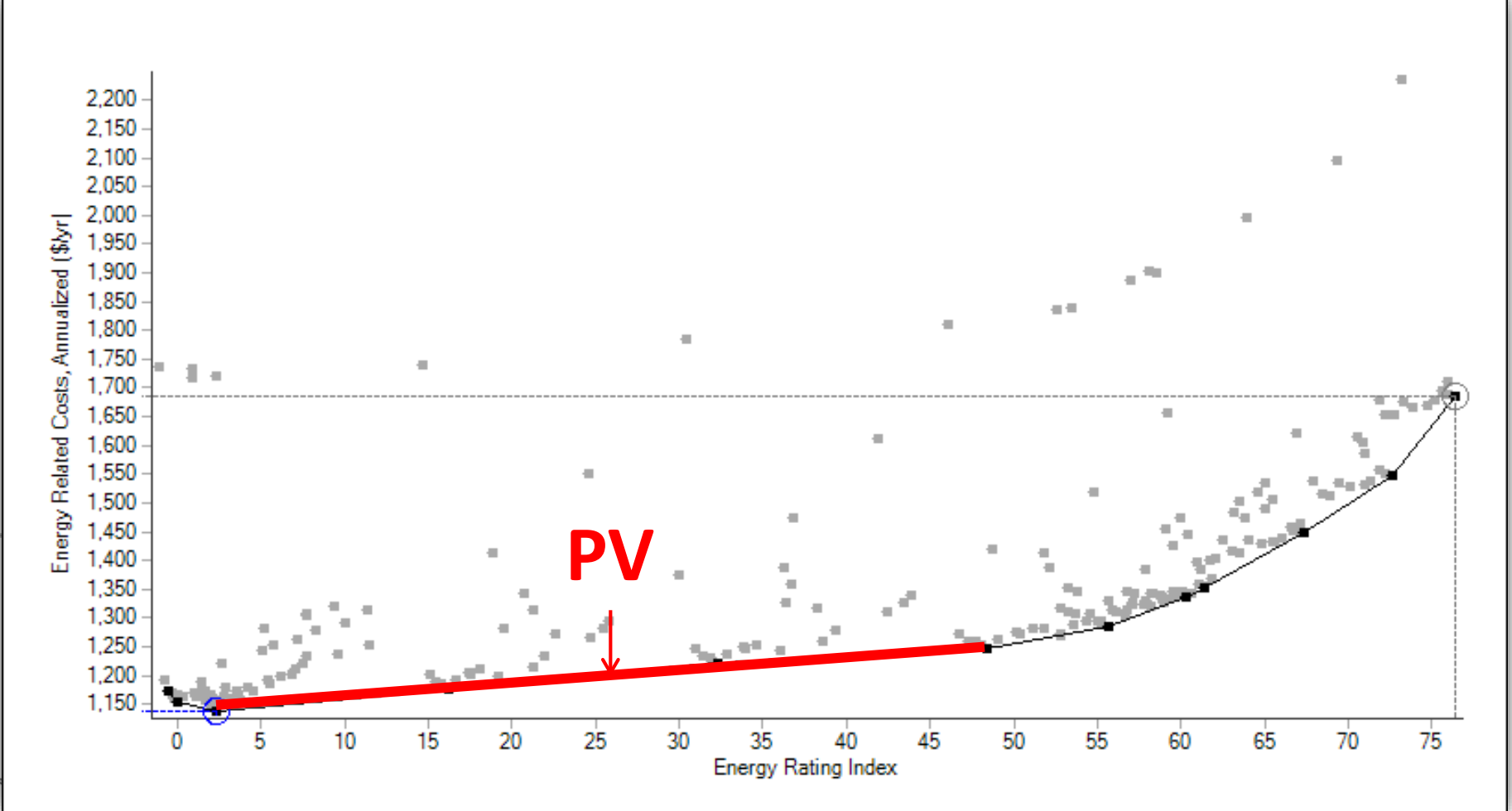
Mixed-Fuel Solar Homes



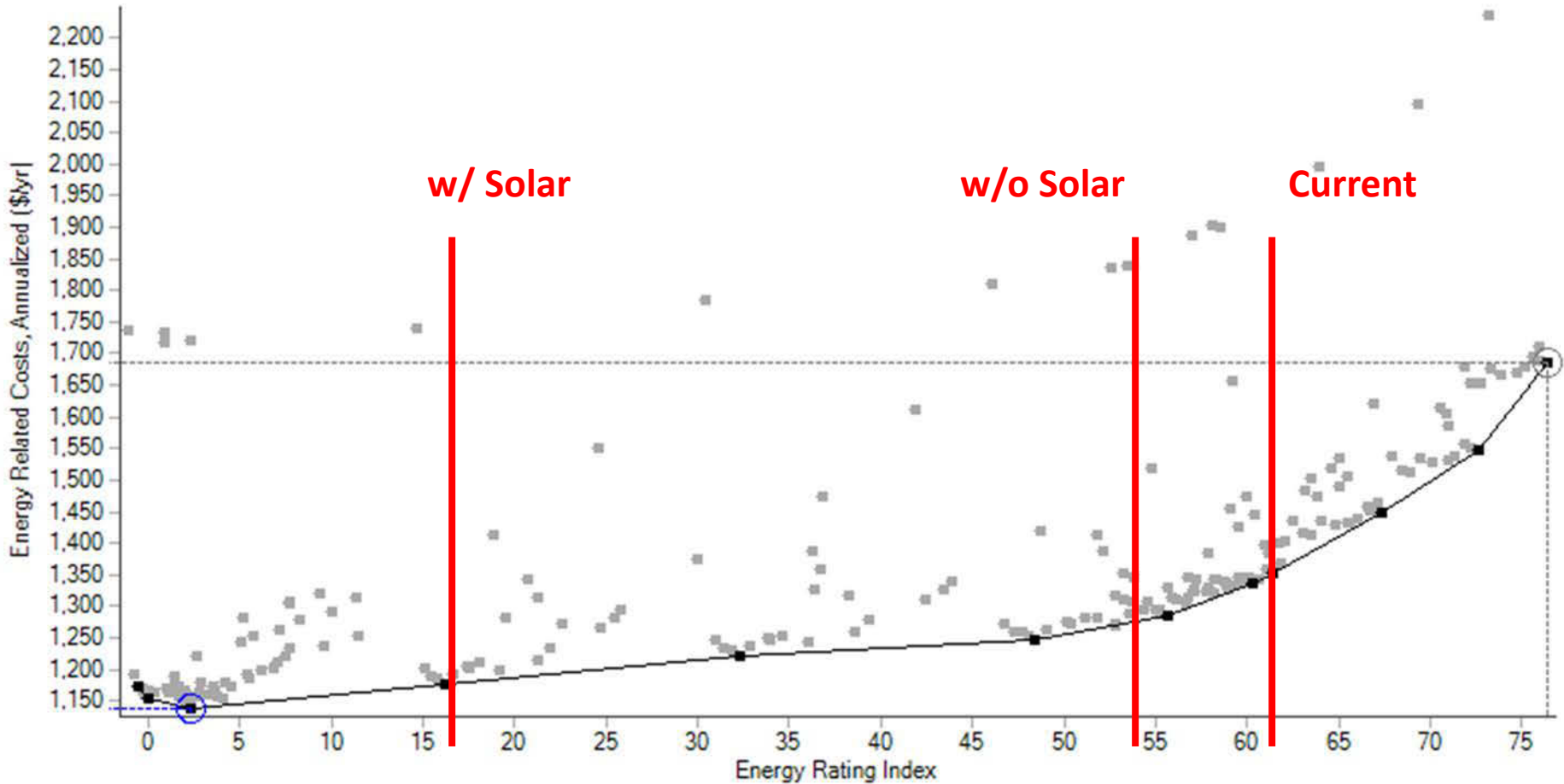
All-Electric Solar Homes



All-Electric Solar Homes

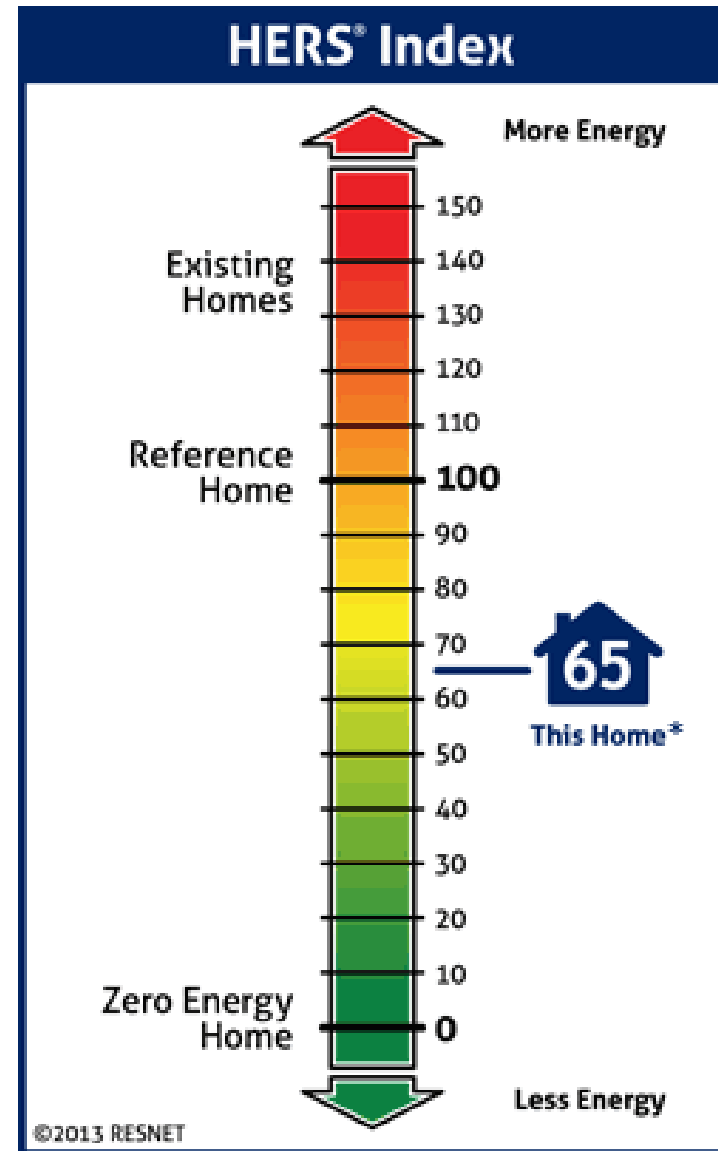
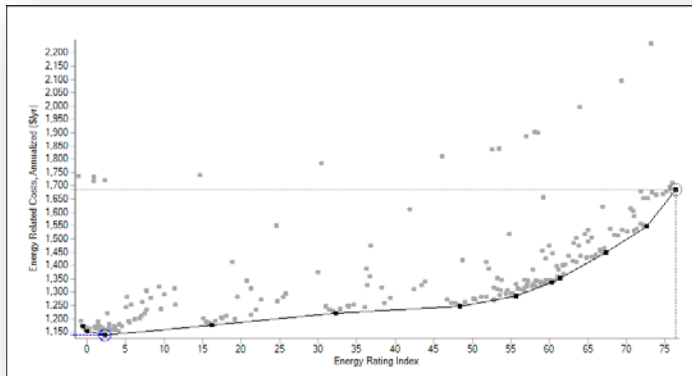


Average HERS Index*



*For discussion/demonstration only. The example from analysis are not weighted by climate or fuel like the RESNET average.

In general, cost-optimal solutions are lower than average HERS rating issued in 2015.



*Sample rating representation.