Optimizing Energy Design with Modeling

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Summary

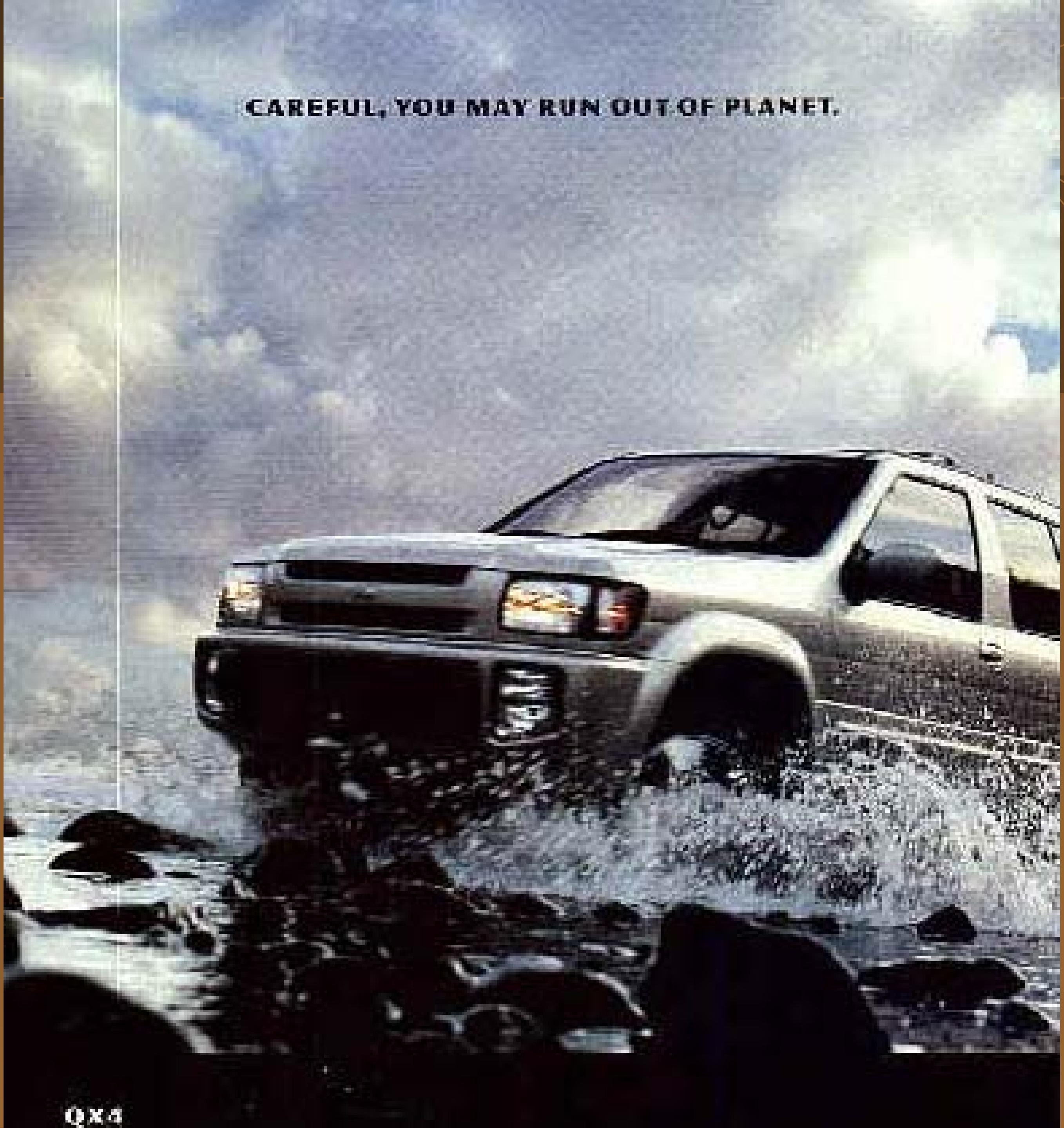
- Why bother?
- Steps to optimize design
- Modeling tools
- Making sense of the data – the laugh test, the smell test, compare

Why Bother?

- Create buildings with the lowest total cost –
  - ownership cost
  - operation cost
  - maintenance cost.
- Minimize demand on the energy supply system
- Reduce global warming
- Decrease pollution

Why Bother?

- Move toward buildings that improve, not deplete, the environment
  - Resource friendly
  - Safe, friendly and healthy for occupant and workers
  - Durable


CAREFUL, YOU MAY RUN OUT OF PLANET.
QX4

Too Typical:

- Rule of thumb
- How it was done the last time.

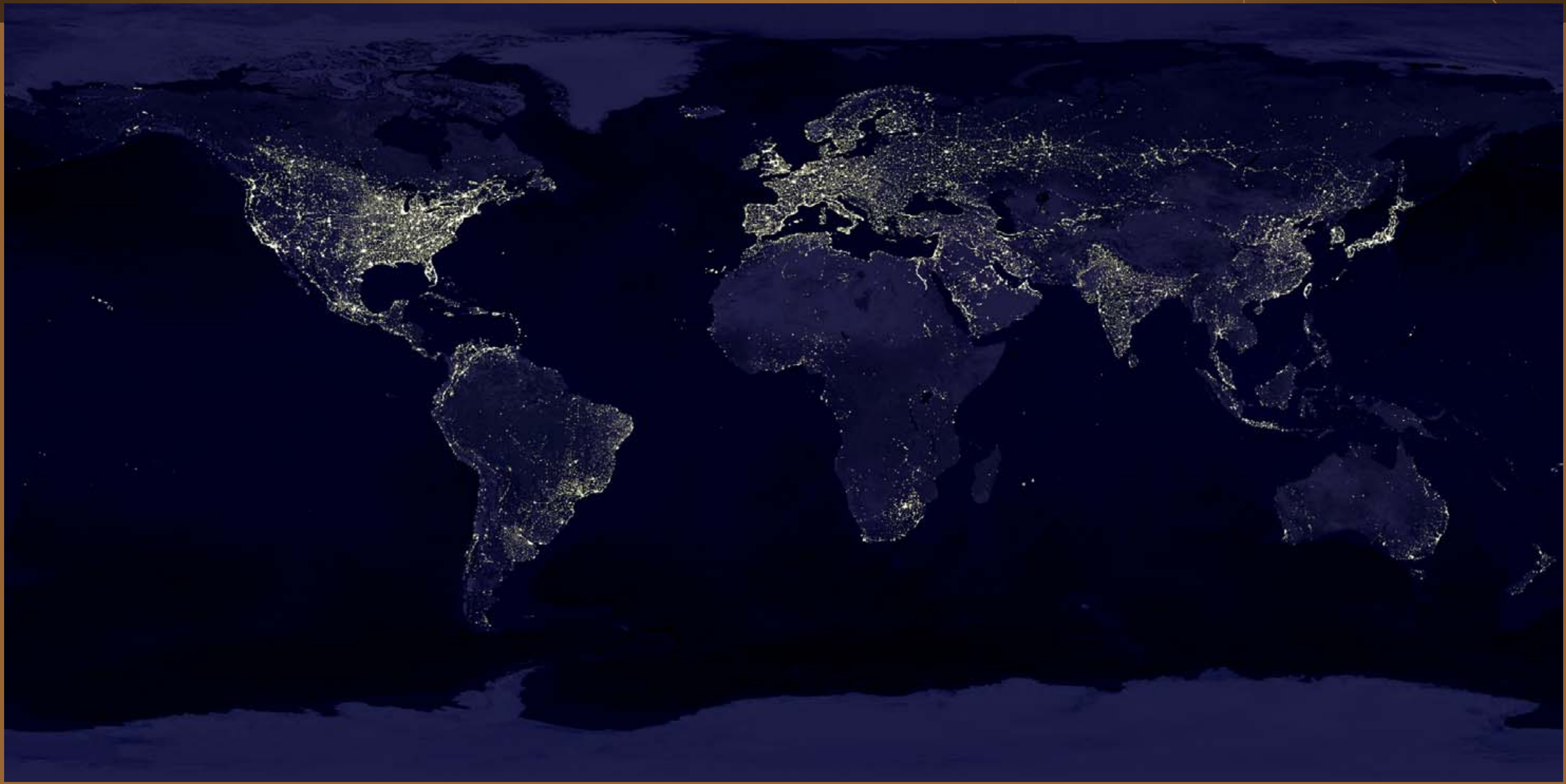
- The result:
  - excess energy use
  - lack of comfort
  - poor indoor air quality
  - high O&M expenses

Steps to Optimizing Energy Design

- Set Goals
- Understand the building
- Whole Think: Building as a SYSTEM
- Choose the tools: Simpler first -- more complex IF and when needed
- Evaluate the options – costs and benefits
- Optimization

Goals

– Hard to get there without a map
– Energy Goals



Energy Goals

- Goals
  - Metrics
    - Systems

Energy Goals

- Goal – Save energy
  - Metrics – How do you know if you got to your goal?
    - Systems

Energy Metrics

- % reduction compared to code – cost or energy
- Energy usage/demand limit
- Energy cost limit
- Carbon emissions limit
- Net zero/zero carbon

Energy Metrics

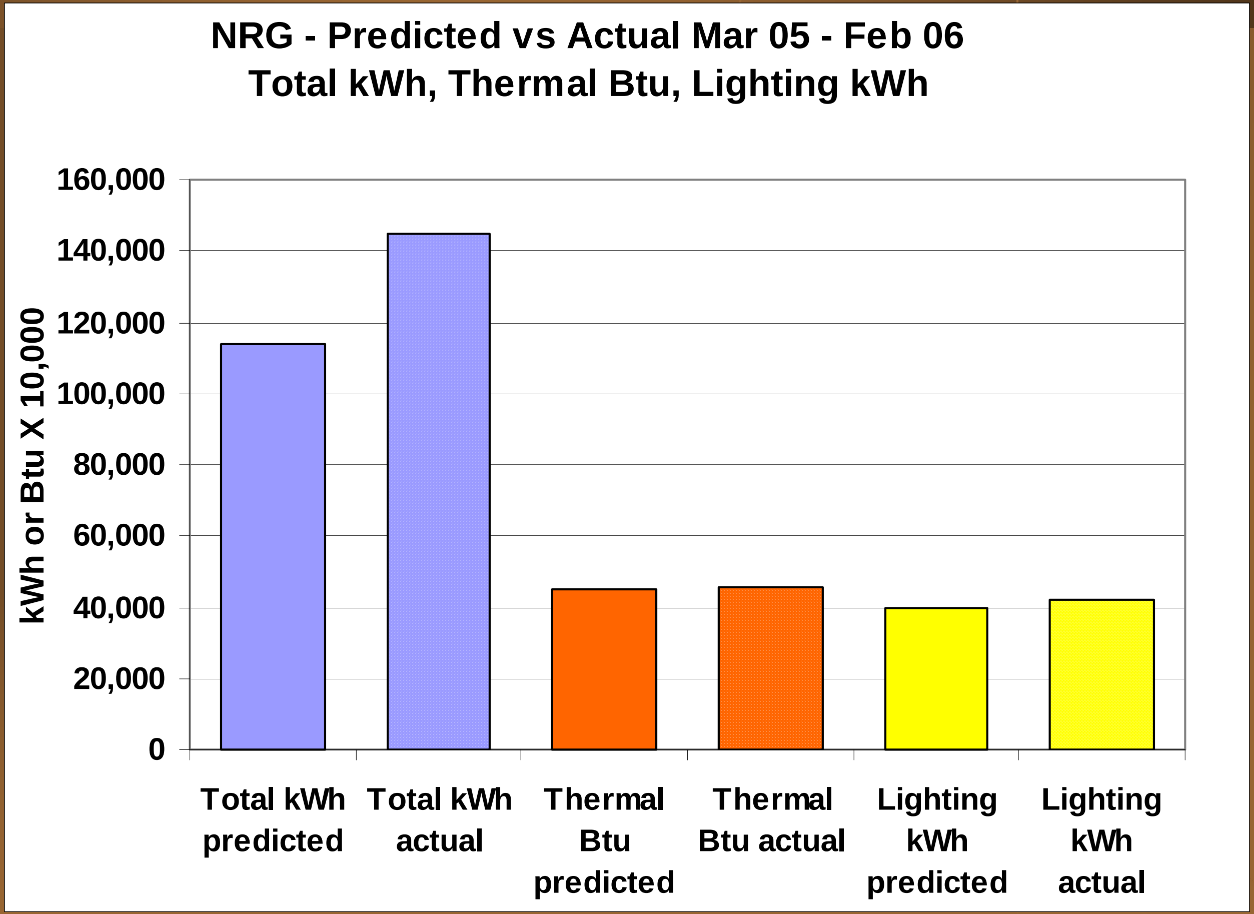
- Cost-effectiveness metrics
  - Fixed Budget
  - Cash flow
  - Present value
  - Payback or return on investment
  - EVT screening tool

Energy Metrics

- LEED metrics for energy
- Vermont Builds Greener metrics
- Vermont Energy Star Homes metrics
- Federal tax credit metric

Energy Metrics

- Benchmark for tracking actual building energy use



Understand the Building – Model Inputs

- Look carefully at the loads in the building
- Who is doing What Where When?

Understand the Building

- **Who**:
  - How many people in each area?

Understand the Building

- **What**:
  - What indoor climate conditions are required in each area?
  - What electrical loads are in each area – lights and other loads?

Understand the Building

- **Where**:
  - Tabulate this information, by room number or zone.

Understand the Building

- **When**:
  - When are how many people in what areas?
  - What loads are not coincident?
  - Tabulate a schedule.

Science Center Laboratory Occupancy
OCCUPANCY SCHEDULES
Total Building, with Diversity

Hour	5	6	7	8	9	10	11
Weekday Avg Occ.	1	1	5	32	32	41	42
Weekend Avg Occ.	1	1	6	6	6	7	7
Weekday Peak Occ.	1	1	8	52	52	54	55
Weekend Peak Occ.	0	0	11	11	11	11	11

Understand the Building

- **Evaluate the base-line building -- *if using comparison to baseline in metrics***
- Define a base-line building
  - lowest cost building that meets Vermont Energy code
  - ASHRAE 90.1 baseling
  - Efficiency VT baseline
  - LEED baseline
  - What the owner or architect brings to the table initially.

Understand the Building

- Look carefully at outdoor design conditions
- Look carefully at indoor requirements

Tons of Cooling Required for 1000 cfm			
Indoor Condition	Temp.	75 F	78F
	RH	50%	50%
Design condition	DB/WB		
Burlington Energy Code	84/69	1.9	1.6
Typical	90/73	3.2	2.9

Choosing the Tool(s)

- **Match the tool to the need**
  - **Component analysis or whole building?**
- **How accurate do you need to be?**
- **How accurate can you AFFORD to be?**

Choosing the Tool(s)

- **Load models versus energy models**
- **For schematic design**
  - **Simple enough that you can afford to 'get it up' easily and do multiple runs to answer questions**
- **For design development**
  - **More detail may be required**
- **For verification, detailed enough to have a decent chance at accuracy**

Choosing the Tool(s)

- **The simplest tool that meets the need**
  - Example: Hand calculation of peak and annual ventilation loads , with and without energy recovery – create a simple spreadsheet

Tons of Cooling Required for 1000 cfm			
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	RH	50%	50%
Design condition	DB/WB		
Burlington Energy Code	84/69	1.9	1.6
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Residential Tools

- **Spreadsheet – UA analysis**
- **REM-Rate**
- **Energy-10**
- **Renewables –**
  - **PV-Watts**
  - **RET-Screen**

Residential Tools

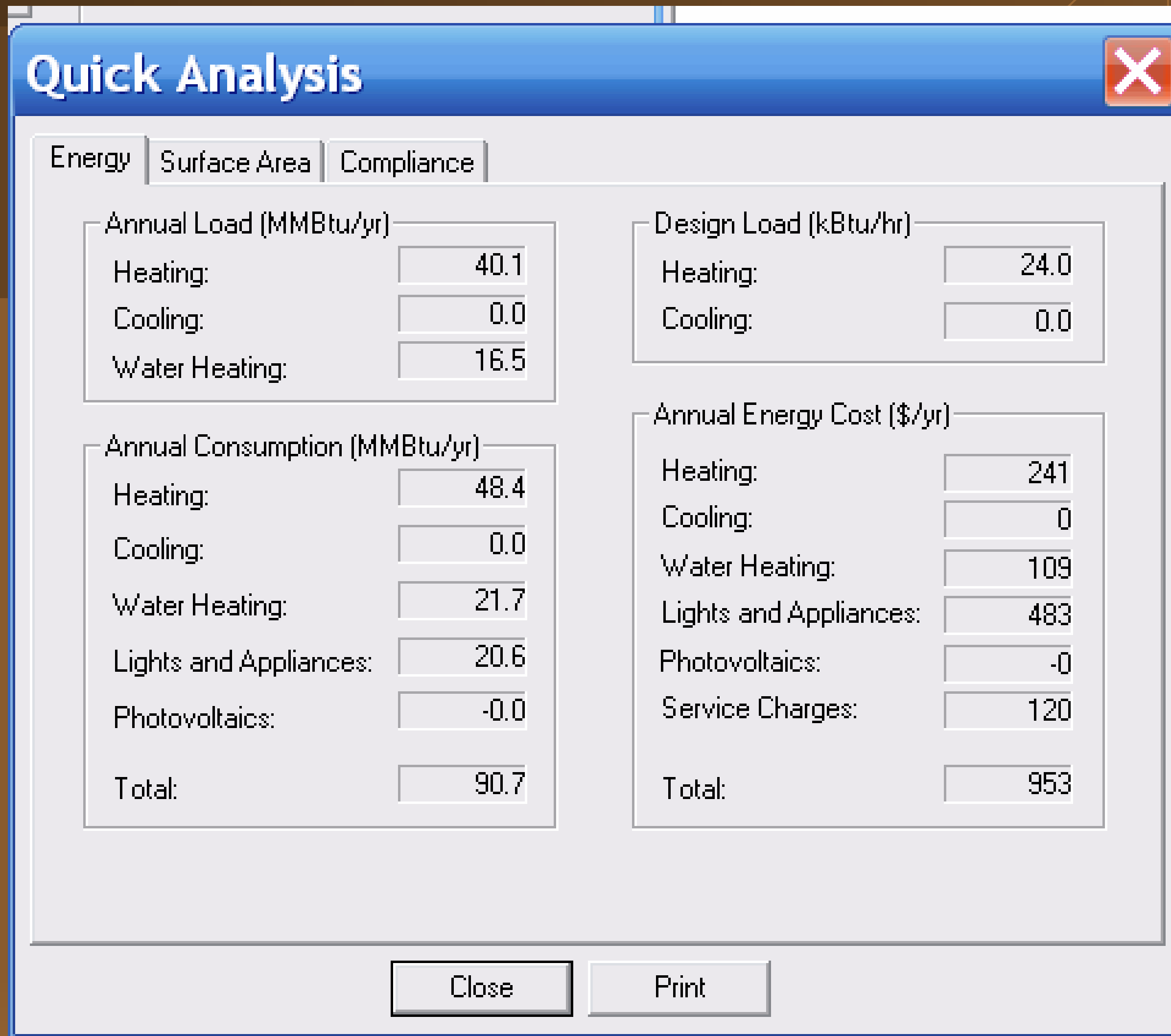
- Spreadsheet – UA analysis
  - Totally transparent
  - Good for the laugh and smell tests
  - Good for peak loads
  - Decent for annual loads
    - Demo?

Residential Tools

- **REM-Rate – modified UA analysis**
  - **Does a good job with solar and internal gains**
  - **Good for peak loads and annual loads**
  - **Vermont ENERGY STAR Homes compliance tool**
  - **Tax credit compliance**

Residential Tools

- REM-Rate – modified UA analysis
  - Very easy to use
  - Not totally transparent – (but you can find background)
  - Licensed to accredited HERS providers, or provided as REM/Design for $277


Quick Analysis
Energy
Surface Area
Compliance
Annual Load (MMBtu/yr)
Heating: 40.1
Cooling: 0.0
Water Heating: 16.5
Annual Consumption (MMBtu/yr)
Heating: 48.4
Cooling: 0.0
Water Heating: 21.7
Lights and Appliances: 20.6
Photovoltaics: -0.0
Total: 90.7
Design Load (kBtu/hr)
Heating: 24.0
Cooling: 0.0
Annual Energy Cost ($/yr)
Heating: 241
Cooling: 0
Water Heating: 109
Lights and Appliances: 483
Photovoltaics: -0
Service Charges: 120
Total: 953
Close
Print

Residential Tools

- **Energy-10 – 8,760 hour simulation**
  - **As detailed as you want to get – need to explore**
  - **Has a nice quick entry**
  - **Not transparent**
  - **Does a good job with solar and internal gains**
  - **Good for peak loads and annual loads**

Residential Tools

- Energy-10 – 8,760 hour simulation
  - Can get detailed output, including monthly
  - Has a learning curve, but not steep or long
  - A bit buggy
  - Good for residential and commercial
  - Cost $375
    - Demo?

Renewable Tools

- PV-Watts
  - On-line and easy to use
  - Monthly output

S: Vermont - Burlington - Mozilla Firefox

History Bookmarks Tools Help

http://rredc.nrel.gov/solar/codes_algs/PVWATTS/version1/US/Vermont/Burlington.html

weather.com - Local W... Google

PV Watts

Click on **Calculate** if default values are acceptable, or after selecting your system specifications. Click on **Help** for information about system specifications. To use a DC to AC derate factor other than the default, click on **Derate Factor Help** for information.

Station Identification:

WBAN Number:	14742
City:	Burlington
State:	Vermont

PV System Specifications:

DC Rating (kW):	1	
DC to AC Derate Factor:	0.77	DERATE FACTOR HELP
Array Type:	Fixed Tilt	
Fixed Tilt or 1-Axis Tracking System:		
Array Tilt (degrees):	44.5	(Default = Latitude)
Array Azimuth (degrees):	180.0	(Default = South)

Energy Data:

Cost of Electricity (cents/kWh):	Default = State Average

Calculate HELP Reset Form

ET 4 Microsof... 3 Adobe R... 9 Microsoft... Inbox for an... Microsoft Po... PVWATTS: V...

S: AC Energy and Cost Savings - Mozilla Firefox

History Bookmarks Tools Help

http://rredc.nrel.gov/solar/codes_algs/PVWATTS/version1/US/code/pvwattsv1.cgi

weather.com - Local W... Google

PV Watts

AC Energy & Cost Savings

Cautions for Interpreting the Results

Station Identification	
City:	Burlington
State:	Vermont
Latitude:	44.47° N
Longitude:	73.15° W
Elevation:	104 m
PV System Specifications	
DC Rating:	1.0 kW
DC to AC Derate Factor:	0.770
AC Rating:	0.8 kW
Array Type:	Fixed Tilt
Array Tilt:	44.5°
Array Azimuth:	180.0°
Energy Specifications	
Cost of Electricity:	12.9 ¢/kWh

Results

Month	Solar Radiation ($kWh/m^2/day$)	AC Energy (kWh)	Energy Value ($)
1	3.12	79	10.19
2	4.01	92	11.87
3	4.91	120	15.48
4	5.05	113	14.58
5	5.51	121	15.61
6	5.42	114	14.71
7	5.47	117	15.09
8	5.46	118	15.22
9	4.70	101	13.03
10	3.79	87	11.22
11	2.37	54	6.97
12	2.15	52	6.71
Year	4.33	1167	150.54

ET | 4 Microsof... | 3 Adobe R... | 9 Microsoft... | Inbox for an... | Microsoft Po... | PVWATTS: A...

Renewable Tools

- **RET Screen**
  - **Free download**
  - **Very easy to use (*mondo* Excel spreadsheet)**
  - **Annual output**
  - **Has economics module**
    - **Demo?**

Daylighting Tools

- Energy-10
- Skycalc (for skylights) -- free
- Physical model
- Radiance

SkyCalc: Skylight Design Assistant - Graphic Results

Company Name: Company ABC, Inc.

Project Description: Skylighting Project

Effective Aperture = 1.11%, Skylight to Floor Ratio (SFR) = 4.61%

Average daylight footcandles (fc)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Jan	0	0	0	0	0	0	0	2	8	18	27	34	34	31	23	13	4	1	0	0	0	0	0	0
Feb	0	0	0	0	0	0	0	3	12	25	34	38	44	41	34	22	10	2	0	0	0	0	0	0
Mar	0	0	0	0	0	0	2	8	21	35	46	53	55	52	45	31	16	4	0	0	0	0	0	0
Apr	0	0	0	0	0	0	5	17	33	47	58	64	66	59	50	39	23	8	2	0	0	0	0	0
May	0	0	0	0	0	2	9	23	40	54	63	68	69	67	59	46	29	12	3	0	0	0	0	0
Jun	0	0	0	0	0	3	11	25	43	55	66	68	72	67	58	47	32	14	5	1	0	0	0	0
Jul	0	0	0	0	0	2	9	24	42	56	68	70	74	68	61	49	32	15	5	1	0	0	0	0
Aug	0	0	0	0	0	1	6	19	37	53	67	71	72	68	57	44	26	11	3	0	0	0	0	0
Sep	0	0	0	0	0	0	4	13	30	44	54	62	60	54	46	33	16	5	1	0	0	0	0	0
Oct	0	0	0	0	0	0	2	9	23	37	47	51	53	46	35	20	7	2	0	0	0	0	0	0
Nov	0	0	0	0	0	0	0	4	12	22	31	35	36	32	22	11	3	0	0	0	0	0	0	0
Dec	0	0	0	0	0	0	0	2	8	17	25	30	32	27	19	9	3	0	0	0	0	0	0	0

Design Illuminance = 50 fc

< 1 fc; < 25 fc; < 50 fc; > 50 fc;

SkyCalc: Skylight Design Assistant - Tabular Results

Company Name: Company ABC, Inc.
Project Description: Skylighting Project

Electric Lighting Usage	kWh/yr		
Ltg. Energy without Skylights	616,781	Lighting Fraction Saved	19%
Lighting Energy w/ Skylights	502,202	Full daylighting (h/yr)	1,135

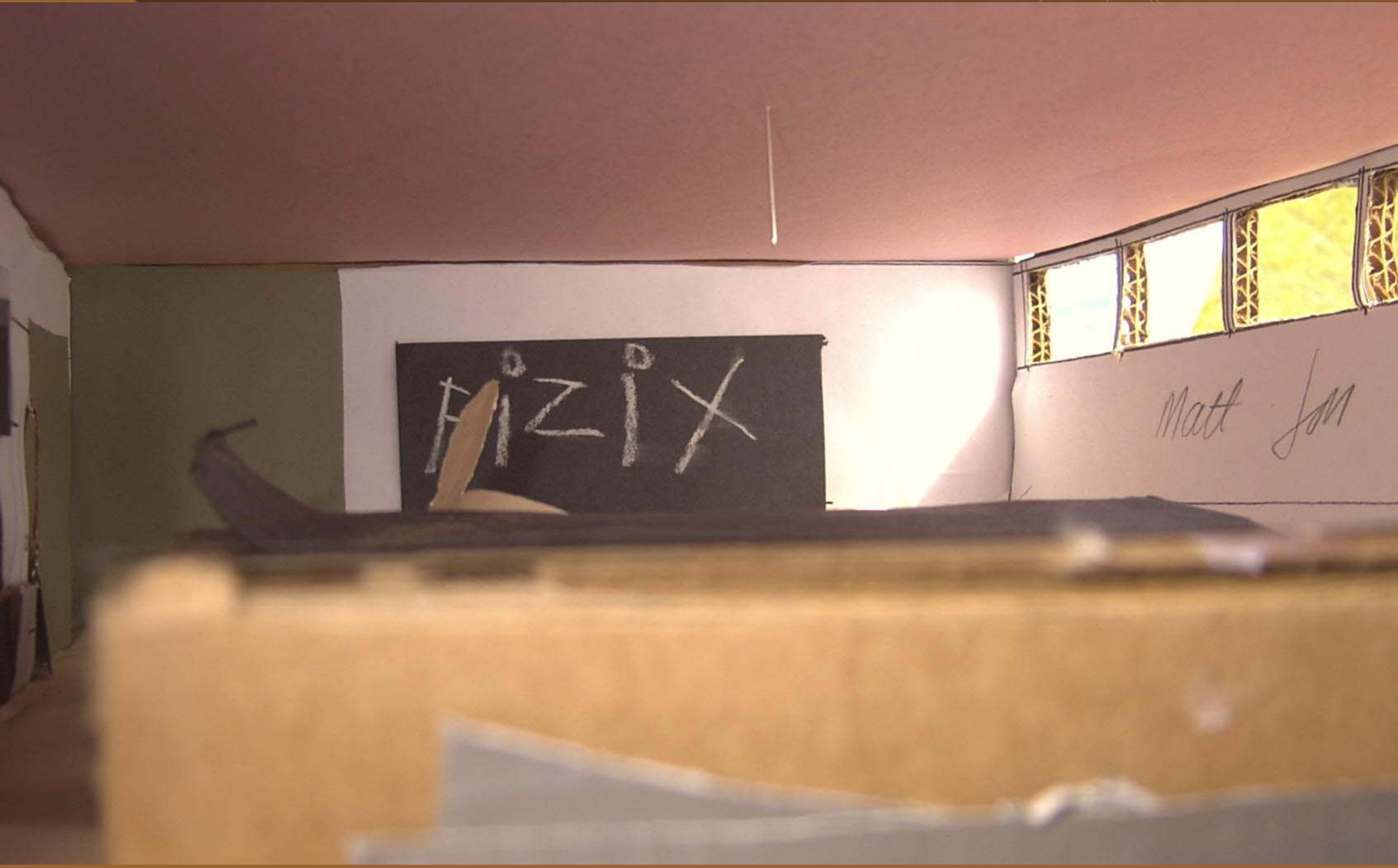
Savings from Design Skylighting System

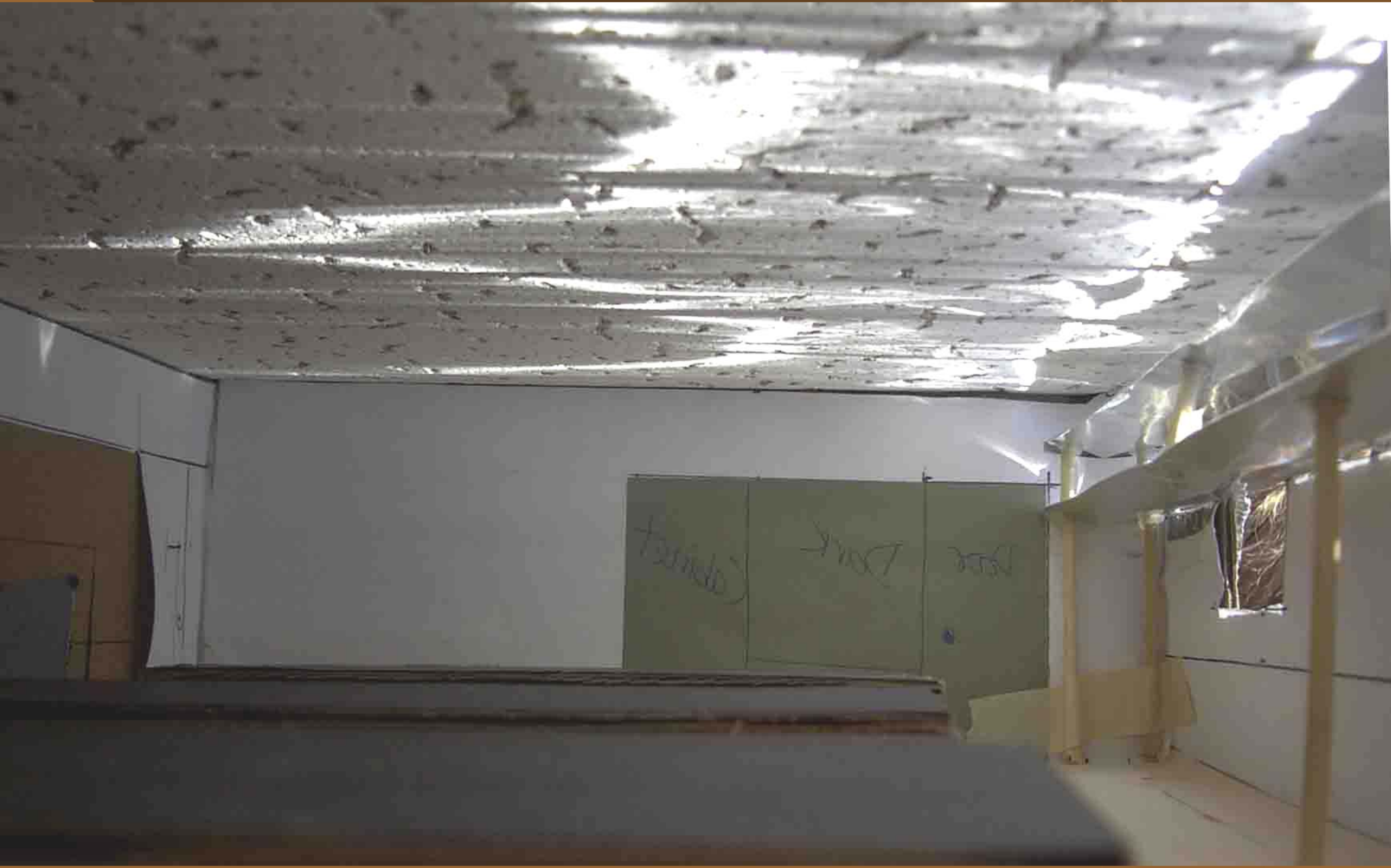
Savings		Annual Energy Savings (kWh/yr)	Annual Cost Savings ($/yr)
Lighting		114,579	$13,406
Cooling		2,384	$279
Heating		-56,857	-$1,180
Total		**60,106**	**$12,505**


Glue Stic
18
STICKS
South
East


INPUT


CPIU 009389 7


FIZIX
Matt



Commercial Building Tools

- **Spreadsheet -- souped up UA**
- **Bin analysis**
- **Energy-10**
- **TRACE**
- **HAP**
- **EQuest**

Commercial Tools

- **Spreadsheet -- souped up UA**
  - **Fast**
  - **Transparent**
  - **Flexible**
  - **Get to make your own mistakes!**
  - **You can sniff everything!**
    - **demo**

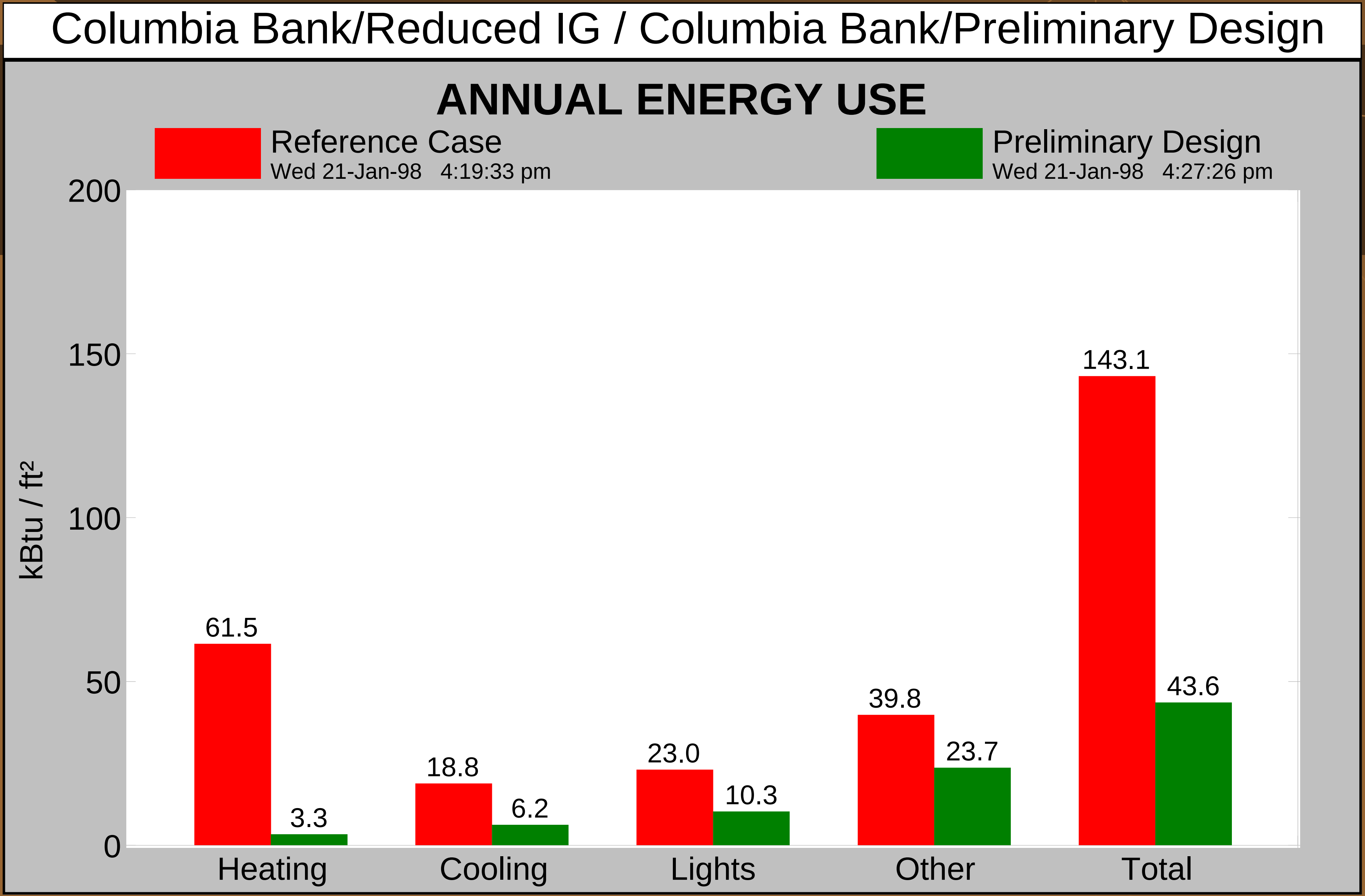
Commercial Tools

- **Bin analysis**
  - **Good for discrete loads where efficiency/load varies with outside temperature**
  - **Example – average monthly efficiency of ASHP**
    - **Demo?**

Commercial Tools

- **Energy-10**
  - **Very powerful**
  - **Very easy to use**
  - **Has some daylighting capability**
  - **Great graphic output**
  - **EXCELLENT SCHEMATIC TOOL**

Energy-10



Columbia Bank/Reduced IG / Columbia Bank/Preliminary Design
ANNUAL ENERGY USE
Reference Case
Wed 21-Jan-98 4:19:33 pm
Preliminary Design
Wed 21-Jan-98 4:27:26 pm
kBtu / ft²
200
150
100
50
0
61.5
3.3
18.8
6.2
23.0
10.3
39.8
23.7
143.1
43.6
Heating
Cooling
Lights
Other
Total

Commercial Tools

- **Energy-10**
  - **Two zones max**
  - **Not a mechanical system design tool**
  - **Not a compliance tool**

Commercial Tools

- Energy-10
  - Glazing %'s
  - Daylighting, first cut
  - Insulation levels
  - Air leakage
  - Fuel choices
  - Interactions of choices
    - Demo?

Commercial Tools

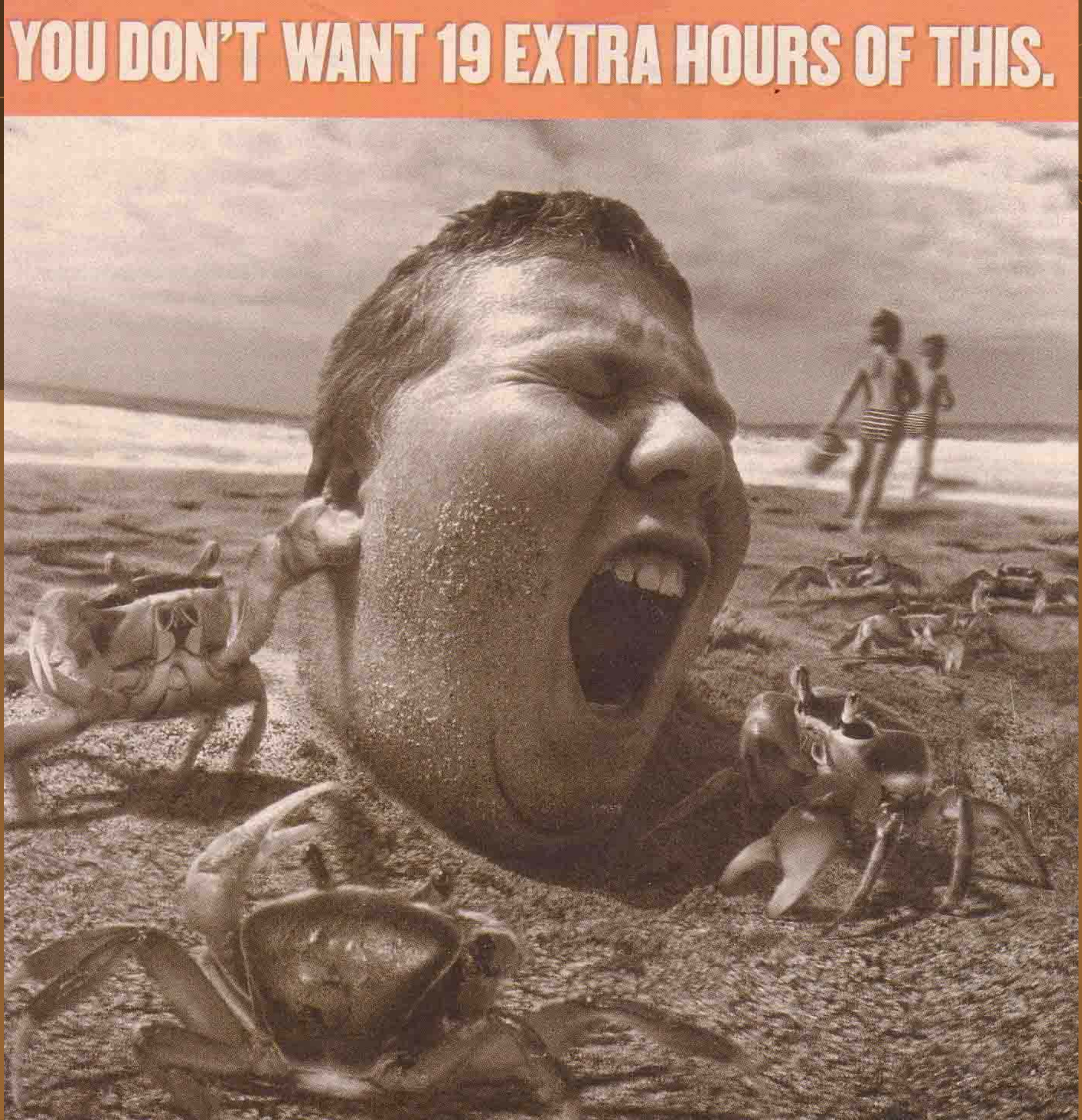
- **TRACE and HAP**
  - **Equipment manufacturer's software**
  - **Originally loads only, now energy also**
  - **System design software**
  - **Many zones possible**
  - **Very detailed**
  - **LEED compliance**
  - **EVT savings calculations**

Commercial Tools

- **TRACE and HAP**
  - **8,760 hours or quasi-hourly**
  - **Tricky to find all the details**
  - **Steep, long learning curve**
  - **Tends to include that manufacturer’s equipment data**
  - **Long run time for complex or many-zone buildings**
  - **Expensive**

Commercial Tools

- **TRACE and HAP**
  - **Tempting to use same tool for loads, energy design and compliance**


YOU DON'T WANT 19 EXTRA HOURS OF THIS.

Commercial Tools

- EQuest
  - User-friendly interface for DOE-2
  - Graphical input front end
  - Two levels of wizards – schematic and design development
  - Free download

Commercial Tools

- EQuest
  - Very detailed -- a lot of flexibility
  - Many zones possible
  - Generic equipment data
  - LEED and EVT compliance

  - Tricky to find all the details
  - Long, steep learning curve
  - User list serve

Making Sense Out of the Results

- **SNIFF THE INPUTS !!**
  - **Outside and inside design conditions**
  - **W/sq.ft. lighting**
  - **Plug loads**
  - **Ventilation assumptions**
  - **Numbers of people**
  - **Controls selected**

Making Sense Out of the Results

- **Pose questions to be answered before choosing or running tool**
- **Do a rough approximation of savings prior to running an EEM**
- **Do measures individually first, SMELL, then run package**
- **interactive measures can be overstated 10-30% if not run interactively**
  - ***Thanks to Marlin Addison***

Making Sense Out of the Results

- **Order in which interactive measures are run effects individual savings**
- **Present packages to the owners/design team**

Use Parameters to Smell the Results

- **Design load or peak parameters**
  - Peak heating load: Btu/sq.ft-hr or kW/sq.m
  - Peak cooling load: Sq.ft/ton of cooling
  - W/sq.ft. installed lighting

Use Parameters to Smell the Results

- Energy usage parameters
- Total energy use:
  - Kwh/sq.m-year or Btu/sq.ft-yr
    - Varies with building type….
    - CBECS numbers
    - Site versus source energy

Benchmark - 2003 CBECS1 National Average Source Energy Use			
	kBtu/sq.ft source	% electric	kBtu/sq.ft site
Campus Level University	280	63%	120
Restaurant/cafeteria	612	53%	302

http://www.eia.doe.gov/emeu/cbecs/

National Average Source and Site Energy Use and Performance Comparisons by Building Type

Magnitude of Errors in Modeling

- **+/- 7% best case with best input, best operator, checked against real building data**
- **~+/-20% is more typical and can be much worse**

- **SNIFF THE INPUTS!**
- **SNIFF THE RESULTS!**

- **SNIFF AGAIN!!!**


Golden
Harvest

Use Parameters to Smell the Results

- Energy usage parameters
  - Heating Btu/sq.ft.-dday (kWh/sq.m-yr)
  - kWh/month electricity
  - Peak electric demand
  - Lighting kWh/sq.ft.-yr
  - % renewable (thermal and electric)

Look at End Use Loads to Smell the Results

- **Look for the Big Numbers**
- What are the big energy users?
  - Ventilation?
  - Windows?
  - Envelope?
  - Internal gains -- equipment or people?
  - Equipment efficiencies?

Sources of Errors in Modeling

- **unfamiliar equipment**
- **controls not actually operating as modeled**
- **operations schedules**
- **equipment sizing issues**
- **Interactions**
  - ***Thanks again, Marlin!***

Sources of Errors in Modeling

- **air leakage rates**
- **actual equipment efficiencies vs. expected**
- **Unfamiliar variables (don’t what they are talking about)**
- **Variables with unknown values (dirt factor on PV’s, part load efficiencies)**
  - ***Play with variable inputs to see what’s important***

Go Back and Look !!!

- **Gather energy bill data and compare to model**
  - **weather, schedules, setpoints, occupancy levels, energy intensity of equipment, etc., etc., effect results**
  - ***but at least LOOK***
  - **Fuel usage release form**
  - **The WMAP/Energy Balance Challenge!!**

The WMAP/Energy Balance Challenge!!

- Basic building data
- Total energy use

Optimizing Energy Design: Follow-up is Critical!

- Track carefully through design process
- Track carefully during construction!

Optimizing Energy Design with Modeling: Summary

- Set goals AND metrics
- Understand the Building:
  - Who is doing What When Where
  - Think whole-building/whole-system
- Choose tool to match the need –
  - less = more
- Double check inputs – *LAUGH/SNIFF!*
- ***Laugh/sniff the results !!***
- Find critical loads
- Track through design and construction
- Go back and get energy bills

Thank you