# WHOLE HOUSE ENERGY DESIGN

# AND

# SOLAR HOT WATER OPTIONS

*Better Buildings By Design Conference – February 13, 2008*

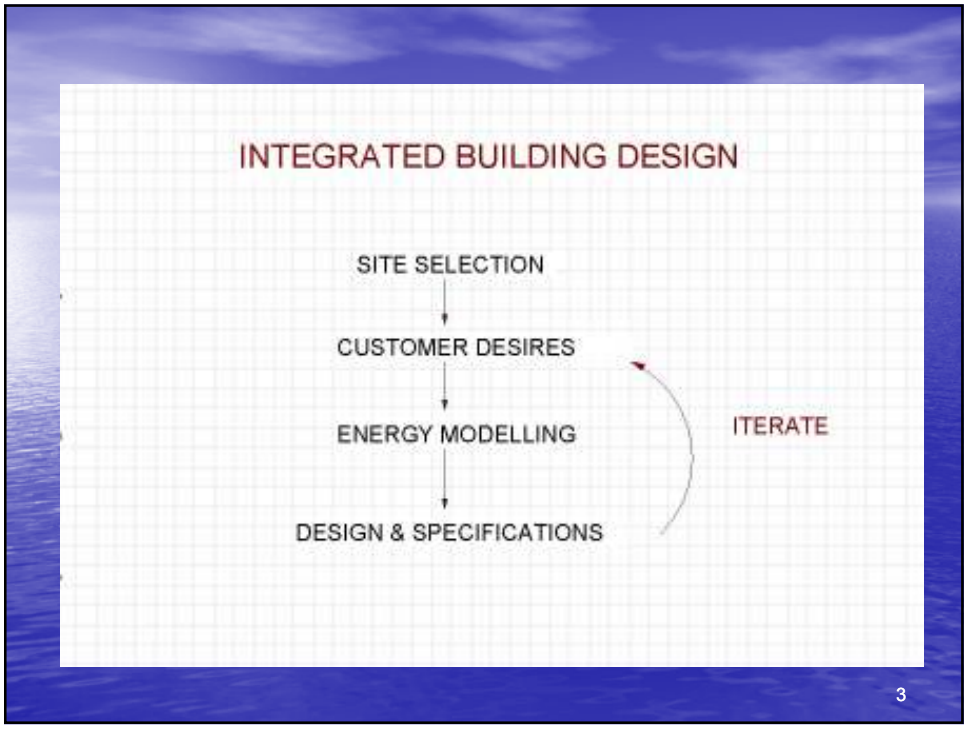
*Andrew R. Cay, A. R. Cay Company, Inc. (603) 363-4888/101 cayco@verizon.net*

1

## WHOLE HOUSE ENERGY DESIGN

- FULLY INTEGRATED DESIGN PROCESS
  - Architectural, engineering, energy and building sciences
  - Renewable designer, suppliers & installers
- APPLIES TO EXISTING AND NEW BUILDINGS
  - Same Process, More about best fit with existing bldgs
- FOCUSES ON CONSERVATION
  - Reduce loads (Btu & kwh), reduce costs of construction, energy and maintenance

2




# OBJECTIVE

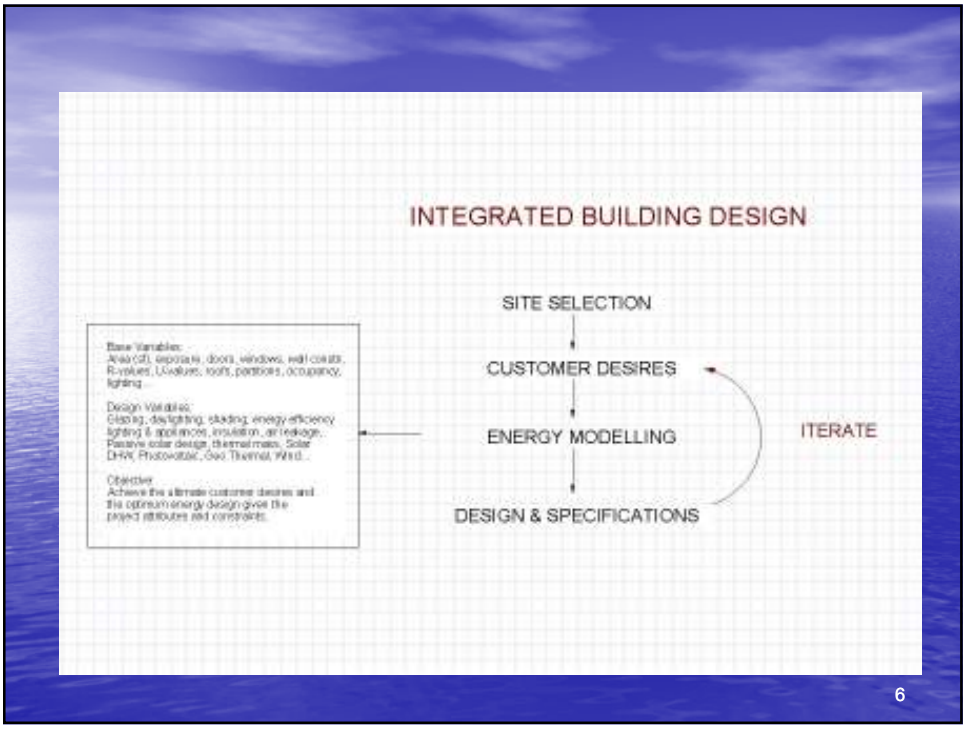
- GIVE THE CUSTOMER WHAT THEY WANT
  - Make them feel good about their new carbon footprint and their exposure to increasing fuel prices
- GET THE BEST ENERGY DESIGN POSSIBLE
- RESULT, GOOD FOR:
  - Your customer
  - The environment
  - Our country's energy independence and competitiveness in global markets
  - You and your business; this is our future!

4

# CHALLENGES

- ALL THE USUAL
  - The site constraints, customer desires versus budget, coordination of professionals, schedule, change orders
- NEW CUSTOMER CONSCIOUSNESS AND COMMITMENT
  - Sustainable building practices and energy efficiency (real or superficial commitment)
- FOCUS ON CONSERVATION
  - Lower the load
  - Use what's free and low cost first
- INTEGRATED DESIGN
  - Getting the professionals on board
  - Figuring out a process (design, schedule, competing interests)
  - Who's in charge???
- CERTIFICATION, QUALITY CONTROL, REGULATION

5




6

# ENERGY MODELING

- INHERENTLY COMPLEX
  - Requires intimate knowledge of the climate and site characteristics
  - Involves many interrelated variables
  - Decisions are driven by costs and achievement of energy objectives
  - Many iterative calculations are required
  - Don't attempt it on an excel spreadsheet

7

# ENERGY MODELING – CONT'D

- GOOD NEWS – SOFTWARE IS AVAILABLE
  - One comprehensive program – Energy-10, DOE, SBIC
  - Resfen – Window Energy Loads/Daylighting (Free download)
  - F Chart – Specific to solar thermal and Photvoltaic modeling

8

## EXAMPLE – USING ENERGY-10

- 2,100 SF SF HOME, 1 STORY
- STANDARD CONSTRUCTION
  - 2 X 6 stick frame, R-19/38, default values windows, HVAC efficiency, air infiltration, etc
- HEATING, NO A/C
- SOUTHERN VERMONT LOCATION

9

## EXAMPLE – REFERENCE CASE RESULTS

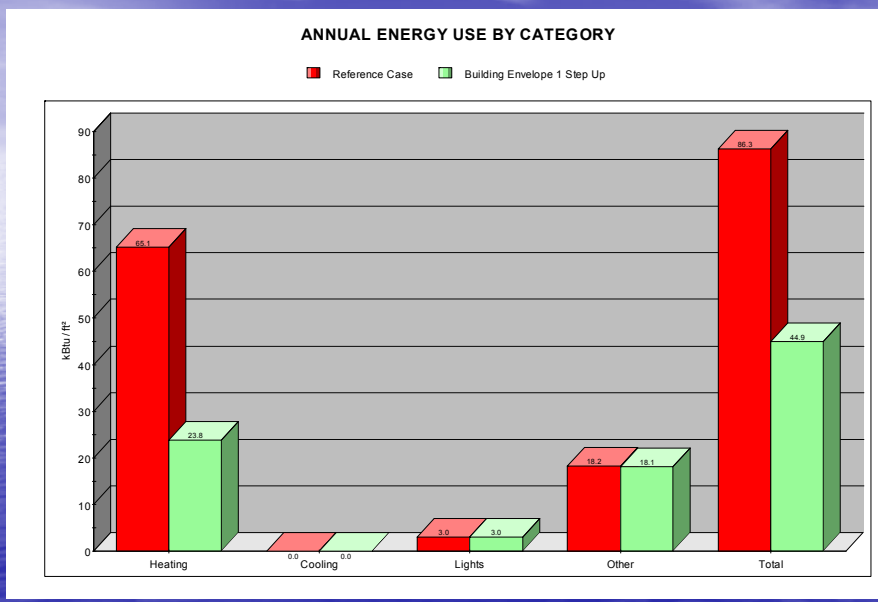
| | | |
|---|---|---|
| • ELECTRICAL USE, kWh | | 7,014 |
| – Equals kBtu | | 23,933 |
| • FUEL USE (GAS), kBtu | | 157,293 |
| – HW | 20,542 | |
| – Heating | 136,751 | |
| • TOTAL ENERGY, kBtu | | 181,226 |

10

# BUILDING ENVELOPE IMPROVEMENTS, 1 STEP UP

- 6 INCH SIPs, R-22.4 (From R-17.7)
- Ceiling Cellulose – R-45 (From R-38)
- Air Infiltration - 0.2 NAC/hr (From 0.6)

11

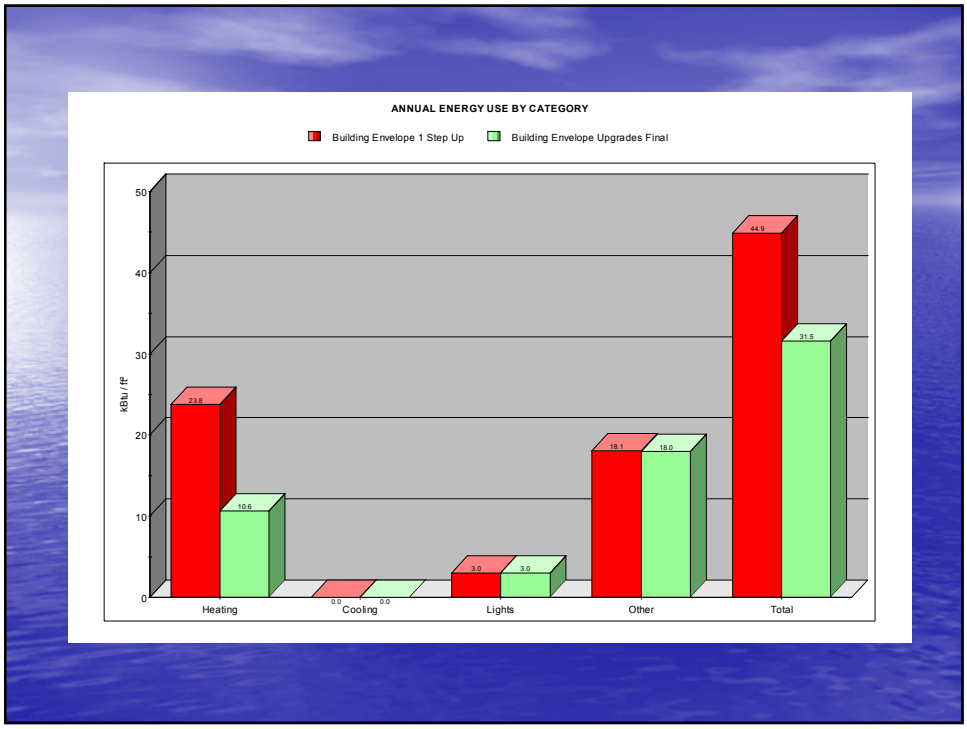


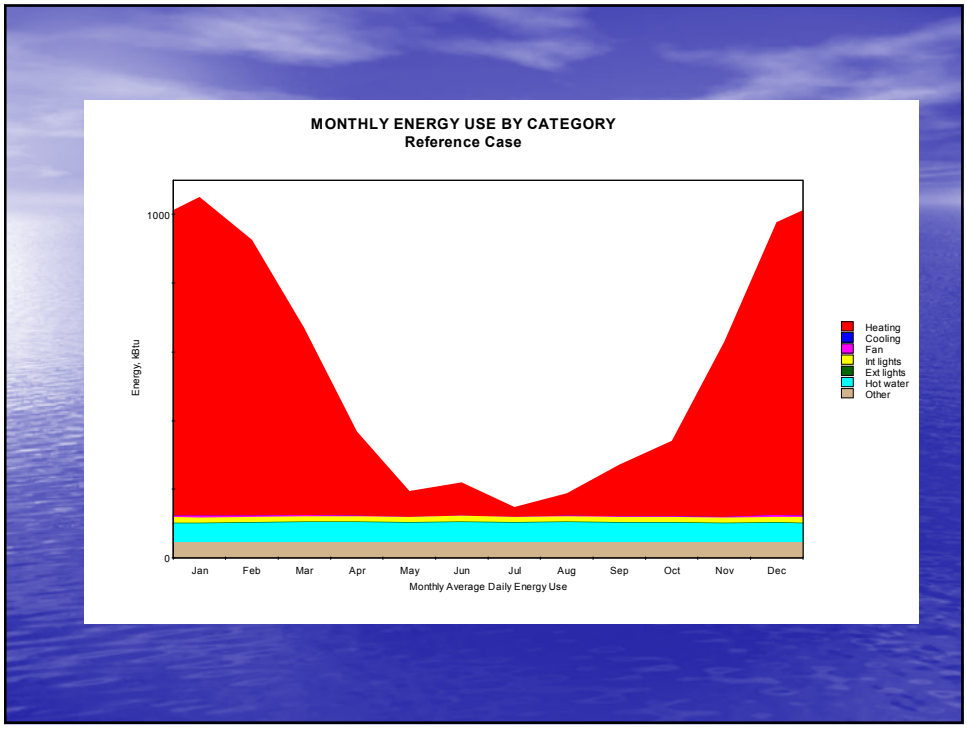

12

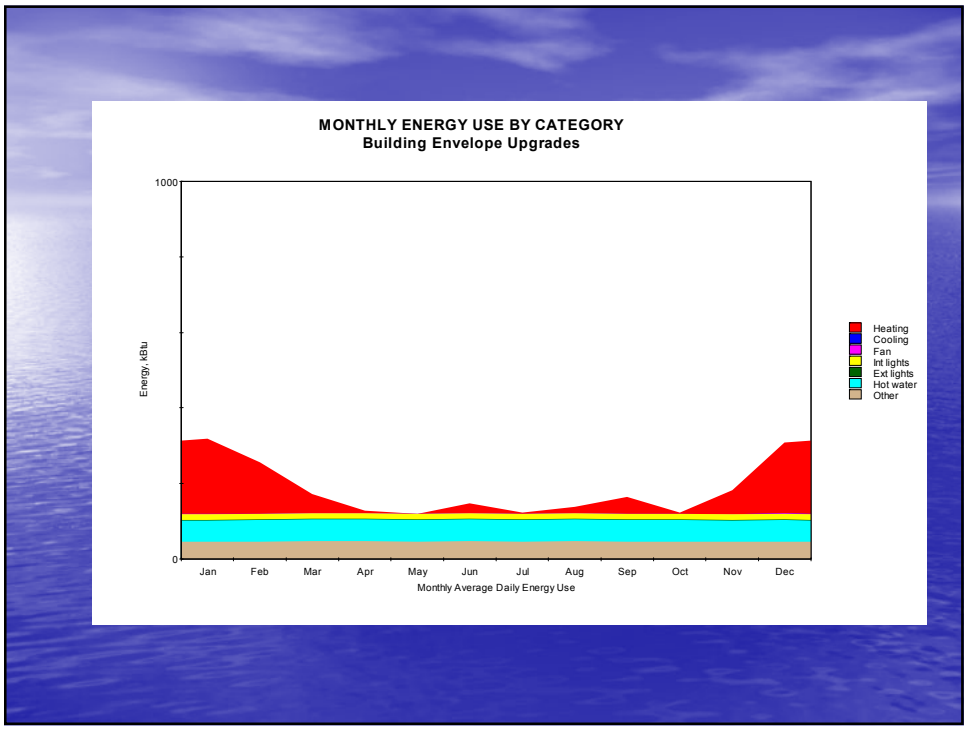
# BUILDING ENVELOPE FINAL IMPROVEMENTS

- ICF's, R-32
- Ceiling Cellulose – R-70 (Yes, 20 Inches)
- Air Infiltration - 0.07 NAC/hr

13

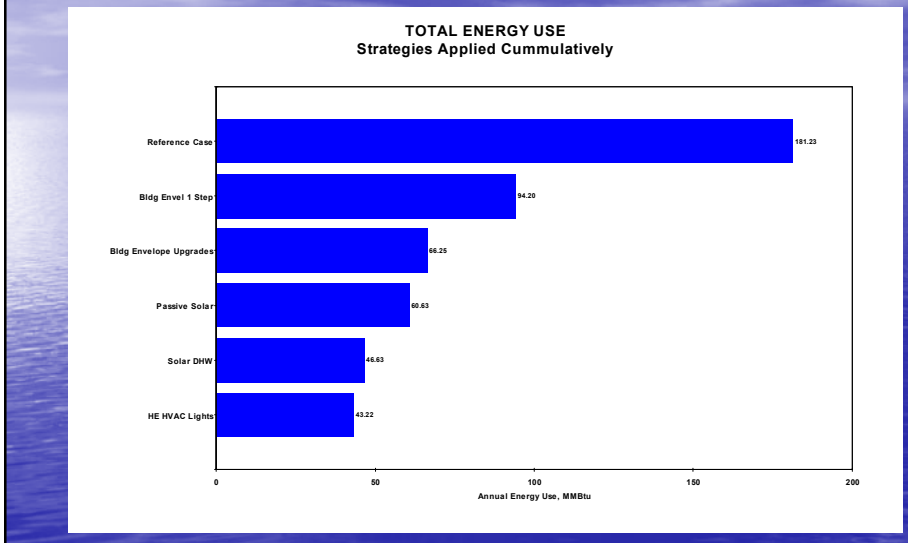



MONTHLY ENERGY USE BY CATEGORY
Reference Case
1000
0
Energy, kBtu
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Monthly Average Daily Energy Use
Heating
Cooling
Fan
Int lights
Ext lights
Hot water
Other


MONTHLY ENERGY USE BY CATEGORY
Building Envelope Upgrades
1000
0
Energy, kBtu
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Monthly Average Daily Energy Use
Heating
Cooling
Fan
Int lights
Ext lights
Hot water
Other

## SUMMARY OF ENERGY SCENARIOS
## (Units in kBtu)

| USE CATEGORY | Reference Case | 1 Step Up | Final Bldg Envelope |
|---|---|---|---|
| ELECTRIC | 23,932 | 23,659 | 23,461 |
| HEAT | | | |
| DHW | 20,542 | 20,542 | 20,542 |
| SPACE | 136,751 | 50,002 | 22,242 |
| S/T HEAT | 157,293 | 70,544 | 42,784 |
| TOTAL | 181,225 | 94,203 | 66,245 |
| REDUCTION AMOUNT | | 87,022 | 27,958 |
| % REDUCTION | | 48% | 30% |
| TOTAL REDUCTION AMOUNT | | 87,022 | 114,980 |
| CUMM TOTAL % REDUCTION | | 48% | 63% |




18

**SUMMARY OF ENERGY SCENARIOS**
**(Units in kBtu)**

| USE CATEGORY | Reference Case | 1 Step Up | Final Bldg Envelope | Passive Solar | Solar DHW | HE HVAC & Lights |
|---|---|---|---|---|---|---|
| ELECTRIC | 23,932 | 23,659 | 23,461 | 23,522 | 23,563 | 21,970 |
| HEAT | | | | | | |
| DHW | 20,542 | 20,542 | 20,542 | 20,542 | 6,540 | 6,540 |
| SPACE | 136,751 | 50,002 | 22,242 | 16,561 | 16,594 | 14,707 |
| S/T HEAT | 157,293 | 70,544 | 42,784 | 37,103 | 23,134 | 21,247 |
| TOTAL | 181,225 | 94,203 | 66,245 | 60,625 | 46,697 | 43,217 |
| REDUCTION AMOUNT | | 87,022 | 27,958 | 5,620 | 13,928 | 3,480 |
| % REDUCTION | | 48% | 30% | 8% | 23% | 7% |
| TOTAL REDUCTION AMOUNT | | 87,022 | **114,980** | **120,599** | **134,527** | **138,008** |
| CUMM TOTAL % REDUCTION | | 48% | **63%** | **67%** | **74%** | **76%** |

**SUMMARY OF ENERGY SCENARIO ECONOMIC BENEFITS**

| USE CATEGORY | Reference Case | 1 Step Up | Final Bldg Envelope | Passive Solar | Solar DHW | HE HVAC & Lights |
|---|---|---|---|---|---|---|
| TOTAL BTU'S SAVED | | 87,021,960 | 114,979,856 | 120,599,440 | 134,527,496 | 138,007,900 |
| BTU/GALLON (PROPANE) | | 92,000 | 92,000 | 92,000 | 92,000 | 92,000 |
| BOILER EFFICIENCY, Assumed | | 85% | 85% | 85% | 85% | 85% |
| ACTUAL BTUs/GAL | | 78,200 | 78,200 | 78,200 | 78,200 | 78,200 |
| # GALLONS SAVED/YR | | 1,113 | 1,470 | 1,542 | 1,720 | 1,765 |
| SAVINGS AT $3/GAL | | **$ 3,338** | **$ 4,411** | **$ 4,627** | **$ 5,161** | **$ 5,294** |
| SAVINGS AT $5/Gal | | **$ 5,564** | **$ 7,352** | **$ 7,711** | **$ 8,602** | **$ 8,824** |

19

# NOW THE FUN BEGINS!

- ALL THINGS RENEWABLE
  - Solar DHW & Space Heating
  - Solar Photovoltaic
  - Wind
  - Geo-Thermal
  - Bio-Mass
- DESIGN REFINEMENTS & SELECTIONS
- MAKING IT HAPPEN

20

## REAL EXAMPLES/HOT WATER SPACE HEATING TOO!

21

## WEST BRATTLEBORO HOUSE EXAMPLE

- NEW CONSTRUCTION
- SITE
  - Flat, open, very good sun exposure
- CUSTOMER
  - Strong commitment to sustainability, wants no fossil fuels on site, wishes to add PV in future
  - Wants 3 bedrooms, 2 baths, 2 offices
- OBJECTIVE – GETTING TO NET ZERO ENERGY

22

# PROJECT SPECIFICATIONS

- THERMAL ENVELOPE
  - ICF R-32 Walls, No thermal bridging, Cellulose R-70 Ceiling, Slab @ R-10 (basement 600 sf)
  - South Windows, Cardinal Glass LoE-178, U-Value - .26, SHGC - .64, Other Marvin Integrity
  - Natural Air Change Rate Expected .10 or better

23

# PROJECT SPECS – CONT'D

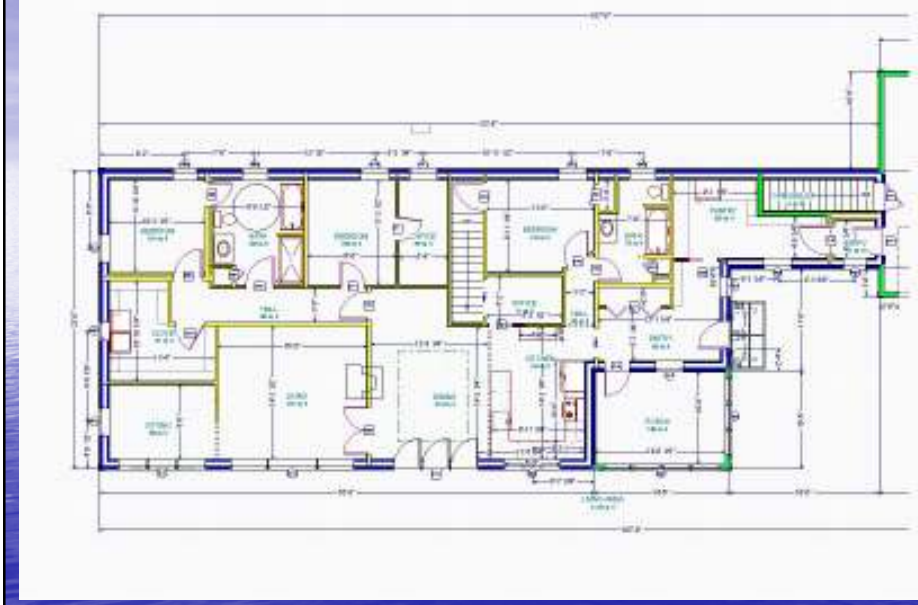
- AIR EXCHANGE
  - Renew EV200 Air to air HRV
- PASSIVE SOLAR DESIGN
  - True south house positioning
  - 12% Due south glazing
  - Overhangs 2 feet
  - Daytime thermal slab for glazing above 7%, 6 ½ inch thickness

24

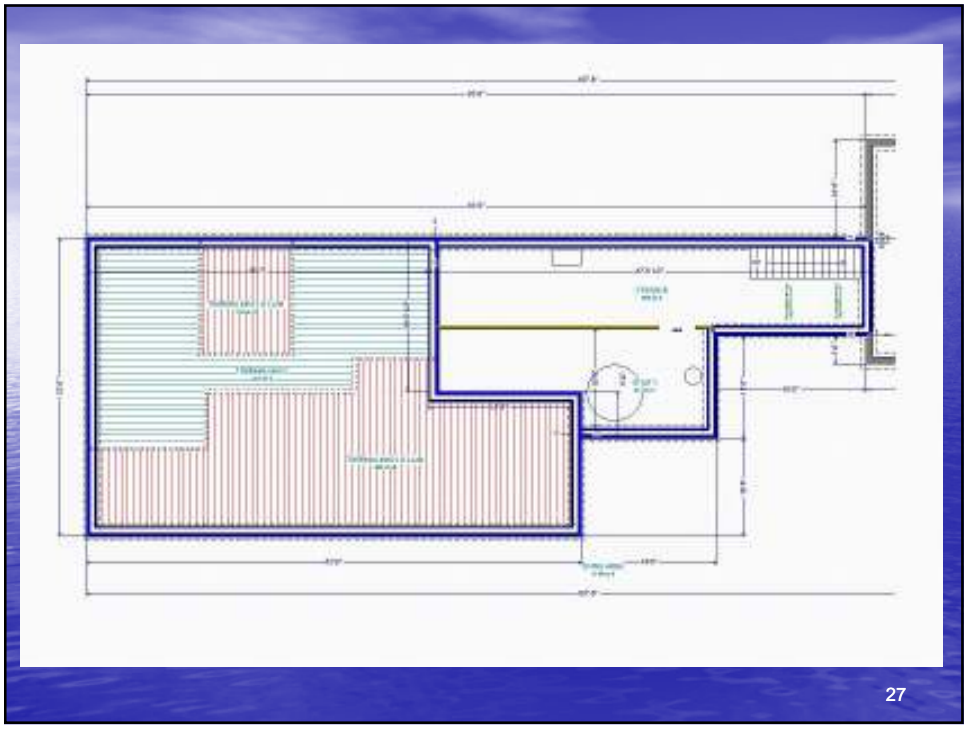
# PROJECT SPEC'S – CONT'D

- 8 – 32 SF GOBI HOT WATER COLLECTORS
- 6,205 CU FT SAND MASS IN INSULATED VAULT
- 2,400 LF PEX RUNNING THROUGH SAND MASS
- > 12 MBTU HEAT HOLDING CAPACITY
  - Above 90 degrees F usable
- 1,000 GALLON STORAGE TANK
- BACK-UP ELECTRIC HOT WATER TANK
- 4.5 KwH BACK-UP ELECTRIC WATER HEATER

25

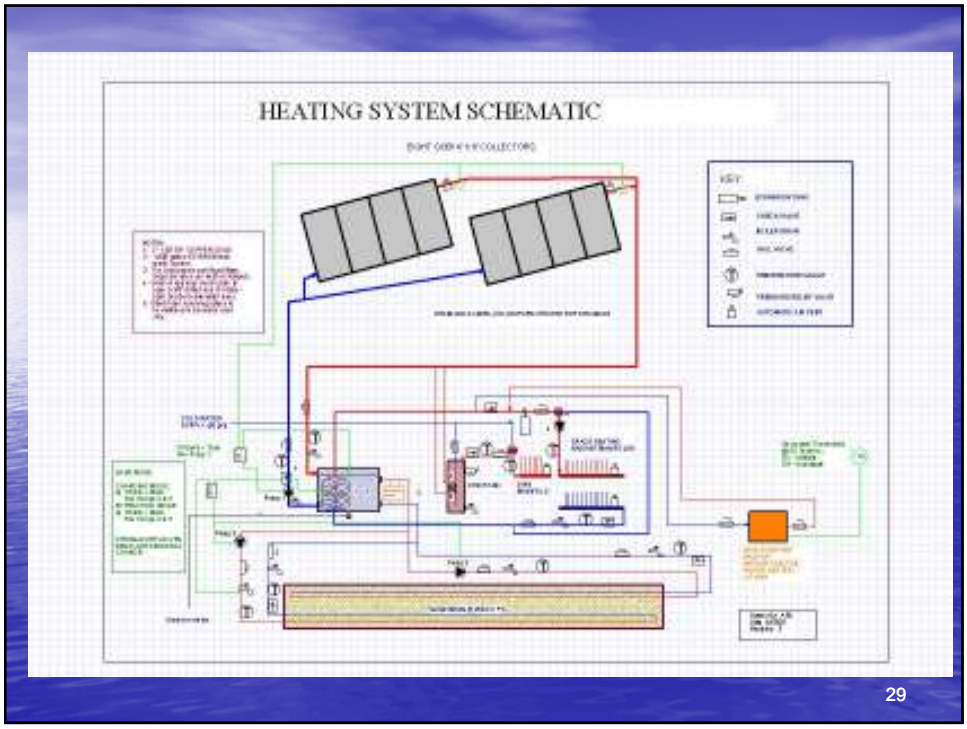


26



27


28

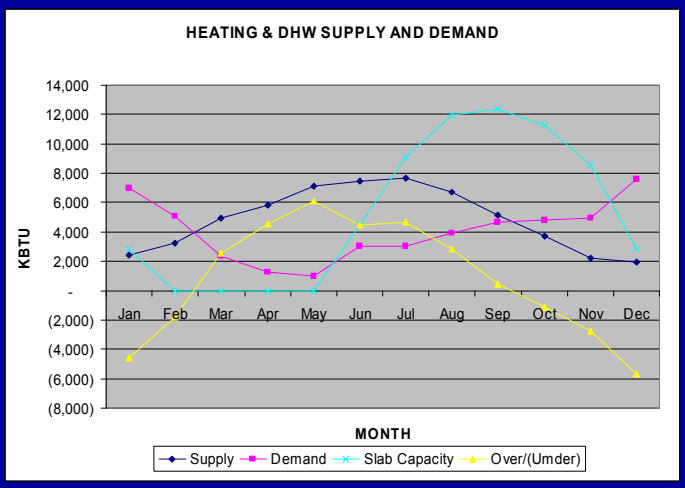



SUMMARY OF SUPPLY & DEMAND

| | Supply | Demand | Over/(Umder) | Slab Capacity | Energy Needed | Avg Slab Temp |
|---|---|---|---|---|---|---|
| Jan | 2,415,136 | 7,018,000 | (4,602,864) | 2,843,999 | (1,758,865) | 106.18 |
| Feb | 3,241,370 | 5,065,000 | (1,823,630) | - | (1,823,630) | 90.00 |
| Mar | 4,914,380 | 2,330,000 | 2,584,380 | - | - | |
| Apr | 5,802,372 | 1,256,000 | 4,546,372 | - | - | 90.00 |
| May | 7,113,235 | 993,000 | 6,120,235 | - | - | 90.00 |
| Jun | 7,461,300 | 3,011,000 | 4,450,300 | 4,450,300 | - | 115.33 |
| Jul | 7,681,974 | 3,040,300 | 4,641,674 | 9,091,974 | - | 141.74 |
| Aug | 6,728,736 | 3,895,000 | 2,833,736 | 11,925,710 | - | 157.87 |
| Sep | 5,131,824 | 4,666,000 | 465,824 | 12,391,534 | - | 160.52 |
| Oct | 3,688,789 | 4,794,000 | (1,105,211) | 11,286,323 | - | 154.23 |
| Nov | 2,213,196 | 4,957,000 | (2,743,804) | 8,542,519 | - | 138.61 |
| Dec | 1,910,480 | 7,609,000 | (5,698,520) | 2,843,999 | - | 106.18 |
| | 58,302,792 | 48,634,300 | 9,668,492 | | (3,582,496) | |

| | | |
|---|---|---|
| Energy Used, kwh | - | (1,049.67) |
| Cost | $ | 132.26 |

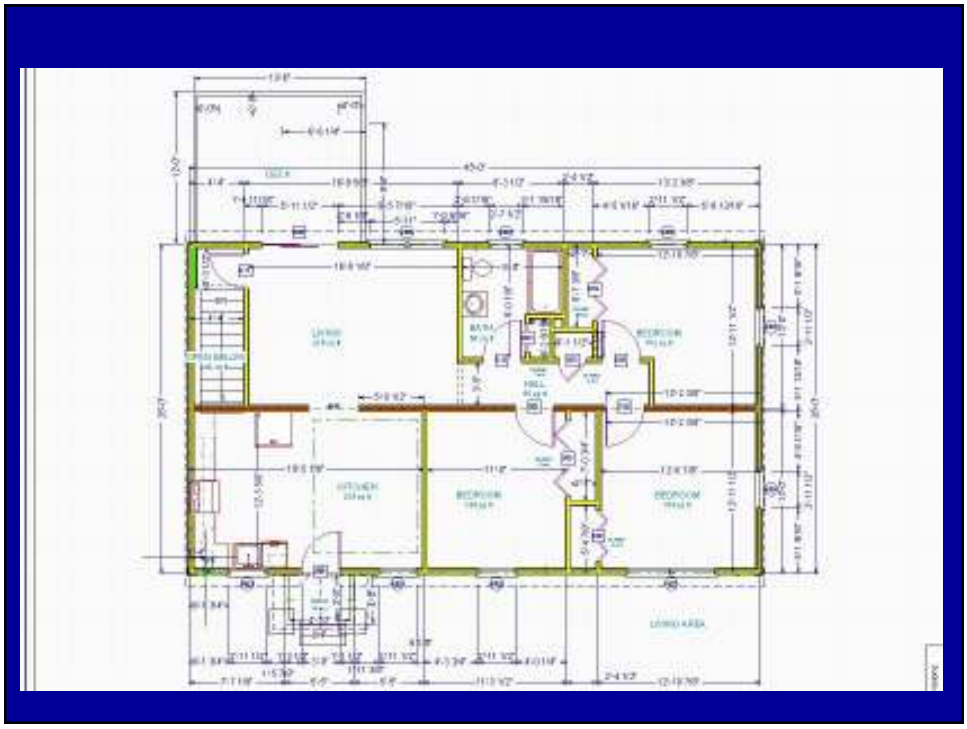
30

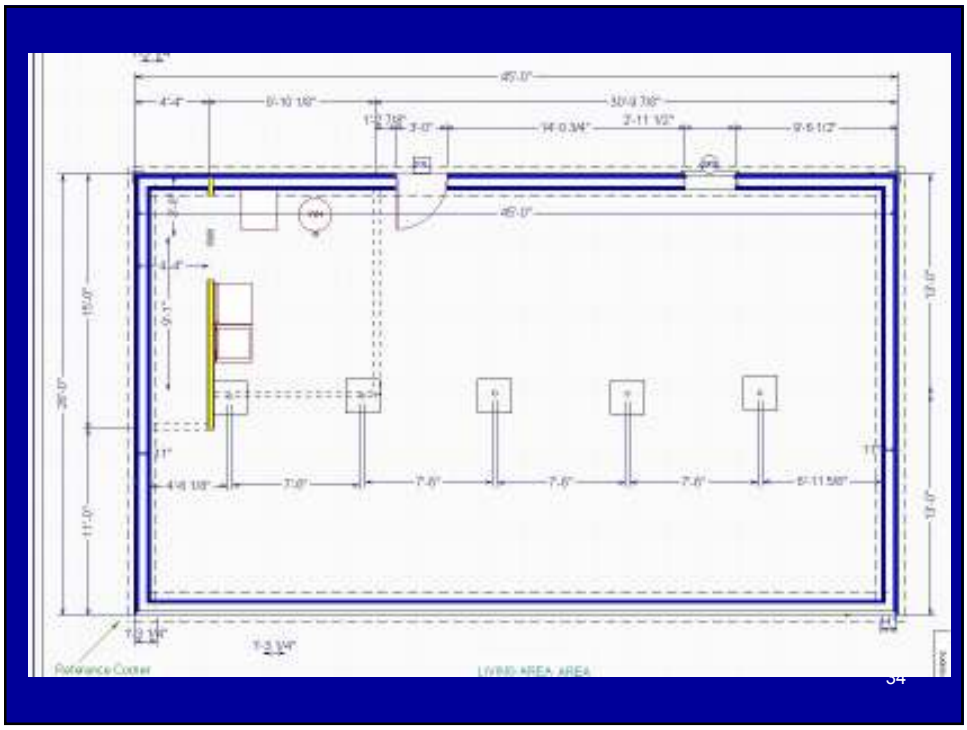



31

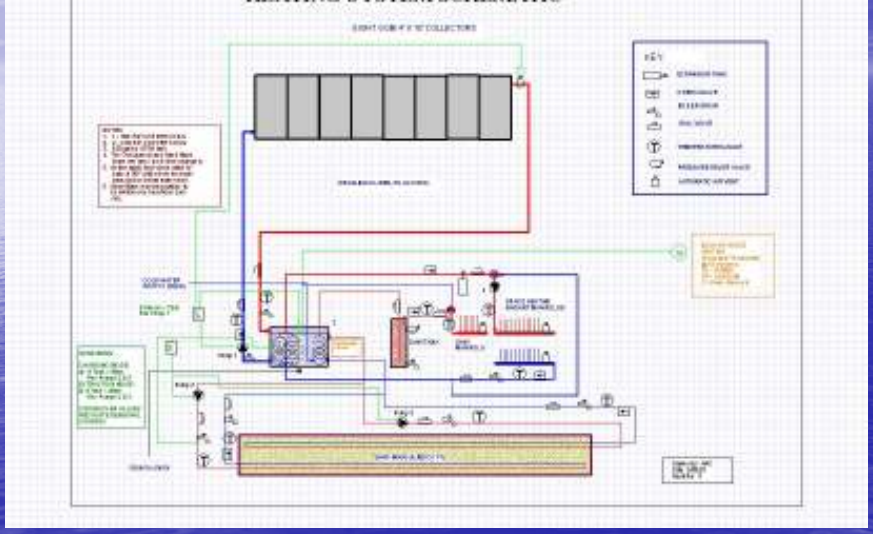
# SOLAR HOT WATER FOR HUMANITY

32





35



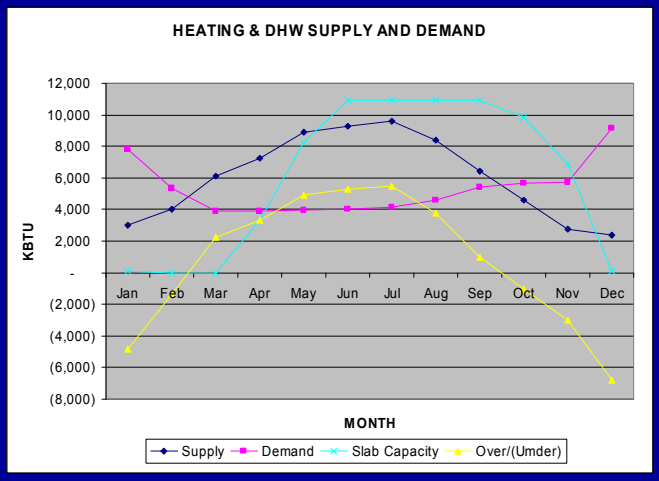

36

SUMMARY OF SUPPLY & DEMAND

| | Supply | Demand | Over/(Umder) | Slab Capacity | Energy Needed | Mass Temp |
|---|---|---|---|---|---|---|
| Jan | 3,013,312 | 7,839,000 | (4,825,688) | 90,111 | (4,735,578) | |
| Feb | 4,044,186 | 5,369,000 | (1,324,814) | - | (1,324,814) | |
| Mar | 6,131,564 | 3,870,000 | 2,261,564 | - | - | 80 |
| Apr | 7,239,492 | 3,880,000 | 3,359,492 | 3,359,492 | - | 105 |
| May | 8,875,027 | 3,954,000 | 4,921,027 | 8,280,519 | - | 143 |
| Jun | 9,309,300 | 4,045,000 | 5,264,300 | 10,912,669 | - | 163 |
| Jul | 9,584,630 | 4,133,000 | 5,451,630 | 10,912,669 | - | 163 |
| Aug | 8,395,296 | 4,619,000 | 3,776,296 | 10,912,669 | - | 163 |
| Sep | 6,402,864 | 5,388,000 | 1,014,864 | 10,912,669 | - | 163 |
| Oct | 4,602,421 | 5,655,000 | (1,052,579) | 9,860,090 | - | 155 |
| Nov | 2,761,356 | 5,738,000 | (2,976,644) | 6,883,446 | - | 132 |
| Dec | 2,383,664 | 9,177,000 | (6,793,336) | 90,111 | - | 81 |
| | 72,743,112 | 63,667,000 | 9,076,112 | 72,214,446 | (6,060,392) | |

| | | |
|---|---|---|
| kwh Used | | (1,776) |
| Cost | $ | 213.08 |

37




38

39

# THINGS LEARNED ABOUT SAND STORAGE

- DON'T SKIMP ON THE INSULATION
  - Particularly between the mass and the house
  - If higher temps are needed, be able to store them
- WATERPROOFING AND DRAINAGE IS CRITICAL
  - Inside and Out
- LATERAL OUTSIDE WATERPROOFING AND INSULATING WILL ENHANCE STORAGE
  - Thermal Lag, Blanket Effect
- LARGER WATER TANKS WITH SEPARATE COMPARTMENTS ENHANCE EFFICIENCIES
  - 2k Gallons not too much
- CONTROLS NEED TO BE NO-BRAINERS FOR THE CUSTOMER'S BENEFIT
- SAND IS GOOD/WATER IS BETTER?
  - (But that's for another day…)

40

# FINAL REMARKS

- WHAT DOES IT TAKE TO DO SPACE HEATING?
  - Storage (Get it when you can!)
  - Low Loads (Integrated Building Design)
  - Low Temperature Water (Radiant Heat Distribution)
- WHY HASN'T IT HAPPENED BEFORE?
  - Our addiction to cheap oil w/o consideration of the consequences
- CONSERVATION IS THE FOUNDATION TO ALL SUSTAINABLE AND RENEWABLE CHOICES
  - The least expensive changes occur first with conservation
- NEW AND EXISTING BUILDINGS ARE BOTH SUITABLE FOR IBD
- PROFESSIONAL COLLABORATION IS KEY!
- RELIABILITY, CREDIBILITY AND PROFESSIONAL INTEGRITY
  - Keys to the industry's success!
  - We don't want to repeat the agonies of the 1975-1985 era!
- INTEGRATED BUILDING DESIGN IS OUR FUTURE AND OUR RESPONSIBILTY

41

Be the change you wish to see in the world…

-Gandhi

42