Analysis

If you are doing this for your home, then the calculated values for annual heating and cooling costs should not be more than 10% to 15% off from your actual electric and gas bills. They should be lower than your actual bills because the calculations do not include electricity for lighting and appliances and electric or gas for heating water, and cooking.

The important thing to look at is how changes in roof and wall color affect the heating and cooling loads. Play with the numbers, to see the variation in energy use between double and single pane windows; look at the "tables" and change the roof U-value to what it would be like if you had a radiant barrier or an attic ventilator; add insulation to the roof. These are the major projects that will do the most good for a residence or light commercial building. The estimated savings can be compared to the actual cost of the project, to get a payback and to make a decision on whether or not to do the project.

When it comes to regular upkeep of the place, it makes no sense at all not to install light colored shingles if you are in a warm climate; or dark colored shingles if you are in a cold climate since the cost is the same no matter what color you choose. This is also a good time to add a radiant barrier to the roof deck for next to nothing. Wall color selection can be predicated by a similar decision, when it comes time to repaint. Adding a ventilating fan should not be too expensive; and increasing the amount of insulation in the attic is a do it your self job; and can even be done one section at a time - whatever insulation you add, wherever you add it, will help.

No matter what project you do, be sure and talk it over with a contractor or somebody at the building supply house. For example, find out how much attic insulation you have now, what kind it is, and how old it is; and this will help others advise you how much more would do you the best good. Re-roofing is almost always done by roofing contractors, and they will give you ideas on the attic insulation; and also price a radiant barrier, which often can be installed as an integral component to the roof deck itself.

CHICAGO

It's an odd notion, to think of roofing renovations as an energy conservation project. Most people think it's just a routine maintenance task, until they look at the numbers.

Consider as an example a 100,000 sq.ft. square building with a built-up roof and nominal attic insulation. If you do an annual energy analysis of this building you will get the energy costs shown in Figure 1. These assume (1) a dark colored roof, (2) the cooling is provided by an air cooled chiller, (3) the building has medium colored exterior walls with 25% double paned glass windows, and (4) the electricity rate is $0.08/kwh. The figures do not include any electricity demand charges.

Figure 1

Annual cooling costs for the building envelope

	Dallas	Chicago
Walls	1655	942
Glass	9472	6765

Roof____14,649____5875

The roof load is the dominant factor in both climates. It is evident that a good way to reduce summer cooling loads is to focus on roof projects. What sort of things could be done?

Ventilation

The most effective remedy that can be implemented with minimal expense is to power ventilate the attic space. Figure 2 shows some numbers for the ASHRAE equivalent R-value of attic ventilation, assuming R-10 cooling insulation in place and 90 degree ventilation air, versus the cooling cost for our 100,000 sq.ft. building.

Figure 2

Annual cooling costs for ventilated attics

	R-value	Dallas	Chicago
No ventilation	11.9	7840	2375
Natural vent.	13.9	6940	1898
0.5 cfm/sq.ft.	17.9	4690	1707
1.0 cfm/sq.ft.	22	3452	1136
1.5 cfm/sq.ft.	25	2889	1111

Ventilation is not always a viable alternative for commercial buildings with lay in ceilings. A notable exception is buildings with a high occupancy - schools, shopping malls, restaurants, and movie theaters. These buildings all have a high outside air requirement, so a steady volume of air must be exhausted from the occupied space. An ideal solution is to draw this air out through the ceiling, taking the lighting heat load with it. So not only will the need for any return air ductwork be negated, the return fan power use is replaced by the attic ventilation fan power use.

Roof Color

Another effective remedy is to change the color of the roof itself. Figure 3 shows the dramatic effect of roof colors on cooling loads.

Figure 3

Annual cooling loads versus roof color

	Dallas	Chicago
Light	8166	22424
Med	11,327	4042
Dark	14,649	5875

Peak Loads

So far all the comparison values have been for annual cooling loads and their associated costs. Another important consideration is the effect these projects would have on the peak cooling load. This is important because it will allow smaller AC equipment to be used for the building - with less energy usage and a lower peak electricity demand. Or, if the project is done on an existing facility, the present equipment can be used to condition a larger space, operate the system beyond its normal useful lifetime (i.e. because of a lower average load on the equipment), or even stage equipment with simple controls to keep all the equipment operating optimally.

Even though it is more difficult to quantify, then, peak load reduction is a big plus for an energy conscientious roofing job. Consider the numbers for the ventilation projects, in Figure 4.

Figure 4

Peak loads for attic ventilation rates

	Dallas	Chicago
No ventilation	344,400	294,000
Natural vent.	311,600	266,000
0.5 cfm/sq.ft.	229,600	196,000
1.0 cfm/sq.ft.	184,500	157,500
1.5 cfm/sq.ft.	164,000	140,000

TORONTO

Consider a 2000 sq.ft. residence with a truss roof and batt insulation in the attic, a slab foundation, and large windows on all walls. Now look at a few low-cost modifications

Assuming a $1.25 propane rate, and a location in Toronto we can look at the impact on the annual costs. First check out the affect of roof color, as indicated in Figure 1. Most people assume a dark colored roof is a big plus in a cold climate. Are they right? And what about metal vs. wood trusses, what difference do they make? Metal trusses with double the insulation still have a higher heating cost than wood construction, and the color of the roof doesn't make much difference at all.

Figure 1

Varying The Roof Color

Color	L	M	D

R-19, metal ____378______354______334

R-11, wood ____323______303______285

The program prints out the peak load and annual cost attributed to each building element. The building has a lot of glass, say eight 6ft. x 4ft. windows on each side. Will external shading help reduce this load? Are storm windows worth the extra cost and trouble? The numbers in Figure 2 tell an interesting story.

Most people automatically assume that storm windows are the way to go – everybody has them. Theoretically, they ARE more efficient, reducing the winter heating bills by roughly half (remember, these values are for that part of the load due to the windows only). However, if you already have double paned windows, storm windows (or, essentially triple paned windows) only save an additional ten percent, at best.

Figure 2

Glass Heatling Costs

Glazing	N	S	E	W
Single plane windows	585	456	476	476
W/ storm Windows	315	282	249	249

Now look at the impact of using 4 in. wood studs with R-11 insulation versus 6 in. wood stud walls with, say, R-19 insulation. Many homeowners are convinced this will give them an extremely efficient home. Are they right? Figure 3 gives the results. The thicker walls are indeed more efficient, but the total annual energy savings is small compared to the additional initial construction cost of the residence.

Figure 2 will also resolve the issue of evergreen trees keeping the winter sun from shading the building. Shaded elements are the equivalent of north facing elements, for both walls and glass. The cost of winter shading is not substantial – especially since the entire face is not usually completely shaded. The values for walls in Figure 3 substantiate this perspective for walls as well. So keep the big shade trees – they don't cost you much in the winter, and make up for it in the summer.

Figure 3

Varying Wall Insulation

Wall Insulation	N	S	E	W
Air Space, R-0	218	171	194	194
4 in. walls, R-11	87	69	78	78
6 in. walls, R-19	55	43	49	49

In this case, what is commonly assumed to be a great energy saving project, doesn't do much good for either annual cost reduction. How would you convince an owner of this, without having some solid numbers to convince them otherwise? It would be far more energy efficient to use regular 4 in. stud walls, and to devote the cost savings to reducing the load in other areas.

There are many other projects that can be studied with ease:

1. single vs. double paned windows

2. internal and external shading of windows

3. radiant barriers in the attic

4. outside air infiltration

5. duct leakage and losses

6. attic ventilation

Industry standard reference tables are provided in the software to give representative U-values for most common roof, wall, and glass types as well as other building envelope parameters. Finally, the three major projects featured here were analyzed in less than half an hour, so this is not a complex program to learn and use at all.

Conclusion

A quality home is more than just first class materials and craftsmanship. It's also an efficient, comfortable building that will have low utility bills, regardless of utility rates. A quick analysis of the peak and annual loads not only will keep the hvac contractor honest, in providing properly sized equipment, but keep the architect and the general contractor honest too. Ultimately it will make the owner happy, when he or she is pleasantly surprised by years of thrifty heating and cooling bills.

LOS ANGELES

Consider a 5000 sq.ft. luxury residence with flat masonry roof with built up roofing, a slab foundation, and large windows on all walls. Now look at a few low-cost modifications

Assuming a $0.08/kwh electric rate, central air, and a location in Los Angeles we can look at the impact on the peak loads and annual costs. First check out the affect of roof color, as indicated in Figure 1. At first glance it looks like a wash – what you save in the winter with a dark roof, you lose in the summer; and vice versa. However, the heating costs are calculated using an all-electric system. If propane or natural gas were used, these costs would be reduced by half or more. This would make the light colored roof much more economical overall.

Figure 1

Varying the Roof Color

	cooling		heating	
Color	Peak Loads	Annual Cost	Peak Loads	Annual Cost
Light	37,500	360	31,250	803
Medium	47,500	595	31,250	752
Dark	47,500	833	31,250	709

The program prints out the peak load and annual cost attributed to each building element. The building has a lot of glass, say eight 6ft. x 6ft. windows on each side. Will external shading help reduce this load? Are double paned windows worth the extra cost? The numbers in Figure 2 tell an interesting story.

Most people automatically assume that double paned windows are the most energy efficient. Theoretically, they ARE always the most efficient, but in a temperate climate like Los Angeles, they don’t save that much either in peak loads or annual costs. Far greater savings come from external shading. (A shaded window has the equivalent load of a north-facing exposure.) Landscape shading reduces the cooling load far more than high efficiency windows. A similar affect occurs during the winter, especially for deciduous trees that loose their leaves in the winter, letting the winter sun warm the building.

Figure 2

Glass Cooling Loads

	single		double	
Exposure	Peak Loads	Annual Cost	Peak Loads	Annual Cost
N	6,624	150	5,472	120
S	11,520	354	9,504	300
E	23,328	404	19,584	381
W	23,328	404	19,584	381

Now look at the impact of using 4 in. studs with R-11 insulation versus 6 in. stud walls with, say, R-19 insulation. Many homeowners are convinced this will give them an extremely efficient home. Are they right? Figure 3 gives the results.

Figure 3

Varying Wall Insulation

Wall Insulation	N	S	E	W
Air Space, R-0	14	21	38	38
4 in. walls, R-11	5	8	16	16
6 in. walls, R-19	3	5	11	11

In this case, what is commonly assumed to be a great energy saving project, doesn't do much good for either annual cost or peak load reduction. In fact, the benefits of wall insulation at all are questionable!

How would you convince an owner of this, without having some solid numbers to convince them otherwise? It would be far more energy efficient to not install insulation in the walls at all, and to devote the cost savings to reducing the load in other areas, such as increasing landscape shading.

There are many other projects that can be studied with ease:

7. single vs. double paned windows

8. internal and external shading of windows

9. radiant barriers in the attic

10. outside air infiltration

11. duct leakage and losses

12. attic ventilation

Industry standard reference tables are provided in the software to give representative U-values for most common roof, wall, and glass types as well as other building envelope parameters. Finally, the three major projects featured here were analyzed in less than half an hour, so this is not a complex program to learn and use at all.

Conclusion

A quality home is more than just first class materials and craftsmanship. It's also an efficient, comfortable building that will have low utility bills, regardless of utility rates. A quick analysis of the peak and annual loads not only will keep the hvac contractor honest, in providing properly sized equipment, but keep the architect and the general contractor honest too. Ultimately it will make the owner happy, when he or she is pleasantly surprised by years of thrifty heating and cooling bills.

DALLAS

Consider a 5000 sq.ft. luxury residence with flat masonry roof with built up roofing, a slab foundation, and 25% double paned windows on all walls. Now look at a few low-cost modifications

Assuming a $0.08/kwh electric rate, central air, and a location in Dallas, Texas we can look at the impact on the peak cooling load and annual cooling costs. First check out the affect of roof color, as indicated in Figure 1. There is only a small effect on the peak loads, but the annual cost varies by almost 50%.

Figure 1

Varying the Roof Color

Color	Peak Loads	Annual Cost
Light	51,250	$1183
Medium	61,250	1503
Dark	61,250	1832

Now, install a thermostat controlled attic fan to provide power ventilation when the outside temperature is above 90F. The computer results are shown in Figure 2. The cost savings are only about $600 per year, but the peak load is reduced by 2/3's – meaning a much smaller unit, smaller ductwork, and a smaller electrical service.

Figure 2

Varying Attic Ventilation

Ventilation	Peak Loads	Annual Cost
No ventilation	41,640	$992
0.5 cfm/sqft.	34,300	800
1.5 cmf/sqft.	17,150	353

Now look at the impact of using 4 in. studs with R-11 insulation versus 6 in. stud walls with, say, R-19 insulation. Many homeowners here in Texas are convinced this will give them an extremely efficient home. Are they right? Figure 3 gives the results.

Figure 3

Varying Wall Insulation

Wall Insulation	Peak Loads	Annual Cost
Air Space, R-0	15,357	$581
4 in. walls, R-11	6,040	235
6 in. walls, R-19	3,500	148

In this case, what is commonly assumed to be a great energy saving project, doesn't do much good for either annual cost or peak load reduction. Well, theoretically they DO reduce the values by 50%, but the net savings is practically a toss up. How would you convince an owner of this, without having some solid numbers to convince them otherwise?

There are many other projects that can be studied with ease:

13. single vs. double paned windows

14. internal and external shading of windows

15. radiant barriers in the attic

16. outside air infiltration

17. duct leakage and losses

Industry standard reference tables are provided in the software to give representative U-values for most common roof, wall, and glass types as well as other building envelope parameters. Finally, the three major projects featured here were analyzed in less than half an hour, so this is not a complex program to learn and use at all.

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DENVER

Consider a 2000 sq.ft. residence with a truss roof and batt insulation in the attic, a slab foundation, and large windows on all walls. Now look at a few low-cost modifications

Assuming a $0.08/kwh electric and $1.25/gal propane rate, and a location in Denver we can look at the impact on the annual costs. First check out the affect of roof color, as indicated in Figure 1. Most people assume a dark colored roof is a big plus in a cold climate. Are they right? How about electric versus gas heating? Is gas the bonus it's supposed to be? (Keep in mind these costs are for specific building elements, not the whole residence.) The answer is a surprising wash for roof color, and propane is cheaper, but perhaps not enough so. At least, additional savings from water heating and cooking with gas would be needed to justify a propane system.

Figure 1

Varying the Roof Color

Color	Elect	Propane
Light	263	196
Medium	246	184
Dark	232	173

The program prints out the peak load and annual cost attributed to each building element. The building has a lot of glass, say eight 6ft. x 4ft. windows on each side. Will external shading help reduce this load? Are storm windows worth the extra cost and trouble? The numbers in Figure 2 tell an interesting story.

Most people automatically assume that storm windows are the way to go – everybody has them. Theoretically, they ARE more efficient, reducing the winter heating bills by roughly half (using electric heat now). However, if you already have double paned windows, storm windows (or, essentially triple paned windows) only save an additional ten percent, at best.

Figure 2

Glass Heating Costs

Glazing for windows	N	S	E	W
Single pane windows	489	381	400	400
With storm Windows	264	236	208	208

Now look at the impact of using 4 in. wood studs with R-11 insulation versus 6 in. wood stud walls with, say, R-19 insulation. Many homeowners are convinced this will give them an extremely efficient home. Are they right? Figure 3 gives the results. The thicker walls are indeed more efficient, but the total annual energy savings is small compared to the additional initial construction cost of the residence.

Figure 2 will also resolve the issue of evergreen trees keeping the winter sun from shading the building. Shaded elements are the equivalent of north facing elements, for both walls and glass. The cost of winter shading is not substantial – especially since the entire face is not usually completely shaded. The values for walls in Figure 3 substantiate this perspective for walls as well. So keep the big shade trees – they don't cost you much in the winter, and make up for it in the summer.

Figure 3

Varying Wall Insulation

Wall Insulation	N	S	E	W
4 in. walls, R-11	150	118	133	133
6 in. walls, R-19	60	47	53	53

In this case, what is commonly assumed to be a great energy saving project, doesn't do much good for annual cost reduction. How would you convince an owner of this, without having some solid numbers to convince them otherwise? It would be far more energy efficient to use regular 4 in. stud walls, and to devote the cost savings to reducing the load in other areas.

There are many other projects that can be studied with ease:

18. single vs. double paned windows
19. internal and external shading of windows
20. radiant barriers in the attic
21. outside air infiltration
22. duct leakage and losses
23. attic ventilation

Industry standard reference tables are provided in the software to give representative U-values for most common roof, wall, and glass types as well as other building envelope parameters. Finally, the three major projects featured here were analyzed in less than half an hour, so this is not a complex program to learn and use at all.

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TABLES

AC Equipment Efficiencies (EER)

Window Unit	6.8
Wall Unit	6.2
Central Air Cooled	6.5

Heat System Efficiencies (COP)

Gas Furnace	60-80%
Oil Fired Boiler	60-70%
Gas Fired Boiler	65-75%
Electric Boiler	95-100%
Electric Strip Heater	100%
Heat Pump	175-250%

Roof U-Values

Frame construction with 7.25" air space	0.21
Frame construction with R-19 blanket insulation	0.053
Flat masonry roof with built up roofing	0.211
Built up roof with rigid deck insulation	0.112
Wood construction flat roof and ceiling	0.159
Flat roof with R-18 batt insulation	0.046
Metal construction flat roof and ceiling	0.158
Metal roof with sand aggregate plaster	0.189
Pitched roof - heat flow up	0.246
Pitched roof - heat flow down	0.141

Glass U-Values

Single Pane	1.1
Double Pane	.52 - .38
Low e Coating	.37 - .48
Triple Pane	0.38
Storm Windows	0.48

Wall U-Values

Frame walls with 3.5" air space	0.206
Wood frame walls with 3.5" R-11 insulation	0.081
Solid masonry wall with 1" air space	0.257
Masonry wall with 1" extruded polystyrene	0.127
Framed partition with 3.5" air space	0.29
Partition with 3.5" R-11 insulation	0.083
Masonry wall (brick + 8" blocks)	0.171
Masonry wall with cores filled with insulation	0.14
Masonry cavity wall with 2.5" air space	0.204
Masonry wall with insulation fill	0.128
Masonry partition with 4" concrete blocks	0.308
Partition with 4" gypsum tile	0.262