Low Heating Costs

One of the more common questions from HAP users involves low heating costs. Typically, the questions take this form:

"When I finish the energy analysis, I find little or no heating cost, but I know my building requires substantial heating. What's wrong?"

This problem is usually due to one of a number of modeling pitfalls or input errors that will be discussed in this article. To help users correct these problems, this article outlines how to troubleshoot the situation.

First, generate the air system simulation reports for all systems involved in the study, as indicated in Figure 1. Energy analysis requires a good air system simulation. This is the start of the chain of calculations that determine the amount of cooling and heating needed and eventually yields associated operating costs. Low or non-existent heating loads, which may be the eventual reason for low heating costs, may be verified from these three reports "checked" in Figure 1.
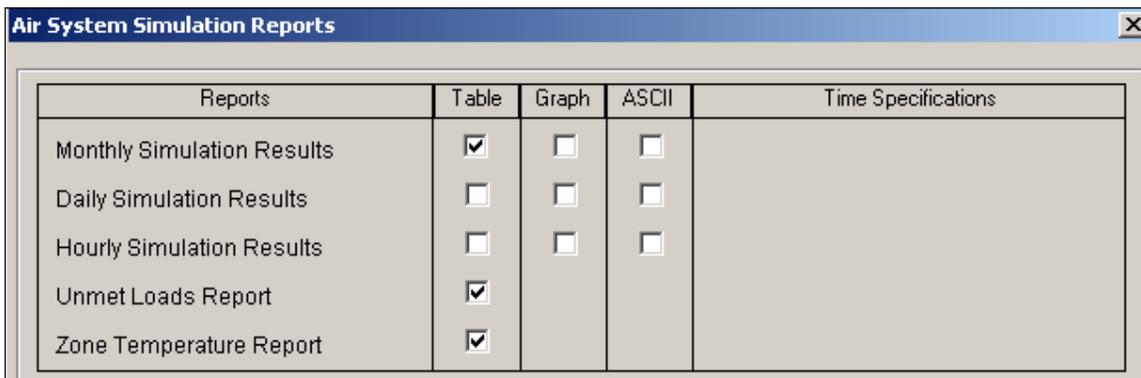

Figure 1 - Air System Simulation Reports for Diagnosing Low Heating Costs

The "Monthly Simulation Results" reports the **Air System Simulation Results** to indicate the heating loads for all heating coils in the hydronic system. This report is shown in Figure 2. Inspect the numbers in all rows and columns that have heating coils. Do they make sense?

Figure 10 shows this report for a DX cooling and gas heating system.

If the air system monthly simulation summary printout shows unusually low or zero heating coil loads, the problem lies with zoning decisions, schedules, spaces, or air system inputs.

Air System Simulation Results (Table 1):

Month	Preheat Coil Load (kBTU)	Central Cooling Coil Load (kBTU)	Terminal Heating Coil Load (kBTU)	Zone Heating Coil Load (kBTU)
January	3028	398	6463	323
February	1727	1637	4889	271
March	627	1389	1514	114
April	13	10002	272	21
May	0	22336	18	3
June	0	42037	0	0
July	0	37980	0	0
August	0	48118	0	0
September	0	29024	0	0
October	12	11428	118	11
November	231	195	1836	56
December	2747	112	7144	365
Total	**8385**	**204657**	**22255**	**1164**

Figure 2 – Air System Simulation Results - Coil Loads

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The "Unmet Loads Report" reports the **Unmet Load Statistics** to indicate how many hours the system is capable of offsetting the loads, as shown in Figure 3. The right column indicates the total number of hours with equipment loads while the other columns indicate hours where the system cannot meet the loads. A large number of unmet loads indicate the possibility of undersized heating equipment. If this is the case, refer to the section titled, **"Use realistic equipment capacity and efficiency values."** The report in Figure 3 shows an example of a good simulation.

2. Unmet Load Statistics - Terminal Heating Unit - WSHP

Month	Equipment Capacity is Sufficient (hrs)	Capacity Insufficient by 0%-5% (hrs)	Capacity Insufficient by 5%-10% (hrs)	Capacity Insufficient by >10% (hrs)	Total Hours with Unmet Loads	Total Hours with Equipment Loads
January	742	0	0	0	0	742
February	318	0	0	0	0	318
March	86	0	0	0	0	86
April	16	0	0	0	0	16
May	2	0	0	0	0	2
June	0	0	0	0	0	0
July	0	0	0	0	0	0
August	0	0	0	0	0	0
September	0	0	0	0	0	0
October	18	0	0	0	0	18
November	126	0	0	0	0	126
December	662	0	0	0	0	662
Total	**1970**	**0**	**0**	**0**	**0**	**1970**

Figure 3 - Air System Simulation Report – Unmet Loads

A third report, shown in Figure 4, is the "Zone Temperature Report" identified as the **Zone Temperature Statistics**. This indicates the minimum and maximum zone temperatures for both occupied and unoccupied time periods along with the number of hours the zone is within the desired control range. The presence of a significant number of hours outside the throttling range indicates the zones are not in control.

1. Zone Temperature Statistics

Zone Name	Occ Max Zone Temp (°F)	Occ Hours > 5.0 °F Above Throt. Range	Occ Hours 0 to 5.0 °F Above Throt. Range	Occ Cooling Setpoint plus Throt. Range (°F)	Occ Hours Within Throt. Range or Dead-band	Occ Heating Setpoint minus Throt. Range (°F)	Occ Hours 0 to 5.0 °F Below Throt. Range	Occ Hours > 5.0 °F Below Throt. Range	Occ Min Zone Temp (°F)	Unocc Max Zone Temp (°F)	Unocc Cooling Setpoint plus Throt. Range (°F)	Unocc Heating Setpoint minus Throt. Range (°F)	Unocc Min Zone Temp (°F)
Zone 1	75.0	0	2	75.0	2964	67.0	0	0	68.9	85.5	88.0	57.0	59.7

Figure 4 - Zone Temperature Statistics

After correcting any equipment capacity values, review the air system inputs for missing heating coils or incorrect inputs for control settings. One of the common problems is forgetting to input a preheat coil or central heating coil. Setting the proper leaving air temperature on these coils may also cause modeling problems, such as setting the leaving air temperature on a preheat coil higher than the discharge air temperature of the downstream cooling coil.

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In addition to the previous suggestions, the following four rules should be used to troubleshoot low heating costs:

Use enough detail when modeling building zones to preserve load diversity. Avoid oversimplification when modeling the zones. When the entire building is lumped into a single zone, interior heat gains offset perimeter heat losses resulting in little or no net heating load, as shown in Figure 5.
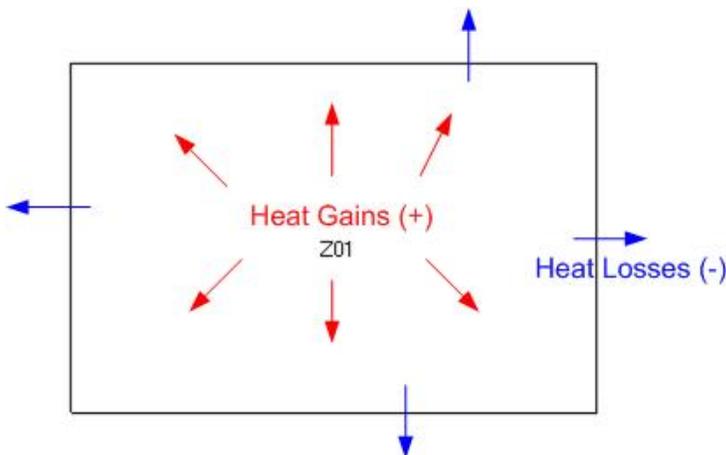

Figure 5 - Entire Building Modeled as Single Zone (Poor Zoning)

If the building is divided into a number of separate zones, the individual loads in each zone will be preserved and heat gains and losses will not cancel each other. For the best results, every region served by a thermostat should be modeled as a separate zone. Often this is impractical because of the large number of zones involved. Frequently, highly accurate results can be obtained by simply grouping rooms on each exposure and the interior into separate zones served by the air system, as shown in Figure 6.

In this scheme, the unique thermal loads experienced on each exposure, the interior can be separately analyzed, and the diversity of loads in the building can be successfully modeled. As a result, internal heat gains will not cancel perimeter heat losses and the more accurate building heating and cooling loads will be considered.
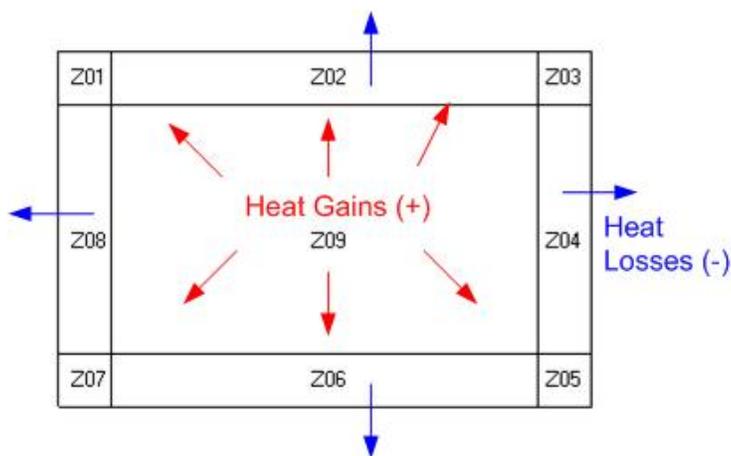

Figure 6 - Perimeter/Core Separated by Exposure (Good Zoning)

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Use realistic profiles and profile assignments in the schedules to model the variation of internal loads. Avoid oversimplifying internal load schedules and using inappropriate design load profiles. If you have not added profiles for energy use or edited the profile day type assignments, this will be a problem. The default fractional profiles in the schedules are set to 100%, meaning all assigned internal load components are in-use during all operating hours, 24 hours per day. If internal load components such as lights, people or other electric equipment are not actually operated this way, then excessive heat gains are being modeled and can offset the heat losses in a zone. As a rule, it's always best to use profiles that accurately represent the hourly variation of internal loads, as shown in Figure 7.
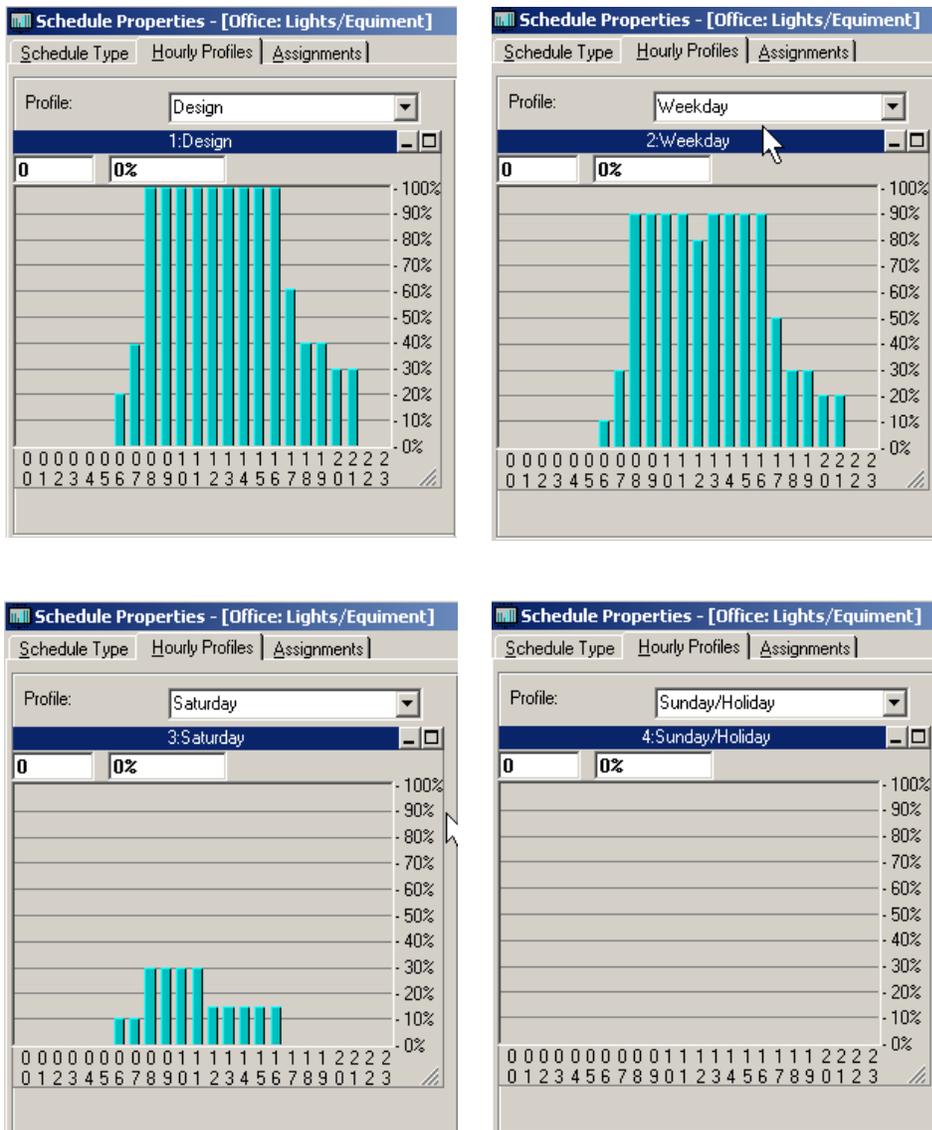
Figure 7- Typical Lighting Schedules

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Four profiles are used: One for design load and three for energy analysis. The design day profile allows for proper peak load sizing. The weekday profile allows for a typical use for energy analysis as do the Saturday and Sunday/Holiday profiles

Fractional profiles are assigned to each of the Day Types in HAP. There are eight-day types used in HAP energy simulation calculations:Monday through Sunday and a Holiday. Under the Assignments tab of the Schedule Properties, insure you have appropriate profiles assigned each of the day types, as shown in Figure 8.

Use appropriate values for all space inputs. Examine all your space inputs and insure they are appropriate for the building being analyzed. Pay special attention to default values used in place of actual values. If a default value used is different from the actual characteristic of the building, this will have an effect on simulation results. For example, if a building weight default of "medium" is used when the building weight really qualifies as "light", this can contribute to low heating loads. Heavier buildings tend to store heat longer, so afternoon heat gains are more likely to be carried over into nighttime hours where they can offset heat losses. For this reason, using default values can be risky.

Figure 8 - Schedule Profile Assignments for Each Day Type

Don't forget infiltration. Many people assume that buildings today have negligible infiltration due to tight construction and positive pressure created by the introduction of ventilation air. However, during unoccupied periods, especially during the heating season, when systems are in night setback and the ventilation fans are off, air pressure gradients created by vapor pressure differences, wind, stack effects, and opening and closing of doors, create infiltration. Quantifying infiltration rates can be an arduous task involving many calculations and depending on the number of doors, windows, and penetrations in the building envelope, as well as building height (stack effect), local wind loads, and other usage factors. Research has indicated that typical infiltration rates in newer buildings with tighter envelopes range between 0.3 and 0.5 air changes per hour, while older buildings with poor weather-stripping may leak as much as 1.0 air change per hour during the heating season[1].
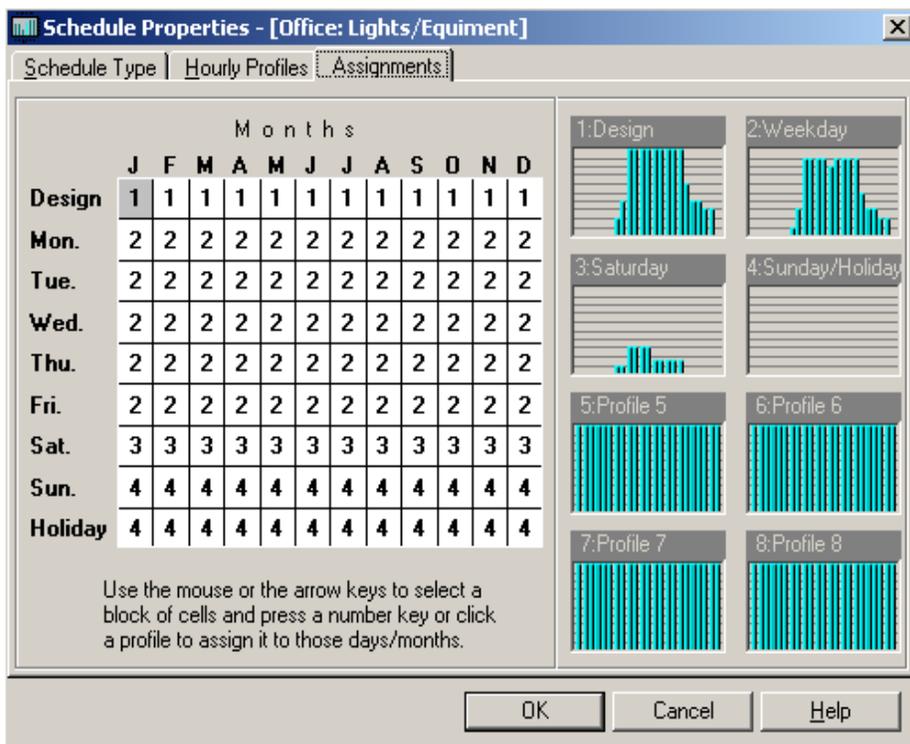
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HAP allows you to define a single infiltration rate for energy analysis simulation calculations and also the ability to limit infiltration to unoccupied times only when fans are off, or alternatively may be specified for all hours, as shown in Figure 9. This value is used for all months, in heating and cooling periods. Therefore, if you want to analyze infiltration in the heating season only you will need to adjust the input value to account for average seasonal infiltration rates.

Figure 9 - Space Infiltration Input Screen

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Examine the columns of data under heating coil loads. If the coil heating loads on the **Monthly Simulation Results** seem correct, but the heating coil equipment load and heating coil input do not correlate, the problem probably lies in the equipment modeling. Figure 10 illustrates proper load and coil simulation results. The equipment tab of the air system input, shown in Figure 11 must be edited before running energy analysis simulations.

Monthly Simulation Results for D28 - RTU D2 - Classroom D101

Project Name: HAP42 Advanced Handout_03_01_05   10/31/2005
Prepared by: 03:33PM

Air System Simulation Results (Table 1) :

Month	Central Cooling Coil Load (kBTU)	Central Cooling Eqpt Load (kBTU)	Central Unit Clg Input (kWh)	Central Heating Coil Load (kBTU)	Central Heating Eqpt Load (kBTU)	Central Heating Coil Input (kBTU)	Central Heating Misc. Electric (kWh)
January	0	0	0	3420	3420	4171	11
February	99	99	8	2312	2312	2820	8
March	88	88	7	1152	1152	1404	4
April	1444	1444	124	190	190	231	1
May	3599	3599	325	23	23	29	0
June	7858	7858	706	0	0	0	0
July	7773	7773	724	0	0	0	0
August	8986	8986	816	0	0	0	0
September	4254	4254	367	1	1	1	0
October	1301	1301	112	163	163	199	1
November	0	0	0	1016	1016	1239	3
December	0	0	0	3347	3347	4081	11
Total	35402	35402	3189	11624	11624	14176	39

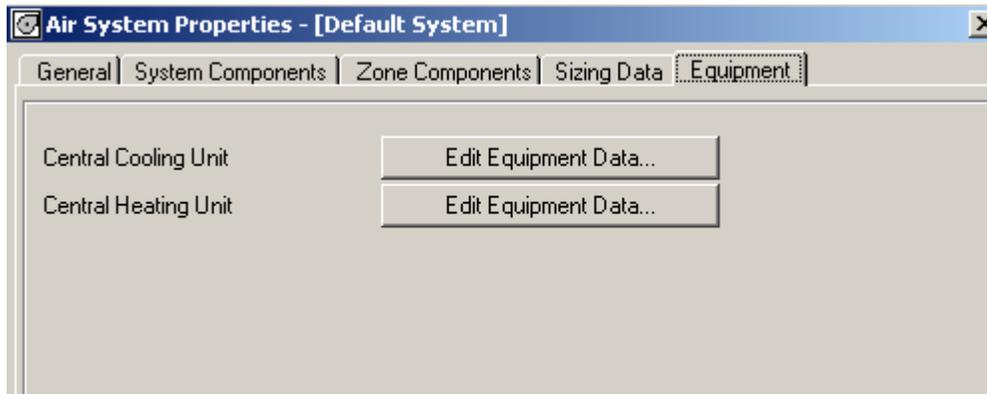**Figure 10 - DX Cooling Gas Heating System (Package Roof Top)**

Figure 11 - Air System Equipment Tab

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TIP: If you run the design loads first, the estimated maximum loads are displayed for your reference as shown in Figure 12.

Use realistic equipment capacity and efficiency values. When modeling non-hydronic systems such as packaged rooftop units with gas heat, DX split systems, WSHPs or DX fan coils, HAP requires definition of the heating plant capacity and input energy in the Systems Property input screen under the Equipment tab, as indicated in Figure 11. It is easy to overlook these inputs. This results in little or no heating plant loads for non-hydronic system types since the default value for gross heating capacity is 1.0 MBH. This would show up as a capacity insufficiency on the report in Figure 3.

For other hydronic systems, with combustion or user-defined heating plants, plant efficiencies must be specified after creating a heating plant. Using inappropriate values for heating plant inputs can also contribute to low heating costs. For example, some users accidentally enter the full-load efficiency when the program asks for the average seasonal efficiency. As a result, the plant energy consumption is much lower than it should be. Realistic seasonal or part load values, preferably obtained from manufacturer's literature, should always be used to obtain accurate simulation results.

TIP: If you have a multiple zone terminal system, make sure to edit the equipment for every zone.

Finally, if the simulation outputs show heating energy that seems correct, the problem may lie in the fuel rate inputs. Make sure the following rule is observed:

Make sure fuel conversion factors and rates are correct. An incorrectly specified fuel conversion factor or fuel rate can cause heating costs to "disappear." HAP simulations produce heating energy consumption data in kBTU. The user must specify a conversion factor relating kBTU to the fuel units (e.g. 100 kBTU/therm of gas), and a rate factor relating cost to fuel units (e.g., $/therm). If a mistake is made in entering either of these factors, large errors in operating cost results can occur. Therefore, it is useful to check these inputs, especially if the plant simulation results show large heating loads, but the cost output shows little or no heating costs.

Figure 12 - System Heating Equipment Input Screen

References

1. *Building Envelope* by Keith Elder; Energy User News, BNP Media Publishing, Troy, MI; Web page article. Published 11/21/2000.