PIV Energy Modeling
Application Guide
PIV Energy Modeling Application Guide

Table of Contents

Introduction: .......................................................................................................................... 3
User Interface ......................................................................................................................... 3
File ......................................................................................................................................... 4
   Save ................................................................. 4
   Open ........................................................................ 4
   Upload Weather Table ........................................ 4
   Edit Schedule Customer Information: ...................... 5
   Print ...................................................................... 5
   Exit5 ..................................................................... 5
Help: .................................................................................................................................. 5
   Instructions .......................................................... 5
   What is the Belimo Energy Valve™? ................. 6
Application Data .................................................................................................................. 6
   Closest Major City .................................................. 6
   Climate Zone Number .............................................. 6
   Building Type ........................................................ 6
   Building Total Design Flow .................................. 6
   Supply Air Setpoints Cooling and Heating ................. 7
   Occupancy Level Selection .................................... 7
   Indoor Ambient Setpoints Cooling and Heating ........ 7
   Design Cooling Water ΔT, Design Heating Water ΔT 7
   Type of Chillers ...................................................... 7
   Quantity of Chillers ............................................... 7
   Total Size of Chillers .............................................. 7
   Installation Cost ..................................................... 7
   Utility Cost ........................................................... 7
   Annual Building Total Electricity Consumption .......... 8
   Load Breakdown Display ........................................... 8
Climate Zones ....................................................................................................................... 9
Weather Data: ....................................................................................................................... 11
   Weather Data Creation Utility, Data Structure: ........... 11
Building Data: ....................................................................................................................... 11
   Building Load Distribution Pie Charts: ................... 12
   Building Types: ..................................................... 12
      Apartment Building: ........................................... 12
      Hospital: ............................................................ 12
      Large Office: ..................................................... 13
      Medium Office: .................................................. 13
      School: .............................................................. 14
Schedules ............................................................................................................................... 14
Calculate ............................................................................................................................... 14
   View Details ......................................................... 14
Cooling Formulas and Calculations .................................................................................... 15
   Design GPM Calculation ........................................ 15
Heating Formulas and Calculations .......................................................... 23
  Design GPM Calculation ........................................................................ 23
  Total heating Load Calculation .............................................................. 23
  Skin Load Factor Calculation (heating) ................................................... 23
  Outside Air Load Factor Calculation (heating) ....................................... 23
  Skin Load Calculation (heating) ............................................................. 24
  OA Load Calculation (heating) ............................................................... 24
  Lighting Load Calculation (heating) ....................................................... 24
  People Load Calculation (heating) ......................................................... 25
  Plug Load Calculation (heating) ............................................................. 25
  Sum of Hourly Loads (heating) .............................................................. 26
  Total Heating Load Calculation ............................................................ 26
  Hourly Flow Calculation (heating) ......................................................... 27
  Pressure Dependent Valve Flow Calculation (heating) ......................... 27
  Savings Calculation (heating) ............................................................... 27
  Dollar Savings Calculation ................................................................... 28
  R.O.I. Calculation .................................................................................. 29
  Possible LEED Point Calculation .......................................................... 30

Appendix ............................................................................................... 31
  Building Zones and Load Calculations .................................................. 31
    Apartment Details .............................................................................. 31
    Hospital Details .................................................................................. 32
    Large Office Details ........................................................................... 33
    Medium Office Details ...................................................................... 34
    School Details .................................................................................... 35
  Schedules ........................................................................................... 36
    HVAC Schedules ............................................................................... 36
    Lighting Schedules ........................................................................... 36
    People Schedules ............................................................................. 37
**Introduction:**

The PIV Energy Modeling tool is part of SelectPro. The modeling tool objective is to give everyone in the industry the capability to model the energy savings, with a reasonable error margin. When using Pressure Independent Characterized Control Valves (PICCV) and Electronic Pressure Independent Vales (ePIV) in comparison to pressure dependent valves (Characterized Control Valves (CCV) or globes).

The user enters a minimum amount of variables and is able to obtain a quick comparison of energy usage between the two types of valves. Even though the software requires minimum user entries, the calculations are very complex. It uses a set of hourly calculations on the background to obtain the different building HVAC load with predefined building types along with the city weather data and climate zone. The calculations structure complies with ASHRAE 90.1-2010 Appendix G regarding requirements for simulation programs. The program even provides the calculation tables so that the user can use the modeling as part of an Exceptional Calculation Method.

**User Interface**

The PIV Energy Modeling module can be accessed through the SelectPro splash page by clicking on the option **PI Valves Energy Modeling**, through the Module drop down menu and by clicking on the link displayed on the valves module.

The user interface is divided in two sections, data entry and results.

If the user changes any default value, the new value is saved and it is displayed the next time the user opens the module.
File

File menu has the following options:

- **Save**
  Users have the option to save the information to a file. The user inputs and results are saved in the file for future reference/load.

- **Open**
  This feature allows the user to load the data stored in a file from the “Save” option.

- **Upload Weather Table**.
  This selection brings up a file upload/browse window that allows the user to import a custom weather table. Imported files are in Excel format. The imported data overrides the default weather data from the **Closest Major City** selection. This option also allows the user to generate its own weather file. A blank template is provided for this purpose. When selecting a custom weather data, the form displays “Custom” under “Closest Major City”
**Edit Schedule Customer Information:**
Pop up window, with data stored from SelectPro. The user can override the preexisting values. The information entered on this screen is used to populate the report obtained from the “Print” option.

**Print**
The option to print a model report; it includes customer information, the user entry, the building load information and the savings results.

**Exit**
The user is prompted to save the project before closing the program.

**Help:**
Displays help instructions.

**Instructions**
Opens the instruction document.

PIV Energy Modeling Application Guide
**What is the Belimo Energy Valve™?**

The Energy Valve is a two-way pressure independent control valve that optimizes, documents and proves water coil performance. For more information, go to [www.energyvalve.com](http://www.energyvalve.com).

**Application Data**

<table>
<thead>
<tr>
<th>Application Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Closest Major City</td>
</tr>
<tr>
<td>2. Building Type</td>
</tr>
<tr>
<td>3. Building Total Design Flow</td>
</tr>
<tr>
<td>4. Supply Air Setpoint</td>
</tr>
<tr>
<td>5. Variable CO2 based indoor air system - Demand Control Ventilation (DCV) (use people schedule)</td>
</tr>
<tr>
<td>6. Indoor Ambient Setpoint</td>
</tr>
<tr>
<td>7. Design LT</td>
</tr>
<tr>
<td>8. Quantity and Type of Chillers</td>
</tr>
<tr>
<td>9. Total Size of Chillers</td>
</tr>
<tr>
<td>10. Installation Cool Pressure Independent $</td>
</tr>
<tr>
<td>11. Utility Cost</td>
</tr>
<tr>
<td>12. Annual Building Total Electricity Consumption</td>
</tr>
</tbody>
</table>

**Closest Major City**

The users can select from a drop down menu the city closest to their location. This selection provides weather data for savings calculation. The option to enter their zip code or postal code, will also automatically select the nearest city available.

**Climate Zone Number**

Based on the city selection, an alpha numeric nomenclature that corresponds to the climate zone on the city is displayed. If the user selects a custom weather file, the user will manually enter the climate zone number. Procedure about how to calculate a city climate zone is described in the Climate Zone section, further information can be obtained from ASHRAE.

**Building Type**

The option to select from a drop down menu the building type a user is modeling. These are the options:

- Hospital
- Large Office
- Medium Office
- Apartment
- School

This selection provides the load data and schedules described on the building data section.

**Building Total Design Flow**

This is manually entered by the user, for heating and for cooling. The units are GPM, the default value is 0.
Supply Air Setpoints Cooling and Heating
The cooling and heating setpoints are populated with default values of 55°F for cooling and 80°F for heating. The users have the options to modify these values. The temperature units are in Fahrenheit.

Occupancy Level Selection
Users have the option to select Variable CO2 based outside air control system or Demand Control Ventilation (DCV). The DCV option uses the people schedule included with the selected building type. The constant amount of outside air supplied during occupied hours uses the maximum scheduled occupancy. The default option is Variable CO2 based outside air control system. If users select the second option, the People load % defaults to 95% if the schedule people % is above zero and to 0% if the people schedule is at zero.

Indoor Ambient Setpoints Cooling and Heating
Default values of 73°F for cooling and 68°F for heating are populated on each field, but it can be overridden by the user. The units are in Fahrenheit.

Design Cooling Water ΔT, Design Heating Water ΔT
Default values of 40°F for heating and 12°F for cooling are populate on each field, but each value can be overridden by the user. The units are in Fahrenheit.

Type of Chillers
Users can select from a drop down menu the type of chillers used in the building. This drop down menu includes:
- Water Cooled
- Air Cooled

Quantity of Chillers
The user manually enters the quantity of chillers in the building modeled. The value default is 0.

Total Size of Chillers
The user manually enters the total size of all chillers used in the building modeled. The unit for this entry is in tons. The value default is 0.

Installation Cost
The user manually enters the total cost of installation in dollars. This includes the material and labor costs. This value is used for the Return On Investment (ROI) calculation. The value default is 0.

Utility Cost
The user manually enter the unit electricity cost in dollars per KW/h, a value of 0.12 $/KWh is already populated. This value will be used for the ROI calculation. The user should manually
enter the utility cost price inflation year over year in percentage. A default value of 3% is already populated, but users have the ability to override this value.

**Annual Building Total Electricity Consumption**
The user should manually enter the total annual building electricity consumption in KWh, the value defaults is 0. This value can be obtained from other building modeling applications.

**Load Breakdown Display**
The cooling and heating load pie charts are displayed

This window displays the building type typical load breakdown percentages in pie chart format for cooling and heating. This information is based on the **Building Type** selection and the climate zone. By clicking on “Modify Percentages” the user can change these values. This information can come from other modeling or load calculation applications.

On this screen the user can manually type in the load percentages for each load type in the corresponding window. If the total loads do not add up to 100%, the “OK” button is disabled until all the values entered total up to 100. When “OK” is clicked, it transfers the percentage values into the pie chart and re-scales the proportions accordingly.
Climate Zones

The software models each type of building using its climate zone, as defined by ASRAE in 90.1

CLIMATE ZONE MAP SHOWN BELOW FROM ASHRAE 90.1.
The table below illustrates base cities and their climate zones using ASHRAE 90.1 calculations.

<table>
<thead>
<tr>
<th>ZONES</th>
<th>BASE</th>
<th>ADDITIONAL</th>
<th>ADDITIONAL</th>
<th>ADDITIONAL</th>
<th>ADDITIONAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1A</td>
<td>MIAMI</td>
<td>RIO DE JANEIRO</td>
<td>SANTO DOMINGO</td>
<td>GUADAJARA</td>
<td></td>
</tr>
<tr>
<td>1B</td>
<td>RIYADH</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2A</td>
<td>HOUSTON</td>
<td>JACKSONVILLE</td>
<td>SAN ANTONIO</td>
<td>NEW ORLEANS</td>
<td></td>
</tr>
<tr>
<td>2B</td>
<td>PHOENIX</td>
<td>LIMA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3A</td>
<td>MEMPHIS</td>
<td>ATLANTA</td>
<td>DALLAS</td>
<td>MONTERREY</td>
<td>BUENOS AIRES</td>
</tr>
<tr>
<td>3B</td>
<td>EL PASO</td>
<td>LOS ANGELES</td>
<td>LUBBOCK</td>
<td>SAN DIEGO</td>
<td>MEXICO CITY</td>
</tr>
<tr>
<td>3C</td>
<td>SAN FRANCISCO</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4A</td>
<td>BALTIMORE</td>
<td>NASHVILLE</td>
<td>KANSAS CITY</td>
<td>NEW YORK</td>
<td>VERACRUZ</td>
</tr>
<tr>
<td>4B</td>
<td>ALBUQUERQUE</td>
<td>SACRAMENTO</td>
<td>SEATTLE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4C</td>
<td>SALEM</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5A</td>
<td>CHICAGO</td>
<td>BOSTON</td>
<td>OMAHA</td>
<td>CLEVELAND</td>
<td></td>
</tr>
<tr>
<td>5B</td>
<td>BOISE</td>
<td>DENVER</td>
<td>LAS VEGAS</td>
<td>ALBUQUERQUE</td>
<td>LA PAZ</td>
</tr>
<tr>
<td>5C</td>
<td>VANCOUVER</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6A</td>
<td>BURLINGTON</td>
<td>PORTLAND, m</td>
<td>GREEN BAY</td>
<td>OTTAWA</td>
<td></td>
</tr>
<tr>
<td>6B</td>
<td>HELENA</td>
<td>MEDICINE HAT</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>DULUTH</td>
<td>EDMONTON</td>
<td>QUEBEC CITY</td>
<td>PRINCE GEORGE</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>FAIRBANKS</td>
<td>FT SMITH</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>USA</td>
<td>CANADA</td>
<td>MEXICO</td>
<td>INTERNATIONAL</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
If a city is not on the list a monthly design day can be calculated using the following procedure as illustrated in ASHRAE 90.1.

Enter the maximum outdoor air dry bulb temperature for the month.

From this value and the **Daily Temperature Range**, the dry bulb profile for the month is generated using the equation:

\[
DB(hr) = DBMAX \times RANGE \times (PCR/100)
\]

where,
- \(DBMAX\) = Maximum Dry Bulb Temperature for this month, deg F [deg C]
- \(RANGE\) = Daily Range for this month, deg F [deg C]
- \(PCR\) = Percentage of Daily Range, % (See Table 3.4 below)

**Table 3.4 Percentage of Daily Range**

<table>
<thead>
<tr>
<th>Time, hour</th>
<th>% of Daily Range (PCR)</th>
<th>Time, hour</th>
<th>% of Daily Range (PCR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>87</td>
<td>13</td>
<td>11</td>
</tr>
<tr>
<td>2</td>
<td>92</td>
<td>14</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>96</td>
<td>15</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>99</td>
<td>16</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>100</td>
<td>17</td>
<td>10</td>
</tr>
<tr>
<td>6</td>
<td>98</td>
<td>18</td>
<td>21</td>
</tr>
<tr>
<td>7</td>
<td>93</td>
<td>19</td>
<td>34</td>
</tr>
<tr>
<td>8</td>
<td>84</td>
<td>20</td>
<td>47</td>
</tr>
<tr>
<td>9</td>
<td>71</td>
<td>21</td>
<td>50</td>
</tr>
<tr>
<td>10</td>
<td>66</td>
<td>22</td>
<td>68</td>
</tr>
<tr>
<td>11</td>
<td>39</td>
<td>23</td>
<td>76</td>
</tr>
<tr>
<td>12</td>
<td>23</td>
<td>24</td>
<td>82</td>
</tr>
</tbody>
</table>

*Adapted from Table 2, Chapter 26, 1999 ASHRAE Handbook of Fundamentals

**Weather Data:**

The software also contains a database of historical weather data for most major cities in the USA. This data is obtained from DOE weather data database. This information can be downloaded at: [http://apps1.eere.energy.gov/buildings/energyplus/weatherdata_about.cfm](http://apps1.eere.energy.gov/buildings/energyplus/weatherdata_about.cfm)

**Weather Data Creation Utility, Data Structure:**

In addition if the city is not available the software has a feature that allows the user to create a weather data table specific for that city. The file is created in Excel and the user needs to enter average dry bulb temperatures for each hour of the day, for each month.

**Building Data:**

In order to simplify the user entry the software has a selection of building types. The assumption is that each building type has a similar distribution of HVAC loads regardless of their size. Each building type load distribution is specific and it is defined by the type of structure, occupancy, appliances and OA requirements, it is also affected by its climate zone.
**Building Load Distribution Pie Charts:**
The HVAC loads (skin, OA, lights, people, plugs) are calculated for each type of building. The result are stored on an average load distribution pie chart, this average then is modified for each specific city according to its climate zone. In addition, if the Consultant Engineer requires a different load distribution for the building the load distribution can be modified. The heating distribution is calculated using the external HVAC loads.

**Building Types:**
The user can select between:
- Apartment Building
- Hospital
- Large Office
- Medium Office
- School

**Apartment Building:**
Rectangular 3 story building with 8 apartments and 1 corridor per floor.
Total conditioned zones area= 3,135 M² [33,744 ft²].
See more details in the Appendix.

![APARTMENT AVERAGE COOLING](chart)

**Hospital:**
5 story building, with multiple zones.
Total conditioned zones area= 22,422 M² [241,348 ft²].
See more details in the Appendix.

![HOSPITAL AVERAGE COOLING](chart)
Large Office:
3 story square building with 4 perimeter and 1 core zones per floor with plenum distribution.
Total conditioned zones area= 46,320 M² [498,584 ft²].
See more details on the Appendix.

Medium Office:
3 story square building with 4 perimeter and 1 core zones per floor with plenum distribution.
Total conditioned zones area= 6,643 M² [71,504 ft²].
See more details in the Appendix.
School:
2 story building with multiple zones.
Total conditioned zones area = 19,592 M² [210,886 ft²].
See more details in the Appendix.

![School Average Cooling](image)

Schedules
The modeling uses a typical schedule for each type of building. These schedules follow the ones included in ASHRAE 90.1-2004 Appendix G. See appendix for details.

Calculate
All values must be filled for the Calculate button to be enabled. When Users click on the “Calculate” button the savings are displayed in their respective window.

View Details
This link opens an excel file that contains all the hourly cooling and heating loads calculations and the savings calculations inside each bin.
The following section describes the formulas and procedures used to calculate PI Valves savings:

**Cooling Formulas and Calculations**

**Design GPM Calculation**
The user input value entered for cooling.

**Total Cooling Load Calculation**
The model uses the following formula to calculate the total design cooling load:

\[
BTUh = 500 \times GPM \times \Delta T
\]

Where:
- Cooling GPM = user entered value
- Cooling \( \Delta T \) = user entered value

**Skin Load Factor Calculation (cooling)**
First, calculates the design skin load:

Design skin load \( BTUh \) = skin load \% \times \text{total cooling load}

Where:
- Design skin load \% = found in load breakdown tables for each building type
- Total cooling load = calculated value

Then apply the formula below:

Skin load factor (cooling) = design skin load \( BTUh \) / (max temp (of the whole year) - IAS)

Where:
- Design skin load \( BTUh \) = value calculated above
- Max temp = maximum temperature value in the temperature table for the city selected
- IAS = indoor ambient cooling setpoint temperature, user entered value

**Outside Air Load Factor Calculation (cooling)**
First, calculates the outside air (OA) load:

Design OA load \( BTUh \) = OA load \% \times \text{total cooling load}

Where:
OA load % = found in load breakdown tables for each building type
Total cooling load = calculated value
Then apply the formula below:

OA load factor = design OA load BTUh / (max temp - SAS)

Where:
Design OA load BTUh = value calculated above
Max temp = maximum temperature value in the temperature table for the city selected
SAS = supply air setpoint temperature, user entered value

**Skin Load Calculation (cooling)**
Applies the following formula:

Cooling skin load BTUh = (outdoor temp -IAS) x skin load factor (for every hour, day for the year)

Where:
Outdoor temp = temperature value for each hour in the temperature table for the city selected
IAS = indoor ambient cooling setpoint temperature, user entered value
Skin load factor = calculated value

The model enters the resulting value in the skin load column for each hour in the cooling load table.

**OA Load Calculation (cooling)**
Applies the following formula:

Cooling OA load BTUh = ((outdoor temp -SAS) X OA load factor (for every hour, day for the year)) x (people load %/100)

Where:
Outdoor temp = temperature value for each hour in the temperature table for the city selected
SAS = supply air cooling setpoint temperature, user entered value
OA load factor = calculated value
People load % = value found in the people schedule for that hour and day type

Enters the resulting value in the OA load columns (week, Saturday or Sunday) for each hour in the cooling load table.
**Lighting Load Calculation (cooling)**

First, calculates the design lighting load:

Design lighting load BTUh = lighting load % x cooling load

Where:
Lighting load % = value found in load breakdown tables for each building type
Cooling load = calculated value

Then calculate actual lighting load:

Lighting load BTUh = (design lighting load x hourly %) / 100 (for every hour, day for the year)

Where:
Design lighting load = value calculated above
Hourly % = percentage value for each hour and day of the week (week, Saturday or Sunday) found in the lighting schedule table for each building type and city

Enters the resulting value in the lighting load columns (week, Saturday or Sunday) for each hour in the cooling load table.

**People Load Calculation (cooling)**

First, calculate the design people load:

Design people load BTUh = people load % x cooling load

Where:
People load % = value found in load breakdown tables for each building type
Cooling load = calculated value

Then calculate actual people load:
If the value selected on ventilation is **Demand Control Ventilation** the model uses the people schedule if the value is **Constant Amount of Outside Air** then the **People Load %** defaults to 95% if the schedule people % is above zero, and to 0% if the schedule people is at zero.

People load BTUh= (design people load x hourly %) / 100 (for every hour, day for the year)

Where:
Design people load = value calculated above
Hourly % = percentage value for each hour and day of the week (week, Saturday or Sunday) found in the people schedule table for each building type and city
Enters the resulting value in the people load columns (week, Saturday or Sunday) for each hour in the cooling load table.

**Plug Load Calculation (cooling)**

First, calculates the design plug load:

Design plug load BTUh = plug load % x cooling load

Where:
Plugging load % = value found in load breakdown tables for each building type
Cooling load = calculated value

Then actual plug load is calculated:

Plug load BTUh = (design plug load x hourly %) / 100 (for every hour, day for the year)

Where:
Design plug load = value calculated above
Hourly % = percentage value for each hour and day of the week (week, Saturday or Sunday) found in the people schedule table for each building type and city

Enters the resulting value in the plug load columns (week, Saturday or Sunday) for each hour in the cooling load table.

**Sum of Hourly Loads (cooling)**

The total load is summed for each hour and day type (week, Saturday or Sunday). If the total cooling load is greater than zero, the cooling load is used for that hour. If the total cooling load is negative for that hour, then 40% of the internal loads including outside air is totaled (outside air, lighting, people, and plug loads). This 40% internal load represents the core zone cooling load even in the winter. If the outside air load is negative in the winter, it may balance the core cooling load. If the core load is positive (outside air, lighting, people and plug), this load will be used as the hourly cooling load. The sum of all hours for each bin will be displayed on the details window.

**Total Cooling Load Calculation**

The model divides the total hourly cooling load by the total design load and gets the hourly percentage of design load.

Hourly percentage of design load = total hourly cooling load / total design load x 100

Where:
Total hourly load BTUh = sum of hourly loads
Total design load BTUh = design cooling load

Then the model enters the percentages in each column for perimeter zones (P Zones) and core zones (C Zones) for each hour and day type. If the building has periods of time that the HVAC is not allowed to run, we eliminate those hours (see HVAC Schedule). Then multiplies each hour by the total days of the month for that day type (week, Saturday or Sunday) and sort the number of hours into % load bins (5%, 10%, 20%, 30%, etc..) based on the load percentage, until we get the number of hours at 100%.

Example:
For week days, the load represents 1% of the design load, 1% on Saturday and 0% on Sunday (HVAC off) for hour #7.
If there are 21 week days in this particular month, and 5 weekends, enter 26 in the 5% column (21 weekdays + 5 Saturdays + 0 Sundays) for hour #7.
Then repeat for the 24 hours of each typical day of each month of the year.

Then total up all the hours for the year into each bin: 5%, 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90% and 100%.

The sum of all hours for each bin is displayed on the details window.

**PI Valves Secondary Pump Hourly Flow Calculation (cooling)**
The model applies the following formula:

PI valves secondary pump hourly chilled water flow (GPM) = Cooling Design Flow (GPM) x % Load x Hours for that % (for every hour, day for the year)

Where:
Cooling design flow= User entered value
% load hours= load % in increments of 10%
Hours= hours for each BIN

The model then multiplies each flow value by the total number of days for that hour.

The total values for each bin are displayed in the details window.
The sum of all the BINs is the total cooling secondary pump annual savings.

**Pressure Dependent Valves Secondary Pump Flow Calculation (cooling)**
The model applies the following formula to each total value for each BIN:

The pressure dependent water flow is calculated for each BIN using a relationship obtained by simulating a system with pressure dependent flow valves with pressure fluctuations from 5-30
psi. The calculations were made following the logic from ASHRAE publication: “A New Approach to Modeling the Energy Performance of Hydronic Systems with Pressure Dependent Control Valves, McHenry Wallace Jr”.

Where:
PIV flow = flow, calculated value

The total values for each bin is displayed on the details window. The sum of all the BINs is the total Pressure Dependent valves cooling secondary pump annual consumption.

**Chiller Plant Pumps Savings Calculation**

**Chiller Individual Capacity**
The model divides the total chiller capacity by the number of chillers to get the individual capacity of each chiller.

Chiller capacity tons = Total chiller capacity / number of chillers

Where:
Total chiller capacity tons = entered value
Number of chillers = entered value

**Water Cooled Chillers**
This calculation process is used if the type of chiller selected is water cooled.

First, calculates the primary flow:

Primary flow (GPM) = chiller capacity x 24 / ΔT

Where:
Chiller capacity = calculated value
ΔT = user input for cooling

If the calculated loop flow from the pump savings calculation is larger than the calculated flow for the first chiller, more chillers must be started until the primary flow is larger than the secondary flow. If both flows (PIV flow) and (pressure dependent flow) require the use of the same number of chillers, then ignore the additional chiller flow for that hour. If the flow requires additional chillers this is multiplied by the condensing and the chilled water pumps flow.

We need to convert this extra water in extra KW for each pump, condensing + primary chilled water. We can assume 19 watts per GPM for the condenser and 22 W/GPM for Primary chilled
water flow, 3GPM/ton for the condensing, 2.4 GPM/ton CHW pump.(Values from ASHRAE 90.1-2010 Appendix G)

For the pumps GPM usage the model uses the following formula.

Additional condensing pumps GPM per chiller= If (PD Chillers > PIV Chillers, then (3 x ton x Number of Hours)*(PD Chillers - PIV chillers), else 0).

Additional CHW pumps GPM per chiller= If (PD Chillers > PIV Chillers, then (2.4 x ton x Number of Hours)*(PD Chillers - PIV chillers), else 0).

Then recalculates the ΔT based of flow.

ΔT = total cooling building load / (500 x total pressure dependent flow).

Where:
Total cooling building load BTUh = calculated value
Total pressure dependent flow GPM = pressure dependent flow value.

**Air Cooled Chillers**
This calculation process is used if the user selects air cooled.

The models use the same procedure as before but the condensing water flow is 0.

**Secondary Pump Flow Savings Calculation (cooling)**
Apply the following formula for savings in %:

Flow difference GPM = pressure dependent valve flow – pressure independent valve flow.

Where:
Pressure dependent valve Secondary pumps flow GPM = calculated value.
Pressure independent valve flow GPM = calculated value.

Then:

Total flow difference GPM = flow difference x total hours.

Where:
Flow difference GPM = value calculated above.
Total hours = calculated total hours for each bin.

Then adds up the total flows in each bin for the flow differences and the pressure dependent flow.

PIV Energy Modeling Application Guide
Then:

Secondary pump savings cooling % = (flow difference total for all bins / total pressure dependent flow for all bins) \times 100.

The model applies the following formula for savings in BTU:

Total cooling savings KW = Flow (GPM) \times 22(W/GPM) / 1000.

Where:
Flow = Total flow difference GPM calculated above.

The result is rounded to the nearest unit.

Then:

Total cooling savings BTU = total cooling savings KW \times 3412.

Where:
Total cooling savings KW = KW calculated above.

**Total Savings Chiller Plant Pumps**

To obtain the KWh of the chilled water pumps use the follow formula:

Total cooling savings KW = Flow (GPM) \times 22(W/GPM) / 1000.

To obtain the KWh of the condensing water pumps use the follow formula:

Total cooling savings KW = Flow (GPM) \times 19(W/GPM) / 1000.

Where:
Flow= total annual GPM calculated from the hourly BIN.

If it is a water cooled chiller both values will be used on the total savings calculation, if it is an air cooled the condenser water pump is zero.
Heating Formulas and Calculations

Design GPM Calculation
The model uses the user input value entered in for heating.

Total heating Load Calculation
Uses the following formula to calculate the total design heating load:

\[ \text{BTU}h = 500 \times \text{GPM} \times \Delta T. \]

Where:
- GPM = calculated value
- Heating \( \Delta T \) = user input in for heating

Skin Load Factor Calculation (heating)
First, calculate the design skin load:

Design skin load BTU\( h \) = skin load % x total heating load.

Where:
- Design skin load % = found in load breakdown tables for each building type
- Total heating load = value calculated with the heating \( \Delta T \)
- This value should be positive (+)

Then apply the formula below:

Skin load factor (heating) = design skin load BTU\( h \) / (min temp (of the whole year) - IAS)

Where:
- Design skin load BTU\( h \) = value calculated above
- Min temp = minimum temperature value in the temperature table for the city selected
- IAS = indoor ambient heating setpoint temperature, user entered value

Outside Air Load Factor Calculation (heating)
First, calculate the outside air (OA) load:

Design OA load BTU\( h \) = OA load % x total heating load
This value should be positive (+)

Where:
OA load % = found in load breakdown tables for each building type
Total heating load = calculated value

Then apply the formula below:

OA load factor (heating) = design OA load BTUh / (min temp (of the whole year) - SAS)

Where:
Design OA load BTUh = value calculated above
Min temp = minimum temperature value in the temperature table for the city selected
SAS = supply air heating setpoint temperature, user entered value

**Skin Load Calculation (heating)**

Apply the following formula:

Heating skin load BTUh = (outdoor temp -IAS) x skin load factor (for every hour, day for the year)
This value should be positive (+)

Where:
Outdoor temp = temperature value for each hour in the temperature table for the city selected
IAS = indoor ambient heating setpoint temperature, user entered value
Skin load factor = calculated value

The resulting value is entered in the skin load column for each hour in the heating load table.

**OA Load Calculation (heating)**

Apply the following formula:

Heating OA load BTUh = (outdoor temp -SAS) X OA load factor (for every hour, day for the year)
This value should be positive (+)

Where:
Outdoor temp = temperature value for each hour in the temperature table for the city selected
SAS = supply air heating setpoint temperature, user entered value
OA load factor = calculated value

Enter the resulting value in the OA load columns (week, Saturday or Sunday) for each hour in the heating load table.

**Lighting Load Calculation (heating)**

First, calculate the design lighting load:
Design lighting load BTUh = lighting load % x Cooling load

Where:
Lighting load % = value found in load breakdown tables for each building type
Heating load = calculated value

Then calculate actual lighting load:

Lighting load BTUh = (design lighting load x hourly %) / 100 (for every hour, day for the year)

Where:
Design lighting load = value calculated above
Hourly % = percentage value for each hour found in the lighting schedule table for each building type and city

Enters the resulting value in the lighting load columns (week, Saturday or Sunday) for each hour in the heating load table.

**People Load Calculation (heating)**

First, calculates the design people load:

Design people load BTUh = people load % x cooling load

Where:
People load % = If the value selected for ventilation is Demand Control Ventilation the model uses the people schedule for the type of building. If the value is Constant Amount of Outside Air then the People Load % defaults to 95% if the schedule people % is above zero, and to 0% if the schedule people is at zero.

Heating load = calculated value

Then calculates actual people load:

People load BTUh = (design people load x hourly %) / 100 (for every hour, day for the year)

Where:
Design people load = value calculated above
Hourly % = percentage value for each hour found in the people schedule table for each building type and city

The model enters the resulting value in the people load columns (week, Saturday or Sunday) for each hour in the heating load table.
Plug Load Calculation (heating)

First, calculate the design plug load:

Design plug load BTUh = plug load % x cooling load

Where:
Plug load % = value found in load breakdown tables for each building type
Heating load = calculated value

Then calculate actual plug load:

Plug load BTUh = (design plug load x hourly %) / 100 (for every hour, day for the year)

Where:
Design plug load = value calculated above
Hourly % = percentage value for each hour found in the people schedule table for each building type and city

Enter the resulting value in the plug load columns (week, Saturday or Sunday) for each hour in the heating load table.

Sum of Hourly Loads (heating)

The total load is summed for each hour and day type (week, Saturday or Sunday). 60% of the internal loads (Lighting, people and plug) plus 100% of the skin and OA load is totaled. The 40% internal load represents the core zone cooling load even in the winter. The core loads is zero on the heating calculations.

Total Heating Load Calculation

Divide the total hourly heating load by the total design load and get the hourly percentage of design load.

Hourly percentage of design load = total hourly heating load / total design load x 100

Where:
Total hourly heating load BTUh = sum of hourly loads, calculated value
Total design load BTUh = design cooling load, calculated value

The model multiplies each hour by the total days of the month for that day type (week, Saturday or Sunday) and sort the number of hours into % load bins (5%, 10%, 20%, 30%, etc..) based on the load percentage, until we get the number of hours at 100%. If the percentage is negative, the hours into the bins for that load percentage are not added.
Then total up all the hours for the year into each bin: 5%, 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90% and 100%.

The values are displayed on the details page.

**Hourly Flow Calculation (heating)**

Apply the following formula:

PI valves secondary pump hourly chilled water flow (GPM) = heating design flow (GPM) x % load x hours for that % (for every hour, day for the year)

Where:
- Heating design flow = User entered value
- % Load Hours = load % in increments of 10%
- Hours = Hours for each BIN

The model multiplies each flow value by the total number of days for that hour.

**Pressure Dependent Valve Flow Calculation (heating)**

Apply the following formula:

Pressure dependent water flow is calculated for each BIN using a relationship obtained by simulating a system with pressure dependent flow valves with pressure fluctuations from 5-30 psi. The calculations were made following the logic from ASHRAE publication: “A New Approach to Modeling the Energy Performance of Hydronic Systems with Pressure Dependent Control Valves, McHenry Wallace Jr.”

Where:
- PIV flow = flow, calculated value

Enter the total value into the heating flow data table under pressure dependent valve.

**Savings Calculation (heating)**

Apply the following formula for savings in %:

Flow difference GPM = pressure dependent valve flow – PIV flow

Where:
- Pressure dependent valve flow GPM = flow, calculated value
- PIV flow GPM = flow, calculated value

Then:
Total flow difference GPM = flow difference x total hours

Where:
Flow difference GPM = value calculated above
Total hours = total hours for each bin, calculated value

Then the model adds up the total flows in each bin for the flow differences and the pressure dependent flow.

Then:

Savings heating % = (flow difference total for all bins / total pressure dependent flow for all bins) x 100

Then recalculate the ΔT based of flow

ΔT = Design heating load / (500 x pressure dependent flow)

Where:
Design heating load BTUh = calculated value
Pressure dependent flow GPM = pressure dependent flow value

Apply the following formula for savings in BTU:

Total heating savings KW = Flow (GPM) x 19(W/GPM) / 1000

Where:
Flow = Total flow difference GPM calculated above

The result is rounded to the nearest unit.

Then:

Total heating savings BTU = total heating savings KW x 3412

Where:
Total heating savings KW = KW calculated above

**Dollar Savings Calculation**

Apply the following formula:

Savings ($) = Total KWh Savings x Utility Cost

PIV Energy Modeling Application Guide
Where:
Utility Cost ($): user entered value

For Cooling:
Total KWh Savings: Secondary Pump savings ($) + Chilled Water Pump Savings ($) + Condensing Water Pump Savings ($)

For Heating:
Total KWh Savings: calculated value

Total Savings ($) = Cooling Savings + Heating Savings

\textit{\textbf{R.O.I. Calculation}}

First calculate the installation cost difference between the pressure dependent valves and PIV’s.

\text{Installation cost difference ($) = pressure dependent cost – PIV cost}

Where:
Pressure dependent cost ($) = entered value
PIV cost ($) = entered value

Then:

\text{Year(s) = installation cost difference / Total Savings}

Where:
Installation cost difference ($) = value calculated above
Total Savings ($) = calculated value (adjusted with inflation rate)

Inflation adjustment:

\text{Future ROI Value= Total Savings / (1+%inflation) ^ years}

Where: Total Savings ($): calculated value
% Inflation: entered value
Years: calculated value
**Possible LEED Point Calculation**

The model divides the total savings in KWh by the Annual Building Electric Consumption, entered value, and then converts this value to percent. For the LEED points uses the following table:

<table>
<thead>
<tr>
<th>% Savings Range</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.5</td>
<td>3.5</td>
</tr>
<tr>
<td>3.5</td>
<td>5.5</td>
</tr>
<tr>
<td>5.5</td>
<td>7.5</td>
</tr>
<tr>
<td>7.5</td>
<td>9.5</td>
</tr>
<tr>
<td>9.5</td>
<td>11.5</td>
</tr>
<tr>
<td>11.5</td>
<td>13.5</td>
</tr>
<tr>
<td>13.5</td>
<td>15.5</td>
</tr>
<tr>
<td>15.5</td>
<td>17.5</td>
</tr>
<tr>
<td>17.5</td>
<td>19.5</td>
</tr>
<tr>
<td>19.5</td>
<td>21.5</td>
</tr>
<tr>
<td>21.5</td>
<td>23.5</td>
</tr>
<tr>
<td>23.5</td>
<td>25.5</td>
</tr>
<tr>
<td>25.5</td>
<td>27.5</td>
</tr>
<tr>
<td>27.5</td>
<td>29.5</td>
</tr>
<tr>
<td>29.5</td>
<td>31.5</td>
</tr>
<tr>
<td>31.5</td>
<td>33.5</td>
</tr>
<tr>
<td>33.5</td>
<td>35.5</td>
</tr>
<tr>
<td>35.5</td>
<td>37.5</td>
</tr>
<tr>
<td>37.5</td>
<td>39.5</td>
</tr>
</tbody>
</table>
Appendix

Building Zones and Load Calculations

Apartment Details
## Hospital Details

### Hospital Zone Summary

<table>
<thead>
<tr>
<th>Zone Name</th>
<th>Condition (YN)</th>
<th>Multiplier (Y/N)</th>
<th>Area (ft²)</th>
<th>Volume (ft³)</th>
<th>Flow-In Ceiling Height (ft)</th>
<th>Gene Ray Gap (in)</th>
<th>Window Glass Area (ft²)</th>
<th>People (M/F) People</th>
<th>Lights (Watt)</th>
<th>Electric Flag and Process (Watt)</th>
<th>Gas Flag and Process (Watt)</th>
<th>SWH</th>
<th>Ventilation (Total/Person) (ft³/hr)</th>
<th>Exhaust (L/S)</th>
<th>Installation (AC/H)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basement</td>
<td>Y</td>
<td></td>
<td>1</td>
<td>4000</td>
<td>1500</td>
<td>120</td>
<td>1.0</td>
<td>0/0</td>
<td>2000</td>
<td>0.08</td>
<td>0.01</td>
<td></td>
<td>251.87</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>ER_Cam1_Multi_Fix_1</td>
<td>Y</td>
<td></td>
<td>4</td>
<td>1200</td>
<td>16000</td>
<td>110</td>
<td>1</td>
<td>50/50</td>
<td>5</td>
<td>0.80</td>
<td>0.80</td>
<td></td>
<td>211.31</td>
<td>20.67</td>
<td></td>
</tr>
<tr>
<td>ER_Trauma_Multi_Fix_1</td>
<td>Y</td>
<td></td>
<td>4</td>
<td>1200</td>
<td>16000</td>
<td>100</td>
<td>1</td>
<td>50/50</td>
<td>5</td>
<td>0.80</td>
<td>0.80</td>
<td></td>
<td>211.31</td>
<td>20.67</td>
<td></td>
</tr>
<tr>
<td>ER_Trauma_Multi_Fix_1</td>
<td>Y</td>
<td></td>
<td>4</td>
<td>1200</td>
<td>16000</td>
<td>100</td>
<td>1</td>
<td>50/50</td>
<td>5</td>
<td>0.80</td>
<td>0.80</td>
<td></td>
<td>211.31</td>
<td>20.67</td>
<td></td>
</tr>
<tr>
<td>ER_Trauma_Multi_Fix_1</td>
<td>Y</td>
<td></td>
<td>4</td>
<td>1200</td>
<td>16000</td>
<td>100</td>
<td>1</td>
<td>50/50</td>
<td>5</td>
<td>0.80</td>
<td>0.80</td>
<td></td>
<td>211.31</td>
<td>20.67</td>
<td></td>
</tr>
<tr>
<td>ER_Trauma_Multi_Fix_1</td>
<td>Y</td>
<td></td>
<td>4</td>
<td>1200</td>
<td>16000</td>
<td>100</td>
<td>1</td>
<td>50/50</td>
<td>5</td>
<td>0.80</td>
<td>0.80</td>
<td></td>
<td>211.31</td>
<td>20.67</td>
<td></td>
</tr>
</tbody>
</table>

### AVERAGE COOLING

- **SKIN**: 25%
- **LIGHTING**: 21%
- **PEOPLE**: 16%
- **PUCLOAD**: 15%
- **OA**: 15%
## Schedules:

### HVAC Schedules

<table>
<thead>
<tr>
<th>Hour</th>
<th>Apartment</th>
<th>Hospital</th>
<th>Large Office</th>
<th>Medium Office</th>
<th>School</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>On</td>
<td>On</td>
<td>On</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td>2</td>
<td>On</td>
<td>On</td>
<td>On</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td>3</td>
<td>On</td>
<td>On</td>
<td>On</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td>4</td>
<td>Off</td>
<td>Off</td>
<td>Off</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td>5</td>
<td>Off</td>
<td>Off</td>
<td>Off</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td>6</td>
<td>Off</td>
<td>Off</td>
<td>Off</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td>7</td>
<td>Off</td>
<td>Off</td>
<td>Off</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td>8</td>
<td>Off</td>
<td>Off</td>
<td>Off</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td>9</td>
<td>Off</td>
<td>Off</td>
<td>Off</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td>10</td>
<td>Off</td>
<td>Off</td>
<td>Off</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td>11</td>
<td>Off</td>
<td>Off</td>
<td>Off</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td>12</td>
<td>Off</td>
<td>Off</td>
<td>Off</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td>13</td>
<td>Off</td>
<td>Off</td>
<td>Off</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td>14</td>
<td>Off</td>
<td>Off</td>
<td>Off</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td>15</td>
<td>Off</td>
<td>Off</td>
<td>Off</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td>16</td>
<td>Off</td>
<td>Off</td>
<td>Off</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td>17</td>
<td>Off</td>
<td>Off</td>
<td>Off</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td>18</td>
<td>Off</td>
<td>Off</td>
<td>Off</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td>19</td>
<td>Off</td>
<td>Off</td>
<td>Off</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td>20</td>
<td>Off</td>
<td>Off</td>
<td>Off</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td>21</td>
<td>Off</td>
<td>Off</td>
<td>Off</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td>22</td>
<td>Off</td>
<td>Off</td>
<td>Off</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td>23</td>
<td>Off</td>
<td>Off</td>
<td>Off</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td>24</td>
<td>Off</td>
<td>Off</td>
<td>Off</td>
<td>Off</td>
<td>Off</td>
</tr>
</tbody>
</table>

### Lighting Schedules

<table>
<thead>
<tr>
<th>Hour</th>
<th>Apartment</th>
<th>Hospital</th>
<th>Large Office</th>
<th>Medium Office</th>
<th>School</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>20</td>
<td>20</td>
<td>10</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>2</td>
<td>20</td>
<td>20</td>
<td>10</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td>20</td>
<td>20</td>
<td>10</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>4</td>
<td>10</td>
<td>10</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>5</td>
<td>10</td>
<td>10</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>6</td>
<td>20</td>
<td>20</td>
<td>10</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>7</td>
<td>40</td>
<td>40</td>
<td>10</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>8</td>
<td>50</td>
<td>50</td>
<td>10</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>9</td>
<td>40</td>
<td>40</td>
<td>10</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>10</td>
<td>40</td>
<td>40</td>
<td>10</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>11</td>
<td>25</td>
<td>30</td>
<td>10</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>12</td>
<td>25</td>
<td>30</td>
<td>10</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>13</td>
<td>25</td>
<td>30</td>
<td>10</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>14</td>
<td>25</td>
<td>30</td>
<td>10</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>15</td>
<td>25</td>
<td>30</td>
<td>10</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>16</td>
<td>25</td>
<td>30</td>
<td>10</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>17</td>
<td>25</td>
<td>30</td>
<td>10</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>18</td>
<td>25</td>
<td>30</td>
<td>10</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>19</td>
<td>60</td>
<td>60</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>20</td>
<td>80</td>
<td>70</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>21</td>
<td>90</td>
<td>80</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>22</td>
<td>80</td>
<td>70</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>23</td>
<td>60</td>
<td>50</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>24</td>
<td>30</td>
<td>30</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
</tbody>
</table>
### People Schedules

<table>
<thead>
<tr>
<th>Hour</th>
<th>Apartment</th>
<th>Hospital</th>
<th>Large Office</th>
<th>Medium Office</th>
<th>School</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>9:00</td>
<td>9:00</td>
<td>9:00</td>
<td>9:00</td>
<td>9:00</td>
</tr>
<tr>
<td>2</td>
<td>9:00</td>
<td>9:00</td>
<td>9:00</td>
<td>9:00</td>
<td>9:00</td>
</tr>
<tr>
<td>3</td>
<td>9:00</td>
<td>9:00</td>
<td>9:00</td>
<td>9:00</td>
<td>9:00</td>
</tr>
<tr>
<td>4</td>
<td>9:00</td>
<td>9:00</td>
<td>10:00</td>
<td>9:00</td>
<td>9:00</td>
</tr>
<tr>
<td>5</td>
<td>9:00</td>
<td>9:00</td>
<td>9:00</td>
<td>9:00</td>
<td>9:00</td>
</tr>
<tr>
<td>6</td>
<td>9:00</td>
<td>9:00</td>
<td>9:00</td>
<td>9:00</td>
<td>9:00</td>
</tr>
<tr>
<td>7</td>
<td>10:00</td>
<td>10:00</td>
<td>10:00</td>
<td>10:00</td>
<td>10:00</td>
</tr>
<tr>
<td>8</td>
<td>10:00</td>
<td>10:00</td>
<td>10:00</td>
<td>10:00</td>
<td>10:00</td>
</tr>
<tr>
<td>9</td>
<td>10:00</td>
<td>10:00</td>
<td>10:00</td>
<td>10:00</td>
<td>10:00</td>
</tr>
<tr>
<td>10</td>
<td>10:00</td>
<td>10:00</td>
<td>10:00</td>
<td>10:00</td>
<td>10:00</td>
</tr>
<tr>
<td>11</td>
<td>10:00</td>
<td>10:00</td>
<td>10:00</td>
<td>10:00</td>
<td>10:00</td>
</tr>
<tr>
<td>12</td>
<td>10:00</td>
<td>10:00</td>
<td>10:00</td>
<td>10:00</td>
<td>10:00</td>
</tr>
<tr>
<td>13</td>
<td>10:00</td>
<td>10:00</td>
<td>10:00</td>
<td>10:00</td>
<td>10:00</td>
</tr>
<tr>
<td>14</td>
<td>10:00</td>
<td>10:00</td>
<td>10:00</td>
<td>10:00</td>
<td>10:00</td>
</tr>
<tr>
<td>15</td>
<td>10:00</td>
<td>10:00</td>
<td>10:00</td>
<td>10:00</td>
<td>10:00</td>
</tr>
<tr>
<td>16</td>
<td>10:00</td>
<td>10:00</td>
<td>10:00</td>
<td>10:00</td>
<td>10:00</td>
</tr>
<tr>
<td>17</td>
<td>10:00</td>
<td>10:00</td>
<td>10:00</td>
<td>10:00</td>
<td>10:00</td>
</tr>
<tr>
<td>18</td>
<td>10:00</td>
<td>10:00</td>
<td>10:00</td>
<td>10:00</td>
<td>10:00</td>
</tr>
<tr>
<td>19</td>
<td>10:00</td>
<td>10:00</td>
<td>10:00</td>
<td>10:00</td>
<td>10:00</td>
</tr>
<tr>
<td>20</td>
<td>10:00</td>
<td>10:00</td>
<td>10:00</td>
<td>10:00</td>
<td>10:00</td>
</tr>
<tr>
<td>21</td>
<td>10:00</td>
<td>10:00</td>
<td>10:00</td>
<td>10:00</td>
<td>10:00</td>
</tr>
<tr>
<td>22</td>
<td>10:00</td>
<td>10:00</td>
<td>10:00</td>
<td>10:00</td>
<td>10:00</td>
</tr>
<tr>
<td>23</td>
<td>10:00</td>
<td>10:00</td>
<td>10:00</td>
<td>10:00</td>
<td>10:00</td>
</tr>
<tr>
<td>24</td>
<td>10:00</td>
<td>10:00</td>
<td>10:00</td>
<td>10:00</td>
<td>10:00</td>
</tr>
</tbody>
</table>