**Building Source**

The building set is based on research carried out at the Pacific Northwest Laboratory (PNL). The United States office building stock was categorized using a statistically valid sample of the nation's office building sector known as the Commercial Building Energy Consumption Survey (CBECS) [EIA 1986, 1989]. The categories were developed using a statistical technique known as cluster analysis based on attributes such as size, age and location. Twenty buildings representing the existing building stock as of 1979 were described by Briggs et al (1987) and five buildings representing expected construction between 1980 and 1995 were described by Crawley et al (1992). A summary of the representative buildings is shown in Table 1.

**Table 1: Summary of Office Building Set**

| Bldg No | Floor Area $m^2$ ($ft^2$) | Floors | Year Built | Location |
|---|---|---|---|---|
| 1 | 576 (6,200) | 1 | 1939 | Indianapolis, Indiana |
| 2 | 604 (6,500) | 3 | 1920 | Toledo, Ohio |
| 3 | 743 (8,000) | 1 | 1954 | El Paso, Texas |
| 4 | 929 (10,000) | 2 | 1970 | Washington D.C. |
| 5 | 1,486 (16,000) | 2 | 1969 | Madison, Wisconsin |
| 6 | 2,044 (22,000) | 2 | 1953 | Lake Charles, Louisiana |
| 7 | 2,601 (28,000) | 4 | 1925 | Des Moines, Iowa |
| 8 | 3,716 (40,000) | 5 | 1908 | St. Louis, Missouri |
| 9 | 3,902 (42,000) | 2 | 1967 | Las Vegas, Nevada |
| 10 | 4,274 (46,000) | 3 | 1967 | Salt Lake City, Utah |
| 11 | 13,935 (150,000) | 6 | 1968 | Cheyenne, Wyoming |
| 12 | 16,723 (180,000) | 6 | 1918 | Portland, Oregon |
| 13 | 26,942 (290,000) | 11 | 1929 | Pittsburgh, Pennsylvania |
| 14 | 26,942 (290,000) | 6 | 1948 | Amarillo, Texas |
| 15 | 27,871 (300,000) | 12 | 1966 | Raleigh, North Carolina |
| 16 | 28,800 (310,000) | 10 | 1964 | Fort Worth, Texas |
| 17 | 53,884 (580,000) | 19 | 1965 | Minneapolis, Minnesota |
| 18 | 67,819 (730,000) | 10 | 1957 | Boston, Massachusetts |
| 19 | 68,748 (740,000) | 28 | 1967 | New York, New York |
| 20 | 230,399 (2,480,000) | 45 | 1971 | Los Angeles, California |
| 21 | 1,022 (11,000) | 2 | 1986 | Greensboro, North Carolina |
| 22 | 1,208 (13,000) | 2 | 1986 | Tucson, Arizona |
| 23 | 1,579 (17,000) | 2 | 1986 | Scranton, Pennsylvania |
| 24 | 38,090 (410,000) | 9 | 1986 | Pittsburgh, Pennsylvania |
| 25 | 46,452 (500,000) | 14 | 1986 | Savannah, Georgia |

To simulate the energy use of the buildings the PNL research team used the DOE2 program (Curtis et al. 1984). The necessary input variables for use in DOE2 were derived from six principal sources for this process: the NBECS building characteristics profiles, calibration against NBECS billing data, inferred from end-use metered data, generated from models based on technical literature, and inferred from characteristic data (Taylor et al. 1989 and Bonneville Power Administration 1989). The assumptions used in determining the DOE2 input parameters are discussed in detail in the PNL project report.

Occupancy, lighting, receptacle, and service hot water load schedules were determined by the PNL project team from directly measured data from the End-Use Load and Consumer Assessment Program (ELCAP) conducted by PNL. Schedules for infiltration, hvac operation, ventilation, heating setpoints, and cooling setpoints were also determined from the measured data. The techniques used to develop these schedules are described in the PNL project report.

**Physical Model**

In order to utilize the TRNSYS Type 56 model, the physical parameters that define the buildings need to be entered. These parameters are taken from the PNL report and a description of the derivation of the parameters is contained in those reports. How those parameters were used in the TRNSYS models will be discussed in this report.

Floor Plans

Floor plans for the individual buildings were contained in the PNL reports. The plans were simplified to be rather generic and did not include any details as to the interior layout/construction of the buildings. They simply laid out the exterior dimensions and orientations of the buildings. The individual building schematics are presented later in the report.

Walls/Roofs/Windows

Since the building modeling done in the PNL reports utilized the DOE2 program, the wall types for the buildings were described as combination of DOE2 layers. To replicate these walls in TRNSYS the DOE2 layers were added into a new library of TRNSYS wall types. The DOE2 layers used and their physical properties are shown in Table 2. Rather than specifying a specific type of insulation for each individual building, a single type of insulation properties was selected for the buildings and then the thickness varied for the individual buildings. The insulation layer used in the walls and roofs had a u-value of 2.38 $W/m^2$ K (0.42 Btu/h $ft^2$ R). With the wall and roof descriptions from the PNL report of the DOE2 models, the same wall and roof types could be specified in TRNSYS by combining the layers in the appropriate order to create a wall type. Rather than specifying the layers for the slab and ceilings between floors, they were simply assigned a u-value that matched the value used in the DOE2 model. Once the wall types were created in TRNSYS they were checked against the DOE2 models to ensure that the u-values matched.

No data was provided in the PNL reports for the internal walls of the buildings, so walls constructed of gypsum board and 2X4 studs were used in the models. For the capacitance of the zones, ten times the capacitance of air was used for all occupied zones to account for the materials and furnishings in the zones.

According to the PNL report, the windows used in the DOE2 models were either single or double pane windows with wood, metal or improved metal frames. To model the windows in TRNSYS the standard TRNSYS single or double pane window was selected and then the u-value of the frame was adjusted to the appropriate value. The window and frame u-values are shown in Table 3. The total area of the window surface is not specified in the report. Instead it is report as the wall-to-window ratio (WWR). In the TRNSYS model this ratio is applied to non-plenum portion of the exterior walls.

**Table 2: Wall/Roof Layers**

| DOE2 Code | Description | Thickness | Conductivity | Density | Spec. Heat | Resistance |
|---|---|---|---|---|---|---|
| | | m (ft) | kJ/hr-m-K (Btu/hr-ft-F) | $kg/m^3$ ($lb/ft^3$) | kJ/kg-K (Btu/lb-F) | $hr\text{-}m^2\text{-}K/kJ$ ($hr\text{-}ft^2\text{-}F/Btu$) |
| AS01 | Aluminum or steel siding | 0.001524 (0.005) | 161.97 (26) | 7690 (480) | 0.42 (0.1) | |
| BK01 | 10 cm (4 in) common brick | 0.10159 (0.3333) | 2.596 (0.4167) | 1920 (120) | 0.84 (0.2) | 0.039 (0.8) |
| BK02 | 20 cm (8 in) common brick | 0.20321 (0.6667) | 2.596 (0.4167) | 1920 (120) | 0.84 (0.2) | 0.078 (1.6) |
| BK05 | 10 cm (4 in) face brick | 0.10159 (0.3333) | 4.720 (0.7576) | 1920 (120) | 0.92 (0.22) | 0.021 (0.44) |
| BR01 | 0.95 cm (3/8 in) built-up roofing | 0.00954 (0.0313) | 5.851 (0.939) | 1120 (70) | 1.5 (0.35) | 0.016 (0.33) |
| CC04 | 15 cm (6 in) concrete heavy weight dried aggregate 63.5 kg (140 lbs) | 0.1524 (0.5) | 4.720 (0.7576) | 2240 (140) | 0.84 (0.2) | 0.032 (0.66) |

| | | | | | | |
|---|---|---|---|---|---|---|
| CC23 | 5 cm (2 in) concrete light weight 36.3 kg (80 lbs) | 0.05081 (0.1667) | 1.298 (0.2083) | 1280 (80) | 0.84 (0.2) | 0.039 (0.8) |
| CC24 | 10 cm (4 in) concrete light weight 36.3 kg (80 lbs) | 0.1059 (0.3333) | 1.298 (0.2083) | 1280 (80) | 0.84 (0.2) | 0.078 (1.6) |
| CB06 | 15 cm (6 in) hollow heavy weight concrete block | 0.1524 (0.5) | 3.461 (0.5555) | 1360 (85) | 0.84 (0.2) | 0.044 (0.9) |
| CB11 | 20 cm (8 in) hollow heavy weight concrete block | 0.20321 (0.6667) | 3.776 (0.606) | 1100 (69) | 0.84 (0.2) | 0.054 (1.1) |
| CB42 | 10 cm (4 in) concrete filled light weight concrete block | 0.10159 (0.3333) | 2.302 (0.3695) | 1670 (104) | 0.84 (0.2) | 0.044 (0.9) |
| GP01 | 1.3 cm (1/2 in) gypsum or plaster board | 0.01271 (0.0417) | 0.5770 (0.0926) | 800 (50) | 0.84 (0.2) | 0.022 (0.45) |
| GP02 | 1.6 cm (5/8 in) gypsum or plaster board | 0.01588 (0.0521) | 0.5770 (0.0926) | 800 (50) | 0.84 (0.2) | 0.027 (0.56) |
| GP06 | 1.9 cm (3/4 in) sand aggregate gypsum plaster | 0.01905 (0.0625) | 2.951 (0.4736) | 1680 (105) | 0.84 (0.2) | 0.0064 (0.13) |
| PW03 | 1.3 cm (1/2 in) plywood | 0.01271 (0.0417) | 0.4156 (0.0667) | 540 (34) | 1.2 (0.29) | 0.031 (0.63) |
| PW04 | 1.6 cm (5/8 in) plywood | 0.01588 (0.0521) | 0.4156 (0.0667) | 540 (34) | 1.2 (0.29) | 0.038 (0.78) |
| PW05 | 1.9 cm (3/4 in) plywood | 0.01905 (0.0625) | 0.4156 (0.0667) | 540 (34) | 1.2 (0.29) | 0.046 (0.94) |
| ST01 | 2.5 cm (1 in) stone | 0.02539 (0.0833) | 6.490 (1.0416) | 2240 (140) | 0.84 (0.2) | 0.0039 (0.08) |
| SC01 | 2.5 cm (1 in) stucco | 0.02539 (0.0833) | 2.596 (0.4167) | 2660 (166) | 0.84 (0.2) | 0.0098 (0.2) |
| WD01 | 1.9 cm (3/4 in) soft wood | 0.01905 (0.0625) | 0.4156 (0.0667) | 510 (32) | 1.4 (0.33) | 0.046 (0.94) |
| AL21 | 1.9 to 10 cm (3/4 to 4 in) vertical wall air layer | | | | | 0.044 (0.89) |
| AL23 | 1.9 to 10 cm (3/4 to 4 in) horizontal roof air layer | | | | | 0.043 (0.87) |
| AL33 | 10 cm (4 in) or more horizontal roof air layer | | | | | 0.045 (0.92) |

**Table 3 : Window Properties**

| Description | U-Value $W/m^2 K$ (Btu/h $ft^2 R$) |
|---|---|
| Single Pane | 5.79 (1.02) |
| Double Pane | 1.42 (0.25) |
| Wood Frame | 3.12 (0.55) |
| Metal Frame | 12.89 (2.27) |
| Improved Metal Frame | 6.81 (1.20) |

Wingwalls

The geometry of the buildings led to situations where a portion of the building could be shaded by a different portion of the building. This reduction in the incident solar radiation can have a dramatic effect on the loads. To account for this phenomenon, the TRNSYS wingwall type was utilized. However every building wall was treated as a single surface and not broken up by floor. This means that for each floor the

average solar incident value for the entire wall was applied. The geometry of the wingwalls used was determined from the individual building schematics included in the PNL report.

Zoning

In the original PNL study, the buildings were zoned with each floor containing an interior zone, four exterior zones and a plenum. The four exterior zones corresponded to the four cardinal compass directions. This method of zoning leads to the situation where there are zones that are composed of non-adjacent portions of the building. These zones could have significantly different amounts of incident solar radiation depending on wingwall shading. Therefore, it was decided that the zones would be broken down into distinct sections. This did, in some cases, dramatically increase the number of zones in the individual building models, but that was considered a small price to pay for the increased calculation accuracy.

As in "traditional" building energy simulation, not all of the floors in a building are included in the model. Just the bottom and top floors are included along with a single floor that is representative of the middle floors. The total load of the middle floors is then calculated by multiplying the loads of the representative middle floor by the number of middle floors.

The zoning used for the individual building models is described later in the individual building sections.

Loads and Schedules

The loads due to lighting, occupancy, and receptacles (equipment) are specified using two different inputs. The first input is the maximum load of that type. For lighting and receptacle loads this is the watts per square meter and for occupancy this is the occupancy density (square meters per person). The second input for the internal loads is the schedule applied to the maximum value. The schedules included in the PNL report were 24 hour schedules for weekday, Saturday and Sunday. There were individual schedules for lighting, occupancy, and equipment. These schedules were taken from the PNL report and entered into the TRNSYS models. The schedules are entered in TRNSYS using the MultiSched TESS component. The schedules used are outlined in Tables 4 - 10.

**Table 4: Schedule 9.2 (Buildings 1, 2, 3, 10 & 18)**

| | Lighting | | | Occupancy | | | Equipment | | |
|---|---|---|---|---|---|---|---|---|---|
| Hour | Weekday | Saturday | Sunday | Weekday | Saturday | Sunday | Weekday | Saturday | Sunday |
| 1 | 0.154 | 0.155 | 0.140 | 0.008 | 0.009 | 0.008 | 0.496 | 0.513 | 0.501 |
| 2 | 0.152 | 0.149 | 0.140 | 0.005 | 0.002 | 0.000 | 0.495 | 0.494 | 0.490 |
| 3 | 0.149 | 0.147 | 0.141 | 0.004 | 0.000 | 0.000 | 0.495 | 0.490 | 0.487 |
| 4 | 0.148 | 0.145 | 0.141 | 0.003 | 0.000 | 0.000 | 0.496 | 0.491 | 0.488 |
| 5 | 0.146 | 0.145 | 0.140 | 0.002 | 0.000 | 0.000 | 0.496 | 0.492 | 0.489 |
| 6 | 0.144 | 0.144 | 0.139 | 0.002 | 0.002 | 0.001 | 0.497 | 0.512 | 0.502 |
| 7 | 0.151 | 0.149 | 0.138 | 0.079 | 0.038 | 0.016 | 0.578 | 0.534 | 0.513 |
| 8 | 0.319 | 0.168 | 0.136 | 0.346 | 0.067 | 0.015 | 0.739 | 0.552 | 0.513 |
| 9 | 0.613 | 0.221 | 0.150 | 0.710 | 0.123 | 0.026 | 0.902 | 0.570 | 0.514 |
| 10 | 0.745 | 0.266 | 0.178 | 0.890 | 0.163 | 0.046 | 0.994 | 0.578 | 0.513 |
| 11 | 0.750 | 0.276 | 0.180 | 0.899 | 0.182 | 0.055 | 1.000 | 0.590 | 0.521 |
| 12 | 0.752 | 0.280 | 0.184 | 0.810 | 0.167 | 0.052 | 0.999 | 0.591 | 0.522 |
| 13 | 0.751 | 0.278 | 0.183 | 0.626 | 0.129 | 0.040 | 0.994 | 0.592 | 0.522 |
| 14 | 0.749 | 0.275 | 0.183 | 0.882 | 0.175 | 0.056 | 0.982 | 0.584 | 0.521 |
| 15 | 0.747 | 0.270 | 0.182 | 0.864 | 0.171 | 0.056 | 0.963 | 0.582 | 0.522 |
| 16 | 0.736 | 0.265 | 0.183 | 0.772 | 0.159 | 0.056 | 0.870 | 0.574 | 0.521 |
| 17 | 0.617 | 0.250 | 0.180 | 0.594 | 0.136 | 0.052 | 0.769 | 0.561 | 0.519 |
| 18 | 0.441 | 0.211 | 0.165 | 0.396 | 0.100 | 0.041 | 0.693 | 0.552 | 0.519 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 19 | 0.281 | 0.184 | 0.164 | 0.204 | 0.074 | 0.039 | 0.611 | 0.546 | 0.517 |
| 20 | 0.195 | 0.170 | 0.164 | 0.064 | 0.054 | 0.038 | 0.526 | 0.535 | 0.517 |
| 21 | 0.181 | 0.159 | 0.162 | 0.041 | 0.047 | 0.029 | 0.512 | 0.537 | 0.517 |
| 22 | 0.171 | 0.152 | 0.157 | 0.029 | 0.036 | 0.021 | 0.505 | 0.534 | 0.516 |
| 23 | 0.164 | 0.149 | 0.154 | 0.019 | 0.024 | 0.014 | 0.501 | 0.537 | 0.520 |
| 24 | 0.158 | 0.145 | 0.152 | 0.013 | 0.015 | 0.009 | 0.498 | 0.534 | 0.516 |

**Table 5: Schedule 9.5 (Buildings 6, 7, 8, 14, 21 & 23)**

| | Lighting | | | Occupancy | | | Equipment | | |
|---|---|---|---|---|---|---|---|---|---|
| Hour | Weekday | Saturday | Sunday | Weekday | Saturday | Sunday | Weekday | Saturday | Sunday |
| 1 | 0.155 | 0.155 | 0.140 | 0.009 | 0.009 | 0.005 | 0.496 | 0.513 | 0.500 |
| 2 | 0.152 | 0.149 | 0.140 | 0.006 | 0.002 | 0.000 | 0.496 | 0.494 | 0.489 |
| 3 | 0.150 | 0.148 | 0.140 | 0.004 | 0.000 | 0.000 | 0.495 | 0.490 | 0.487 |
| 4 | 0.148 | 0.145 | 0.140 | 0.003 | 0.000 | 0.000 | 0.496 | 0.491 | 0.488 |
| 5 | 0.146 | 0.145 | 0.139 | 0.002 | 0.000 | 0.000 | 0.496 | 0.492 | 0.489 |
| 6 | 0.145 | 0.144 | 0.139 | 0.002 | 0.002 | 0.001 | 0.497 | 0.512 | 0.500 |
| 7 | 0.151 | 0.150 | 0.138 | 0.079 | 0.041 | 0.014 | 0.578 | 0.537 | 0.510 |
| 8 | 0.319 | 0.175 | 0.136 | 0.346 | 0.082 | 0.013 | 0.739 | 0.562 | 0.510 |
| 9 | 0.613 | 0.240 | 0.149 | 0.710 | 0.152 | 0.023 | 0.902 | 0.587 | 0.511 |
| 10 | 0.745 | 0.291 | 0.173 | 0.890 | 0.200 | 0.040 | 0.994 | 0.598 | 0.510 |
| 11 | 0.750 | 0.301 | 0.175 | 0.899 | 0.219 | 0.048 | 1.000 | 0.611 | 0.517 |
| 12 | 0.752 | 0.305 | 0.178 | 0.810 | 0.201 | 0.045 | 1.000 | 0.612 | 0.518 |
| 13 | 0.751 | 0.303 | 0.177 | 0.627 | 0.155 | 0.035 | 0.995 | 0.613 | 0.518 |
| 14 | 0.750 | 0.300 | 0.177 | 0.886 | 0.212 | 0.049 | 0.986 | 0.604 | 0.516 |
| 15 | 0.748 | 0.295 | 0.177 | 0.871 | 0.207 | 0.050 | 0.970 | 0.603 | 0.518 |
| 16 | 0.746 | 0.290 | 0.177 | 0.817 | 0.196 | 0.049 | 0.912 | 0.594 | 0.516 |
| 17 | 0.670 | 0.276 | 0.174 | 0.661 | 0.169 | 0.046 | 0.800 | 0.576 | 0.515 |
| 18 | 0.502 | 0.230 | 0.162 | 0.464 | 0.124 | 0.036 | 0.719 | 0.564 | 0.515 |
| 19 | 0.330 | 0.196 | 0.160 | 0.269 | 0.090 | 0.034 | 0.642 | 0.554 | 0.514 |
| 20 | 0.212 | 0.174 | 0.160 | 0.097 | 0.060 | 0.033 | 0.547 | 0.539 | 0.513 |
| 21 | 0.184 | 0.161 | 0.159 | 0.046 | 0.049 | 0.026 | 0.514 | 0.538 | 0.514 |
| 22 | 0.174 | 0.154 | 0.154 | 0.032 | 0.037 | 0.018 | 0.507 | 0.535 | 0.513 |
| 23 | 0.166 | 0.150 | 0.152 | 0.021 | 0.025 | 0.012 | 0.502 | 0.537 | 0.516 |
| 24 | 0.160 | 0.146 | 0.150 | 0.014 | 0.016 | 0.008 | 0.498 | 0.534 | 0.513 |

**Table 6: Schedule 9.7 (Buildings 4, 5, 9, 11 & 22)**

| | Lighting | | | Occupancy | | | Equipment | | |
|---|---|---|---|---|---|---|---|---|---|
| Hour | Weekday | Saturday | Sunday | Weekday | Saturday | Sunday | Weekday | Saturday | Sunday |
| 1 | 0.156 | 0.156 | 0.141 | 0.009 | 0.010 | 0.006 | 0.497 | 0.513 | 0.502 |
| 2 | 0.152 | 0.149 | 0.141 | 0.006 | 0.002 | 0.000 | 0.496 | 0.494 | 0.490 |
| 3 | 0.150 | 0.148 | 0.141 | 0.004 | 0.001 | 0.000 | 0.495 | 0.490 | 0.487 |
| 4 | 0.148 | 0.145 | 0.141 | 0.003 | 0.000 | 0.000 | 0.496 | 0.491 | 0.488 |
| 5 | 0.146 | 0.145 | 0.140 | 0.002 | 0.000 | 0.000 | 0.496 | 0.492 | 0.489 |
| 6 | 0.145 | 0.144 | 0.139 | 0.002 | 0.002 | 0.001 | 0.497 | 0.512 | 0.503 |
| 7 | 0.151 | 0.150 | 0.138 | 0.079 | 0.044 | 0.017 | 0.578 | 0.541 | 0.515 |
| 8 | 0.319 | 0.182 | 0.136 | 0.346 | 0.096 | 0.016 | 0.739 | 0.572 | 0.516 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 9 | 0.613 | 0.260 | 0.152 | 0.710 | 0.182 | 0.028 | 0.902 | 0.604 | 0.516 |
| 10 | 0.745 | 0.316 | 0.181 | 0.890 | 0.237 | 0.050 | 0.994 | 0.619 | 0.516 |
| 11 | 0.750 | 0.326 | 0.184 | 0.899 | 0.256 | 0.059 | 1.000 | 0.632 | 0.524 |
| 12 | 0.752 | 0.330 | 0.187 | 0.810 | 0.234 | 0.056 | 1.000 | 0.633 | 0.525 |
| 13 | 0.751 | 0.328 | 0.187 | 0.627 | 0.182 | 0.044 | 0.996 | 0.634 | 0.525 |
| 14 | 0.750 | 0.325 | 0.187 | 0.888 | 0.249 | 0.060 | 0.987 | 0.625 | 0.523 |
| 15 | 0.748 | 0.321 | 0.186 | 0.874 | 0.244 | 0.061 | 0.973 | 0.623 | 0.525 |
| 16 | 0.746 | 0.315 | 0.187 | 0.836 | 0.233 | 0.060 | 0.933 | 0.615 | 0.523 |
| 17 | 0.697 | 0.302 | 0.183 | 0.699 | 0.202 | 0.057 | 0.819 | 0.592 | 0.522 |
| 18 | 0.538 | 0.251 | 0.168 | 0.504 | 0.150 | 0.044 | 0.734 | 0.575 | 0.521 |
| 19 | 0.362 | 0.209 | 0.166 | 0.307 | 0.108 | 0.042 | 0.659 | 0.563 | 0.520 |
| 20 | 0.229 | 0.180 | 0.166 | 0.125 | 0.069 | 0.041 | 0.565 | 0.544 | 0.519 |
| 21 | 0.186 | 0.163 | 0.164 | 0.049 | 0.052 | 0.032 | 0.516 | 0.539 | 0.520 |
| 22 | 0.176 | 0.155 | 0.158 | 0.034 | 0.039 | 0.022 | 0.508 | 0.535 | 0.518 |
| 23 | 0.167 | 0.151 | 0.156 | 0.023 | 0.026 | 0.015 | 0.502 | 0.538 | 0.523 |
| 24 | 0.160 | 0.147 | 0.153 | 0.015 | 0.016 | 0.009 | 0.499 | 0.534 | 0.518 |

**Table 7: Schedule 11.0 (Buildings 12, 16, 17, 19 & 24)**

| | Lighting | | | Occupancy | | | Equipment | | |
|---|---|---|---|---|---|---|---|---|---|
| Hour | Weekday | Saturday | Sunday | Weekday | Saturday | Sunday | Weekday | Saturday | Sunday |
| 1 | 0.160 | 0.159 | 0.144 | 0.014 | 0.013 | 0.009 | 0.498 | 0.514 | 0.510 |
| 2 | 0.155 | 0.151 | 0.144 | 0.008 | 0.004 | 0.000 | 0.496 | 0.495 | 0.491 |
| 3 | 0.151 | 0.149 | 0.144 | 0.005 | 0.002 | 0.000 | 0.495 | 0.490 | 0.487 |
| 4 | 0.149 | 0.146 | 0.144 | 0.003 | 0.001 | 0.000 | 0.495 | 0.491 | 0.488 |
| 5 | 0.147 | 0.146 | 0.142 | 0.002 | 0.001 | 0.000 | 0.496 | 0.492 | 0.490 |
| 6 | 0.145 | 0.144 | 0.141 | 0.002 | 0.002 | 0.002 | 0.497 | 0.512 | 0.511 |
| 7 | 0.151 | 0.151 | 0.139 | 0.079 | 0.058 | 0.029 | 0.578 | 0.555 | 0.533 |
| 8 | 0.319 | 0.212 | 0.145 | 0.346 | 0.155 | 0.042 | 0.738 | 0.613 | 0.542 |
| 9 | 0.613 | 0.339 | 0.184 | 0.710 | 0.302 | 0.080 | 0.902 | 0.673 | 0.552 |
| 10 | 0.745 | 0.418 | 0.236 | 0.889 | 0.388 | 0.122 | 0.993 | 0.703 | 0.556 |
| 11 | 0.750 | 0.429 | 0.240 | 0.898 | 0.408 | 0.136 | 0.999 | 0.718 | 0.569 |
| 12 | 0.751 | 0.433 | 0.245 | 0.810 | 0.372 | 0.127 | 1.000 | 0.719 | 0.570 |
| 13 | 0.752 | 0.431 | 0.244 | 0.629 | 0.288 | 0.099 | 0.998 | 0.720 | 0.571 |
| 14 | 0.751 | 0.428 | 0.244 | 0.894 | 0.402 | 0.138 | 0.994 | 0.711 | 0.568 |
| 15 | 0.750 | 0.424 | 0.243 | 0.886 | 0.396 | 0.138 | 0.986 | 0.708 | 0.569 |
| 16 | 0.748 | 0.418 | 0.244 | 0.875 | 0.388 | 0.137 | 0.974 | 0.703 | 0.567 |
| 17 | 0.747 | 0.412 | 0.239 | 0.855 | 0.373 | 0.130 | 0.954 | 0.691 | 0.563 |
| 18 | 0.727 | 0.381 | 0.215 | 0.751 | 0.318 | 0.107 | 0.853 | 0.656 | 0.557 |
| 19 | 0.593 | 0.322 | 0.204 | 0.566 | 0.246 | 0.092 | 0.757 | 0.624 | 0.550 |
| 20 | 0.416 | 0.256 | 0.195 | 0.368 | 0.171 | 0.081 | 0.683 | 0.595 | 0.545 |
| 21 | 0.263 | 0.195 | 0.184 | 0.179 | 0.103 | 0.057 | 0.597 | 0.569 | 0.541 |
| 22 | 0.191 | 0.165 | 0.171 | 0.056 | 0.052 | 0.036 | 0.520 | 0.541 | 0.535 |
| 23 | 0.178 | 0.158 | 0.167 | 0.036 | 0.035 | 0.025 | 0.508 | 0.541 | 0.540 |
| 24 | 0.167 | 0.151 | 0.162 | 0.023 | 0.021 | 0.015 | 0.502 | 0.536 | 0.534 |

**Table 8: Schedule 11.8 (Buildings 20 & 25)**

| | Lighting | | | Occupancy | | | Equipment | | |
|---|---|---|---|---|---|---|---|---|---|
| Hour | Weekday | Saturday | Sunday | Weekday | Saturday | Sunday | Weekday | Saturday | Sunday |
| 1 | 0.164 | 0.163 | 0.144 | 0.018 | 0.017 | 0.009 | 0.500 | 0.515 | 0.510 |
| 2 | 0.157 | 0.154 | 0.144 | 0.010 | 0.006 | 0.001 | 0.497 | 0.495 | 0.491 |
| 3 | 0.152 | 0.150 | 0.144 | 0.006 | 0.003 | 0.000 | 0.495 | 0.490 | 0.487 |
| 4 | 0.149 | 0.147 | 0.144 | 0.003 | 0.002 | 0.000 | 0.495 | 0.491 | 0.488 |
| 5 | 0.147 | 0.146 | 0.142 | 0.002 | 0.001 | 0.000 | 0.496 | 0.492 | 0.490 |
| 6 | 0.145 | 0.144 | 0.141 | 0.002 | 0.003 | 0.002 | 0.497 | 0.513 | 0.511 |
| 7 | 0.151 | 0.152 | 0.139 | 0.078 | 0.068 | 0.029 | 0.578 | 0.566 | 0.533 |
| 8 | 0.319 | 0.235 | 0.145 | 0.345 | 0.200 | 0.042 | 0.738 | 0.645 | 0.542 |
| 9 | 0.613 | 0.400 | 0.184 | 0.710 | 0.395 | 0.079 | 0.902 | 0.726 | 0.552 |
| 10 | 0.745 | 0.496 | 0.234 | 0.889 | 0.504 | 0.120 | 0.993 | 0.768 | 0.555 |
| 11 | 0.750 | 0.508 | 0.239 | 0.897 | 0.526 | 0.134 | 0.999 | 0.783 | 0.568 |
| 12 | 0.751 | 0.512 | 0.244 | 0.810 | 0.478 | 0.125 | 1.000 | 0.785 | 0.569 |
| 13 | 0.752 | 0.510 | 0.243 | 0.630 | 0.371 | 0.097 | 0.999 | 0.786 | 0.570 |
| 14 | 0.755 | 0.507 | 0.243 | 0.896 | 0.520 | 0.136 | 0.996 | 0.777 | 0.567 |
| 15 | 0.750 | 0.503 | 0.242 | 0.891 | 0.514 | 0.137 | 0.991 | 0.774 | 0.569 |
| 16 | 0.749 | 0.497 | 0.243 | 0.882 | 0.506 | 0.135 | 0.982 | 0.769 | 0.566 |
| 17 | 0.748 | 0.492 | 0.238 | 0.871 | 0.492 | 0.129 | 0.970 | 0.759 | 0.563 |
| 18 | 0.746 | 0.466 | 0.214 | 0.844 | 0.459 | 0.110 | 0.942 | 0.744 | 0.561 |
| 19 | 0.711 | 0.436 | 0.210 | 0.720 | 0.391 | 0.099 | 0.832 | 0.692 | 0.553 |
| 20 | 0.560 | 0.359 | 0.202 | 0.528 | 0.294 | 0.088 | 0.743 | 0.647 | 0.547 |
| 21 | 0.383 | 0.266 | 0.190 | 0.331 | 0.197 | 0.064 | 0.668 | 0.616 | 0.545 |
| 22 | 0.241 | 0.195 | 0.174 | 0.144 | 0.100 | 0.041 | 0.577 | 0.571 | 0.538 |
| 23 | 0.187 | 0.166 | 0.167 | 0.049 | 0.045 | 0.025 | 0.515 | 0.546 | 0.541 |
| 24 | 0.174 | 0.158 | 0.163 | 0.031 | 0.028 | 0.016 | 0.506 | 0.538 | 0.534 |

**Table 9: Schedule 18.0 (Building 13)**

| | Lighting | | | Occupancy | | | Equipment | | |
|---|---|---|---|---|---|---|---|---|---|
| Hour | Weekday | Saturday | Sunday | Weekday | Saturday | Sunday | Weekday | Saturday | Sunday |
| 1 | 0.737 | 0.512 | 0.384 | 0.777 | 0.478 | 0.325 | 0.874 | 0.742 | 0.664 |
| 2 | 0.622 | 0.437 | 0.337 | 0.601 | 0.364 | 0.245 | 0.772 | 0.661 | 0.604 |
| 3 | 0.447 | 0.329 | 0.267 | 0.403 | 0.243 | 0.164 | 0.696 | 0.611 | 0.569 |
| 4 | 0.285 | 0.230 | 0.201 | 0.210 | 0.127 | 0.086 | 0.614 | 0.563 | 0.537 |
| 5 | 0.196 | 0.176 | 0.163 | 0.058 | 0.035 | 0.024 | 0.518 | 0.506 | 0.499 |
| 6 | 0.159 | 0.153 | 0.147 | 0.012 | 0.009 | 0.007 | 0.497 | 0.513 | 0.511 |
| 7 | 0.152 | 0.153 | 0.142 | 0.079 | 0.079 | 0.057 | 0.578 | 0.577 | 0.562 |
| 8 | 0.319 | 0.259 | 0.207 | 0.346 | 0.249 | 0.164 | 0.738 | 0.679 | 0.628 |
| 9 | 0.613 | 0.466 | 0.350 | 0.710 | 0.495 | 0.331 | 0.902 | 0.783 | 0.696 |
| 10 | 0.745 | 0.581 | 0.447 | 0.888 | 0.629 | 0.435 | 0.992 | 0.838 | 0.732 |
| 11 | 0.749 | 0.592 | 0.453 | 0.895 | 0.651 | 0.452 | 0.997 | 0.853 | 0.746 |
| 12 | 0.750 | 0.597 | 0.458 | 0.808 | 0.590 | 0.412 | 0.999 | 0.855 | 0.748 |
| 13 | 0.751 | 0.595 | 0.458 | 0.629 | 0.459 | 0.321 | 1.000 | 0.857 | 0.749 |
| 14 | 0.751 | 0.593 | 0.458 | 0.900 | 0.648 | 0.456 | 1.000 | 0.850 | 0.746 |
| 15 | 0.752 | 0.589 | 0.457 | 0.900 | 0.645 | 0.457 | 1.000 | 0.850 | 0.748 |
| 16 | 0.752 | 0.584 | 0.458 | 0.899 | 0.640 | 0.455 | 0.999 | 0.848 | 0.746 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 17 | 0.751 | 0.579 | 0.453 | 0.897 | 0.631 | 0.449 | 0.997 | 0.842 | 0.743 |
| 18 | 0.751 | 0.553 | 0.430 | 0.894 | 0.608 | 0.430 | 0.994 | 0.838 | 0.741 |
| 19 | 0.750 | 0.539 | 0.427 | 0.891 | 0.596 | 0.425 | 0.991 | 0.836 | 0.737 |
| 20 | 0.749 | 0.531 | 0.426 | 0.886 | 0.584 | 0.422 | 0.986 | 0.829 | 0.734 |
| 21 | 0.749 | 0.521 | 0.424 | 0.881 | 0.576 | 0.406 | 0.981 | 0.829 | 0.733 |
| 22 | 0.748 | 0.514 | 0.415 | 0.874 | 0.562 | 0.389 | 0.974 | 0.823 | 0.729 |
| 23 | 0.747 | 0.511 | 0.410 | 0.867 | 0.547 | 0.376 | 0.967 | 0.822 | 0.732 |
| 24 | 0.746 | 0.507 | 0.406 | 0.858 | 0.533 | 0.363 | 0.958 | 0.813 | 0.722 |

**Table 10: Schedule 21.0 (Building 15)**

| | Lighting | | | Occupancy | | | Equipment | | |
|---|---|---|---|---|---|---|---|---|---|
| Hour | Weekday | Saturday | Sunday | Weekday | Saturday | Sunday | Weekday | Saturday | Sunday |
| 1 | 0.748 | 0.659 | 0.609 | 0.875 | 0.742 | 0.685 | 0.975 | 0.915 | 0.881 |
| 2 | 0.747 | 0.653 | 0.609 | 0.867 | 0.728 | 0.671 | 0.967 | 0.890 | 0.856 |
| 3 | 0.746 | 0.651 | 0.609 | 0.859 | 0.720 | 0.664 | 0.958 | 0.878 | 0.845 |
| 4 | 0.738 | 0.642 | 0.603 | 0.781 | 0.655 | 0.604 | 0.878 | 0.812 | 0.784 |
| 5 | 0.628 | 0.550 | 0.516 | 0.609 | 0.511 | 0.472 | 0.777 | 0.728 | 0.708 |
| 6 | 0.456 | 0.404 | 0.381 | 0.412 | 0.348 | 0.321 | 0.699 | 0.683 | 0.669 |
| 7 | 0.293 | 0.273 | 0.254 | 0.220 | 0.216 | 0.195 | 0.618 | 0.630 | 0.623 |
| 8 | 0.319 | 0.299 | 0.270 | 0.346 | 0.329 | 0.291 | 0.738 | 0.736 | 0.717 |
| 9 | 0.613 | 0.576 | 0.521 | 0.710 | 0.661 | 0.591 | 0.902 | 0.878 | 0.845 |
| 10 | 0.745 | 0.721 | 0.667 | 0.888 | 0.836 | 0.761 | 0.992 | 0.954 | 0.914 |
| 11 | 0.749 | 0.733 | 0.674 | 0.895 | 0.860 | 0.780 | 0.997 | 0.971 | 0.930 |
| 12 | 0.750 | 0.738 | 0.680 | 0.808 | 0.779 | 0.708 | 0.999 | 0.973 | 0.932 |
| 13 | 0.751 | 0.737 | 0.680 | 0.629 | 0.607 | 0.551 | 1.000 | 0.975 | 0.934 |
| 14 | 0.751 | 0.734 | 0.680 | 0.900 | 0.858 | 0.786 | 1.000 | 0.968 | 0.931 |
| 15 | 0.752 | 0.731 | 0.679 | 0.900 | 0.855 | 0.787 | 1.000 | 0.967 | 0.933 |
| 16 | 0.752 | 0.726 | 0.680 | 0.899 | 0.850 | 0.785 | 0.999 | 0.966 | 0.930 |
| 17 | 0.751 | 0.720 | 0.675 | 0.897 | 0.840 | 0.778 | 0.997 | 0.959 | 0.927 |
| 18 | 0.752 | 0.696 | 0.652 | 0.900 | 0.822 | 0.762 | 1.000 | 0.959 | 0.928 |
| 19 | 0.752 | 0.682 | 0.649 | 0.899 | 0.811 | 0.757 | 0.999 | 0.958 | 0.925 |
| 20 | 0.751 | 0.674 | 0.649 | 0.897 | 0.801 | 0.755 | 0.997 | 0.953 | 0.923 |
| 21 | 0.751 | 0.664 | 0.647 | 0.894 | 0.794 | 0.739 | 0.994 | 0.954 | 0.922 |
| 22 | 0.750 | 0.657 | 0.637 | 0.891 | 0.780 | 0.723 | 0.991 | 0.949 | 0.917 |
| 23 | 0.749 | 0.654 | 0.633 | 0.886 | 0.766 | 0.709 | 0.986 | 0.948 | 0.920 |
| 24 | 0.749 | 0.650 | 0.628 | 0.881 | 0.752 | 0.696 | 0.981 | 0.941 | 0.909 |

HVAC Parameters/Schedules

The setpoints and fan operation are also scheduled in the models. The cooling setpoint is based on a setpoint temperature and a set-up temperature. The heating setpoint is based on a setpoint temperature and a set-back temperature. The set-back and set-up temperatures are used based on schedules that are weekday, Saturday and Sunday. The fan operation schedule, which is also a weekday, Saturday and Sunday schedule, is used to determine when outside air is being introduced into the building through the ventilation system. The amount of outside air included in the ventilation stream is a parameter in the model and that is coupled with the fan operation schedule for use in the energy usage calculations. The schedules used are outline in Table 11.

**Table 11: HVAC Schedules**

| Schedule | Buildings | Weekday | | Saturday | | Sunday | |
|---|---|---|---|---|---|---|---|
| | | Setpoint On | Fan On | Setpoint On | Fan On | Setpoint on | Fan on |
| 9.2 | 1, 2, 3, 10, 18 | 6 to 20 | 7 to 20 | 7 to 20 | 8 to 20 | 10 to 17 | 11 to 17 |
| 9.5 | 6, 7, 8, 14, 21, 23 | 6 to 20 | 7 to 20 | 7 to 20 | 8 to 20 | 0 | 0 |
| 9.7 | 4, 5, 9, 11, 22 | 6 to 20 | 7 to 20 | 7 to 20 | 8 to 20 | 10 to 17 | 11 to 17 |
| 11.0 | 12, 16, 17, 19, 24 | 6 to 22 | 7 to 22 | 6 to 22 | 7 to 22 | 8 to 21 | 9 to 21 |
| 11.8 | 20, 25 | 6 to 22 | 7 to 22 | 6 to 22 | 7 to 22 | 8 to 21 | 9 to 21 |
| 18.0 | 13 | 1 to 24 | 1 to 24 | 1 to 24 | 1 to 24 | 1 to 24 | 1 to 24 |
| 21.0 | 15 | 1 to 24 | 1 to 24 | 1 to 24 | 1 to 24 | 1 to 24 | 1 to 24 |

Elevators

For most of the buildings taller than a single story, there are elevators included in the buildings. Since the elevator shafts provide a continuous airspace for the entire height of the building, it was desired to treat them in the model as a single zone. For buildings with multiple elevators, no benefit could be determined for treating each elevator shaft separately, so the elevators were modeled as a single elevator zone. No data was provided on the physical dimensions of the elevators in the PNL reports and it was decided to use a ten foot by ten foot square area for each elevator in the building.

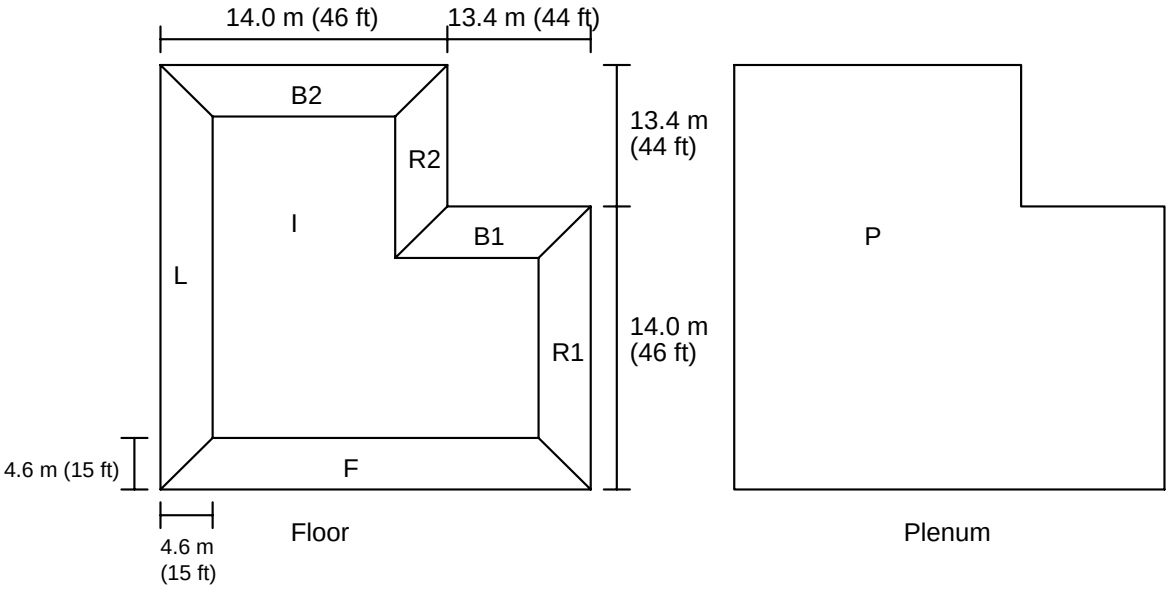
Weather

The PNL report included the city where each building is located. For the TRNSYS simulations, the weather data used for this study was TMY2 files for the closest location available for the actual location of the buildings. The locations of the individual buildings are shown in Table 1.

Individual Building Parameters

For each of the twenty-five buildings modeled in this study, the floor plans and individual parameters used in the models are presented in the following section. These schematic plans and parameter values were determined from the PNL reports and there derivation is discussed in those reports.

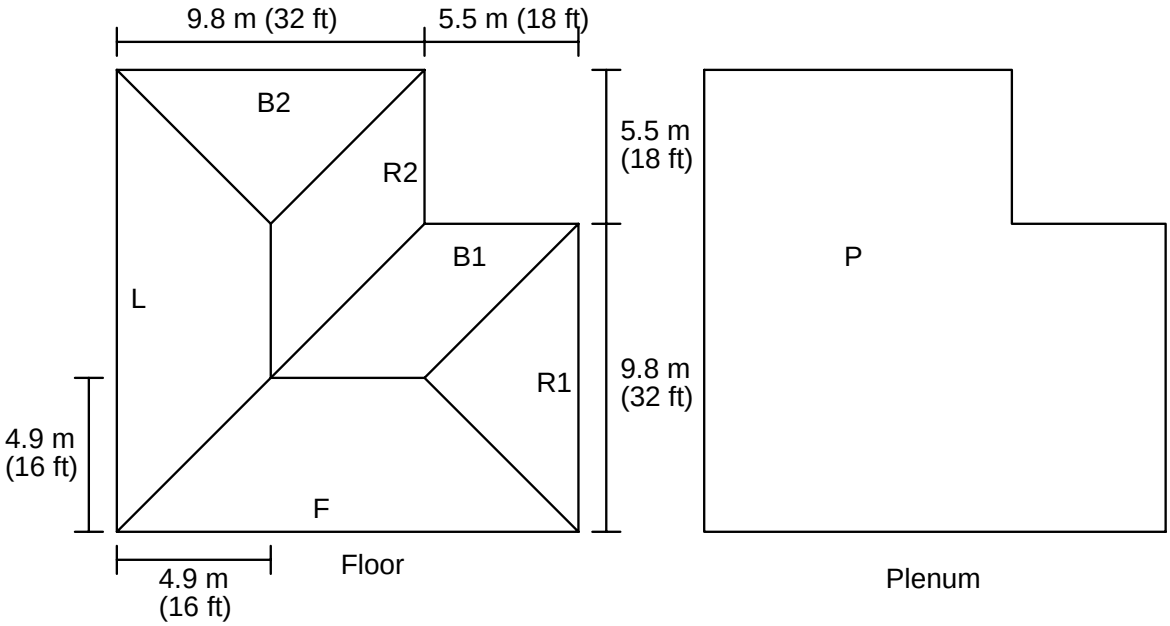
Building 1



Number of Floors = 1
Wall materials = WD01, WD01, WLIN, GP06
Roof materials = BR01, WD01, AL23, RFIN
Wall insulation thickness = 0.018 m (0.059 ft)
Roof insulation thickness = 0.014 m (0.046 ft)
Glass description – single, wood frame
Wall to window ratio = 0.23
Slab u-value = 2.27 W/m$^2$ K (0.4 Btu/h ft$^2$ R)
Ceiling u-value = 5.68 W/m$^2$ K (1.0 Btu/h ft$^2$ R)
Schedule = 9.2

Ceiling height = 3.35 m (11 ft)
Plenum height = 0.3 m (1 ft)
Number of elevators = 0
Lighting = 22.2 W/m$^2$ (2.06 W/ft$^2$)
Receptacle = 7.1 W/m$^2$ (0.66 W/ft$^2$)
Occupancy = 44 m$^2$/person (480 ft$^2$/person)
Heating setback = 18.9 C (66 F)
Heating setpoint = 21.7 C (71 F)
Cooling setpoint = 23.9 C (75 F)
Cooling setup = 37.2 C (99 F)

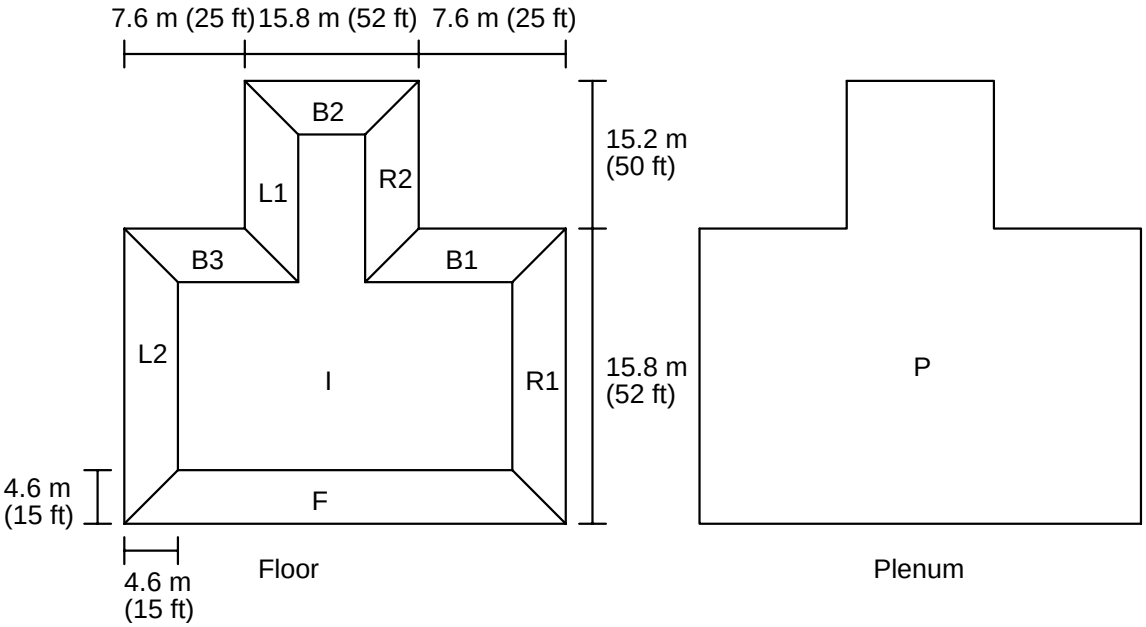
Building 2




Number of Floors = 3
Wall materials = BK05, AL21, BK02, WLIN, GP06
Roof materials = BR01, WD01, AL23, RFIN
Wall insulation thickness = 0.013 m (0.044 ft)
Roof insulation thickness = 0.032 m (0.105 ft)
Glass description – single, wood frame
Wall to window ratio = 0.27
Slab u-value = 2.27 W/m$^2$ K (0.4 Btu/h ft$^2$ R)
Ceiling u-value = 5.68 W/m$^2$ K (1.0 Btu/h ft$^2$ R)
Schedule = 9.2

Ceiling height = 3.35 m (11 ft)
Plenum height = 0.3 m (1 ft)
Number of elevators = 0
Lighting = 18.0 W/m$^2$ (1.67 W/ft$^2$)
Receptacle = 6.2 W/m$^2$ (0.58 W/ft$^2$)
Occupancy = 47 m$^2$/person (510 ft$^2$/person)
Heating setback = 18.9 C (66 F)
Heating setpoint = 21.7 C (71 F)
Cooling setpoint = 25.0 C (77 F)
Cooling setup = 37.2 C (99 F)

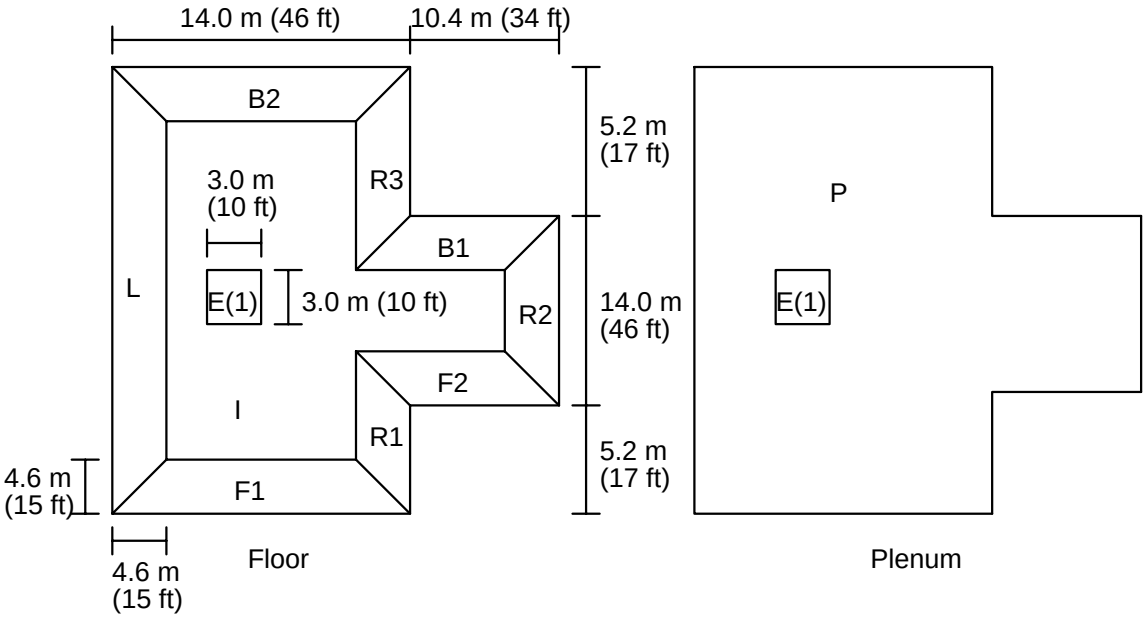
Building 3




Number of Floors = 1
Wall materials = BK05, AL21, BK01, WLIN, GP06
Roof materials = BR01, WD01, AL23, RFIN
Wall insulation thickness = 0.011 m (0.033 ft)
Roof insulation thickness = 0.020 m (0.065 ft)
Glass description – single, metal frame
Wall to window ratio = 0.24
Slab u-value = 2.27 W/m$^2$ K (0.4 Btu/h ft$^2$ R)
Ceiling u-value =5.68 W/m$^2$ K (1.0 Btu/h ft$^2$ R)
Schedule = 9.2

Ceiling height = 2.74 m (9 ft)
Plenum height = 0.3 m (1 ft)
Number of elevators = 0
Lighting = 22.5 W/m$^2$ (2.09 W/ft$^2$)
Receptacle = 6.9 W/m$^2$ (0.64 W/ft$^2$)
Occupancy = 41 m$^2$/person (440 ft$^2$/person)
Heating setback = 18.9 C (66 F)
Heating setpoint = 21.7 C (71 F)
Cooling setpoint = 23.9 C (75 F)
Cooling setup = 37.2 C (99 F)

Building 4



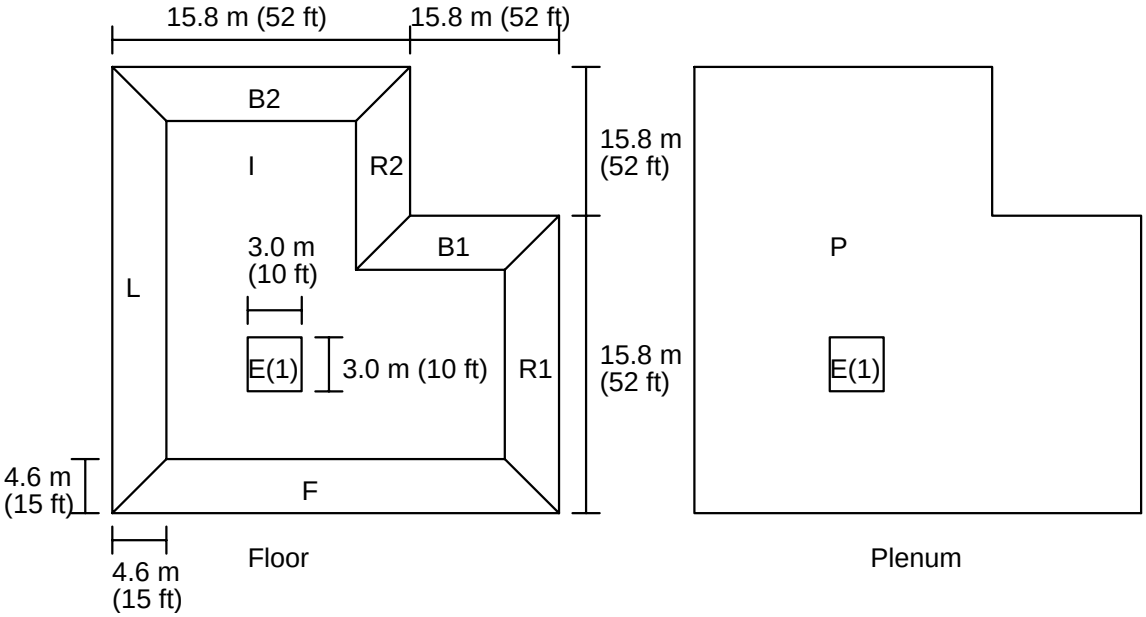

Number of Floors = 2

Ceiling height = 2.74 m (9 ft)

Wall materials = CB42, WLIN, CB11, GP02
Roof materials = BR01, RFIN, PW05
Wall insulation thickness = 0.014 m (0.047 ft)
Roof insulation thickness = 0.049 m (0.161 ft)
Glass description – single, improved metal frame
Wall to window ratio = 0.23
Slab u-value = 2.27 W/m$^2$ K (0.4 Btu/h ft$^2$ R)
Ceiling u-value = 2.61 W/m$^2$ K (0.46 Btu/h ft$^2$ R)
Schedule = 9.7

Plenum height = 0.61 m (2 ft)
Number of elevators = 1
Lighting = 25.4 W/m$^2$ (2.36 W/ft$^2$)
Receptacle = 7.5 W/m$^2$ (0.70 W/ft$^2$)
Occupancy = 32 m$^2$/person (340 ft$^2$/person)
Heating setback = 18.9 C (66 F)
Heating setpoint = 21.7 C (71 F)
Cooling setpoint = 23.3 C (74 F)
Cooling setup = 37.2 C (99 F)

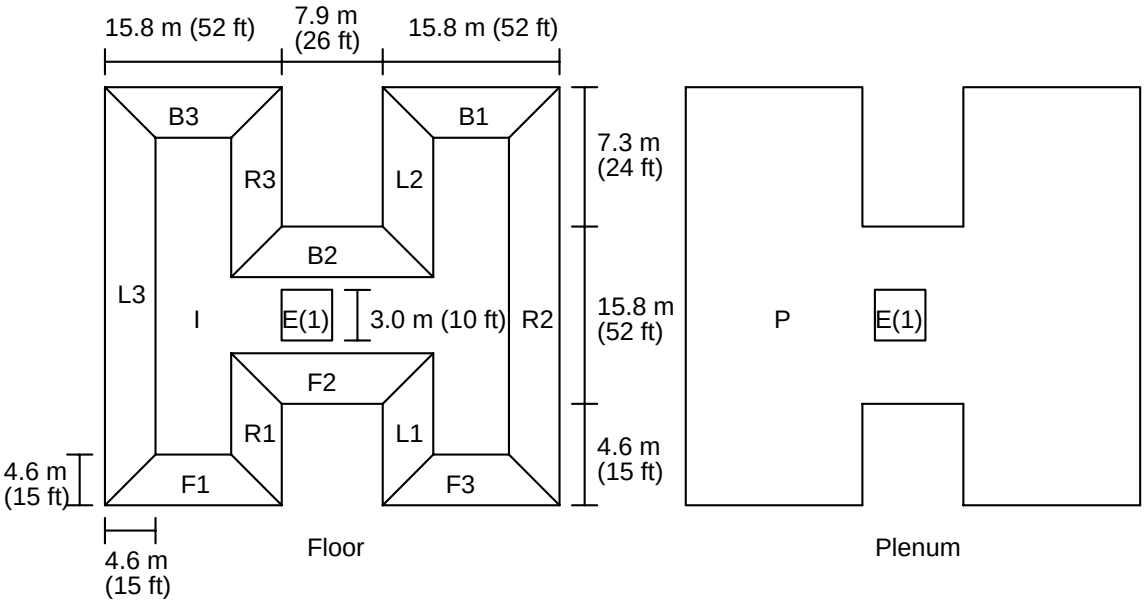
Building 5




Number of Floors = 2
Wall materials = WD01, PW03, WLIN, GP02
Roof materials = BR01, RFIN, PW05
Wall insulation thickness = 0.023 m (0.076 ft)
Roof insulation thickness = 0.081 m (0.265 ft)
Glass description – double, metal frame
Wall to window ratio = 0.27
Slab u-value = 2.27 W/m$^2$ K (0.4 Btu/h ft$^2$ R)
Ceiling u-value = 2.61 W/m$^2$ K (0.46 Btu/h ft$^2$ R)
Schedule = 9.7

Ceiling height = 2.74 m (9 ft)
Plenum height = 0.61 m (2 ft)
Number of elevators = 1
Lighting = 28.2 W/m$^2$ (2.62 W/ft$^2$)
Receptacle = 7.5 W/m$^2$ (0.70 W/ft$^2$)
Occupancy = 35 m$^2$/person (380 ft$^2$/person)
Heating setback = 18.3 C (65 F)
Heating setpoint = 21.1 C (70 F)
Cooling setpoint = 23.3 C (74 F)
Cooling setup = 37.2 C (99 F)

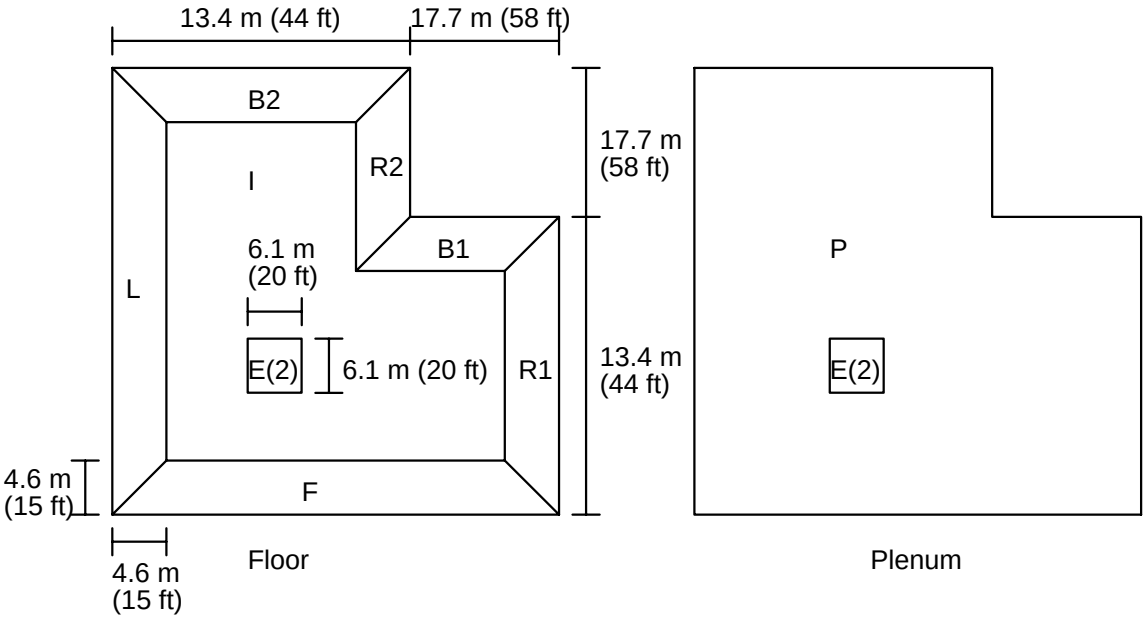
Building 6




Number of Floors = 2
Wall materials = BK05, AL21, CB06, WLIN, GP06
Roof materials = BR01, RFIN, PW05
Wall insulation thickness = 0.0003 m (0.001 ft)
Roof insulation thickness = 0.032 m (0.105 ft)
Glass description – single, metal frame
Wall to window ratio = 0.24
Slab u-value = 2.27 W/m$^2$ K (0.4 Btu/h ft$^2$ R)
Ceiling u-value = 2.61 W/m$^2$ K (0.46 Btu/h ft$^2$ R)
Schedule = 9.5

Ceiling height = 2.74 m (9 ft)
Plenum height = 0.91 m (3 ft)
Number of elevators = 1
Lighting = 20.3 W/m$^2$ (1.89 W/ft$^2$)
Receptacle =6.7 W/m$^2$ (0.62 W/ft$^2$)
Occupancy = 40 m$^2$/person (430 ft$^2$/person)
Heating setback = 18.9 C (66 F)
Heating setpoint = 21.7 C (71 F)
Cooling setpoint = 23.9 C (75 F)
Cooling setup = 37.2 C (99 F)

Building 7



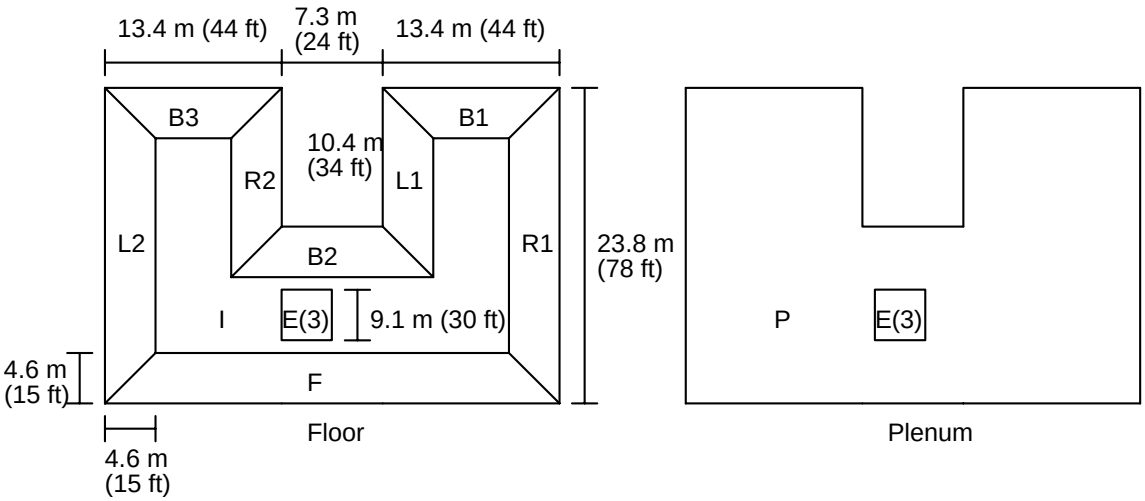

Number of Floors = 4

Ceiling height = 2.74 m (9 ft)

Wall materials = BK05, AL21, BK02, WLIN, GP06
Roof materials = BR01, RFIN, WD01
Wall insulation thickness = 0.014 m (0.046 ft)
Roof insulation thickness = 0.044 m (0.144 ft)
Glass description – single, wood frame
Wall to window ratio = 0.22
Slab u-value = 2.27 W/m$^2$ K (0.4 Btu/h ft$^2$ R)
Ceiling u-value = 4.20 W/m$^2$ K (0.74 Btu/h ft$^2$ R)
Schedule = 9.5

Plenum height = 0.91 m (3 ft)
Number of elevators = 2
Lighting = 18.0 W/m$^2$ (1.67 W/ft$^2$)
Receptacle = 6.2 W/m$^2$ (0.58 W/ft$^2$)
Occupancy = 46 m$^2$/person (500 ft$^2$/person)
Heating setback = 18.9 C (66 F)
Heating setpoint = 21.7 C (71 F)
Cooling setpoint = 23.9 C (75 F)
Cooling setup = 37.2 C (99 F)

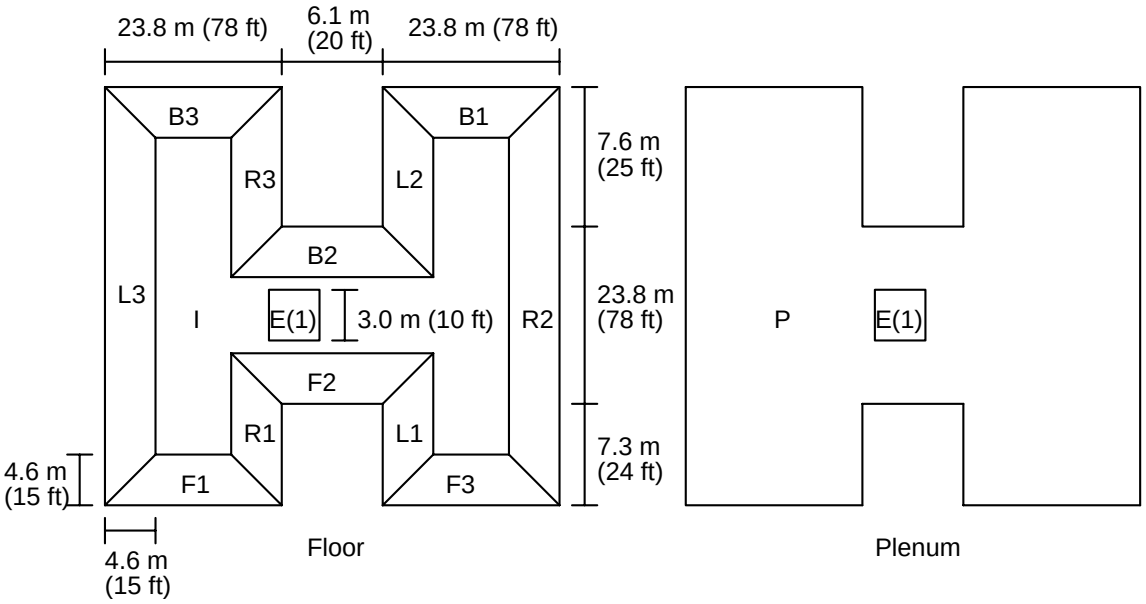
Building 8




Number of Floors = 5
Wall materials = BK05, AL21, CB06, WLIN, GP06
Roof materials = BR01, RFIN, WD01
Wall insulation thickness = 0.015 m (0.048 ft)
Roof insulation thickness = 0.019 m (0.063 ft)
Glass description – single, wood frame
Wall to window ratio = 0.27
Slab u-value = 2.27 W/m$^2$ K (0.4 Btu/h ft$^2$ R)
Ceiling u-value = 4.20 W/m$^2$ K (0.74 Btu/h ft$^2$ R)
Schedule = 9.5

Ceiling height = 2.74 m (9 ft)
Plenum height = 0.91 m (3 ft)
Number of elevators = 3
Lighting = 21.1 W/m$^2$ (1.96 W/ft$^2$)
Receptacle = 7.2 W/m$^2$ (0.67 W/ft$^2$)
Occupancy = 40 m$^2$/person (430 ft$^2$/person)
Heating setback = 18.3 C (65 F)
Heating setpoint = 21.1 C (70 F)
Cooling setpoint = 23.9 C (75 F)
Cooling setup = 37.2 C (99 F)

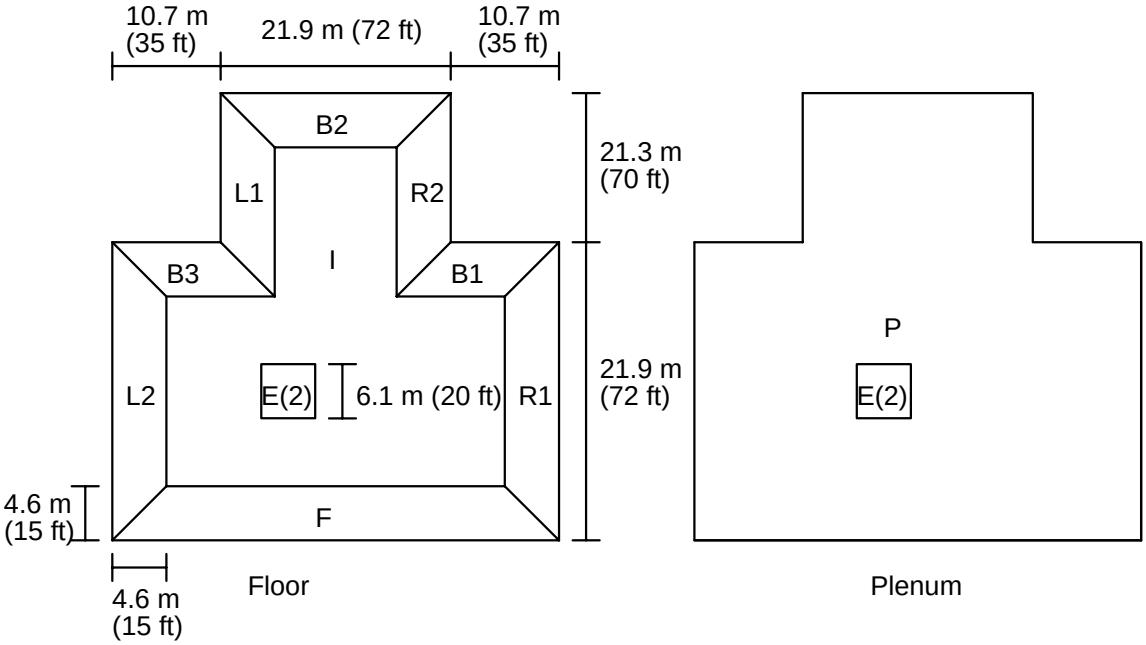
Building 9




Number of Floors = 2
Wall materials = SC01, PW04, WLIN, GP02
Roof materials = BR01, RFIN, PW05
Wall insulation thickness = 0.016 m (0.053 ft)
Roof insulation thickness = 0.037 m (0.120 ft)
Glass description – single, metal frame
Wall to window ratio = 0.21
Slab u-value = 2.27 W/m$^2$ K (0.4 Btu/h ft$^2$ R)
Ceiling u-value = 2.61 W/m$^2$ K (0.46 Btu/h ft$^2$ R)
Schedule = 9.7

Ceiling height = 2.74 m (9 ft)
Plenum height = 0.91 m (3 ft)
Number of elevators = 1
Lighting = 23.5 W/m$^2$ (2.18 W/ft$^2$)
Receptacle = 5.5 W/m$^2$ (0.51 W/ft$^2$)
Occupancy = 71 m$^2$/person (760 ft$^2$/person)
Heating setback = 19.4 C (67 F)
Heating setpoint = 22.2 C (72 F)
Cooling setpoint = 23.9 C (75 F)
Cooling setup = 37.2 C (99 F)

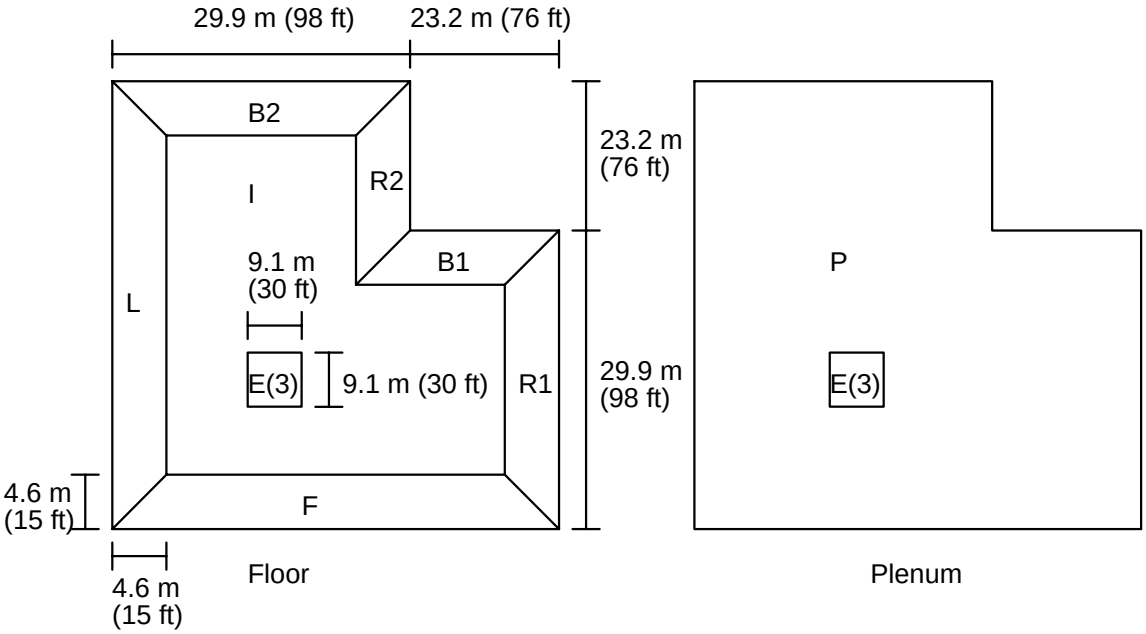
Building 10



Number of Floors = 3
Wall materials = CB42, WLIN, CB11, GP02
Roof materials = BR01, RFIN, PW05
Wall insulation thickness = 0.017 m (0.056 ft)
Roof insulation thickness = 0.060 m (0.196 ft)
Glass description – double, metal frame
Wall to window ratio = 0.26
Slab u-value = 2.27 W/m$^2$ K (0.4 Btu/h ft$^2$ R)
Ceiling u-value = 2.61 W/m$^2$ K (0.46 Btu/h ft$^2$ R)
Schedule = 9.2

Ceiling height = 2.74 m (9 ft)
Plenum height = 0.91 m (3 ft)
Number of elevators = 2
Lighting = 28.0 W/m$^2$ (2.60 W/ft$^2$)
Receptacle = 7.6 W/m$^2$ (0.71 W/ft$^2$)
Occupancy = 34 m$^2$/person (370 ft$^2$/person)
Heating setback = 18.3 C (65 F)
Heating setpoint = 21.1 C (70 F)
Cooling setpoint = 23.3 C (74 F)
Cooling setup = 37.2 C (99 F)

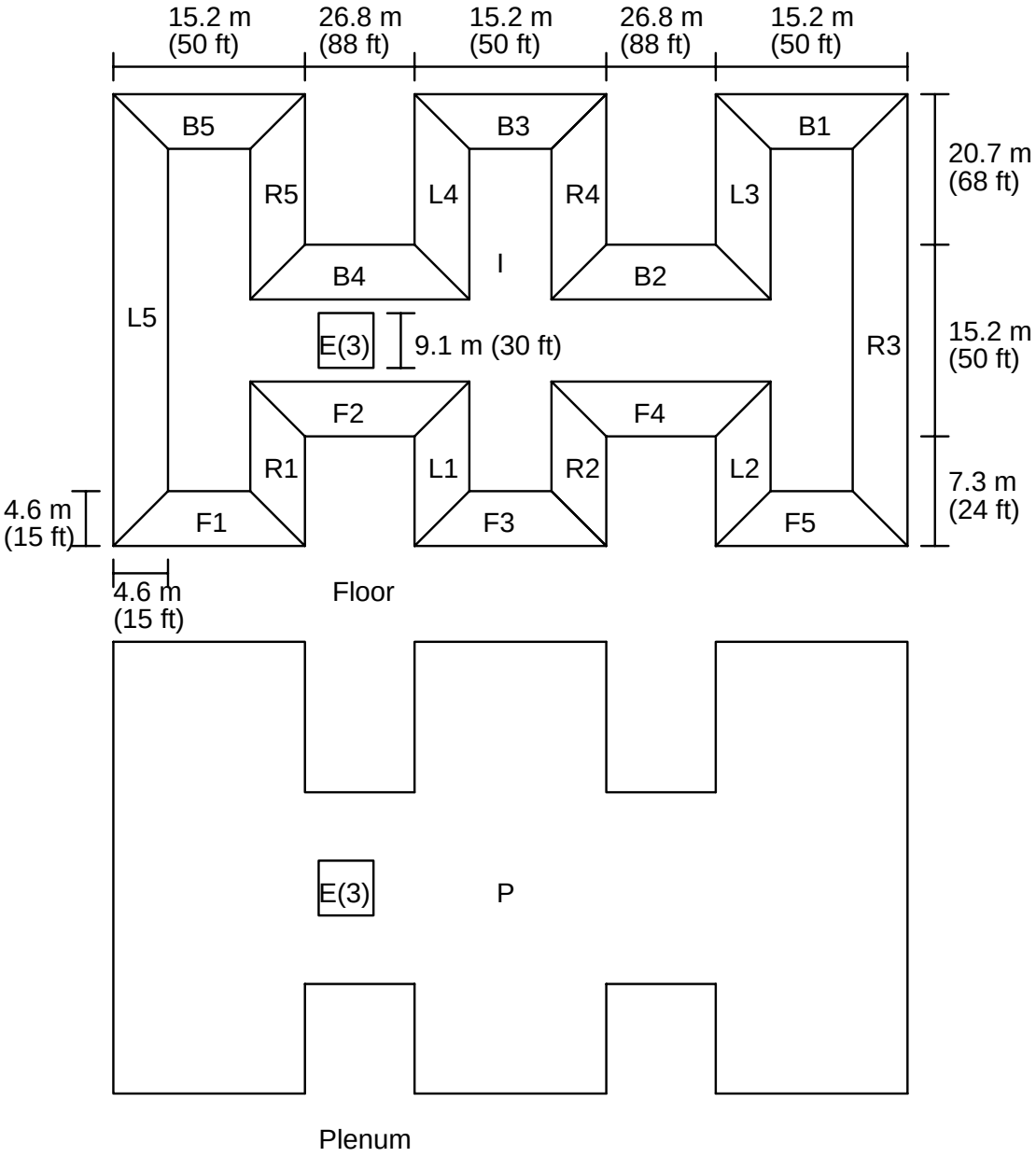
Building 11




Number of Floors = 6
Wall materials = CC23, WLIN, GP02
Roof materials = BR01, RFIN, AS01
Wall insulation thickness = 0.030 m (0.100 ft)
Roof insulation thickness = 0.079 m (0.258 ft)
Glass description – double, metal frame
Wall to window ratio = 0.41
Slab u-value = 2.27 W/m$^2$ K (0.4 Btu/h ft$^2$ R)
Ceiling u-value = 2.61 W/m$^2$ K (0.46 Btu/h ft$^2$ R)
Schedule = 9.7

Ceiling height = 2.74 m (9 ft)
Plenum height = 0.91m (3 ft)
Number of elevators = 3
Lighting = 23.6 W/m$^2$ (2.19 W/ft$^2$)
Receptacle = 6.7 W/m$^2$ (0.62 W/ft$^2$)
Occupancy = 40 m$^2$/person (430 ft$^2$/person)
Heating setback = 18.9 C (66 F)
Heating setpoint = 21.7 C (71 F)
Cooling setpoint = 23.9 C (75 F)
Cooling setup = 37.2 C (99 F)

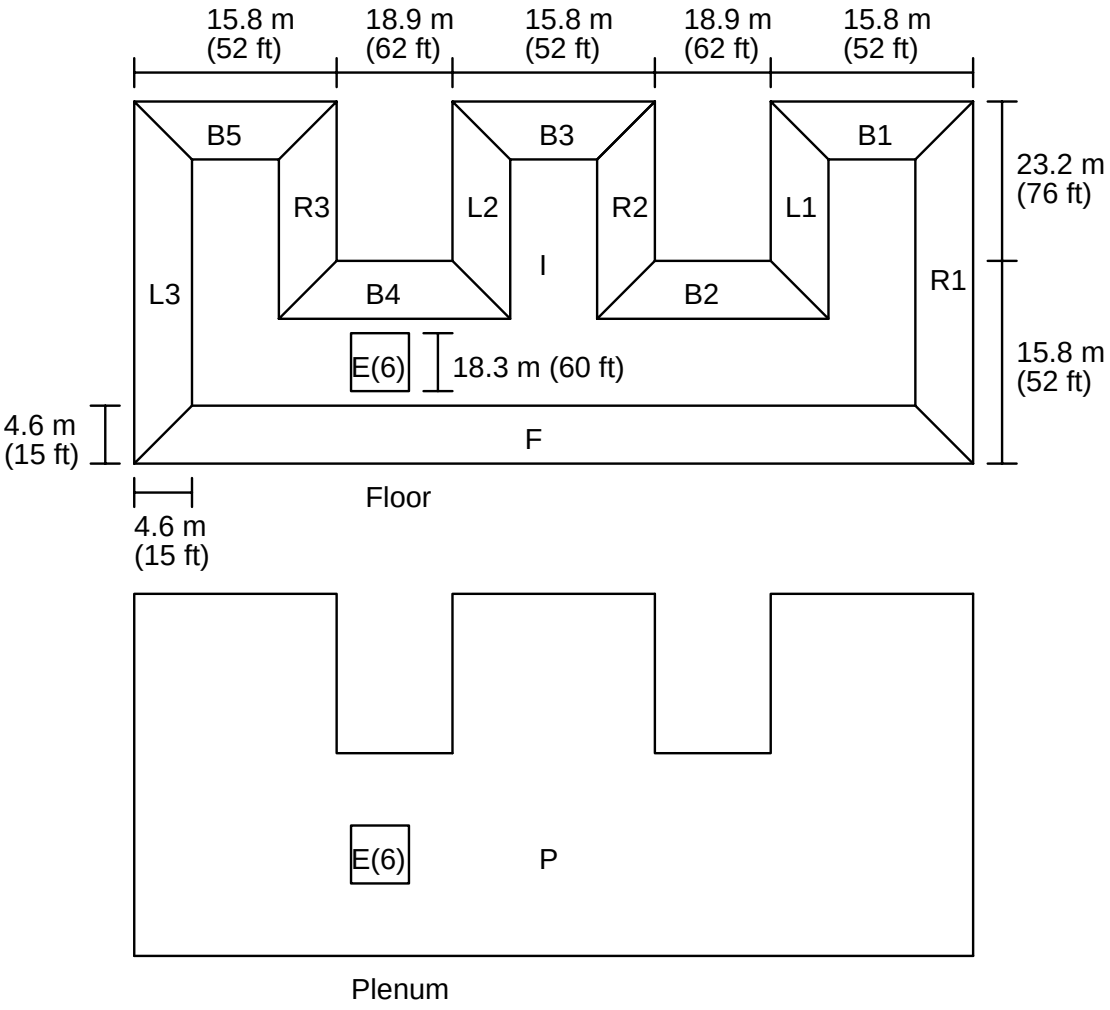
Building 12




Number of Floors = 6
Wall materials = BK05, AL21, CB06, WLIN, GP06
Roof materials = BR01, WD01, AL33, RFIN
Wall insulation thickness = 0.019 m (0.061 ft)
Roof insulation thickness = 0.033 m (0.108 ft)
Glass description – single, wood frame
Wall to window ratio = 0.32
Slab u-value = 2.27 $W/m^2$ K (0.4 Btu/h $ft^2$ R)
Ceiling u-value = 5.68 $W/m^2$ K (1.0 Btu/h $ft^2$ R)
Schedule = 11.0

Ceiling height = 3.66 m (12 ft)
Plenum height = 0.3 m (1 ft)
Number of elevators = 3
Lighting = 19.1 $W/m^2$ (1.77 $W/ft^2$)
Receptacle = 5.0 $W/m^2$ (0.46 $W/ft^2$)
Occupancy = 137 $m^2$/person (1470 $ft^2$/person)
Heating setback = 18.9 C (66 F)
Heating setpoint = 21.7 C (71 F)
Cooling setpoint = 25.0 C (77 F)
Cooling setup = 37.2 C (99 F)

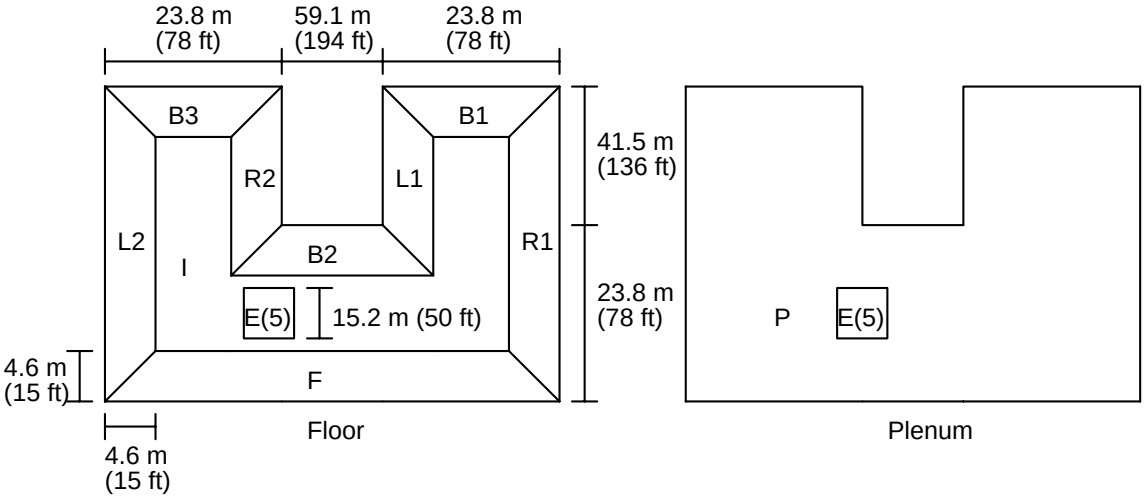
Building 13




Number of Floors = 11
Wall materials = ST01, AL21, CB06, WLIN, GP06
Roof materials = BR01, RFIN, CC04
Wall insulation thickness = 0.021 m (0.068 ft)
Roof insulation thickness = 0.035 m (0.116 ft)
Glass description – single, wood frame
Wall to window ratio = 0.37
Slab u-value = 2.27 W/m$^2$ K (0.4 Btu/h ft$^2$ R)
Ceiling u-value = 4.20 W/m$^2$ K (0.74 Btu/h ft$^2$ R)
Schedule = 18.0

Ceiling height = 2.74 m (9 ft)
Plenum height = 0.91 m (3 ft)
Number of elevators = 6
Lighting = 18.0 W/m$^2$ (1.67 W/ft$^2$)
Receptacle = 7.1 W/m$^2$ (0.66 W/ft$^2$)
Occupancy = 34 m$^2$/person (370 ft$^2$/person)
Heating setback = 18.9 C (66 F)
Heating setpoint = 21.7 C (71 F)
Cooling setpoint = 23.3 C (74 F)
Cooling setup = 37.2 C (99 F)

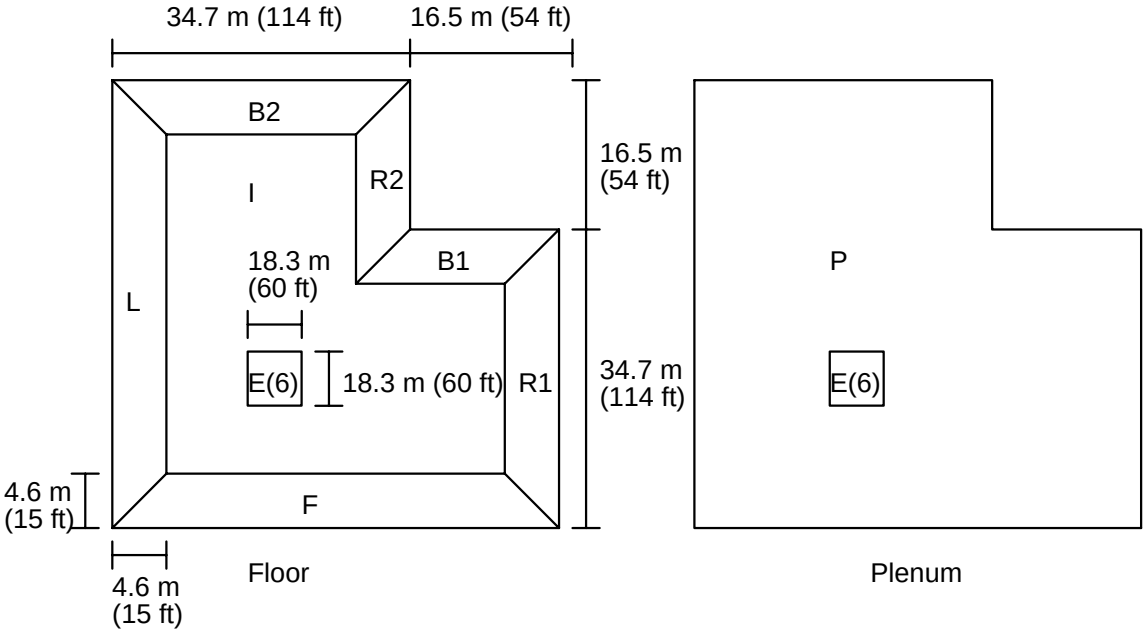
Building 14




Number of Floors = 6
Wall materials = BK05, AL21, CB06, WLIN, GP06
Roof materials = BR01, RFIN, CC24
Wall insulation thickness = 0.014 m (0.045 ft)
Roof insulation thickness = 0.018 m (0.060 ft)
Glass description – single, wood frame
Wall to window ratio = 0.25
Slab u-value = 2.27 W/m$^2$ K (0.4 Btu/h ft$^2$ R)
Ceiling u-value = 4.20 W/m$^2$ K (0.74 Btu/h ft$^2$ R)
Schedule = 9.5

Ceiling height = 2.74 m (9 ft)
Plenum height = 0.91 m (3 ft)
Number of elevators = 5
Lighting = 19.7 W/m$^2$ (1.83 W/ft$^2$)
Receptacle = 6.5 W/m$^2$ (0.60 W/ft$^2$)
Occupancy = 46 m$^2$/person (490 ft$^2$/person)
Heating setback = 18.9 C (66 F)
Heating setpoint = 21.7 C (71 F)
Cooling setpoint = 24.4 C (76 F)
Cooling setup = 37.2 C (99 F)

Building 15



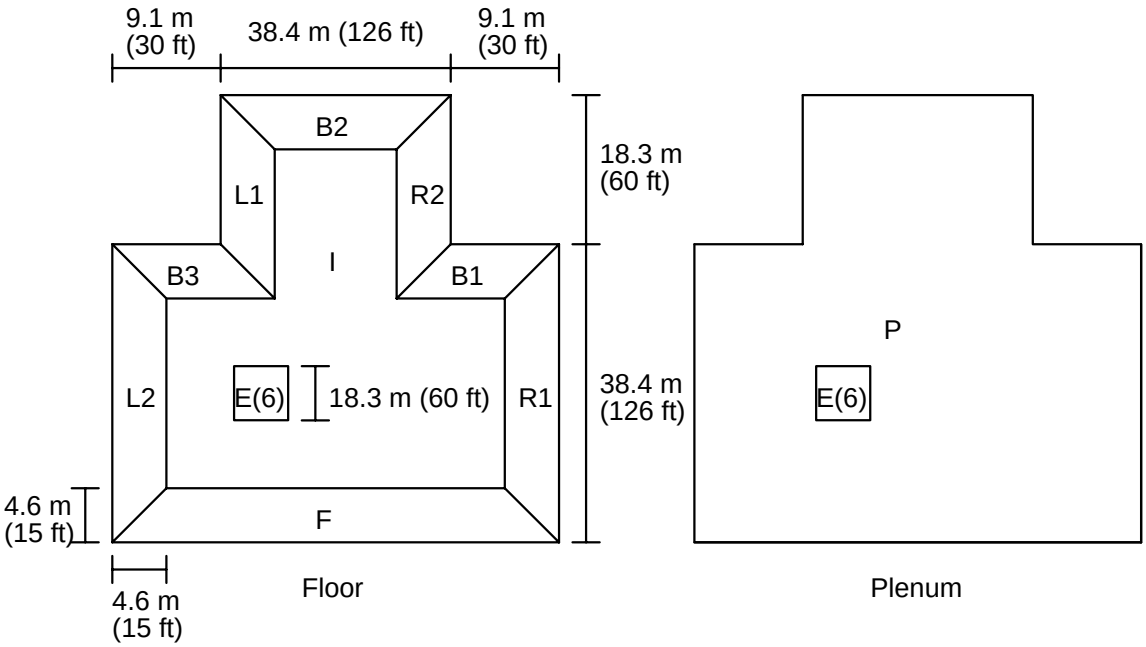

Number of Floors = 12
Wall materials = AS01, WLIN, GP02
Roof materials = BR01, RFIN, AS01
Wall insulation thickness = 0.023 m (0.075 ft)

Ceiling height = 2.74 m (9 ft)
Plenum height = 0.91 m (3 ft)
Number of elevators = 6
Lighting = 21.8 W/m$^2$ (2.03 W/ft$^2$)

Roof insulation thickness = 0.047 m (0.155 ft)
Glass description – single, improved metal frame
Wall to window ratio = 0.41
Slab u-value = 2.27 W/m$^2$ K (0.4 Btu/h ft$^2$ R)
Ceiling u-value = 2.61 W/m$^2$ K (0.46 Btu/h ft$^2$ R)
Schedule = 21.0

Receptacle = 7.3 W/m$^2$ (0.68 W/ft$^2$)
Occupancy = 31 m$^2$/person (330 ft$^2$/person)
Heating setback = 18.9 C (66 F)
Heating setpoint = 21.7 C (71 F)
Cooling setpoint = 23.3 C (74 F)
Cooling setup = 37.2 C (99 F)

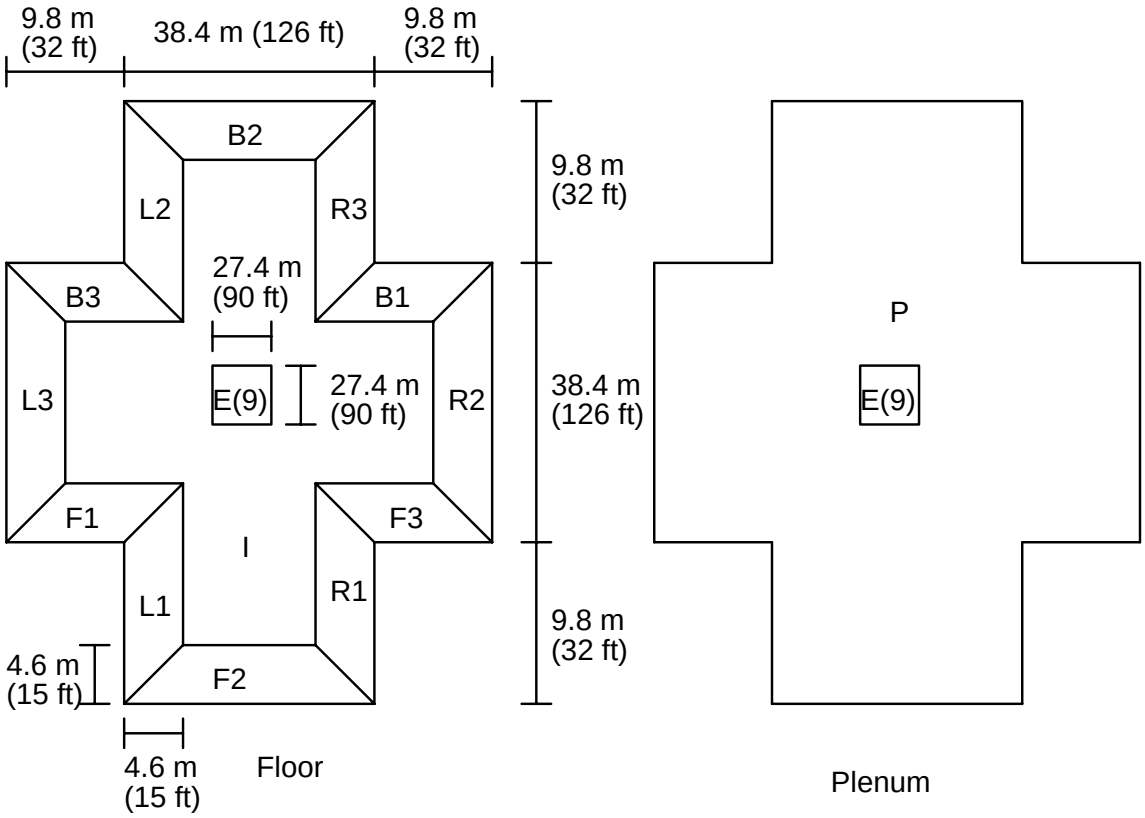
Building 16




Number of Floors = 10
Wall materials = CC23, WLIN, GP02
Roof materials = BR01, RFIN, AS01
Wall insulation thickness = 0.016 m (0.054 ft)
Roof insulation thickness = 0.047 m (0.155 ft)
Glass description – single, metal frame
Wall to window ratio = 0.43
Slab u-value = 2.27 W/m$^2$ K (0.4 Btu/h ft$^2$ R)
Ceiling u-value = 2.61 W/m$^2$ K (0.46 Btu/h ft$^2$ R)
Schedule = 11.0

Ceiling height = 2.74 m (9 ft)
Plenum height = 0.91 m (3 ft)
Number of elevators = 6
Lighting = 23.1 W/m$^2$ (2.15 W/ft$^2$)
Receptacle = 6.6 W/m$^2$ (0.61 W/ft$^2$)
Occupancy = 42 m$^2$/person (450 ft$^2$/person)
Heating setback = 19.4 C (67 F)
Heating setpoint = 22.2 C (72 F)
Cooling setpoint = 24.4 C (76 F)
Cooling setup = 37.2 C (99 F)

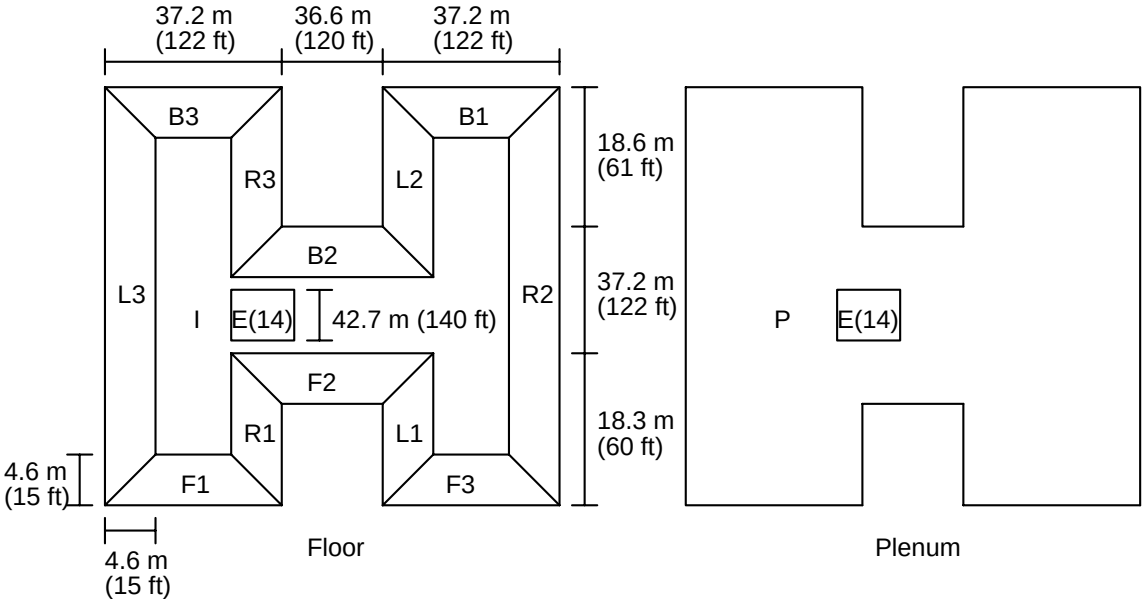
Building 17




Number of Floors = 19
Wall materials = CC23, WLIN, GP02
Roof materials = BR01, RFIN, AS01
Wall insulation thickness = 0.028 m (0.093 ft)
Roof insulation thickness = 0.086 m (0.282 ft)
Glass description – double, metal frame
Wall to window ratio = 0.38
Slab u-value = 2.27 W/m$^2$ K (0.4 Btu/h ft$^2$ R)
Ceiling u-value = 2.61 W/m$^2$ K (0.46 Btu/h ft$^2$ R)
Schedule = 11.0

Ceiling height = 2.74 m (9 ft)
Plenum height = 0.91 m (3 ft)
Number of elevators = 9
Lighting = 24.8 W/m$^2$ (2.30 W/ft$^2$)
Receptacle = 6.8 W/m$^2$ (0.63 W/ft$^2$)
Occupancy = 41 m$^2$/person (440 ft$^2$/person)
Heating setback = 19.4 C (67 F)
Heating setpoint = 22.2 C (72 F)
Cooling setpoint = 24.4 C (76 F)
Cooling setup = 37.2 C (99 F)

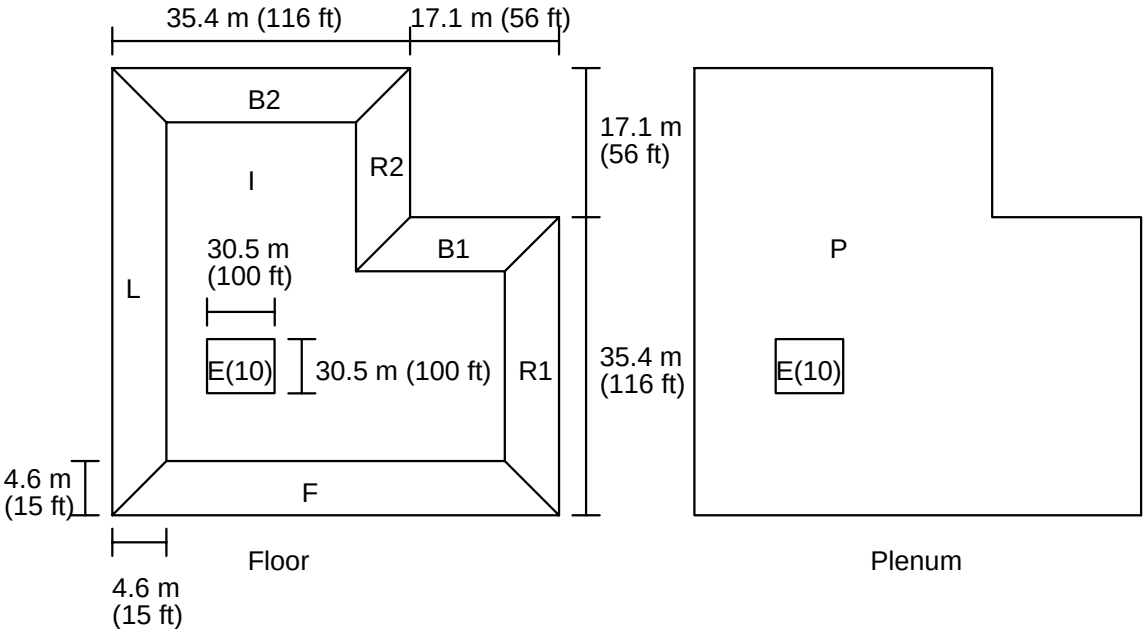
Building 18




Number of Floors = 10
Wall materials = BK05, AL21, GP01, WLIN, GP06
Roof materials = BR01, RFIN, CC24
Wall insulation thickness = 0.020 m (0.066 ft)
Roof insulation thickness = 0.030 m (0.100 ft)
Glass description – single, metal frame
Wall to window ratio = 0.25
Slab u-value = 2.27 W/m$^2$ K (0.4 Btu/h ft$^2$ R)
Ceiling u-value = 2.61 W/m$^2$ K (0.46 Btu/h ft$^2$ R)
Schedule = 9.2

Ceiling height = 2.74 m (9 ft)
Plenum height = 0.91 m (3 ft)
Number of elevators = 14
Lighting = 29.7 W/m$^2$ (2.76 W/ft$^2$)
Receptacle = 9.6 W/m$^2$ (0.89 W/ft$^2$)
Occupancy = 23 m$^2$/person (250 ft$^2$/person)
Heating setback = 18.3 C (65 F)
Heating setpoint = 21.1 C (70 F)
Cooling setpoint = 25.0 C (77 F)
Cooling setup = 37.2 C (99 F)

Building 19



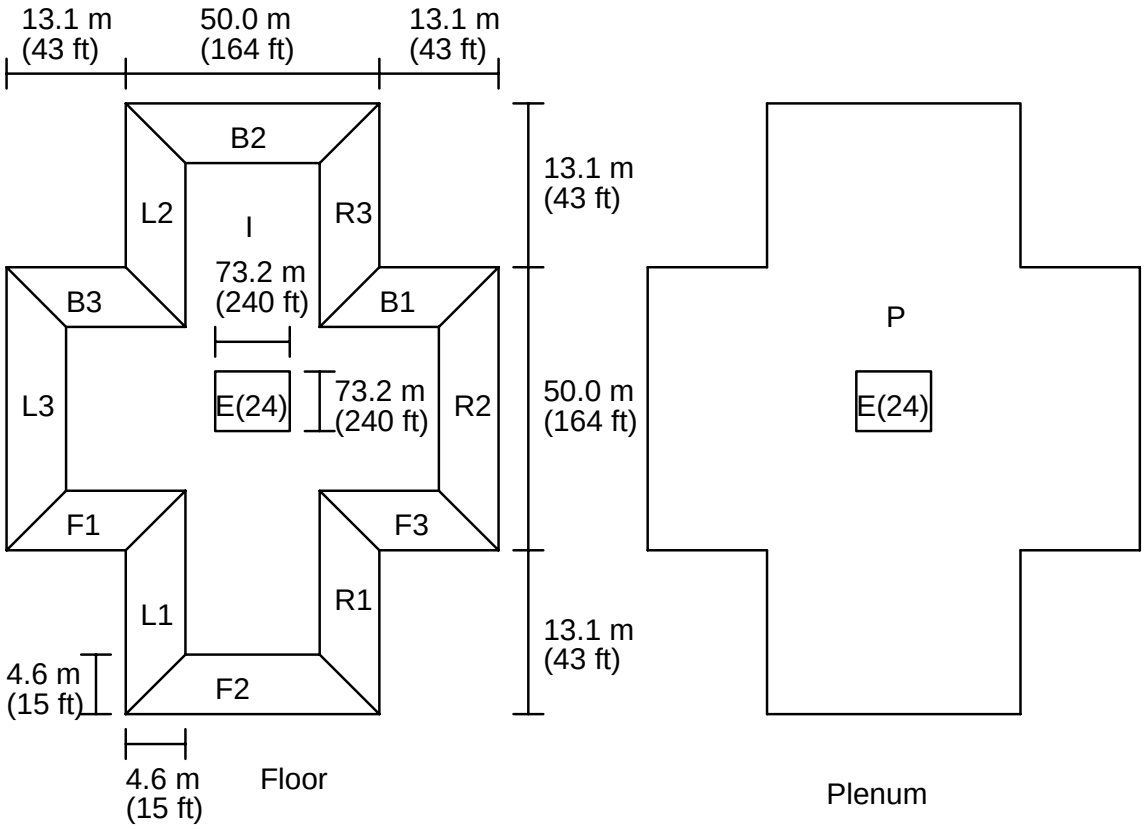

Number of Floors = 28

Ceiling height = 2.74 m (9 ft)

Wall materials = AS01, WLIN, GP02
Roof materials = BR01, RFIN, AS01
Wall insulation thickness = 0.030 m (0.098 ft)
Roof insulation thickness = 0.053 m (0.175 ft)
Glass description – single, improved metal frame
Wall to window ratio = 0.48
Slab u-value = 2.27 W/m$^2$ K (0.4 Btu/h ft$^2$ R)
Ceiling u-value = 2.61 W/m$^2$ K (0.46 Btu/h ft$^2$ R)
Schedule = 11.0

Plenum height = 0.91 m (3 ft)
Number of elevators = 10
Lighting = 26.5 W/m$^2$ (2.46 W/ft$^2$)
Receptacle = 8.1 W/m$^2$ (0.75 W/ft$^2$)
Occupancy = 29 m$^2$/person (310 ft$^2$/person)
Heating setback = 18.9 C (66 F)
Heating setpoint = 21.7 C (71 F)
Cooling setpoint = 24.4 C (76 F)
Cooling setup = 37.2 C (99 F)

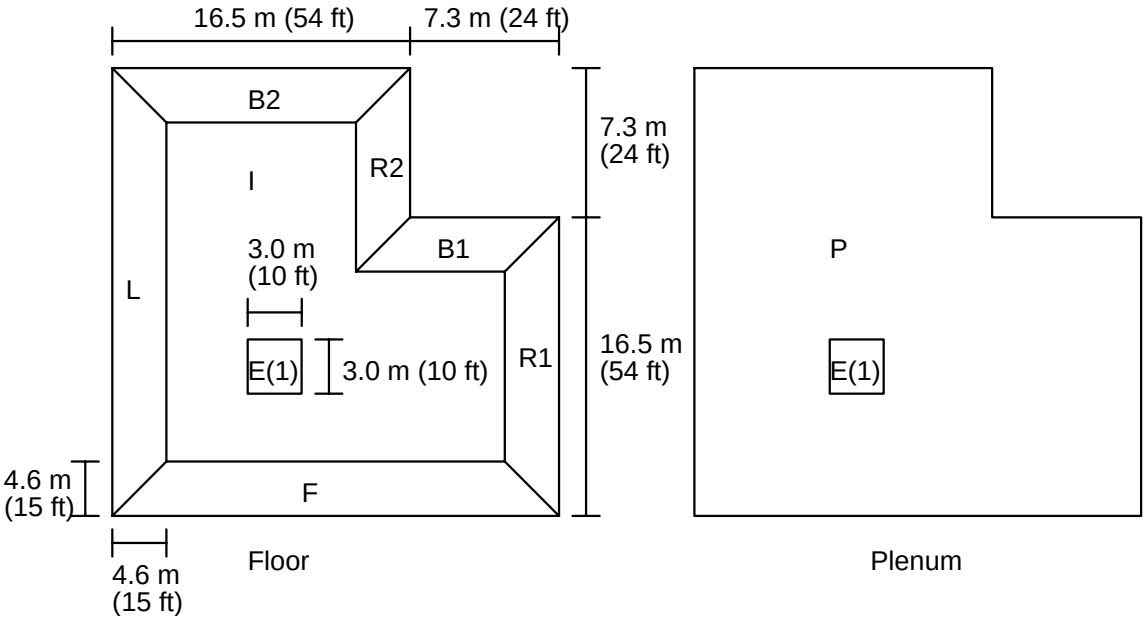
Building 20




Number of Floors = 45
Wall materials = GL01, WLIN, GP02
Roof materials = BR01, RFIN, AS01
Wall insulation thickness = 0.023 m (0.077 ft)
Roof insulation thickness = 0.054 m (0.177 ft)
Glass description – single, metal frame
Wall to window ratio = 0.47
Slab u-value = 2.27 W/m$^2$ K (0.4 Btu/h ft$^2$ R)
Ceiling u-value = 2.61 W/m$^2$ K (0.46 Btu/h ft$^2$ R)
Schedule = 11.8

Ceiling height = 2.74 m (9 ft)
Plenum height = 0.91 m (3 ft)
Number of elevators = 24
Lighting = 25.5 W/m$^2$ (2.37 W/ft$^2$)
Receptacle = 8.4 W/m$^2$ (0.78 W/ft$^2$)
Occupancy = 25 m$^2$/person (270 ft$^2$/person)
Heating setback = 18.9 C (66 F)
Heating setpoint = 21.7 C (71 F)
Cooling setpoint = 25.0 C (77 F)
Cooling setup = 37.2 C (99 F)

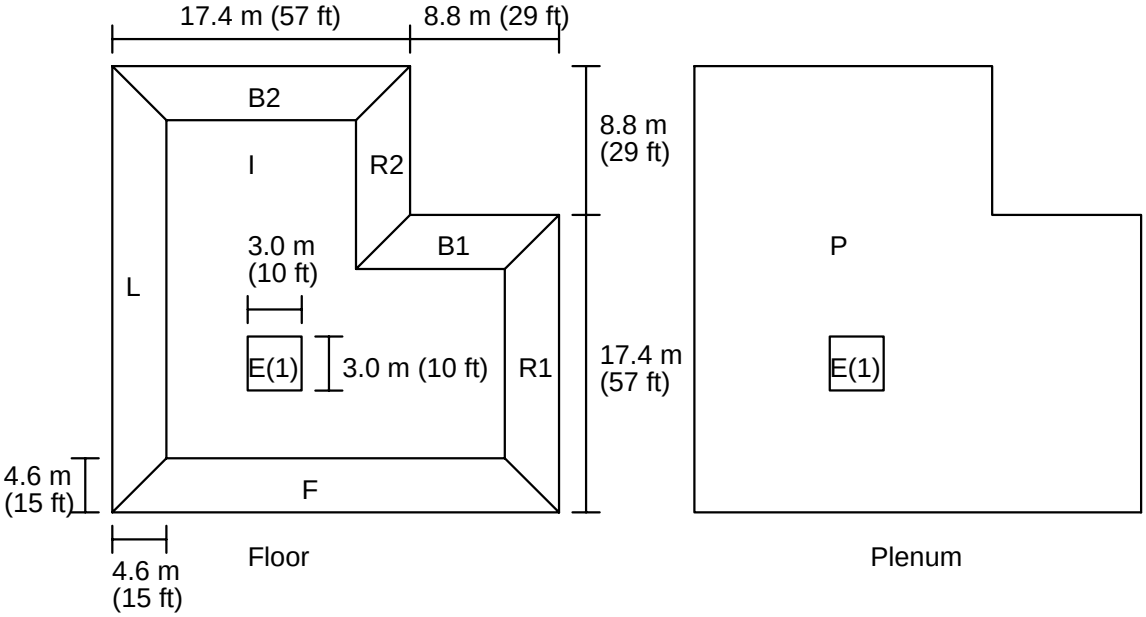
Building 21




Number of Floors = 2
Wall materials = BK05, AL21, CB06, WLIN, GP06
Roof materials = BR01, RFIN, AS01
Wall insulation thickness = 0.048 m (0.156 ft)
Roof insulation thickness = 0.141 m (0.462 ft)
Glass description – double, improved metal frame
Wall to window ratio = 0.18
Slab u-value = 2.27 W/m$^2$ K (0.4 Btu/h ft$^2$ R)
Ceiling u-value = 2.61 W/m$^2$ K (0.46 Btu/h ft$^2$ R)
Schedule = 9.5

Ceiling height = 2.74 m (9 ft)
Plenum height = 0.91 m (3 ft)
Number of elevators = 1
Lighting = 18.5 W/m$^2$ (1.72 W/ft$^2$)
Receptacle = 7.5 W/m$^2$ (0.70 W/ft$^2$)
Occupancy = 31 m$^2$/person (330 ft$^2$/person)
Heating setback = 18.3 C (65 F)
Heating setpoint = 21.1 C (70 F)
Cooling setpoint = 23.9 C (75 F)
Cooling setup = 37.2 C (99 F)

Building 22



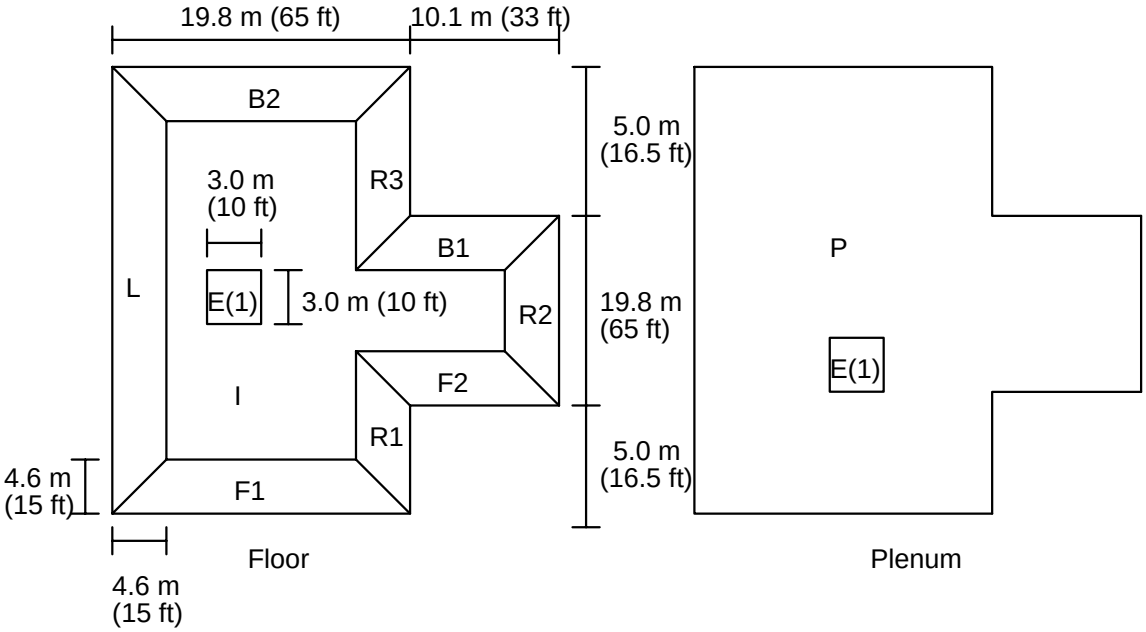

Number of Floors = 2

Ceiling height = 2.74 m (9 ft)

Wall materials = SC01, PW04, WLIN, GP02
Roof materials = BR01, RFIN, AS01
Wall insulation thickness = 0.029 m (0.095 ft)
Roof insulation thickness = 0.141 m (0.462 ft)
Glass description – single, improved metal frame
Wall to window ratio = 0.22
Slab u-value = 2.27 W/m$^2$ K (0.4 Btu/h ft$^2$ R)
Ceiling u-value = 2.61 W/m$^2$ K (0.46 Btu/h ft$^2$ R)
Schedule = 9.7

Plenum height = 0.91 m (3 ft)
Number of elevators = 1
Lighting = 18.5 W/m$^2$ (1.72 W/ft$^2$)
Receptacle = 6.2 W/m$^2$ (0.58 W/ft$^2$)
Occupancy = 46 m$^2$/person (500 ft$^2$/person)
Heating setback = 18.3 C (65 F)
Heating setpoint = 21.1 C (70 F)
Cooling setpoint = 23.9 C (75 F)
Cooling setup = 37.2 C (99 F)

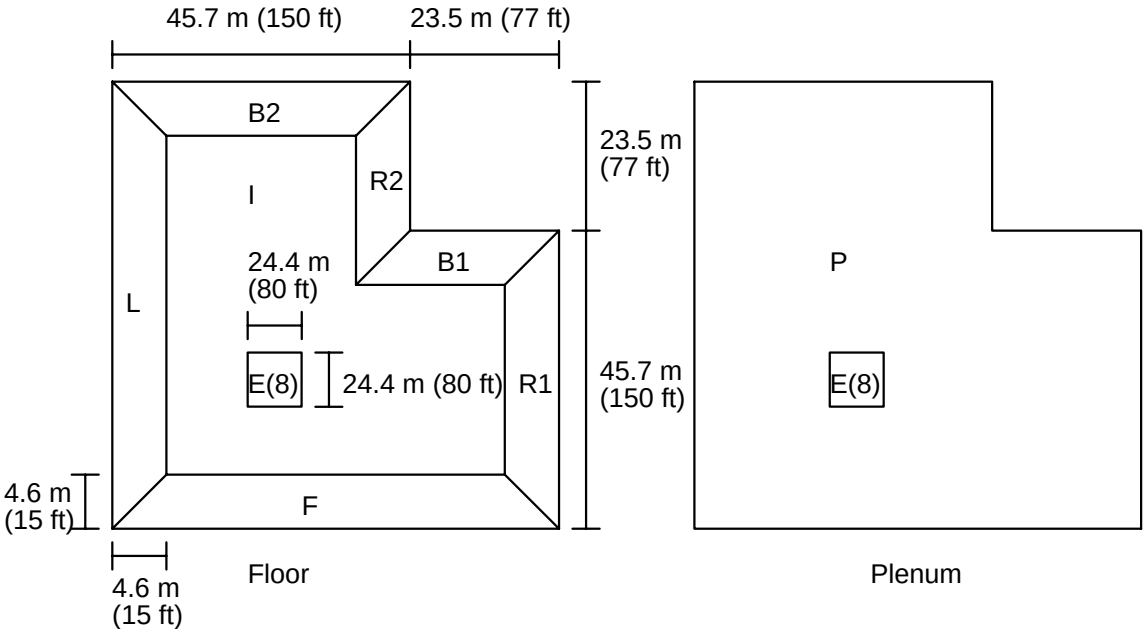
Building 23




Number of Floors = 2
Wall materials = BK05, AL21, GP01, WLIN, GP06
Roof materials = BR01, RFIN, AS01
Wall insulation thickness = 0.071 m (0.234 ft)
Roof insulation thickness = 0.141 m (0.462 ft)
Glass description – double, improved metal frame
Wall to window ratio = 0.18
Slab u-value = 2.27 W/m$^2$ K (0.4 Btu/h ft$^2$ R)
Ceiling u-value = 2.61 W/m$^2$ K (0.46 Btu/h ft$^2$ R)
Schedule = 9.5

Ceiling height = 2.74 m (9 ft)
Plenum height = 0.91 m (3 ft)
Number of elevators = 1
Lighting = 18.5 W/m$^2$ (1.72 W/ft$^2$)
Receptacle = 7.5 W/m$^2$ (0.70 W/ft$^2$)
Occupancy = 32 m$^2$/person (340 ft$^2$/person)
Heating setback = 18.3 C (65 F)
Heating setpoint = 21.1 C (70 F)
Cooling setpoint = 23.9 C (75 F)
Cooling setup = 37.2 C (99 F)

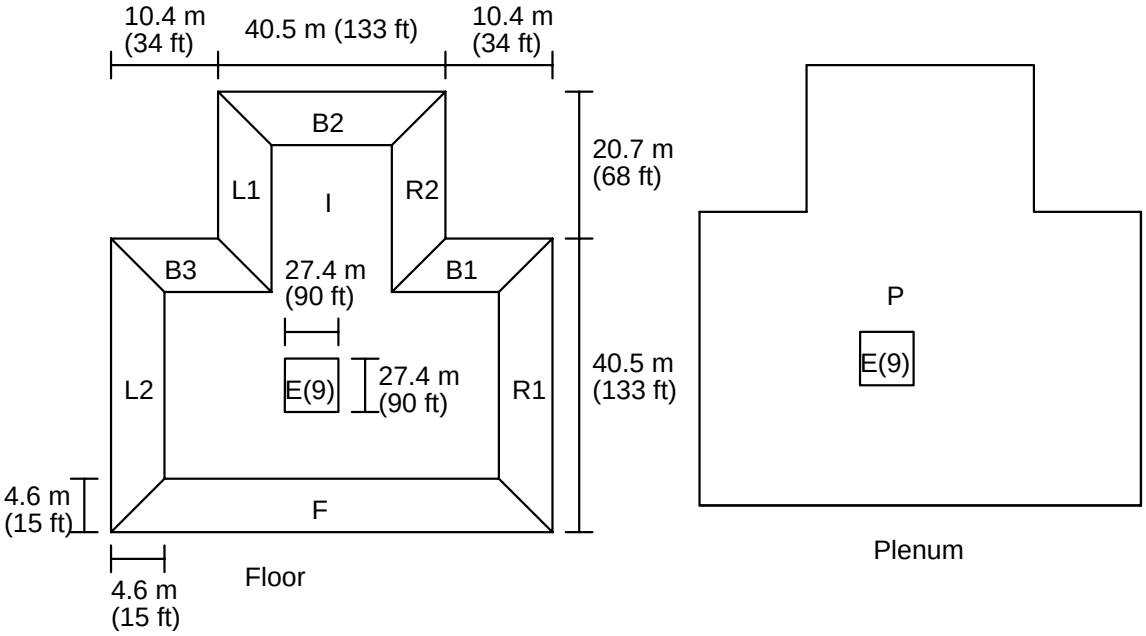
Building 24




Number of Floors = 9
Wall materials = AS01, WLIN, GP02
Roof materials = BR01, RFIN, AS01
Wall insulation thickness = 0.082 m (0.268 ft)
Roof insulation thickness = 0.141 m (0.462 ft)
Glass description – double, metal frame
Wall to window ratio = 0.38
Slab u-value = 2.27 W/m$^2$ K (0.4 Btu/h ft$^2$ R)
Ceiling u-value = 2.61 W/m$^2$ K (0.46 Btu/h ft$^2$ R)
Schedule = 11.0

Ceiling height = 2.74 m (9 ft)
Plenum height = 0.91 m (3 ft)
Number of elevators = 8
Lighting = 16.1 W/m$^2$ (1.50 W/ft$^2$)
Receptacle = 8.3 W/m$^2$ (0.77 W/ft$^2$)
Occupancy = 26 m$^2$/person (280 ft$^2$/person)
Heating setback = 18.3 C (65 F)
Heating setpoint = 21.1 C (70 F)
Cooling setpoint = 23.9 C (75 F)
Cooling setup = 37.2 C (99 F)

Building 25



Number of Floors = 14
Wall materials = AS01, WLIN, GP02
Roof materials = BR01, RFIN, AS01
Wall insulation thickness = 0.039 m (0.129 ft)
Roof insulation thickness = 0.116 m (0.379 ft)
Glass description – single, metal frame
Wall to window ratio = 0.49
Slab u-value = 2.27 W/$m^2$ K (0.4 Btu/h $ft^2$ R)
Ceiling u-value = 2.61 W/$m^2$ K (0.46 Btu/h $ft^2$ R)
Schedule = 11.8

Ceiling height = 2.74 m (9 ft)
Plenum height = 0.91 m (3 ft)
Number of elevators = 9
Lighting = 16.1 W/$m^2$ (1.50 W/$ft^2$)
Receptacle = 5.8 W/$m^2$ (0.54 W/$ft^2$)
Occupancy = 57 $m^2$/person (610 $ft^2$/person)
Heating setback = 18.3 C (65 F)
Heating setpoint = 21.1 C (70 F)
Cooling setpoint = 23.9 C (75 F)
Cooling setup = 37.2 C (99 F)

**REFERENCES**


Taylor, Z.T., and R.G. Pratt, 1989. *Description of Electrical Energy Use in Commercial Buildings in the Pacific Northwest*, DOE/BP-13795-22, December 1989. Bonneville Power Administration, Portland, Oregon.

Bonneville Power Administration. 1989. *The Commercial Audit Database, A Descriptive Data Summary*, Volume 1 and 2, March 1989. Office of Energy Resources, Bonneville Power Administration, U.S. Department of Energy, Portland, Oregon.

EIA. 1986. *1983 Nonresidential Building Energy Consumption Survey*. Energy Information Administration, U.S. Department of Energy

EIA. 1989. *1986 Nonresidential Building Energy Consumption Survey*. Energy Information Administration, U.S. Department of Energy

Briggs, R., D. Crawley, and D. Belzer. 1987. *Analysis and categorization of the office building stock.* GRI-87/0244 by Battelle, Pacific Northwest Laboratory, for Gas Research Institute.

Briggs, R., D. Crawley, and J.S. Schliesing. 1992. *Energy requirements for office buildings. Volume 1, Existing buildings*. GRI-90/0236.1 by Battelle, Pacific Northwest Laboratory, for Gas Research Institute.

Crawley, D., and J. Schliesing. 1992. *Energy requirements for office buildings. Volume 2, Recent and future buildings*. GRI-90/0236.2 by Battelle, Pacific Northwest Laboratory, for Gas Research Institute.

Curtis, R., B. Birdsall, W. Buhl, E. Erdam, J. Eto, J. Hirsch, K. Olson, and R. Winkelmann. 1984. "DOE-2 building energy use analysis program." LBL-18046, Lawrence Berkeley Laboratory.

Walton, G., 1989. *AIRNET – A Computer Program for Building Airflow Network Modeling*. NISTIR 89-4072 National Institute of Standards and Technology.

Klein, S. 1992. *TRNSYS – A transient system simulation program*. Engineering Experiment Station Report 38-13. Solar Energy Laboratory, University of Wisconsin-Madison.

Hensen, J. 1996 "Modelling coupled heat and ari flow: ping-pong vs. onions." 16th AIVC Conference, Air Infiltration and Ventilation Centre.