LIC

```
# Function: CP Model Equation

bldg.sim <- function(oa.temp, setpoint, u.value, air.chg) {

  # Assumptions
  baseload <- 25200
  #u.value <- 1.5  # watts per sq. meter/K building envelope conductance  SI
  area <- 7500  # sq. meter envelope area  SI
  volume <- 37800  # cubic meter volume (conditioned space) (assumption) SI
  #air.chg <- 1  # air change per hr.
  rho <- 1.2  # kg/m cubed density of air  SI
  cp <- 0.27  # watt hrs./cubic meter in K specific heat of air  SI
  cool.slope <- 2695  # cooling slope (from lm)
  cool.cp <- 62.76  # cooling CP (from CP model)
  #setpoint <- 76  # cooling setpoint (assumption)
  #oa.temp

  # Cooling Coefficient
  cool.coef <- ((((u.value * area) + (volume * air.chg * rho * cp)) / 1000) * 0.556) * (30*24)
  # convert from watts to kw, = kwh per F (multiply by 0.556)

  # Cooling Efficiency
  cool.eff <- cool.coef / cool.slope

  # Internal Loads
  i.loads <- -cool.coef * (cool.cp - setpoint)

  # Total Electricity
  total.e <- ifelse(oa.temp - cool.cp > 0,
    baseload + (cool.slope * (oa.temp - cool.cp)),
    baseload) # E = expected kWh at Toa - CP MODEL EQUATION

  # Parameters
  parameters <- c(u.value, area, volume, air.chg, rho, cp, cool.slope, cool.cp,
                  cool.eff, setpoint, baseload, oa.temp, total.e, i.loads)
  # as.data.frame(parameters)
  names(parameters) <- c('u-value', 'surface area', 'volume', 'air changes', 'density of air',
                         'specific heat of air', 'cooling slope', 'cooling change-point',
                         'cooling efficiency', 'setpoint', 'baseload', 'outdoor air temp.',
                         'total electricity', 'internal loads')

  return(cbind(total.e, cool.coef, cool.eff, i.loads))
  # Return
  #return(
  #cat("Expected kWh at Toa:", total.e,
      #"\nCooling Coefficient:", cool.coef,
      #"\nCooling Efficiency:", cool.eff,
      #"\nInternal Loads:", i.loads,
      #"\nParameters\n",
      #parameters
```

```
      #))
}

bldg.sim(50, 76, 1.5, 1)
```

```
##      total.e cool.coef cool.eff  i.loads
## [1,]   25200  9406.399 3.490315 124540.7
```

Simulation

Assumptions made for model can be simulated

Sim #1: Toa – use CP Model Equation and simulate Toa from 10-100 degrees F in steps of 5 degrees

The first simulation using the building changepoint model uses a temperature range from 10 to 100 deg. F by 5 degree incrememnts. All other parameters are kept constant (thermostat setpoint: 76 deg. F, u value: 1.5, air exchange: 1).

```
library(devtools)
```

```
## Warning: package 'devtools' was built under R version 3.3.2
```

```
scipen=9999

sim.temps <- seq(from = 10, to = 100, by = 5)

temp.range.results <- lapply(sim.temps, FUN = bldg.sim,  setpoint = 76, u.value = 1.5, air.chg = 1)

temp.range.results <- as.data.frame(do.call(rbind, temp.range.results))
temp.range.results <- cbind(sim.temps, temp.range.results)
print(temp.range.results)
```

```
##    sim.temps  total.e cool.coef cool.eff  i.loads
## 1         10  25200.0  9406.399 3.490315 124540.7
## 2         15  25200.0  9406.399 3.490315 124540.7
## 3         20  25200.0  9406.399 3.490315 124540.7
## 4         25  25200.0  9406.399 3.490315 124540.7
## 5         30  25200.0  9406.399 3.490315 124540.7
## 6         35  25200.0  9406.399 3.490315 124540.7
## 7         40  25200.0  9406.399 3.490315 124540.7
## 8         45  25200.0  9406.399 3.490315 124540.7
## 9         50  25200.0  9406.399 3.490315 124540.7
## 10        55  25200.0  9406.399 3.490315 124540.7
## 11        60  25200.0  9406.399 3.490315 124540.7
## 12        65  31236.8  9406.399 3.490315 124540.7
## 13        70  44711.8  9406.399 3.490315 124540.7
## 14        75  58186.8  9406.399 3.490315 124540.7
## 15        80  71661.8  9406.399 3.490315 124540.7
## 16        85  85136.8  9406.399 3.490315 124540.7
## 17        90  98611.8  9406.399 3.490315 124540.7
```

```
## 18        95 112086.8  9406.399 3.490315 124540.7
## 19       100 125561.8  9406.399 3.490315 124540.7
```

```
summary(temp.range.results)
```

```
##    sim.temps        total.e         cool.coef       cool.eff
##  Min.   : 10.0   Min.   : 25200   Min.   :9406   Min.   :3.49
##  1st Qu.: 32.5   1st Qu.: 25200   1st Qu.:9406   1st Qu.:3.49
##  Median : 55.0   Median : 25200   Median :9406   Median :3.49
##  Mean   : 55.0   Mean   : 47600   Mean   :9406   Mean   :3.49
##  3rd Qu.: 77.5   3rd Qu.: 64924   3rd Qu.:9406   3rd Qu.:3.49
##  Max.   :100.0   Max.   :125562   Max.   :9406   Max.   :3.49
##     i.loads
##  Min.   :124541
##  1st Qu.:124541
##  Median :124541
##  Mean   :124541
##  3rd Qu.:124541
##  Max.   :124541
```

Sim #2: Tset – substitute other values from 50 to 75, in steps of 5 degrees – this simulates setting the thermostat lower or higher

The second simulation using the building changepoint model uses a thermostat temperature set range from 50 to 75 deg. F by 5 degree incrememnts. All other parameters are kept constant (temperature: 76 deg. F, u value: 1.5, air exchange: 1).

```
library(devtools)
scipen=9999

sim.Tset <- seq(from = 50, to = 75, by = 5)

Tset.range.results <- lapply(sim.Tset, FUN = bldg.sim, oa.temp = 76, u.value = 1.5, air.chg = 1)

Tset.range.results <- as.data.frame(do.call(rbind, Tset.range.results))
Tset.range.results <- cbind(sim.Tset, Tset.range.results)
print(Tset.range.results)
```

```
##   sim.Tset total.e cool.coef cool.eff    i.loads
## 1       50 60881.8  9406.399 3.490315 -120025.65
## 2       55 60881.8  9406.399 3.490315  -72993.66
## 3       60 60881.8  9406.399 3.490315  -25961.66
## 4       65 60881.8  9406.399 3.490315   21070.33
## 5       70 60881.8  9406.399 3.490315   68102.33
## 6       75 60881.8  9406.399 3.490315  115134.33
```

```
summary(Tset.range.results)
```

```
##     sim.Tset        total.e        cool.coef       cool.eff
##  Min.   :50.00   Min.   :60882   Min.   :9406   Min.   :3.49
##  1st Qu.:56.25   1st Qu.:60882   1st Qu.:9406   1st Qu.:3.49
```

```
##  Median :62.50   Median :60882   Median :9406   Median :3.49
##  Mean   :62.50   Mean   :60882   Mean   :9406   Mean   :3.49
##  3rd Qu.:68.75   3rd Qu.:60882   3rd Qu.:9406   3rd Qu.:3.49
##  Max.   :75.00   Max.   :60882   Max.   :9406   Max.   :3.49
##     i.loads
##  Min.   :-120026
##  1st Qu.: -61236
##  Median :  -2446
##  Mean   :  -2446
##  3rd Qu.:  56344
##  Max.   : 115134
```

Sim #3: U – substitute other values: 0.25, 0.18, 0.12, 0.09 – this simulates adding insulation, etc. to tighten building envelope

The third simulation using the building changepoint model uses building insulation coefficient range from 0.09 to 0.25 by 0.1 degree incrememnts. All other parameters are kept constant (temperature: 76 deg. F, thermostat setpoint: 76 deg. F, air exchange: 1).

```
sim.insulation <- seq(from = 0.6, to = 2, by = 0.2)

insulation.range.results <- lapply(sim.insulation, FUN = bldg.sim, oa.temp = 76, setpoint = 76, air.chg

insulation.range.results <- as.data.frame(do.call(rbind, insulation.range.results))
insulation.range.results <- cbind(sim.insulation, insulation.range.results)
print(insulation.range.results)
```

```
##   sim.insulation total.e cool.coef cool.eff   i.loads
## 1            0.6 60881.8  6704.239 2.487658  88764.13
## 2            0.8 60881.8  7304.719 2.710471  96714.48
## 3            1.0 60881.8  7905.199 2.933284 104664.84
## 4            1.2 60881.8  8505.679 3.156096 112615.19
## 5            1.4 60881.8  9106.159 3.378909 120565.55
## 6            1.6 60881.8  9706.639 3.601721 128515.90
## 7            1.8 60881.8 10307.119 3.824534 136466.26
## 8            2.0 60881.8 10907.599 4.047347 144416.61
```

```
summary(insulation.range.results)
```

```
##  sim.insulation    total.e        cool.coef        cool.eff
##  Min.   :0.60   Min.   :60882   Min.   : 6704   Min.   :2.488
##  1st Qu.:0.95   1st Qu.:60882   1st Qu.: 7755   1st Qu.:2.878
##  Median :1.30   Median :60882   Median : 8806   Median :3.268
##  Mean   :1.30   Mean   :60882   Mean   : 8806   Mean   :3.268
##  3rd Qu.:1.65   3rd Qu.:60882   3rd Qu.: 9857   3rd Qu.:3.657
##  Max.   :2.00   Max.   :60882   Max.   :10908   Max.   :4.047
##     i.loads
##  Min.   : 88764
##  1st Qu.:102677
##  Median :116590
##  Mean   :116590
##  3rd Qu.:130503
##  Max.   :144417
```

Sim #4: V – substitute other values: 1 to 3, in steps of 0.5 – this simulates improved/worse ventilation/infiltration flow rate (lower is)

The fourth simulation using the building changepoint model uses building ventilation / infiltration flow rate range from 0.09 to 0.25 by 0.1 degree incrememnts. All other parameters are kept constant (temperature: 76 deg. F, thermostat setpoint: 76 deg. F, u value: 1.5).

```
sim.V <- seq(from = 1, to = 3, by = 0.5)

V.range.results <- lapply(sim.V, FUN = bldg.sim,  oa.temp = 76, setpoint = 76, u.value = 1.5)

V.range.results <- as.data.frame(do.call(rbind, V.range.results))
V.range.results <- cbind(sim.V, V.range.results)
print(V.range.results)
```

```
##   sim.V total.e cool.coef cool.eff  i.loads
## 1   1.0 60881.8  9406.399 3.490315 124540.7
## 2   1.5 60881.8 11857.799 4.399925 156997.3
## 3   2.0 60881.8 14309.198 5.309536 189453.8
## 4   2.5 60881.8 16760.598 6.219146 221910.3
## 5   3.0 60881.8 19211.997 7.128756 254366.8
```

```
summary(V.range.results)
```

```
##      sim.V        total.e        cool.coef        cool.eff
##  Min.   :1.0   Min.   :60882   Min.   : 9406   Min.   :3.490
##  1st Qu.:1.5   1st Qu.:60882   1st Qu.:11858   1st Qu.:4.400
##  Median :2.0   Median :60882   Median :14309   Median :5.310
##  Mean   :2.0   Mean   :60882   Mean   :14309   Mean   :5.310
##  3rd Qu.:2.5   3rd Qu.:60882   3rd Qu.:16761   3rd Qu.:6.219
##  Max.   :3.0   Max.   :60882   Max.   :19212   Max.   :7.129
##     i.loads
##  Min.   :124541
##  1st Qu.:156997
##  Median :189454
##  Mean   :189454
##  3rd Qu.:221910
##  Max.   :254367
```