Figures: Trend Analysis

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Contents

1 Introduction

This file includes figures and analysis for Section 3.3.1 Trend in Setting Optimal Commitment Level for Periodic Demand.

We start by aggregating the different regions and SKUs together to a single timeseries of total VM demand, and normalize this to a 100 unit peak over that time window.

```
data <- read_parquet("../hourly_normalized.parquet")
dim(data)
```

```
## [1] 524832      4
```

```
head(data)
```

```
## # A tibble: 6 x 4
##   USAGE_HOUR          REGION_NUM INSTANCE_TYPE NORM_USAGE
##   <dttm>                   <dbl> <chr>              <dbl>
## 1 2021-02-01 00:00:00          2 A                    172
## 2 2021-02-01 00:00:00          4 F                      1
## 3 2021-02-01 00:00:00          1 I                      9
## 4 2021-02-01 00:00:00          4 I                      8
## 5 2021-02-01 00:00:00          3 I                      6
## 6 2021-02-01 00:00:00          1 A                    169
```

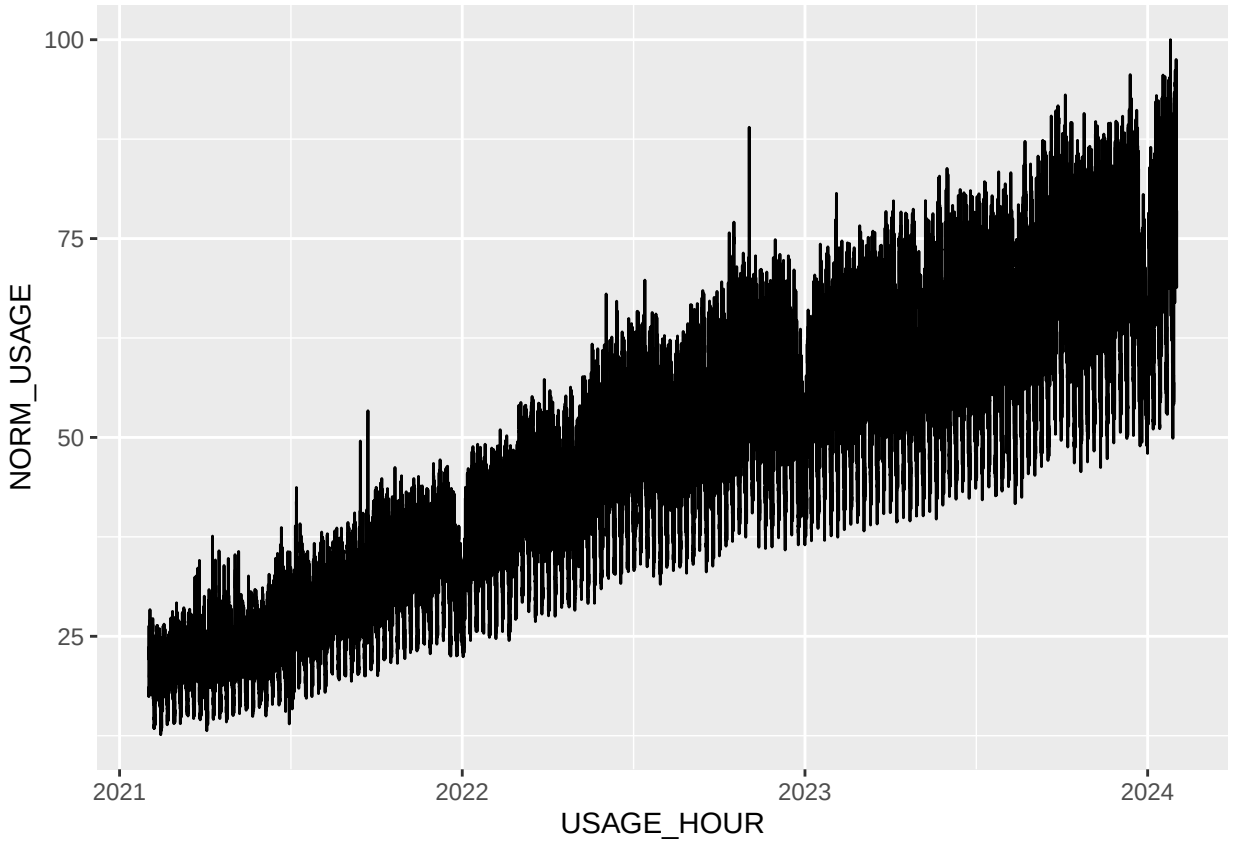
```
range(data$USAGE_HOUR)
```

```
## [1] "2021-02-01 00:00:00 UTC" "2024-01-31 23:00:00 UTC"
```

```r
data.all <- data %>% group_by(USAGE_HOUR) %>% summarise(across(NORM_USAGE, sum))
data.all$NORM_USAGE = 100*data.all$NORM_USAGE / max(data.all$NORM_USAGE)
head(data.all)
```

```
## # A tibble: 6 x 2
##   USAGE_HOUR          NORM_USAGE
##   <dttm>                   <dbl>
## 1 2021-02-01 00:00:00       18.4
## 2 2021-02-01 01:00:00       18.6
## 3 2021-02-01 02:00:00       17.6
## 4 2021-02-01 03:00:00       17.4
## 5 2021-02-01 04:00:00       19.7
## 6 2021-02-01 05:00:00       20.4
```

```r
ggplot(data.all, aes(x=USAGE_HOUR, y=NORM_USAGE)) + geom_line()
```



2 Weekly Pattern Analysis

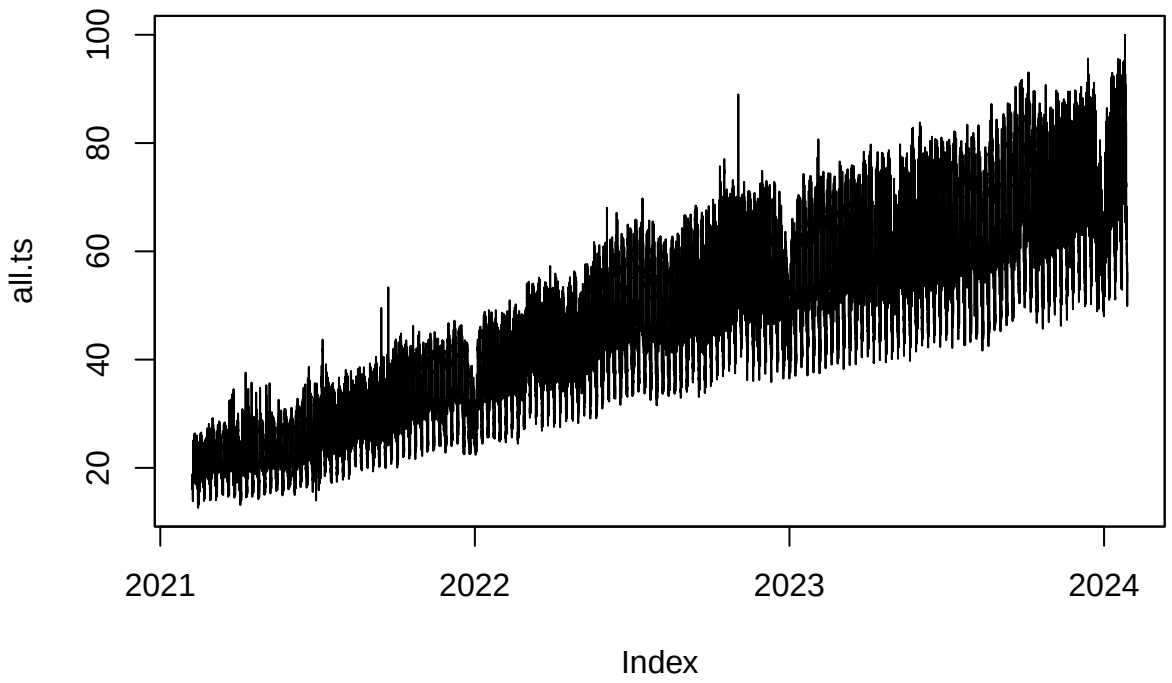
We trim the start and end of our timeseries to align our dataset with Sunday through Saturday weeks so we can split it up in 7 day chunks and look at the distribution of weekly patterns.

We then generate timeseries of the maximum, minimum, and mean of each day.

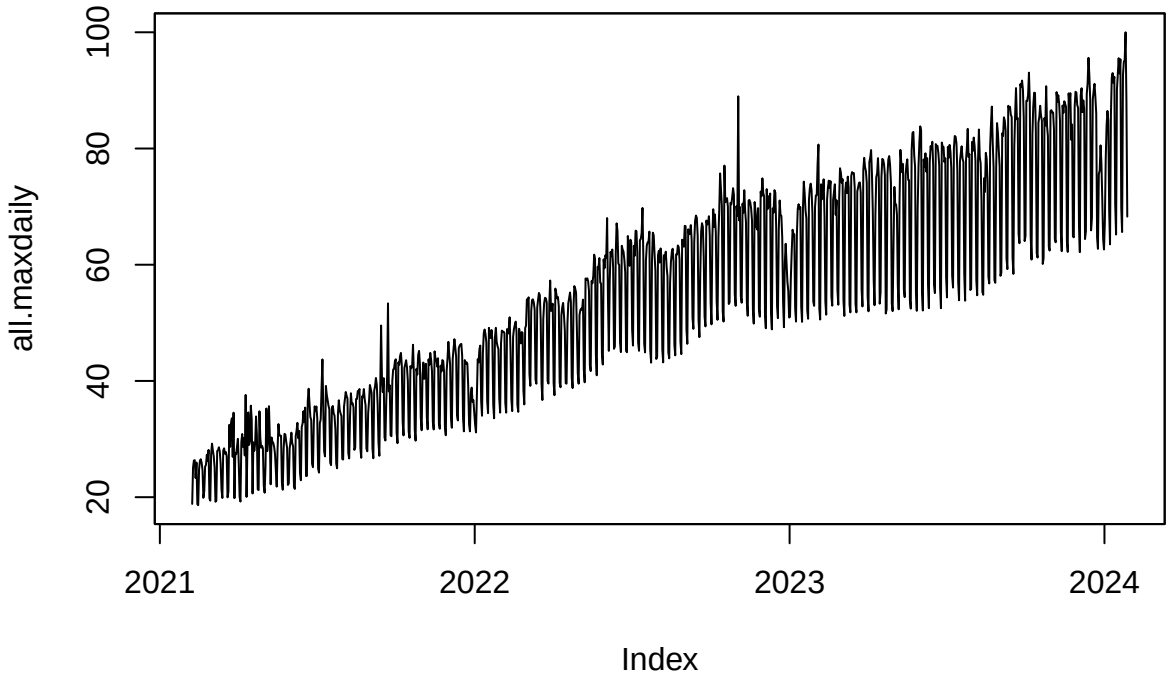
```r
all <- data.all %>% subset(USAGE_HOUR >= as.POSIXct("2021-02-07", tz="UTC")) %>%
  subset(USAGE_HOUR < as.POSIXct("2024-01-28", tz="UTC"))
range(all$USAGE_HOUR)
```

```
## [1] "2021-02-07 00:00:00 UTC" "2024-01-27 23:00:00 UTC"
```

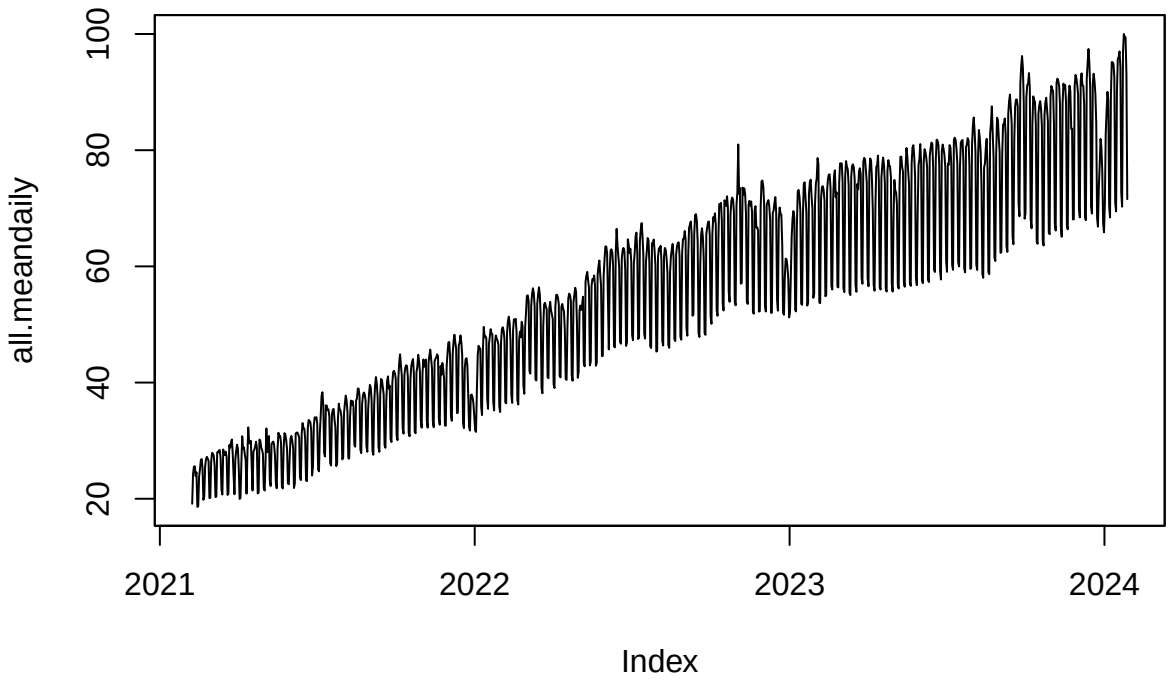
```r
all.ts <- zoo(all$NORM_USAGE, all$USAGE_HOUR)
# Compute the maximumes over each day.
all.maxdaily <- rollapply(all.ts, width=24, by=24, FUN=max)
all.meandaily <- rollapply(all.ts, width=24, by=24, FUN=mean)
all.mindaily <- rollapply(all.ts, width=24, by=24, FUN=min)
plot(all.ts)
```



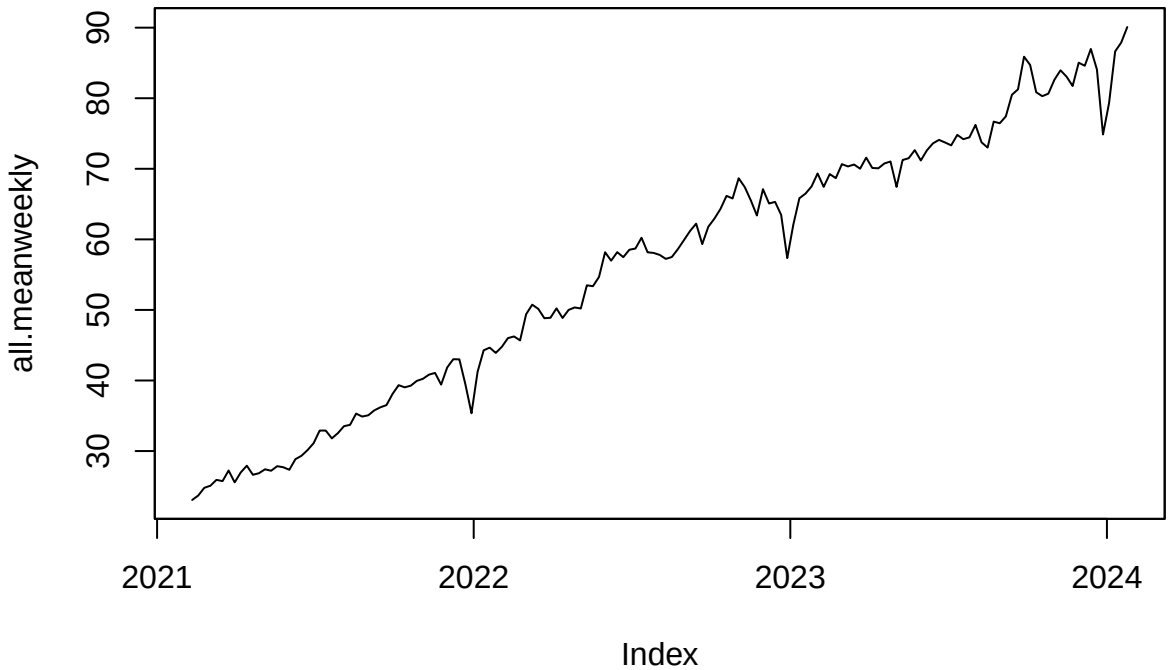

```r
plot(all.maxdaily)
```




```r
all.meandaily <- 100*all.meandaily/(max(all.meandaily))
plot(all.meandaily)
```




```
all.meanweekly <- rollapply(all.meandaily, width=7, by=7, FUN=mean)
plot(all.meanweekly)
```




```
growthmultiple.3yr <- max(range(all.meanweekly)) / min(range(all.meanweekly))
growthrate.3yr <- growthmultiple.3yr ^ (1/3)
print(growthmultiple.3yr)
```

```
## [1] 3.904665
```

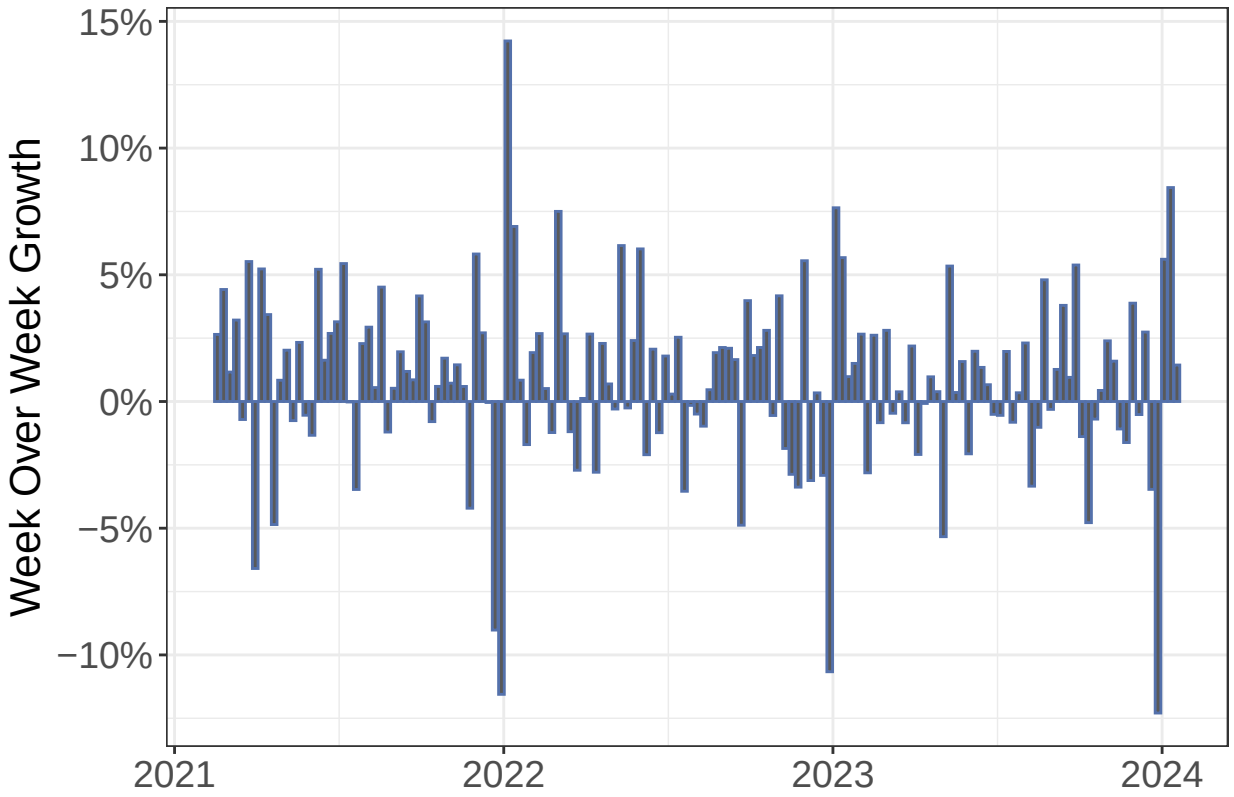
```
print(growthrate.3yr)
```

```
## [1] 1.574688
```

2.1 Figure 5

Week over week growth timeseries.

```
library(scales)
growth.rate <- diff(all.meanweekly) / head(all.meanweekly, -1)
growth.rate.df <- data.frame(time=time(growth.rate), value=as.numeric(growth.rate))
ggplot(growth.rate.df, aes(x=time, y=value)) + geom_bar(stat="identity", color="#5471AB") + theme_bw() +
```



How many weeks is the trend negative?

```
length(which(diff(all.meanweekly) < 0 )) / length(diff(all.meanweekly))
```

```
## [1] 0.3701299
```

3 Sensitivity Analysis of Trend and Period for Commitment Savings

First lets pick a week of data to start with:

```
data.subset <- data.all %>%
  subset(USAGE_HOUR >= as.POSIXct("2024-01-21", tz="UTC")) %>%
  subset(USAGE_HOUR < as.POSIXct("2024-01-28", tz="UTC"))
range(data.subset$USAGE_HOUR)
```

```
## [1] "2024-01-21 00:00:00 UTC" "2024-01-27 23:00:00 UTC"
```

```
dim(data.subset)
```

```
## [1] 168   2
```

Needed helper functions from optimization.Rmd

```
data.subset.orig <- data.subset
```

3.1 Table 3

We now do a sensitivity analysis on the costs for different annual trend and number of weeks.

```
data.subset <- data.subset.orig
#data.subset$NORM_USAGE <- data.subset$NORM_USAGE * 10

ExtendWeek <- function(df, weeks=1, trend=0.05) {
  daily.trend <- (1+trend)^(1/365)
  df.tmp <- df
  for (w in seq(weeks)) {
    df.new <- df
    df.new$USAGE_HOUR <- df.new$USAGE_HOUR + (w*7*86400)
    df.new$NORM_USAGE <- df.new$NORM_USAGE * daily.trend^(rep(seq(((w-1)*7)+1,((w-1)*7)+7),each=24))
    #df.new$DEMAND <- df.new$DEMAND * daily.trend^(rep(seq(((w-1)*7)+1,((w-1)*7)+7),each=24))
    df.tmp <- rbind(df.tmp, df.new) %>% arrange(USAGE_HOUR)
  }
  return(df.tmp)
}

# 100 steps was not enough to generate full table accurately.
steps <- 30000

for (annual.trend in c(.1, .25, .5, .75, 1)) {
  # Extend our dataset n weeks into future at specified annual trend
  df.week.1 <- ExtendWeek(data.subset, weeks=1, trend=annual.trend)
  df.week.2 <- ExtendWeek(data.subset, weeks=2, trend=annual.trend)
  df.week.4 <- ExtendWeek(data.subset, weeks=4, trend=annual.trend)
  df.week.8 <- ExtendWeek(data.subset, weeks=8, trend=annual.trend)

  # Filter out the actuals and only consider the future.
  df.forecast.1 <- df.week.1 %>% subset(USAGE_HOUR > max(data.subset$USAGE_HOUR))
  df.forecast.2 <- df.week.2 %>% subset(USAGE_HOUR > max(data.subset$USAGE_HOUR))
  df.forecast.4 <- df.week.4 %>% subset(USAGE_HOUR > max(data.subset$USAGE_HOUR))
  df.forecast.8 <- df.week.8 %>% subset(USAGE_HOUR > max(data.subset$USAGE_HOUR))

  # Find lowest cost SP on the actuals
  lowest.actuals <- findMinSPLevel.2(data.subset, steps)

  # Compute lowest cost on the forecast
  lowest.forecast.1 <- findMinSPLevel.2(df.forecast.1, steps)
  lowest.forecast.2 <- findMinSPLevel.2(df.forecast.2, steps)
  lowest.forecast.4 <- findMinSPLevel.2(df.forecast.4, steps)
  lowest.forecast.8 <- findMinSPLevel.2(df.forecast.8, steps)

  # Compute cost of the week1 forecast with our min SP level found from actuals
  cost.base.1 <- FindCost(df.forecast.1, lowest.actuals)
  cost.base.2 <- FindCost(df.forecast.2, lowest.actuals)
  cost.base.4 <- FindCost(df.forecast.4, lowest.actuals)
  cost.base.8 <- FindCost(df.forecast.8, lowest.actuals)
  cost.forecast.1 <- FindCost(df.forecast.1, lowest.forecast.1)
  cost.forecast.2 <- FindCost(df.forecast.2, lowest.forecast.2)
```

```
  cost.forecast.4 <- FindCost(df.forecast.4, lowest.forecast.4)
  cost.forecast.8 <- FindCost(df.forecast.8, lowest.forecast.8)

  print(paste0(" Annual Trend: ", annual.trend,
               sprintf(" CostBase:1 %0.7f", cost.base.1), sprintf(" Cost1Wk: %0.7f", cost.forecast.1),
               sprintf(" CostBase:2 %0.7f", cost.base.2), sprintf(" Cost2Wk: %0.7f", cost.forecast.2),
               sprintf(" CostBase:4 %0.7f", cost.base.4), sprintf(" Cost4Wk: %0.7f", cost.forecast.4),
               sprintf(" CostBase:8 %0.7f", cost.base.8), sprintf(" Cost8Wk: %0.7f", cost.forecast.8)))
  print(paste0(sprintf(" CostDelta.1: %0.7f", cost.base.1 - cost.forecast.1),
               sprintf(" CostDelta.2: %0.7f", cost.base.2 - cost.forecast.2),
               sprintf(" CostDelta.4: %0.7f", cost.base.4 - cost.forecast.4),
               sprintf(" CostDelta.8: %0.7f", cost.base.8 - cost.forecast.8)))

  print("")
}
```

```
## [1] " Annual Trend: 0.1 CostBase:1 14494.5175470 Cost1Wk: 14494.4153616 CostBase:2 29093.9118974 Cos
## [1] " CostDelta.1: 0.1021854 CostDelta.2: 0.1021859 CostDelta.4: 0.1021858 CostDelta.8: 3.8253154"
## [1] ""
## [1] " Annual Trend: 0.25 CostBase:1 14515.0953006 Cost1Wk: 14514.8558493 CostBase:2 29170.9914238 Co
## [1] " CostDelta.1: 0.2394513 CostDelta.2: 0.2394511 CostDelta.4: 3.5393320 CostDelta.8: 32.8397205"
## [1] ""
## [1] " Annual Trend: 0.5 CostBase:1 14544.5000878 Cost1Wk: 14544.0776849 CostBase:2 29282.9114239 Cos
## [1] " CostDelta.1: 0.4224029 CostDelta.2: 1.9681066 CostDelta.4: 14.0702544 CostDelta.8: 141.3641222
## [1] ""
## [1] " Annual Trend: 0.75 CostBase:1 14569.4128531 Cost1Wk: 14568.8907534 CostBase:2 29378.9036382 Co
## [1] " CostDelta.1: 0.5220997 CostDelta.2: 4.0283987 CostDelta.4: 30.5086578 CostDelta.8: 283.2709930
## [1] ""
## [1] " Annual Trend: 1 CostBase:1 14591.0313988 Cost1Wk: 14590.4228362 CostBase:2 29463.1189561 Cost2
## [1] " CostDelta.1: 0.6085625 CostDelta.2: 6.1130679 CostDelta.4: 51.8426906 CostDelta.8: 446.4012950
## [1] ""
```

```
for (weeks in c(1, 2, 4,8)) { #} c(1,2,4,8)) {
  for (annual.trend in c(.1, .25, .5, .75, 1)) {
    # Extend our dataset n weeks into future at specified annual trend
    df.tmp <- ExtendWeek(data.subset, weeks=weeks, trend=annual.trend)
    # Find lowest cost on the actuals
    lowest.actuals <- findMinSPLevel.2(data.subset, steps)
    # Filter out the actuals and only consider the future.
    df.forecast <- df.tmp %>% subset(USAGE_HOUR > max(data.subset$USAGE_HOUR))
    # Compute lowest cost on the forecast
    lowest.forecast <- findMinSPLevel.2(df.forecast, steps)
    # Compute cost of the forecast with our min SP level found from actuals
    cost.base <- FindCost(df.forecast, lowest.actuals)
    # Compute cost of the forecast with our min SP level found from forecast
    cost.forecast <- FindCost(df.forecast, lowest.forecast)
    #
    extra.cost <- ((1000000*cost.base) / cost.forecast) - 1000000
    #extra.cost <- ((cost.1 / cost.forecast) * 1000000) - 1000000
    print(paste0(" Weeks: ", weeks, sprintf(" MaxVal: %0.1f", max(df.tmp$NORM_USAGE)), sprintf(" Trend:
                 sprintf(" LowActuals: %0.3f", lowest.actuals),
                 sprintf(" LowForecast: %0.7f", lowest.forecast),
                 sprintf(" BaseCost: %0.3f", cost.base),
                 sprintf(" Cost2: %0.3f", cost.forecast),
```

```
                sprintf(" Extra Cost: %0.4f", extra.cost),
                sprintf(" CostDelta: %0.7f", (cost.base - cost.forecast)),
                #sprintf(" CostDeltaPct: %0.4f", 100*(cost.base - cost.forecast)/cost.base),
                sprintf(" CostPM: %0.4f", (1000000/cost.base) * (cost.base-cost.forecast))))
  }
  print("")
}
```

```
## [1] " Weeks: 1 MaxVal: 100.1 Trend: 0.10 LowActuals: 78.215 LowForecast: 78.3176196 BaseCost: 14494.5
## [1] " Weeks: 1 MaxVal: 100.3 Trend: 0.25 LowActuals: 78.215 LowForecast: 78.4548855 BaseCost: 14515.0
## [1] " Weeks: 1 MaxVal: 100.6 Trend: 0.50 LowActuals: 78.215 LowForecast: 78.6378371 BaseCost: 14544.5
## [1] " Weeks: 1 MaxVal: 100.8 Trend: 0.75 LowActuals: 78.215 LowForecast: 78.7375339 BaseCost: 14569.4
## [1] " Weeks: 1 MaxVal: 101.0 Trend: 1.00 LowActuals: 78.215 LowForecast: 78.8239977 BaseCost: 14591.0
## [1] ""
## [1] " Weeks: 2 MaxVal: 100.3 Trend: 0.10 LowActuals: 78.215 LowForecast: 78.3176205 BaseCost: 29093.9
## [1] " Weeks: 2 MaxVal: 100.7 Trend: 0.25 LowActuals: 78.215 LowForecast: 78.4548853 BaseCost: 29170.9
## [1] " Weeks: 2 MaxVal: 101.3 Trend: 0.50 LowActuals: 78.215 LowForecast: 78.6378367 BaseCost: 29282.9
## [1] " Weeks: 2 MaxVal: 101.9 Trend: 0.75 LowActuals: 78.215 LowForecast: 78.8217093 BaseCost: 29378.9
## [1] " Weeks: 2 MaxVal: 102.3 Trend: 1.00 LowActuals: 78.215 LowForecast: 79.0934808 BaseCost: 29463.1
## [1] ""
## [1] " Weeks: 4 MaxVal: 100.7 Trend: 0.10 LowActuals: 78.215 LowForecast: 78.3176200 BaseCost: 58372.8
## [1] " Weeks: 4 MaxVal: 101.6 Trend: 0.25 LowActuals: 78.215 LowForecast: 78.7251534 BaseCost: 58675.7
## [1] " Weeks: 4 MaxVal: 102.9 Trend: 0.50 LowActuals: 78.215 LowForecast: 79.2517125 BaseCost: 59120.1
## [1] " Weeks: 4 MaxVal: 104.1 Trend: 0.75 LowActuals: 78.215 LowForecast: 79.6677866 BaseCost: 59508.1
## [1] " Weeks: 4 MaxVal: 105.1 Trend: 1.00 LowActuals: 78.215 LowForecast: 80.0207646 BaseCost: 59855.7
## [1] ""
## [1] " Weeks: 8 MaxVal: 101.4 Trend: 0.10 LowActuals: 78.215 LowForecast: 78.5368608 BaseCost: 117257
## [1] " Weeks: 8 MaxVal: 103.4 Trend: 0.25 LowActuals: 78.215 LowForecast: 79.3202076 BaseCost: 118483
## [1] " Weeks: 8 MaxVal: 106.2 Trend: 0.50 LowActuals: 78.215 LowForecast: 80.2564811 BaseCost: 120346
## [1] " Weeks: 8 MaxVal: 108.6 Trend: 0.75 LowActuals: 78.215 LowForecast: 81.2114315 BaseCost: 122027
## [1] " Weeks: 8 MaxVal: 110.8 Trend: 1.00 LowActuals: 78.215 LowForecast: 81.8779822 BaseCost: 123562
## [1] ""
```

```
df.tmp <- ExtendWeek(data.subset, weeks=1, trend=0.05)
lowest.1 <- findMinSPLevel(data.subset, 100)
df.forecast <- df.tmp %>% subset(USAGE_HOUR > max(data.subset$USAGE_HOUR))
lowest.forecast <- findMinSPLevel(df.forecast, 100)
cost.1 <- FindCost(df.forecast, lowest.1)
cost.forecast <- FindCost(df.forecast, lowest.forecast)
cost.1
```

```
## [1] 14487.02
```

```
cost.forecast
```

```
## [1] 14487.01
```

3.1.1 Pull in PlotBoxes from optimization.Rmd

```
PlotBoxes <- function(df, sp.level=NULL, title=FALSE, ylim=NULL) {
  days <- c("S", "M", "T", "W", "R", "F", "S")
  p <- ggplot(df) +
          geom_rect_pattern(aes(xmin=xmin, xmax=xmax, ymin=ymin, ymax=ymax,
                                fill=Pricing, pattern=Pricing),
                            colour=NA, pattern_size=0.25,
```

```
                            pattern_spacing=0.02) +
          theme_bw() +
          theme(axis.text=element_text(size=15),
                axis.title=element_text(size=15),
                legend.text = element_text(size=15),
                legend.title = element_blank(),
                legend.position="bottom",
                strip.text=element_text(size=15)) +
          ylab("Cost") + xlab("") +
          scale_pattern_manual(values=c("none", "none", "stripe")) +
          scale_x_continuous(breaks=seq(from=as.POSIXct("2024-06-02 12:00:00"),
                                        to=as.POSIXct("2024-06-15 12:00:00"),
                                        length.out=14),
                             labels=rep(days,2)) +
          scale_fill_manual(values=c("orange", "darkgreen", "red"))
  if (title) {
    if (!is.null(sp.level)) {
      cost.premium  <- TotalCostPremium(df)
      p <- p + ggtitle(paste0("c=", round(sp.level, 1), " ", "C(c)=", round(cost.premium, 0)))
    }
  }
  if (!is.null(ylim)) {
    p <- p+ylim(ylim)
  }
  return(p)
}
```

3.2 Figure 6

We create a new data frame from our existing week extended out 8 weeks with 100% annual trend and compare the SP level that would be set on the initial data vs the 8-week forecast.

```
df.tmp<-ExtendWeek(data.subset, weeks=8, trend=1)
lowest.1 <- findMinSPLevel(data.subset, 100)
df.forecast <- df.tmp %>% subset(USAGE_HOUR > max(data.subset$USAGE_HOUR))
lowest.forecast <- findMinSPLevel(df.forecast, 100)
cost.1 <- FindCost(df.forecast, lowest.1)
cost.forecast <- FindCost(df.forecast, lowest.forecast)
cost.1
```

```
## [1] 123557.4
```

```
cost.forecast
```

```
## [1] 123118.4
```

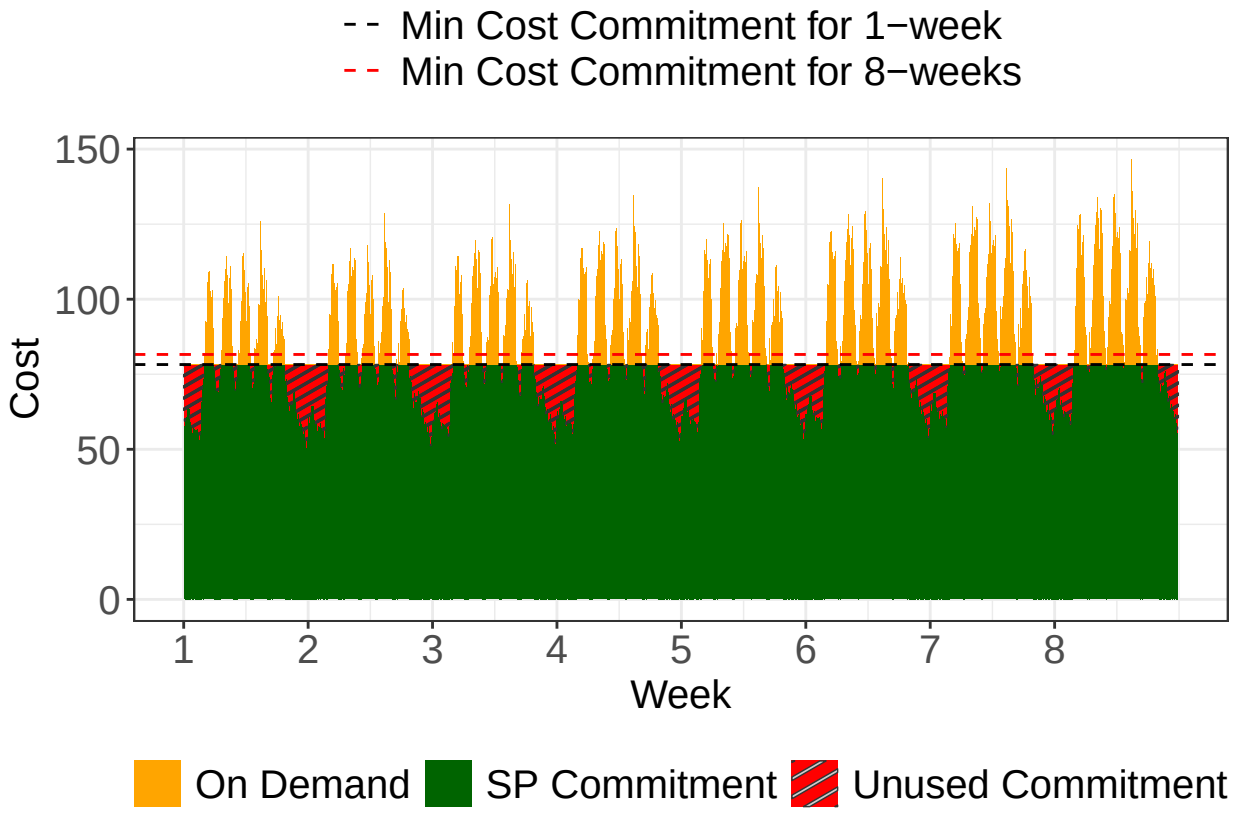
```
PlotBest.2 <- function(df, sp.level, annotated.level) {
  df.ann <- AnnotateSPRILevel(df, sp.level)
  df.boxes <- GenerateBoxes(df.ann)
  brks <- seq(from=min(df.boxes$xmin), to=max(df.boxes$xmax), by=(60*60*24*7))
  p <- PlotBoxes(df.boxes)
  p <- p +
    scale_x_continuous(breaks=brks, labels=1:length(brks)) +
    geom_hline(aes(yintercept=sp.level,
                   linetype="Min Cost Commitment for 1-week"),
               color="black") +
```

```
    geom_hline(aes(yintercept=annotated.level,
                   linetype="Min Cost Commitment for 8-weeks"),
               color="red") +
    scale_linetype_manual(name="Commitment Level",
                          values=c("dashed", "dashed"),
                          guide=guide_legend(
                            position="top",
                            direction="vertical",
                            override.aes = list(color=c("black", "red")))) +
    xlab("Week")
  return(p)
}

p <- PlotBest.2(df.forecast, lowest.1, lowest.forecast)
```

```
## Scale for x is already present.
## Adding another scale for x, which will replace the existing scale.
```

```
p
```



4 Laddering

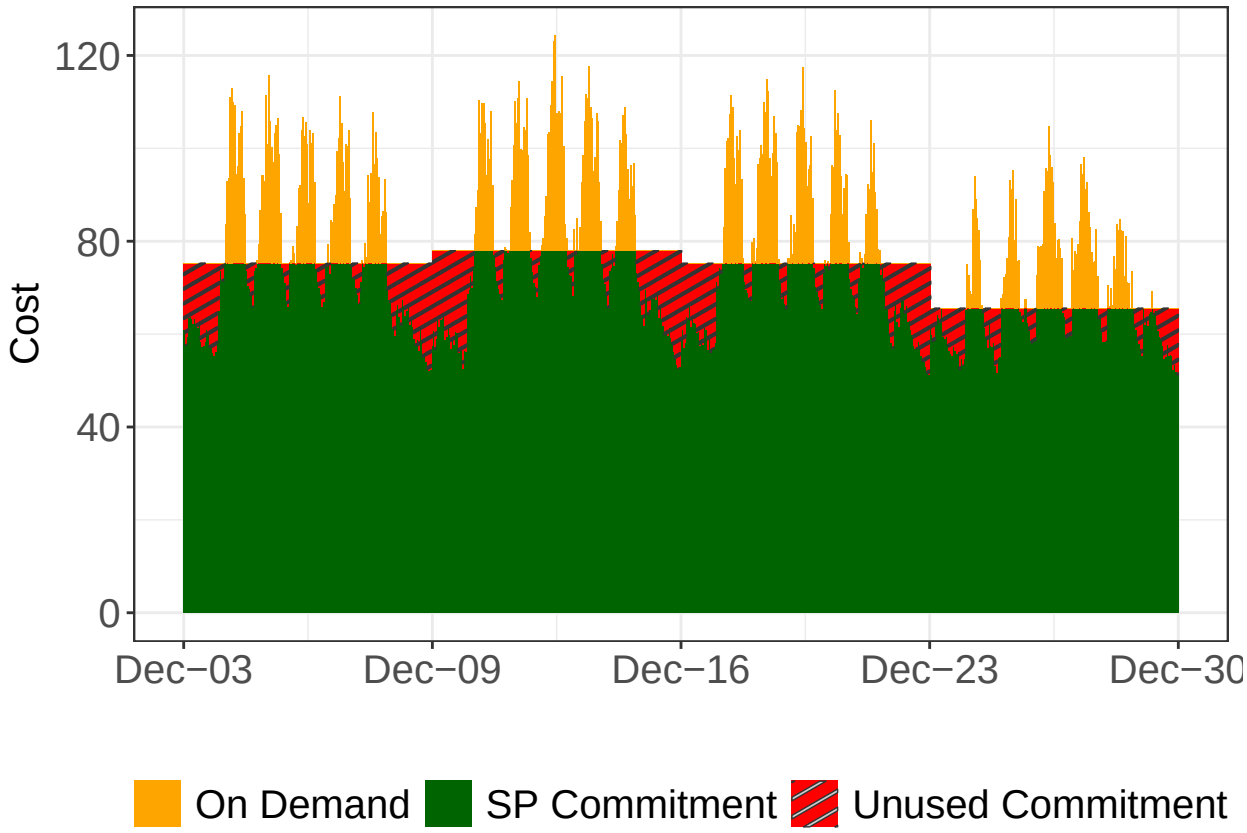
We consider the 4 weeks between 12/3 and 12/31/2023 to consider the impact of laddering.

```
PlotBoxes.2 <- function(df, sp.level=NULL, title=FALSE, ylim=NULL, weeks=1) {
  daysdelta = round(as.numeric(max(df$xmax) - min(df$xmin)))
  p <- ggplot(df) +
          geom_rect_pattern(aes(xmin=xmin, xmax=xmax, ymin=ymin, ymax=ymax,
```

```
                                fill=Pricing, pattern=Pricing),
                            colour=NA, pattern_size=0.25,
                            pattern_spacing=0.02) +
          theme_bw() +
          theme(axis.text=element_text(size=15),
                axis.title=element_text(size=15),
                legend.text = element_text(size=15),
                legend.title = element_blank(),
                legend.position="bottom",
                strip.text=element_text(size=15)) +
          ylab("Cost") + xlab("") +
          scale_pattern_manual(values=c("none", "none", "stripe")) +
          scale_x_continuous(breaks=seq(from=as.POSIXct(min(df$xmin), tz="UTC"),
                                        to=as.POSIXct(max(df$xmax), tz="UTC"),
                                        length.out=5),
                             labels=format(as.Date(seq(from=as.POSIXct(min(df$xmin), tz="UTC"),
                                        to=as.POSIXct(max(df$xmax), tz="UTC"),
                                        length.out=5)), "%b-%d")) +
#                                         to=min(df$xmin) + daysdelta*86400 - 60*60*12,
#                                         length.out=daysdelta),
#                              labels=rep(days, round(daysdelta/7))) +
          scale_fill_manual(values=c("orange", "darkgreen", "red"))
  if (title) {
    if (!is.null(sp.level)) {
      cost.premium  <- TotalCostPremium(df)
      p <- p + ggtitle(paste0("c=", round(sp.level, 1), " ", "C(c)=", round(cost.premium, 0)))
    }
  }
  if (!is.null(ylim)) {
    p <- p+ylim(ylim)
  }
  return(p)
}
```

```
data.tmp <- data.all %>%
  subset(USAGE_HOUR >= as.POSIXct("2023-12-03", tz="UTC")) %>%
  subset(USAGE_HOUR < as.POSIXct("2023-12-31", tz="UTC"))
# Re-normalize just these 4 weeks to 100
data.tmp$NORM_USAGE <- data.tmp$NORM_USAGE * (100/max(data.tmp$NORM_USAGE))
data.w1 <- subset(data.tmp, USAGE_HOUR < as.POSIXct("2023-12-10", tz="UTC"))
data.w2 <- subset(subset(data.tmp, USAGE_HOUR < as.POSIXct("2023-12-17", tz="UTC")),
                  USAGE_HOUR >= as.POSIXct("2023-12-10", tz="UTC"))
data.w3 <- subset(subset(data.tmp, USAGE_HOUR < as.POSIXct("2023-12-24", tz="UTC")),
                  USAGE_HOUR >= as.POSIXct("2023-12-17", tz="UTC"))
data.w4 <- subset(subset(data.tmp, USAGE_HOUR < as.POSIXct("2024-01-01", tz="UTC")),
                  USAGE_HOUR >= as.POSIXct("2023-12-24", tz="UTC"))
minlev.1 <- findMinSPLevel(data.w1, steps=100)
minlev.2 <- findMinSPLevel(data.w2, steps=100)
minlev.3 <- findMinSPLevel(data.w3, steps=100)
minlev.4 <- findMinSPLevel(data.w4, steps=100)
minlev <- findMinSPLevel(data.tmp, steps=100)
data.1 <- AnnotateSPRILevel(data.tmp, sp.level=minlev.4)
data.1$SPRI_LEVEL[data.1$USAGE_HOUR < as.POSIXct("2023-12-24", tz="UTC")] <- minlev.3
data.1$SPRI_LEVEL[data.1$USAGE_HOUR < as.POSIXct("2023-12-17", tz="UTC")] <- minlev.2
```

```
data.1$SPRI_LEVEL[data.1$USAGE_HOUR < as.POSIXct("2023-12-10", tz="UTC")] <- minlev.1
data.b <- GenerateBoxes(data.1)
show(PlotBoxes.2(data.b))
```



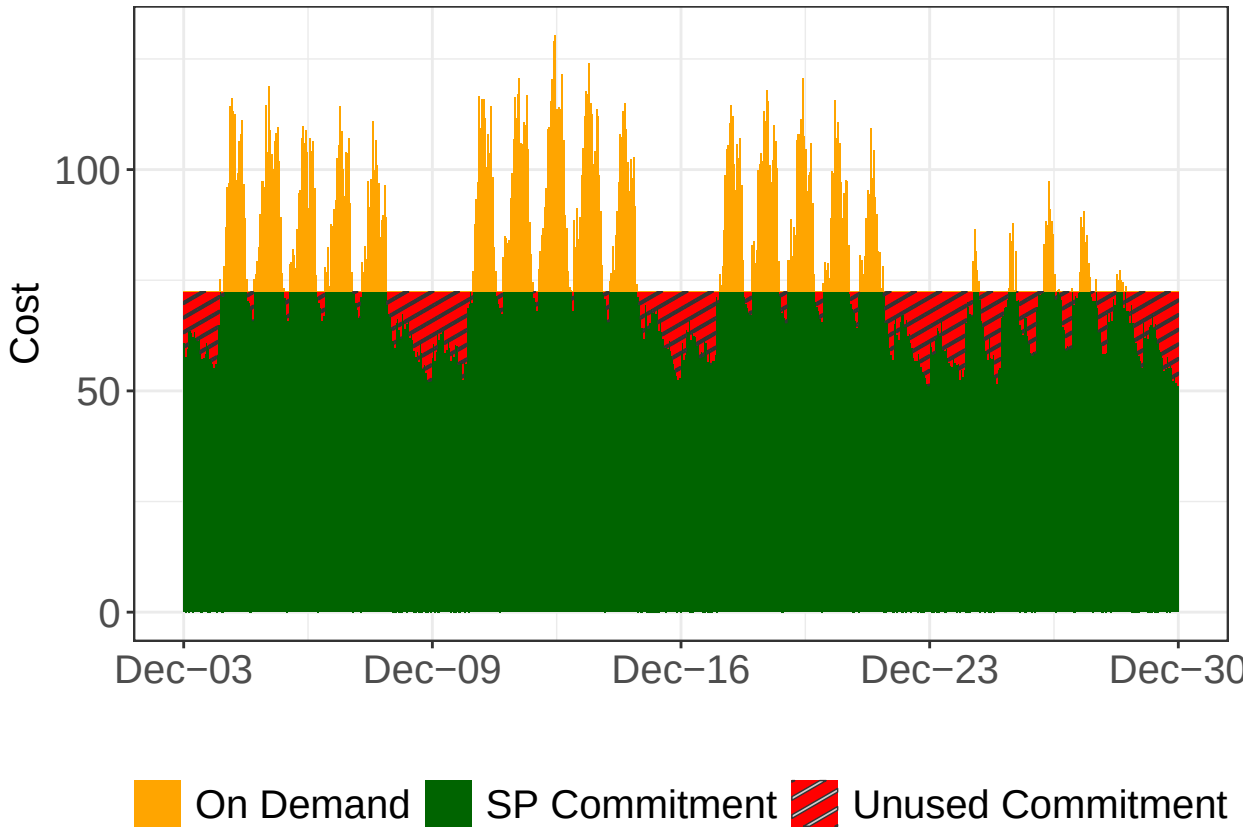

```
print(minlev.1)
```

```
## [1] 75.27263
```

```
data.one <- AnnotateSPRILevel(data.tmp, sp.level=minlev)
data.oneb <- GenerateBoxes(data.one)
print(TotalCostPremium(data.oneb))
```

```
## [1] 55647.1
```

```
show(PlotBoxes.2(data.oneb))
```




```
print(TotalCostPremium(data.b))
```

```
## [1] 55183.8
```

```
minlev.1
```

```
## [1] 75.27263
```

```
TotalCostPremium(data.b) / TotalCostPremium(data.oneb)
```

```
## [1] 0.9916742
```

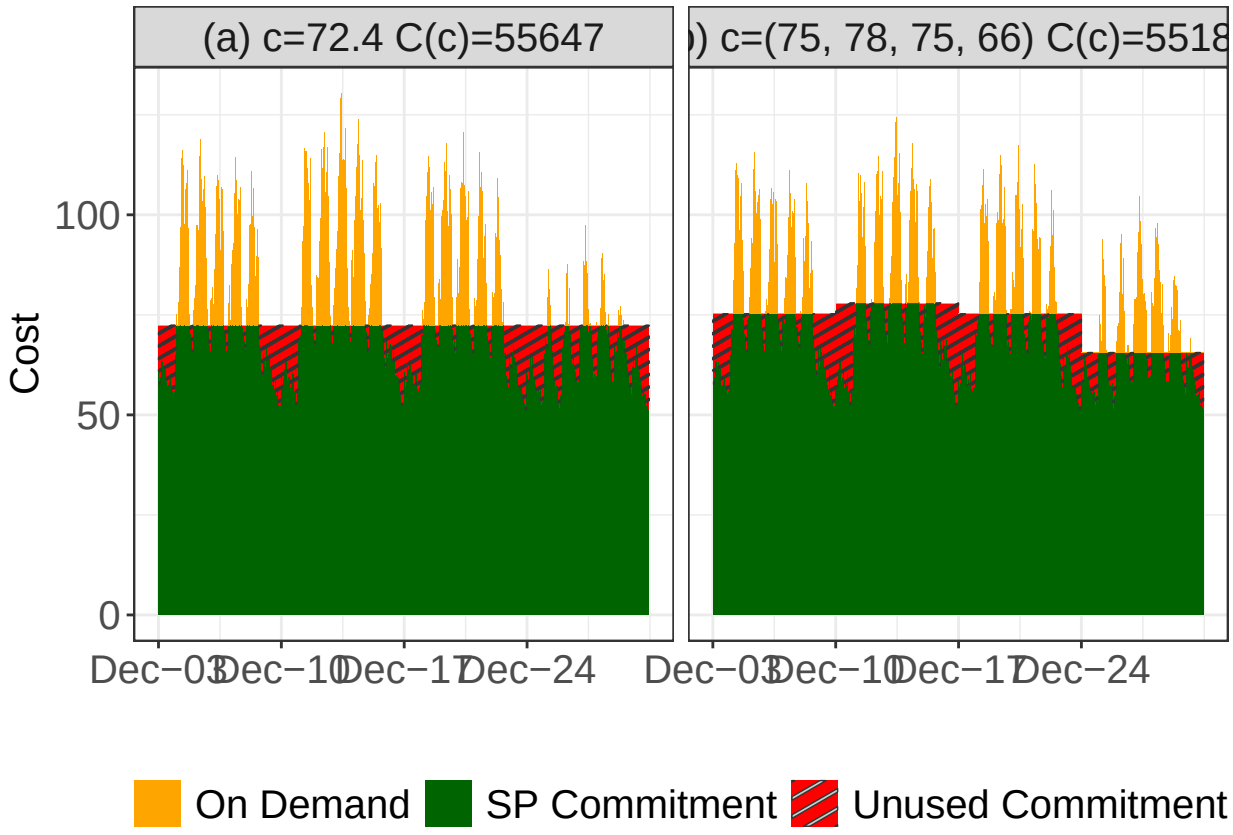
```
Plot3x3 <- function(df, start.date="2024-01-07", end.date="2024-01-21", weekdays=FALSE) {
  days <- c("S", "M", "T", "W", "R", "F", "S")
  p <- ggplot(df) +
    geom_rect_pattern(aes(xmin=xmin, xmax=xmax, ymin=ymin, ymax=ymax,
                          fill=Pricing, pattern=Pricing),
                      colour=NA, pattern_size=0.25, pattern_spacing=0.02) +
    theme_bw() +
    theme(axis.text=element_text(size=15), axis.title=element_text(size=15),
     #      axis.text.x = element_text(angle=90),
          legend.text = element_text(size=15), legend.title = element_blank(),
          legend.position="bottom", strip.text=element_text(size=15)) +
    ylab("Cost") + xlab("") +
    scale_pattern_manual(values=c("none", "none", "stripe"))
  if (weekdays) {
    p <- p + scale_x_continuous(breaks=seq(from=as.POSIXct(start.date, tz="UTC"),
                                    to=as.POSIXct(end.date, tz="UTC"),
                                    length.out=14),
                      labels=rep(days,2))
```

```
  } else {
     p <- p + scale_x_continuous(breaks=c(as.POSIXct("2023-12-03", tz="UTC"),
                                          as.POSIXct("2023-12-10", tz="UTC"),
                                          as.POSIXct("2023-12-17", tz="UTC"),
                                          as.POSIXct("2023-12-24", tz="UTC")),
                                 labels=date_format("%b-%d"))
#                                          seq(from=as.POSIXct(min(df$xmin), tz="UTC"),
#                                          to=as.POSIXct(max(df$xmax), tz="UTC"),
#                                          length.out=5),
#                                 labels=format(as.Date(seq(from=as.POSIXct(min(df$xmin), tz="UTC"),
#                                          to=as.POSIXct(max(df$xmax), tz="UTC"),
                                         #length.out=5)), "%b-%d"))
    #p <- p + scale_x_datetime(breaks = "1 week", minor_breaks = "1 day", labels=date_format("%b-%d"))
    #, limits=c(min(df$xmin), max(df$xmax)))
  }
  p <- p +
    scale_fill_manual(values=c("orange", "darkgreen", "red")) +
    facet_wrap(~panel.title)
  return(p)
}
```

4.1 Figure 9

```
data.oneb$panel.title <- paste0("(a) c=", round(minlev, 1), " C(c)=", round(TotalCostPremium(data.oneb)
data.b$panel.title <- paste0("(b) c=(", round(minlev.1, 0), ", ", round(minlev.2, 0), ", ", round(minlev

fig9 <- rbind(data.b, data.oneb)
Plot3x3(fig9, start.date="2023-12-17", end.date="2023-12-31")
```


(a) c=72.4 C(c)=55647
) c=(75, 78, 75, 66) C(c)=5518
Cost
100
50
0
Dec−03
Dec−10
Dec−17
Dec−24
Dec−03
Dec−10
Dec−17
Dec−24
On Demand
SP Commitment
Unused Commitment