A tool box for a climate neutral housing sector: Compiling and comparing results for different renovation rates

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1 Import Intermediate Results

Import the modified, representative data-set and prepare for visualization. *share_data* splits the relevant data between different building types, which will be helpful in subsequent visualizations.

```
immo_clean <- read.csv(file=
              here::here('Intermediate_Results/data_clean_representative.csv'))

share_data <- data.frame(
  group = c("+", "A", "B", "C", "D", "E", "F", "G", "H"),
  all   = immo_clean %>% group_by(efficiency_class) %>%
    summarise(share_effclasses=sum(renovation_weight)/
                sum(immo_clean$renovation_weight)),
  house = immo_clean %>% filter(type=="House") %>%
    group_by(efficiency_class) %>%
    summarise(share_effclasses=sum(renovation_weight)/
                sum(immo_clean$renovation_weight[immo_clean$type=="House"])),
  flat  = immo_clean %>% filter(type=="Apartment") %>%
    group_by(efficiency_class) %>%
    summarise(share_effclasses=sum(renovation_weight)/
                sum(immo_clean$renovation_weight[immo_clean$type=="Apartment"]))
)

share_data <- select(share_data, group, all.share_effclasses,
                     house.share_effclasses, flat.share_effclasses)
colnames(share_data) <- c("group", "All", "Houses" , "Apartments")
share_data_long <- pivot_longer(share_data, cols = c(All, Houses, Apartments),
                                names_to = "groups", values_to = "percentage")
```

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```r
write.csv(share_data_long, file=here::here("Results/distribution_buildings.csv"),
          row.names = FALSE)
```

Import climate goals as defined before:

```r
climate_goals <- read.csv(here::here(
                  "Intermediate_Results/global_buildings_climate_goals2040.csv"))
climate_goals$rate <- "Climate goal"
```

2 Merge Results for Different Renovation Rates

Here, we import results for different renovation rates, previously created in complete_code.Rmd. At the same time, the data is reshaped to a long format and the results for different renovation rates are merged. This will subsequently make visualization easier.

```r
file_names <- list.files(path = here::here("Intermediate_Results"),
                         pattern = "^immo_progress_\\d+(\\.\\d+)?\\.csv$",
                            full.names = TRUE)

# Create a list of data frame names
df_list <- c()
# Loop through each rate and import the corresponding CSV file
# into separate data frames
for (file in file_names) {
  rate <- as.numeric(gsub(".*_(\\d+(\\.\\d+)?)\\.csv", "\\1", basename(file)))
  withoutpoint <- gsub("\\.", "", as.character(rate))
  df_name <- paste("df_", withoutpoint, sep = "")
  df <- read.csv(file)
  df <- df %>% mutate(rate = rate)
  df <- pivot_longer(df,
                      cols = -c(year, rate),
                      names_to = "Variable",
                      values_to = "Value")
  assign(paste("df_", rate, sep=""), df)
  df_list <- append(df_list, paste("df_", rate, sep=""))
}

# Combine the dataframes into a single dataframe
df_list <- lapply(df_list, get)
long_df <- bind_rows(df_list)

write.csv(long_df, file = here::here("Results/comparing_renovation_rates.csv"),
                                     row.names = FALSE)
```

3 Compare Results for Different Renovation Rates

3.1 Traditional Energy Mix

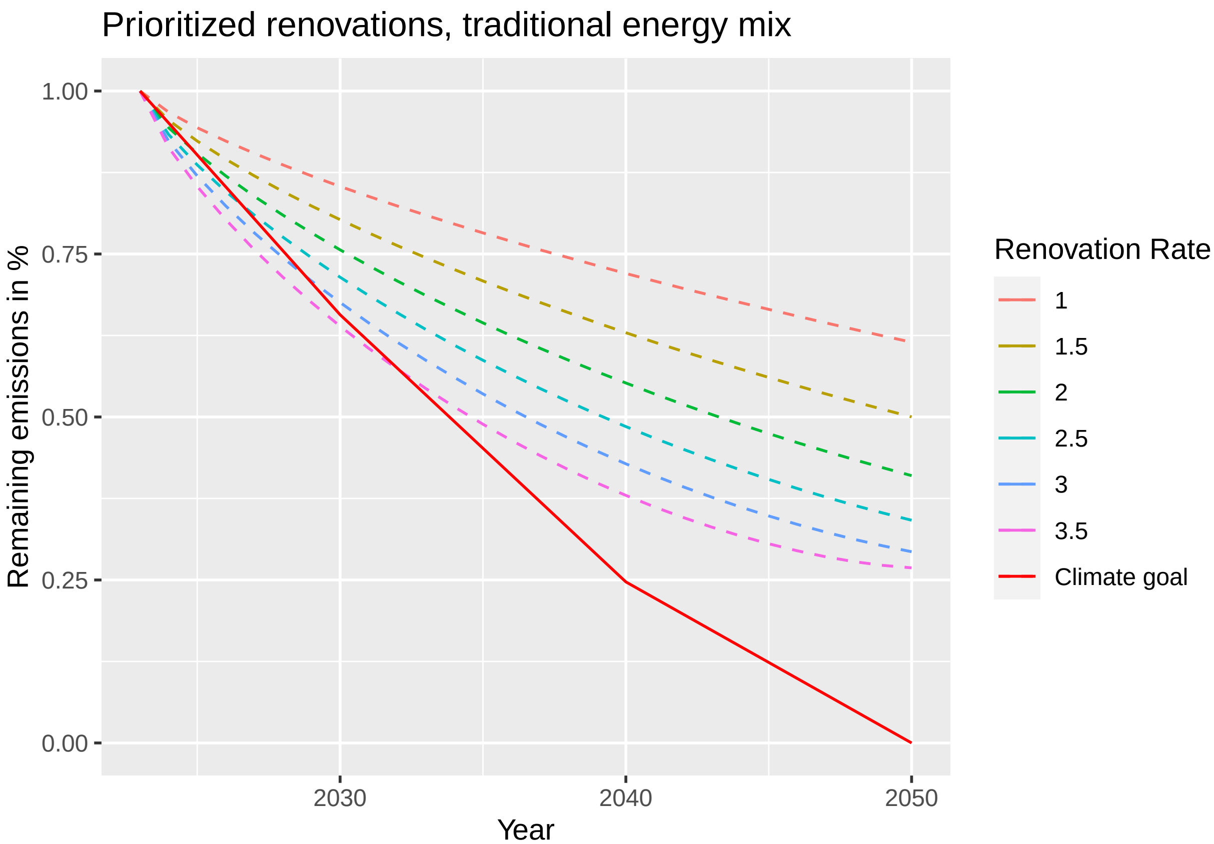
3.1.1 Plot: Prioritized Renovations and Traditional Energy Mix

With this graph, we show how many GHG can be saved in a scenario with the prioritization of renovating the worst performing buildings and a traditional energy mix. For reference, the graph also plots the climate goals.

```
filtered_data <- subset(long_df, Variable == "relative_ghg_old_prio")
filtered_data_truncated <- subset(filtered_data, year <= 2050)

colors <-  scales::hue_pal()(6)[1:6]
line_colors <- c(colors, "red")

# Create a ggplot with lines for different rates
p1 <- ggplot(filtered_data_truncated, aes(x = year, y = Value,
                                          color = as.factor(rate))) +
  geom_line(linetype="dashed") +
  geom_line(data=climate_goals, aes(x=year, y=rel_reduction)) +
  labs(title = "Prioritized renovations, traditional energy mix") +
  xlab("Year") +
  ylab("Remaining emissions in %") +
  scale_color_manual(name = "Renovation Rate",
                     values = line_colors)
  ylim(0,1.05)
```

```
## <ScaleContinuousPosition>
##  Range:
##  Limits:    0 -- 1.05
```

```
p1
```



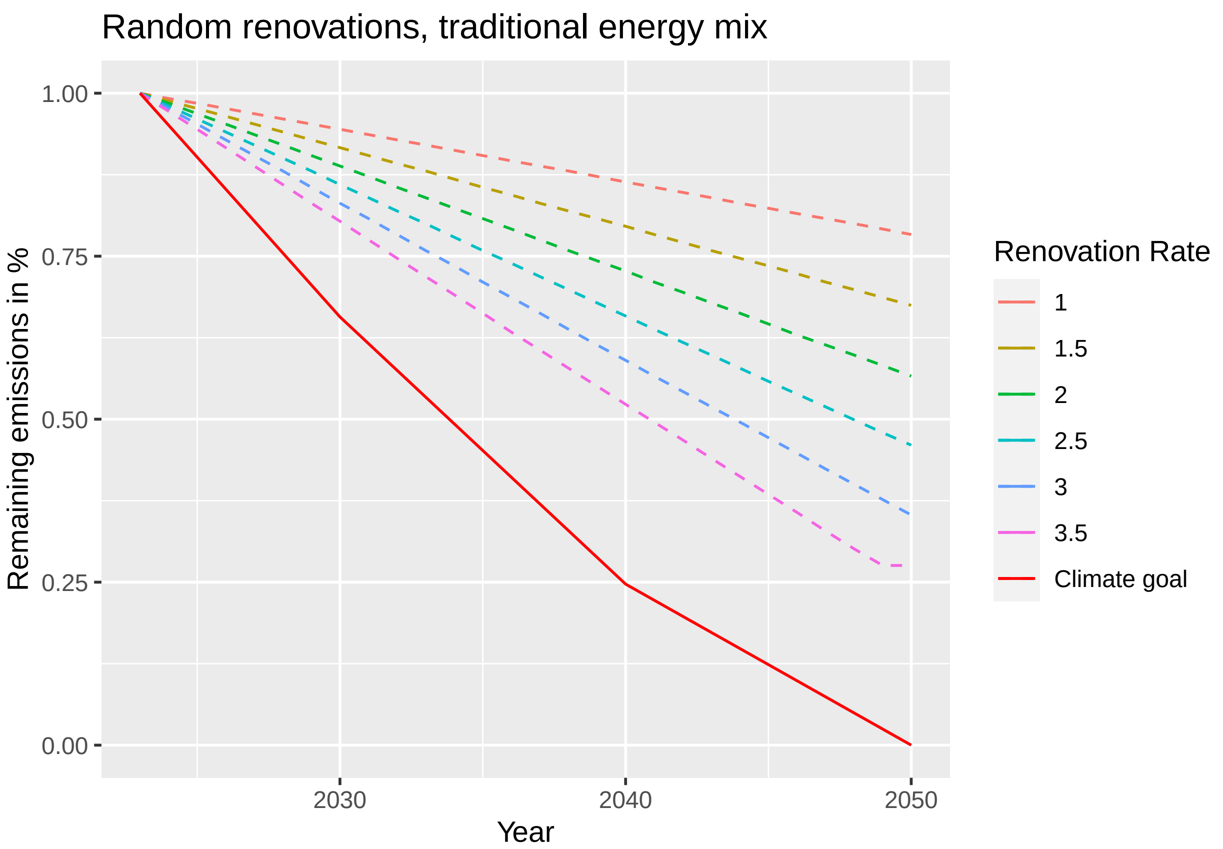
3.1.2 Plot: Randomized Renovations and Traditional Energy Mix

Plot the scenario with random renovations and traditional energy mix for various renovation rates. This graph shows how many GHG can be saved for different renovation rates with random renovations and a traditional energy mix. For reference, the graph also plots the climate goals.

```
filtered_data <- subset(long_df, Variable == "relative_ghg_old_rand")
filtered_data_truncated <- subset(filtered_data, year <= 2050)

#Create a ggplot with lines for different rates
p2 <- ggplot(filtered_data_truncated, aes(x = year, y = Value,
                                          color = as.factor(rate))) +
  geom_line(linetype="dashed") +
  geom_line(data=climate_goals, aes(x=year, y=rel_reduction)) +
  labs(title = "Random renovations, traditional energy mix") +
  xlab("Year") +
  ylab("Remaining emissions in %") +
  scale_color_manual(name = "Renovation Rate",
                     values = line_colors)
  ylim(0,1.05)
```

```
## <ScaleContinuousPosition>
##  Range:
##  Limits:    0 -- 1.05
```

```
p2
```



3.2 Neutral Energy Mix

3.2.1 Plot: Prioritized Renovations and Neutral Energy Mix

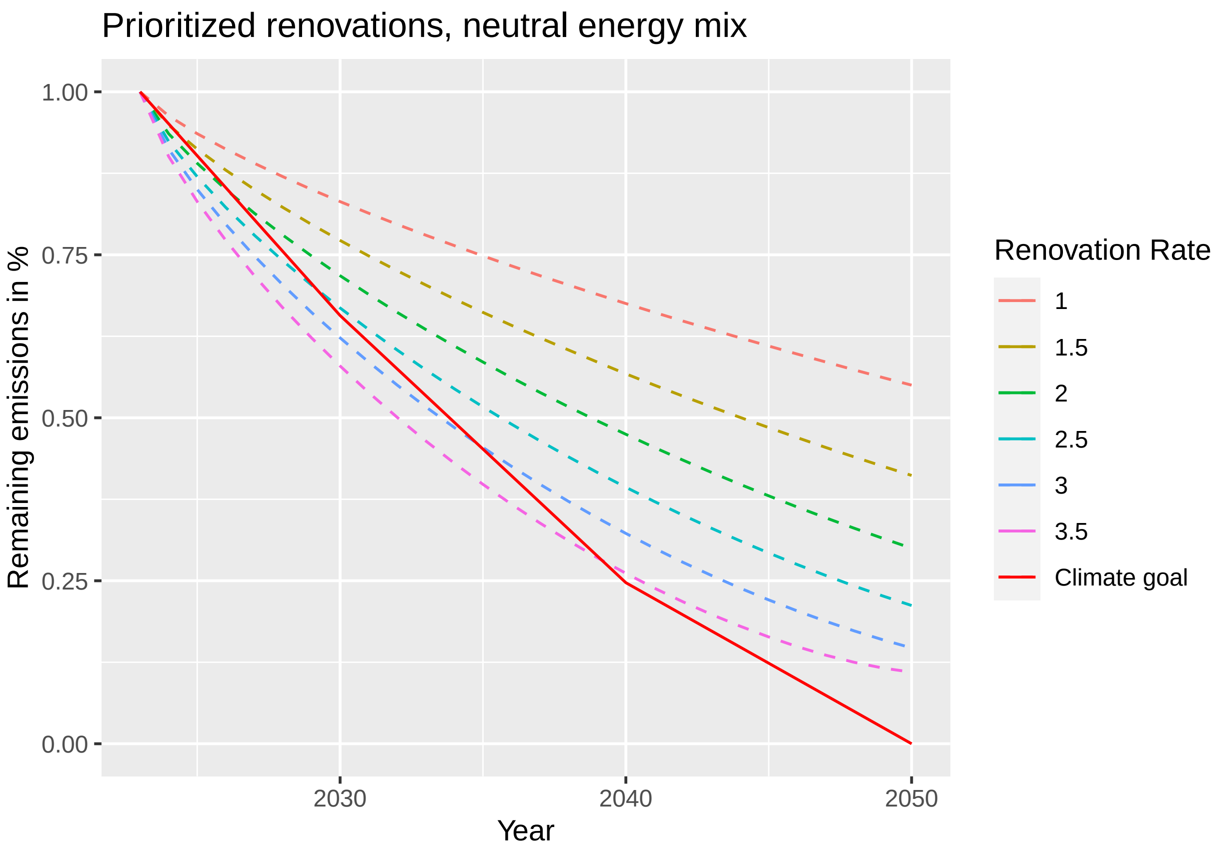
In this graph we show how many GHG can be saved in a scenario with prioritization of renovating worst performing buildings and a neutral energy mix. Here, neutral is defined as having decarbonized energy provision for heating pumps, while district heating is still provided as in the past. For reference, the graph also plots the climate goals.

```
filtered_data <- subset(long_df, Variable == "relative_ghg_neutral_prio")
filtered_data_truncated <- subset(filtered_data, year <= 2050)

colors <-  scales::hue_pal()(6)[1:6]
line_colors <- c(colors, "red")

# Create a ggplot with lines for different rates
p3 <- ggplot(filtered_data_truncated, aes(x = year, y = Value,
                                          color = as.factor(rate))) +
  geom_line(linetype="dashed") +
  geom_line(data=climate_goals, aes(x=year, y=rel_reduction)) +
  labs(title = "Prioritized renovations, neutral energy mix") +
  xlab("Year") +
  ylab("Remaining emissions in %") +
```

```
  scale_color_manual(name = "Renovation Rate",
                     values = line_colors)
  ylim(0,1.05)
```

```
## <ScaleContinuousPosition>
##  Range:
##  Limits:    0 -- 1.05
```

```
p3
```



3.2.2 Plot: Randomized Renovations and Neutral Energy Mix

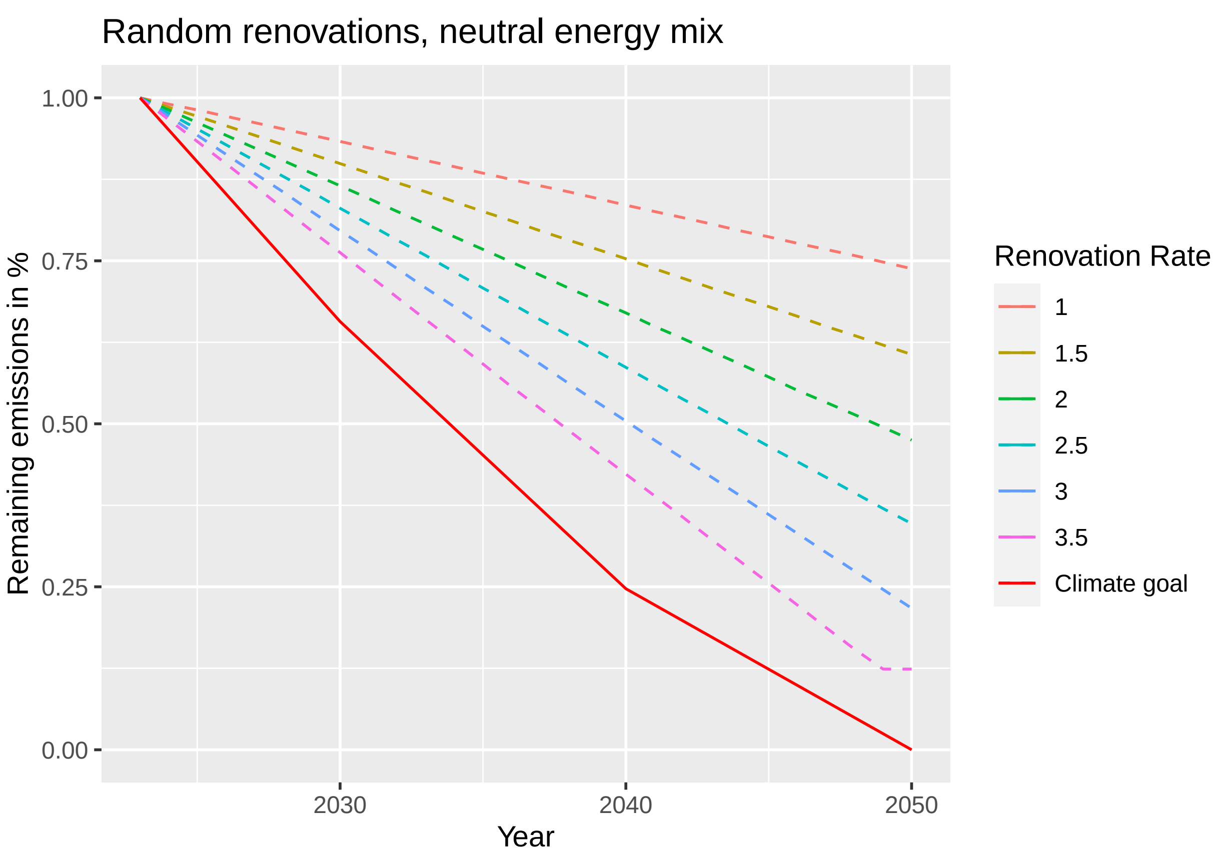
Plot the scenario with random renovations and neutral energy mix for various renovation rates. This graph shows how many GHG can be saved in a scenario with random renovations and a neutral energy mix. Here, neutral is defined as having decarbonized energy provision for heating pumps, while district heating remains provided as in the past. For reference, the graph also plots the climate goals.

```
filtered_data <- subset(long_df, Variable == "relative_ghg_neutral_rand")
filtered_data_truncated <- subset(filtered_data, year <= 2050)

#Create a ggplot with lines for different rates
p4 <- ggplot(filtered_data_truncated, aes(x = year, y = Value,
                                          color = as.factor(rate))) +
  geom_line(linetype="dashed") +
```

```
  geom_line(data=climate_goals, aes(x=year, y=rel_reduction)) +
  labs(title = "Random renovations, neutral energy mix") +
  xlab("Year") +
  ylab("Remaining emissions in %") +
  scale_color_manual(name = "Renovation Rate",
                     values = line_colors)
  ylim(0,1.05)
```

```
## <ScaleContinuousPosition>
##  Range:
##  Limits:    0 -- 1.05
```

```
p4
```



3.3 Fully Decarbonized Energy Mix

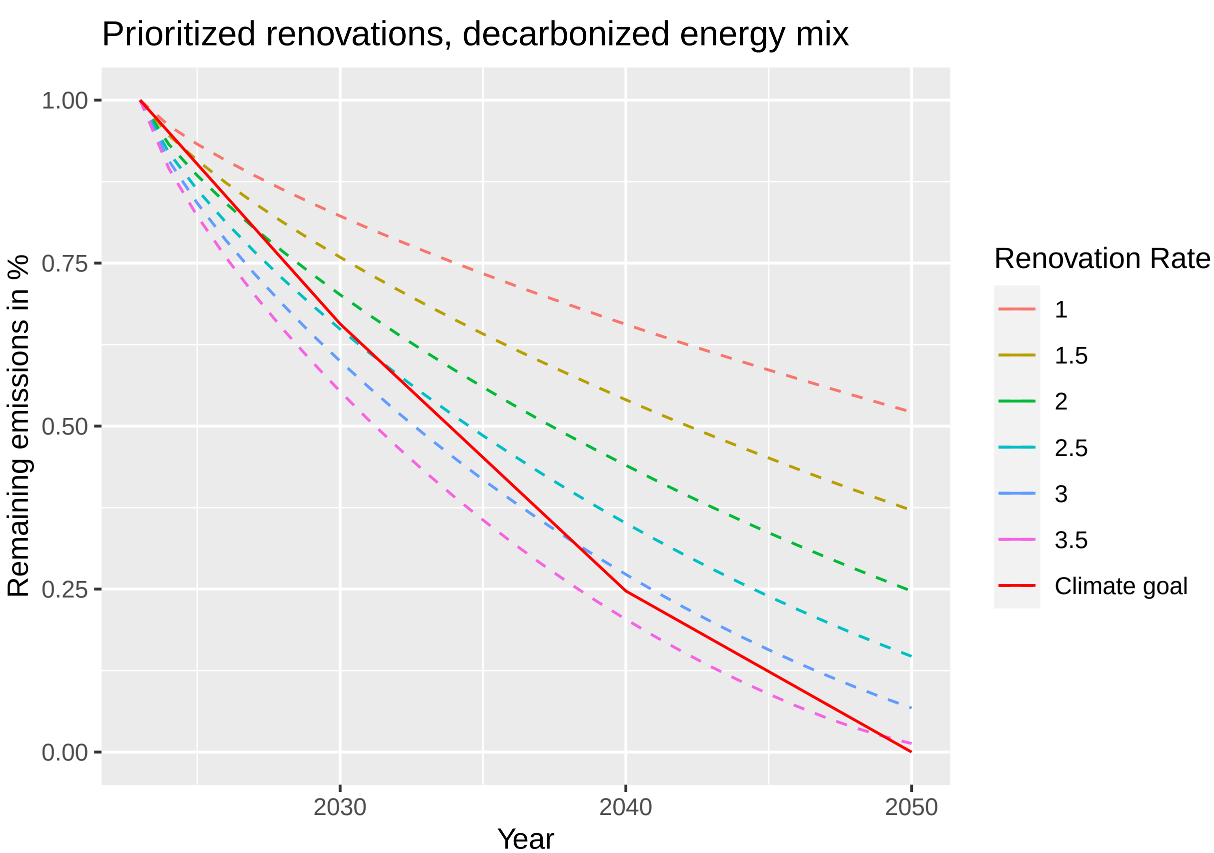
3.3.1 Plot: Prioritized Renovations and Fully Decarbonized Energy Mix

With this graph we show how many GHG can be saved in a scenario with prioritization of renovating worst performing buildings and a fully decarbonized energy mix. Fully decarbonized is defined as having decarbonized energy provision for heating pumps as well as decarbonized provision of district heating. For reference, the graph also plots the climate goals.

```r
filtered_data <- subset(long_df, Variable == "relative_ghg_decarb_prio")
filtered_data_truncated <- subset(filtered_data, year <= 2050)

colors <-  scales::hue_pal()(6)[1:6]
line_colors <- c(colors, "red")

# Create a ggplot with lines for different rates
p5 <- ggplot(filtered_data_truncated, aes(x = year, y = Value,
                                          color = as.factor(rate))) +
  geom_line(linetype="dashed") +
  geom_line(data=climate_goals, aes(x=year, y=rel_reduction)) +
  labs(title = "Prioritized renovations, decarbonized energy mix") +
  xlab("Year") +
  ylab("Remaining emissions in %") +
  scale_color_manual(name = "Renovation Rate",
                     values = line_colors)
  ylim(0,1.05)
```

```
## <ScaleContinuousPosition>
##  Range:
##  Limits:    0 -- 1.05
```

```r
p5
```



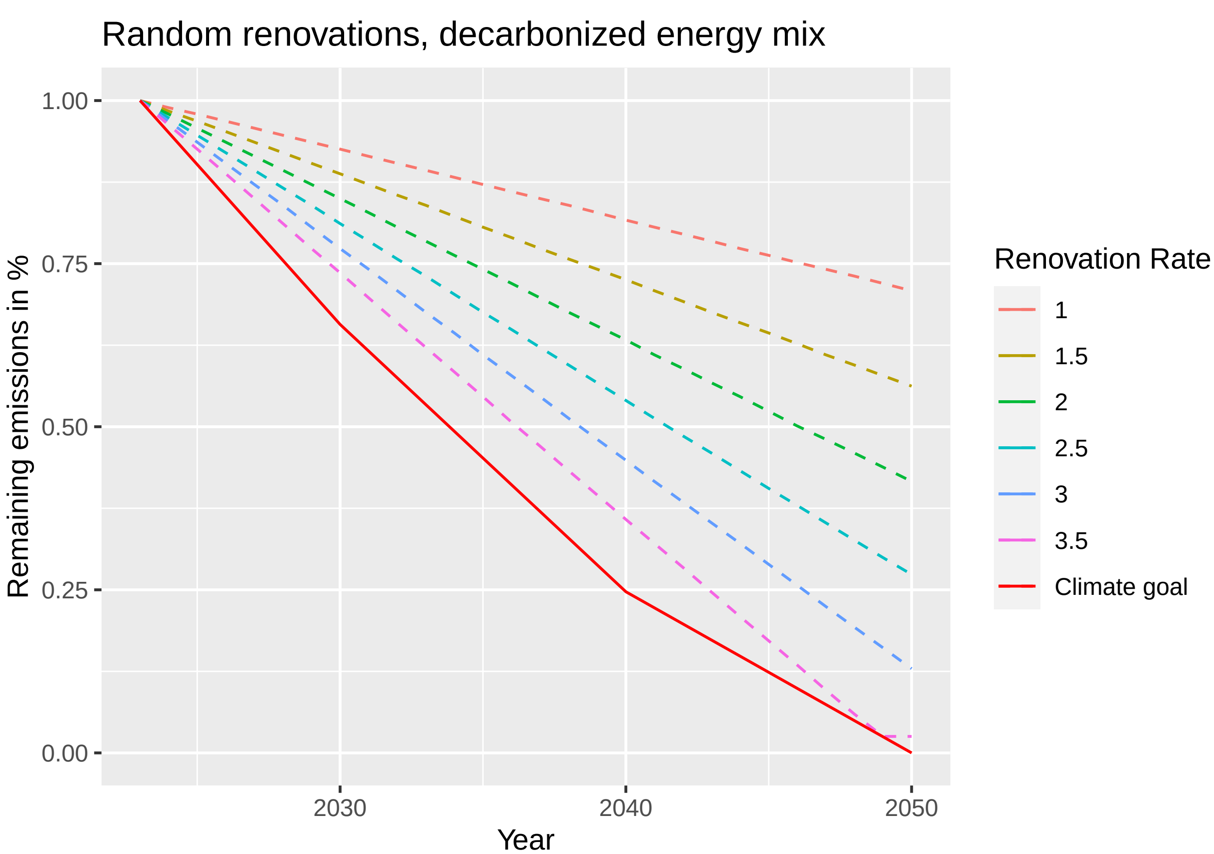
3.3.2 Plot: Randomized Renovations and Fully Decarbonized Energy Mix

With this graph we show how many GHG can be saved in a scenario with a random order of renovations and a fully decarbonized energy mix. Fully decarbonized is defined as having decarbonized energy provision for heating pumps as well as decarbonized provision of district heating. For reference, the graph also plots the climate goals.

```
filtered_data <- subset(long_df, Variable == "relative_ghg_decarb_rand")
filtered_data_truncated <- subset(filtered_data, year <= 2050)

#Create a ggplot with lines for different rates
p6 <- ggplot(filtered_data_truncated, aes(x = year, y = Value,
                                          color = as.factor(rate))) +
  geom_line(linetype="dashed") +
  geom_line(data=climate_goals, aes(x=year, y=rel_reduction)) +
  labs(title = "Random renovations, decarbonized energy mix") +
  xlab("Year") +
  ylab("Remaining emissions in %") +
  scale_color_manual(name = "Renovation Rate",
                     values = line_colors)
  ylim(0,1.05)
```

```
## <ScaleContinuousPosition>
##  Range:
##  Limits:    0 -- 1.05
```

```
p6
```



4 Supplementary Graphs

4.1 Distribution of Efficiency Classes

In this graph we show the distribution of efficiency classes by building types.

```
p7 <- ggplot(share_data_long, aes(x = group, y = percentage, fill = groups)) +
  geom_bar(stat = "identity", position = "dodge", alpha = 0.7) +
  labs(title = "Distribution of efficiency classes by type of building") +
  xlab("Efficiency class") +
  ylab("Percent") +
  scale_fill_manual(values = c("blue", "green", "red"))+
  guides(fill=guide_legend(title="Type of building:"),
         override.aes = list(fill = c("All",
                                      "Apartments",
                                      "Single- and two-family buildings")))


pdf(file = "../Graphs/plot_histogram.pdf",
    width = 6,
    height = 4)
p7
dev.off()
```

```
## pdf
##   2
```

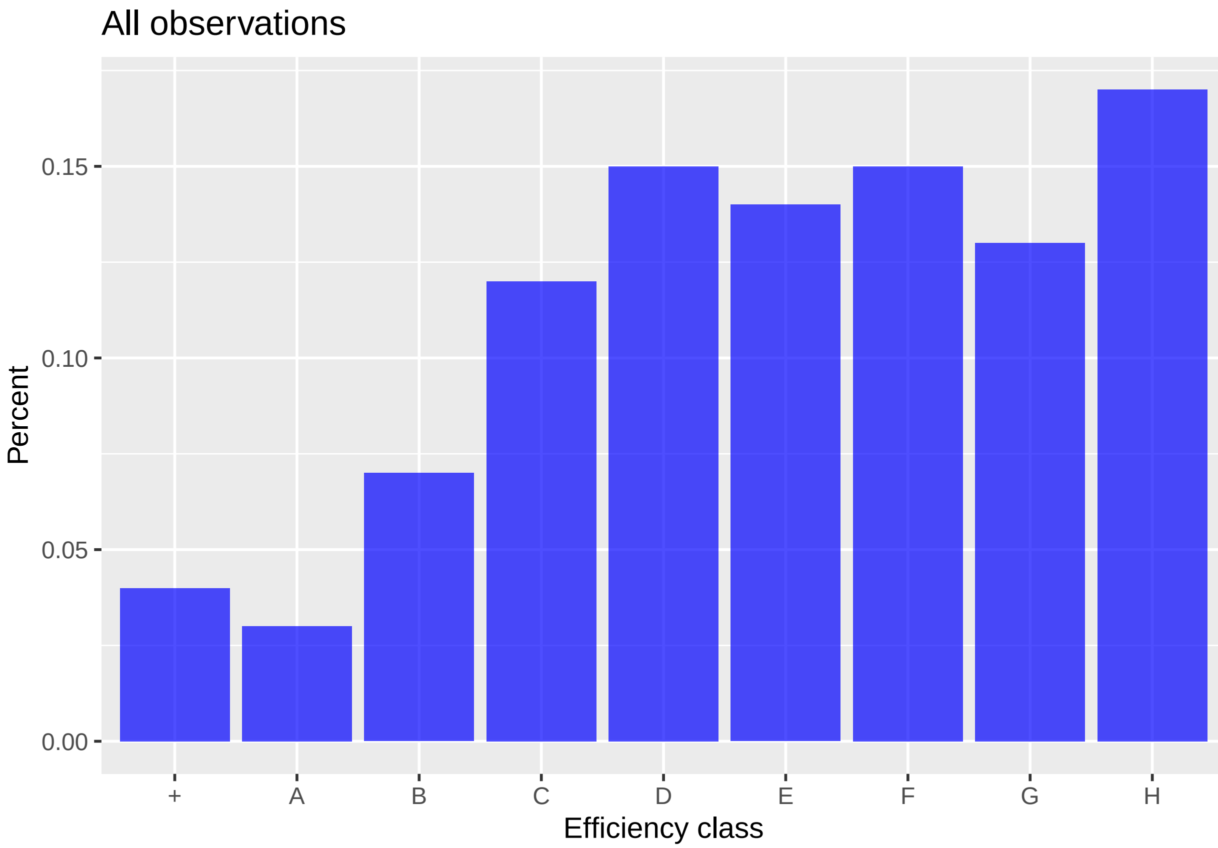
4.2 Supplementary Graphs

With these plots we show the distribution of efficiency classes for different subsets of the data.

Source

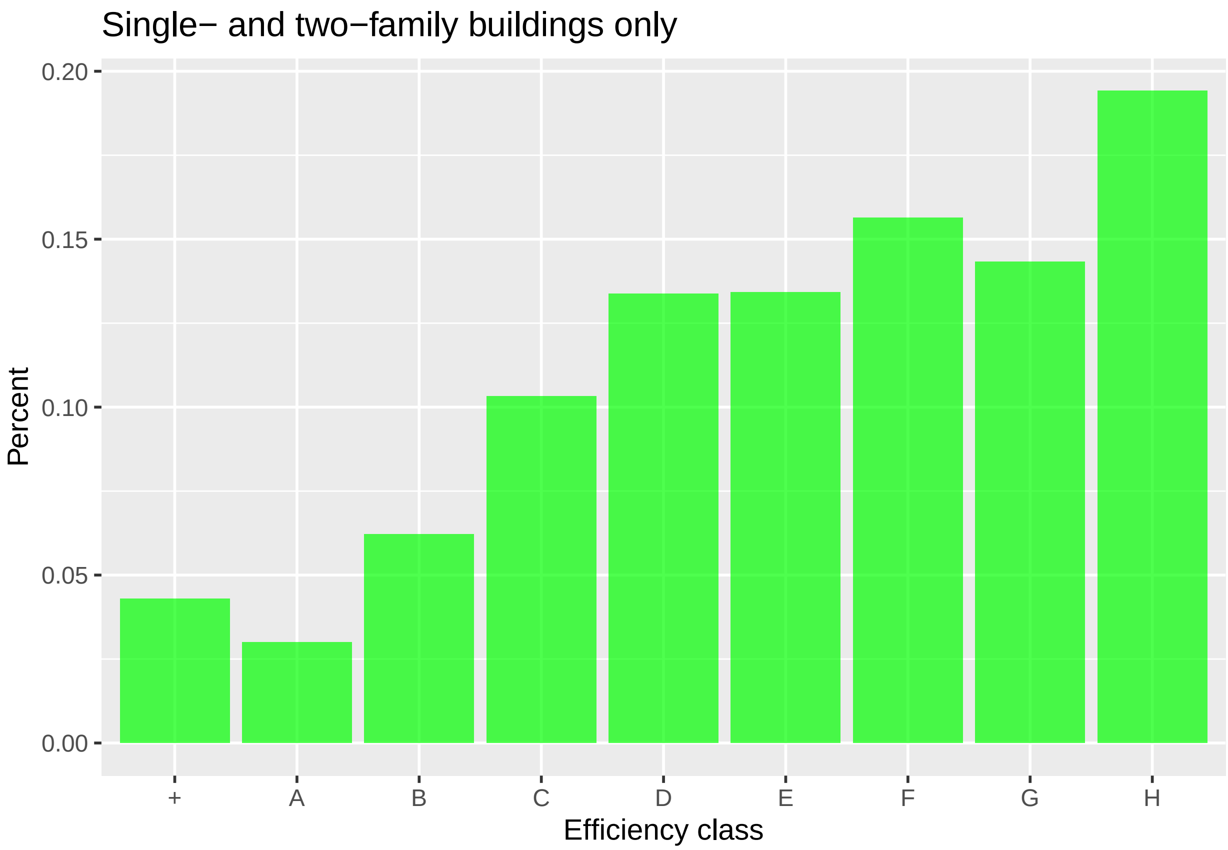
```
p8 <- ggplot(share_data, aes(x = group, y = All)) +
  geom_bar(stat = "identity", fill = "blue", alpha = 0.7) +
  labs(title = "All observations") +
  xlab("Efficiency class") +
  ylab("Percent")

# Create the second histogram for Haus
p9 <- ggplot(share_data, aes(x = group, y = Houses)) +
  geom_bar(stat = "identity", fill = "green", alpha = 0.7) +
  labs(title = "Single- and two-family buildings only") +
  xlab("Efficiency class") +
  ylab("Percent")

# Create the third histogram for Wohnung
p10 <- ggplot(share_data, aes(x = group, y = Apartments)) +
  geom_bar(stat = "identity", fill = "red", alpha = 0.7) +
  labs(title = "Apartments only") +
  xlab("Efficiency class") +
  ylab("Percent")
```

```
p8
```



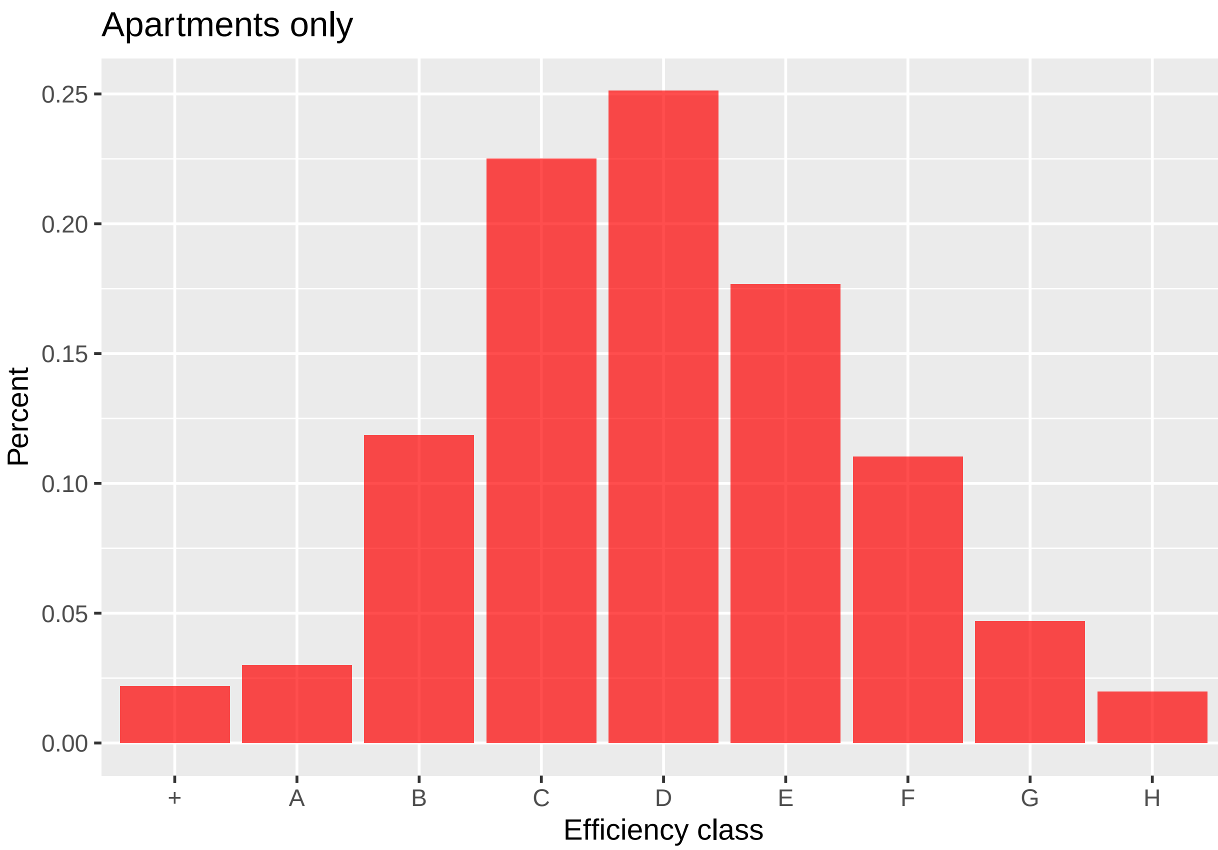
All observations
Percent
0.15
0.10
0.05
0.00
+
A
B
C
D
E
F
G
H
Efficiency class


```
p9
```



Single− and two−family buildings only
0.20
0.15
0.10
0.05
0.00
Percent
+
A
B
C
D
E
F
G
H
Efficiency class


```
p10
```


Apartments only
Percent
0.25
0.20
0.15
0.10
0.05
0.00
+
A
B
C
D
E
F
G
H
Efficiency class