MJ2685/MJ2686 HT17
SMART CITIES AND CLIMATE MITIGATION STRATEGIES

The second generation of energy declarations

- Analysis of recommended and implemented energy efficiency measures and its impacts.

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SUMMARY

The energy demand in buildings represent a large amount of energy in Sweden and the demand has to decrease in a sustainable future by using various mechanisms such as use of energy efficient equipment. The energy declaration was introduced in 2006 in order to facilitate an efficient energy use and a good indoor environment. The declaration have now been in use long enough, constitute a duplicated and comparable source of data on building efficiency. This study explores the possibilities to use this data to answer if the reported energy efficiency in buildings have improved and if the recommendation on energy measures done in the declarations have been implemented and if it led to improved energy efficiency.

The result shows that some buildings had improved but that some had worsened, and that just a few had followed the given recommendations. The result is inconclusive and can't provide answer on the particular questions since the set of data is too small and several uncertainties is detected.

However, the use of data from the energy declarations seems to have a large potential. With a growing amount of second generation declaration, with the use of the data, further research is recommended, especially on how to improve the quality, the organisation of the collected data, and the effectiveness of the recommendations.

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INTRODUCTION

Background

The energy consumption of buildings in Sweden

The building and service sector is responsible for almost 40% of the national energy consumption, representing 143 TWh (2015) and 90% of the energy consumption in the sector origin from premises and households. The Energy consumption in the sector has decreased since the beginning of the 2000 century, with one exception because of a unusual cold winter 2010. The reduction is mainly due to a decreasing supplied energy for heating and tap water. The energy supplied for heating building and tap water is decreasing, but still (2015) contributes to 53% of the total energy demand in the sector, corresponding to 76 TWh. The contributing factors to the reduction is more energy efficient buildings, change from oil heating system to electricity or district heating system and a increasing use of heat pumps (Energimyndigheten, 2017). The distribution of different heat system is different depending on the location in the country, but in Stockholm is approximately 80% of the buildings connected to district heating and the rest uses heat pumps (Lönngren, 2018).

National and international regulation

National regulation regarding building energy rest on the framework directive *Directive for energy performance of buildings* (2010/31/EU), building on (2002/91/EG). The directive requires that the members, in a suitable way, should fulfil five areas: A methodology for quantifying the energy performance of a building, set up minimum requirements on energy efficiency in new buildings, minimum requirements for building that are changed or rebuilt, energy certification of buildings and also inspection of heating and ventilation system (Energimyndigheten, 2018).

European Union energy ministers negotiated in 2017 for increased energy efficiency enhancements, 30% energy efficiency until the year 2030, including a common approach to building energy performance (Regeringen, 2018).

The national response to the original directive (2002/91/EG), that won legal force in January 2003, was the law of energy declarations for buildings that got legal force during October 2006 (Energimyndigheten, 2018). The energy declaration have evolved accordingly to new demands. In 2014 was a new classification system introduced instead of the earlier energy level system (Boverket, 2017).

The Swedish Energy Declaration

To fulfil the framework directive from EU and with the purpose to facilitate an efficient use of energy and a good indoor environment in buildings, an energy declaration was introduced. The national board on housing, building and planning are responsible for the rules and supervision of the energy declaration and also responsible of keeping the register of declarations and on request make them available for the public (Boverket, 2017).

The energy declaration contains information of the heated area in the building (A_{temp}), the energy demand of the building including heating, cooling and tap water. The declaration contains information about prevailing heating system and ventilation and suggested improvements to increase the energy

performance of the building (Boverket, 2017). See appendix C for a comprehensive template of the energy declaration.

New buildings and buildings that are larger than 250$m^3$and used by the public and buildings that is to be sold or rented out is obligated to conduct an energy declaration. The declaration must be done by a approved energy expert and is valid for 10 years (Boverket, 2017).

The potential value of the collected data

The energy declarations is constituting the main source of data on building energy (Pasichnyi et al., 2018) and is a source of information on the energy performance of different buildings public available, making it possible to compare and to see the development on performance for a specific building (Boverket, 2017). But it could also provide information on a more systematic level that can support the city planners and the city authority to take more efficient decisions. With the collected data could the patterns of energy performance in different areas of the city or a for a certain kind of building be distinguished, the implementation of recommended measures and their actual improvements of energy performance be identified and mapped. Pasichnyi et al. (2018) points out that the energy declaration have potential to be used in a extended way, different than it initially was intended to and that puts new demands on the gathered data and the way it is managed.

The Energy declaration is valid for 10 years, and thus is the second generation of declaration for many buildings conducted during 2017 and 2018. This provides the opportunity to analyse the development of energy performance over time and find useful patterns. It is interesting to evaluate if the energy declaration have given the intended effect, i.e. more efficient buildings, therefore are two areas of interest emerging: Have the individual buildings improved their energy efficiency, and do the recommendations in the declaration leads to improvements?

Aim and objectives

The aim is to process, analyse and visualize data collected in the energy declaration to better understand the development of energy performance in buildings and evaluate the impact of the energy declaration.

Objectives:

1. How many buildings have improved or worsened their energy performance in Stockholm County?

2. How much effect on the energy performance does the recommendations have for those building that follows them?

METHODOLOGY

The foundational source of information to answer our objectives, relied on a large data set of energy declarations, which are gathered by the National Board on Housing, Building and Planning (Boverket). A data set from Boverket was therefore obtained with energy declarations (from whole Sweden) for buildings from the time period of 2007-06-30 to 2018-06-30. The obtained data set from Boverket contained approximately 1.6 million registered energy declarations, with corresponding 163 input variables from the energy declaration.

The pre-processing and analysis were mainly performed in R-studio, a free open-source IDE (integrated development environment) for R, which is a free software environment for statistical computing and graphics. R was used since it is a popular software used among academics and recommended by our supervisor. The exact algorithms used in the method can be found in appendix B.

For the first objective, which only concerned Stockholm County, data from Stockholm County was extracted from the given data set. In order to analyse whether buildings have improved or worsened their energy performance, two energy declaration from the same building had to be compared during different time periods (time period 1 and time period 2), with regard to energy performance (consumed kWh per square meters, per year), where $\Delta\, EP$is the difference of energy performance

$$\Delta\, EP\ = EP_1\ - EP_2\ (kWh/m^2)$$

For this objective two time periods were chosen, time period 1: 2007-06-30 to 2017-06-30 and time period 2: 2017-06-30 to 2018-06-30. These time periods were chosen because of the interest on how buildings have changed the last period of time. Two data sets were created for each time period, and buildings who had done an energy declaration in both time periods were matched using identification attributes as zip code number, address, house id number and property designation. Although the matched buildings doesn't per se mean that they are unique buildings, since apartments in the same building also have unique identification attributes, by removing duplicates (based on identification attributes) from the same building, unique buildings can be acquired.

For the second objective, the investigation was conducted on all buildings available in the declarations that performed energy declaration at least twice (for buildings from the time period of 2007-06-30 to 2018-06-30, from whole Sweden). The reason for choosing the whole data available is because at this point it was already known that the quality of data is too poor for the purpose of the below-described analysis.

The objective was to identify the number of buildings that followed a certain recommendation for improvement in terms of energy performance and find out which recommendation contributes to bigger improvement. 'Recommendations' is a separate section in energy declaration, which upon filled-in by an expert, tells the building-owner what shall be changed in order to achieve better energy performance. There are three general types of recommendations: Control Technics, Installation Technics, and Building Technics, which were named for simplicity: A, B, C, respectively. Unfortunately, a lot of buildings had missing data regarding recommendations and therefore were disregarded.

In order to sort out buildings that has followed a certain recommendation, a key assumption was made. If a building was recommended A, B, C (or their combination, which can be visualised in the figure 1 below) in the first declaration but hasn't been recommended to implement the same recommendation(s) in the second declaration – it can be considered as a building that indeed followed

certain recommendation(s). As three recommendation categories were chosen for analysis – the number of their combinations is given by the equation:

$$Number\ of\ equations = \sum_{k=1}^{n=3} \frac{n!}{k!\,(n-k)!} = 7$$

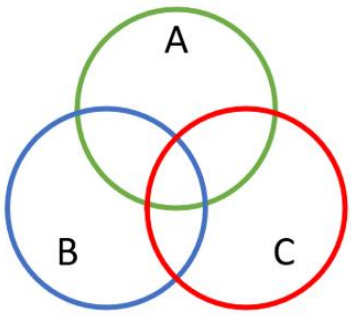

Figure 1. How the implemented categories A, B and C overlap

Then it was compared how much buildings that followed any recommendation(s) improved in terms of energy efficiency and on this basis conclusions were made. The complete code for objective 1 and 2 is found in appendix B. This result shall be interesting from the perspective of energy performance certifiers as well as city planners.

RESULTS

The data considered for this exercise was from 2007 to 2018. Since every declaration is valid for ten years only, there is a need to declare the buildings after a decade or if the building owner seems it to be necessary after an upgrade of the infrastructure.

A different approach on a whole was put in place to find the improvement in Stockholm county buildings. Where the main differentiators/parameters like “IdFastBet","IdHusnr", "IdPostnr”, were used to filter the unique buildings. Based on which 284 unique buildings were found to be declared again in the second round. But of which only 200 were improved and the rest were on the contrary worsened. Interestingly, the buildings have improved by 32.4 kWh/m2 on an average and worsened by 27 kWh/m2 on an average.

Table 1. Summary of Total energy declarations made in Sweden 2007-2018

	Value	Percentage
Declarations in total	1655967	100
Unique declarations (out of total)	1033695	62.42
Unique declarations, made more than once per building (out of unique)	6829	0.66
Unique declarations, made more than once and being eligible for analysis (out of unique that made more than one)	3067	44.91
Buildings that followed any advice (out of all eligible)	25	0.82

Observing the table 1 above, it can be seen that the number of unique buildings were only ~62% of the total and only 0.66% were audited in the second round. This shows the number of ~6800 approx. out of which 50% were analysable. Out of the whole 3000 approx. households of Sweden, it was only 25 households that followed the advice of declarations.

Below is table 2 showing the summary of improvements under different recommendations: The different classes of recommendation, like A, B, C and so on, are explained in appendix B.

Table 2. Summary of buildings with various recommendation types

	A	B	C	AB	AC	BC	ABC
How many uniq, buildings were recommended to improve any of recommendations or their combinations	1248	1066	272	412	37	17	14
How many uniq, building actually followed a particular advice	14	8	2	1	0	0	0
How many of the ones that followed advises, also improved their energy performance	7	4	1	1	0	0	0

As per the numbers shown in the above table, it clearly shows the recommendation Type A was the most recommended. But at the same time when the advice was followed, only a success rate of 50% was observed. Same analogy goes with the recommendation type B & C which shows the same behaviour.

DISCUSSION

By answering the first objective of the study, one can see the point to be pondered here is the ratio of 7:3 improved to worsened but have to see on how it affects the overall energy efficiency targets of the city. Secondly, it is seen from the other aim of seeing the effectiveness of recommendations revealed that the same recommendation will not be applicable in all the cases, but the recommendation has to tailored to the specific regions and keeping in mind with its surrounding conditions.

There are various shortcomings in this study, both depending on the methodology and the set of data that was available. Regarding the method should the risk for certain errors be acknowledged: for buildings that improved their energy efficiency in another way than by implementing certain recommendation(s) it is likely that in the newer declaration the recommendation changes as it would no longer be necessary.

Regarding the input data many irregularities were found such as, there were many missing values in the dataset, many ambiguities with various declarations assigned for the same building, assumptions for removing duplicates considering various combinations of parameters, format of the data in the energy declaration etc. It is quite unrealistic to come to a conclusion on the effectiveness of a particular decision with such a less amount of data which does not represent all kinds of composition of buildings and neighbourhoods. Furthermore, the collected data set with energy declaration doesn't cover all buildings who changed their energy performance during the time period, only those who ordered an energy audit during the period. This imply that there are probably an unknown number of buildings who were retrofitted but didn't go through an energy audit, hence couldn't be analysed. Therefore, it's not wise to jump to conclusions with such a few data outputs.

The analysis could be more effective if it was done with some more relevant data from a particular region/county i.e. more unique buildings with second round of audit plus if the advice was followed. Further, investigating the effect of that particular recommendation in the chosen county could have been more effective and concluding on the effectiveness of the recommendation.

Further Scope of discussion could be extended onto the design of the energy declaration format. There were many shortcomings which were observed when the data analysis was carried out like how the building information was logged. Thus, the future work for this initiative could be working on to making the declaration form more usable and finding the most optimized design.

Further research in the area is proposed because the data could constitute a important input for creating decision support for city authorities and planers. Once more data of buildings with multiple energy declarations is available, following topics for prospective discussion could be address:

- *What are the prospective benefits for the stakeholders?*
- *How can the process of policy-implementation in buildings be improved/speed-up based on the data?*
- *What data should be compared?*
- *Which energy-efficiency improvements, that haven't been made yet, will improve energy efficiency the most?*
- *What error emerge while processing the data and why?*

- *How could behavioural science be included to study the effects of recommendations and use the results to tweak and tailor make future recommendations*

CONCLUSION

This project highlights the important information that can be obtained from the energy declarations. The buildings that improved their energy performance since the last declaration were identified and further comparison was made among the recommendations that were suggested during the first declaration and the ones that were actually implemented by the owners. Such information, combined with macroeconomic indicators, could lead to more owner friendly or personalized recommendations that would have the anticipated effect.

The processing of data, however, has highlighted some important insights and most important among all is that there is a dire need to improve the process of energy declarations, especially the energy audit forms and the way data is stored as this data could be a source of deep insight into energy consumption evolution of buildings.

The most important point to note here is that it's too early to compare the old and new declarations in order to get insights into the evolution of energy consumption in buildings. The energy declarations ware made mandatory in 2007, however, not all the energy declarations were done in the year 2007 rather the process of first ever energy declarations continued throughout the coming years. Thus, energy declarations of a vast majority of buildings have still not expired and it's not possible to draw any general conclusion based on limited data set. Hence, it is recommended to carry out a similar study in the future when a sufficient amount of data is available.

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Appendix

Appendix A. Recommendation Classes

Recommendation Classes	**Recommendations**
Type A	AtgForslagStyrTeknisk
Type B	AtgForslagInstTeknisk
Type C	AtgForslagByggTeknisk
Type AB	Type A & Type B
Type AC	Type A & Type C

Appendix B

R algorithm for objective 1

```
### STEP 1: Make sure stringsAsFactors=FALSE, to keep columns as
characters
data_0_25 <- read.csv2("C:/Users/Hedy Mahmoudi/OneDrive/KTH 2018-
2019/Smart Cities and Climate Mitigation Strategies
MJ2685/R/R_workshop/DSM/DSM/data/data_0_25.csv", stringsAsFactors =
FALSE)
data_25_50 <- read.csv2("C:/Users/Hedy Mahmoudi/OneDrive/KTH 2018-
2019/Smart Cities and Climate Mitigation Strategies
MJ2685/R/R_workshop/DSM/DSM/data/data_25_50.csv", stringsAsFactors =
FALSE)
data_50_ <- read.csv2("C:/Users/Hedy Mahmoudi/OneDrive/KTH 2018-
2019/Smart Cities and Climate Mitigation Strategies
MJ2685/R/R_workshop/DSM/DSM/data/data_50_.csv", stringsAsFactors =
FALSE)
# Double check by using str()


### binding three data frames

total_data <- rbind(data_0_25, data_25_50, data_50_)


### STEP 2: Filter the three data sets containing only dates after 2017-06-29
for column "Godkand" and "Idlan" == "Stockholms län"
# Fix date format for
library(lubridate) #Open package for dates and the function ymd()
ymd(total_data$Godkand) # ymd() takes a vector representing year, month,
and day, and converts it to a Date vector, it choosed Date and not POSIXct
total_data$Godkand <- ymd(total_data$Godkand)  #save to df


library("tidyverse") #open package dplyr

new_data <- filter(total_data, Godkand> '2017-06-29', IdLan == "Stockholms
län")

old_data <- filter(total_data, Godkand<=  '2017-06-29', IdLan == "Stockholms
län")

matching_buildings <- merge(new_data, old_data,
by=c("IdFastBet","IdPostnr" ,"IdHusnr", "IdAdr"))


## Save merge_total
write_csv(matching_buildings, path = "data_output/matching_buildings.csv")

### Find the difference of EgiEnergiPrestanda
df_E <- select(matching_buildings, IdFastBet, IdPostnr ,IdHusnr, IdAdr,
EgiEnergiPrestanda.y, EgiEnergiPrestanda.x)
df_E$deltaE <- df_E$EgiEnergiPrestanda.y - df_E$EgiEnergiPrestanda.x
write_csv(df_E, path = "data_output/df_E.csv")
improved_E<- filter(df_E, deltaE>0)
worsened_E<- filter(df_E, deltaE<0)

#Try to find only unique buildings
df_E_unique <- df_E[!duplicated(df_E [,c("IdFastBet","IdHusnr", "IdPostnr")]),]
write_csv(df_E_unique, path = "data_output/df_E_unique.csv")
# For unique buildings
improved_E_unique <- filter(df_E_unique, deltaE>0)
worsened_E_unique <- filter(df_E_unique, deltaE<0)
#Average improved/worsened energy performance
sum(improved_E_unique$deltaE)/nrow(improved_E_unique) #32.435
sum(worsened_E_unique$deltaE)/nrow(worsened_E_unique) #-27.07143

# percentage
nrow(improved_E_unique)/nrow(df_E_unique)*100 # 70.42254 %
nrow(worsened_E_unique)/nrow(df_E_unique)*100 # 29.57746 %
```

R algorithm for objective 2

```
library(lubridate) #Open package for dates and the function ymd()
library(tidyverse) #open package dplyr

data_0_25 <- read.csv2("data/data_0_25.csv", stringsAsFactors = FALSE)
data_25_50 <- read.csv2("data/data_25_50.csv", stringsAsFactors = FALSE)
data_50_ <- read.csv2("data/data_50_.csv", stringsAsFactors = FALSE)

total_data0 <- rbind(data_0_25, data_25_50, data_50_) # bind 3 datasets into
one
total_data0$Godkand <- ymd(total_data0$Godkand) # fix data format

# ALL BUILDINGS:
total_data0 <- total_data0[order(total_data0$IdFastBet),] # sort data by
IdFastBet

# UNIQUE DECLARATIONS:
total_data_unq <- total_data0 %>%
distinct(IdFastBet,IdPostnr,IdHusnr,Godkand, .keep_all = TRUE)
# grouping unique declarations
total_data_grouped <- total_data_unq %>%
group_by(IdFastBet,IdPostnr,IdHusnr) %>% count
# BUILDINGS THAT MADE TWO OR MORE DECLARATIONS
total_data_grouped_2 <- filter(total_data_grouped, n >= 2)
# merging with big table in order to get missing rows (the last function deleted
them)
```

```
total_data <- merge(total_data_unq, total_data_grouped_2, by=c("IdFastBet",
"IdPostnr", "IdHusnr"))
# BUILDINGS THAT MADE TWO OR MORE DECLARATIONS (with all rows)
total_data <- total_data %>% distinct(IdFastBet,IdPostnr,IdHusnr,Godkand,
.keep_all = TRUE)
# renaming columns for simplicity
colnames(total_data)[colnames(total_data)=="AtgForslagStyrTeknisk"] <- "A"
colnames(total_data)[colnames(total_data)=="AtgForslagInstTeknisk"] <- "B"
colnames(total_data)[colnames(total_data)=="AtgForslagByggTeknisk"] <- "C"
# deleting rows that have either NA or null in at least one of the columns
mentioned above
total_data <- total_data[!apply(is.na(total_data) | total_data$A == "" |
total_data$B == "" | total_data$C == "", 1, all),]
# DECLARATIONS THAT ARE ELIGIBLE FOR RECOMMENDATION
ANALYSIS
data_elg <- total_data %>% drop_na(A, B, C)

AY <- filter(data_elg, A == "Ja", B == "Nej", C == "Nej") # only A
AN <- filter(data_elg, A == "Nej") # whatever but not A
BY <- filter(data_elg, A == "Nej", B == "Ja", C == "Nej") # only B
BN <- filter(data_elg, B == "Nej") # whatever but not B
CY <- filter(data_elg, A == "Nej", B == "Nej", C == "Ja") # only C
CN <- filter(data_elg, C == "Nej") # whatever but not C
ABY <- filter(data_elg, A == "Ja", B == "Ja", C == "Nej") # only A and B
ABN <- filter(data_elg, A == "Nej", B == "Nej") # whatever but not A and not B
ACY <- filter(data_elg, A == "Ja", B == "Nej", C == "Ja") # only A and C
ACN <- filter(data_elg, A == "Nej", C == "Nej") # whatever but not A and not C
BCY <- filter(data_elg, A == "Nej", B == "Ja", C == "Ja") # only B and C
BCN <- filter(data_elg, B == "Nej", C == "Nej") # whatever but not B and not C
ABCY <- filter(data_elg, A == "Ja", B == "Ja", C == "Ja") # A and B and C
ABCN <- filter(data_elg, A == "Nej", B == "Nej", C == "Nej") # nothing (not A
and not B and not C)

merge_A0 <- merge(AY, AN, by=c("IdFastBet", "IdPostnr", "IdHusnr",
"IdAdr"))
merge_B0 <- merge(BY, BN, by=c("IdFastBet", "IdPostnr", "IdHusnr",
"IdAdr"))
merge_C0 <- merge(CY, CN, by=c("IdFastBet", "IdPostnr", "IdHusnr",
"IdAdr"))
merge_AB0 <- merge(ABY, ABN, by=c("IdFastBet", "IdPostnr", "IdHusnr",
"IdAdr"))
merge_AC0 <- merge(ACY, ACN, by=c("IdFastBet", "IdPostnr", "IdHusnr",
"IdAdr"))
merge_BC0 <- merge(BCY, BCN, by=c("IdFastBet", "IdPostnr", "IdHusnr",
"IdAdr"))
merge_ABC0 <- merge(ABCY, ABCN, by=c("IdFastBet", "IdPostnr",
"IdHusnr", "IdAdr"))

merge_A <- filter(merge_A0, Godkand.y > Godkand.x)
merge_B <- filter(merge_B0, Godkand.y > Godkand.x)
merge_C <- filter(merge_C0, Godkand.y > Godkand.x)
merge_AB <- filter(merge_AB0, Godkand.y > Godkand.x)
merge_AC <- filter(merge_AC0, Godkand.y > Godkand.x)
merge_BC <- filter(merge_BC0, Godkand.y > Godkand.x)
merge_ABC <- filter(merge_ABC0, Godkand.y > Godkand.x)

merge_A$EnergyDifference <- merge_A$EgiEnergiPrestanda.x -
merge_A$EgiEnergiPrestanda.y
merge_B$EnergyDifference <- merge_B$EgiEnergiPrestanda.x -
merge_B$EgiEnergiPrestanda.y
merge_C$EnergyDifference <- merge_C$EgiEnergiPrestanda.x -
merge_C$EgiEnergiPrestanda.y
merge_AB$EnergyDifference <- merge_AB$EgiEnergiPrestanda.x -
merge_AB$EgiEnergiPrestanda.y
merge_AC$EnergyDifference <- merge_AC$EgiEnergiPrestanda.x -
merge_AC$EgiEnergiPrestanda.y
merge_BC$EnergyDifference <- merge_BC$EgiEnergiPrestanda.x -
merge_BC$EgiEnergiPrestanda.y
merge_ABC$EnergyDifference <- merge_ABC$EgiEnergiPrestanda.x -
merge_ABC$EgiEnergiPrestanda.y

A_impr <- filter(merge_A, EnergyDifference > 0)
B_impr <- filter(merge_B, EnergyDifference > 0)
C_impr <- filter(merge_C, EnergyDifference > 0)
AB_impr <- filter(merge_AB, EnergyDifference > 0)
AC_impr <- filter(merge_AC, EnergyDifference > 0)
BC_impr <- filter(merge_BC, EnergyDifference > 0)
ABC_impr <- filter(merge_ABC, EnergyDifference > 0)

A_nt_impr <- filter(merge_A, EnergyDifference <= 0)
B_nt_impr <- filter(merge_B, EnergyDifference <= 0)
C_nt_impr <- filter(merge_C, EnergyDifference <= 0)
AB_nt_impr <- filter(merge_AB, EnergyDifference <= 0)
AC_nt_impr <- filter(merge_AC, EnergyDifference <= 0)
BC_nt_impr <- filter(merge_BC, EnergyDifference <= 0)
ABC_nt_impr <- filter(merge_ABC, EnergyDifference <= 0)

A_impr$ImprPercent <- A_impr$EnergyDifference /
A_impr$EgiEnergiPrestanda.x * 100
B_impr$ImprPercent <- B_impr$EnergyDifference /
B_impr$EgiEnergiPrestanda.x * 100
C_impr$ImprPercent <- C_impr$EnergyDifference /
C_impr$EgiEnergiPrestanda.x * 100
AB_impr$ImprPercent <- AB_impr$EnergyDifference /
AB_impr$EgiEnergiPrestanda.x * 100
AC_impr$ImprPercent <- AC_impr$EnergyDifference /
AC_impr$EgiEnergiPrestanda.x * 100
BC_impr$ImprPercent <- BC_impr$EnergyDifference /
BC_impr$EgiEnergiPrestanda.x * 100
ABC_impr$ImprPercent <- ABC_impr$EnergyDifference /
ABC_impr$EgiEnergiPrestanda.x * 100

if(nrow(A_impr) != 0){
    ImprMean_A <- mean(A_impr$ImprPercent)
} else {
    ImprMean_A <- 0
}

if(nrow(B_impr) != 0){
    ImprMean_B <- mean(B_impr$ImprPercent)
} else {
    ImprMean_B <- 0
}

if(nrow(C_impr) != 0){
    ImprMean_C <- mean(C_impr$ImprPercent)
} else {
    ImprMean_C <- 0
}

if(nrow(AB_impr) != 0){
    ImprMean_AB <- mean(AB_impr$ImprPercent)
} else {
    ImprMean_AB <- 0
}

if(nrow(AC_impr) != 0){
    ImprMean_AC <- mean(AC_impr$ImprPercent)
} else {
    ImprMean_AC <- 0
}

if(nrow(BC_impr) != 0){
    ImprMean_BC <- mean(BC_impr$ImprPercent)
} else {
    ImprMean_BC <- 0
}

if(nrow(ABC_impr) != 0){
    ImprMean_ABC <- mean(ABC_impr$ImprPercent)
} else {
    ImprMean_ABC <- 0
}

ImprMean_avg <- (ImprMean_A*nrow(A_impr) + ImprMean_B*nrow(B_impr)
+ ImprMean_C*nrow(C_impr) + ImprMean_AB*nrow(AB_impr) +
ImprMean_AC*nrow(AC_impr) + ImprMean_BC*nrow(BC_impr) +
ImprMean_ABC*nrow(ABC_impr)) / (nrow(A_impr) + nrow(B_impr) +
nrow(C_impr) + nrow(AB_impr) + nrow(AC_impr) + nrow(BC_impr) +
nrow(ABC_impr))

cell1 <- nrow(total_data0)
cell2 <- "100"
cell3 <- nrow(total_data_unq)
cell4 <- nrow(total_data_unq)/nrow(total_data0)*100
cell5 <- nrow(total_data_grouped_2)
cell6 <- nrow(total_data_grouped_2)/nrow(total_data_unq)*100
cell7 <- nrow(data_elg)
cell8 <- nrow(data_elg)/nrow(total_data_grouped_2)*100
cell9 <-
nrow(merge_A)+nrow(merge_B)+nrow(merge_C)+nrow(merge_AB)+nrow(me
rge_AC)+nrow(merge_BC)+nrow(merge_ABC)
cell10 <-
(nrow(merge_A)+nrow(merge_B)+nrow(merge_C)+nrow(merge_AB)+nrow(m
erge_AC)+nrow(merge_BC)+nrow(merge_ABC)) / nrow(data_elg) * 100
cell11 <- "-"
cell12 <- ImprMean_avg

output_table3 <-
matrix(c(cell1,cell2,cell3,cell4,cell5,cell6,cell7,cell8,cell9,cell10,cell11,cell12),n
col=2,byrow=TRUE)
colnames(output_table3) <- c("Value","Percentage")
rownames(output_table3) <- c("Declarations in total","Unique declarations
(out of total)","Unique decl. made more than once per building (out of
unique)","Unique decl. made more than once and being eligible for analysis
```

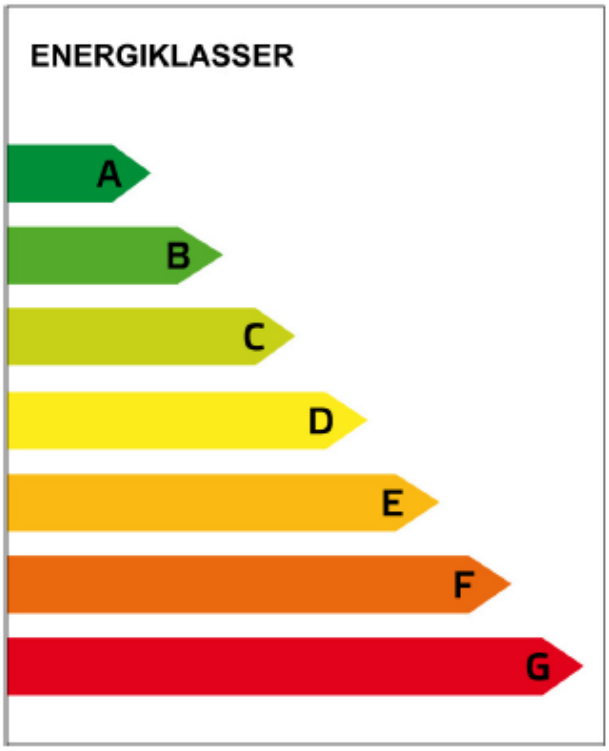
```
(out of unique that made more than one)","Buildings that followed any advice (out of all eligible)","Avarage improvement among those buildings that followed any advice")
output_table3 <- as.table(output_table3)
write.csv(output_table3, file = "data_output/output_table3.csv")
write.table(output_table3, file = "data_output/output_table3.txt", sep="\t")

cell1_1 <- nrow(AY)
cell1_2 <- nrow(AY)/nrow(data_elg)*100
cell1_3 <- nrow(BY)
cell1_4 <- nrow(BY)/nrow(data_elg)*100
cell1_5 <- nrow(CY)
cell1_6 <- nrow(CY)/nrow(data_elg)*100
cell1_7 <- nrow(ABY)
cell1_8 <- nrow(ABY)/nrow(data_elg)*100
cell1_9 <- nrow(ACY)
cell1_10 <- nrow(ACY)/nrow(data_elg)*100
cell1_11 <- nrow(BCY)
cell1_12 <- nrow(BCY)/nrow(data_elg)*100
cell1_13 <- nrow(ABCY)
cell1_14 <- nrow(ABCY)/nrow(data_elg)*100

cell2_1 <- nrow(merge_A)
cell2_2 <- nrow(merge_A)/nrow(AY)*100
cell2_3 <- nrow(merge_B)
cell2_4 <- nrow(merge_B)/nrow(BY)*100
cell2_5 <- nrow(merge_C)
cell2_6 <- nrow(merge_C)/nrow(CY)*100
cell2_7 <- nrow(merge_AB)
cell2_8 <- nrow(merge_AB)/nrow(ABY)*100
cell2_9 <- nrow(merge_AC)
cell2_10 <- nrow(merge_AC)/nrow(ACY)*100
cell2_11 <- nrow(merge_BC)
cell2_12 <- nrow(merge_BC)/nrow(BCY)*100
cell2_13 <- nrow(merge_ABC)
cell2_14 <- nrow(merge_ABC)/nrow(ABCY)*100

cell3_1 <- nrow(A_impr)
cell3_2 <- nrow(A_impr)/nrow(merge_A)*100
cell3_3 <- nrow(B_impr)
cell3_4 <- nrow(B_impr)/nrow(merge_B)*100
cell3_5 <- nrow(C_impr)
cell3_6 <- nrow(C_impr)/nrow(merge_C)*100
cell3_7 <- nrow(AB_impr)
cell3_8 <- nrow(AB_impr)/nrow(merge_AB)*100
cell3_9 <- nrow(AC_impr)
cell3_10 <- nrow(AC_impr)/nrow(merge_AC)*100
cell3_11 <- nrow(BC_impr)
cell3_12 <- nrow(BC_impr)/nrow(merge_BC)*100
cell3_13 <- nrow(ABC_impr)
cell3_14 <- nrow(ABC_impr)/nrow(merge_ABC)*100

cell4_1 <- "-"
cell4_2 <- ImprMean_A
cell4_3 <- "-"
cell4_4 <- ImprMean_B
cell4_5 <- "-"
cell4_6 <- ImprMean_C
cell4_7 <- "-"
cell4_8 <- ImprMean_AB
cell4_9 <- "-"
cell4_10 <- ImprMean_AC
cell4_11 <- "-"
cell4_12 <- ImprMean_BC
cell4_13 <- "-"
cell4_14 <- ImprMean_ABC

output_table4 <-
matrix(c(cell1_1,cell1_2,cell1_3,cell1_4,cell1_5,cell1_6,cell1_7,cell1_8,cell1_9,cell1_10,cell1_11,cell1_12,cell1_13,cell1_14,cell2_1,cell2_2,cell2_3,cell2_4,cell2_5,cell2_6,cell2_7,cell2_8,cell2_9,cell2_10,cell2_11,cell2_12,cell2_13,cell2_14,cell3_1,cell3_2,cell3_3,cell3_4,cell3_5,cell3_6,cell3_7,cell3_8,cell3_9,cell3_10,cell3_11,cell3_12,cell3_13,cell3_14,cell4_1,cell4_2,cell4_3,cell4_4,cell4_5,cell4_6,cell4_7,cell4_8,cell4_9,cell4_10,cell4_11,cell4_12,cell4_13,cell4_14),ncol=14,byrow=TRUE)
colnames(output_table4) <- c("A","A %","B","B %","C","C %","AB","AB %","AC","AC %","BC","BC %","ABC","ABC %")
rownames(output_table4) <- c("How many uniq. builings were recommended to improve any of recommendations or their combinations","How many uniq. building actually followed a particular advice","How many of the ones that followed advises, also improved their energy performance","How much, on avarage, did a particular advise contributed to energy performance improvement")
output_table4 <- as.table(output_table4)
write.csv(output_table4, file = "data_output/output_table4.csv")
write.table(output_table4, file = "data_output/output_table4.txt", sep="\t")
```

Appendix C. Energy declaration version 2.4 (Provided by Boverket dec 2018).

sammanfattning av

ENERGIDEKLARATION

Nybyggnadsår:
Energideklarations-ID: 0



DENNA BYGGNADS
ENERGIKLASS

Energiprestanda:

Krav vid uppförande av ny byggnad [mars 2015]:

Uppvärmningssystem:

Radonmätning:

Ventilationskontroll (OVK):

Åtgärdsförslag:

Energideklarationen i sin helhet finns hos byggnadens ägare.

Energideklarationen är utförd av:

För mer information:
www.boverket.se/energideklaration

Energideklarationen är giltig till:

Sammanfattningen är upprättad enligt Boverkets föreskrifter och allmänna råd (2007:4) om energideklaration för byggnader.

Boverket

Energideklaration

Version: 2.4
Dekl.id: 0

Byggnaden - Identifikation

Län	Kommun	O.B.S! Småhus i bostadsrätt ska deklareras av bostadsrättsföreningen. ☑ Egna hem (privatägda småhus)
Fastighetsbeteckning (anges utan kommunnamn)		Egen beteckning

Husnummer	Prefix byggnadsid	Byggnadsid	Orsak till avvikelse Adressuppgifter är fel/saknas ○

Adress	Postnummer	Postort	Huvudadress ○

Byggnaden - Egenskaper

Typkod	Byggnadskategori

Byggnadens komplexitet ○ Enkel ○ Komplex	Byggnadstyp	Nybyggnadsår

Atemp mätt värde (exkl. Avarmgarage) m²

Finns installerad eleffekt >10 W/m² för uppvärmning och varmvattenproduktion
○ Ja ○ Nej

Är byggnaden skyddad som byggnadsminne?
○ Nej
○ Ja enligt 3 kap KML
○ Ja enligt SBM-förordningen

Är byggnaden en sådan särskilt värdefull byggnad som avses i 8 kap 13 § PBL?
○ Nej
○ Ja, är utpekad i detaljplan eller områdesbestämmelser
○ Ja, är utpekad i annan typ av dokument
○ Ja, egen bedömning

Verksamhet
Fördela enligt nedan:

	Procent av Atemp (exkl. Avarmgarage)
Bostäder (inkl. biarea, t.ex. trapphus och uppvärmd källare)	
Övrig verksamhet - ange vad	
Summa	0

Energianvändning

Verklig förbrukning
Vilken 12-månadsperiod avser energiuppgifterna? (ange första månaden i formatet ÅÅMM)

-

Beräknad förbrukning
Beräknad energianvändning anges för nybyggda/andra byggnader utan mätbar förbrukning och normalårskorrigeras ej

Hur mycket energi har använts för värme och komfortkyla angivet år (ange mätt värde om möjligt)?
Angivna värden ska inte vara normalårskorrigerade

			Mätt värde	Fördelat värde
Fjärrvärme (1)		kWh	○	○
Eldningsolja (2)		kWh	○	○
Naturgas, stadsgas (3)		kWh	○	○
Ved (4)		kWh	○	○
Flis/pellets/briketter (5)		kWh	○	○
Övrigt biobränsle (6)		kWh	○	○
El (vattenburen) (7)		kWh	○	○
El (direktverkande) (8)		kWh	○	○
El (luftburen) (9)		kWh	○	○
Markvärmepump (el) (10)		kWh	○	○
Värmepump-frånluft (el) (11)		kWh	○	○
Värmepump-luft/luft (el) (12)		kWh	○	○
Värmepump-luft/vatten (el) (13)		kWh	○	○
Energi för uppvärmning och varmvatten[1] (∑1)	0	kWh		
Varav energi till varmvattenberedning		kWh	○	○
Fjärrkyla (14)		kWh	○	○

Omvandlingsfaktorer för bränslen i tabellen nedan gäller om inte annat uppmätts:

Eldningsolja	10 000 kWh/m³
Naturgas	11 000 kWh/1 000 m³ (effektivt värmevärde)
Stadsgas	4 600 kWh/1 000 m³
Pellets	4 500-5 000 kWh/ton, beroende av träslag och fukthalt

Källa: Energimyndigheten
För övriga biobränsle varierar värmevärdet beroende av sammansättning och fukthalt. Det är expertens ansvar att omräkna bränslets vikt eller volym till energi på ett korrekt sätt.

Övrig el (ange mätt värde om möjligt)
Angivna värden ska inte vara normalårskorrigerade

			Mätt värde	Fördelat värde
Fastighetsel[2] (16)		kWh	○	○
Hushållsel[3] (16)		kWh	○	○
Verksamhetsel[4] (17)		kWh	○	○
El för komfortkyla (18)		kWh	○	○
Tillägg komfortkyla[5] (19)	0	kWh		
Byggnadens energianvändning[6] (∑3)	0	kWh		
Byggnadens elanvändning[7] (∑4)	0	kWh		

Finns solvärme? ○ Ja ○ Nej
Ange solfångararea: m²
Beräknad energiproduktion: kWh/år

Finns solcellsystem? ○ Ja ○ Nej
Ange solcellsarea: m²
Beräknad elproduktion: kWh/år

Ort (Energi-Index)	Normalårskorrigerat värde (Energi-Index)[8]	Energiprestanda	...varav el	Referensvärde 1 (enligt nybyggnadskrav)	Referensvärde 2 (statistiskt intervall)
	kWh	kWh/m² ,år	kWh/m² ,år	kWh/m² ,år	- kWh/m² ,år

[1] Summa 1-13 (∑1)
[2] Den el som ingår i fastighetsenergin
[3] Den el som ingår i hushållsenergin
[4] Den el som ingår i verksamhetsenergin
[5] Beräkning av värdet sker med utgångspunkt i vilket energislag och typ av kylsystem som används (se Boverkets byggregler, BFS 2008:20 och BFS 2011:6)
[6] Enligt definition i Boverkets byggregler (Summa 1-15, 18-19 (∑3))
[7] Den el som ingår i byggnadens energianvändning (Summa 7-13,15,18-19 (∑4))
[8] Underlag för energiprestanda

Uppgifter om ventilationskontroll

Finns det krav på återkommande ventilationskontroll i byggnaden?	◉ Ja	○ Nej			
Typ av ventilationssystem	☐ FTX	☐ FT	☐ F med återvinning		
	☐ F	☐ Självdrag			
Är ventilationskontrollen utförd vid tidpunkten för energideklarationen?	○ Ja	○ Nej	○ Delvis [10]		% utan anmärkning

[10] Avser när byggnaden har fler ventilationsaggregat

Uppgifter om luftkonditioneringssystem

Finns luftkonditioneringssystem med nominell kyleffekt större än 12kW?	○ Ja	○ Nej

Uppgifter om radon

Är radonhalten mätt?	○ Ja	○ Nej	
Radonhalt		Typ av mätning	Datum för radonmätning
	Bq/m3		

Utförda energieffektiviseringsåtgärder sedan föregående energideklaration

Utförd åtgärd (Dekl.id: 0)

Styr- och reglerteknisk	Installationsteknik	Byggnadsteknik
Värme	☐ Varmvattenbesparande åtgärder	☐ Tilläggsisolering vindsbjälklag/tak
☐ Nya radiatorventiler	☐ Energieffektiv belysning	☐ Tilläggsisolering väggar
☐ Injustering av värmesystem	☐ Isolering av rör och ventilationskanaler	☐ Tilläggsisolering källare/mark
☐ Tids-/behovsstyrning av värmesystem	☐ Byte/installation av värmepump	☐ Byte till energieffektiva fönster/fönsterdörrar
☐ Rengöring och/eller luftning av värmesystem	☐ Byte/installation av energieffektivare värmekälla	☐ Komplettering fönster/fönsterdörrar med innerruta
☐ Maxbegränsning av innetemperatur	☐ Byte/komplettering av ventilationssystem	☐ Tätning fönster/fönsterdörrar/ytterdörrar
☐ Ny inomhusgivare	☐ Återvinning av ventilationsvärme	☐ Annan åtgärd
☐ Byte/installation av tryckstyrda pumpar	☐ Installation av solvärme	
☐ Annan åtgärd	☐ Installation av solceller	
Ventilation	☐ Annan åtgärd	
☐ Injustering av ventilationssystem		
☐ Tidsstyrning av ventilationssystem		
☐ Behovsstyrning av ventilationssystem		
☐ Byte/installation av varvtalsstyrda fläktar		
☐ Annan åtgärd		
Belysning, kylning m.m.		
☐ Tids-/behovsstyrning av belysning		
☐ Tids-/behovsstyrning av kyla		
☐ Annan åtgärd		

Utfört år
Beskrivning av åtgärden

Rekommendationer om kostnadseffektiva åtgärder

Åtgärdsförslag (Dekl.id: 0)

Styr- och reglerteknisk	Installationsteknik	Byggnadsteknik
Värme ☐ Nya radiatorventiler ☐ Injustering av värmesystem ☐ Tids-/behovsstyrning av värmesystem ☐ Rengöring och/eller luftning av värmesystem ☐ Maxbegränsning av innetemperatur ☐ Ny inomhusgivare ☐ Byte/installation av tryckstyrda pumpar ☐ Annan åtgärd **Ventilation** ☐ Injustering av ventilationssystem ☐ Tidsstyrning av ventilationssystem ☐ Behovsstyrning av ventilationssystem ☐ Byte/installation av varvtalsstyrda fläktar ☐ Annan åtgärd **Belysning, kylning m.m.** ☐ Tids-/behovsstyrning av belysning ☐ Tids-/behovsstyrning av kyla ☐ Annan åtgärd	☐ Varmvattenbesparande åtgärder ☐ Energieffektiv belysning ☐ Isolering av rör och ventilationskanaler ☐ Byte/installation av värmepump ☐ Byte/installation av energieffektivare värmekälla ☐ Byte/komplettering av ventilationssystem ☐ Återvinning av ventilationsvärme ☐ Installation av solvärme ☐ Installation av solceller ☐ Annan åtgärd	☐ Tilläggsisolering vindsbjälklag/tak ☐ Tilläggsisolering väggar ☐ Tilläggsisolering källare/mark ☐ Byte till energieffektiva fönster/fönsterdörrar ☐ Komplettering fönster/fönsterdörrar med innerruta ☐ Tätning fönster/fönsterdörrar/ytterdörrar ☐ Annan åtgärd

Minskad energianvändning	Kostnad per sparad kWh
kWh/år	kWh/år

Beskrivning av åtgärden

Övrigt

Har byggnaden deklarerats tidigare? ◯ Ja ◯ Nej	
Har byggnaden besiktigats på plats? ◯ Ja ◯ Nej	Vid nej, vilket undantag åberopas Kommentar

Expert

Förnamn	Efternamn	
Datum för godkännande	E-postadress	
Certifikatnummer	Certifieringsorgan	Behörighetsnivå
Företag		