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EuropeAid/139044/ID/ACT/TR

Reference: CFCU/TR2014/DG/04/A1-04

Activity 1.2.

Report on Energy Consumption Indicators and Energy Efficiency Potential Analysis

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Report on Energy Consumption Indicators and Energy Efficiency Potential Analysis

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This report is prepared by Energy Planning and Management Division of Energy Institute in Istanbul Technical University via ITU NOVA Technology Transfer Office under the project titled “Strengthening Communication and Data Sharing Network among Energy Efficiency Stakeholders” (EuropeAid/139044/ID/ACT/TR and Reference: CFCU/TR2014/DG/04/A1-04) conducted by Energy Efficiency and Management Association (EYODER).

REPORT ON ENERGY CONSUMPTION INDICATORS AND ENERGY EFFICIENCY POTENTIAL ANALYSIS

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1. INTRODUCTION

This report is prepared for Activity 1.2 of the project titled "Strengthening Communication and Data Sharing Network among Energy Efficiency Stakeholders" (EuropeAid/139044/ID/ACT/TR and Reference: CFCU/TR2014/DG/04/A1-04) conducted by Energy Efficiency and Management Association (EYODER). This activity aims to estimate potential energy savings by performing further analyses on "energy efficiency potentials". The target is to identify the potential energy efficiency opportunities by using energy consumption indicators per industrial sub-sectors and building types and find average values for comparison. The analyses will be based on the production volume and energy consumption data to be entered into an online platform by the stakeholders. Analysis of energy consumption data of the stakeholders would enable them to compare their energy efficiency audits and realized projects with other stakeholders. It would be possible to classify the potential energy efficiency by industrial sub-sectors, building types, etc.

The platform will also open communication and cooperation channels among energy efficiency stakeholders since they will have the opportunity to know each other and be aware of their services. When one stakeholder requires a service for any kind of implementation as a result of this savings analysis, s/he will have a chance to go through the database and identify another registered stakeholder that can offer the required services.

This report contains:

- Energy Efficiency Stakeholders Platform (EESP) Structure
- Analyses Methodology
- Descriptive Analytics of the Database
- Future Recommendations
- Results and Discussion

2. ENERGY EFFICIENCY STAKEHOLDERS' PLATFORM

It is aimed to collect data from EESP to establish a database. The energy efficiency stakeholders are not only energy efficiency consulting (EVD) companies (Turkish ESCOs), but also certified energy managers (EM), industrial enterprises that are obliged for conducting energy audits, civil society organizations (CSO), financial institutions, and suppliers, etc. The data will be compiled in the "Energy Efficiency Stakeholders Database (EESD)". The Database is established by using an online content management system (CMS) and customized in accordance with the needs of the project. The energy efficiency stakeholders are able to create an account and enter their own data into the system, easily. The real persons may enter their data relevant to demographic information, educational background, professional experiences, etc. and legal persons such as their sector, number of employees by their age group, gender and education background, areas of activities, energy savings potential, information on their certificates, energy consumption (based on various energy sources such as gas, electricity, etc.). In addition to these mandatory fields, entering financial data (e.g. turnover) will be optional (It is requested by EYODER from both real and legal persons to enter relevant data on their previous or ongoing energy efficiency audits and projects.)

The database will be following the legislation since EVDs are obliged to ensure the 100% confidentiality of their customer data. These data to be received from the EVDs will be anonymized and transferred to the database.

2.1. Structure of the EESP

A domain (http://www.evp.org.tr) is acquired for the platform. A CMS is installed and customized in accordance to the needs of the project. The language of the platform is Turkish. The platform works in

two different modes. The first mode is stakeholder's mode and second one is data provider's mode. A registration form is utilized to register users into the system. An approval by the administrator is needed in order to start using the platform.

The properties of the "stakeholders'" mode are given below:

- The users are entitled as "stakeholder"
- The users can search and filter projects anonymously
- The users can search and communicate with other stakeholders and data providers
- The users can read the announcements and follow the recent developments
- The users can be contacted easily by other stakeholders and data providers
- The users can easily send messages to EYODER and report a problem

The additional properties of the "data providers'" mode are given below:

- The users are entitled as "data provider"
- The users can add their projects to the EESD
- The users can compare their projects with the other projects in the database
- The users can generate visual reports

The main page is of the platform is same for both modes. The users can see the main figures for the projects on the main page (Figure 1).

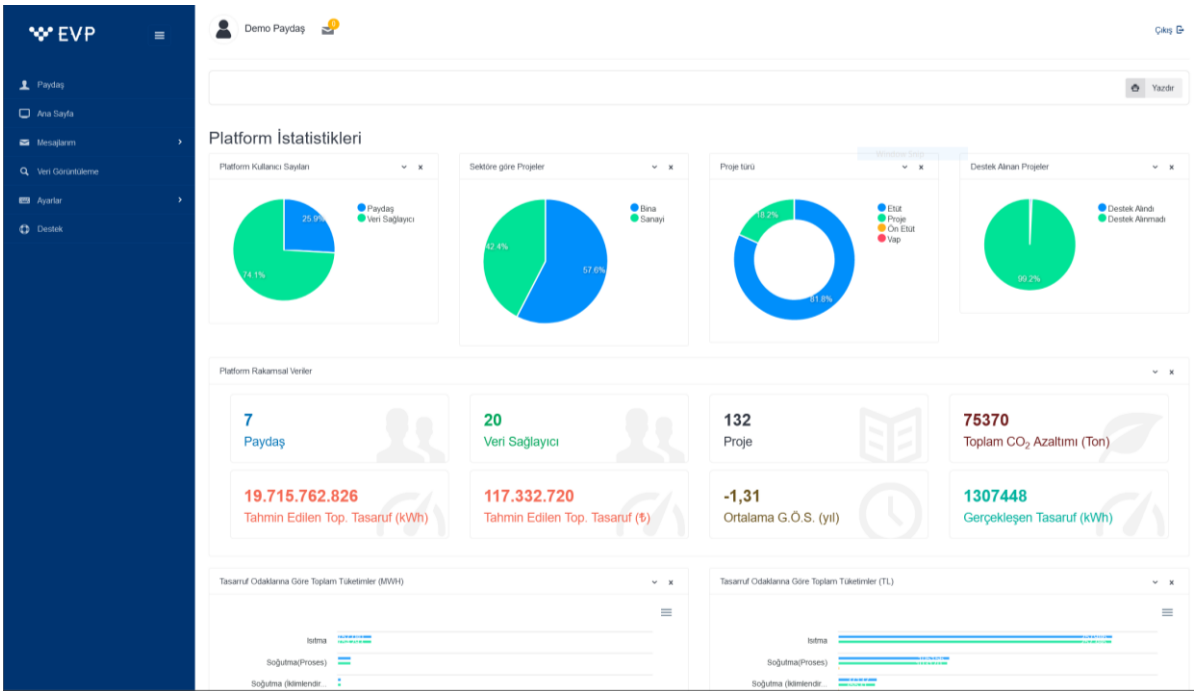

Figure 1. The main page of the EESP

The figures are interactive data visualization tools for users to experience. The users can filter the data categories by clicking on the legend of the figures. Moreover, the figures are configured to show more information by hovering the arrow on the graphical representations.

In order to filter data more accurately, the users can use the "data display" menu (Figure 2).

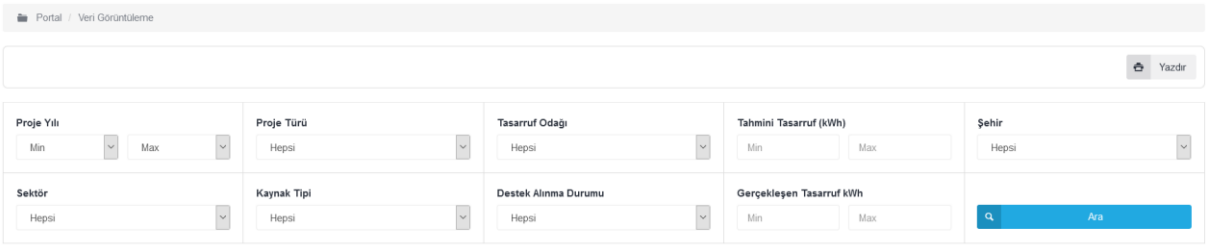

Figure 2. Data display menu

For advanced search, users can use below given categories:

- Project year
- Project type
- Project city
- Energy Efficiency opportunity (potential)
- Estimated savings
- Realized savings
- Sector – Sub sector
- Energy source type
- Financial support

Also, an interactive Turkey map is added in order to see the distribution of the projects by the cities (Figure 3).

Figure 3. Distribution of the projects by the cities

The users can register themselves to the platform as:

- Building audit & project expert
- Industry audit & project expert
- Energy performance certificate expert
- Energy manager
- ISO 50001 consultant
- ISO 50001 auditor

In addition, users can search for other users who have the above-mentioned certificates by name, firm or by specifying the sector (Figure 4).

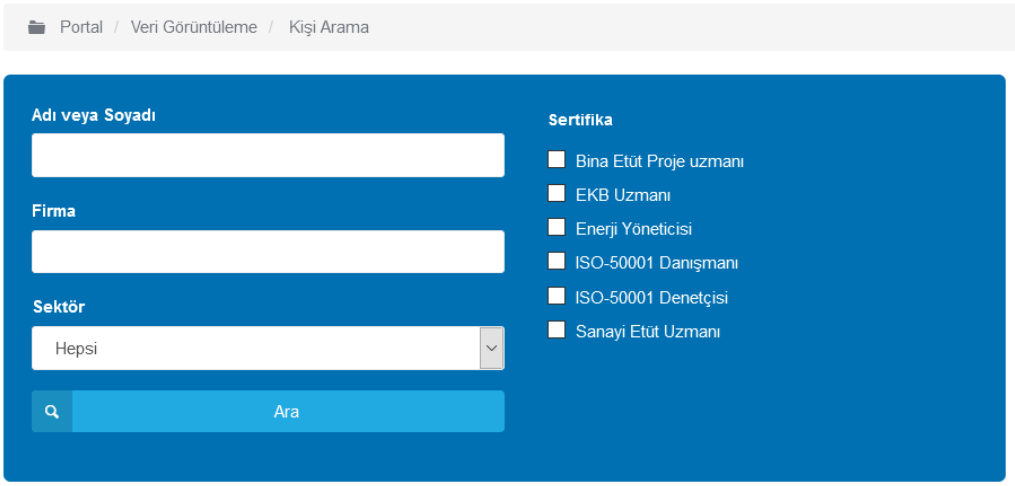

Figure 4. People search interface

The data provider users may enter data through My Projects menu. Also using the same menu, they can export the projects in comma separated values (csv), excel or pdf format. There are two main parts for input project data, project tag and project info part (Figure 5).

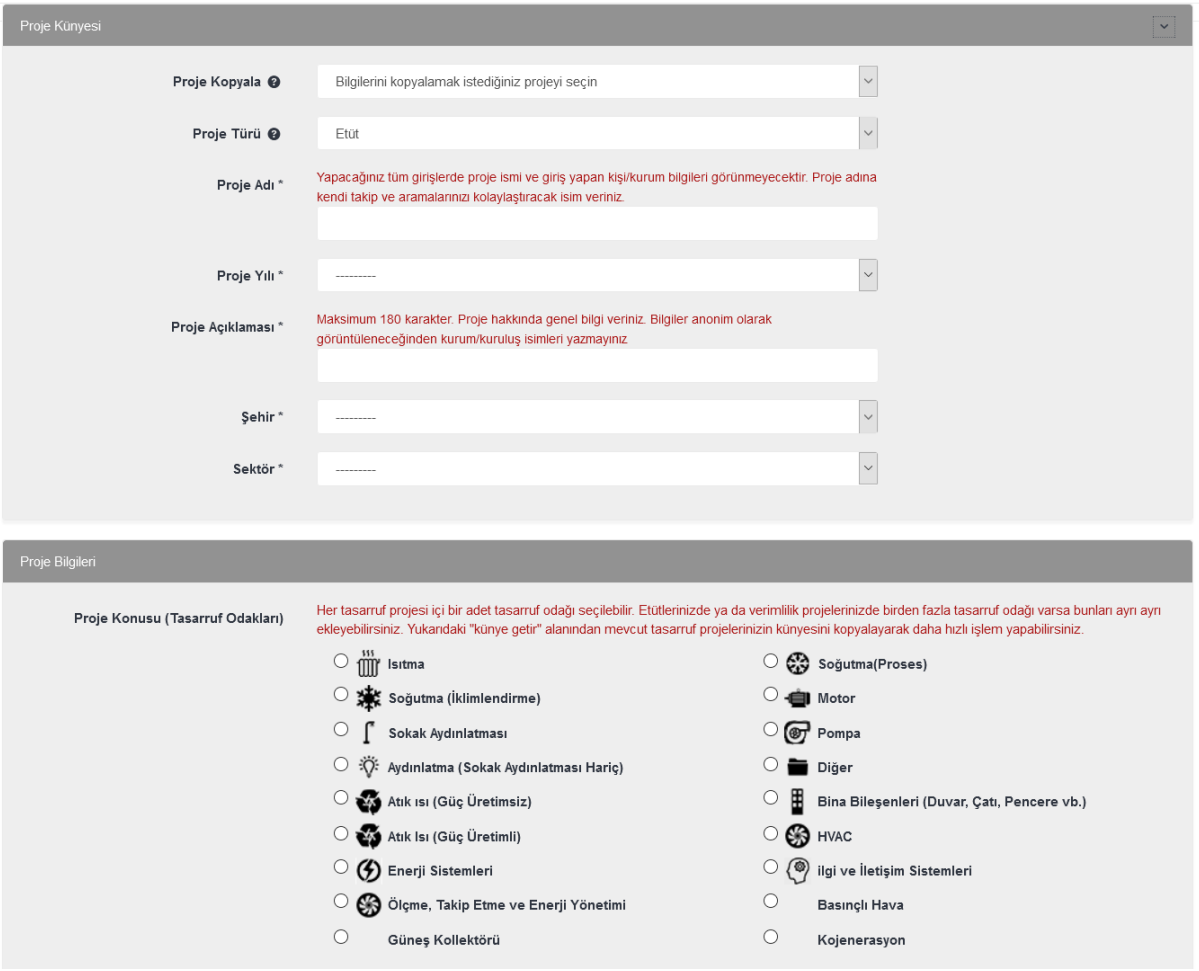

Figure 5. New project data input screen

In the page, user can enter project information as project name, year, city, sector, type etc. For every project some categories are defined for users to select. These categories are:

- Heating
- Cooling (HVAC)
- Street lighting
- Lighting (excluding street lighting)
- Waste heat recovery without power generation
- Waste heat recovery with power generation
- Energy systems
- Measurement, monitoring and energy management
- Solar thermal collectors
- Cooling (process)
- Motors
- Pumps
- Building elements (Walls, roof, windows etc.)
- HVAC
- Compressed air
- Cogeneration
- IT Systems

Then the users need to enter the project type, year of the project, city, sector, subsector, energy source type, energy consumption values before the audit/project, estimated energy consumption values (after the audit/project) and realized energy consumption values (if the project is applied) and initial cost. Also, estimated annual energy reduction, estimated payback time, estimated CO_2 reduction (depending on the energy source) is also calculated automatically from the input (Figure 6).

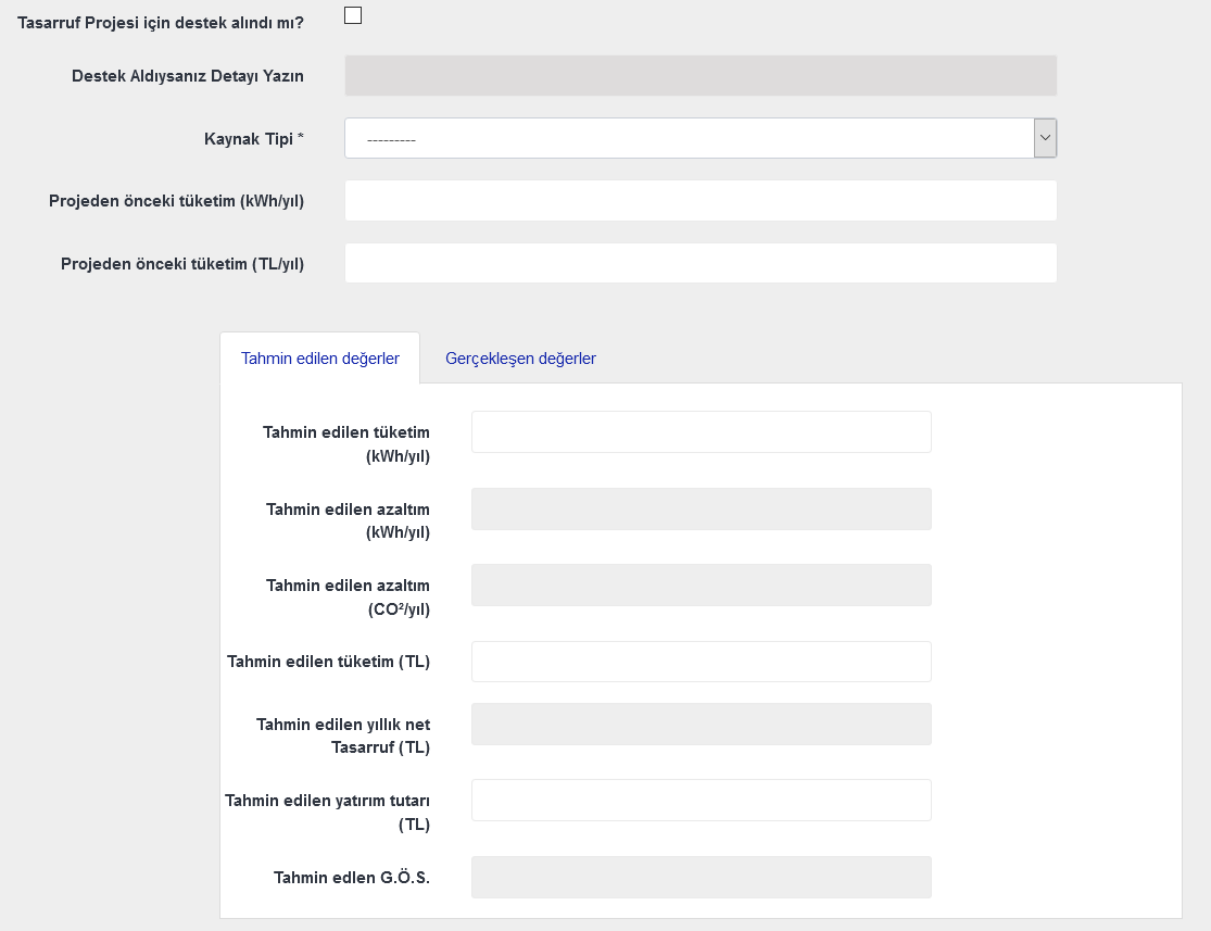

Figure 6. New project input screen

Moreover, in order to simplify data input, users can copy their projects and use the old project as a template and change the values of the project to create a new one.

In the next section collected data that the stakeholders entered to the portal in the scope of the project is analysed.

3. DATA ANALYTICS

In this section, the csv file containing the user generated project information from the database is analysed. The file contains 147 rows of project data that users submitted to the platform during January 2020 (Appendix-1). R statistical programming language is used to analyse the data. R is a free software for statistical computing and graphics. In addition to R language, a free programming interface for R, R Studio, is utilized.

3.1. Methodology

In this part the methodology used to analyse data is elaborated. The online platform facilitates the data input process. Periodically the data control and correction process can be done by the platform admin. Firstly the data is exported to a csv file using the admin panel of the platform. The csv files can be opened used text editors, excel or other software.

First step in the data analysis is exploring the raw data, the csv file. The data file should be imported into the data analysis software. The exploration of the raw data consists of below given steps:

- Understanding the structure of the data
- Describing the data
- Visualizing the data

There are various functions in the R to help to explore the raw data. Ggplot2 and dplyR packages are used to analyse the data. The data consists of several categorical (city, project type etc.) and numerical (reduction, year etc.) variables. The data is converted into appropriate variables with appropriate variable types. Then the data is checked for outliers and missing values. In order to do that, descriptive statistical analyses are done. Outliers can be defined as extreme values distant from the other values. Measurement errors, experimental error or data entry error may lead to outliers in a data set. Missing values are just empty cells. Lack of information or data entry error may also lead to missing values. Using descriptive statistics like mode, median, mean etc. the distribution of the variables are analysed. Also, visual tools like histograms, boxplots and bar graphs are used to understand the distribution of the data and outliers in the data set.

In order to count and summarize every variable in the data set, histograms and bar plots are used. Histograms are used for continuous data whereas bar plots are used for categorical data. For a deeper analysis, the data is decomposed into categories. Firstly, the realized projects are analysed, then the audits.

For every project type (realized or audit), first the data is decomposed into sectors, then into subsectors. For every subsector the amount of energy efficiency potential and payback time is analysed and means are given. Since the data does not cover the all subsectors, only available data is used to summarize the data.

Energy efficiency potential and the payback time of the investment can be considered as a “performance indicator” for the projects. So, the mean energy efficiency potential, reduction in energy consumption and payback times are given for every type of project. It is aimed to find average numbers for energy efficiency potential and payback times for every sector and subsector.

3.2. Analysing Overall Data

The project type could be selected as audit or energy efficiency project. It can be seen from Figure 7 that around 83.7% of the projects are audit projects.

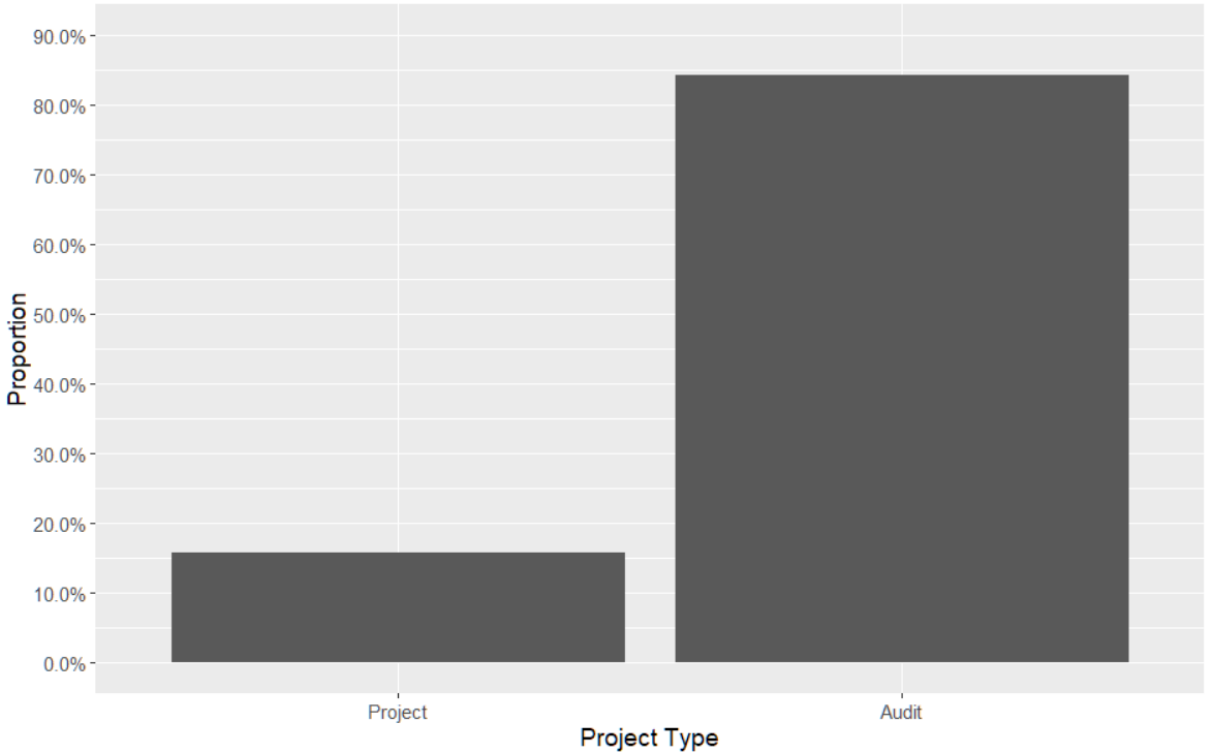

Figure 7. Proportion of the project types

The distribution for the year that projects belong to is given in Figure 8. The oldest project in the database is in 2015 while the newest projects are in 2019 as can be seen from the figure.

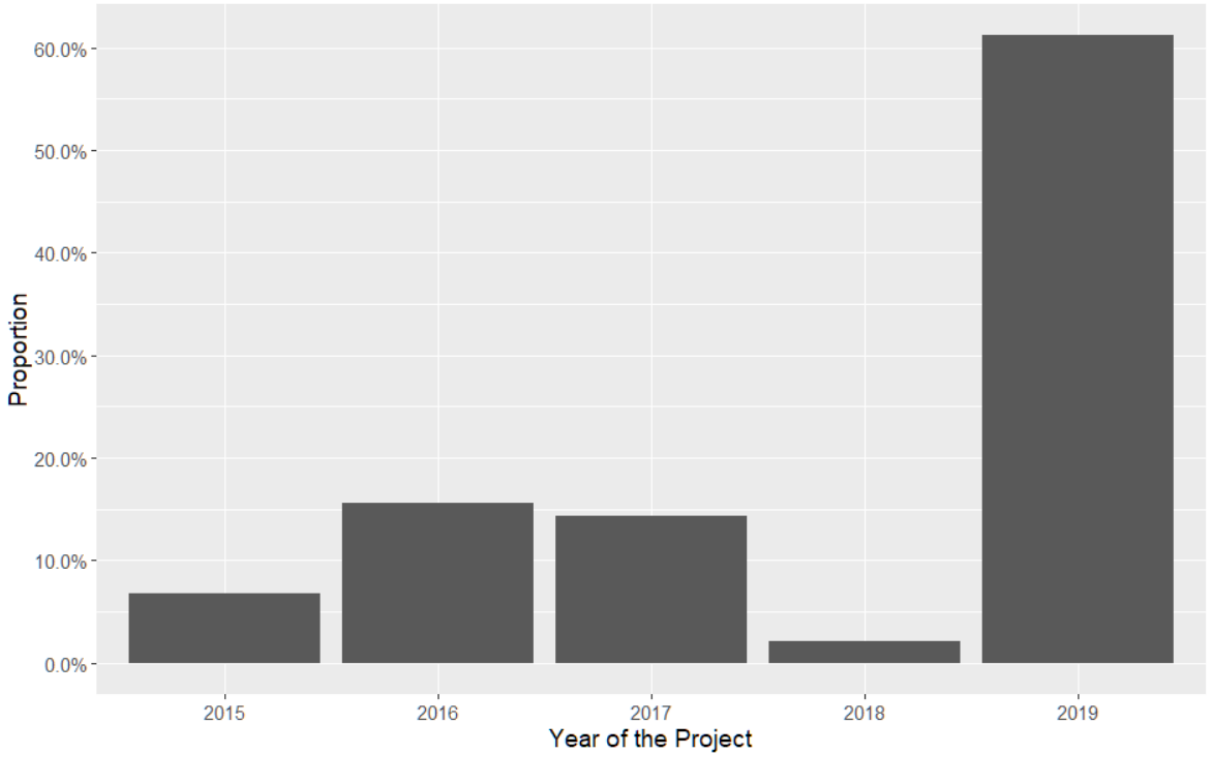

Figure 8. Year of the projects

The geographical distribution of the projects is given in Figure 9. More than half of the projects are in Istanbul (70) then Sakarya (12) and Ankara (11), respectively.

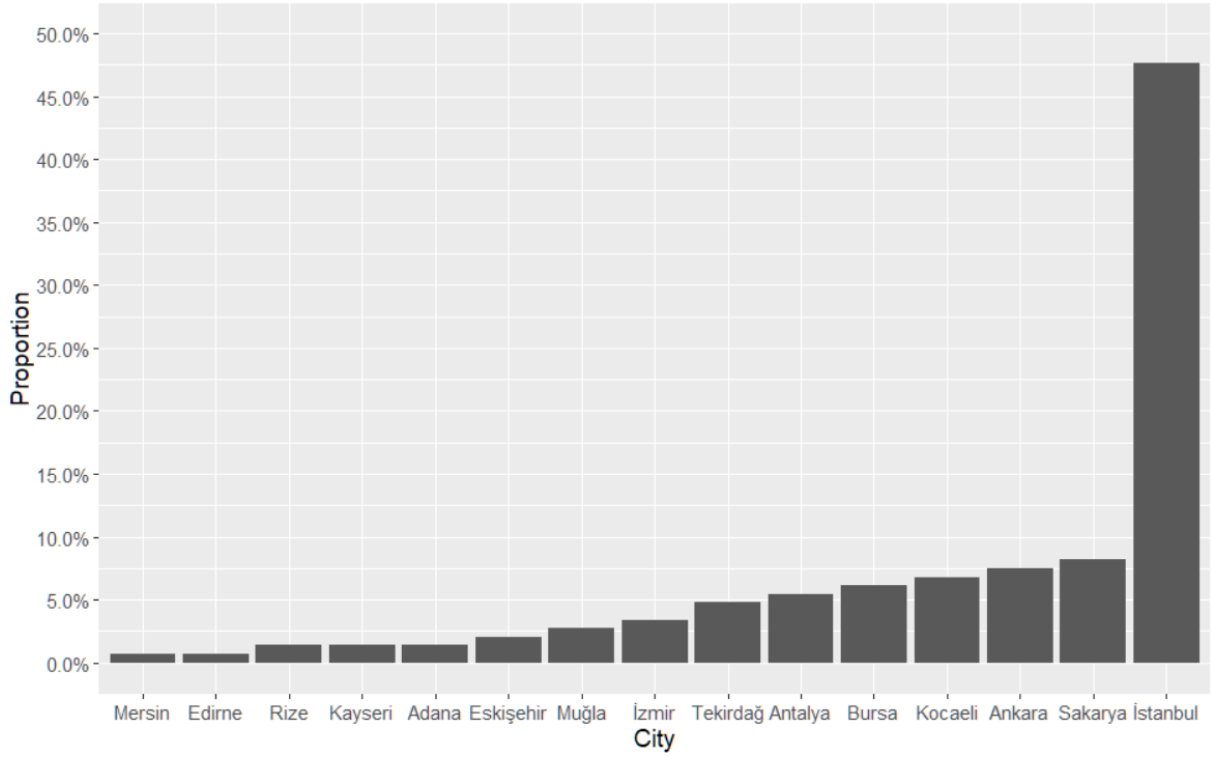

Figure 9. Distribution of the geographical location of the project

There are two main categories for the sector: industry and buildings. 42.9% of the projects are for industry and 57.1% of the projects are for buildings sector (Figure 10).

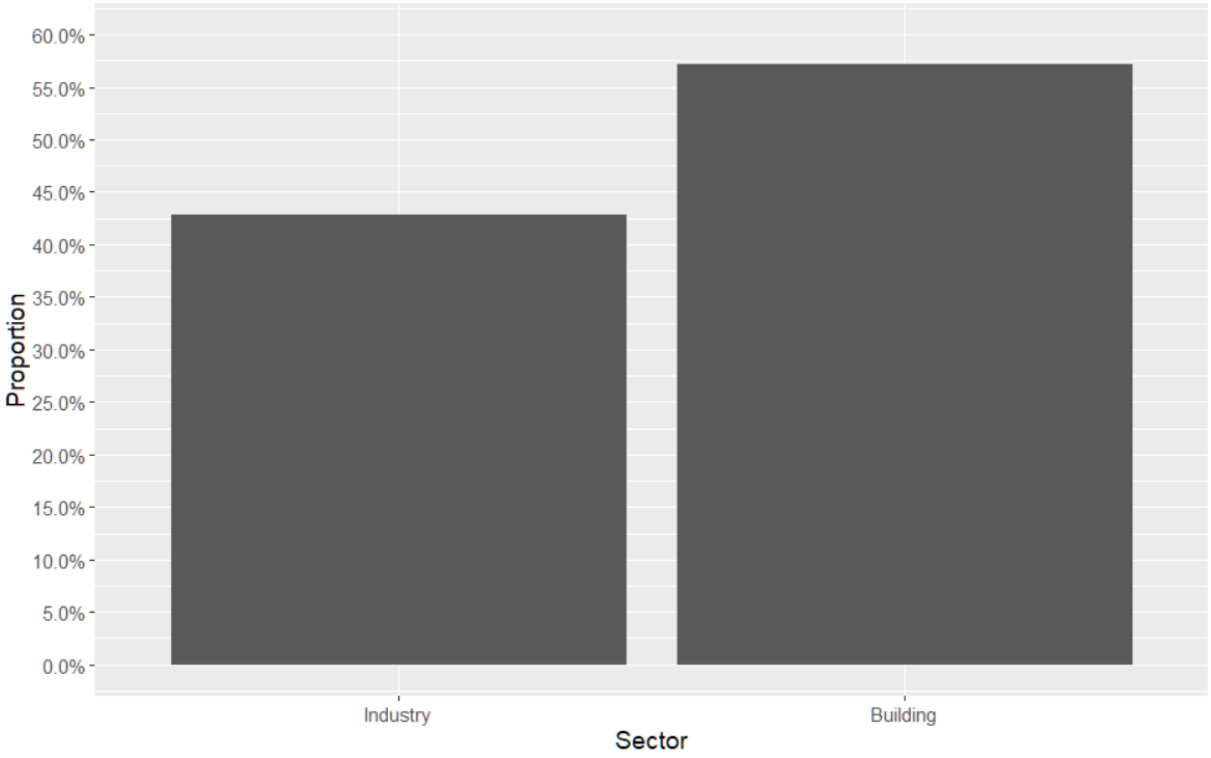

Figure 10. Distribution of the main sectors

When subsectors are analysed and coloured according to main sectors, it can be seen that most projects are in Educational Buildings (Figure 11).

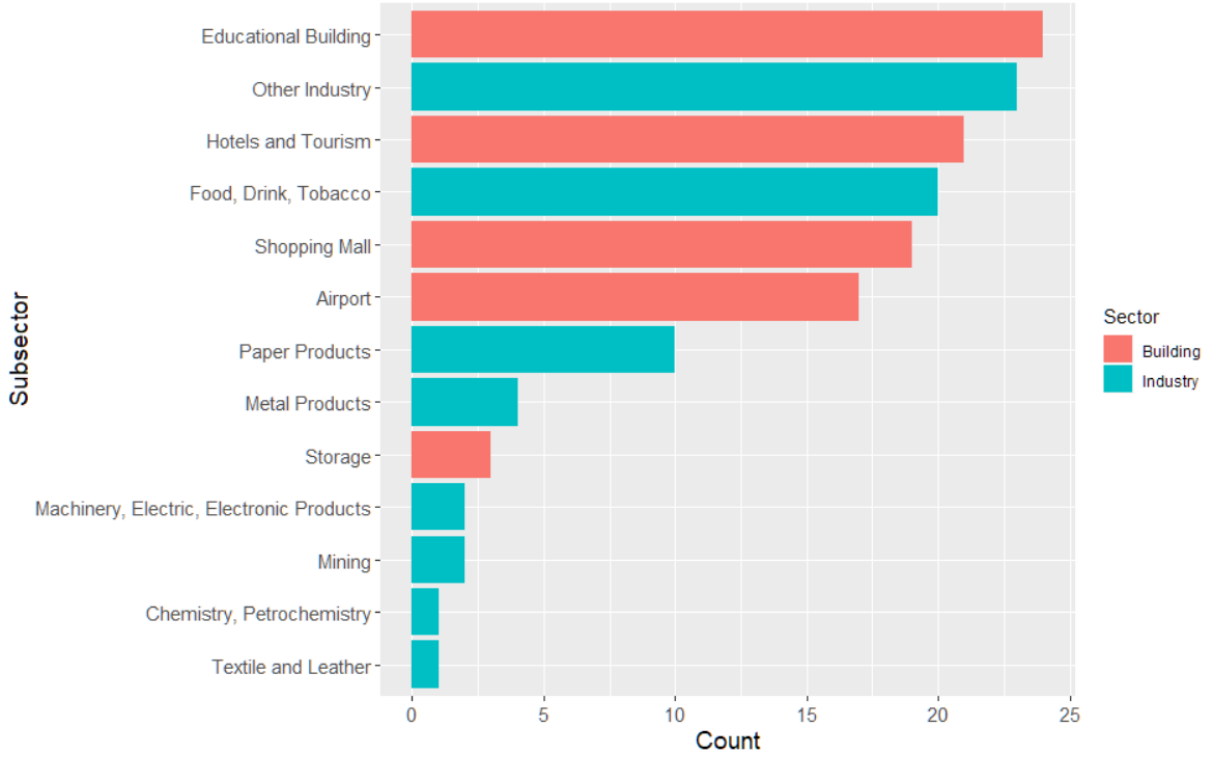

Figure 11. Distribution of the subsectors according to main sectors

And the main application types are given in Figure 12 coloured for main sectors.

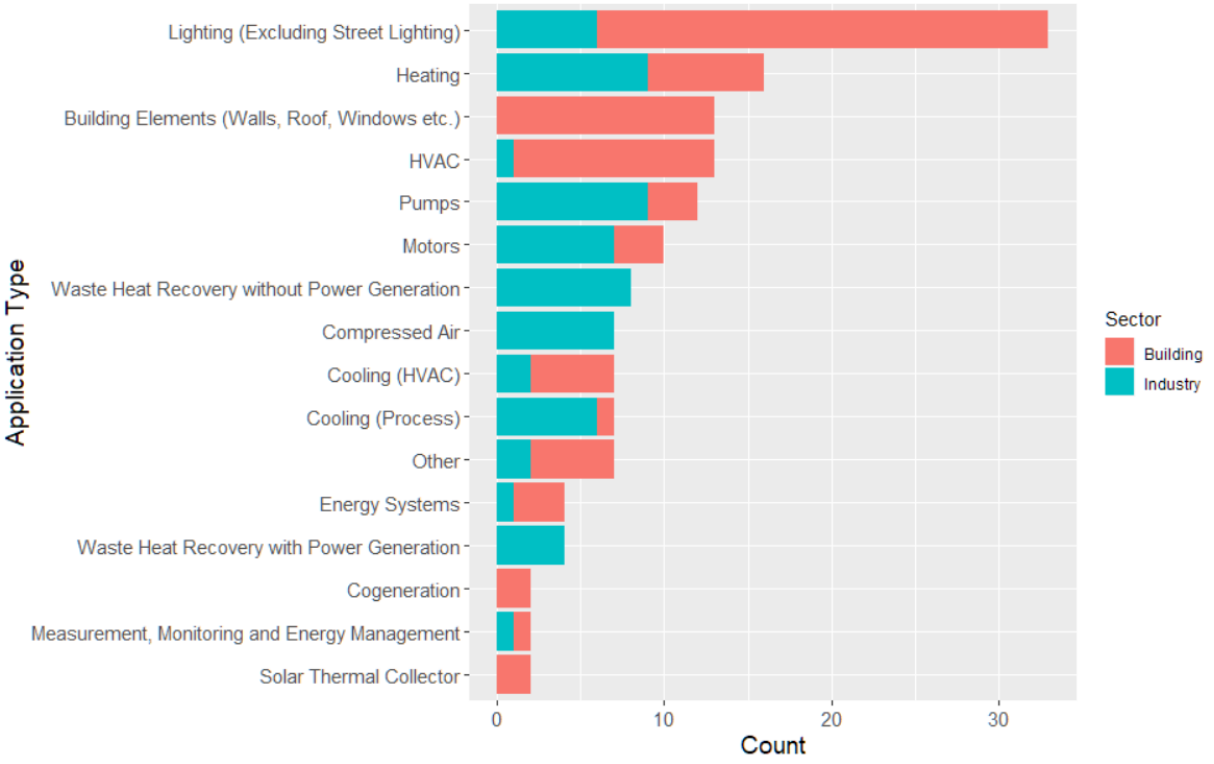

Figure 12. Distribution of the applications according to main sectors

When the energy source type is checked. It can be said that the distribution between electrical energy and natural gas is balanced between sectors as seen in Figure 13. The main source is electrical energy for 100 projects.

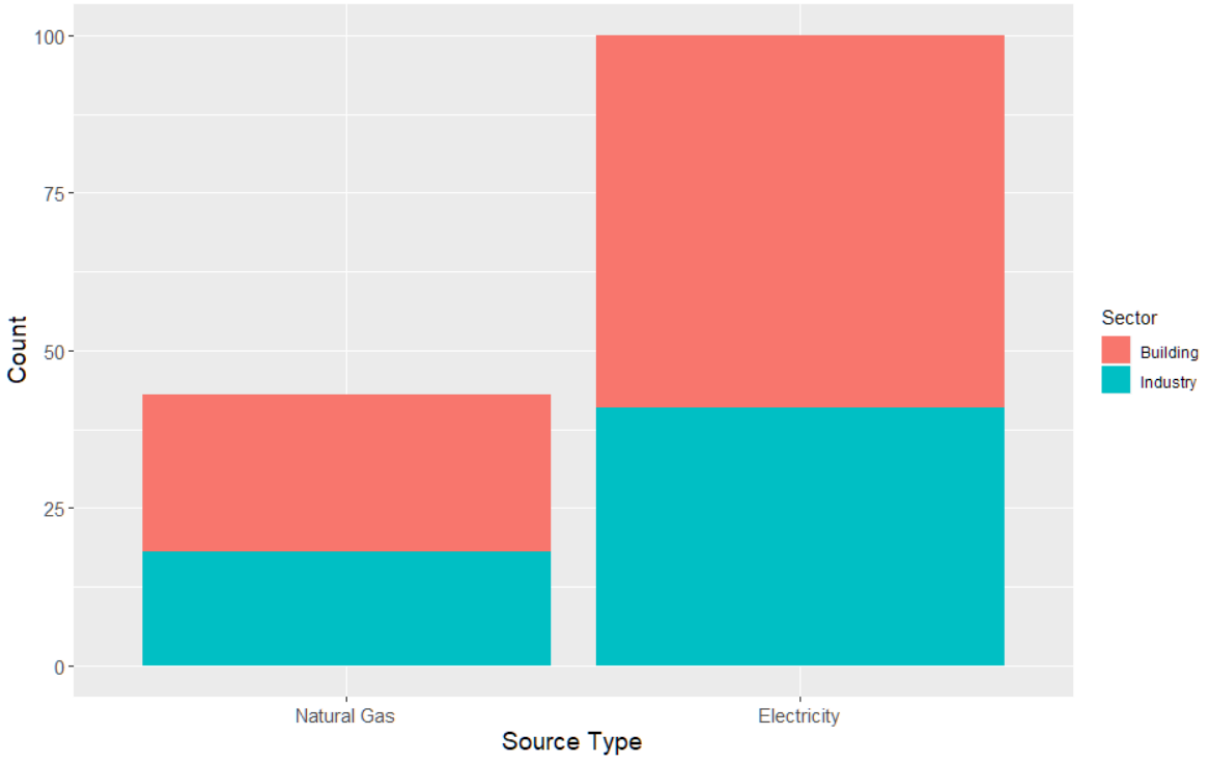

Figure 13. Distribution of the source type according to main sectors

3.3. Analysing Realized Project Data

First project results, then audit results will be given. There are total of 24 projects that users entered into database as "realized" projects. When the data is analysed it can be seen that all the projects are school projects belonging to 12 educational buildings. The projects categorized as improving lighting systems and buildings elements of the schools. The average annual energy consumption for these projects are 131 404 kWh/year with a maximum of 422 482 kWh/year and a minimum of 14 075 kWh/year. The estimated maximum energy consumption reduction is 51.7% and minimum reduction is 16.9%. The distribution of the reduction is given in Figure 14 and it can be seen that it is close to a normal distribution with a mean of 32.5% reduction and with a standard deviation of 8%.

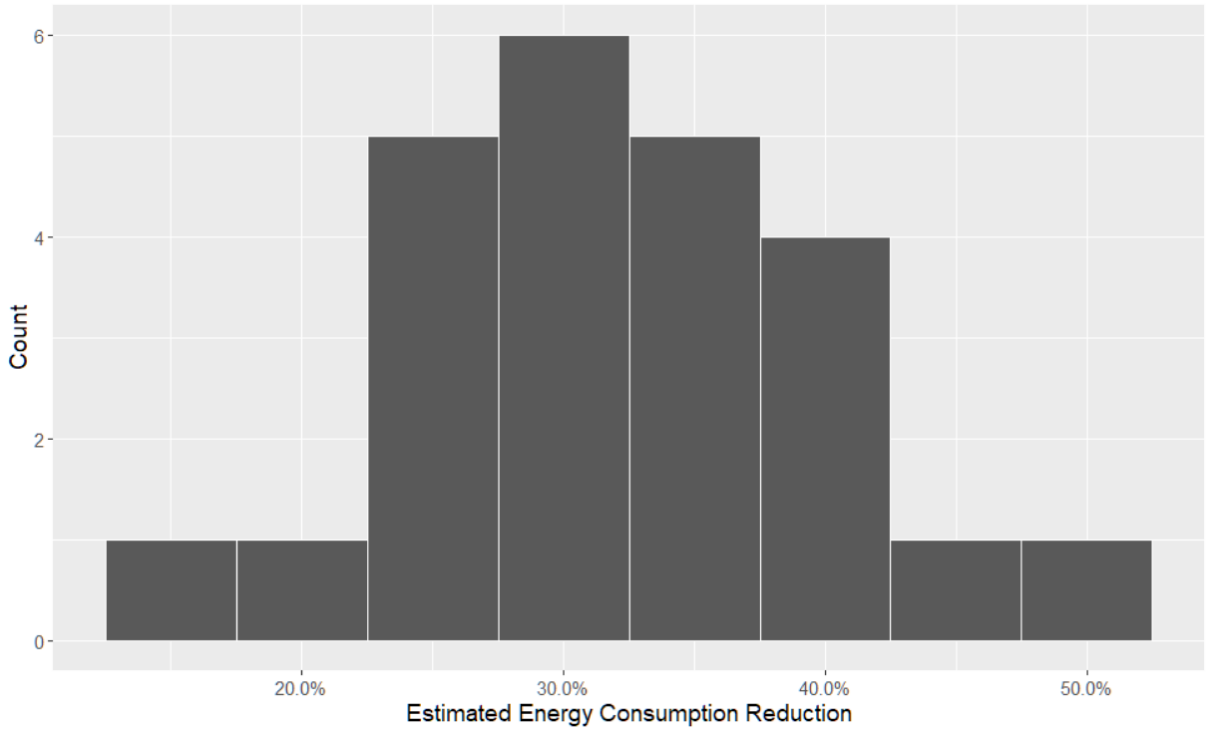

Figure 14. Distribution of the energy consumption reduction for school projects

Moreover, if the energy efficiency potentials are decomposed by the application categories it can be calculated that for the building elements improvement an average of 34% energy consumption reduction is estimated and for the lighting systems 31.1% reduction are estimated. Figure 15 shows the distribution of the reduction by application category.

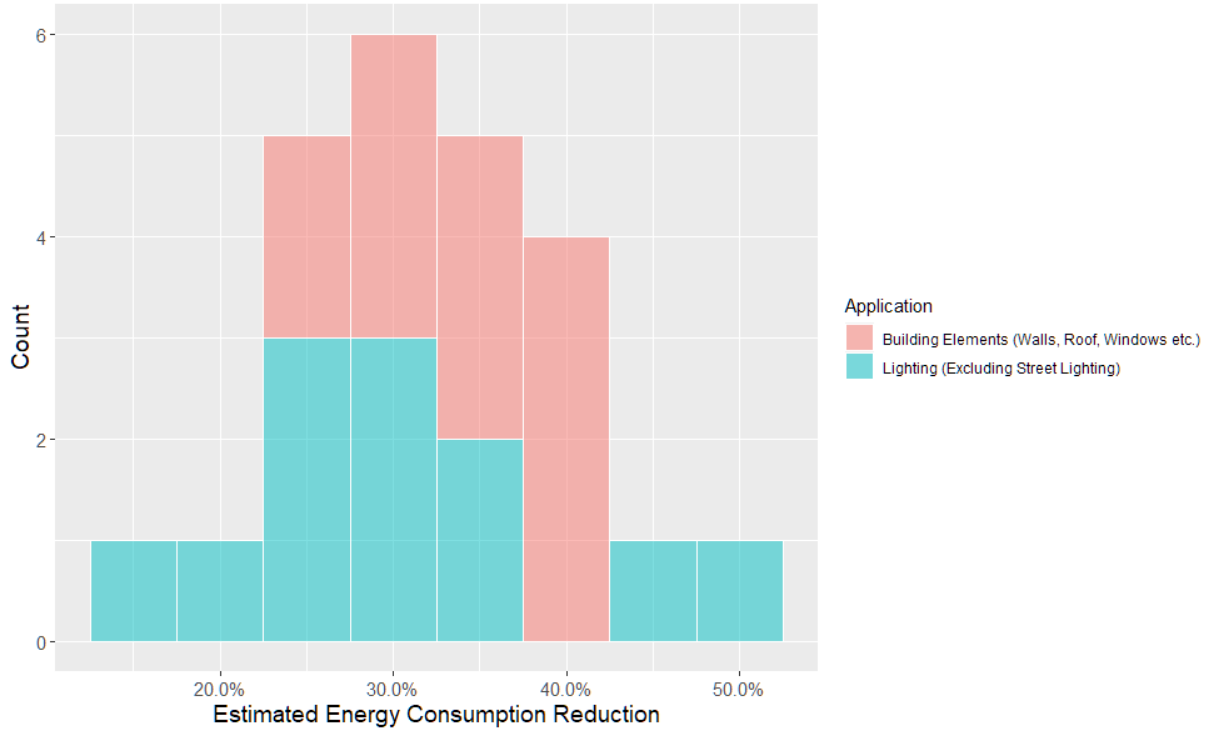

Figure 15. Distribution of the estimated energy consumption reduction for school projects by application categories

If the annual estimated annual savings in TL/year is analyzed, it can be seen that an average of 6289 TL/year savings is foreseen with a minimum of 1 486 TL/year and a maximum of 18 358 TL/year. The data is decomposed into the application category, the calculated value for average estimated savings for building elements is 7 903 TL/year while the value for lighting projects is 4 675 TL/year. It can be said that improving building elements results in more savings.

The realized data is also available in the database for 12 schools. When the difference between the real and estimated annual energy consumption reduction in kWh/year is compared, the distribution can be seen in Figure 16.

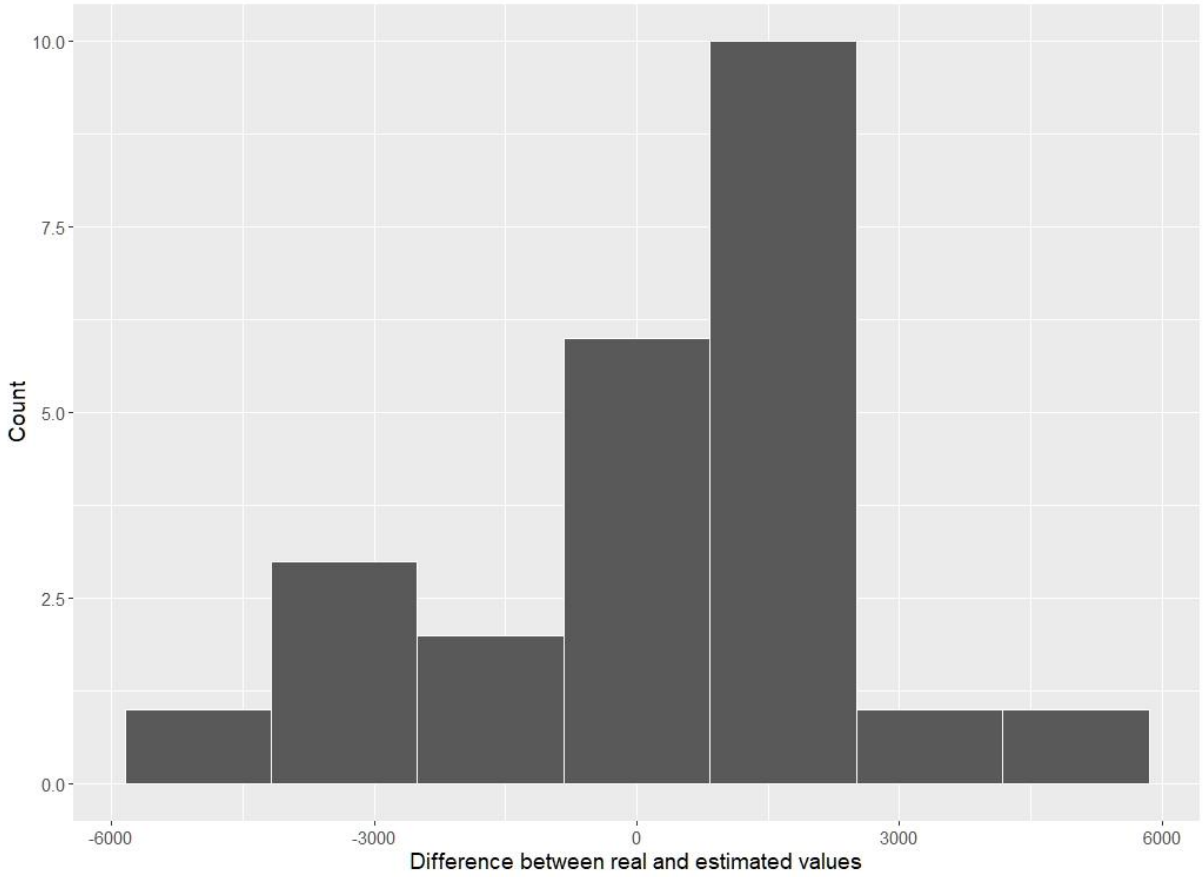

Figure 16. Distribution of the difference between real and estimated values [kWh/Year]

If the difference between the estimated and real energy consumption reduction are decomposed into the categories, it can be concluded that the estimation in lighting systems has less error than the estimations in the building elements. Figure 17 shows the difference between the real and estimated values.

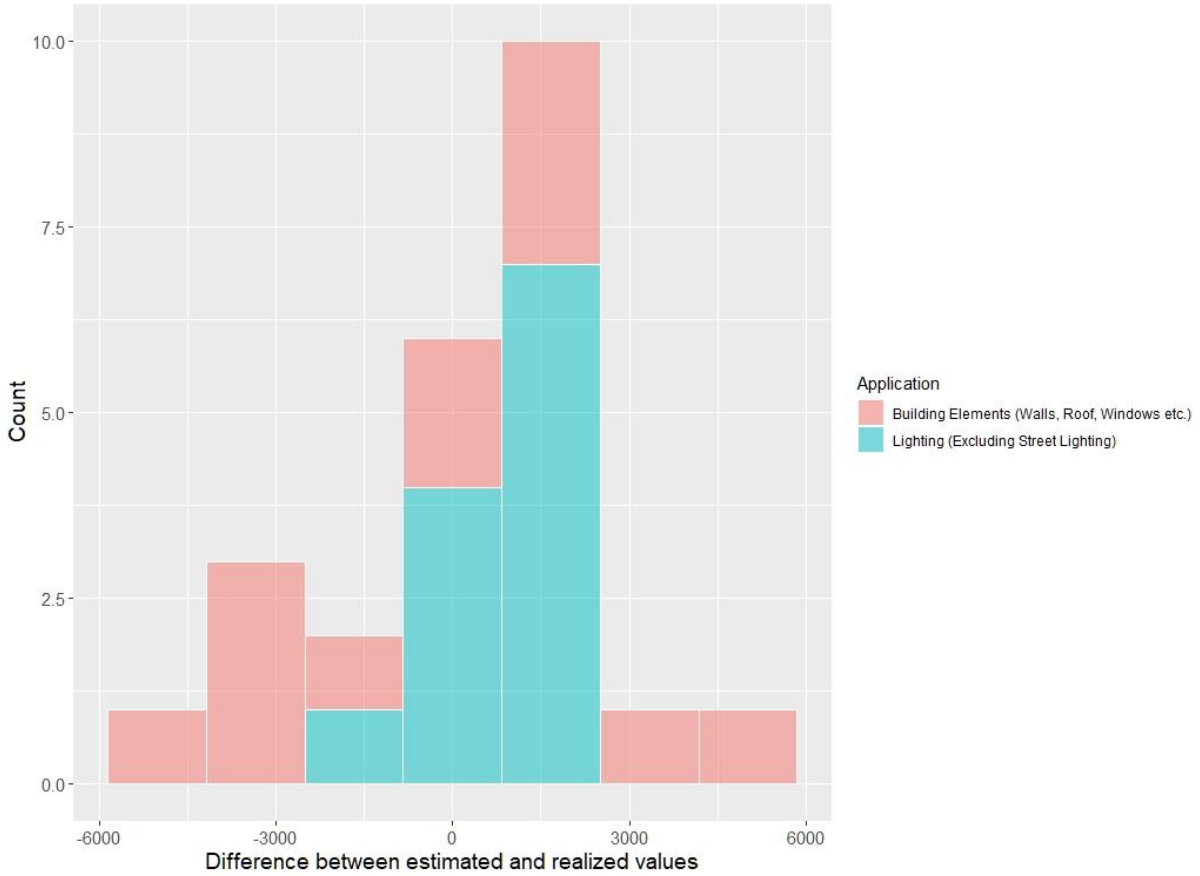

Figure 17. Distribution of the difference between real and estimated values for application categories [kWh/Year]

The distribution of realized investment values decomposed by the application type is given in Figure 18 with an average of 29 208 TL and a minimum of 8 000 TL with a maximum of 65 000 TL. It can be seen from the figure that the initial costs of the building element projects are higher on average.

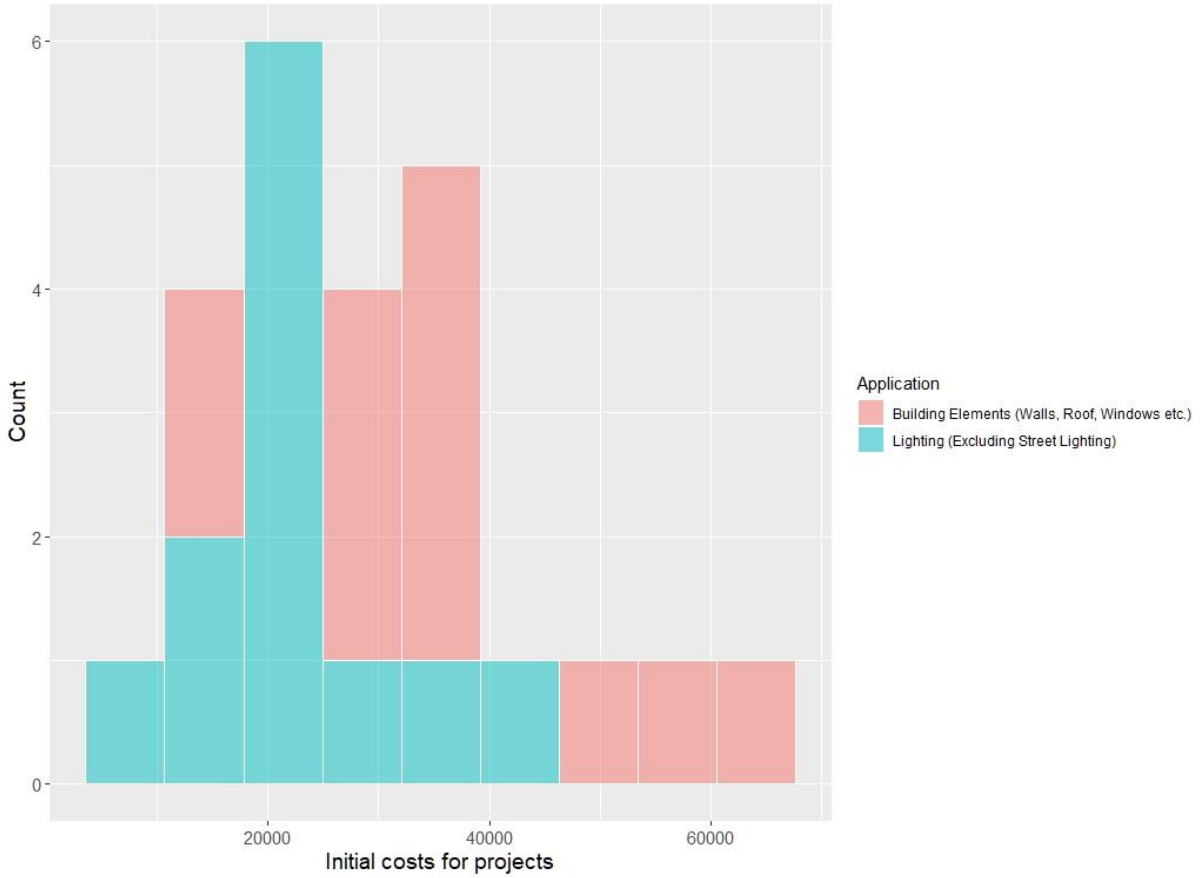

Figure 18. Distribution of the initial costs of the projects by category [TL]

Realized energy consumption reduction in kWh/year for the projects are given in Figure 19 by application category. It can be concluded that the building elements projects results in more reduction than lighting projects. The average reduction for building elements projects is 76 105 kWh/year with a minimum of 22 960 kWh/year and a maximum of 174 801 kWh/year. For lighting systems, average reduction is 12 076 kWh/year with a minimum of 4 220 kWh/year and a maximum of 18 709 kWh/year.

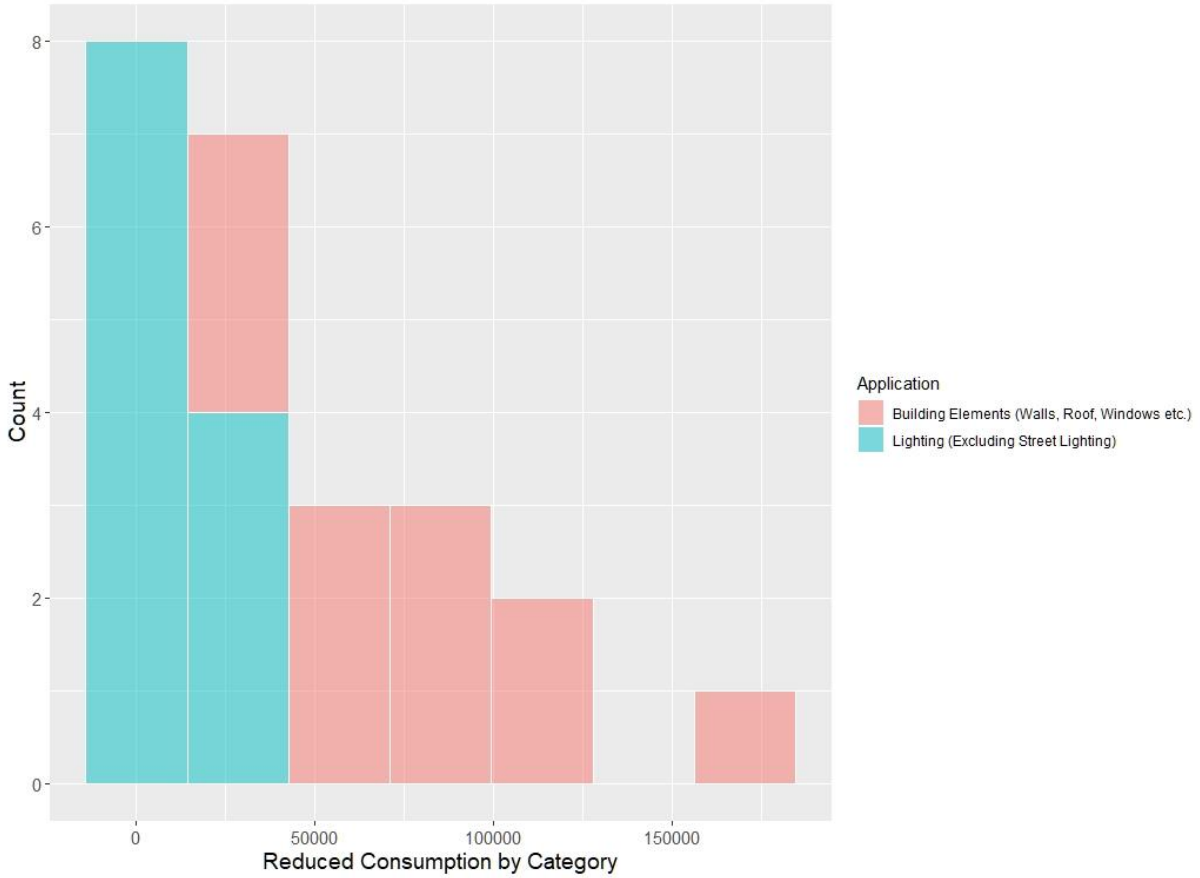

Figure 19. Distribution of the energy consumption reduction by category [kWh/Year]

Savings in TL/year are given in the Figure 20. The projects on the building systems resulted in an average of 7 867 TL/year savings and the projects on lighting systems resulted in 5 017 TL/year savings. Since the energy source for the systems that are related to building elements is natural gas and the energy source for the lighting systems is electricity, the gap between the kWh/year and TL/year savings is decreased for lighting and building element systems.

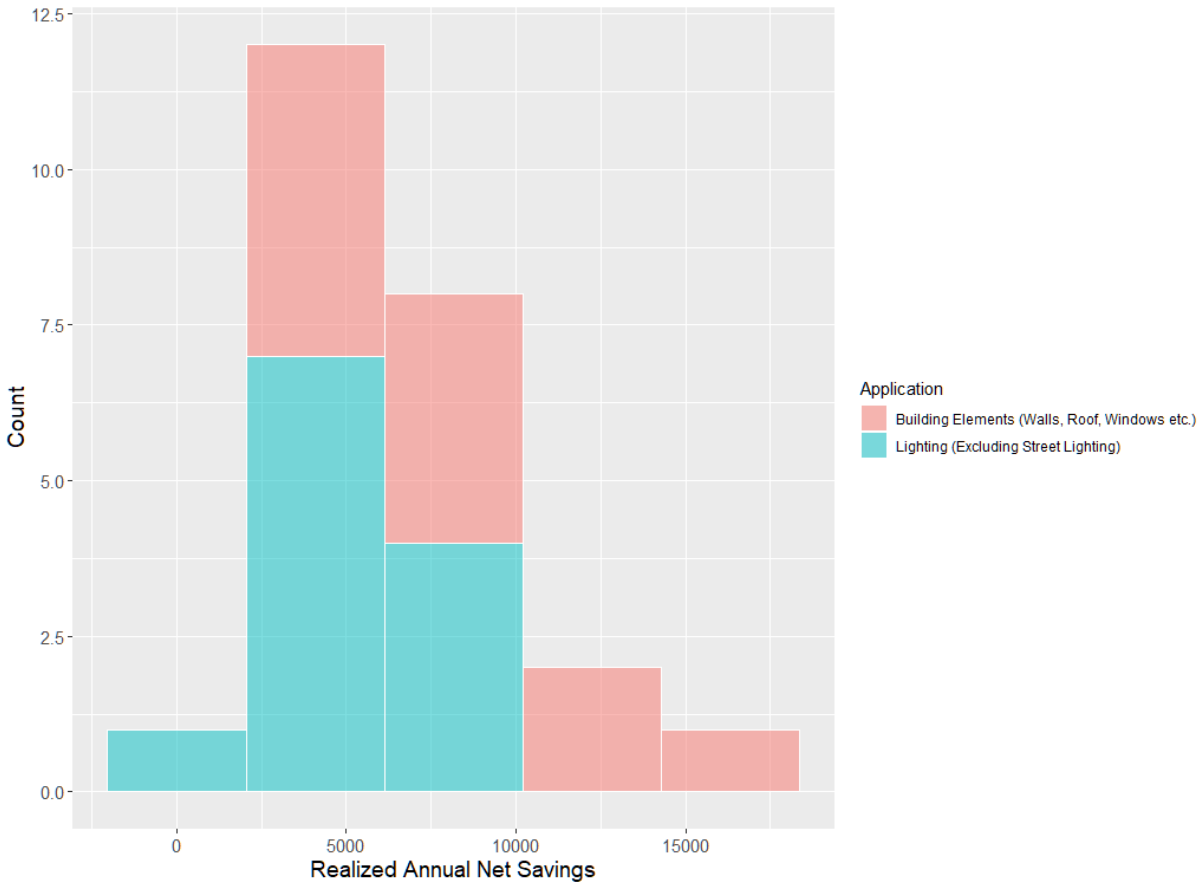

Figure 20. Realized annual savings by category [TL/Year]

Finally, if the payback times are calculated used initial cost and annual savings an average of 4.84 years of payback time is found for all school projects. The payback time average for building elements is 5.06 years and 4.61 years for lighting projects. The distribution of payback times is given in Figure 21 by application categories.

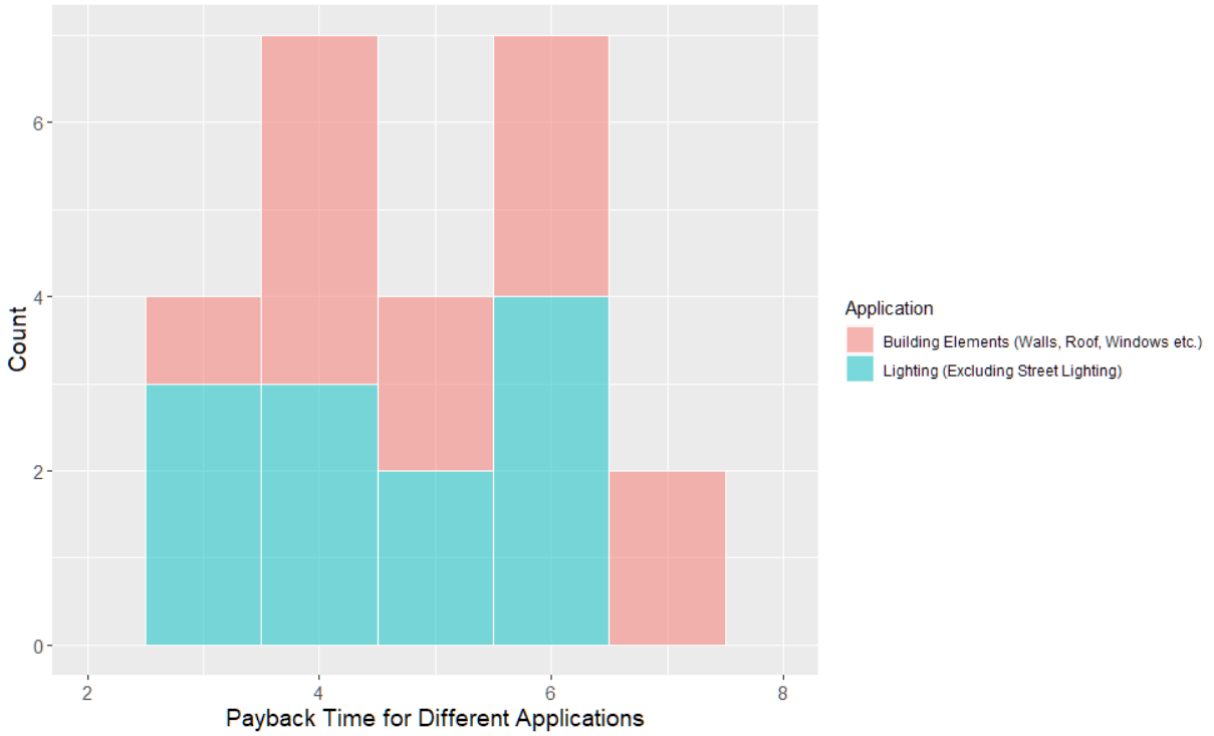

Figure 21. Distribution of payback times for different applications [Year]

In the next section “Audit” data will be analysed using the dataset obtained from the platform.

3.4. Analysing Audit Data

In this section audit data is analysed by decomposing the data into main sectors as “Industry” and “Building”. The subsectors that the database contains by main sectors are given in Figure 22. There are 123 entries for the audits, 60 for building projects and 63 for industry projects. The most frequent project subsector for the industry projects is other sectors whereas the most frequent one for the building sector is hotels.

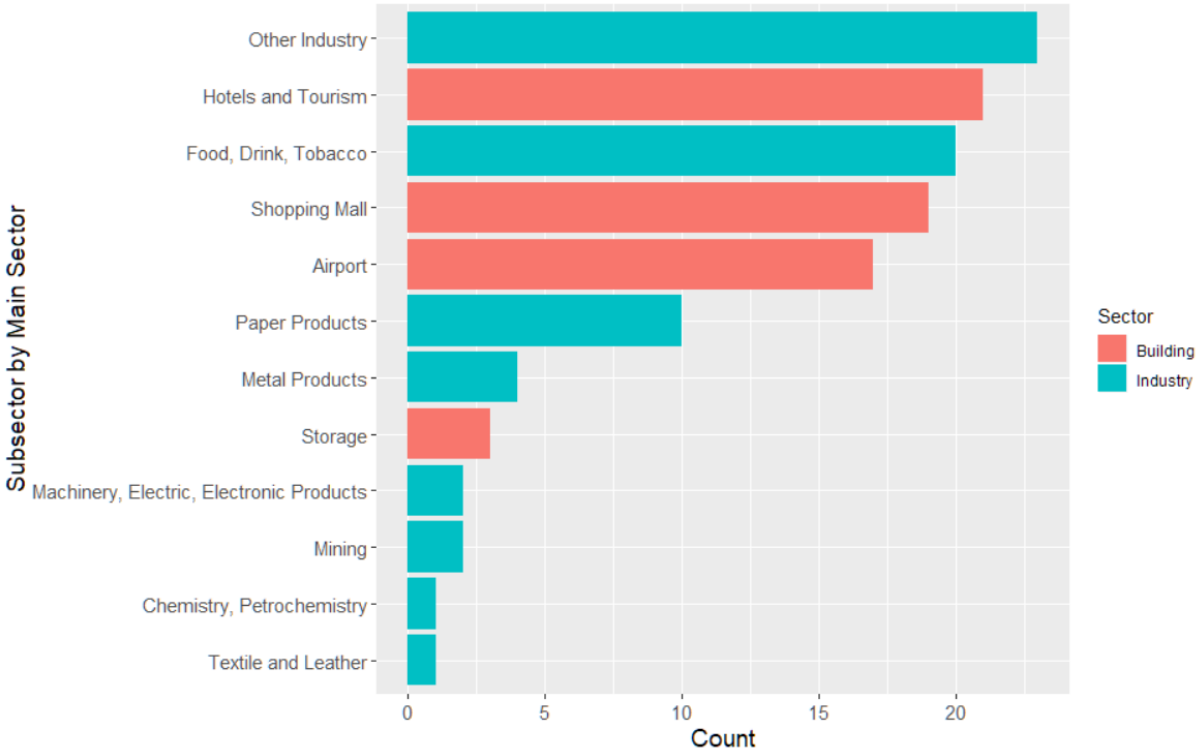

Figure 22. Distribution of subsectors by main sectors

Firstly, the industrial projects will be analysed. The distribution of audit results of industrial projects by subsector is given in Figure 23.

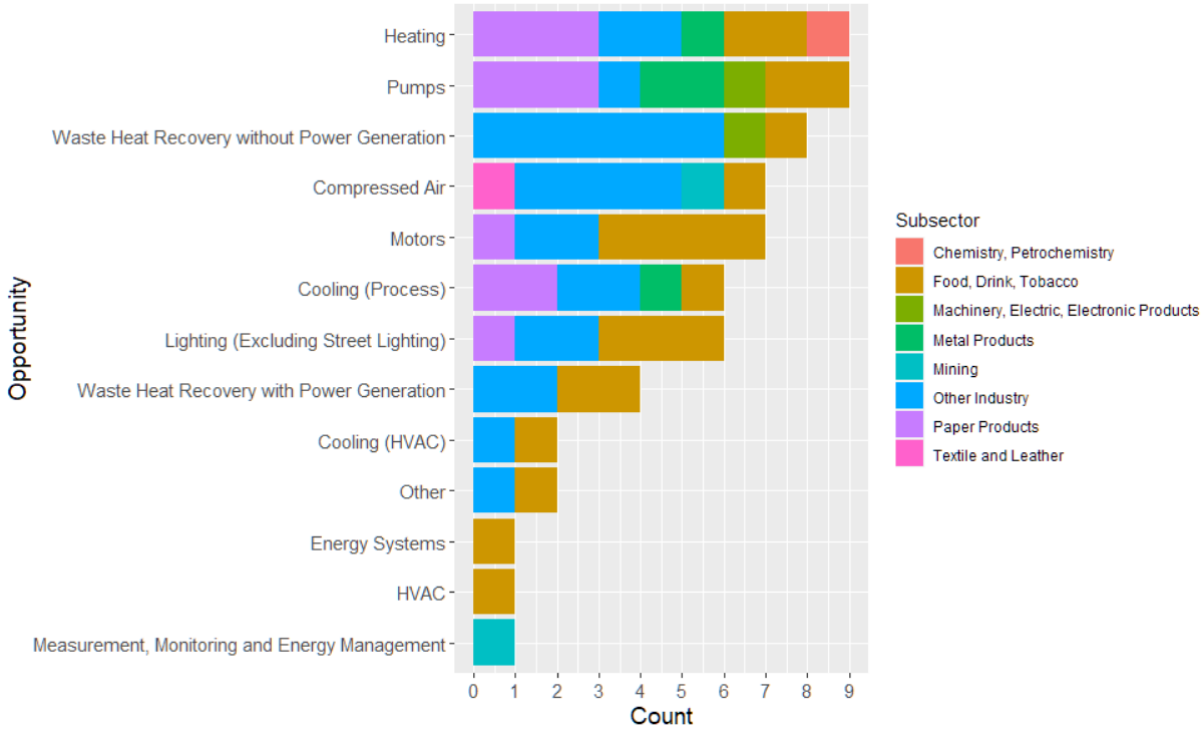

Figure 23. Distribution of opportunities for industry by subsectors

For industrial projects, the estimated annual energy consumption reduction by different subsectors in kWh/year is given in Figure 24. The maximum reduction is 11 247 250 kWh/year and the minimum is 6 451 kWh/year.

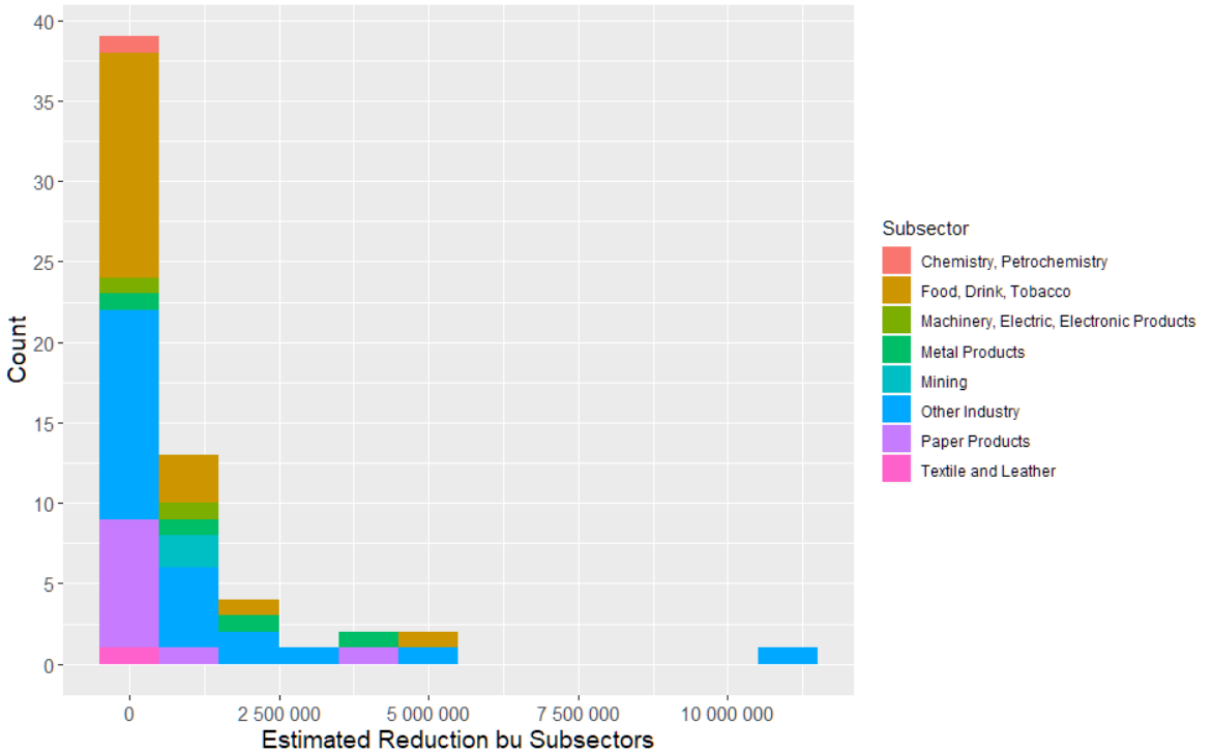

Figure 24. Estimated energy consumption reduction by subsector [kWh/year]

The distribution of estimated annual net savings (TL/year) is given in Figure 25 with a minimum saving of 2 774 TL/year and maximum saving of 13 796 362 TL/year.

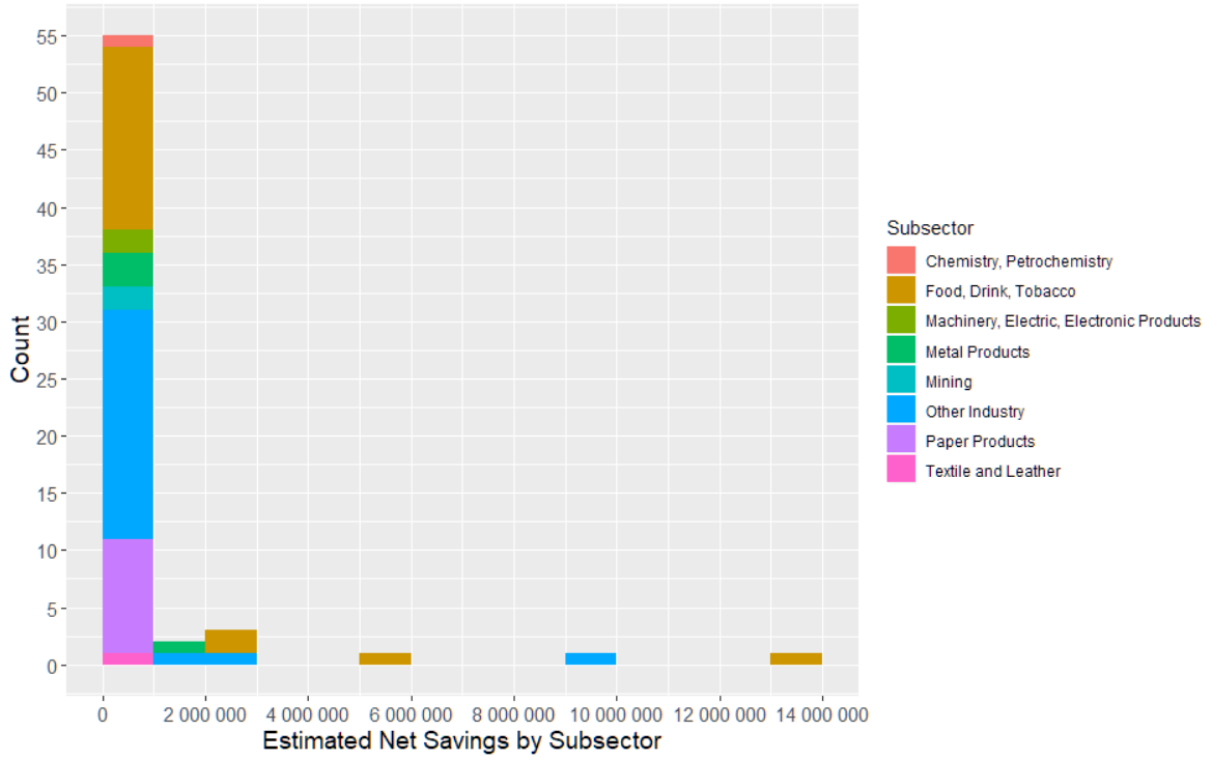

Figure 25. Estimated net savings by subsector [TL/year]

The estimated payback time for the audits are given in Figure 26. The minimum payback time is 0.52 years and the maximum is 9.8 years.

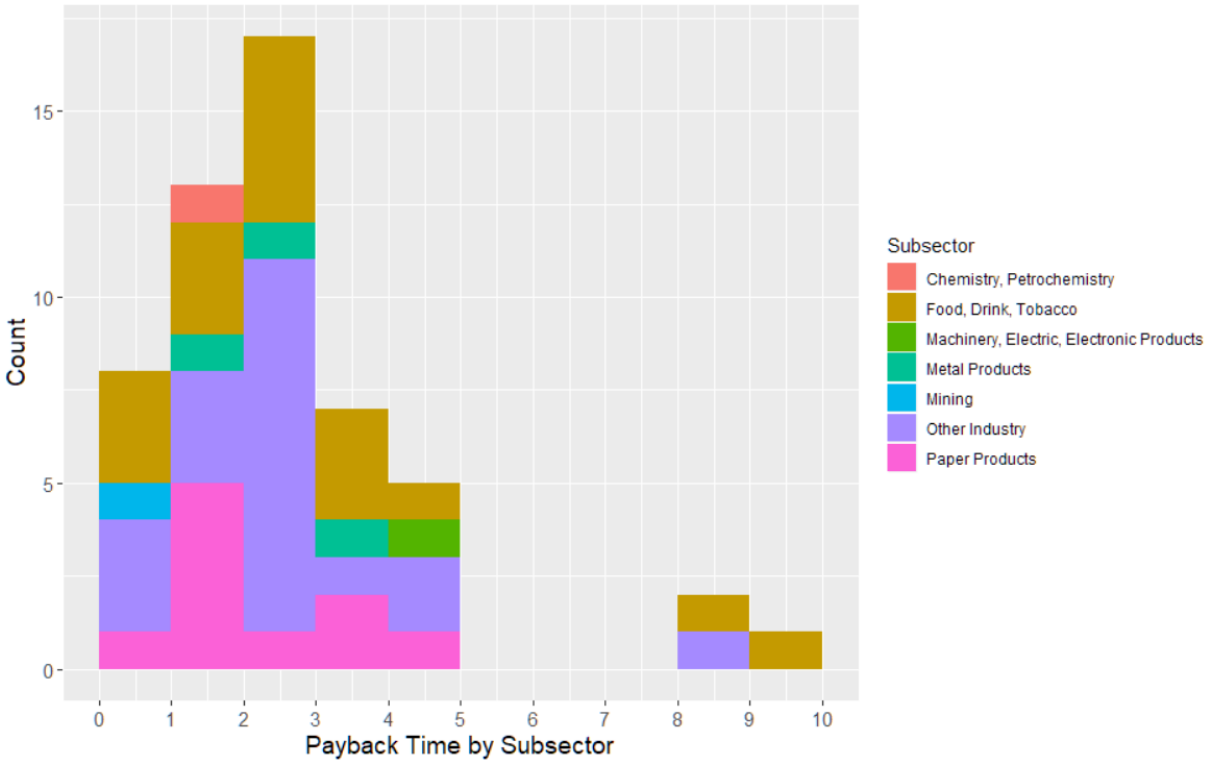

Figure 26. Estimated payback time by subsector [year]

When the building audits are analysed, the distribution of the projects by subsectors is given in Figure 27. It can be seen from the figure that 28% of the projects are HVAC and Cooling (HVAC) projects and 25% of the projects are lighting projects.

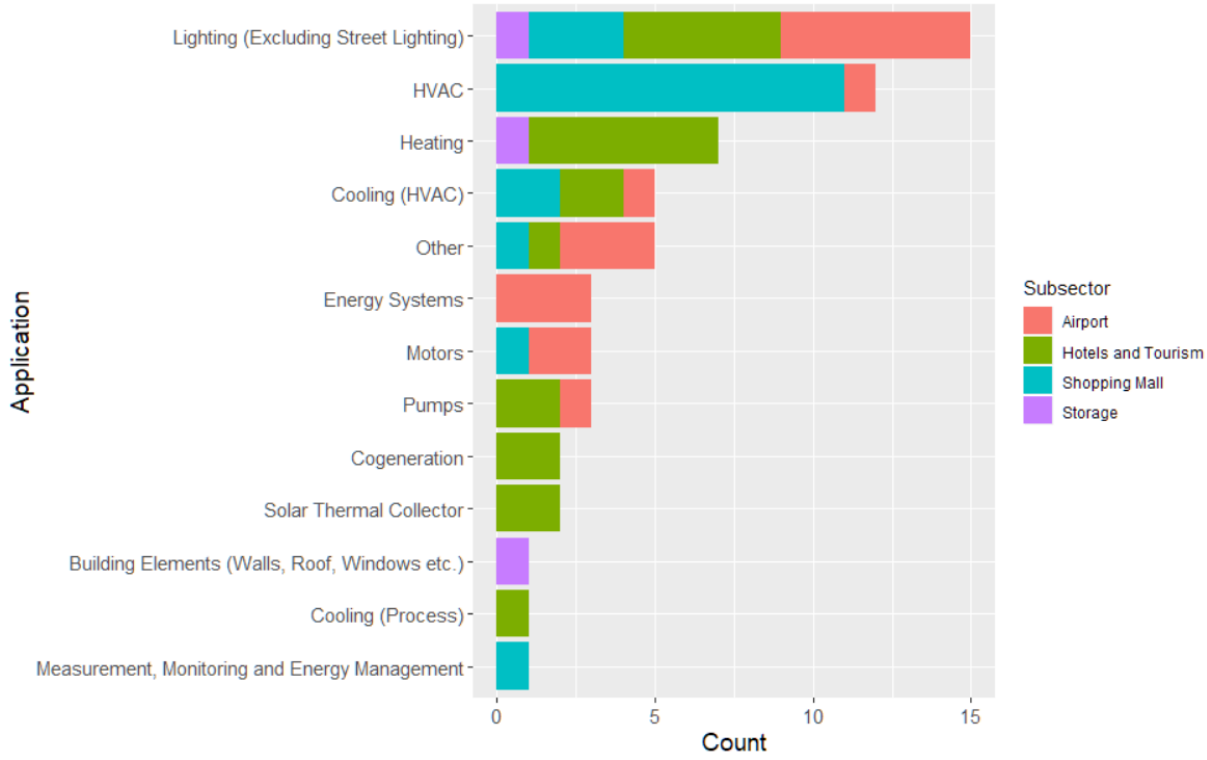

Figure 27. Distribution of applications for buildings by subsectors

For building projects, the estimated annual energy consumption reduction by different subsectors in kWh/year is given in Figure 28. The maximum reduction is 11 156 793 kWh/year and the minimum is 7 200 kWh/year.

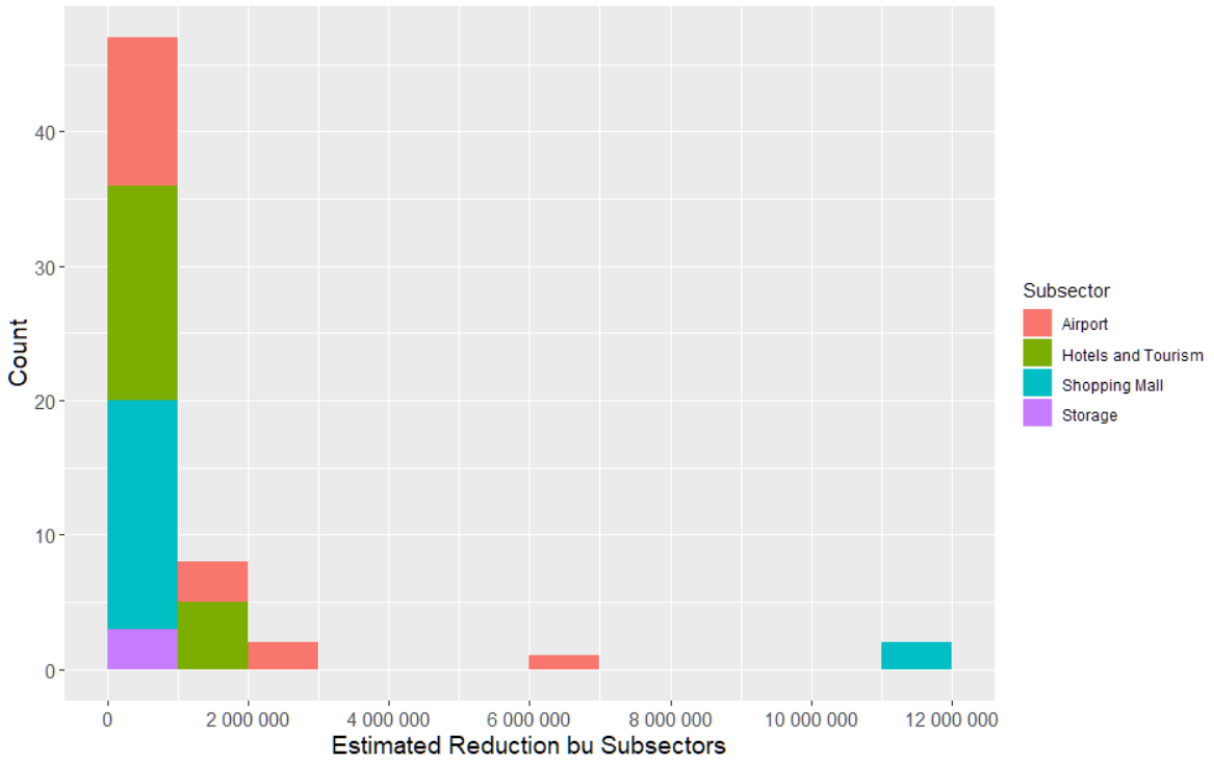

Figure 28. Estimated energy consumption reduction by subsector [kWh/Year]

The distribution of estimated annual net savings (TL/year) is given in Figure 29 with a minimum saving of 4 536 TL/year and maximum saving of 360 0311 TL/year.

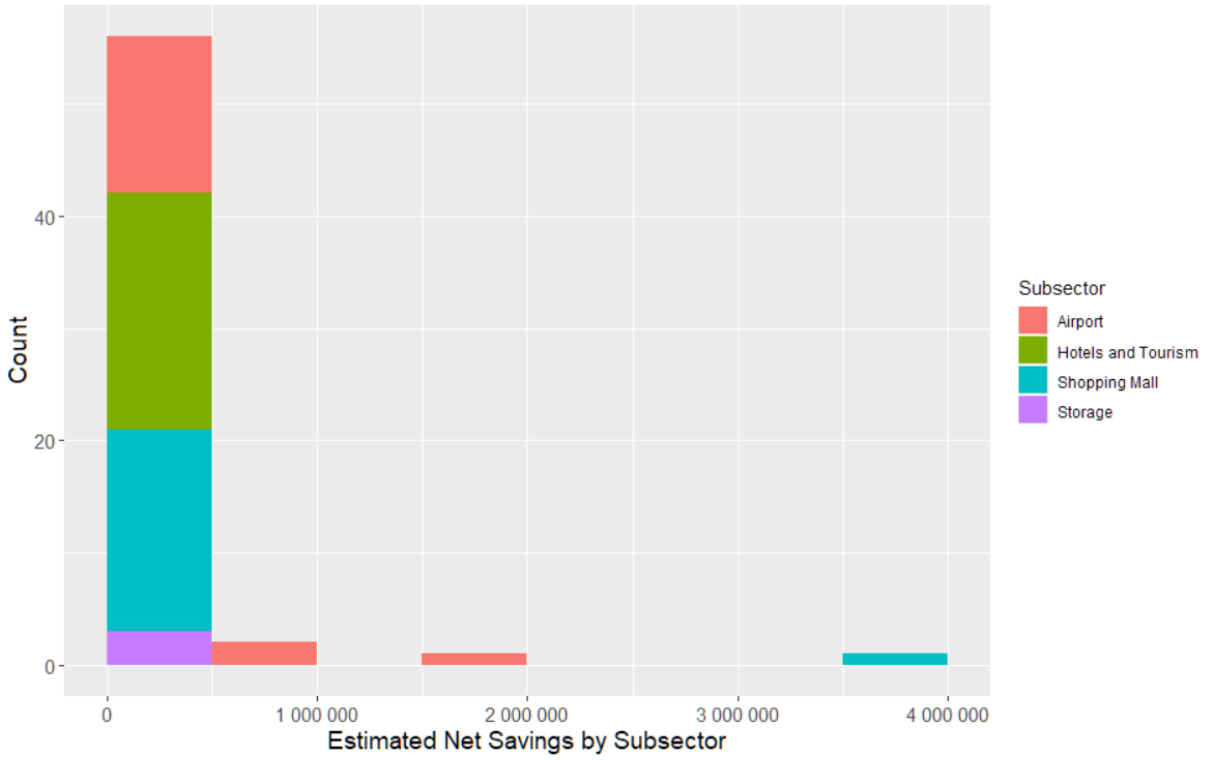

Figure 29. Estimated net savings by subsector [TL/Year]

The estimated payback time for the building audits are given in Figure 30. The minimum payback time is 0.2 years and the maximum is 19.7 years.

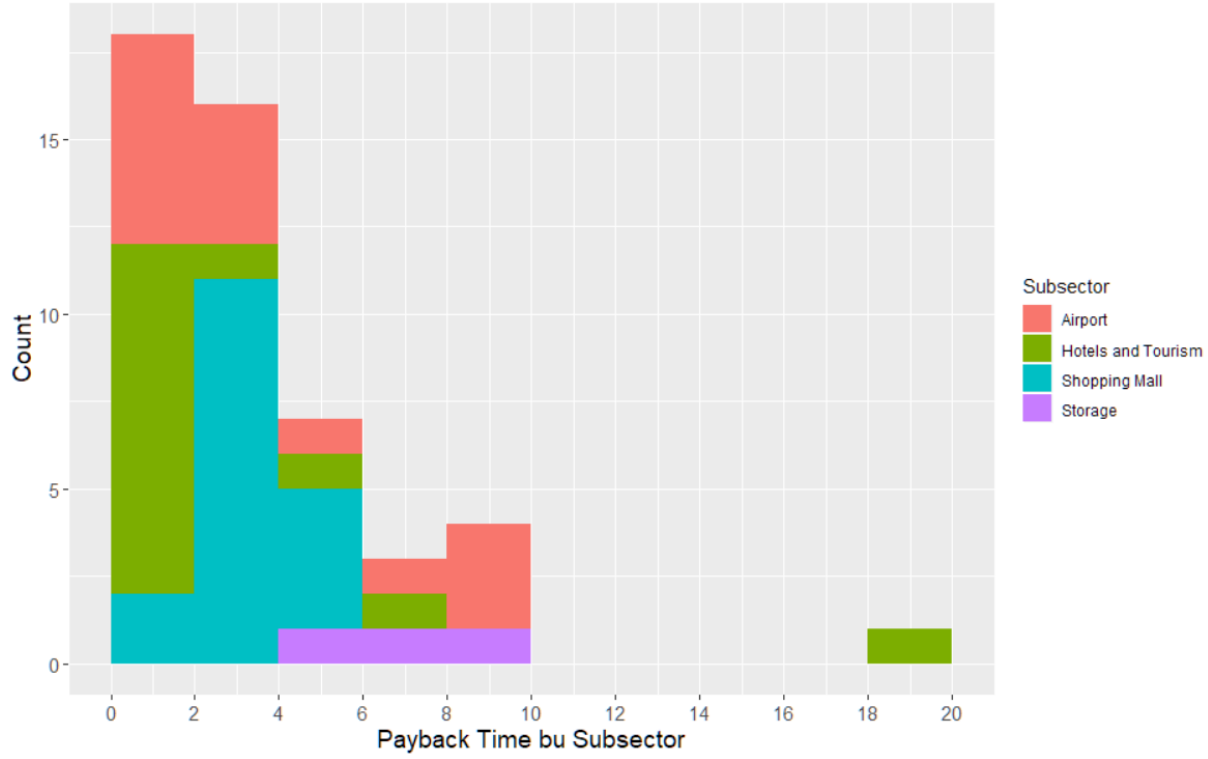

Figure 30. Estimated payback time by subsector [Year]

Lastly, all the estimated annual energy efficiency potential is converted to CO_2 emissions for all projects decomposed by main sector. The histogram of the calculations for both Building and Industry sector is given in Figure 31.

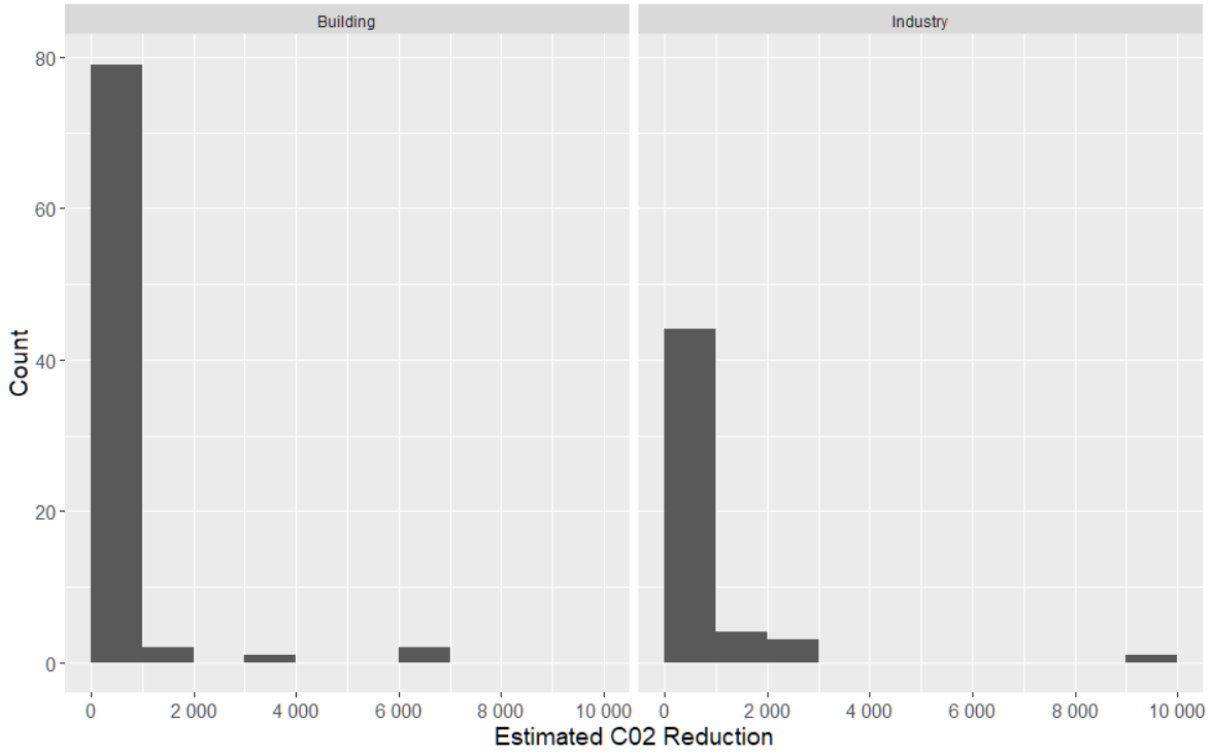

Figure 31. Estimated CO2 reduction for both main sectors [Tonnes/year]

4. CONCLUSION & DISCUSSION

In this report, the database generated from the EESP is analysed using data science and data visualization techniques. The methodology to analyse the platform data is also given. Descriptive statistics are given for main project types (audits and realized projects). 12 realized school projects are investigated thoroughly and visualized accordingly. The savings and the payback time are given as a potential savings indicator.

The audits are analysed in two main categories, industrial audits and building audits. The main sectors are analysed by subsectors and application types. Estimated energy efficiency potentials, energy savings and payback times are given for different subsectors.

In order to create a methodology in data analysis that described in section 3.1, a script that automates the process in R statistical programming language is written. With the new information, it will be easier to use the same metrics to evaluate the data using the scripts. EYODER personnel have been trained to reuse the codes. The support for the analyses will be provided in the future.

During January 2020, the data has been entered into the portal by stakeholders. In one month, 147 projects have been added to the system. Since the present data is not sufficient to generalize, it will only be a guide to show the achievements for different types of projects and applications. As the database grows larger, it will be easier to generalize the energy efficiency potential for each category and subsector using data analysis tools prepared for this project.

Appendix 1. Dataset Sample

Efficiency Focus	Project Type	Project Year	City	Sector	Subsector	Source_Type	Consumption_Before_Kwh_Year	Estimated_Consumption_Kwh_Year	Estimated_Reduction_Kwh_Year	Estimated_CO2_Reduction	Consumption_Before_TL_Year	Estimated_Investment_Cost_TL_Year	Estimated_Net_Saving_TL_Year	Estimated_Payback_Time	Realized_Consumption_Kwh_Year	Reduced_Consumption_Kwh_Year	Reduced_CO2_Ton	Realized_Investment_TL_Year	Realized_Net_Savings_TL_Year	Realized_Payback_Time
HVAC	Audit	2016	Antalya	Building	Shopping Mall	Electricity	4950134	4713219	236915	134.8	1579093	185900	79130	2,35	None	None	None	None	None	None
Lighting (Excluding Street Lighting)	Audit	2019	Sakarya	Industry	Other Industry	Electricity	328680	130680	198000	113.26	147906	132261	89100	1,48	None	None	None	None	None	None
Cooling (Process)	Audit	2019	Sakarya	Industry	Paper Products	Natural Gas	475833720	474566279	1267441	633.72	61619308	330900	187573	1,76	None	None	None	None	None	None
Heating	Audit	2019	Sakarya	Industry	Paper Products	Natural Gas	475833720	475474120	359600	179.8	61619308	67600	55763	1,21	None	None	None	None	None	None
Motors	Audit	2019	Sakarya	Industry	Paper Products	Electricity	475833720	475666279	167441	95.78	61619308	279277	85083	3,28	None	None	None	None	None	None
Heating	Audit	2019	Sakarya	Industry	Paper Products	Natural Gas	475833720	475746604	87116	None	61619308	48800	12929	3,77	None	None	None	None	None	None
Pumps	Audit	2019	Sakarya	Industry	Paper Products	Electricity	475833720	475751162	82558	47.22	61619308	56600	42106	1,34	None	None	None	None	None	None
Pumps	Audit	2019	Sakarya	Industry	Paper Products	Electricity	475833720	475780240	53480	30.59	61619308	36250	27319	1,33	None	None	None	None	None	None
Heating	Audit	2019	Sakarya	Industry	Paper Products	Natural Gas	475833720	475802325	31395	15.7	61619308	4300	4682	0,92	None	None	None	None	None	None
Building Elements (Walls, Roof, Windows etc.)	Project	2016	İstanbul	Building	Educational Building	Natural Gas	180710	105000	75710	37.86	18692	45000	7831	5,75	100520	80190	40,10	47000	8294	5,67
Lighting (Excluding Street Lighting)	Project	2016	İstanbul	Building	Educational Building	Electricity	17095	8250	8845	5.06	7101	21000	3674	5,72	7295	9800	5,61	23000	4071	5,65
Cooling (Process)	Audit	2017	Sakarya	Industry	Metal Products	Electricity	1947524	609624	1337900	None	408980	930614	263949	3,53	None	None	None	None	None	None
Pumps	Audit	2019	İstanbul	Industry	Metal Products	Electricity	14691866	10531668	4160198	None	5435990	1850467	1539273	1,20	None	None	None	None	None	None
Pumps	Audit	2016	Kocaeli	Industry	Metal Products	Electricity	3045457	1521254	1524203	None	730909	97300	365809	0,27	None	None	None	None	None	None
Cooling (HVAC)	Audit	2019	Kocaeli	Building	Shopping Mall	Electricity	560000	277228	282772	161.75	406960	1183720	205495	5,76	None	None	None	None	None	None
Lighting (Excluding Street Lighting)	Audit	2019	Kocaeli	Building	Shopping Mall	Electricity	515577	252326	263251	150.58	374677	369427	191308	1,93	None	None	None	None	None	None
Motors	Audit	2019	Kocaeli	Building	Shopping Mall	Electricity	1193999	1145075	48924	27.98	867696	95689	35554	2,69	None	None	None	None	None	None
Lighting (Excluding Street Lighting)	Audit	2019	Kocaeli	Building	Shopping Mall	Electricity	157680	119837	37843	21.65	114588	10620	27501	0,39	None	None	None	None	None	None
Measurement, Monitoring and Energy Management	Audit	2019	Kocaeli	Building	Shopping Mall	Electricity	963133	934238	28895	16.53	699922	50000	20997	2,38	None	None	None	None	None	None
Lighting (Excluding Street Lighting)	Audit	2019	Antalya	Building	Hotels and Tourism	Electricity	72270	36135	36135	20.67	65766	18000	32883	0,55	None	None	None	None	None	None
Lighting (Excluding Street Lighting)	Audit	2019	Muğla	Building	Hotels and Tourism	Electricity	14400	7200	7200	4.12	9072	8000	4536	1,76	None	None	None	None	None	None
Lighting (Excluding Street Lighting)	Audit	2019	Antalya	Building	Hotels and Tourism	Electricity	20000	10000	10000	5.72	11000	5000	5500	0,91	None	None	None	None	None	None
Lighting (Excluding Street Lighting)	Audit	2019	Muğla	Building	Hotels and Tourism	Electricity	20000	3000	17000	9.72	11800	3500	10030	0,35	None	None	None	None	None	None
Lighting (Excluding Street Lighting)	Audit	2019	Antalya	Building	Hotels and Tourism	Electricity	18000	9000	9000	5.15	9540	8500	4770	1,78	None	None	None	None	None	None