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# Manchester Energy Efficiency Insights



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# 1. Introduction

In England and Wales, Energy Performance Certificates (EPCs) serve significant purposes in assessing and reporting on the country's building and construction sector's energy performance. Given the growing global and national efforts to monitor and control the impacts of climate change, tracking EPCs and their activities is becoming more of a necessity to policymakers, builders, and local governments. This paper attempts to analyze the EPCs at the local authority of Manchester from 2014 to 2024. The intention is to determine and reveal how the energy performance of the properties has been changing, and to identify potential patterns or trends in the data that may not have been previously recognized.

The EPC Dataset includes some very useful pieces of information on residential structures, such as the energy performance rating, CO<sub>2</sub> emissions, type of house and type of heating, levels of insulation, and heating efficiency, as well as the availability of various alternative heating efficiency improvements (if any) that would serve to insulate and to improve the building in terms of heating (or energy) efficiency. This information is essential in terms of understanding and divining the different locations at which various parts of the Greater Manchester area may be classified or tiered in terms of Energy efficiency, housing decarbonization, and climate action initiatives.

Primarily, the objectives of the report are to explain how to bring in data from Microsoft SQL Server, transfer data from Microsoft SQL Server to Power BI, and make effective use of Microsoft Power BI in the creation of a dashboard. The steps that were taken in this part of the project were importing the data, cleaning, transforming, and modeling the data. In addition, a range of interactive data visualization and analytical dashboards were tailored by employing sophisticated data modeling and DAX (Data Analysis Expressions). By converting intricate historical data into visual representations and EPC datasets into easily digestible visualizations, the project assists in the recognition of energy efficiency gaps and the support of local authorities in attaining their environmental goals by evaluating the historical data of a building.

## 2. Methodology

### 2.1. Importing Data

To create the dashboard, we obtained and imported the required dataset – Manchester - from the official police data website

Dataset: <https://epc.opendatacommunities.org/downloads/domestic#local-authority>

Next, open the dataset on the EXCEL sheet, then drop the columns that contain very large text descriptions because these columns can prevent successful import into SQL Server.

### 2.2. Creating a Database in SQL

Database > New Database > Database Name (energy) > ok Double click on energy> Task > Import Flat File > Next > Browse > Dataset (Manchester)> Next > Then insert allow nulls > next > finish

### 2.3. Data Cleaning Part

Next, after importing into the SQL Server again, drop the columns that are unimportant to the analysis using the T-SQL code.

```
ALTER TABLE certificate
DROP COLUMN
    LMK_KEY,
    ADDRESS2,
    POSTCODE,
    CONSTITUENCY,
    HOT_WATER_ENERGY_EFF,
    HOT_WATER_ENV_EFF,
    WINDOWS_ENERGY_EFF,
    WINDOWS_ENV_EFF,
    WALLS_ENERGY_EFF,
    NUMBER_HABITABLE_ROOMS,
    NUMBER_HEATED_ROOMS,
    LOW_ENERGY_LIGHTING,
    WALLS_ENV_EFF,
    MAINHEAT_ENERGY_EFF,
    MAINHEAT_ENV_EFF,
    MAINHEATC_ENERGY_EFF,
    MAINHEATC_ENV_EFF,
    LIGHTING_ENERGY_EFF,
    LIGHTING_ENV_EFF,
    WIND_TURBINE_COUNT,
    FLOOR_HEIGHT,
    ADDRESS,
    LOCAL_AUTHORITY_LABEL,
    CONSTITUENCY_LABEL,
    POSTTOWN;
```

Next, we looked at the null sum of the remaining columns.

```

SELECT
SUM(CASE WHEN CURRENT_ENERGY_RATING IS NULL THEN 1 ELSE 0 END) AS CURRENT_ENERGY_RATING_Nulls,
SUM(CASE WHEN POTENTIAL_ENERGY_RATING IS NULL THEN 1 ELSE 0 END) AS POTENTIAL_ENERGY_RATING_Nulls,
SUM(CASE WHEN CURRENT_ENERGY_EFFICIENCY IS NULL THEN 1 ELSE 0 END) AS CURRENT_ENERGY_EFFICIENCY_Nulls,
SUM(CASE WHEN POTENTIAL_ENERGY_EFFICIENCY IS NULL THEN 1 ELSE 0 END) AS POTENTIAL_ENERGY_EFFICIENCY_Nulls,
SUM(CASE WHEN PROPERTY_TYPE IS NULL THEN 1 ELSE 0 END) AS PROPERTY_TYPE_Nulls,
SUM(CASE WHEN BUILT_FORM IS NULL THEN 1 ELSE 0 END) AS BUILT_FORM_Nulls,
SUM(CASE WHEN TRANSACTION_TYPE IS NULL THEN 1 ELSE 0 END) AS TRANSACTION_TYPE_Nulls,
SUM(CASE WHEN ENVIRONMENT_IMPACT_CURRENT IS NULL THEN 1 ELSE 0 END) AS ENVIRONMENT_IMPACT_CURRENT_Nulls,
SUM(CASE WHEN ENVIRONMENT_IMPACT_POTENTIAL IS NULL THEN 1 ELSE 0 END) AS ENVIRONMENT_IMPACT_POTENTIAL_Nulls,
SUM(CASE WHEN ENERGY_CONSUMPTION_CURRENT IS NULL THEN 1 ELSE 0 END) AS ENERGY_CONSUMPTION_CURRENT_Nulls,
SUM(CASE WHEN ENERGY_CONSUMPTION_POTENTIAL IS NULL THEN 1 ELSE 0 END) AS ENERGY_CONSUMPTION_POTENTIAL_Nulls,
SUM(CASE WHEN CO2_EMISSIONS_CURRENT IS NULL THEN 1 ELSE 0 END) AS CO2_EMISSIONS_CURRENT_Nulls,
SUM(CASE WHEN CO2_EMISSIONS_POTENTIAL IS NULL THEN 1 ELSE 0 END) AS CO2_EMISSIONS_POTENTIAL_Nulls,
SUM(CASE WHEN LIGHTING_COST_CURRENT IS NULL THEN 1 ELSE 0 END) AS LIGHTING_COST_CURRENT_Nulls,
SUM(CASE WHEN LIGHTING_COST_POTENTIAL IS NULL THEN 1 ELSE 0 END) AS LIGHTING_COST_POTENTIAL_Nulls,
SUM(CASE WHEN HEATING_COST_CURRENT IS NULL THEN 1 ELSE 0 END) AS HEATING_COST_CURRENT_Nulls,
SUM(CASE WHEN HEATING_COST_POTENTIAL IS NULL THEN 1 ELSE 0 END) AS HEATING_COST_POTENTIAL_Nulls,
SUM(CASE WHEN HOT_WATER_COST_CURRENT IS NULL THEN 1 ELSE 0 END) AS HOT_WATER_COST_CURRENT_Nulls,
SUM(CASE WHEN HOT_WATER_COST_POTENTIAL IS NULL THEN 1 ELSE 0 END) AS HOT_WATER_COST_POTENTIAL_Nulls,

SUM(CASE WHEN CONSTRUCTION_AGE_BAND IS NULL THEN 1 ELSE 0 END) AS CONSTRUCTION_AGE_BAND_Nulls
FROM certificate;

```

Then, we removed rows that could detect null values.

```

DELETE FROM certificate
WHERE CURRENT_ENERGY_RATING IS NULL
OR POTENTIAL_ENERGY_RATING IS NULL
OR CURRENT_ENERGY_EFFICIENCY IS NULL
OR POTENTIAL_ENERGY_EFFICIENCY IS NULL
OR PROPERTY_TYPE IS NULL
OR BUILT_FORM IS NULL
OR TRANSACTION_TYPE IS NULL
OR ENVIRONMENT_IMPACT_CURRENT IS NULL
OR ENVIRONMENT_IMPACT_POTENTIAL IS NULL
OR ENERGY_CONSUMPTION_CURRENT IS NULL
OR ENERGY_CONSUMPTION_POTENTIAL IS NULL
OR CO2_EMISSIONS_CURRENT IS NULL
OR CO2_EMISSIONS_POTENTIAL IS NULL
OR LIGHTING_COST_CURRENT IS NULL
OR LIGHTING_COST_POTENTIAL IS NULL
OR HEATING_COST_CURRENT IS NULL
OR HEATING_COST_POTENTIAL IS NULL
OR HOT_WATER_COST_CURRENT IS NULL
OR HOT_WATER_COST_POTENTIAL IS NULL
OR CONSTRUCTION_AGE_BAND IS NULL;

```

Next, we looked for only the string data type columns that contained values as “NO DATA” and got the sum of those values.

```

SELECT
SUM(CASE WHEN PROPERTY_TYPE = 'NO DATA!' THEN 1 ELSE 0 END) AS PROPERTY_TYPE_NO_DATA,
SUM(CASE WHEN BUILT_FORM = 'NO DATA!' THEN 1 ELSE 0 END) AS BUILT_FORM_NO_DATA,
SUM(CASE WHEN TRANSACTION_TYPE = 'NO DATA!' THEN 1 ELSE 0 END) AS TRANSACTION_TYPE_NO_DATA,
SUM(CASE WHEN CONSTRUCTION_AGE_BAND = 'NO DATA!' THEN 1 ELSE 0 END) AS CONSTRUCTION_AGE_BAND_NO_DATA
FROM certificate;

```

After identifying the sum of the “NO DATA”, we update the “NO DATA” values to null values.

```

UPDATE certificate
SET BUILT_FORM = NULL
WHERE BUILT_FORM = 'NO DATA!';

UPDATE certificate
SET CONSTRUCTION_AGE_BAND = NULL
WHERE CONSTRUCTION_AGE_BAND = 'NO DATA!';

DELETE FROM certificate
WHERE BUILT_FORM IS NULL
   OR CONSTRUCTION_AGE_BAND IS NULL
   OR PROPERTY_TYPE IS NULL
   OR TRANSACTION_TYPE IS NULL;

select * from certificate

```

Then we removed the rows that updated to null values and finally looked at the clean dataset.

```

UPDATE certificate
SET BUILT_FORM = NULL
WHERE BUILT_FORM = 'NO DATA!';

UPDATE certificate
SET CONSTRUCTION_AGE_BAND = NULL
WHERE CONSTRUCTION_AGE_BAND = 'NO DATA!';

DELETE FROM certificate
WHERE BUILT_FORM IS NULL
   OR CONSTRUCTION_AGE_BAND IS NULL
   OR PROPERTY_TYPE IS NULL
   OR TRANSACTION_TYPE IS NULL;

select * from certificate

```

## 2.4 Imported the Datasets into Power BI

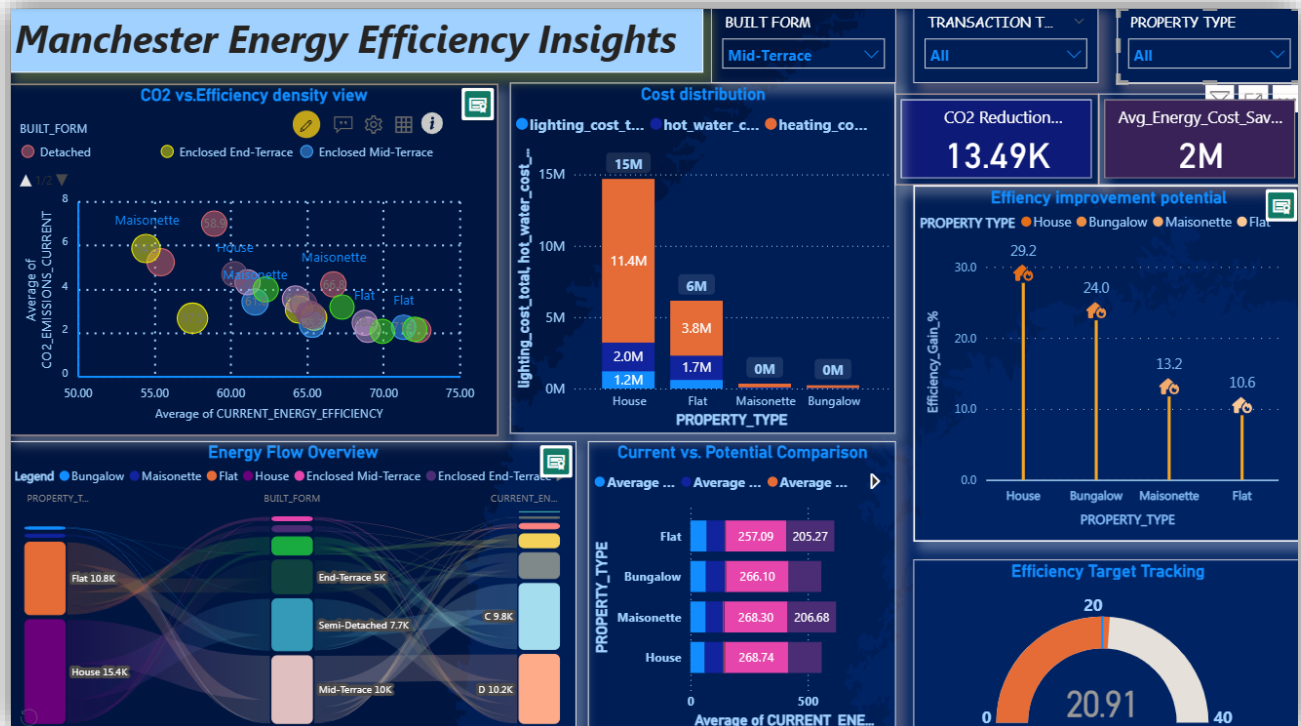
Next, import the datasets into Power BI through the following steps

Get data > SQL server > server name > Database name > ok

Then select the “ energy” datasets, which we imported

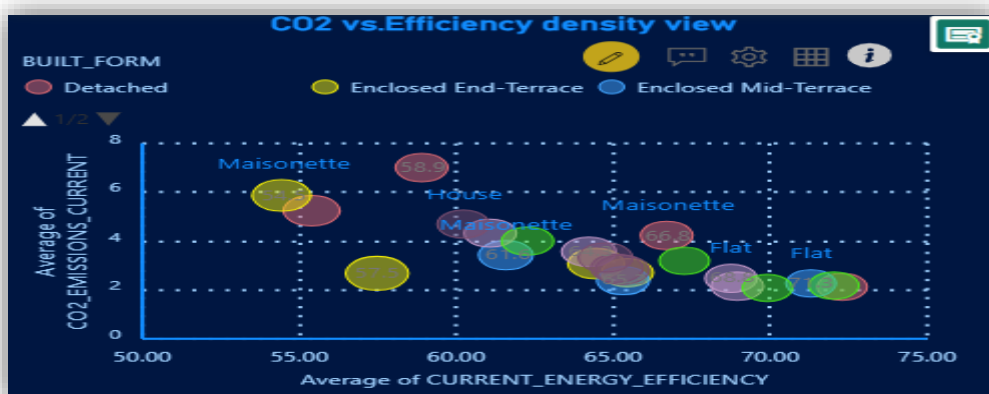
### 3. Visualization

#### 3.1. Dashboard Review



The "Manchester Energy Efficiency Insights" dashboard above is designed to use the advanced visualization capabilities of Power BI to provide more engaging and actionable insights into the data. As the Manchester Energy Efficiency Insights dashboard shows, these visualization capabilities of Power BI enable researchers and decision makers to analyze complex data and discover patterns and insights. There are different visualization modules in the dashboard, and we will examine them one by one.

#### 3.2. CO2 vs. Efficiency density view



The “CO<sub>2</sub> vs. Efficiency Density View” is a bubble chart visualization that illustrates the relationship between energy efficiency, CO<sub>2</sub> emissions, and energy consumption across different property types and building types. The property types used are houses, flats, maisonettes, bungalows, and building types including closed end-terrace and closed mid-terrace.

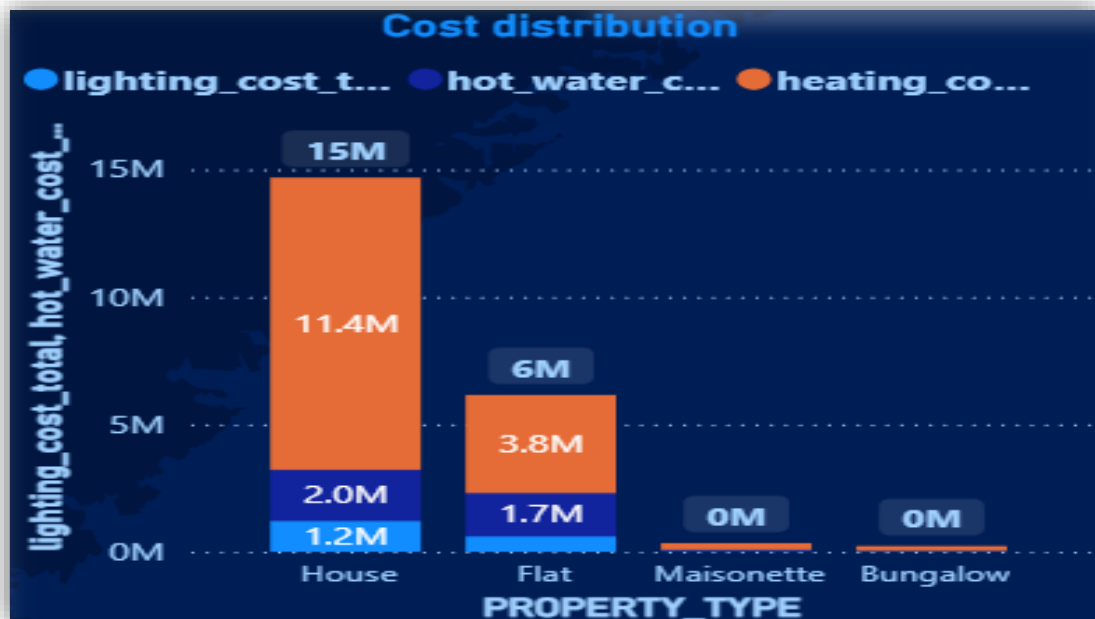
- X-axis — Average energy efficiency level
- Y-axis — Average CO<sub>2</sub> emissions level
- Bubble size — Average energy consumption

This multi-dimensional chart uses property types (play axis) and building types (legends) to clearly identify differences and dynamic contrasts between building structures. The main objective is to A deep analysis of the relationships between levels can be done very effectively. CO<sub>2</sub> vs. Efficiency Density clearly highlights the inverse relationship between current energy efficiency and CO<sub>2</sub> emission levels. The visualization shows that as average energy efficiency increases, CO<sub>2</sub> emissions steadily decrease. This means that efficiency improvements provide direct environmental benefits and that properties with higher EPC ratings (A–C) have a lower carbon . Looking at property types, maisonettes are largely seen to be in the same area, which also represents a significant portion of this dataset. On the other hand, apartments tend to cluster in the higher efficiency areas, showing a better energy performance pattern than other construction types. The overall trend is that CO<sub>2</sub> emission levels consistently decrease as energy efficiency increases. This clearly confirms that properties with higher EPC ratings and efficiency improvements provide direct benefits to the environment.

### Key Insights:

- Increasing energy efficiency levels naturally lead to a reduction in CO<sub>2</sub> emissions. Therefore, the relationship is clear, as improving efficiency directly reduces carbon output.
- Flats and maisonettes generally show higher efficiency and lower emissions, and this is further confirmed when compared to detached or end-terrace types. The structure of these types of houses is the reason why they perform more energy efficiently.
- Mid-terrace buildings operate more efficiently and have lower CO<sub>2</sub> emissions, while detached and end-terrace buildings produce higher emissions, even at the same efficiency level.

### 3.3. Cost distribution



The “Cost Distribution” visualization shows how energy costs are distributed across different property types. This allows you to clearly identify the highest-cost segments among the categories “House”, “Flat”, “Maisonette” and “Bungalow”. Here, a stacked bar chart is used, where the X-axis represents the property type and the Y-axis represents the total energy costs. The data types “*Total Lighting Cost*”, “*Total Heating Cost*” and “*Total Hot Water Cost*” are combined in a single DAX calculation and displayed as layers in the column. This visualization makes it easier to identify the property groups with the highest energy costs, determine the priority of interventions and make data-driven planning easier.

#### DAX Use

```
lighting_cost_total = SUM(certificate[LIGHTING_COST_CURRENT])
```

```
heating_cost_total = SUM(certificate[HEATING_COST_CURRENT])
```

```
heating_cost_total = SUM(certificate[HEATING_COST_CURRENT])
```

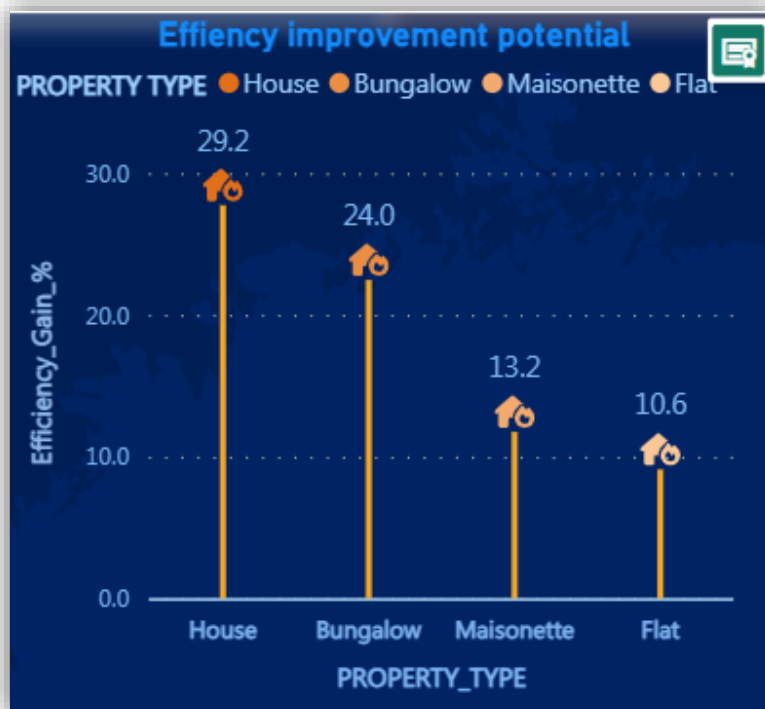
According to the chart, Houses depicts higher total energy costs than all other property types. Specifically, the heating cost of the House type is Rs. 11.4 million, which is the largest contributor

to energy costs. In addition, hot water costs are represented by 2 million and lighting costs by 1.2 million. In contrast, flats show a moderate cost pattern, generating a total cost of about 6 million. Of this, 3.8 million is allocated for heating, 1.7 million for lighting, and 1.2 million for hot water, and although the cost distribution appears to be balanced, heating costs still dominate. In the overall analysis, heating costs become the main component of the energy cost pattern across all property types. They appear to be high for houses, moderate for apartments, and quite low for types such as bungalows and maisonettes.

### Key Insights

- Houses have the highest total energy cost (~15M), dominated by heating and hot water usage.
- Flats show moderate costs (~6M), mainly driven by heating.
- Bungalows and maisonettes show near-zero or very low recorded cost, indicating fewer units or lower average usage.
- Heating is consistently the largest cost driver across all property type

### 3.4. Efficiency Improvement Potential



This lollipop chart visually illustrates the potential for energy efficiency improvements across different property types based on the efficiency gain measure. In this visualization each lollipop point highlight, how much efficiency improvement could be made within a given property type,

making it easy to compare across categories. The goal of this visualization is to identify property types with high opportunities for energy performance improvements. Combined with a clear classification axis that displays specific numerical values, the lollipop format is a more relaxed, readable, and data-driven alternative to traditional bar charts. For better visualization, we created a measure called “Efficiency Gain\_%” using DAX code to calculate how much energy efficiency could be improved as a percentage by comparing potential efficiency to current efficiency.

### DAX Used:

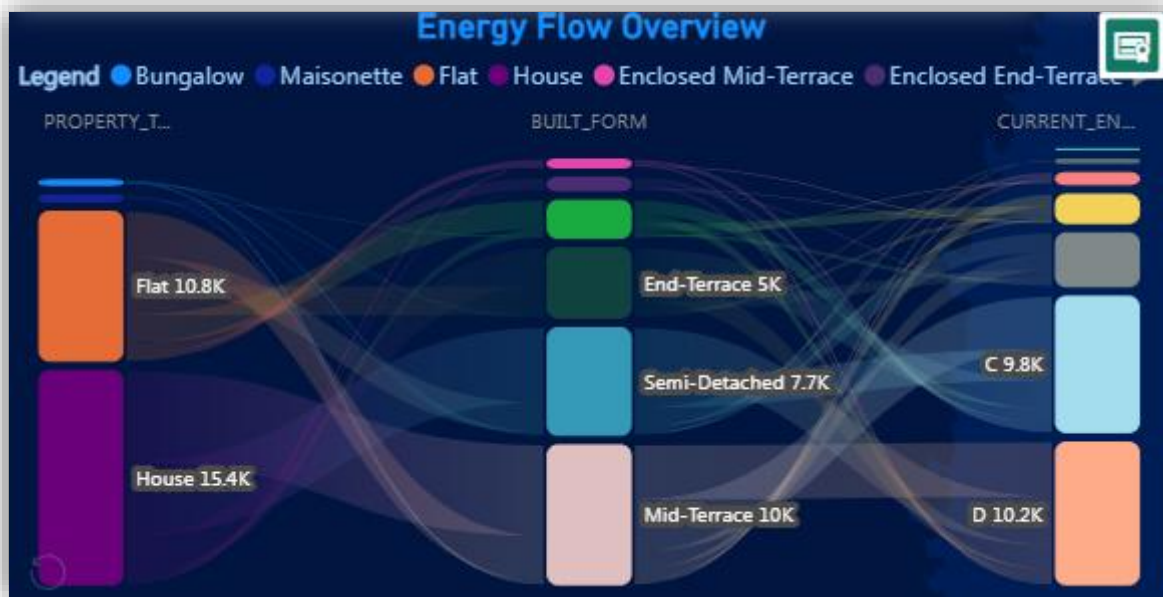
```
Efficiency_Gain_% =  
DIVIDE(  
    (AVERAGE('certificate'[POTENTIAL_ENERGY_EFFICIENCY]) -  
    AVERAGE('certificate'[CURRENT_ENERGY_EFFICIENCY])),  
    AVERAGE('certificate'[CURRENT_ENERGY_EFFICIENCY]),  
    0  
    ) * 100
```

The improvement potential graph shows a clear downward trend from houses to apartments. The house type consistently shows the highest potential for efficiency improvement, with a gain of 29.2%. Bungalows (24%), small houses (13.2%) and finally apartments (10.6%) show the lowest improvement potential. This trend reveals that although large tenements and houses in Manchester have strong attributes, there is a significant lag in their utility efficiency.

### Key Insights:

- Homes generally show higher energy efficiency (29.2%) due to efficient design, reduced heat loss, and internal building structural properties.
- The bungalow type shows the second highest value at 24%, also indicating significant potential for efficiency improvements.
- Flats buildings, due to their helpful design features and reduced external heat loss surfaces, show a flat trend with lower need for improvement. (13.2%)
- Overall, structures such as houses and larger properties benefit most from targeted efficiency improvements, and data patterns show that those building types have greater potential for installing higher efficiency at the level of preparedness.

### 3.5. Energy Flow Overview



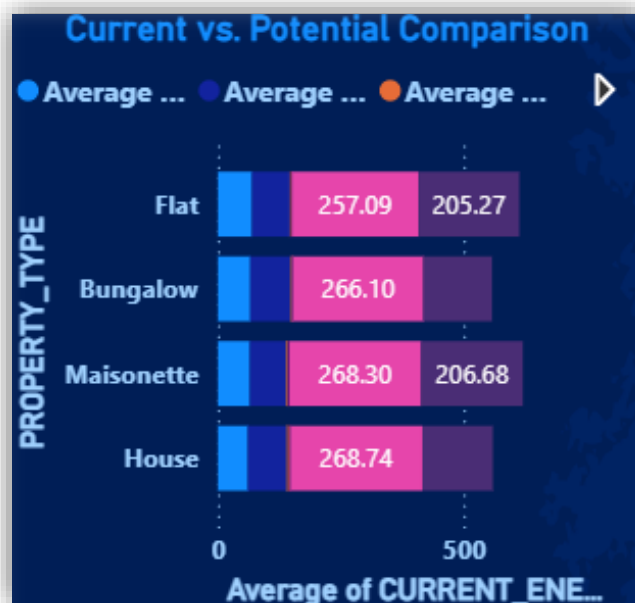
This Sankey chart visually illustrates an overview of energy flows within the property sector in Manchester. The data fields Property Type, Built Form, Transaction Type, Current Energy Rating are interlinked, showing in a clear flow how each category contributes to the overall energy performance. The aim of this visualization is to clearly demonstrate the relationships and movements between property characteristics and their energy ratings. The chart helps to identify property types that are frequently associated with high or low energy efficiency and simplifies the data complexity into a clear characterization. By showing energy efficiency usage patterns across multiple trajectories at once, rather than traditional graphs, this visualization provides a complete view of the distribution of energy within Manchester's properties and building structures.

The Sankey diagram shows a strong upward trend in total energy flow for larger property types, particularly houses and mid-terrace buildings. Houses point out the highest energy flow at 15.4K, representing the largest energy movement through heating, lighting and overall consumption pathways. This indicates that energy movement increases significantly through building categories with larger floor space or structurally open forms. Flats show a moderate flow trend of 10.8K, with enclosed terraces showing more efficient energy paths and lower levels of losses. The overall trend reveals that as building size and external surface area increase, energy flow intensifies and efficiency decreases.

#### Key Insights:

- Houses (15.4K) and mid-terrace buildings (10K) also show the highest consumption, showing the highest values of total energy flow.
- Flats (10.8K) also contribute significantly but remain more efficient due to their smaller size.
- Semi-detached and enclosed terraces appear in the middle range, reflecting mixed insulation and aging building profiles.
- Energy flow patterns highlight where energy losses are most pronounced and, thus, areas requiring upgrade priorities and improvements can be easily identified.

### 3.6. Current vs Potential Comparison



The ‘Current vs Potential Comparison’ visualization compares current and potential energy performance metrics across key factors such as efficiency, CO<sub>2</sub> emissions and energy consumption. It uses a stacked bar chart to analyze in detail the different data fields representing current efficiency, potential efficiency, CO<sub>2</sub> stream, CO<sub>2</sub> potential and energy consumption in one display. The aim of this visualization is to clearly highlight the gap between current and achievable performance levels by comparing current versus potential values. Presenting the data in a stacked format makes it easier for users to identify the property groups with the greatest potential for improvement. This is crucial for revealing the overall efficiency potential and emission reduction opportunities across different property types and provides evidence for policy decisions to identify areas where the greatest environmental and economic benefits can be achieved through targeted energy improvements within the City of Manchester’s buildings sector.

The efficiency and energy consumption levels have fluctuations across all types of properties. Energy usage for apartments will decrease from 257.09 to 205.27 and will have a potential increase of 76.94 from current levels of 69.56. For bungalows, Energy consumption will decrease from 266.10 to 139.31 and will have an increased efficiency from 66.10 to 81.94. For maisonettes, an energy consumption decreases of 268.30 to 206.68 will be accompanied by an increase from 65.29 to 73.94. Houses will see an increase in efficiency from 61.28 to 79.20, with a decrease in energy consumption from 268.74 to 143.37. With bungalows and houses revealing the most consumption levels decrease, all of the property types have improved energy efficiency and decreased energy consumption. maisonettes and apartments demonstrate good improvements on both efficiency and energy consumption.

### Key Insights:

- The potential energy efficiency of all property types is higher than current efficiency, and with the right improvements, performance can be significantly increased.
- Energy consumption in all properties is actively decreasing when moving from current to potential levels, with the largest reductions seen in bungalows and houses in particular.
- Current CO<sub>2</sub> emissions are higher than potential emissions in all properties, showing that energy-efficiency improvements directly reduce environmental impact.
- The potential for efficiency improvements and energy consumption reduction benefits is clearly visible in all property types: apartments, bungalows, maisonettes and houses.
- Regardless of property type, efficiency improvements are universally beneficial, providing strong opportunities for energy savings and CO<sub>2</sub> reductions.

### 3.7. Efficiency Target Tracking



The “Efficiency Target Tracking” visual shows the current average efficiency gain (%) relative to that target, assuming a targeted improvement of 20%. Here, we use a gauge chart to clearly show whether current progress is approaching or falling behind the target. The purpose of this visualization is to monitor and analyze energy efficiency targets in one place. By comparing the current value of the gauge to the target value, stakeholders can easily identify,

- whether the property is on track to meet the targets,
- whether there are areas of low performance that are below target,
- whether there are results that exceed expectations.

The importance of this visualization is that it provides a quick, high-level overview. This simplifies decision-making, creates a way to monitor progress on schedule, helps prioritize interventions when needed, and makes a lasting contribution to successfully achieving long-term energy efficiency goals.

### DAX Used:

We created this measure to calculate the percentage improvement in energy efficiency by comparing average potential efficiency and average current efficiency.

```
Efficiency_Gain_% =  
DIVIDE(  
    (AVERAGE('certificate'[POTENTIAL_ENERGY_EFFICIENCY]) -  
    AVERAGE('certificate'[CURRENT_ENERGY_EFFICIENCY])),  
    AVERAGE('certificate'[CURRENT_ENERGY_EFFICIENCY]),  
    0  
) * 100
```

Efficiency target

```
Efficiency_Target = 20
```

Max efficiency gain

```
Max_Efficiency_Gain = 40
```

Min efficiency gain

```
Min_Efficiency_Gain = 0
```

### 3.8. Card Visualization

Within this dashboard, we created two card visualizations using advanced Dax code that allow users to quickly identify essential information without complex visualizations or too much hassle. They are called Average Energy Cost Saving and CO2 Reduction Potential.

#### ➤ Average Energy Cost Saving

This card visual represents “Average Energy Cost Savings”. It is calculated using a DAX measure that adds up current energy costs and subtracts the total potential cost reduction. This visual shows how much money could be saved on energy bills if all properties were to reach their best energy efficiency. Three slices have been added: “*Property Type*”, “*Building Model*”, and “*Transaction Type*” to allow users to examine and filter how much energy cost savings vary by property category. The importance of this visualization is to provide a quick and clear overview of the financial benefits of energy efficiency improvements. It gives property managers and stakeholders a powerful guide to identifying the property categories that offer the most savings, making data-driven decisions to reduce costs and promoting sustainable energy usage patterns across Manchester’s property sector.

#### DAX Used:

```
Avg_Energy_Cost_Savings =  
(  
    SUM('certificate'[LIGHTING_COST_CURRENT])) +  
    SUM('certificate'[HEATING_COST_CURRENT])) +  
    SUM('certificate'[HOT_WATER_COST_CURRENT]))  
-  
(  
    SUM('certificate'[LIGHTING_COST_POTENTIAL])) +  
    SUM('certificate'[HEATING_COST_POTENTIAL])) +  
    SUM('certificate'[HOT_WATER_COST_POTENTIAL]))
```

#### ➤ CO2 Reduction Potential.

This card visual represents “CO<sub>2</sub> reduction potential”. This visual shows how much carbon dioxide could be reduced if all properties reached their best energy efficiency. It also includes three slices: “Property Type”, “Building Model”, and “Transaction Type”, allowing users to easily examine how much the emission reduction potential varies by different property categories. This measure calculates using DAX measure by subtracting current CO<sub>2</sub> emissions from potential CO<sub>2</sub> emissions

#### DAX Used:

```
CO2_Reduction_Potential =  
SUM('certificate'[CO2_EMISSIONS_CURRENT])) -  
SUM('certificate'[CO2_EMISSIONS_POTENTIAL]))
```

### 3.9. Slicer

- Property Type

Filter data by property types

- Building Model

Filter data by building forms

- Transaction Type

Filter data by transaction types

## 4. Conclusion

By analysing Manchester's Energy Performance Certificate (EPC) data, a comprehensive understanding of the relationships between property characteristics, energy efficiency and carbon emissions, and the differences between building types, is provided. The dashboard, created using SQL Server and Power BI, enables the easy identification and assessment of potential improvements that are more efficient, taking into account the current energy situation, demand and environmental impacts.

The data analysis shows that: high-efficiency properties produce lower CO<sub>2</sub> emissions and lower energy consumption, confirming that the greatest opportunities for improvement exist in houses and larger dwelling types. The comparison of current and potential measurements shows that all property categories can benefit from targeted improvements and reduce CO<sub>2</sub> emissions and energy consumption.

By simultaneously demonstrating efficiency potential, energy flow patterns and target tracking indicators, this project reinforces the need for continued investment in energy renovation strategies across Manchester's housing stock. This will enable data-driven decision-making, prioritization of interventions, and increased progress towards long-term sustainability goals.