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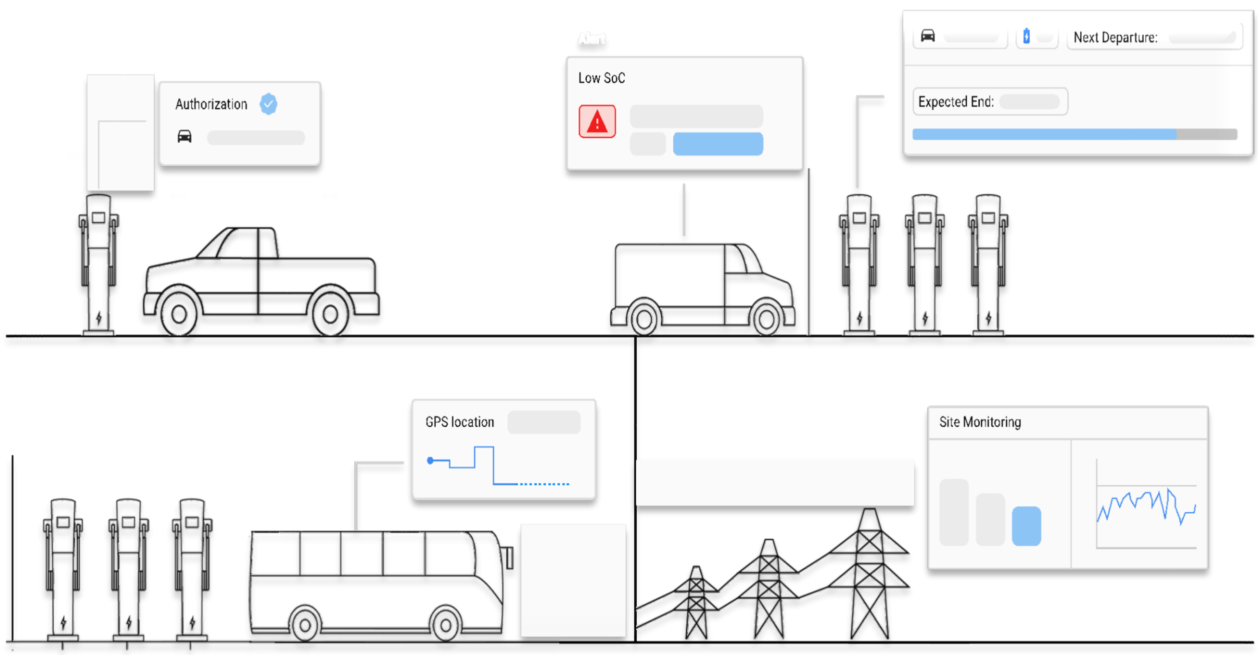
Exploratory Data Analysis For Charging Events



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Executive Summary:

This report highlights key findings of elaborate analysis of charging patterns of the charging stations based on the meter readings of charging events.

Tools Used:

- Python
- Tableau

Metadata:

- **Start Time**: Indicates when the charging session began.
- **Meter Start (Wh)**: Initial meter reading (in watt-hours) at the start of the charging session.
- **Meter End (Wh)**: Meter reading (in watt-hours) at the end of the charging session.
- **Meter Total (Wh)**: Total energy consumed (difference between Meter End and Meter Start).
- **Total Duration (s)**: Duration of the charging session in seconds.
- **Charger Name**: Identifier for the charger used during the session.

Data Quality:

The dataset is very clean with no duplicates, no missing values and requiring only change of data type for : **'Start Time', 'Meter Start (Wh)'** and **'Total Duration (s)'** to date-time, float and integer data types.

Data Exploration:

Summary Statistics:

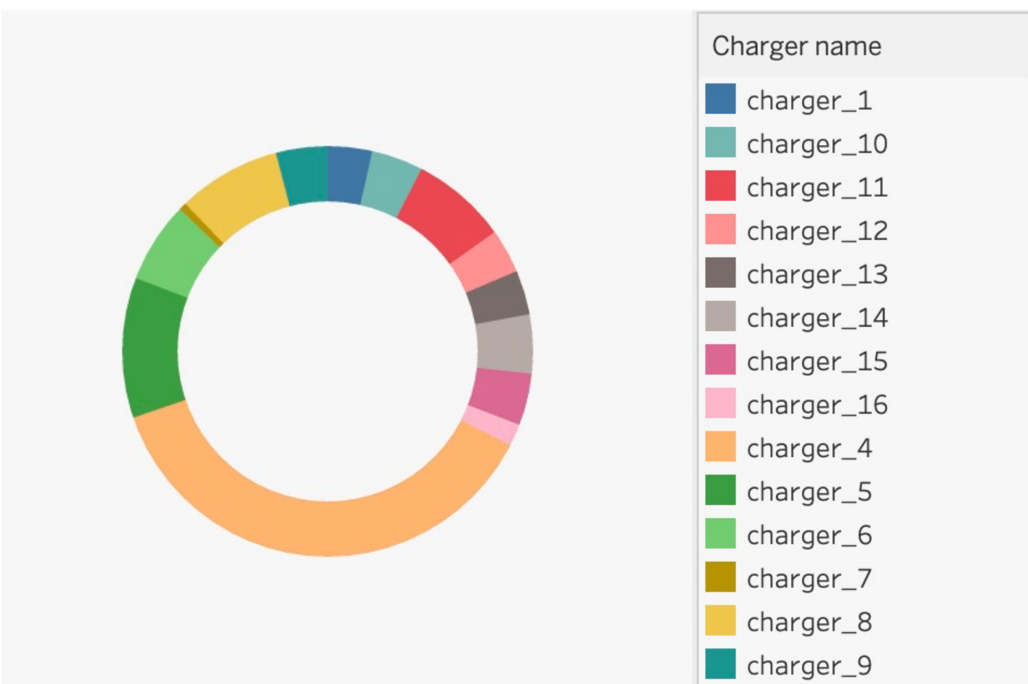
	count	mean	std	min	25%	50%	75%	max
Meter Start (Wh)	277.0	396887.462094	391277.203509	0.0	69009.00	193200.00	743048.00	1204911.00
Meter End(Wh)	277.0	403084.778412	389237.148731	0.0	78665.92	200728.79	750827.79	1204934.59
Meter Total(Wh)	277.0	6197.316318	12260.182878	0.0	0.00	1380.28	6822.50	126350.92
Total Duration (s)	277.0	96510.050542	347270.571069	0.0	12.00	5704.00	73439.00	3020411.00

1. **Meter Start (Wh) and Meter End (Wh)**:
   - **Range of Values**: Both "Meter Start (Wh)" and "Meter End (Wh)" have a wide range of values, from 0 to over 1.2 million watt-hours (Wh). This suggests a diverse set of starting and ending points for energy consumption.
   - **High Variability**: The large standard deviations (over 390,000 Wh) indicate substantial variability or dispersion in the readings. This could be due to different types of equipment or varying energy consumption patterns across different periods or locations.
2. **Meter Total (Wh)**:
   - **Distribution of Consumption**: The average "Meter Total (Wh)" is relatively low compared to the maximum value, indicating that while some periods or instances have very high energy consumption, the typical or median consumption is much lower.
   - **Presence of Zero Values**: The minimum value of 0.0 Wh suggests there are events where no energy was consumed during a specific interval. This could be due to equipment being offline or periods of inactivity.
3. **Total Duration (s)**:
   - **Large Range of Durations**: The duration ranges from 0 seconds to over 3 million seconds (about 33.6 days), suggesting a wide variation in the length of time over which energy consumption is measured.
   - **Significant Spread**: The high standard deviation (over 347,000 seconds) indicates that the duration of energy measurement periods varies widely across records. This could be due to different sampling intervals or irregular recording practices.

Most Recorded Charging Events(Ranked):

charging events by station ID in descending order based on the number of charging events:

1. charger_4 (77)
2. charger_3 (35)
3. charger_2 (28)
4. charger_8 (27)
5. charger_5 (22)
6. charger_11 (13)
7. charger_6 (11)
8. charger_14 (8)
9. charger_10, charger_15, charger_9 (7)
10. charger_13, charger_12, charger_1 (6)
11. charger_16 (3)
12. charger_7 (1)



Most Energy Used(Ranked):

	Charger_name	Total Energy Consumed (Wh)
10	charger_4	404819.65
9	charger_3	226032.37
8	charger_2	186637.08
2	charger_11	185106.91
14	charger_8	168793.67
0	charger_1	145516.29
11	charger_5	84789.69
6	charger_15	80936.71
7	charger_16	44271.07
3	charger_12	38922.82
16	nan	38895.03
12	charger_6	34273.86
5	charger_14	28703.39
1	charger_10	24983.66
15	charger_9	10685.30
4	charger_13	8409.48
13	charger_7	4879.64

Insights:

1. **High Energy Consumption vs. Charging Events**:
   - **Top Energy Consumers**: Charger stations like "charger_4" and "charger_3" are among the highest energy consumers, with 404,819.65 Wh and 226,032.37 Wh respectively. These stations likely handle a significant load of energy-intensive charging sessions.
   - **High Charging Events**: Interestingly, "charger_4" also has the highest number of charging events (77), indicating that it not only consumes a lot of energy but also hosts many charging sessions. This suggests high utilization and popularity of this charger.
2. **Energy Efficiency and Utilization**:
   - **Chargers with High Energy Consumption and Moderate Events**: Stations like "charger_2" and "charger_8" exhibit relatively high energy consumption (186,637.08 Wh and 168,793.67 Wh) paired with a moderate number of charging

events (28 and 27). This could indicate efficient utilization of energy per charging event.

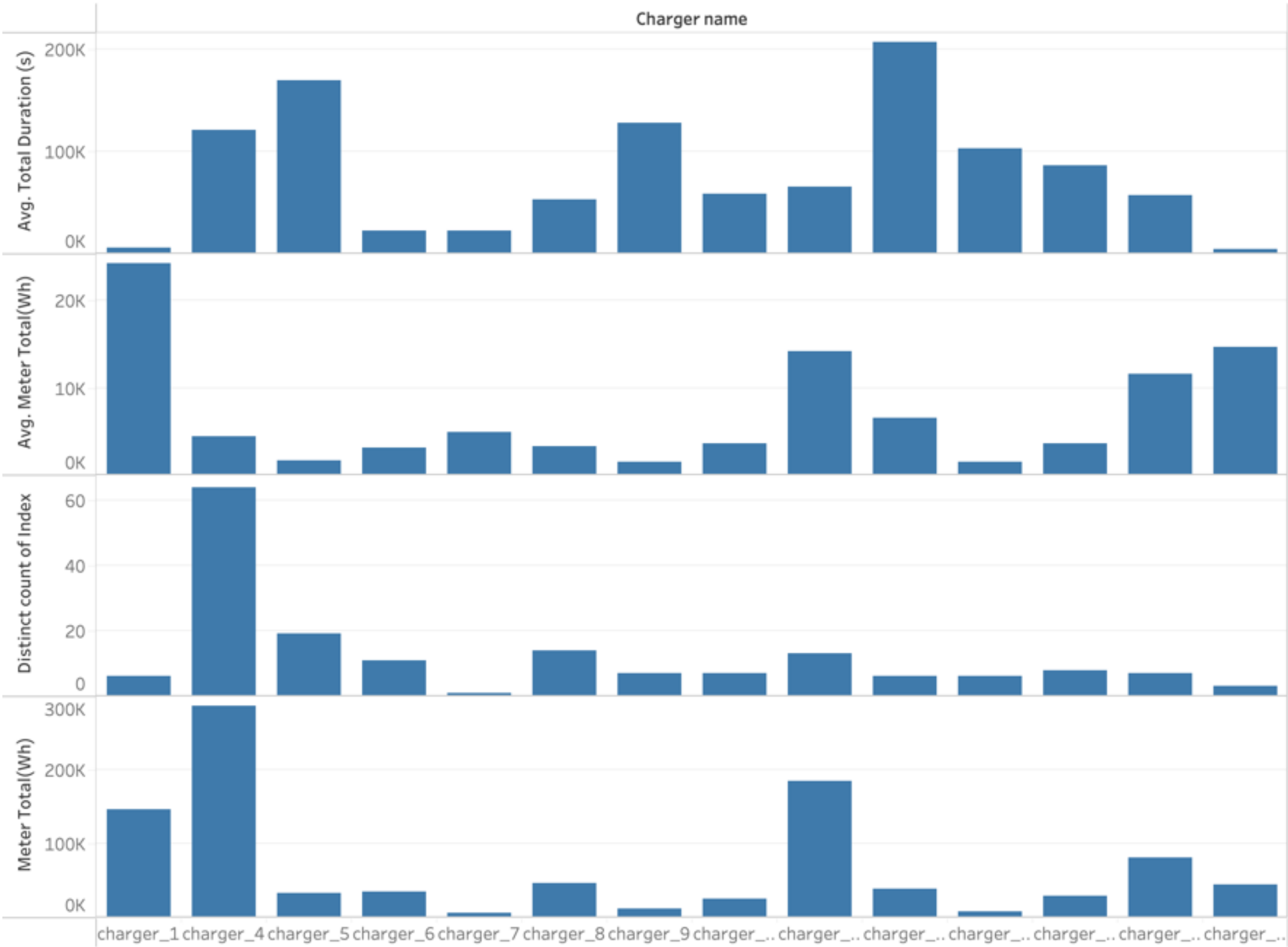
3. **Low Energy Consumption vs. Charging Events**:
    - **Low Consumption, High Events**: Some stations like "charger_7" and "charger_13" have low energy consumption (4,879.64 Wh and 8,409.48 Wh) but also a low number of charging events (1 and 6). This might suggest underutilization of these stations relative to their energy capacity.
4. **Comparative Analysis**:
    - **Insights from Combined Data**: Combining energy consumption with the number of charging events provides a more holistic view of charger station performance.
    - **Identifying Efficiency**: Stations with a high number of charging events relative to their energy consumption are likely more efficient in terms of utilization.

Observations:

- **Popular Chargers**: Charger stations like "charger_4", "charger_3", and "charger_2" stand out both in terms of energy consumption and charging events, indicating high demand and utilization.
- **Underutilized Chargers**: Stations with low energy consumption and charging events may require further investigation to understand reasons for low usage, such as location, accessibility, or service quality.
- **Efficiency Metrics**: Comparing energy consumption against the number of charging events helps identify stations that efficiently manage energy resources while meeting demand.

Recommendations:

- **Performance Optimization**: Focus on optimizing charging operations at high-demand stations to ensure efficient use of energy resources.
- **Service Improvement**: Investigate underutilized stations to identify potential improvements in accessibility or service quality to increase usage.
- **Data-Driven Decisions**: Use insights from energy consumption and charging events to guide infrastructure planning and resource allocation for charging station networks.



Chargers to Investigate for Efficiency or Faults:

1. **charger_7**:
   - **Energy Consumed**: 4,879.64 Wh
   - **Charging Events**: 1
   - **Analysis**: This charger has very low energy consumption coupled with an extremely low number of charging events (1). It appears highly underutilized, which may indicate potential issues like location, accessibility, or technical faults.
2. **charger_13**:
   - **Energy Consumed**: 8,409.48 Wh
   - **Charging Events**: 6
   - **Analysis**: Despite a slightly higher energy consumption than charger_7, charger_13 also has a low number of charging events (6). This station could be another candidate for investigation regarding underutilization or possible faults.
3. **charger_1**:
   - **Energy Consumed**: 145,516.29 Wh
   - **Charging Events**: 6

    - **Analysis**: With a significantly higher energy consumption compared to chargers 7 and 13, charger_1's low number of charging events (6) suggests potential inefficiency or issues attracting users despite higher energy availability.

Factors to Consider:

- **Underutilization**: Chargers with disproportionately low charging events relative to their energy consumption are candidates for further investigation into utilization patterns, user experience, or infrastructure issues.
- **Technical Faults**: Stations with consistently low usage despite reasonable energy availability could indicate underlying technical faults or operational issues affecting performance.

Recommendations for Investigation:

1. **Site Visit and Inspection**: Conduct a physical inspection of chargers like charger_7, charger_13, and potentially charger_1 to assess their operational condition and identify any visible faults or issues.
2. **User Feedback and Analysis**: Gather feedback from users regarding these chargers to understand potential barriers to usage, such as location inconvenience, reliability concerns, or service quality.
3. **Performance Monitoring**: Implement a monitoring system to track charging activity and energy consumption over time to detect anomalies or persistent low usage patterns that may indicate technical problems.

Months in Demand:

	Month	Charging Events
2	January	41
10	February	12
5	March	17
9	April	13
8	May	13
11	June	6
6	July	15
0	August	55
1	September	47
7	October	15
3	November	22
4	December	21

Insights:

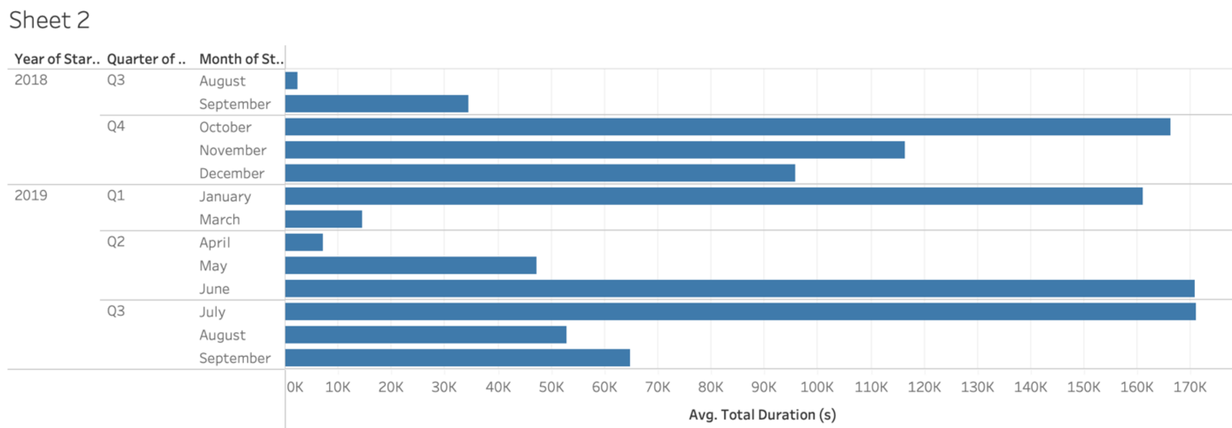
1. **Peak Demand Months**:
    - **August (55 Charging Events)**: August exhibits the highest number of charging events, indicating peak demand for electric vehicle charging during this month.
    - **September (47 Charging Events)**: September follows closely behind August, also experiencing high demand for charging.

This could be due to cars being driven more during winter months for longer amounts of time or for a longer duration and hence requiring charging stations to be on their toes.

2. **Off-Peak or Low Demand Months**:
    - **June (6 Charging Events)**: June shows the lowest number of charging events among all months, indicating a period of low demand or usage for charging stations.
    - **February (12 Charging Events)**, **April (13 Charging Events)**, **May (13 Charging Events)**: These months also demonstrate lower demand compared to peak months like August and September.
3. **Comparison with Start Time Analysis**:
    - The analysis provides additional context by identifying the specific months when charging activity is highest and lowest based on the timestamps of charging events.
    - The months with the highest number of charging events align with the identified peak demand months from the start time data, such as August and September.
    - Conversely, the months with lower charging events, like June, correlate with periods of lower demand observed from the data.

Recommendations:

1. **Resource Allocation**:
    - Allocate resources and staffing based on seasonal demand patterns. Focus additional resources during peak months (e.g., August, September) to ensure optimal service and availability.
2. **Infrastructure Planning**:
    - Use insights from peak and off-peak months to guide infrastructure planning for charging stations. Consider expanding or optimizing capacity in high-demand months and evaluating cost-effective measures for low-demand periods.
3. **Promotions and Incentives**:
    - Implement targeted promotions or incentives during off-peak months to encourage usage and balance demand throughout the year.
4. **Maintenance and Service**:
    - Schedule maintenance and service activities during periods of lower demand to minimize disruptions and optimize operational efficiency.



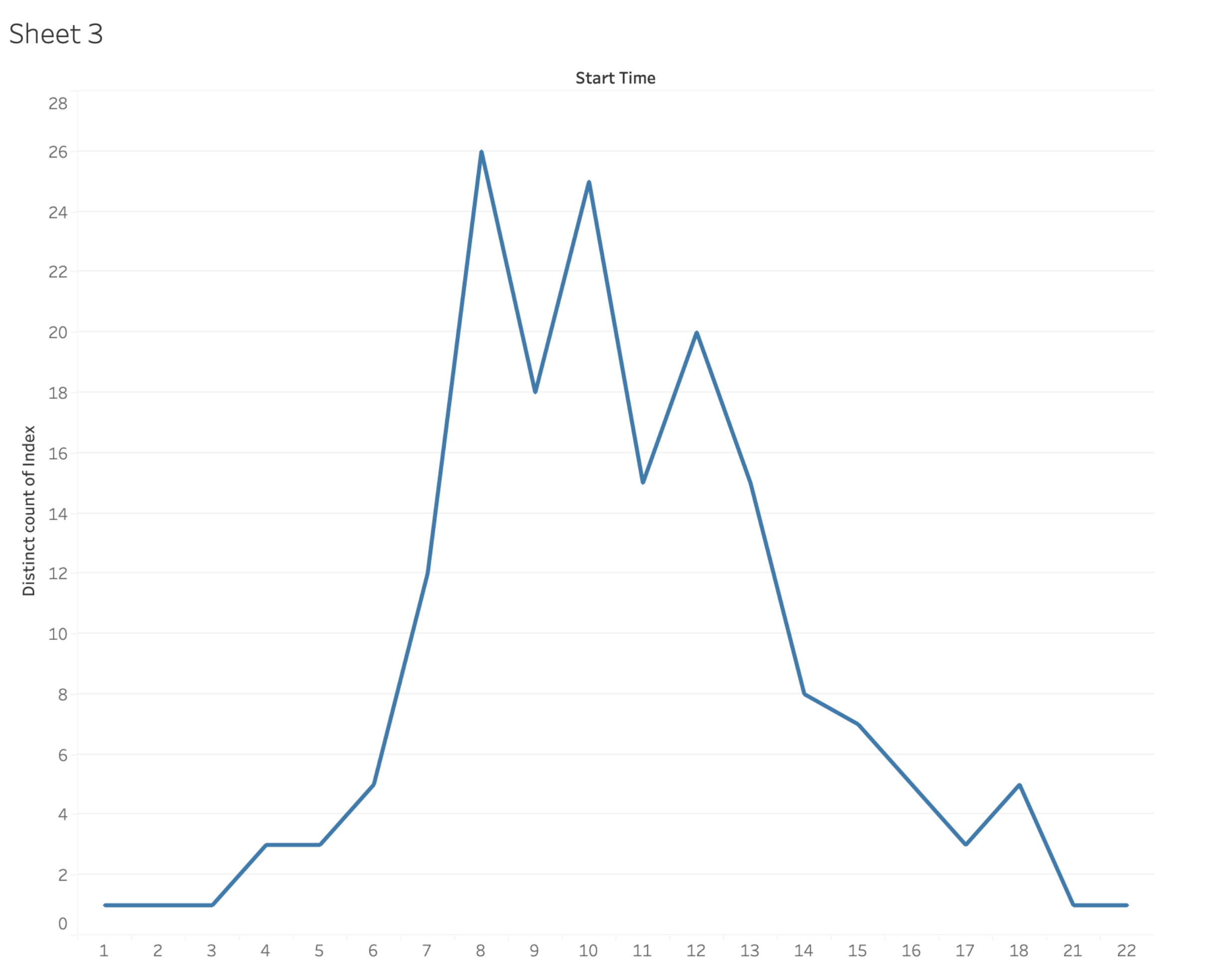
Peak hours of the day(Including 'nan' values)**:**

```
Hourly Distribution of Charging Events:
                                                                 Out[42]:
1      1
2      1
3      1
4      3
5      5
6     15
7     26
8     34
9     34
10    38
11    27
12    25
13    22
14    10
15    10
16     6
17     6
18     5
20     3
21     4
22     1
```

```
The hour with the highest demand is 10:00 with 38 charging events.
The hour with the lowest demand is 1:00 with 1 charging events.
```

- The charging demand starts to increase gradually from early morning (4 AM) and peaks around 10 AM.
- After 10 AM, the number of charging events remains relatively high until early evening (around 5 PM), indicating consistent demand during daytime hours.
- There is a noticeable decrease in charging events during late evening and night hours, with only a few events occurring past 8 PM.
- This is expected as residents would be home and use the charging stations at home to charge their vehicles

Without 'nan' Values:



Conclusion:

1. **Energy Consumption by Chargers:**
    - Charger_4 consumes the highest total energy (404819.65 Wh), indicating it's a high-demand charger.

    - Chargers with lower energy consumption, such as charger_7 and charger_13, might be less efficient or have lower usage rates.
2. **Charging Events by Station:**
    - Charger_4 has the highest number of charging events (77), followed by charger_3 (35) and charger_2 (28), indicating these stations are popular and in high demand.
    - Chargers like charger_7 and charger_16 have very low charging events (1 or 3), suggesting they may be less efficient or have lower usage due to location or other factors.
3. **Monthly Demand for Charging:**
    - August (Month 0) has the highest number of charging events (55), followed by September (47) and January (41), indicating higher demand during these months.
    - June (Month 11) has the lowest number of charging events (6), suggesting lower demand during this period.
4. **Hourly Distribution of Charging Events:**
    - The hour with the highest demand is 10:00 (10 AM) with 38 charging events, indicating peak demand during this time.
    - Early morning hours (1 AM to 4 AM) and late-night hours (after 8 PM) have very low charging events, suggesting lower usage during these times.

Insights and Recommendations:

- **Efficiency and Maintenance:** Chargers with consistently low energy consumption and charging events (e.g., charger_7, charger_16) should be assessed for efficiency and maintenance to ensure optimal performance and usage.
- **Demand Analysis:** Understanding the monthly and hourly patterns of charging demand can help optimize resource allocation and scheduling. For example, additional resources could be deployed during peak hours (e.g., 10 AM) and months of higher demand (e.g., August, September).
- **Service Improvement:** Analyzing the charging data can guide improvements in charging station locations, hours of operation, and service offerings to better match demand patterns.