Smart Grid Management

A Case Study on EV Growth in India

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Problem Statement

India's traditional electricity grid struggles to meet the rising demand from EVs and the fluctuating supply of renewable energy.

This leads to grid instability, inefficiencies, and limited capacity for sustainable energy integration.

Without modernization, the grid risks failing to support future energy needs.

Current Energy Scenario and Future Trend in India

Current Energy Scenario in India (2023):

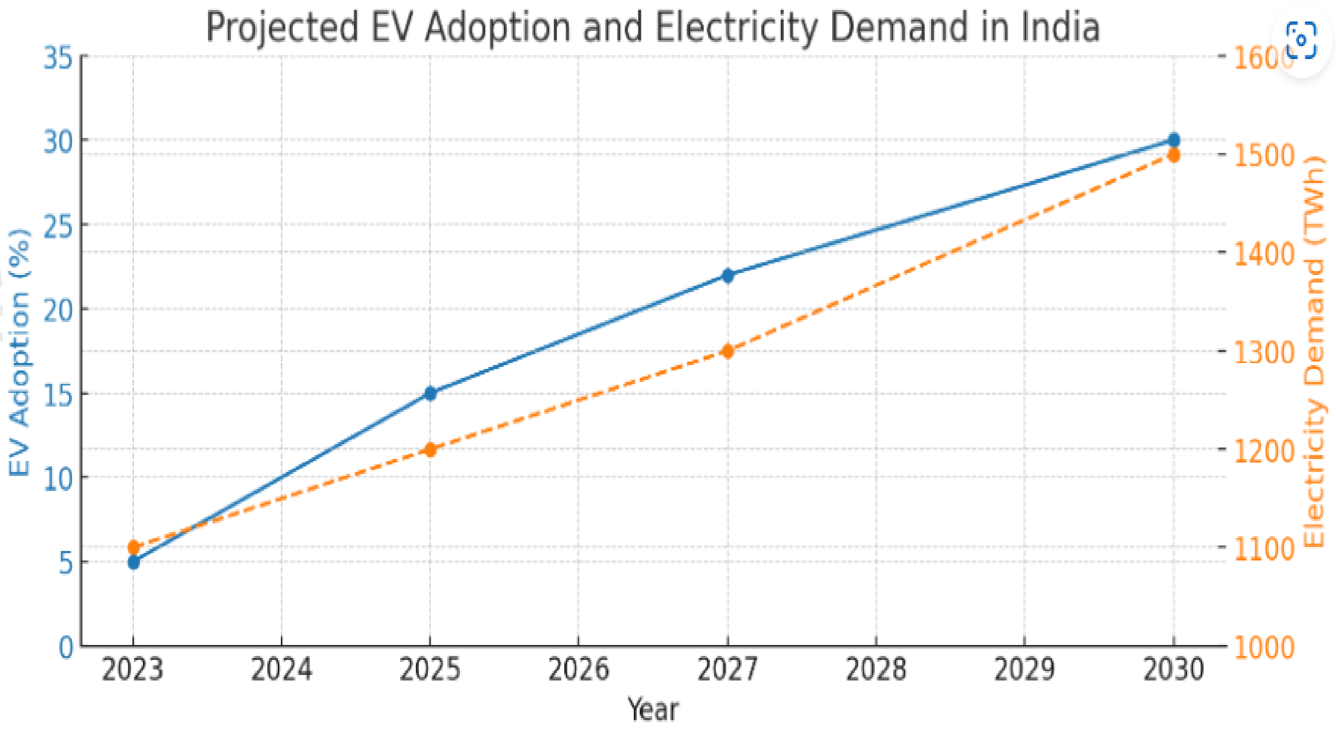
The graph shows that India's electricity mix is predominantly dependent on coal (60%) and renewables (30%).

This highlights the challenge of integrating more renewable energy to support future EV demand.

Future Energy Demand & EV Growth (2023-2030):

The blue line represents the projected growth in EV adoption, reaching 30% by 2030.

The orange dashed line shows the corresponding increase in electricity demand, reaching 1500 TWh, a 20% rise over current demand.



What is Smart Grid Management?

Smart Grid management system is an emerging technology that utilizes machine learning algorithms for efficient distribution and management of electric energy, especially with the increasing adoption of electric vehicles (EVs).

Why Smart Grid Management?

It enables real-time load balancing, optimizes EV charging schedules, and integrates vehicle -to-grid (V2G) technology to enhance grid stability

In the context of managing Electric Vehicle (EV) demands through a Smart Grid, the electrical towers themselves play a supportive role in the overall grid management by ensuring stable electricity transmission and integration of various systems. However, managing EV charging demands involves a combination of smart grid technologies, real-time data management, and coordination across different grid components, including transmission towers, smart meters, and charging stations .

Dynamic Load Balancing

Challenge: EVs add to the overall electricity demand, particularly during peak hours, leading to potential grid overloads.-

Solution:

Real-Time Data Collection: Transmission towers equipped with sensors can monitor power flow, and smart meters at the charging stations can send data about local consumption.

Load Forecasting: By analyzing the data, utilities can predict when and where EV charging is likely to surge, allowing for load balancing .

Dynamic Load Distribution: The system can adjust power distribution through substations and transmission lines , shifting the load to less-congested areas, and preventing grid instability.

Automated Demand Response (ADR): EV chargers can be programmed to delay or adjust charging based on grid demand (e.g., charge during off-peak hours).

Smart Charging Strategies (Time-of-Use Pricing)

Challenge: EVs, especially with high adoption rates, can cause grid strain if all vehicles charge at once.-

Solution:

Time-of-Use (TOU) Pricing:

Smart meters can offer *different electricity rates* throughout the day, encouraging EV owners to charge their vehicles during off-peak hours when electricity demand and prices are lower

<u>Smart Charging Stations:</u> These stations can be integrated with the Smart Grid Management System to automatically adjust charging schedules based on the grid's real-time demand.

<u>Grid-Connected EVs (Vehicle-to-Grid, V2G):</u> Charging stations can allow EVs to not only charge but also return energy to the grid during high-demand periods, helping to stabilize the grid.

Real-Time Monitoring and Fault Detection -

Challenge: EV charging and grid infrastructure could be vulnerable to power fluctuations, particularly during high-demand periods.

Solution:

Fault Detection: Sensors on transmission towers and in the grid can detect any abnormalities caused by EV charging loads, such as overloading of transformers or transmission lines.

Self-Healing Networks: Using automated systems within the Smart Grid, the grid can self-heal by rerouting power around faulty or stressed parts of the system, ensuring uninterrupted power to critical areas like EV charging stations.

EV Charging Station Placement and Infrastructure Design

Challenge: Uneven distribution of EV charging stations can cause localized grid stress.-

Solution:

Optimal Placement: Using real-time data from the smart grid, the placement of charging stations can be optimized to ensure even distribution of demand, reducing the risk of overloading specific areas of the grid.

Smart Grid Integration at Charging Stations: Charging stations can be integrated with the grid's management system to prioritize or stagger charging times, preventing simultaneous charging surges.

5. Communication and Coordination

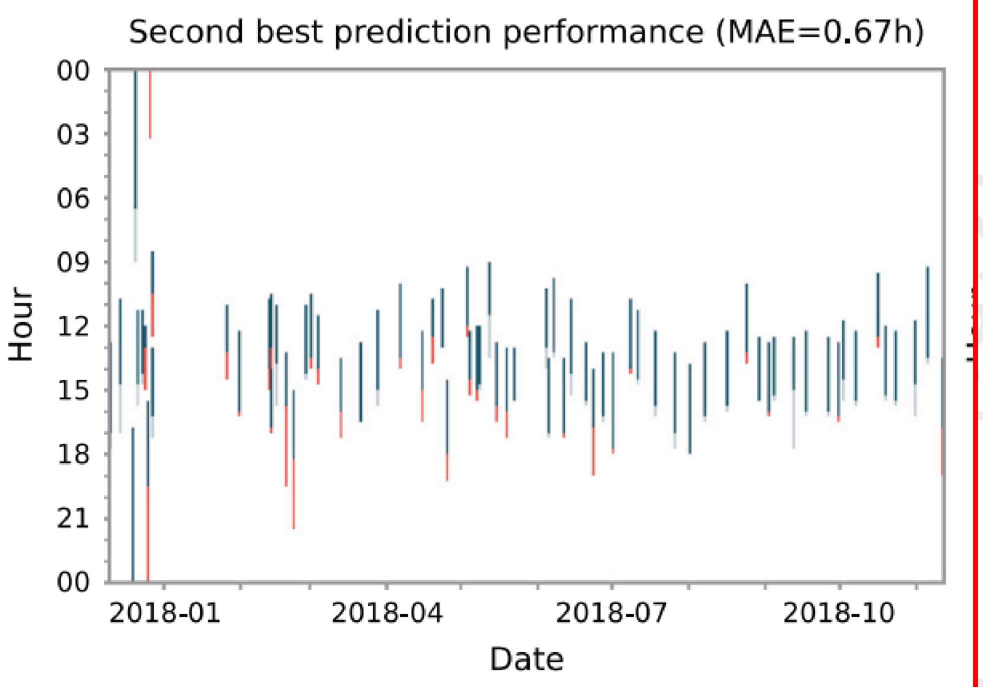
Challenge: Managing the interactions between various EVs, charging stations, and the grid.

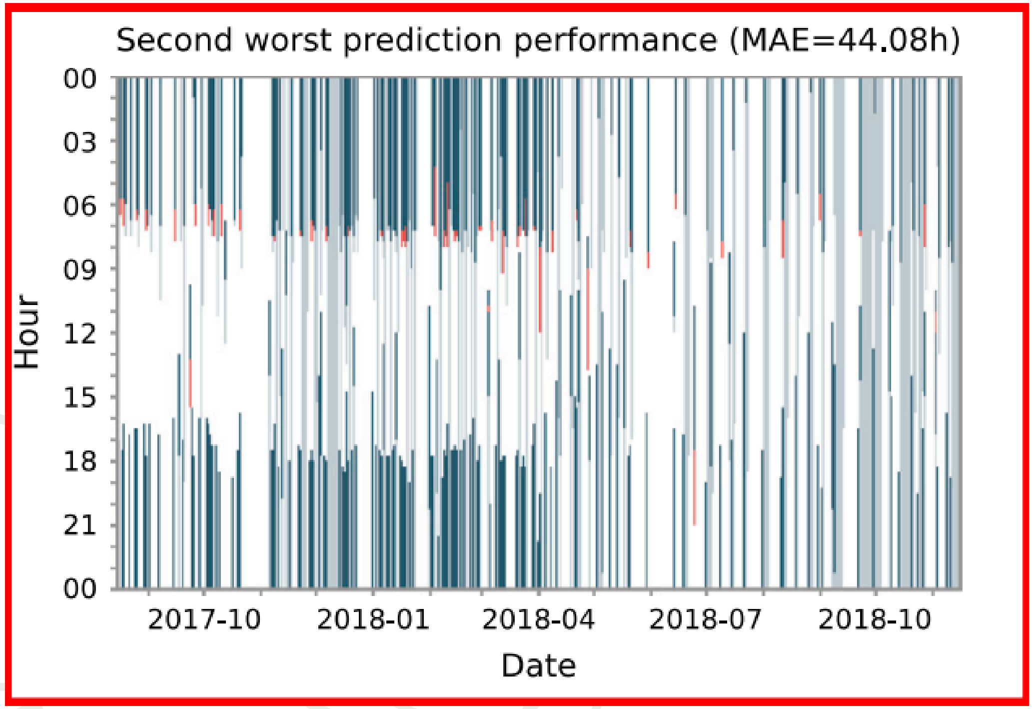
Solution:

Advanced Communication Networks: Transmission towers and the grid's infrastructure rely on wireless communication networks (e.g., 5G, fiber optics) to share data.

Consumer Communication: EV owners can receive notifications via apps or smart devices to charge during off-peak hours or adjust charging patterns based on grid signals.

Best and Worst Predictions





Input Dataset

This dataset consist charging session data for each unique user given an unique identity

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB
1	StartTime	StopTime	ParticipantID	ConsumedkW	CarKW	CarKWh	PluggedInTim	ChargingDura	Duration	weekday	weekend	holiday	Mon	Tue	Wed	Thu	Fri	Sat	Sun	month	StartHour	StartHourNorm	StartCos	StartSin	TimeSinceLas	sessionsToda	LastDuration	LastConsumedkWh
2	2017-03-02 18:13:00+00:00	2017-03-02 18:42:00+00:00	EN1041	1.7	3.6	24	29		0.48333333	1	0	0	0	0	0	1	0	0	0	3	18.2166667	0.75955525	0.06000132	-0.9981983	11.0333333	0	11.2666667	21.13
3	2017-03-02 21:51:00+00:00	2017-03-03 06:53:00+00:00	EN1041	25.71	3.6	24	542		9.03333333	1	0	0	0	0	0	1	0	0	0	3	21.85	0.91104934	0.84784236	-0.53024837	3.15	1	0.48333333	1.7
4	2017-03-03 18:59:00+00:00	2017-03-03 19:54:00+00:00	EN1089	3.43	3.6	6.2	55		0.91666667	1	0	0	0	0	0	0	1	0	0	3	18.9833333	0.79152189	0.25794028	-0.96616086	0.21666667	0	2.18333333	6.18
5	2017-03-03 21:14:00+00:00	2017-03-04 11:12:00+00:00	EN1089	5.47	3.6	6.2	838	82	13.9666667	1	0	0	0	0	0	0	1	0	0	3	21.2333333	0.88533704	0.75150984	-0.65972189	1.33333333	1	0.91666667	3.43
6	2017-03-03 22:06:00+00:00	2017-03-04 10:30:00+00:00	EN1041	25.63	3.6	24	744		12.4	1	0	0	0	0	0	0	1	0	0	3	22.1	0.92147325	0.88072851	-0.47362147	15.2166667	0	9.03333333	25.71
7	2017-03-04 16:43:00+00:00	2017-03-04 21:31:00+00:00	EN1089	5.31	3.6	6.2	288	8	4.8	0	1	0	0	0	0	0	0	1	0	3	16.7166667	0.69701181	-0.32681788	-0.94508734	5.51666667	0	13.9666667	5.47
8	2017-03-05 11:18:00+00:00	2017-03-05 14:04:00+00:00	EN1041	9.83	3.6	24	166		2.76666667	0	1	0	0	0	0	0	0	0	1	3	11.3	0.47116053	-0.98362747	0.18021374	24.8	0	12.4	25.63
9	2017-03-05 17:39:00+00:00	2017-03-06 06:57:00+00:00	EN1041	21.87	3.6	24	798		13.3	0	1	0	0	0	0	0	0	0	1	3	17.65	0.73592773	-0.08830353	-0.99609361	3.58333333	1	2.76666667	9.83
10	2017-03-05 18:27:00+00:00	2017-03-06 12:24:00+00:00	EN1089	5.16	3.6	6.2	1077	85	17.95	0	1	0	0	0	0	0	0	0	1	3	18.45	0.76928423	0.1208701	-0.99266833	20.9333333	0	4.8	5.31
11	2017-03-06 13:43:00+00:00	2017-03-06 14:38:00+00:00	EN1089	3.48	3.6	6.2	55		0.91666667	1	0	0	1	0	0	0	0	0	0	3	13.7166667	0.57192495	-0.89961128	-0.43669159	1.31666667	0	17.95	5.16
12	2017-03-06 16:25:00+00:00	2017-03-07 11:07:00+00:00	EN1089	4.74	3.6	6.2	1122	43	18.7	1	0	0	1	0	0	0	0	0	0	3	16.4166667	0.68450313	-0.40001113	-0.91651028	1.78333333	1	0.91666667	3.48
13	2017-03-06 17:50:00+00:00	2017-03-07 06:21:00+00:00	EN1041	15.59	3.6	24	751		12.5166667	1	0	0	1	0	0	0	0	0	0	3	17.8333333	0.74357192	-0.04037781	-0.99918448	10.8833333	0	13.3	21.87
14	2017-03-07 12:01:00+00:00	2017-03-07 22:22:00+00:00	EN1089	3.86	3.6	6.2	621	82	10.35	1	0	0	0	1	0	0	0	0	0	3	12.0166667	0.50104239	-0.99997855	-0.00654949	0.9	0	18.7	4.74
15	2017-03-07 20:51:00+00:00	2017-03-08 07:17:00+00:00	EN1041	17.76	3.6	24	626		10.4333333	1	0	0	0	1	0	0	0	0	0	3	20.85	0.86935372	0.68158134	-0.73174236	14.5	0	12.5166667	15.59
16	2017-03-07 23:11:00+00:00	2017-03-08 11:21:00+00:00	EN1089	5.54	3.6	6.2	730	73	12.1666667	1	0	0	0	1	0	0	0	0	0	3	23.1833333	0.9666435	0.97811733	-0.20805405	0.81666667	1	10.35	3.86
17	2017-03-08 16:45:00+00:00	2017-03-08 16:54:00+00:00	EN1089	0.47	3.6	6.2	9		0.15	1	0	0	0	0	1	0	0	0	0	3	16.75	0.69840167	-0.31855235	-0.94790527	5.4	0	12.1666667	5.54
18	2017-03-08 16:54:00+00:00	2017-03-08 23:19:00+00:00	EN1089	5.08	3.6	6.2	385	126	6.41666667	1	0	0	0	0	1	0	0	0	0	3	16.9	0.70465601	-0.28106598	-0.95968845	0	1	0.15	0.47
19	2017-03-08 21:08:00+00:00	2017-03-09 06:55:00+00:00	EN1041	23.02	3.6	24	587		9.78333333	1	0	0	0	0	1	0	0	0	0	3	21.1333333	0.88116748	0.73397045	-0.6791814	13.85	0	10.4333333	17.76
20	2017-03-09 18:26:00+00:00	2017-03-09 18:39:00+00:00	EN1041	0.71	3.6	24	13		0.21666667	1	0	0	0	0	0	1	0	0	0	3	18.4333333	0.7685893	0.11653462	-0.99318663	11.5166667	0	9.78333333	23.02
21	2017-03-09 22:30:00+00:00	2017-03-10 06:31:00+00:00	EN1041	24.09	3.6	24	481		8.01666667	1	0	0	0	0	0	1	0	0	0	3	22.5	0.93815149	0.92543829	-0.37889837	3.85	1	0.21666667	0.71
22	2017-03-09 23:44:00+00:00	2017-03-10 12:48:00+00:00	EN1089	5.12	3.6	6.2	784		13.0666667	1	0	0	0	0	0	1	0	0	0	3	23.7333333	0.98957609	0.99785595	-0.06544851	24.4166667	0	6.41666667	5.08
23	2017-03-10 12:22:00+00:00	2017-03-11 10:58:00+00:00	EN1026	8.1	3.6	12	1356		22.6	1	0	0	0	0	0	0	1	0	0	3	12.3666667	0.51563586	-0.99517804	-0.09808504	4.68333333	0	183.883333	10.29
24	2017-03-10 13:46:00+00:00	2017-03-10 14:12:00+00:00	EN1089	1.6	3.6	6.2	26		0.43333333	1	0	0	0	0	0	0	1	0	0	3	13.7666667	0.57400973	-0.89381401	-0.44843785	0.96666667	0	13.0666667	5.12
25	2017-03-10 14:20:00+00:00	2017-03-10 14:57:00+00:00	EN1089	1.35	3.6	6.2	37		0.61666667	1	0	0	0	0	0	0	1	0	0	3	14.3333333	0.59763725	-0.81765355	-0.57571057	0.13333333	1	0.43333333	1.6
26	2017-03-10 17:02:00+00:00	2017-03-11 08:40:00+00:00	EN1119	18.95	7	24	938		15.6333333	1	0	0	0	0	0	0	1	0	0	3	17.0333333	0.71021543	-0.24737861	-0.96891889	4.6	0	0.86666667	5.61
27	2017-03-10 20:12:00+00:00	2017-03-10 20:52:00+00:00	EN1089	2.5	3.6	6.2	40		0.66666667	1	0	0	0	0	0	0	1	0	0	3	20.2	0.84225156	0.54771748	-0.83666335	5.25	2	0.61666667	1.35
28	2017-03-10 21:56:00+00:00	2017-03-11 11:56:00+00:00	EN1089	5.27	3.6	6.2	840		14	1	0	0	0	0	0	0	1	0	0	3	21.9333333	0.91452397	0.85921566	-0.51161357	1.06666667	3	0.66666667	2.5
29	2017-03-10 22:15:00+00:00	2017-03-11 07:03:00+00:00	EN1030	13.94	7	33	528		8.8	1	0	0	0	0	0	0	1	0	0	3	22.25	0.92772759	0.89865576	-0.43865456	1.25	0	0.78333333	5.79
30	2017-03-10 23:11:00+00:00	2017-03-11 10:43:00+00:00	EN1041	17.69	3.6	24	692		11.5333333	1	0	0	0	0	0	0	1	0	0	3	23.1833333	0.9666435	0.97811733	-0.20805405	16.6666667	0	8.01666667	24.09
31	2017-03-11 13:32:00+00:00	2017-03-11 17:52:00+00:00	EN1026	8.59	3.6	12	260		4.33333333	0	1	0	0	0	0	0	0	1	0	3	13.5333333	0.56428075	-0.91954003	-0.39299635	2.56666667	0	22.6	8.1
32	2017-03-11 17:05:00+00:00	2017-03-11 18:32:00+00:00	EN1089	5.38	3.6	6.2	87		1.45	0	1	0	0	0	0	0	0	1	0	3	17.0833333	0.71230021	-0.23466582	-0.9720761	5.15	0	14	5.27
33	2017-03-11 18:08:00+00:00	2017-03-12 10:33:00+00:00	EN1026	0.82	3.6	12	985		16.4166667	0	1	0	0	0	0	0	0	1	0	3	18.1333333	0.75608061	0.03819632	-0.99927025	0.26666667	1	4.33333333	8.59
34	2017-03-11 18:14:00+00:00	2017-03-11 22:29:00+00:00	EN1092	16.3	7	33	255		4.25	0	1	0	0	0	0	0	0	1	0	3	18.2333333	0.76025017	0.06435923	-0.9979268	8.08333333	0	12.2166667	23.93
35	2017-03-11 19:23:00+00:00	2017-03-11 19:46:00+00:00	EN1089	1.4	3.6	6.2	23		0.38333333	0	1	0	0	0	0	0	0	1	0	3	19.3833333	0.80820014	0.35758652	-0.93388001	0.85	1	1.45	5.38
36	2017-03-11 20:14:00+00:00	2017-03-12 15:29:00+00:00	EN1030	52.17	7	33	1155		19.25	0	1	0	0	0	0	0	0	1	0	3	20.2333333	0.84364142	0.55500284	-0.83184845	13.1833333	0	8.8	13.94
37	2017-03-12 00:33:00+00:00	2017-03-12 11:24:00+00:00	EN1089	5.27	3.6	6.2	651		10.85	0	1	0	0	0	0	0	0	0	1	3	0.55	0.02293259	0.98963702	0.14359165	4.78333333	0	0.38333333	1.4
38	2017-03-12 14:00:00+00:00	2017-03-12 14:19:00+00:00	EN1026	0.83	3.6	12	19		0.31666667	0	1	0	0	0	0	0	0	0	1	3	14	0.58373871	-0.86474908	-0.50220418	3.45	0	16.4166667	0.82
39	2017-03-12 14:57:00+00:00	2017-03-14 08:28:00+00:00	EN1026	10.04	3.6	12	2491		41.5166667	0	1	0	0	0	0	0	0	0	1	3	14.95	0.62334955	-0.71440139	-0.69973613	0.63333333	1	0.31666667	0.83
40	2017-03-12 15:43:00+00:00	2017-03-13 08:29:00+00:00	EN1030	2.12	7	33	1006		16.7666667	0	1	0	0	0	0	0	0	0	1	3	15.7166667	0.65531619	-0.56043912	-0.82819563	0.23333333	0	19.25	52.17
41	2017-03-12 16:46:00+00:00	2017-03-12 17:59:00+00:00	EN1089	2.72	3.6	6.2	73		1.21666667	0	1	0	0	0	0	0	0	0	1	3	16.7666667	0.69909659	-0.31441043	-0.94928714	5.36666667	1	10.85	5.27
42	2017-03-12 18:22:00+00:00	2017-03-12 18:40:00+00:00	EN1089	1.03	3.6	6.2	18		0.3	0	1	0	0	0	0	0	0	0	1	3	18.3666667	0.76580959	0.0991713	-0.99507038	0.38333333	2	1.21666667	2.72
43	2017-03-12 18:58:00+00:00	2017-03-13 10:47:00+00:00	EN1089	2.75	3.6	6.2	949		15.8166667	0	1	0	0	0	0	0	0	0	1	3	18.9666667	0.79082696	0.25371923	-0.96727791	0.3	3	0.3	1.03
44	2017-03-12 21:05:00+00:00	2017-03-13 08:22:00+00:00	EN1119	17.53	7	24	677		11.2833333	0	1	0	0	0	0	0	0	0	1	3	21.0833333	0.8790827	0.72501109	-0.68873719	36.4166667	0	15.6333333	18.95
45	2017-03-13 14:55:00+00:00	2017-03-13 20:01:00+00:00	EN1089	5.22	3.6	6.2	306		5.1	1	0	0	1	0	0	0	0	0	0	3	14.9166667	0.62195969	-0.72048467	-0.69347087	4.13333333	0	15.8166667	2.75
46	2017-03-13 18:00:00+00:00	2017-03-14 07:02:00+00:00	EN1030	51.51	7	33	782		13.0333333	1	0	0	1	0	0	0	0	0	0	3	18	0.7505212	0.00327476	-0.99999464	9.51666667	0	16.7666667	2.12
47	2017-03-13 20:45:00+00:00	2017-03-14 07:50:00+00:00	EN1092	25.19	7	33	665		11.0833333	1	0	0	1	0	0	0	0	0	0	3	20.75	0.86518416	0.66217936	-0.74934537	46.2666667	0	4.25	16.3
48	2017-03-13 21:34:00+00:00	2017-03-14 10:43:00+00:00	EN1089	4.6	3.6	6.2	789		13.15	1	0	0	1	0	0	0	0	0	0	3	21.5666667	0.89923558	0.80618455	-0.59166416	1.55	1	5.1	5.22
49	2017-03-14 08:30:00+00:00	2017-03-15 07:36:00+00:00	EN1026	0.94	3.6	12	1386		23.1	1	0	0	0	1	0	0	0	0	0	3	8.5	0.35441279	-0.60998756	0.79241099	0.03333333	0	41.5166667	10.04
50	2017-03-14 17:17:00+00:00	2017-03-14 18:24:00+00:00	EN1089	4.16	3.6	6.2	67		1.11666667	1	0	0	0	1	0	0	0	0	0	3	17.2833333	0.72063933	-0.18343392	-0.98303204	6.56666667	0	13.15	4.6

Models Overview

- **1. HistGradientBoostingRegressor**
- Gradient boosting method for regression tasks.
- Efficient with large datasets and categorical features.
- Handles missing values and reduces overfitting.
- **2.MeanValue**
- Predicts the average value of the training target.
- Simple baseline for regression tasks.
- **3. LinearRegression**
- Finds a linear relationship between features and targets.
- Fast, interpretable, and effective for linearly separable data.

Output dataset

By processing a given input dataset through various ML models, we obtain data on the amount of energy used by each unique vehicle over a specified period of time.

	StartTime	StopTime	ParticipantID	ConsumedkWh	CarKW	CarKWh	PluggedInTime	ChargingDuration	Duration
0	2017-03-02 18:13:00+00:00	2017-03-02 18:42:00+00:00	EN1041	1.7	3.6	24	29		0.48333333
1	2017-03-02 21:51:00+00:00	2017-03-03 06:53:00+00:00	EN1041	25.71	3.6	24	542		9.03333333
2	2017-03-03 18:59:00+00:00	2017-03-03 19:54:00+00:00	EN1089	3.43	3.6	6.2	55		0.91666667
3	2017-03-03 21:14:00+00:00	2017-03-04 11:12:00+00:00	EN1089	5.47	3.6	6.2	838	82	13.9666667
4	2017-03-03 22:06:00+00:00	2017-03-04 10:30:00+00:00	EN1041	25.63	3.6	24	744		12.4
5	2017-03-04 16:43:00+00:00	2017-03-04 21:31:00+00:00	EN1089	5.31	3.6	6.2	288	8	4.8
6	2017-03-05 11:18:00+00:00	2017-03-05 14:04:00+00:00	EN1041	9.83	3.6	24	166		2.76666667
7	2017-03-05 17:39:00+00:00	2017-03-06 06:57:00+00:00	EN1041	21.87	3.6	24	798		13.3
8	2017-03-05 18:27:00+00:00	2017-03-06 12:24:00+00:00	EN1089	5.16	3.6	6.2	1077	85	17.95
9	2017-03-06 13:43:00+00:00	2017-03-06 14:38:00+00:00	EN1089	3.48	3.6	6.2	55		0.91666667
10	2017-03-06 16:25:00+00:00	2017-03-07 11:07:00+00:00	EN1089	4.74	3.6	6.2	1122	43	18.7
11	2017-03-06 17:50:00+00:00	2017-03-07 06:21:00+00:00	EN1041	15.59	3.6	24	751		12.5166667
12	2017-03-07 12:01:00+00:00	2017-03-07 22:22:00+00:00	EN1089	3.86	3.6	6.2	621	82	10.35
13	2017-03-07 20:51:00+00:00	2017-03-08 07:17:00+00:00	EN1041	17.76	3.6	24	626		10.4333333
14	2017-03-07 23:11:00+00:00	2017-03-08 11:21:00+00:00	EN1089	5.54	3.6	6.2	730	73	12.1666667
15	2017-03-08 16:45:00+00:00	2017-03-08 16:54:00+00:00	EN1089	0.47	3.6	6.2	9		0.15
16	2017-03-08 16:54:00+00:00	2017-03-08 23:19:00+00:00	EN1089	5.08	3.6	6.2	385	126	6.41666667
17	2017-03-08 21:08:00+00:00	2017-03-09 06:55:00+00:00	EN1041	23.02	3.6	24	587		9.78333333
18	2017-03-09 18:26:00+00:00	2017-03-09 18:39:00+00:00	EN1041	0.71	3.6	24	13		0.21666667
19	2017-03-09 22:30:00+00:00	2017-03-10 06:31:00+00:00	EN1041	24.09	3.6	24	481		8.01666667
20	2017-03-09 23:44:00+00:00	2017-03-10 12:48:00+00:00	EN1089	5.12	3.6	6.2	784		13.0666667
21	2017-03-10 12:22:00+00:00	2017-03-11 10:58:00+00:00	EN1026	8.1	3.6	12	1356		22.6
22	2017-03-10 13:46:00+00:00	2017-03-10 14:12:00+00:00	EN1089	1.6	3.6	6.2	26		0.43333333
23	2017-03-10 14:20:00+00:00	2017-03-10 14:57:00+00:00	EN1089	1.35	3.6	6.2	37		0.61666667
24	2017-03-10 17:02:00+00:00	2017-03-11 08:40:00+00:00	EN1119	18.95	7	24	938		15.6333333
25	2017-03-10 20:12:00+00:00	2017-03-10 20:52:00+00:00	EN1089	2.5	3.6	6.2	40		0.66666667
26	2017-03-10 21:56:00+00:00	2017-03-11 11:56:00+00:00	EN1089	5.27	3.6	6.2	840		14
27	2017-03-10 22:15:00+00:00	2017-03-11 07:03:00+00:00	EN1030	13.94	7	33	528		8.8
28	2017-03-10 23:11:00+00:00	2017-03-11 10:43:00+00:00	EN1041	17.69	3.6	24	692		11.5333333
29	2017-03-11 13:32:00+00:00	2017-03-11 17:52:00+00:00	EN1026	8.59	3.6	12	260		4.33333333
30	2017-03-11 17:05:00+00:00	2017-03-11 18:32:00+00:00	EN1089	5.38	3.6	6.2	87		1.45
31	2017-03-11 18:08:00+00:00	2017-03-12 10:33:00+00:00	EN1026	0.82	3.6	12	985		16.4166667
32	2017-03-11 18:14:00+00:00	2017-03-11 22:29:00+00:00	EN1092	16.3	7	33	255		4.25
33	2017-03-11 19:23:00+00:00	2017-03-11 19:46:00+00:00	EN1089	1.4	3.6	6.2	23		0.38333333
34	2017-03-11 20:14:00+00:00	2017-03-12 15:29:00+00:00	EN1030	52.17	7	33	1155		19.25
35	2017-03-12 00:33:00+00:00	2017-03-12 11:24:00+00:00	EN1089	5.27	3.6	6.2	651		10.85
36	2017-03-12 14:00:00+00:00	2017-03-12 14:19:00+00:00	EN1026	0.83	3.6	12	19		0.31666667
37	2017-03-12 14:57:00+00:00	2017-03-14 08:28:00+00:00	EN1026	10.04	3.6	12	2491		41.5166667
38	2017-03-12 15:43:00+00:00	2017-03-13 08:29:00+00:00	EN1030	2.12	7	33	1006		16.7666667
39	2017-03-12 16:46:00+00:00	2017-03-12 17:59:00+00:00	EN1089	2.72	3.6	6.2	73		1.21666667
40	2017-03-12 18:22:00+00:00	2017-03-12 18:40:00+00:00	EN1089	1.03	3.6	6.2	18		0.3
41	2017-03-12 18:58:00+00:00	2017-03-13 10:47:00+00:00	EN1089	2.75	3.6	6.2	949		15.8166667
42	2017-03-12 21:05:00+00:00	2017-03-13 08:22:00+00:00	EN1119	17.53	7	24	677		11.2833333
43	2017-03-13 14:55:00+00:00	2017-03-13 20:01:00+00:00	EN1089	5.22	3.6	6.2	306		5.1
44	2017-03-13 18:00:00+00:00	2017-03-14 07:02:00+00:00	EN1030	51.51	7	33	782		13.0333333
45	2017-03-13 20:45:00+00:00	2017-03-14 07:50:00+00:00	EN1092	25.19	7	33	665		11.0833333
46	2017-03-13 21:34:00+00:00	2017-03-14 10:43:00+00:00	EN1089	4.6	3.6	6.2	789		13.15
47	2017-03-14 08:30:00+00:00	2017-03-15 07:36:00+00:00	EN1026	0.94	3.6	12	1386		23.1
48	2017-03-14 17:17:00+00:00	2017-03-14 18:24:00+00:00	EN1089	4.16	3.6	6.2	67		1.11666667

	weekday	weekend	Mon	Tue	Wed	Thu	Fri	Sat	Sun	month	StartHour	StartCos	StartSin
0	1	0	0	0	0	1	0	0	0	3	18.2166667	0.06000132	-0.9981983
1	1	0	0	0	0	1	0	0	0	3	21.85	0.84784236	-0.5302484
2	1	0	0	0	0	0	1	0	0	3	18.9833333	0.25794028	-0.9661609
3	1	0	0	0	0	0	1	0	0	3	21.2333333	0.75150984	-0.6597219
4	1	0	0	0	0	0	1	0	0	3	22.1	0.88072851	-0.4736215
5	0	1	0	0	0	0	0	1	0	3	16.7166667	-0.3268179	-0.9450873
6	0	1	0	0	0	0	0	0	1	3	11.3	-0.9836275	0.18021374
7	0	1	0	0	0	0	0	0	1	3	17.65	-0.0883035	-0.9960936
8	0	1	0	0	0	0	0	0	1	3	18.45	0.1208701	-0.9926683
9	1	0	1	0	0	0	0	0	0	3	13.7166667	-0.8996113	-0.4366916
10	1	0	1	0	0	0	0	0	0	3	16.4166667	-0.4000111	-0.9165103
11	1	0	1	0	0	0	0	0	0	3	17.8333333	-0.0403778	-0.9991845
12	1	0	0	1	0	0	0	0	0	3	12.0166667	-0.9999786	-0.0065495
13	1	0	0	1	0	0	0	0	0	3	20.85	0.68158134	-0.7317424
14	1	0	0	1	0	0	0	0	0	3	23.1833333	0.97811733	-0.2080541
15	1	0	0	0	1	0	0	0	0	3	16.75	-0.3185523	-0.9479053
16	1	0	0	0	1	0	0	0	0	3	16.9	-0.281066	-0.9596884
17	1	0	0	0	1	0	0	0	0	3	21.1333333	0.73397045	-0.6791814
18	1	0	0	0	0	1	0	0	0	3	18.4333333	0.11653462	-0.9931866
19	1	0	0	0	0	1	0	0	0	3	22.5	0.92543829	-0.3788984
20	1	0	0	0	0	1	0	0	0	3	23.7333333	0.99785595	-0.0654485
21	1	0	0	0	0	0	1	0	0	3	12.3666667	-0.995178	-0.098085
22	1	0	0	0	0	0	1	0	0	3	13.7666667	-0.893814	-0.4484379
23	1	0	0	0	0	0	1	0	0	3	14.3333333	-0.8176536	-0.5757106
24	1	0	0	0	0	0	1	0	0	3	17.0333333	-0.2473786	-0.9689189
25	1	0	0	0	0	0	1	0	0	3	20.2	0.54771748	-0.8366634
26	1	0	0	0	0	0	1	0	0	3	21.9333333	0.85921566	-0.5116136
27	1	0	0	0	0	0	1	0	0	3	22.25	0.89865576	-0.4386546
28	1	0	0	0	0	0	1	0	0	3	23.1833333	0.97811733	-0.2080541
29	0	1	0	0	0	0	0	1	0	3	13.5333333	-0.91954	-0.3929964
30	0	1	0	0	0	0	0	1	0	3	17.0833333	-0.2346658	-0.9720761
31	0	1	0	0	0	0	0	1	0	3	18.1333333	0.03819632	-0.9992703
32	0	1	0	0	0	0	0	1	0	3	18.2333333	0.06435923	-0.9979268
33	0	1	0	0	0	0	0	1	0	3	19.3833333	0.35758652	-0.93388
34	0	1	0	0	0	0	0	1	0	3	20.2333333	0.55500284	-0.8318485
35	0	1	0	0	0	0	0	0	1	3	0.55	0.98963702	0.14359165
36	0	1	0	0	0	0	0	0	1	3	14	-0.8647491	-0.5022042
37	0	1	0	0	0	0	0	0	1	3	14.95	-0.7144014	-0.6997361
38	0	1	0	0	0	0	0	0	1	3	15.7166667	-0.5604391	-0.8281956
39	0	1	0	0	0	0	0	0	1	3	16.7666667	-0.3144104	-0.9492871
40	0	1	0	0	0	0	0	0	1	3	18.3666667	0.0991713	-0.9950704
41	0	1	0	0	0	0	0	0	1	3	18.9666667	0.25371923	-0.9672779
42	0	1	0	0	0	0	0	0	1	3	21.0833333	0.72501109	-0.6887372
43	1	0	1	0	0	0	0	0	0	3	14.9166667	-0.7204847	-0.6934709
44	1	0	1	0	0	0	0	0	0	3	18	0.00327476	-0.9999946
45	1	0	1	0	0	0	0	0	0	3	20.75	0.66217936	-0.7493454
46	1	0	1	0	0	0	0	0	0	3	21.5666667	0.80618455	-0.5916642
47	1	0	0	1	0	0	0	0	0	3	8.5	-0.6099876	0.79241099
48	1	0	0	1	0	0	0	0	0	3	17.2833333	-0.1834339	-0.983032

	TimeSinceLastStop	sessionsToday	LastDuration	LastConsumedkWh	dataset	LinearRegression	QuantileRegressor	HistGradientBoostingRegressor	MedianValue	MeanValue	LastValue
0	11.03333333	0	11.26666667	21.13	Train	12.66235352	12.72074563	12.64632372	11.4	11.92868854	11.26666667
1	3.15	1	0.483333333	1.7	Train	10.90332031	9.387313298	9.801989899	11.4	11.92868854	0.483333333
2	0.216666667	0	2.183333333	6.18	Train	10.53405762	11.37860757	12.36358679	11.4	11.92868854	2.183333333
3	1.333333333	1	0.916666667	3.43	Train	10.11523438	10.03521137	10.71273228	11.4	11.92868854	0.916666667
4	15.21666667	0	9.033333333	25.71	Train	10.9987793	9.609091234	8.845996121	11.4	11.92868854	9.033333333
5	5.516666667	0	13.96666667	5.47	Train	13.55932617	12.79856768	9.395031256	11.4	11.92868854	13.96666667
6	24.8	0	12.4	25.63	Train	9.442993164	5.549625995	4.385136107	11.4	11.92868854	12.4
7	3.583333333	1	2.766666667	9.83	Train	13.203125	12.7746875	13.81889409	11.4	11.92868854	2.766666667
8	20.93333333	0	4.8	5.31	Train	12.39331055	12.47270573	6.328585412	11.4	11.92868854	4.8
9	1.316666667	0	17.95	5.16	Train	10.83349609	8.792811992	10.3731599	11.4	11.92868854	17.95
10	1.783333333	1	0.916666667	3.48	Train	10.125	10.74330914	8.783937171	11.4	11.92868854	0.916666667
11	10.88333333	0	13.3	21.87	Train	12.92797852	12.86775924	13.22712268	11.4	11.92868854	13.3
12	0.9	0	18.7	4.74	Train	9.479736328	6.257060611	7.095584694	11.4	11.92868854	18.7
13	14.5	0	12.51666667	15.59	Train	12.68017578	11.61020196	9.788832229	11.4	11.92868854	12.51666667
14	0.816666667	1	10.35	3.86	Train	10.52050781	8.088776695	10.5577621	11.4	11.92868854	10.35
15	5.4	0	12.16666667	5.54	Train	11.86669922	11.86022086	7.690020075	11.4	11.92868854	12.16666667
16	0	1	0.15	0.47	Train	10.32885742	11.03734012	9.68140493	11.4	11.92868854	0.15
17	13.85	0	10.43333333	17.76	Train	12.09790039	11.06111846	9.681867293	11.4	11.92868854	10.43333333
18	11.51666667	0	9.783333333	23.02	Train	12.34887695	12.57673444	12.19532514	11.4	11.92868854	9.783333333
19	3.85	1	0.216666667	0.71	Train	10.47558594	8.342304691	9.496333479	11.4	11.92868854	0.216666667
20	24.41666667	0	6.416666667	5.08	Train	9.005981445	6.138727013	9.455967724	11.4	11.92868854	6.416666667
21	4.683333333	0	183.8833333	10.29	Train	39.22631836	25.80255357	13.64457037	11.4	11.92868854	183.8833333
22	0.966666667	0	13.06666667	5.12	Train	10.01257324	8.309766128	2.665286339	11.4	11.92868854	13.06666667
23	0.133333333	1	0.433333333	1.6	Train	8.710571289	8.154045525	2.006008613	11.4	11.92868854	0.433333333
24	4.6	0	0.866666667	5.61	Train	10.91552734	11.15589538	13.28985257	11.4	11.92868854	0.866666667
25	5.25	2	0.616666667	1.35	Train	10.88574219	11.48554343	12.12078551	11.4	11.92868854	0.616666667
26	1.066666667	3	0.666666667	2.5	Train	10.37475586	9.96995985	10.24029353	11.4	11.92868854	0.666666667
27	1.25	0	0.783333333	5.79	Train	10.59448242	8.645187392	9.564079324	11.4	11.92868854	0.783333333
28	16.66666667	0	8.016666667	24.09	Train	10.12304688	7.654470268	8.355491093	11.4	11.92868854	8.016666667
29	2.566666667	0	22.6	8.1	Train	13.1418457	9.886479958	14.57801275	11.4	11.92868854	22.6
30	5.15	0	14	5.27	Train	13.72412109	13.06372922	11.83223912	11.4	11.92868854	14
31	0.266666667	1	4.333333333	8.59	Train	12.86132813	12.935962	13.79785678	11.4	11.92868854	4.333333333
32	8.083333333	0	12.21666667	23.93	Train	14.48657227	13.87233844	14.26756672	11.4	11.92868854	12.21666667
33	0.85	1	1.45	5.38	Train	12.11523438	12.38237507	12.85368281	11.4	11.92868854	1.45
34	13.18333333	0	8.8	13.94	Train	14.0748291	12.78345149	11.57725666	11.4	11.92868854	8.8
35	4.783333333	0	0.383333333	1.4	Train	7.878173828	10.35910596	10.13153762	11.4	11.92868854	0.383333333
36	3.45	0	16.41666667	0.82	Train	12.72558594	9.866001478	11.17749415	11.4	11.92868854	16.41666667
37	0.633333333	1	0.316666667	0.83	Train	10.95483398	9.835418517	7.590484848	11.4	11.92868854	0.316666667
38	0.233333333	0	19.25	52.17	Train	13.6640625	13.09103873	16.82196433	11.4	11.92868854	19.25
39	5.366666667	1	10.85	5.27	Train	13.36560059	12.93567235	10.13520083	11.4	11.92868854	10.85
40	0.383333333	2	1.216666667	2.72	Train	12.52233887	12.97037005	13.23422885	11.4	11.92868854	1.216666667
41	0.3	3	0.3	1.03	Train	12.77185059	13.27606993	12.8244315	11.4	11.92868854	0.3
42	36.41666667	0	15.63333333	18.95	Train	14.16687012	12.62208223	12.23552272	11.4	11.92868854	15.63333333
43	4.133333333	0	15.81666667	2.75	Train	11.51550293	10.28120597	12.51656092	11.4	11.92868854	15.81666667
44	9.516666667	0	16.76666667	2.12	Train	14.71472168	13.52126448	14.49073699	11.4	11.92868854	16.76666667
45	46.26666667	0	4.25	16.3	Train	11.58166504	11.02719824	11.15789855	11.4	11.92868854	4.25
46	1.55	1	5.1	5.22	Train	10.61157227	10.09240415	11.31127176	11.4	11.92868854	5.1
47	0.033333333	0	41.51666667	10.04	Train	11.19519043	5.254252119	9.912047585	11.4	11.92868854	41.51666667
48	6.566666667	0	13.15	4.6	Train	12.28344727	12.32492563	11.74493945	11.4	11.92868854	13.15

Harnessing Smart Grids: How China meets its Energy Demands

1. **Infrastructure Expansion:**

   China is leading in public charging infrastructure, with over 70% of global public light-duty vehicle chargers located in the country.

   Public charging points are being developed to support the growing EV fleet, including both slow and fast chargers.

   By 2035, public fast chargers are expected to reach 7.5 million

2. **Vehicle-to-Grid (V2G) Technology:**

   China is testing extensive V2G systems, which allow EV batteries to feed electricity back into the grid during peak demand.

   A trial in Jiangsu province demonstrated how 1,277 EVs could offset 12 MW of peak power daily, reducing strain on the grid

Harnessing Smart Grids: How China meets its Energy Demands

3. **Integrated Planning:**

   Smart grids in China incorporate renewable energy sources like solar and wind, ensuring clean energy for EVs.

   The country utilizes advanced modeling, such as the SWITCH-China tool, to optimize energy supply and demand dynamically, accounting for temporal and spatial variations in EV charging

4. **Policy and Incentives:**

   The Chinese government supports EV adoption and grid integration through subsidies, mandating the installation of high-quality charging stations, and encouraging smart charging to optimize grid performance during off-peak hours