Smart Home Energy Management System (SHEMS)

CS-GY 6083 Final Project Report

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I. INTRODUCTION

The integration of cutting-edge technologies and intelligent systems to maximize energy generation, distribution, and consumption in a domestic setting is known as a "smart home energy management system." Such systems are essential for improving the efficacy, affordability, and environmental impact of domestic energy consumption in a time of rising energy demands and a growing focus on sustainability. With the use of sophisticated algorithms, sensors, and networked devices, these systems monitor, evaluate, and regulate a variety of energy-related variables, empowering homeowners to make decisions that suit their tastes, way of life, and environmental objectives. Smart home energy management assists people in decreasing their carbon footprint and makes their energy infrastructure more responsive and resilient by automating and optimizing energy-related procedures.

As they continuously gather data on energy consumption patterns, device usage, and ambient variables, smart home energy management systems produce a substantial amount of data. This abundance of data turns into a useful tool for comprehending and enhancing the system's functionality. However, the sheer volume and complexity of the data necessitate effective management strategies. Extracting valuable insights, seeing patterns, and making informed decisions to improve energy efficiency all depend on proper data management. Through data analysis, users can gain a comprehensive view of their energy usage, identify potential areas for improvement, and tailor the system settings to align with their energy-saving objectives. Moreover, efficient data management facilitates predictive modeling, allowing homeowners to anticipate energy needs and optimize system configurations for optimal performance.

The significance of the right database design in handling massive volumes of data cannot be overstated. A well-structured database is the foundation of every data-intensive system, serving as the framework for efficient data storage, retrieval, and management. Properly designed databases employ techniques such as normalization, indexing, and partitioning to streamline data organization, ensuring that information is stored in a way that minimizes redundancy and optimizes retrieval speed.

The aim of implementing a scalable and resilient database schema was to improve system performance, enable smooth data analysis, and ultimately enable users to make well-informed decisions about how much energy they consume. The foundation for a responsive and successful smart home energy management system was created by this methodical approach to database architecture, highlighting the need for careful data infrastructure in addressing the difficulties presented by large data quantities. In the next section of this paper we present our database design, consisting of five tables outlining the relationships between homes, the devices that are present in said homes, and the customers who own these locations.

II. <u>DESIGN</u>

A database schema serves as the blueprint for the structure of a database, defining tables, fields, relationships, and constraints. During the design phase, the data model is carefully examined to make sure it appropriately captures the characteristics of the data that needs to be kept and optimizes for retrieval and performance. The relationships between tables are established to maintain consistency and support efficient queries. A database-driven application's ability to manage and analyze data effectively and adapt to the changing requirements of the system and its users is largely dependent on the quality of its database schema.

For the problem at hand, we have devised a design involving five tables. The first table is **Customers**, consisting of the customers' details, such as name and billing address. Each customer is assigned a unique *customerID*, allowing their information to be associated with Service Locations that the customer may own. The second table, **ServiceLocations**, gives details about each establishment owned by a customer. This includes address, date of ownership transfer or purchase, square footage, number of bedrooms, and the number of occupants. Each service location is identified by a unique *serviceLocID*. Each location also has devices registered with it, which are defined in the **Devices** table. This table encompasses details intrinsic to each device, such as device type and model number. Each device has its own *deviceID* as well. When a given device is interacted with, its energy consumption is encapsulated in the **EnergyConsumption** table. A record in this table consists of the timestamp when a given event took place, the label of the event, the associated numerical value for that event (temperature increase/decrease), and the total energy consumed by that specific event for that particular device. The EnergyConsumption table utilizes the *deviceID* for each event to maintain atomicity. Finally, the last table is **EnergyPrices**. The price of a kilowatt-hour of energy can fluctuate based on the time of day, so we utilize a *priceTimeID* along with a *zipCode* to represent pricing in a specific region at a particular time of the day.

III. SCHEMA

Customers (
customerID, <PRIMARY KEY>
firstName,
lastName,
streetAddress,
city,
zipCode,
state
)

ServiceLocations (
serviceLocID, <PRIMARY KEY>
customerID, <FOREIGN KEY>
dateTakenOver,
squareFootage,
streetAddress,
city,
zipCode,
state,
unit,
numBedrooms,
numOccupants
)

Devices (
deviceID, <PRIMARY KEY>
serviceLocID, <FOREIGN KEY>
deviceType,
modelNumber
)

EnergyConsumption (
eventTimestamp,
eventLabel,
numValue,
totalEnergyConsumed,
deviceID, <FOREIGN KEY>
priceTimeID <FOREIGN KEY>
)

EnergyPrices (
priceTimeID, <COMPOSITE PRIMARY KEY>
zipCode, <COMPOSITE PRIMARY KEY>
timePeriodStart,
timePeriodEnd,
price
)

IV. TABLE DATA

CUSTOMER TABLE

customerID	firstName	lastName	streetAddress	city	zipCode	state
1	John	Doe	123 Main St	New York	10001	NY
2	Jane	Smith	456 Broadway	New York	10002	NY
3	Robert	Johnson	789 Park Ave	New York	10003	NY
4	Emily	Williams	101 Wall St	New York	10004	NY
5	Michael	Brown	202 Lexington Ave	New York	10005	NY
6	Sophia	Jones	303 5th Ave	New York	10006	NY
7	Daniel	Miller	404 Madison Ave	New York	10007	NY
8	Olivia	Davis	505 Park Pl	New York	10008	NY
9	William	Garcia	606 3rd St	New York	10009	NY
10	Ava	Rodriguez	707 Broadway	New York	10010	NY
11	James	Hernandez	808 Wall St	New York	10011	NY
12	Emma	Lopez	909 Lexington Ave	New York	10012	NY
13	Benjamin	Martinez	1010 Park Pl	New York	10013	NY
14	Mia	Jackson	1111 Madison Ave	New York	10014	NY
15	Elijah	Taylor	1212 5th Ave	New York	10015	NY
16	Grace	Anderson	1313 Broadway	New York	10016	NY
17	Logan	White	1414 Wall St	New York	10017	NY
18	Aiden	Thomas	1515 Lexington A…	New York	10018	NY
19	Isabella	Moore	1616 Park Pl	New York	10019	NY
20	Jackson	Wilson	1717 Madison Ave	New York	10020	NY

SERVICE LOCATIONS TABLE

serviceLocID	customerID	dateTakenOver	squareFootage	streetAddress	city	zipCode	state	unit	numBedrooms	numOccupan...
1	5	2023-01-15	800	123 Main St	New York	10001	NY	Apt 1A	2	3
2	15	2023-02-20	1200	456 Broadway	New York	10002	NY	Unit 2B	3	4
3	18	2023-03-10	1000	789 Park Ave	New York	10003	NY	Apt 3C	2	2
4	1	2023-04-05	900	101 Wall St	New York	10004	NY	Apt 4D	2	1
5	2	2023-05-12	1100	202 Lexington Ave	New York	10005	NY	Unit 5E	3	3
6	15	2023-06-18	950	303 5th Ave	New York	10006	NY	Apt 6F	2	2
7	7	2023-07-22	850	404 Madison Ave	New York	10007	NY	Unit 7G	1	1
8	1	2023-08-30	750	505 Park Pl	New York	10008	NY	Apt 8H	1	1
9	4	2023-09-08	1000	606 3rd St	New York	10009	NY	Apt 9I	2	2
10	6	2023-10-15	800	707 Broadway	New York	10010	NY	Unit 10J	2	3
11	17	2023-11-20	1200	808 Wall St	New York	10011	NY	Apt 11K	3	4
12	20	2023-12-01	1000	909 Lexington Ave	New York	10012	NY	Unit 12L	2	2
13	4	2024-01-05	900	1010 Park Pl	New York	10013	NY	Apt 13M	2	1
14	9	2024-02-10	1100	1111 Madison Ave	New York	10014	NY	Unit 14N	3	3
15	3	2024-03-18	950	1212 5th Ave	New York	10015	NY	Apt 15O	2	2
16	16	2024-04-22	850	1313 Broadway	New York	10016	NY	Unit 16P	1	1
17	10	2024-05-30	750	1414 Wall St	New York	10017	NY	Apt 17Q	1	1
18	13	2024-06-08	1000	1515 Lexington A...	New York	10018	NY	Apt 18R	2	2
19	17	2024-07-15	800	1616 Park Pl	New York	10019	NY	Unit 19S	2	3
20	20	2024-08-20	1200	1717 Madison Ave	New York	10020	NY	Apt 20T	3	4
21	12	2024-09-01	1000	123 Main St	New York	10001	NY	Apt 21U	2	2
22	9	2024-10-10	900	456 Broadway	New York	10002	NY	Unit 22V	2	1
23	18	2024-11-18	1100	789 Park Ave	New York	10003	NY	Apt 23W	3	3
24	8	2024-12-22	950	101 Wall St	New York	10004	NY	Apt 24X	2	2
25	2	2025-01-30	850	202 Lexington Ave	New York	10005	NY	Unit 25Y	1	1
26	15	2025-02-05	750	303 5th Ave	New York	10006	NY	Apt 26Z	1	1
27	11	2025-03-12	1000	404 Madison Ave	New York	10007	NY	Unit 27...	2	2
28	1	2025-04-18	800	505 Park Pl	New York	10008	NY	Apt 28...	2	3
29	3	2025-05-22	1200	606 3rd St	New York	10009	NY	Apt 29...	3	4
30	6	2025-06-30	1000	707 Broadway	New York	10010	NY	Unit 30...	2	2
31	14	2025-07-08	900	808 Wall St	New York	10011	NY	Apt 31...	2	1
32	20	2025-08-15	1100	909 Lexington Ave	New York	10012	NY	Unit 32...	3	3
33	4	2025-09-20	950	1010 Park Pl	New York	10013	NY	Apt 33...	2	2
34	9	2025-10-01	850	1111 Madison Ave	New York	10014	NY	Unit 34...	1	1
35	18	2025-11-10	750	1212 5th Ave	New York	10015	NY	Apt 35II	1	1
36	16	2025-12-18	1000	1313 Broadway	New York	10016	NY	Unit 36JJ	2	2
37	10	2026-01-22	800	1414 Wall St	New York	10017	NY	Apt 37...	2	3
38	13	2026-02-28	1200	1515 Lexington A...	New York	10018	NY	Apt 38LL	3	4
39	17	2026-03-05	1000	1616 Park Pl	New York	10019	NY	Unit 39...	2	2
40	19	2026-04-10	900	1717 Madison Ave	New York	10020	NY	Apt 40...	2	1

DEVICES TABLE

deviceID	serviceLocID	deviceType	modelNumber
1	30	AC	CoolBreeze-3000
2	6	Lights	LED-BrightLite
3	17	Microwave	HeatWave-900
4	23	AC	CoolMax-X1
5	21	Microwave	SmartCook-1200
6	20	Fridge	FrostFree-200
7	24	Fridge	ChillMaster-500
8	30	Fridge	ChillMaster-500
9	17	Microwave	HeatWave-900
10	34	Dryer	UltraDry-800
11	13	AC	CoolBreeze-3000
12	30	Microwave	SmartCook-1200
13	40	Washer	EcoClean-500
14	20	Microwave	SmartCook-1200
15	32	AC	CoolBreeze-3000
16	13	Washer	EcoClean-500
17	16	Fridge	FrostFree-200
18	11	Dryer	QuickDry-700
19	19	Washer	TurboWash-1000
20	22	Washer	EcoClean-500
21	38	Lights	LED-BrightLite
22	34	AC	CoolBreeze-3000
23	34	Microwave	SmartCook-1200
24	40	Fridge	ChillMaster-500
25	30	Lights	LED-BrightLite
26	14	Dryer	QuickDry-700
27	33	Fridge	ChillMaster-500
28	29	Microwave	HeatWave-900
29	19	Fridge	FrostFree-200
30	28	Lights	LED-BrightLite
31	14	Washer	TurboWash-1000
32	13	AC	CoolBreeze-3000
33	5	AC	CoolBreeze-3000
34	2	Microwave	HeatWave-900
35	8	Washer	EcoClean-500
36	31	Lights	LED-BrightLite
37	28	AC	CoolBreeze-3000
38	19	Fridge	ChillMaster-500
39	6	Washer	EcoClean-500
40	16	Washer	EcoClean-500
41	32	Dryer	QuickDry-700
42	36	Washer	TurboWash-1000

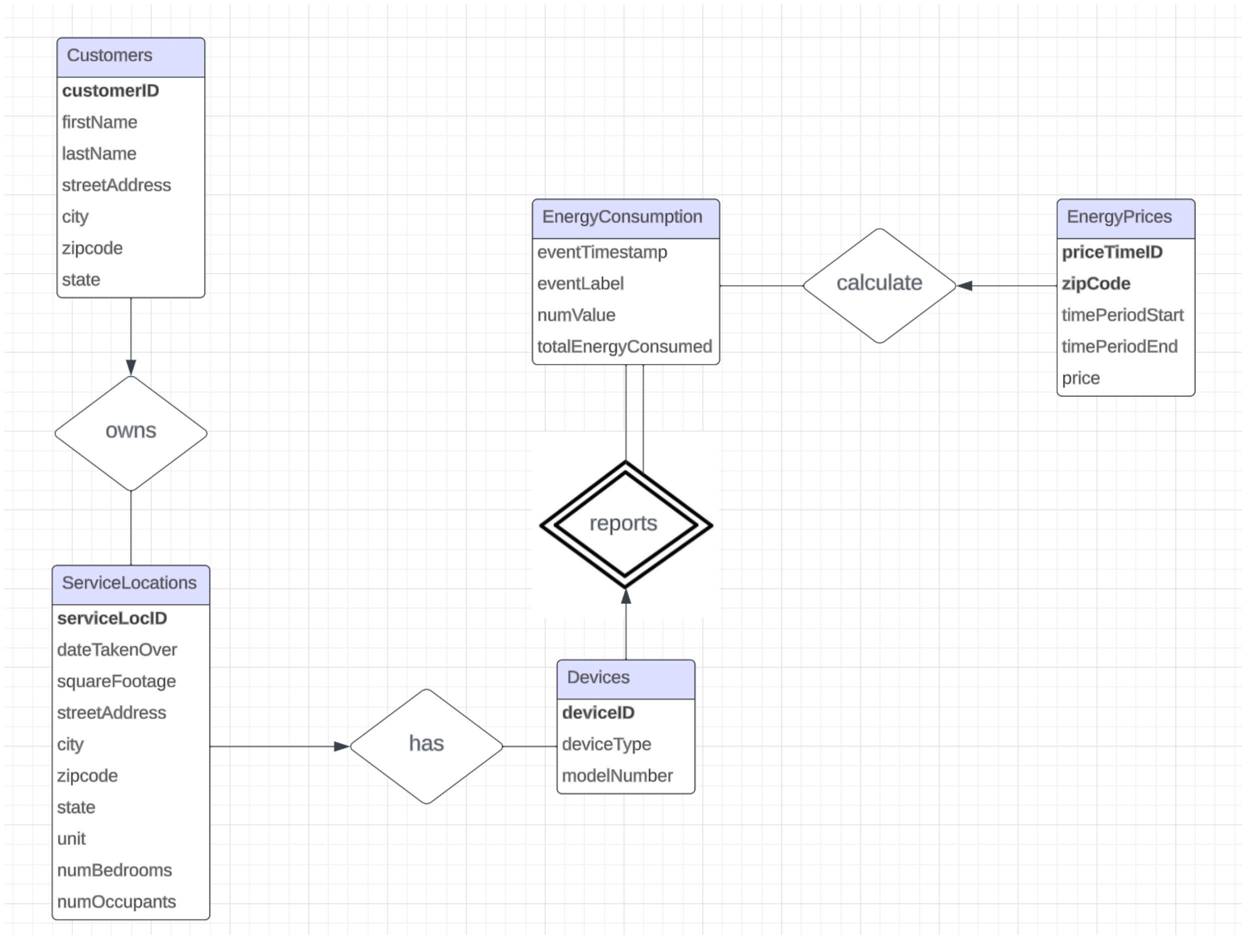
ENERGY CONSUMPTION TABLE

eventTimestamp	eventLabel	numValue	totalEnergyConsum...	deviceID	priceTimeID
2022-08-01 01:00:00	door closed	NULL	0.00	27	1
2022-08-01 01:00:00	medium	NULL	4.00	34	1
2022-08-01 02:00:00	turned off	NULL	0.00	56	1
2022-08-01 03:00:00	turned on	NULL	2.00	2	2
2022-08-01 04:00:00	low	NULL	2.00	57	2
2022-08-01 05:00:00	door closed	NULL	0.00	17	3
2022-08-01 06:00:00	ultra	NULL	12.00	52	3
2022-08-01 07:00:00	medium	NULL	4.00	60	4
2022-08-01 08:00:00	temp raised	78	5.00	1	4
2022-08-01 09:00:00	medium	NULL	4.00	60	5
2022-08-01 10:00:00	ultra	NULL	12.00	53	5
2022-08-01 11:00:00	normal	NULL	8.00	20	6
2022-08-01 12:00:00	low	NULL	2.00	48	6
2022-08-01 13:00:00	normal	NULL	8.00	10	7
2022-08-01 14:00:00	door opened	NULL	4.00	8	7
2022-08-01 15:00:00	quick wash	NULL	4.00	49	8
2022-08-01 16:00:00	low	NULL	2.00	14	8
2022-08-01 17:00:00	ultra	NULL	12.00	80	9
2022-08-01 18:00:00	ultra	NULL	12.00	41	9
2022-08-01 19:00:00	low	NULL	2.00	55	10
2022-08-01 20:00:00	temp raised	77	5.00	51	10
2022-08-01 21:00:00	ultra	NULL	12.00	26	11
2022-08-01 22:00:00	high	NULL	6.00	28	11
2022-08-01 23:00:00	door opened	NULL	4.00	70	12
2022-08-02 00:00:00	temp raised	71	5.00	69	1
2022-08-02 01:00:00	temp raised	77	5.00	37	1
2022-08-02 02:00:00	low	NULL	2.00	55	1
2022-08-02 03:00:00	turned off	NULL	0.00	59	2
2022-08-02 04:00:00	door closed	NULL	0.00	45	2

ENERGY PRICES TABLE

priceTimeID	zipCode	timePeriodSt...	timePeriodEnd	price
1	10001	0:00:00	2:00:00	5.00
1	10002	0:00:00	2:00:00	4.00
1	10003	0:00:00	2:00:00	3.00
1	10004	0:00:00	2:00:00	3.00
1	10005	0:00:00	2:00:00	4.00
1	10006	0:00:00	2:00:00	1.00
1	10007	0:00:00	2:00:00	3.00
1	10008	0:00:00	2:00:00	5.00
1	10009	0:00:00	2:00:00	2.00
1	10010	0:00:00	2:00:00	1.00
1	10011	0:00:00	2:00:00	4.00
1	10012	0:00:00	2:00:00	1.00
1	10013	0:00:00	2:00:00	2.00
1	10014	0:00:00	2:00:00	4.00
1	10015	0:00:00	2:00:00	3.00
1	10016	0:00:00	2:00:00	5.00
1	10017	0:00:00	2:00:00	2.00
1	10018	0:00:00	2:00:00	2.00
1	10019	0:00:00	2:00:00	5.00
1	10020	0:00:00	2:00:00	4.00
2	10001	2:00:00	4:00:00	2.00
2	10002	2:00:00	4:00:00	3.00
2	10003	2:00:00	4:00:00	4.00
2	10004	2:00:00	4:00:00	4.00
2	10005	2:00:00	4:00:00	5.00
2	10006	2:00:00	4:00:00	4.00
2	10007	2:00:00	4:00:00	2.00
2	10008	2:00:00	4:00:00	2.00
2	10009	2:00:00	4:00:00	2.00
2	10010	2:00:00	4:00:00	3.00
2	10011	2:00:00	4:00:00	1.00
2	10012	2:00:00	4:00:00	4.00
2	10013	2:00:00	4:00:00	5.00
2	10014	2:00:00	4:00:00	3.00
2	10015	2:00:00	4:00:00	5.00
2	10016	2:00:00	4:00:00	4.00
2	10017	2:00:00	4:00:00	1.00
2	10018	2:00:00	4:00:00	2.00
2	10019	2:00:00	4:00:00	2.00
2	10020	2:00:00	4:00:00	4.00
3	10001	4:00:00	6:00:00	1.00
3	10002	4:00:00	6:00:00	2.00

V. ER DIAGRAM



VI. ASSUMPTIONS

- For simplicity, we have decided to populate our Energy Consumption Events table with hourly increments, instead of the 5-minute interval increments noted in the problem statement.
- Due to the nature of our data being populated around August and September 2022, we have chosen August 2nd as the “24 hour mark” noted in the first query.
- To help model this problem in a more simplistic manner, we are assuming that the behavior of occupants is relatively similar. That way, the total energy consumed in a service location can be multiplied by the number of occupants living at that given service location.
- Some query results are truncated in the interest of maintaining brevity in our screenshots.

VII. QUERIES

Query 1: List all enrolled devices with their total energy consumption in the last 24 hours, for a specific customer identified by customer ID.

```
SELECT c.customerID, d.deviceID, d.deviceType, d.modelNumber, ec.totalEnergyConsumed
FROM Devices d
JOIN EnergyConsumption ec ON ec.deviceID = d.deviceID
JOIN ServiceLocations sl ON sl.serviceLocID = d.serviceLocID
JOIN Customers c ON c.customerID = sl.customerID
WHERE ec.eventTimestamp >= DATE_SUB('2022-08-02', INTERVAL 24 HOUR)
GROUP BY c.customerID;
```

customerID	deviceID	deviceType	modelNumber	totalEnergyConsum...
6	1	AC	CoolBreeze-3000	5.00
15	2	Lights	LED-BrightLite	2.00
10	3	Microwave	HeatWave-900	4.00
18	4	AC	CoolMax-X1	5.00
12	5	Microwave	SmartCook-1200	4.00
20	6	Fridge	FrostFree-200	0.00
8	7	Fridge	ChillMaster-500	0.00
9	10	Dryer	UltraDry-800	8.00
4	11	AC	CoolBreeze-3000	5.00
19	13	Washer	EcoClean-500	8.00
16	17	Fridge	FrostFree-200	0.00
17	18	Dryer	QuickDry-700	4.00
13	21	Lights	LED-BrightLite	0.00
3	28	Microwave	HeatWave-900	6.00
1	30	Lights	LED-BrightLite	2.00
2	33	AC	CoolBreeze-3000	5.00
14	36	Lights	LED-BrightLite	2.00
7	47	Lights	LED-BrightLite	2.00
11	63	Lights	LED-BrightLite	2.00
5	67	Fridge	FrostFree-200	4.00

Query 2: Calculate the average monthly energy consumption per device type, for the month of August 2022, considering only devices that have been on (i.e., reported data) at least once during that month.

```sql
SELECT d.deviceType, COUNT(ec.eventLabel) as onCount, AVG(ec.totalEnergyConsumed) AS AvgEnergyConsumption
FROM Devices d
JOIN EnergyConsumption ec ON ec.deviceID = d.deviceID
WHERE DATE(ec.eventTimestamp) >= '2022-08-01' AND DATE(ec.eventTimestamp) <= '2022-08-31'
GROUP BY d.deviceType
HAVING COUNT(ec.eventLabel) > 1;
```

deviceType	onCount	AvgEnergyConsumpti...
AC	123	5.000000
Lights	116	0.948276
Microwave	133	4.000000
Fridge	124	1.870968
Dryer	115	8.000000
Washer	135	8.207407

Query 3: Identify cases where a refrigerator door was left open for more than 30 minutes. Output the date and time, the service location, the device ID, and the refrigerator model.

```sql
WITH EventTimes AS (
    SELECT TIME(closed.eventTimestamp) - TIME(opened.eventTimestamp) AS eventTime
    FROM EnergyConsumption closed
    JOIN EnergyConsumption opened ON (closed.eventLabel = 'door closed' AND opened.eventLabel = 'door opened')  AND closed.deviceID = opened.deviceID
)
SELECT DATE(ec.eventTimestamp) as Date, TIME(ec.eventTimestamp) as Time, d.serviceLocID, d.deviceID, d.modelNumber
FROM EnergyConsumption ec
JOIN Devices d ON d.deviceID = ec.deviceID
CROSS JOIN EventTimes et
WHERE d.deviceType = 'Fridge'
AND TIME_TO_SEC(et.eventTime)/60 >= 30
GROUP BY d.deviceID;
```

deviceType	onCount	AvgEnergyConsumpti...
AC	123	5.000000
Lights	116	0.948276
Microwave	133	4.000000
Fridge	124	1.870968
Dryer	115	8.000000
Washer	135	8.207407

Query 4: Calculate the total energy cost for each service location during August 2022, considering the hourly changing energy prices based on zip code.

```
select sl.serviceLocID, sl.unit, sl.streetAddress, sl.city, sl.state, sl.zipCode, sum(ec.totalEnergyConsumed * ep.price) as TotalCost
from ServiceLocations sl
join Devices d on sl.serviceLocID = d.serviceLocID
join EnergyConsumption ec on d.deviceID = ec.deviceID
join EnergyPrices ep on sl.zipCode = ep.zipCode
    and ec.priceTimeID = ep.priceTimeID
where month(ec.eventTimestamp) = 8 and year(ec.eventTimestamp) = 2022
group by sl.serviceLocID, sl.unit, sl.streetAddress, sl.city, sl.state, sl.zipCode;
```

serviceLocID	unit	streetAddress	city	state	zipCode	TotalCost
1	Apt 1A	123 Main St	New York	NY	10001	100.0000
2	Unit 2B	456 Broadway	New York	NY	10002	290.0000
4	Apt 4D	101 Wall St	New York	NY	10004	324.0000
5	Unit 5E	202 Lexington Ave	New York	NY	10005	135.0000
6	Apt 6F	303 5th Ave	New York	NY	10006	390.0000
7	Unit 7G	404 Madison Ave	New York	NY	10007	110.0000
8	Apt 8H	505 Park Pl	New York	NY	10008	44.0000
9	Apt 9I	606 3rd St	New York	NY	10009	74.0000
10	Unit 10J	707 Broadway	New York	NY	10010	112.0000
11	Apt 11K	808 Wall St	New York	NY	10011	480.0000
13	Apt 13M	1010 Park Pl	New York	NY	10013	390.0000
14	Unit 14N	1111 Madison Ave	New York	NY	10014	580.0000
16	Unit 16P	1313 Broadway	New York	NY	10016	240.0000
17	Apt 17Q	1414 Wall St	New York	NY	10017	328.0000
19	Unit 19S	1616 Park Pl	New York	NY	10019	180.0000
20	Apt 20T	1717 Madison Ave	New York	NY	10020	314.0000
21	Apt 21U	123 Main St	New York	NY	10001	1020.00…
22	Unit 22V	456 Broadway	New York	NY	10002	595.0000
23	Apt 23W	789 Park Ave	New York	NY	10003	628.0000
24	Apt 24X	101 Wall St	New York	NY	10004	12.0000
26	Apt 26Z	303 5th Ave	New York	NY	10006	336.0000
27	Unit 27…	404 Madison Ave	New York	NY	10007	24.0000
28	Apt 28…	505 Park Pl	New York	NY	10008	158.0000
29	Apt 29…	606 3rd St	New York	NY	10009	144.0000
30	Unit 30…	707 Broadway	New York	NY	10010	356.0000
31	Apt 31…	808 Wall St	New York	NY	10011	126.0000
32	Unit 32…	909 Lexington Ave	New York	NY	10012	239.0000
33	Apt 33…	1010 Park Pl	New York	NY	10013	196.0000
34	Unit 34…	1111 Madison Ave	New York	NY	10014	1117.0000
35	Apt 35II	1212 5th Ave	New York	NY	10015	316.0000
36	Unit 36JJ	1313 Broadway	New York	NY	10016	200.0000
37	Apt 37…	1414 Wall St	New York	NY	10017	120.0000
38	Apt 38LL	1515 Lexington A…	New York	NY	10018	564.0000
39	Unit 39…	1616 Park Pl	New York	NY	10019	392.0000
40	Apt 40…	1717 Madison Ave	New York	NY	10020	304.0000

Query 5: For each service location, compute its total energy consumption during August 2022, as a percentage of the average total energy consumption during the same time of other service locations that have a similar square footage (meaning, at most 5% higher or lower square footage). Thus, you would output 150% if a service location with 1000 sqft had 50% higher energy consumption than the average of other service locations that have between 950 and 1050 sqft.

```
with AvgEnergyConsumptionPerSL as (
    select sl.serviceLocID, avg(ec.totalEnergyConsumed) as avgConsumed
    from ServiceLocations sl
    join Devices d on sl.serviceLocID = d.serviceLocID
    join EnergyConsumption ec on ec.deviceID = d.deviceID
    where month(ec.eventTimestamp) = 8 and year(ec.eventTimestamp) = 2022
    group by sl.serviceLocID
),
SimilarSquareFootage as (
    select sl2.serviceLocID, ec2.totalEnergyConsumed as energyConsumed
    from ServiceLocations sl2
    join Devices d on sl2.serviceLocID = d.serviceLocID
    join EnergyConsumption ec2 on d.deviceID = ec2.deviceID
    join ServiceLocations sl3 on sl2.serviceLocID <> sl3.serviceLocID
    where abs(sl2.squareFootage - sl3.squareFootage) / sl3.squareFootage <= 0.05
    group by sl2.serviceLocID
)
select servLoc.serviceLocID, servLoc.streetAddress, servLoc.unit, servLoc.city, servLoc.state,
((ssf.energyConsumed / aec.avgConsumed) * 100) + 100 as PercentageConsumed
from ServiceLocations servLoc
join SimilarSquareFootage ssf on servLoc.serviceLocID = ssf.serviceLocID
join AvgEnergyConsumptionPerSL aec on ssf.serviceLocID = aec.serviceLocID;
```

serviceLocID	streetAddress	unit	city	state	PercentageConsumed
1	123 Main St	Apt 1A	New York	NY	100.000000
2	456 Broadway	Unit 2B	New York	NY	279.999991
4	101 Wall St	Apt 4D	New York	NY	220.754717
5	202 Lexington Ave	Unit 5E	New York	NY	200.000000
6	303 5th Ave	Apt 6F	New York	NY	251.351360
7	404 Madison Ave	Unit 7G	New York	NY	372.727304
8	505 Park Pl	Apt 8H	New York	NY	185.714280
9	606 3rd St	Apt 9I	New York	NY	144.444444
10	707 Broadway	Unit 10J	New York	NY	150.000000
11	808 Wall St	Apt 11K	New York	NY	254.054048
13	1010 Park Pl	Apt 13M	New York	NY	180.769233
14	1111 Madison Ave	Unit 14N	New York	NY	250.000000
16	1313 Broadway	Unit 16P	New York	NY	385.000021
17	1414 Wall St	Apt 17Q	New York	NY	201.587302
19	1616 Park Pl	Unit 19S	New York	NY	255.555530
20	1717 Madison Ave	Apt 20T	New York	NY	100.000000
21	123 Main St	Apt 21U	New York	NY	163.157898
22	456 Broadway	Unit 22V	New York	NY	154.054054
23	789 Park Ave	Apt 23W	New York	NY	177.720211
24	101 Wall St	Apt 24X	New York	NY	400.000075
26	303 5th Ave	Apt 26Z	New York	NY	228.155345
27	404 Madison Ave	Unit 27…	New York	NY	100.000000
28	505 Park Pl	Apt 28…	New York	NY	270.454565
29	606 3rd St	Apt 29…	New York	NY	100.000000
30	707 Broadway	Unit 30…	New York	NY	300.000000
31	808 Wall St	Apt 31…	New York	NY	306.521708
32	909 Lexington Ave	Unit 32…	New York	NY	168.571432
33	1010 Park Pl	Apt 33…	New York	NY	100.000000
34	1111 Madison Ave	Unit 34…	New York	NY	183.881583
35	1212 5th Ave	Apt 35II	New York	NY	141.666667
36	1313 Broadway	Unit 36JJ	New York	NY	143.750001
37	1414 Wall St	Apt 37…	New York	NY	261.538471
38	1515 Lexington A…	Apt 38LL	New York	NY	191.358033
39	1616 Park Pl	Unit 39…	New York	NY	151.515151
40	1717 Madison Ave	Apt 40…	New York	NY	100.000000

Query 6: Identify service location(s) that had the highest percentage increase in energy consumption between August and September of 2022.

```
WITH TotalEnergyAugust AS (
    SELECT d.deviceID, sl.serviceLocID, SUM(ec.totalEnergyConsumed) as SumTotalEnergy
    FROM Devices d
    JOIN EnergyConsumption ec ON ec.deviceID = d.deviceID
    JOIN ServiceLocations sl ON sl.serviceLocID = d.serviceLocID
    WHERE DATE(ec.eventTimestamp) BETWEEN '2022-08-01' AND '2022-08-31'
    GROUP BY d.deviceID
),
TotalEnergySeptember AS (
    SELECT d.deviceID, sl.serviceLocID, SUM(ec.totalEnergyConsumed) as SumTotalEnergy
    FROM Devices d
    JOIN EnergyConsumption ec ON ec.deviceID = d.deviceID
    JOIN ServiceLocations sl ON sl.serviceLocID = d.serviceLocID
    WHERE DATE(ec.eventTimestamp) BETWEEN '2022-09-01' AND '2022-09-30'
    GROUP BY d.deviceID
)
SELECT sl.serviceLocID, ((SUM(tes.SumTotalEnergy) - SUM(tea.SumTotalEnergy))) / SUM(tea.SumTotalEnergy) * 100 AS PercentageIncrease
FROM ServiceLocations sl
JOIN TotalEnergyAugust tea ON tea.serviceLocID = sl.serviceLocID
JOIN TotalEnergySeptember tes ON tes.serviceLocID = sl.serviceLocID
GROUP BY sl.serviceLocID
ORDER BY PercentageIncrease DESC
LIMIT 3;
```

serviceLocID	PercentageIncrease
7	52.380952
20	64.102564
8	71.428571