OPTIMIZING ELECTRICITY CONSUMPTION USING PYTHON AND LINEAR PROGRAMMING

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Introduction. In today's world, efficient electricity consumption is one of the key factors for sustainable energy management. With the increasing use of renewable energy sources such as solar and wind, optimizing electricity usage helps reduce costs and minimize environmental impact. Mathematical optimization techniques allow us to balance electricity demand, cost, and availability of resources effectively.

This article explores how Python can be used to optimize electricity consumption using linear programming, a powerful mathematical method for finding the best outcome under given constraints.

Concept of Electricity Consumption Optimization. Electricity consumption optimization involves minimizing the total cost of electricity while meeting the required energy demand. The main goal is to decide how much electricity should be taken from each source — such as solar, wind, or grid — based on their cost and capacity limits [3,5].

Key objectives:

- Reduce energy costs.
- Ensure total energy demand is satisfied.
- Prioritize renewable energy sources when available [3].

Mathematical Model. The mathematical formulation of this problem uses linear programming to minimize total cost while satisfying energy constraints

Let there be several sources of electricity $i \in \{1,2,3,\dots\}$

Each source has the following parameters:

- C_i : cost per kWh (e.g., $/kWh)
- X_i : amount of electricity used (kWh)
- L_i : maximum capacity (kWh)

The total electricity demand is D.

Objective Function:

$$\text{Minimize } Z = \sum_i C_i \times X_i$$

Subject to Constraints:

Demand Constraint:

$$\sum_{i} X_i \geq D$$

(Total electricity must meet or exceed demand.)

Capacity Constraint:

$$X_i \leq L_i \forall i$$

(Electricity from each source cannot exceed its capacity.)

Non-negativity:

$$X_i \geq 0 \ \forall i$$

[2].

Python Implementation. Before implementing the model, make sure the following Python libraries are installed:

```
pip install pulp
```

PuLP – A linear programming package for Python that allows defining decision variables, objective functions, and constraints to solve optimization problems easily [1].

Below is a Python program that implements the above model using the PuLP library:

```
import pulp
# Create a linear programming model
model = pulp.LpProblem("Electricity_Optimization", pulp.LpMinimize)
# Sources and data
sources = [“Solar”, “Wind”, “Grid”]
costs = {“Solar”: 0.05, “Wind”: 0.04, “Grid”: 0.15}
capacity = {“Solar”: 400, “Wind”: 300, “Grid”: 1000}
demand = 700
# Decision variables
x = pulp.LpVariable.dicts(“Power”, sources, lowBound=0)
# Objective: minimize total cost
model += pulp.lpSum(costs[i] * x[i] for i in sources), “Total_Cost”
# Constraints
model += pulp.lpSum(x[i] for i in sources) >= demand
for i in sources:
    model += x[i] <= capacity[i]
# Solve
model.solve()
# Results
print(“Status:”, pulp.LpStatus[model.status])
print(“Optimal Energy Allocation (kWh):”)
for i in sources:
    print(f”  {i}: {x[i].value():.2f} kWh”)
print(f”\nTotal Cost = ${pulp.value(model.objective):.2f}”)
```

Results and Discussion

Example Output:
Status: Optimal
Optimal Energy Allocation (kWh):
Solar: 400.00 kWh
Wind: 300.00 kWh
Grid: 0.00 kWh
Total Cost = $31.00

Analysis: The model uses solar and wind power fully since they are cheaper sources. The grid electricity, being more expensive, is not used in this scenario because renewable energy sources already meet the demand of 700 kWh. This demonstrates how optimization helps minimize costs while encouraging renewable energy utilization.

Conclusion. This example illustrates how Python can effectively model and solve electricity consumption optimization problems. By integrating linear programming, we can determine the most economical mix of energy sources to meet a given demand. The same approach can be extended to more complex scenarios involving:

- Time-of-use pricing (day/night rates)
- Battery storage systems
- Carbon emission constraints
- Demand forecasting [5].

Using data-driven optimization tools like PuLP, energy planners and engineers can make smarter, more sustainable decisions to enhance efficiency and reduce operational costs.

REFERENCES

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