Decision Project

Demand-side Management of Smart Appliance Based on Optimization Prediction Tools

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Subsection 1

Introduction

Background

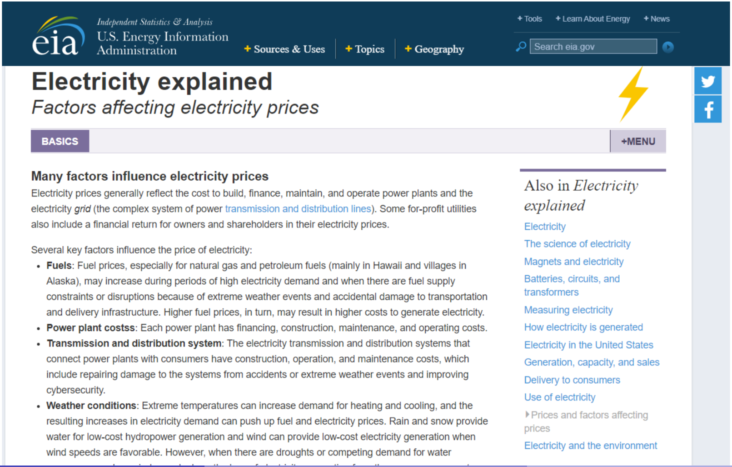
- What is Demand-side management?
  Demand-side management is one approach that can be applied to efficiently manage a site's energy consumption with the aim of cutting the costs of electrical energy supply.
- To be brief, the purpose is to get a lower cost for electricity consumption.
- Stakeholders: customers and companies of smart appliance.

Problem Statement

- If we can allocate working time to smart appliance according to the flowing electricity price, we can make great benefits.
- The decision-maker should be the smart appliance itself, to decide which time to start working in order to get the lowest cost of electricity.
- How to get the value of flowing electricity price?
  We need to build a prediction model for it.

Next Step

- Whether or not to build a model ourselves?
  Building a model ourselves is too complicated and not reliable due to the number of factors involved and lack of data access.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Electricity explained

Factors affecting electricity prices

BASICS +MENU

Many factors influence electricity prices

Electricity prices generally reflect the cost to build, finance, maintain, and operate power plants and the electricity *grid* (the complex system of power transmission and distribution lines). Some for-profit utilities also include a financial return for owners and shareholders in their electricity prices.

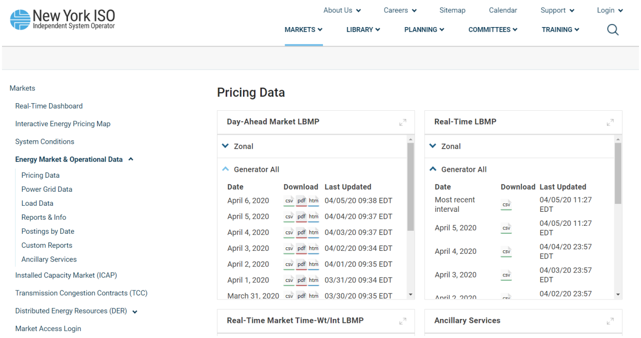
Several key factors influence the price of electricity:

- **Fuels**: Fuel prices, especially for natural gas and petroleum fuels (mainly in Hawaii and villages in Alaska), may increase during periods of high electricity demand and when there are fuel supply constraints or disruptions because of extreme weather events and accidental damage to transportation and delivery infrastructure. Higher fuel prices, in turn, may result in higher costs to generate electricity.
- **Power plant costss**: Each power plant has financing, construction, maintenance, and operating costs.
- **Transmission and distribution system**: The electricity transmission and distribution systems that connect power plants with consumers have construction, operation, and maintenance costs, which include repairing damage to the systems from accidents or extreme weather events and improving cybersecurity.
- **Weather conditions**: Extreme temperatures can increase demand for heating and cooling, and the resulting increases in electricity demand can push up fuel and electricity prices. Rain and snow provide water for low-cost hydropower generation and wind can provide low-cost electricity generation when wind speeds are favorable. However, when there are droughts or competing demand for water

Also in *Electricity explained*
Electricity
The science of electricity
Magnets and electricity
Batteries, circuits, and transformers
Measuring electricity
How electricity is generated
Electricity in the United States
Generation, capacity, and sales
Delivery to consumers
Use of electricity
Prices and factors affecting prices
Electricity and the environment

Data we have

- Instead of building a model ourselves, we will use the forecast electricity price data generated by NYISO (NewYork Independent System Operator).
- The source of data: https://www.nyiso.com/energy-market-operational-data
- LBMP: locational based marginal pricing



Data Descrption

- Forecast electricity price data: every hour's LBMP based on forecast everyday(every hour's price, one-day ahead).

1	Time Stamp	Name	PTID	LBMP ($/MWHr)	Marginal Cost Losses ($/MWHr)	Marginal Cost Congestion ($/MWHr)
2	11/01/2019 00:00	CAPITL	61757	20.18	0.38	-14.37
3	11/01/2019 00:00	CENTRL	61754	7.4	0.09	-1.88
4	11/01/2019 00:00	DUNWOD	61760	16.45	0.52	-10.51
5	11/01/2019 00:00	GENESE	61753	6.84	0.03	-1.39
6	11/01/2019 00:00	H Q	61844	5.16	-0.17	0.09
7	11/01/2019 00:00	HUD VL	61758	16.29	0.45	-10.42
8	11/01/2019 00:00	LONGIL	61762	16.59	0.66	-10.51
9	11/01/2019 00:00	MHK VL	61756	7.64	0.07	-2.14
10	11/01/2019 00:00	MILLWD	61759	16.49	0.48	-10.59
11	11/01/2019 00:00	N.Y.C.	61761	16.53	0.59	-10.51
12	11/01/2019 00:00	NORTH	61755	5.03	-0.4	0
13	11/01/2019 00:00	NPX	61845	17.9	0.4	-12.08
14	11/01/2019 00:00	O H	61846	7.16	0.02	-1.71
15	11/01/2019 00:00	PJM	61847	9.06	0.16	-3.47
16	11/01/2019 00:00	WEST	61752	7.34	0.11	-1.8
17	11/01/2019 01:00	CAPITL	61757	17.69	0.34	-12.28
18	11/01/2019 01:00	CENTRL	61754	6.76	0.08	-1.61
19	11/01/2019 01:00	DUNWOD	61760	14.52	0.48	-8.97
20	11/01/2019 01:00	GENESE	61753	6.27	0.02	-1.18
21	11/01/2019 01:00	H Q	61844	5	-0.16	-0.09
22	11/01/2019 01:00	HUD VL	61758	14.38	0.41	-8.9
23	11/01/2019 01:00	LONGIL	61762	14.74	0.65	-9.02
24	11/01/2019 01:00	MHK VL	61756	6.95	0.05	-1.83
25	11/01/2019 01:00	MILLWD	61759	14.55	0.44	-9.05
26	11/01/2019 01:00	N.Y.C.	61761	14.59	0.54	-8.98
27	11/01/2019 01:00	NORTH	61755	4.68	-0.39	0
28	11/01/2019 01:00	NPX	61845	15.94	0.38	-10.49
29	11/01/2019 01:00	O H	61846	6.74	0.04	-1.63
30	11/01/2019 01:00	PJM	61847	8.36	0.15	-3.14

Data Description

- Historical real-time electricity price data: real-world recorded LBMP(every 5 minutes' price, continuously updated to today)
  we use the mean value of 12 every 5 minutes' price within each hour to represent its every hours' real-time electricity price.

	A	B	C	D	E	F	G	H
1	Time Stamp	Name	PTID	LBMP ($/MWHr)	Marginal Cost Losses ($/MWHr)	Marginal Cost Congestion ($/MWHr)		
2	11/01/2019 00:05:00	CAPITL	61757	19.46	1.14	0		
3	11/01/2019 00:05:00	CENTRL	61754	18.36	0.04	0		
4	11/01/2019 00:05:00	DUNWOD	61760	19.89	1.58	0		
5	11/01/2019 00:05:00	GENESE	61753	17.83	-0.49	0		
6	11/01/2019 00:05:00	H Q	61844	17.93	-0.39	0		
7	11/01/2019 00:05:00	HUD VL	61758	19.73	1.41	0		
8	11/01/2019 00:05:00	LONGIL	61762	20.28	1.96	0		
9	11/01/2019 00:05:00	MHK VL	61756	18.47	0.15	0		
10	11/01/2019 00:05:00	MILLWD	61759	19.82	1.5	0		
11	11/01/2019 00:05:00	N.Y.C.	61761	20.12	1.8	0		
12	11/01/2019 00:05:00	NORTH	61755	17.66	-0.66	0		
13	11/01/2019 00:05:00	NPX	61845	17.93	1.23	1.62		
14	11/01/2019 00:05:00	O H	61846	17.4	-0.92	0		
15	11/01/2019 00:05:00	PJM	61847	18.15	-0.17	0		
16	11/01/2019 00:05:00	WEST	61752	17.51	-0.81	0		
17	11/01/2019 00:10:00	CAPITL	61757	19.56	1.18	0		
18	11/01/2019 00:10:00	CENTRL	61754	18.38	0	0		
19	11/01/2019 00:10:00	DUNWOD	61760	19.96	1.58	0		
20	11/01/2019 00:10:00	GENESE	61753	17.85	-0.53	0		
21	11/01/2019 00:10:00	H Q	61844	17.99	-0.39	0		
22	11/01/2019 00:10:00	HUD VL	61758	19.79	1.42	0		
23	11/01/2019 00:10:00	LONGIL	61762	20.35	1.97	0		
24	11/01/2019 00:10:00	MHK VL	61756	18.54	0.17	0		
25	11/01/2019 00:10:00	MILLWD	61759	19.89	1.51	0		
26	11/01/2019 00:10:00	N.Y.C.	61761	20.18	1.8	0		
27	11/01/2019 00:10:00	NORTH	61755	17.7	-0.68	0		
28	11/01/2019 00:10:00	NPX	61845	18.01	1.25	1.62		
29	11/01/2019 00:10:00	O H	61846	17.4	-0.97	0		
30	11/01/2019 00:10:00	PJM	61847	18.18	-0.2	0		

Subsection 2

Formalism

Decision Problem Formalism

Having these price data, We need to generate a recommendation about which time to start working given required working time and working time range to save the cost.

Parameters we have here

H: length of the given working time range set by householders.
$L \in [1, H]$: working hours for smart appliance to complete the work
$Y =< Y_H, Y_H - 1, \ldots, Y_1 >$: price on hours h= H,...,1

The decision maker's action set:

Smart appliance needs to choose a starting working time (certain hour h to start working) to complete the job. $h \in [1, H - L + 1]$(range of left available starting working hours)

Payoffs: The loss function

Let $L(h, y)$ denote the losses incurred by electricity usage by smart appliance. $L(h, y)$=$\sum_h^{h+L-1} Y_h$

Decision criterion

The decision criterion for smart appliance is: choose the start working hour that minimizes losses in expectation:

$$h^* = \underset{h \in \mathbb{H}}{\operatorname{argmin}} \; E[L(h, Y)]$$

where the expectation is taken over the distribution of Y. This distribution represents the information about uncertain electricity price we can predict using the predicted price data for smart appliance to make decision to work.

Data generating process

We will use historical real-time and forecast price data to fit a model. Then we can predict the realized price one-day ahead according to the day-ahead predicted data by NYISO.

Build Prediction Model

$X1_h$: historic predicted electricity price.
$Y1_h$: historic real-time electricity price.
$X2_h$: day-ahead predicted electricity price.
$Y2_h$: random state variable indicating realized value of electricity price.

The process can be concluded as follows: historic predicted price($X1_h$) + historic real-time price($Y1_h$) + –> linear model and error distribution $Y1_h = \beta_0 + \beta_1 X1_h + \varepsilon_i$ –>given the day-ahead predicted price($X2_h$) –> predict the distribution of the realized price($Y2_h$).

The parameter space:

In this case, we represent the randomness of unobserved thing as the error distribution of the linear model we build (the fluctuation of price).

The process for getting better information:

After getting the real-time price data of the new day, we will fit it into the model to get better results for the future(make calibration).

Some assumptions we have for our model:

Firstly, it is supposed that there is a linear relationship between predicted price and real-time price.
Secondly, the error term ε_i follows a normal distribution: $\varepsilon_i \sim N(0, \sigma_\varepsilon^2)$.
Finally, the process is assumed to be stationary, which means that there is no trend over time and months, years.

Subsection 3

Summary

The purpose of this project

- Build a simple application. After inputing location, working time and working time range, it will suggest a working time for the user.
- Examine the error distribution of our model, whether it follows our assumption. Is there a tendency that higher price brings higher fluctuation.
- Examine the reliability of NYISO's prediction accuracy, whether it has a biase in its prediction and whether we can make adjustments to it.

Future improvement

- The result of the real-time updated data will be used to test the model's performance and help refine the model.
- Integrate the prediction model rather than directly applying NYISO's prediction data. Evaluate other electricity price prediction models.
- Add a working time preference variable to our loss function, e.g. set a higher preference level value if you would like your washing to be done as soon as possible.

Thank you

- Thanks for watching!
- Any Questions?