Mining and Analyzing "Multi-Meters in One" Comprehensive Energy Data

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Abstract. In the present paper, the massive comprehensive energy data was utilized to establish energy consumption analysis model, energy consumption suggestion model, energy consumption loss model, vacant household discrimination, holiday energy consumption analysis model, and so on. The comprehensive energy data was fully excavated, which can guide customers to use energy scientifically, help enterprises to save energy and reduce losses, and provide data support for government decision-making.

1. Introduction

With the wide application of "Internet +", the resident customers urgently need convenient and saving energy consumption, and experience a good sense of using energy to handle business without leaving home. The energy supply enterprises urgently need to solve the problems such as high loss and poor precision service to improve management and service level. and make government decisions, smart city construction and "interconnection". In addition, government decision-making, smart city construction and the development of "Internet + government services" needs timely and accurate energy data support [1].

At present, the number of "multi-meters in one" acquisition and access customers of Shandong Electric Power Company has reached more than 1.1 million. The massive data acquisition is only sent to water, gas and heat enterprises for meter reading and settlement, and the data value cannot be fully exploited. The data of electricity, water, gas and heat are independent. How to establish the relationship between the data of electricity, water, gas and heat so as to realize the analysis of abnormal energy consumption and improve the economic benefits of energy supply enterprises? Based on the electricity, water, gas and heat energy consumption data of customer, how to optimize the customer's energy consumption mode through the electric water gas heat data analysis, give the customer energy recommendations, and reduce the customer's energy cost. The government urgently needs the results of housing vacancy rate analysis to guide the formulation of housing price policy. How to accurately analyze the housing vacancy rate through the correlation analysis of electric water, gas and heat data. The above contents are the focus of this paper [2-3].

2. Referenced Data Resources

This paper is based on the basic archives information, data collection and events of electricity, water, gas and heat. The external data are introduced appropriately according to the needs of analysis dimension and depth. The data sources are mainly divided into the following two parts: internal data and external data.

2.1. Internal Data

The internal data mainly include the following: 124 kinds of data of "multi-meter in one" customer, such as basic archives information of electricity, water, gas and heat, assets information of meter, topological relationship of meter (mainly including desk area topological relationship, pipeline topological relationship), category of energy use, unit price of energy use, relationship of quantity and price, etc.) ; 26 items of data such as meter's electric energy indication value, opening cover record, voltage phase break etc.; 12 items of data such as water meter status word, accumulated water flow indication value and fault information etc; 13 items of data such as status word, current instantaneous flow velocity and fault information of gas meter, 18 items of data such as instantaneous flow velocity, inlet temperature and return water temperature of heat meter, totalling 450 million items of data.

2.2. External Data

The external data are mainly statistics and technical data issued by price bureau, statistics bureau, meteorological bureau, energy bureau, transportation industry, third party authoritative census structure, research institutes and technical organizations, mainly including 24 items of data such as energy ladder and price, energy category price, natural gas combustion value, energy heating utilization efficiency, heating and refrigeration efficiency for ground source heat (cold) pump and pollutant emissions from various energy sources when they generate 1 kilojoule of heat, etc.

3. Analysis of User Energy Consumption Data

3.1. Analysis of Basic Energy Consumption

The analysis of basic energy consumption includes two parts, that is, the proportion of energy consumption and the composition of energy consumption. The proportion of energy consumption and consumption ranking are calculated according to consumption and unit price. In addition, the electrical heat is converted into thermal energy, and the composition and ranking of energy consumption are calculated from two dimensions of thermal energy consumption and water energy consumption. The energy consumption levels of customers in different regions are displayed through the average and ranking of energy consumption at different levels [4-5].

Taking the energy consumption of a customer in June 2019 as an example, the energy consumption status of the customer is shown in Table 1. The energy consumption proportion of each item for this user can be calculated according to formula (1).

Table 1. Energy consumption status of a customer in June 2019

Category of Energy Consumption	Quantity	Unit Price	Amount of Money (Yuan)
Electricity	248kWh	0.5469Yuan/kWh	135.63
Natural gas	22m^3	3.6Yuan/ m^3	79.20
Water	11 m^3	4.2Yuan/ m^3	46.20
Heat	20kcal	26.7Yuan/ kcal	534.00

$$p_{ci} = \frac{Q_i \times P_i}{\sum\limits_{i=1}^{n} Q_i \times P_i} \times 100\% \tag{1}$$

p_{ci} :Proportion of energy consumption.

Q_i :Step energy consumption quantity.

P_i :Step unit price.

3.2. Suggestion Model for Energy Consumption

The current energy consumption cost model is established based on the data of step electricity price, step gas price, calorific value of electric energy, calorific value of natural gas, combustion efficiency, heat utilization rate and electro-thermal conversion rate and so on.

$$\begin{cases} \dfrac{p_1}{q_1 \eta_1 \mu_1} < \dfrac{p_2}{q_2 \eta_2 \mu_2} \\[2ex] \dfrac{p_1}{q_1 \eta_1 \mu_1} = \dfrac{p_2}{q_2 \eta_2 \mu_2} \\[2ex] \dfrac{p_1}{q_1 \eta_1 \mu_1} > \dfrac{p_2}{q_2 \eta_2 \mu_2} \end{cases} \tag{2}$$

Where, p is the energy step unit price, q is the calorific value of energy, η is the energy heat utilization efficiency, μ is the energy combustion efficiency, and this coefficient is 100% for non-combustion energy. When the energy cost of Energy 1 is less than that of Energy 2, Energy 1 is recommended; when the energy cost of Energy 1 is equal to that of Energy 2, Energy 1 and Energy 2 are both acceptable; when the energy cost of Energy 1 is greater than that of Energy 2, Energy 2 is recommended.

Calculate the cost of electricity and gas to produce one kilojoule of heat using electric energy and gas energy respectively. As shown in Table 2, we get the most economical energy consumption decision of customers at present, aiming at the energy source with the lowest cost.

Table 2. Energy consumption recommendation

Gas(m³) ecommendation (kW·h)	Step I	Step II	Step III
Step I(Peak)	Gas	Electricity	Electricity
Step I(Valley)	Electricity	Electricity	Electricity
Step II(Peak)	Gas	Electricity	Electricity
Step II(Valley)	Electricity	Electricity	Electricity
Step III(Peak)	Gas	Gas	Gas
Step III(Valley)	Gas	Gas	Electricity

For example, a customer's current electricity consumption is in Step I, and the gas consumption is in Step II. The energy consumption is required at 18:00 a.m. on a certain day in June (the valley electricity price during the non-heating period is executed). Table 1 show that it is more economical to choose electricity. For instance, this customer heats 100kg of water, using electricity can save 0.56Yuan and 9.98% of the cost, compared with using gas.

3.3. Annual Comprehensive Energy Consumption Plan

Based on the total amount of electricity and gas energy used by customers in the previous year, the objective function is established aiming at the lowest total energy consumption cost. The total energy consumption of customers is expressed by electric energy. The annual energy utilization plan of electricity and gas energy is obtained (see Table 3) via the equivalent conversion of gas energy into electrical energy (Q Electricity = 5.684 Q Gas). When the customer's actual energy consumption deviates from the given energy plan, the optimal energy consumption scheme can be dynamically generated based on particle swarm optimization according to the current energy consumption.

Table 3. Energy consumption recommendation

Interval Name	Amount of energy consumption (kWh)	Energy consumption plan
Interval I	[0,1227)	Without comprehensive energy consumption plan, the customers can use more gas to reduce energy consumption costs, and the corresponding gas consumption volume is in the range of [0,216 m³].
Interval II	[1227,6027)	The customers use 216 m³ of gas, and the excess part is replaced by electricity. The corresponding total amount of electricity consumption is in the range of [0,4800 kWh].
Interval III	[6027, +∞)	After the customers use 216 m³ of gas and 4800 kWh of electricity, the excess part is replaced by gas. The corresponding total gas consumption volume is in the range of [216 m³, +∞).

For example, a customer in 2017 used 2021 kWh of electricity and 314 m³ of gas, and the total energy used by this customer was 3805.776 kWh. This energy consumption amount was located in Interval II. According to the comprehensive energy consumption plan, the customer used 216m³ of gas, the excess part is replaced by electricity, and it is required that 98 m³ (314 m³-216 m³) is equivalently converted into 557.032 kWh of electricity energy, and the total amount of electric consumption is:

$$2021 \text{ kWh} + 557.032 \text{ kWh} = 2578.032 \text{ (kWh)}.$$

Namely, the customer in 2018 will use 216 m³ of natural gas and 2578.032 kWh of electricity, which cost is lowest. The energy cost of this scheme is 45.72 yuan lower than that of last year. Converting amount of electricity-gas inter-replacing to every month, the monthly plan for using electricity and gas in 2018 can be obtained.
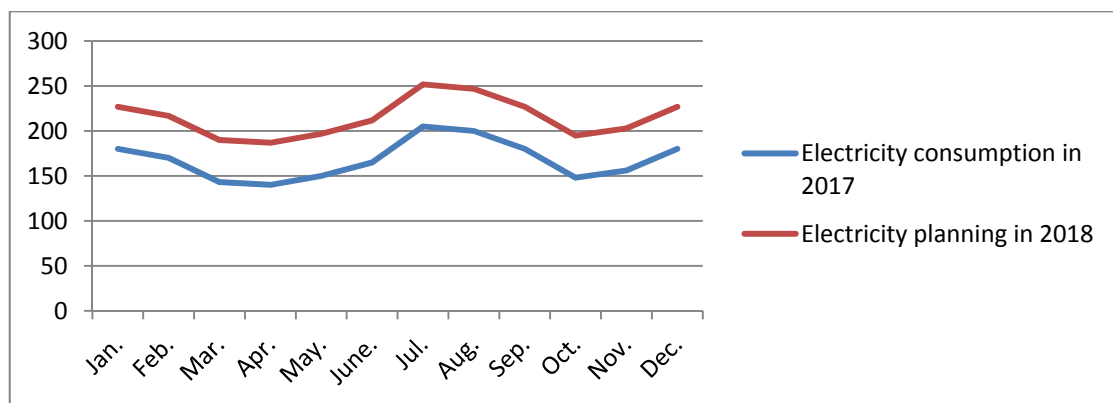
Figure 1. Annual energy curve of a customer

4. Data Analysis of Energy Supply Enterprises

4.1. Analysis of Energy Conservation and Loss Reduction

The loss calculation models are constructed according to electricity, water, heat and gas meters, respectively. The model can be the assessment object of a certain energy supply enterprise or the whole energy supply enterprise. In the present paper, a loss calculation model of "assessment unit - assessment object-input/output metering point". The system first needs to maintain the assessment unit for the assessment of energy supply enterprises, then takes the assessment area as the assessment object, followed by allocating the input/output metering point according to the actual situation on side. After configuring the loss calculation model, calculate the loss by using the loss calculation formula [6-7]. The formula is as follows:

$$\begin{cases} \Delta Q = Q_{input} - Q_{output} \\[4pt] Q_{input} = \sum_{i=1}^{n} Q_{iinput} \\[4pt] Q_{output} = \sum_{j=1}^{m} Q_{joutput} \\[4pt] \delta = \dfrac{\Delta Q}{Q_{input}} \times 100\% \end{cases} \tag{3}$$

ΔQ :Energy consumption amount

Q_{input} :Total energy input

Q_{output} :Total energy output

Q_{iinput} :Energy consumption amount of input metering point configured in the ith assessment unit

$Q_{joutput}$:Energy consumption amount of output metering point configured in the jth assessment unit

δ :Loss rate

4.2. Analysis of Potential Customers for Electricity Power Replacing
The energy consumption level is divided based on the criteria for classifying the consumption class. By the comparative analysis of the electricity consumption situation among different users, select the users whose total energy cost is in the same class, together with the proportion of electricity cost not less than 20% and more than 60% in the same community, and the electric energy substitution promotion of common household appliances and high-end appliances are carried out respectively.

5. Analysis of the Government Over all Energy

5.1. Analysis of Housing Vacancy Rate
The calculation of vacant households can be applied to value-added services and data sharing. In particular, the value-added services can exploit the non-electric information value of electric power data and develop customer drainage through residential housing use information. In terms of data sharing, it can provide housing use to government management departments, assist government decision-making and improve macro-management ability.

The energy consumption of urban residents is zero or very low for consecutive six months or more. The judgment model is that the various energy consumption monthly is less than or equal to N_i (i = 1,2,3,4; representing the four types of electricity, water, gas and heat energy), or the daily energy consumption is less than or equal to M_i (i=1,2,3,4; representing the four types of electricity, water, gas and heat energy).

N_i is the peak threshold of various energy consumption monthly of vacant households. When the various energy consumption monthly are all less than the corresponding threshold N_i, the user is judged to be vacant household. Otherwise, it is considered that the residential behavior occurred.

M_i is the peak threshold of various energy consumption daily of vacant households. When the various energy consumption daily are all less than the corresponding threshold M_i, the user is judged to be vacant household. Otherwise, it is considered that the residential behavior occurred.

5.2. Analysis of Typical Energy Consumption in Holidays and Festivals
The analysis of typical energy consumption in holidays and festivals is to depict the households who use electricity regularly on fixed holidays, mainly in the form of inflow and outflow. The population mobility of residents in the community is reflected by describing the changes of residents' electricity consumption during the Spring Festival and National Day holidays.

If the average level of electricity consumption before the festival is lower than that during the festival, and the electricity consumption before the festival is at the level of vacant households, it indicates that it is inflow households. If the electricity consumption before the festival is higher than that during the festival, and the electricity consumption during the festival is below the average level of the electricity consumption before the festival, it indicates that it is an outflow family.

The computational model is as follows:

$$I_e = [\frac{\log(1+Q_h)}{\log(1+Q_a)} \quad 1]*100, Q_a \leq Q^*$$

(4)

$$O_e = [\frac{\log(1+Q_a)}{\log(1+Q_h)} \quad 1]*100, Q_h \leq Q_a$$

(5)

I_e :Inflow index

O_e :Outflow index

Q_h :Represent the average daily energy consumption level of residents in a community during a holiday

Q_a : Represent the average daily energy consumption level of residents in the three months before the Ffestival

Q^* : Represent the average daily electricity consumption level of vacant households

The increase in household inflow (out) index indicates that the injection (out) behavior is more obvious. Finally, the comparison is conducted according to the proportion of the inflow and outflow households in each district. If there are more inflow households, the district is an inflow-type residential area; if there are more outflow households, the district is an outflow-type residential area.

5.3. Analysis of Urban Supporting Plan

The consumption level and consumption behavior of customers are evaluated through the establishment of a discrete two-dimensional analysis model of the occupancy rate and the average level of energy consumption for customers in the area, which provides a reference for urban supporting plan. For example, in areas with high occupancy rate and low average energy consumption, the government needs to strengthen the policy for benefiting the people, such as allocating more public transport resources, while in areas with high occupancy rate and average energy consumption, it needs to plan high-end business support and education and medical resources.

5.4. Analysis of Urban Industrial Energy Consumption

The energy consumption and pollutant emission of a single product are calculated based on the industrial productivity and energy consumption, and referring to the emission standards of electricity, gas and heat pollutants. The optimal energy utilization ratio of a single product is further calculated according to the conversion standards of electricity, gas, heat and standard coal, so as to reduce the cost of energy use and decrease the pollutant emission, and provide data support for the government to carry out environmental protection, high energy-consuming enterprise governance or energy replacement plan [8].

6. END

The diverse needs of customers for intelligent energy use is satisfied by mining and analyzing comprehensive energy data in the present paper, which effectively avoids the high-level energy consumption of customers, and reduces the energy consumption cost; automatically identify and accurately locate the abnormalities, faults, energy stealing, crossed meters and other issues of energy meter, so as to avoid customer safety problems caused by leakage of water and air. The real statistical analysis has been achieved, including housing vacancy rate, personnel mobility in holidays and

festivals, urban industrial energy consumption, etc., which will provide accurate support for municipal planning, energy regulation, energy conservation and emission reduction, infrastructure construction and "Internet + government services", offering accurate data support for national policy formulation and macroeconomic regulation.

7. References

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