Better Understanding of Energy Consumption via Energy Information and Management System

Tao Wang*, Taomei Zhu*
Tongji Zhejiang College, Jiaxing 314000, China
*Corresponding author e-mail: zhtm126@126.com, wwt263_cn@sina.com

Abstract. Energy crisis will still be a global issue for long time. Governments at all levels are making more efforts to resolve the energy problems in China. However, conflict between the increasing energy consumption (and demand) in social development and the limited energy resources worldwide. Energy conservation becomes an important objective in all kinds of processes and activities. An information and management system is proposed in this paper, in particular aiding the industry sector and sub-sectors to understand better the energy data and make better decisions in energy management.

1. Introduction

Why do we need to understand the energy consumption data? Broadly speaking, there are limited energy resources but continuously growing demands for usable energy. Worldwide, energy efficiency has been high on the political agenda for decades. Most countries set goals to consume less energy and to decrease their carbon dioxide emissions [1]. With the increase in energy consumption in China, energy problem has also been highly concerned by Chinese governments at all levels. Energy issue also becomes a bottleneck restricting economy progress in many areas and local enterprises. To seek solutions of energy problem, scientific efforts have also been made to research the characteristics of energy structure, key influential factors [3] and indicators of energy consumption [4], etc. The most important indicators of energy consumption of a country or a region are total final energy (consumed) and energy efficiency. The latter is expressed in energy intensity in many countries.

However, the key challenge is the lack of availability of energy data. The International Energy Agency (IEA) who provides authoritative research and analysis on energy data and ways to ensure reliable, affordable and clean energy for its member countries and beyond, stated in its annual reports on energy efficiency indicators [1] that there is still a gap between energy declarations and actions for an important reason of lacking proper data. Besides, most existing data for energy consumption and energy efficiency are collected in statistical methodologies. It takes a long term and requires a certain scale of sample to support policy-making on the base of statistical energy data.

Real-time and direct measurement data of energy were usually not available mainly due to the high costs in implementing individual equipment for all size of the sample and the labor during all the cycle of data collection and other technique issues, such as data communication and data mining. However, with a rapid development of technologies, direct measurement data of energy consumption are gradually obtainable from the bottom layer of data production. Moreover, objectives of the energy data analysis may not only be the predefined indicators but also potential findings in processing dynamic data.
In this paper, an energy information and management system is proposed particularly based on the direct measurement data of energy consumption in industry sector, while statistical data are also allowed to be imported and exported. It also aims to provide support in decision-making in energy management and achieve the purpose of energy conservation.

2. Energy data in industry sector

2.1. Energy consumption of industry

As defined by IEA, energy consumption can be mainly broken down into four sectors: residential, industry, transport and services. The shares of these sectors can be very variable from a country to another. The industry accounts for 29% of total final consumption (TFC) globally while the share of industry reaches almost a half of TFC in China, in 2011. Even in China, this share varies across different provinces or regions, depending on the degree of industry and the structure of sub-sectors in local industry. Fig. 1 shows the shares of industry sector in total final consumption respectively for the world, China and a region of China. In the case of the surveyed region of China, four-fifths of TFC is in the industry sector. It means that the industry can be the first sector to look at for energy savings. Besides, direct measurements are often privileged in the case of energy audits (industry, buildings, etc.) when there is a need of detailed information rather than for efficiency indicators, not as that in residential sector with privacy issues [2]. It should be noted that the sub-sectors defined for industry may vary from countries, e.g. when metering energy consumption in the region of China, upstream power generation, construction and distribution of electricity, gas and water are included. However they are beyond the sub-sector list of industry sector defined by IEA. Nevertheless, industry takes the largest share of TFC.

2.2. Categories of energy data in industry

Theoretically, all energy-using activities across industries should be covered in terms of industrial energy consumption. However, it is very difficult to carry out the measurement to all the energy-using activities. In statistics or direct measurement, energy data have to be classified and defined in details. According to energy sources, the consumption of coal, natural gas, oil, electricity, heat and other form of energy used in industrial activities should be metered. Therefore energy consumption can be expressed in various units (ton, joule, kWh, etc.). An industrial enterprise may use one or more types of energy, depending on the sub-sector it belongs to and its production and manufacture engineering. Nationally, the consumption of coal accounts for more than 60% of TFC in China. However, in some regions the largest share of local TFC is electricity. And some electricity-intensive sub-sectors drives almost more than a half of the electricity final consumption. Enterprises in these sub-sectors are good starting points to install energy measurement equipment and connect to the network.

Figure 1. Shares of industry sector in TFC for the world, China and a region of China.
Energy efficiency indicators, not collected by direct measurement, but obtained by analyzing all collected and historical data. Energy intensity of a country is often used as an energy efficiency indicator for that country. It is expressed by the ratio of the total primary energy supply (TPES) divided by the gross domestic product (GDP) of the country. Similarly, energy intensity of a province or a region can be calculated when its TPES and GDP are available. However, energy intensity of a sub-sector or an enterprise is more often indicated by consumption per unit of physical output or consumption per value added. These disaggregated indicators are of most interest to energy efficiency analysis.

3. Information and management system of energy consumption

3.1. The user of system
The proposed system can commonly be used by any of the following groups of user: industrial enterprises who are the energy utilities and realizes the fundamental measurement and collect the direct energy data; industry associations (of sub-sector, e.g. iron and steel, chemical and petrochemical, pulp and paper, etc.) who are very important sub-sector data providers currently and interested in sub-sector industry data collection and analysis; and administrative organizations at corresponding level, such as the governmental offices responsible for of industry and/or energy management, who have the authority to monitor the energy consumption of all sectors, make energy balance and other energy related policies.

3.2. System structure
The information and management system is designed in a hierarchical architecture, as Fig. 2 shows.

In data production layer, energy metering equipment is installed in the energy-using entities, and theoretically it collects real-time energy consumption data of these entities. Strictly speaking, this layer is excluded in the information and management system. However it the most important foundation of the upper layers. Therefore interfaces and communication protocols are required to connect and update data to the network, more specifically to a database or a cloud data pool. An energy audit can also update the holistic analysis (statistical data) of all energy inputs and outputs to the system.
A second layer is designed for data storage and processing. In methodology of direct measurement, a mass of data are gathered in the network every day. All energy and activity data of measurement and statistics are reorganized in this layer, prepared for different applications. Role information of the system users and other configuration data are stored as well.

According to the approach and purpose of the analysis, the applications based on energy data are defined to provide descriptive energy consumption information, predictive analytics of some specific indicators automatically driven by the historical and real-time data, and prescriptive analytics mainly in validation and optimization approaches at a general level which can be used for policy-making support.

3.3. Main functions
From a bottom-up perspective, the system allows the users to get better understanding of the energy consumption by monitoring the energy data by sources and facilities of each plant or enterprise connected, recording the energy use and loss at different stages of production, analyzing the energy efficiency in various visualized graphics and suggesting probable trends of energy consumption in a short period of time.

From a top-down perspective, by supporting of the system, a governmental user can easily get the indicator information and make further adjustments in energy balance and energy policies, and an energy-using enterprise user can directly take actions to control the energy consumption or seek ways to save energy in production. New technologies and optimized methodologies are researched and promoted for energy conservation while the energy data at all levels are analyzed.

Besides, it can be a platform to collect other related information of the data providers, such as administrative attribute, sectoral and sub-sectoral attribute, industrial added value, etc.

4. Challenges faced in system implementation
First challenge in promoting the implementation of this system is to be authorized so that the users can gain more confidence and willingness to use the system for energy control and management.

Difficulties associated with the collection of energy data are the cost to install all hardware and software for direct measurement, verification of the validity and integrity of collected data. Other technical challenges may also lie on the correctly connecting and updating data to the network, as well as the real-time data processing while the data size is continuously increasing.

Fortunately, technologies such as wireless communications, internet of things (IoT) and cloud computing make it technically feasible and even possible to cut the costs significantly.

5. Conclusion
In this paper the energy consumption data are firstly studied. The industrial energy consumption accounts for a large share of total final consumption in China. Besides, direct measurements can be privileged in industrial energy utilities. In many cases, more detailed information can be collected at sub-sector level. All these provide favorable conditions to start the real-time collection of energy data and implement the information and management system in industry, for the very purpose of energy conversation. The information and management system is user-oriented designed. Energy consumption information is displayed in various forms, to support different users to make better decisions in energy management and plan at corresponding level.

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