Green Computing Wanted: Electricity Consumptions in the IT industry and by Household Computers in Five Major Chinese Cities

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***Abstract*—Exhausted energy consumption becomes a world-wide issue nowadays. Computing contributes a large portion of energy consumption. The concept of green computing has been popularized. Along with the rapid development of China, energy issue becomes more and more important. We believe that green computing would play a very important role in China. However, past publications mainly focused on electricity consumption in data centers, while there are other important sources of electricity consumption in computing. The concept of green computing should be also applied to these sources. In this paper, we present and analyze the data on the electricity consumptions in the IT industry (including the telecommunication and computer industries) and by household computers in five major Chinese cities during 2005-2009. The analysis will demonstrate the necessity of green computing in the IT industry and in household computers in China.**

Keywords-energy/electricity consumption; IT industry; household computers; energy efficiency; green computing

I. INTRODUCTION

Exhausted energy consumption becomes a world-wide issue nowadays. Computing contributes a large portion of energy consumption. For example, according to the report from US Environmental Protection Agency (EPA) [3], data centers in US consumed about 60 billion kWh in 2006, which was roughly 1.5 percent of the total US electricity consumption. It would be over 8 percent of the total US electricity consumption in 2020. Note that these data showed only the electricity consumption by data centers but did not include that by other computing facilities.

More and more people believe that enhancing the effective utilization rate of the energy in computing would avoid lots of energy wastes. Then the concept of green computing has been popularized. Green computing can enable computer systems, people, society and natural environment in better harmony, and reach the goals of energy-saving, environment-protection and cost-saving [8].

China is among the fastest-growing countries in the world and has shown great achievements. Along with the rapid development of China, "Energy, which has a bearing on both economic and national security, is of importance and a major constraining factor to the economic and social development of China" [1].

We believe that green computing would play a very important role in China. However, past publications mainly focused on electricity consumption in data centers, while there are other important sources of electricity consumption in computing. The concept of green computing should also be applied to these sources.

In this paper, we analyze the data on the electricity consumptions in the IT industry and by household computers in five major Chinese cities during 2005-2009. The analysis will demonstrate the necessity of green computing in the IT industry and in household computers in China.

This paper is organized as follows. In section II, we show some related work. In section III, we present and analyze the data on the electricity consumption in the IT industry in five major Chinese cities during 2005-2009. In section IV, we discuss the electricity consumption by household computers in these five cities. And in section V we give the conclusion.

II. RELATED WORK

Many publications discussed the energy issues in servers and data centers and showed the urgent demands for green computing. A study in 2007 [9] estimated the total electricity consumption of the servers in the US and in the world. Electricity consumption associated with servers had doubled from 2000 to 2005. According to a McKinsey study in 2008 [4], the utilization ratio of servers rarely exceeded 6%, which is a source of low energy efficiency. Some publications presented the energy data on data centers in Asia-pacific region and China. According to the data from IDC in 2008 [6], the electricity consumption by data centers in Asia-pacific region had been increasing annually in a rate of 23%, which was quite higher than the global average annual rate of 16.7%. Another paper gave an estimate to the electricity consumption in data centers in China and analyzed their energy efficiency [11]. It estimated that the total electricity consumption by the data centers was around 36.4 billion kWh, which accounted for 1% of the total Chinese electricity consumption. The authors predicated that the electricity consumption would continue to increase rapidly. They also indicated that the current energy efficiency of data centers was relatively low and there would be greater potential for energy saving in data centers.

Though many publications gave evidences on the demands for green computing, they mainly focused on data centers. However, there are other important sources of electricity consumption in computing. For example, household computes are also a big source of electricity

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consumption, and another big source is the whole IT industry. We will address these fields in this paper.

III. Electricity Consumption in the IT Industry in Five Major Chinese Cities

In this section, we present and make projections of the data on the electricity consumption in the IT industry in five major Chinese cities during 2005-2015: Beijing, Shenyang, Guangzhou, Hangzhou and Wuhan.

Table I shows the electricity consumptions in the IT industry, in all the industries and the percentage of that in the IT industry over that in all the industries in Beijing from 2005 to 2009. The electricity consumption in the IT industry was 2.46 billion kWh in 2009, which was more than twice of that in 2005. The percentage of electricity consumption occupied by IT industries had increased from 2.40% in 2005 to 4.03% in 2009. This indicated that IT industry in Beijing would potentially be an important source for energy saving.

We can give projections on the electricity consumption in the IT industry in 2015. In order to make the projections as fair as possible, we use a methodology as described below:

1). We project three values of the electricity consumption in all the industries in Beijing in 2015 based on those in 2005-2009: one value by linear regression as E_L, one value by quadratic regression as E_Q, and one value using the same value in 2009 as E_S assuming in a stabilized situation (which is over-optimistic)

2). We project three values of the percentage of the electricity consumption in the IT industry over in all the industries in Beijing in 2015 based on those in 2005-2009: one value by linear regression as P_L, one value by quadratic regression as P_Q, and one value using the same value in 2009 as P_S which is over-optimistic.

3). We get nine productions by multiply $\{E_L, E_Q, E_S\}$ with $\{P_L, P_Q, P_S\}$; these nine productions are nine projections on the electricity consumption in the IT industry in 2015 following different assumptions. For example, $E_S * P_S$ predicts a stabilized situation which is over-optimistic.

By the data from table I we can project the data in 2015 as below:

E_L = 80.045 billion kWh P_L = 6.88 %
E_Q = 68.598 billion kWh P_Q = 5.23 %
E_S = 61.036 billion kWh P_S = 4.03 %

Now we can get nine projections on the electricity consumption in the IT industry in Beijing in 2015 following different assumptions, as shown in Fig. 1.

In Fig. 1, each bar represents a projection on the electricity consumption in the IT industry in Beijing in 2015 with one assumption. The solid part of a bar represents $E_S * P_S$, which is the same as the real electricity consumption in the IT industry in Beijing in 2009, while the shallow part of a bar represents the predicated increase of the electricity consumption in 2015 compared with that in 2009.

From the data in Fig. 1, we can see that $E_L * P_L$ reaches the highest value as 5.50 billion kWh, which is more than twice than that in 2009. Even with a modest projection, $E_Q * P_Q$, the projected electricity consumption in the IT industry in Beijing in 2015 will be 3.59 billion kWh, which has a 45.9% increase than that in 2009.

TABLE I. Electricity consumptions in the IT industry and in all the industries in Beijing (billion kWh) (raw data from [5])

Year	IT industry	All the industries	%
2005	1.154	48.162	2.40
2006	1.372	51.570	2.66
2007	1.865	56.034	3.33
2008	2.240	57.342	3.91
2009	2.460	61.036	4.03

There will be two ways to alleviate the potential rapid increase of the electricity consumption in the IT industry: 1) keep a slow increase rate or even decrease the total electricity consumption, and 2) keep a slow increase rate or even decrease the percentage of the electricity consumption in the IT industry over that in all the industries.

Green computing, which would effectively increase the energy efficiency in the computing, would be able to both help slow down the increase rate of the total electricity consumption and decrease the percentage of the electricity consumption in the IT industry over that in all the industries.

For example, if green computing could be applied in the IT industry in Beijing, we could be able to at least maintain a stable value of the percentage of the electricity consumption in the IT industry over that in all the industries, i.e. P_S, by increasing the energy efficiency in the computing in the IT industry. With a modest assumption on the electricity consumption in all the industries in Beijing in 2015, i.e. E_Q, we could get the lowest projected electricity consumption in the IT industry in 2015, which is presented by the data of $E_Q * P_S$ in fig. 1. In such circumstance, the projected electricity consumption in the IT industry in Beijing in 2015 will be 2.76 billion kWh, which has only a 12.2% increase than that in 2009. The potential energy saving between this assumption with the assumption $E_L * P_L$ is 2.74 billion kWh, which will be more than the total electricity consumption in the IT industry in 2009; and the potential energy saving between this assumption with the modest assumption $E_Q * P_Q$ is 0.82 billion kWh, which will be 33.5% of the electricity consumption in the IT industry in 2009.

From the analysis above, we can see that green computing will be important in alleviating the potential rapid increase of the electricity consumption in the IT industry in Beijing.

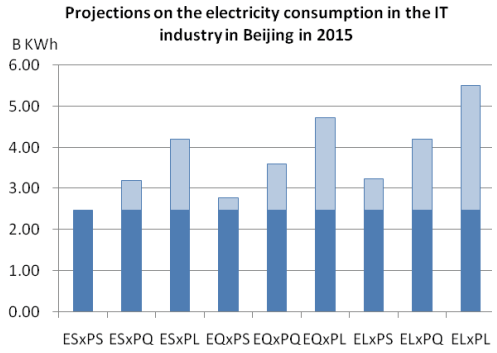

Figure 1. The projections on the electricity consumption in the IT industry in Beijing in 2015 following different assumptions

We also investigated the electricity consumption in the IT industry in four second-tier cities in China. Those cities though not as developed as Beijing, have shown rapid developing speed. We can get a more comprehensive view on the electricity consumption in the IT industry in China.

From the electricity consumptions in the IT industry, in all the industries and the percentage of that in the IT industry over that in all the industries in Shenyang from 2005 to 2009 [7], we can obtain the electricity consumption in the IT industry in Shenyang had increased 0.11 billion kWh from 2005 to 2009. The percentage of the electricity consumption occupied by the IT industry had increased from 1.49% in 2005 to 1.80% in 2009. This indicates that there is potential for the IT industry in Shenyang to save electricity.

In our projection, the potential energy saving between the lowest projected electricity consumption with the largest projected data is 0.37 billion kWh, which will be more than the total electricity consumption in the IT industry in Shenyang in 2009; and the potential energy saving between the lowest assumption with the modest assumption is 0.08 billion kWh, which will be 26.7% of the electricity consumption in the IT industry in 2009.

Guangzhou is another two-tier city who strengths its IT industry constantly. Guangzhou has suffered a rapid increase of electricity consumption in the IT industry. From the data of Guangzhou from 2005 to 2009 [13], the electricity consumed in 2009 was 2.84 times more than that in 2005. This indicated that IT industry would be an important source for energy saving in Guangzhou.

In our projection, the potential energy saving between the modest assumption with the largest projected electricity consumption in the IT industry in Guangzhou in 2015 is 0.68 billion kWh, which will be more than the total electricity consumption in the IT industry in Guangzhou in 2008.

From the data of Hangzhou from 2005 to 2009 [12], we can obtain that the electricity consumption in the IT industry was 0.492 billion kWh in 2009, which was three times as much as that in 2005. The percentage of electricity consumption occupied by IT industries had increased year after year. This indicated that growth rate of energy consumption in the IT industry was far more than average. So IT industry in Hangzhou would potentially be an important source for energy saving.

In our projection, the potential energy saving between the optimum assumption with the worst assumption is nearly 2.0 billion kWh, which will be more than four times larger than that of the total electricity consumption in the IT industry in Hangzhou in 2009.

TABLE II. THE NUMBER OF HOUSEHOLD COMPUTERS IN FIVE MAJOR CHINESE CITIES (MILLION)

City	2005	2006	2007	2008	2009
Beijing	4.03	4.44	4.33	4.13	4.74
Shenyang	1.06	1.03	1.34	1.52	2.03
Guangzhou	2.10	2.21	2.36	2.77	3.07
Hangzhou	1.55	1.56	1.74	1.75	1.87
Wuhan	1.47	1.57	1.78	1.74	1.87

From the data of Wuhan from 2005 to 2009 [10], we can get that even though the electricity consumption in the IT industry in Wuhan is not as high as that in other four cities presented, the percentage of electricity consumption occupied by IT industries had increased from 0.01% in 2005 to 0.40% in 2009 year after year, which indicated energy consumption in the IT industry had increased constantly and it would be an important source for energy saving.

In our projection, the potential energy saving between this assumption with the worst assumption is 0.92 billion kWh, which will be more than nine times as much as the electricity consumption in the IT industry in Wuhan in 2009; and the potential energy saving between the optimum assumption with the modest assumption is 0.19 billion kWh, which will be more than the electricity consumption in the IT industry in 2009.

IV. ELECTRICITY CONSUMPTION BY HOUSEHOLD COMPUTERS IN FIVE MAJOR CHINESE CITIES

In this section, we analyze the data on the electricity consumption by household computers in five major Chinese cities during 2005-2009 to illustrate the importance of green computing in terms of household computers.

With the data obtained from Statistical Yearbook in these five cities from 2005-2010 [5, 7, 10, 12, 13], we can get the number of household computers per 100 residents have and the number of households since 2005-2009. By calculation of these two terms we can obtain the total computers that households have in their daily life from 2005-2009 in these five major cities.

Table II shows the number of household computers in five major cities in China from 2005-2009. We can make projections on the number of household computers in 2015 based on that in 2005-2009 with the same method presented in section III. In order to make the projections as fair as possible, we project two values of the number of household computers in these five cities in 2015: one value by linear regression as N_L, one value by quadratic regression as N_Q.

Fig. 2 shows the real number of household computers and the projected data of household computers in Beijing from 2005-2015. We can get the projected number of household computers in Beijing in 2015:

$N_L = 5.23$, $N_Q = 6.58$ million computers

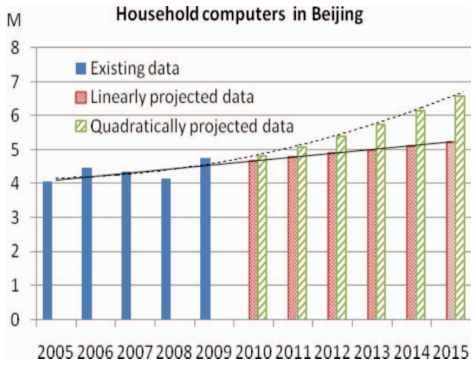

Figure 2. The real number of household computers and the projected data in Beijing from 2005 to 2015

As the average power of household computers is between 36 W and 250 W [2], we can make a modest assumption that the power of household computers is around 100 W. By power management or replacing the old computers with energy-efficient ones [14], it is possible that electricity consumption of 0.1 kWh could be saved per household computer per day. With the two projected numbers of household computers in Beijing in 2015, two projections of electricity saving would be made. Thus 0.19 billion kWh and 0.24 billion kWh could be saved per year corresponding to linear regression and quadratic regression by the household computers in Beijing. The saved electricity will take up 7.76% and 9.76% of the electricity consumption in the IT industry in Beijing in 2009 respectively, which is quite large.

From the analysis, we can see that there is also great potential for green computing to alleviate the increase of electricity consumption by household computers in Beijing.

We can get the projection on the number of household computers in Shenyang in 2015 is:

$$N_L = 3.33, N_Q = 7.49 \text{ million computers}$$

0.12 billion kWh and 0.27 billion kWh will be saved per year by the household computers by linear regression and quadratic regression respectively, which would take up 40.55% and 91.15% of the electricity consumption in the IT industry in Shenyang in 2009. The saved energy is quite large that great potential for energy saving could be made.

The projection on the number of household computers in Guangzhou in 2015 is:

$$N_L = 4.49, N_Q = 7.39 \text{ million computers}$$

With the method of linear regression and quadratic regression, we can save 0.16 billion kWh and 0.27 billion kWh per year respectively. These two terms respectively takes up 23.1% and 37.99% of the electricity consumption in the IT industry in Guangzhou in 2009.

The projected number of household computers in Hangzhou in 2015 is:

$$N_L = 2.36, N_Q = 2.53 \text{ million computers}$$

The amount of electricity saved by the two projections is 0.086 billion kWh and 0.092 billion kWh per year respectively. IT industry in Hangzhou in 2009 consumed 0.49 billion kWh. The percentages of the saved electricity in household computers over the IT industry in Hangzhou in 2009 are 17.56% and 18.83% respectively. The saved electricity takes up a large proportion that green computing could be applied to save the electricity.

The trend of the number of household computers is generally increasing from the data in 2005-2009 in Wuhan and we predict it would continue increasing before it reaches some value, but due to mathematical property, when we tried to apply the quadratic regression on the projection, it showed a decreasing trend, which we believe is unreasonable. Thus we choose only linear regression to predict the number of household computers in Wuhan in 2015 as follows:

$$N_L = 2.36 \text{ million computers}$$

2.36 million computers could save 0.086 billion kWh per year. The electricity saved by household computers takes up around 86% of the electricity consumption in the IT industry in Wuhan in 2009, which is very large.

V. CONCLUSION

We have presented and analyzed the data on the electricity consumptions in the IT industry and by household computers in five major Chinese cities during 2005-2009. The potential electricity saving in the IT industry would be up to 2.74, 0.37, 0.68, 2.0 and 0.92 billion kWh in Beijing, Shenyang, Guangzhou, Hangzhou and Wuhan in 2015, which would be 1.1 times, 1.2 times, 0.97 times, 4.1 times and 9.2 times the total electricity consumptions in the IT industry in the corresponding cities in 2009. As most cities in China have been enduring a rapid development in the IT industry, the situation of energy consumption would be similar. Thus green computing is of great importance to decrease the energy consumption in the IT industry in China.

The potential energy savings by household computers in the five cities would be up to 0.24, 0.27, 0.27, 0.092 and 0.086 billion kWh in 2015, which would be 9.76%, 91.15%, 37.99%, 18.83%, and 86% of the electricity consumption in the IT industry in the corresponding cities in 2009. Thus green computing is also important for household computers.

Though highly important, green computing has not yet caused enough attention to the local government or penetrated deeply enough in human's daily life. The government should enforce the IT industry to adopt the concept of green computing. And the residents should also apply the green computing techniques/methods to their household computers.

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