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Tian-Jian Yang
Yue-Jun Zhang
Jin Huang
Ruo-Hong Peng

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Center for Energy and Environmental Policy Research
Beijing Institute of Technology
No.5 Zhongguancun South Street, Haidian District
Beijing 100081
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Yi-Ming Wei
Director of Center for Energy and Environmental Policy Research, Beijing Institute of Technology

For more information, please contact the office:

Address:
Director of Center for Energy and Environmental Policy Research
Beijing Institute of Technology
No.5 Zhongguancun South Street
Haidian District, Beijing 100081, P.R. China

Access:
Tel: +86-10-6891-8551
Fax: +86-10-6891-8651
Email: ceeper@vip.163.com
Website: http://ceep.bit.edu.cn/english/index.htm

Estimating the energy saving potential of telecom operators in China

Tian-Jian Yang [a], Yue-Jun Zhang [b, c *], Jin Huang [a], Ruo-Hong Peng[a]

[a] *School of Economics and Management, Beijing University of Posts and Telecommunications, Beijing 100876, China*

[b] *School of Management and Economics, Beijing Institute of Technology, Beijing 100081, China*

[c] *Center for Energy and Environmental Policy Research, Beijing Institute of Technology, Beijing 100081, China*

Abstract: A set of models are employed to estimate the potential of total energy saved of productions and segmented energy saving for telecom operators in China. During the estimation, the total energy saving is divided into that by technology and management, which are derived from technical reform and progress, and management control measures and even marketing respectively, and the estimating methodologies for energy saving potential of each segment are elaborated. Empirical results from China Mobile indicate that, first, the technical advance in communications technology accounts for the largest proportion (70%-80%) of the total energy saved of productions in telecom sector of China. Second, technical reform brings about 20%-30% of the total energy saving. Third, the proportions of energy saving brought by marketing and control measures appear relatively smaller, just less than 3%. Therefore, China's telecom operators should seize the opportunity of the revolution of communications network techniques in recent years to create an advanced network with lower energy consumption.

Keywords: energy saving potential, telecom operator, China

1. Introduction

The national target of energy saving during China's 11th Five Year Plan (FYP) has been roughly achieved (Price et al., 2011). And China's 12th FYP further requires that from 2011 to 2015, energy consumption per unit of GDP (i.e., energy intensity) should be decreased by 16%. As for China's telecom operators, with the rapid growth of subscribers and telecommunications traffic in recent years, its energy consumption has been always maintaining robust increasing and

* Corresponding author. Tel./ Fax: 86-10-68918651. E-mail: zyjmis@126.com (Yue-Jun Zhang).

energy saving has become an important threat to sustainable development. Take China Mobile, one of the largest mobile service providers in China, for example, it consumes energy like electricity, gasoline, diesel oil, and natural gas etc., and electricity accounts for over 80% of the total energy consumption. In 2011, the total energy consumption of China Mobile exceeds 1.8 million tonnes of coal equivalent and electricity consumption reaches over 13 billion KWh. Under this circumstance, China's SASAC (State-owned Assets Supervision and Administration Commission), as the regulating department of China Mobile, has set China Mobile as the category of Focused enterprise from the General enterprise[i], and required China Mobile should equip full-time staff for energy saving management, periodically submit energy saving reports and evaluate energy saving effect. Meanwhile, with the constant growth of China Mobile, especially the large-scale deployment of the Three Generation network, its energy consumption may keep stable increasing in the near future, so great pressure and threats will be faced by China Mobile under the energy saving restraints from the government. Overall, the energy saving for China's telecom operators should be and have been attached close attention these years.

The Chinese Ministry of Industry and Information Technology (MIIT) announced that the overall energy consumption per unit of telecom traffic for the communications industry should reduce by 10% by the end of the 12th FYP. In order to achieve this goal, telecom operators are taking effective and numerous measures in many fields. These measures have achieved some energy-saving effect. Each year telecom operators may set energy saving targets, like electricity consumption per unit of telecommunications traffic, so as to assess the work they have done and roughly estimate the saved energy at the end of the year. With regard to the targets set each year, by means of interview, we have learned that the managers and specialists of energy saving in China Mobile do not make sure whether the energy saving targets are reasonable and feasible. Therefore they are eager to exactly identify the potential for energy saving in the next few years and at least they can put forward feasible annual targets of energy saving.

According to recent research, there are some methodologies to calculate the saved energy for a corporation (such as GB/T 13234-2009) and other methodologies to calculate the saved energy of technological measures (such as GB/T 13471-2008). For example, the GB/T 13234-2009 (AQSIQ and SAC, 2009) defines the "energy saved of productions" as the index to calculate the annual saved energy for a corporation in China. However, for calculating the annual energy saving for telecom operators, there exist some problems (Yang et al., 2011b). For example, through the GB/T 13234-2009, the total "energy saved of productions" by the whole telecom operator can be calculated, but the energy saved by technological measures according to GB/T 13471-2008 only accounts for a little part (average 20%-30%) of the total energy saved of productions. It is thus clear that a large disparity of energy saving exists, which has often been ignored. Put another way, the telecom operators in China almost do not exactly know how much potential of energy saving they have and where the energy saving may come from.

The purpose of this study is to estimate and analyze the segments of total energy saving for telecom operators in detail, especially providing the detailed estimating segmented model for energy saved by technical advance according to the classification of communication equipment. At last we also propose some suggestions for decision makers to set proper assessment indicators and to work out better energy saving plan based on the estimation of energy saving potential. In this way, we attempt to answer the following questions: (1) where does the energy saving room come from for the telecom operators in China; (2) how to estimate the segmented energy saving potential; and (3) how much is the energy saving potential for each segment; so as to help the telecom operators in China to reasonably assess the difficulty of energy saving and scientifically determine the energy saving plan.

The empirical case in this research refers to the largest provincial branch of China Mobile, what is called A company here. China Mobile has signed the Green Action Plan in 2007 and promised to reduce energy consumption. In 2010, China Mobile Limited was selected as the only one of Chinese mainland enterprises in the Dow Jones Sustainability Indexes (DJSI) for the third consecutive year (CMCC, 2011).

The paper proceeds as follows. Section 2 presents the literature review of energy saving and its potential estimation. Section 3 deals with the calculating methodology and the data used in the empirical analysis. Section 4 proposes the empirical results. Finally, Section 5 concludes the paper and puts forward some policy implications.

2. Literature review

There has been a body of research on energy saving and its potential in the past years. We focus on the research which elaborates the frameworks and methodologies to estimate energy saving amount and potential at first, and then review main existing related research on energy saving in telecom sector.

In fact, many environmental protection organizations, such as the WWF (WWF, 2010), EVO, BSI, IPCC, have conducted a great deal of important research on energy saving measurement and most of the studies are based on the LCA input-output analysis.

These studies can be roughly divided into two categories; one is from a corporate perspective and the other is from a project perspective. Research from a corporate perspective often provides principles and methods to analyze the energy saving situation of a corporate. For instance, WBCSD and WRI (2004) put forward the GHG Protocol for Corporate Accounting, which contains systematical principles, concepts, and methods for quantifying and reporting GHG reductions for a corporate. And the GB/T 13234-2009 (AQSIQ and SAC, 2009) issued by Chinese government specifies the classification and basic calculating principles of corporate energy savings. And research from a project perspective mainly discusses the calculating frameworks and procedures for energy saving and emissions reduction of projects. For instance, UNFCCC tries to calculate the emission reduction of a CDM project. It conducts various research methods on different scenarios to carry out suitable baselines and monitoring methodologies, which define the boundary, baseline, project emission and the emission reduction. Similar studies include the IPMVP (EVO, 2002), which contains the concepts and options for determining energy savings, and the GHG Protocol for Project Accounting (WBCSD and WRI, 2005). The IPMVP provides the measurement and verification plan, which defines four basic options for deriving routine adjustments of energy use in the base year.

On basis of these basic frameworks and methodologies, many scholars have conducted an array of research on the topic of energy saving potential in various fields, like building industry, steel industry, chemical industry and telecom industry. For instance, Sardianou (2007) develops a model to empirically investigate the main determinants of household energy conservation patterns and possible energy saving in Greece. Zhao et al. (2009) describe the energy consumption situation and reality of commercial building in Tianjin of China according to statistics and field investigation. Lin et al. (2011) evaluate the energy saving potential of Chinese steel industry by studying its future potential energy efficiency gap. Dutta et al. (2010) make a foray into the energy demand for steel, aluminum and cement industries in India and explore the potential of any future reduction in their energy consumption. Lin et al. (2012) find that in chemical industry of China there is a long-run equilibrium relationship between electricity intensity and technology, labor, electricity prices and industry structure.

While in telecom industry, energy saving research mainly focuses on energy saving potential estimation by ICT (Information and communication technology) solutions and energy efficiency improvement brought by technical measures in base stations, equipment rooms and terminals on basis of the GHG Protocol for Project Accounting (WBCSD and WRI, 2005). For example, GESI and the Climate Group (2008) demonstrate the potential role the ICT sector can play in mitigating climate change. And they outline the required policy support of smart implementation of ICTs, including standard implementation, secure communication of information within and between sectors and financing for research and pilot projects. Yang et al. (2011a) calculate the CO_2e emission reduction potential brought about by low-carbon ICTs of the wireless telecom sector of Chongqing Mobile, the entire China Mobile Group and the whole China in 2009, and the CO_2e emission reduction potentials in 2010，2020 and 2030 are calculated in four main important fields of China. Buttazzoni et al. (2008) provide a quantitative assessment of the emissions reduction potential of individual ICT solutions (reference year 2030), highlighting opportunities for synergies and low carbon feedbacks. To our knowledge, little work refers to energy saving potential of telecom sector's own (i.e., Green of ICTs), rather than energy saving potential of other industries brought by ICTs applied to the industry (i.e., Green by ICTs).

It should be noted that research on energy efficiency improvement in the telecom industry begins with the study of the energy-efficient air conditioning in communications equipment room (Yang, 1983). Later on, more and more research on energy-saving measures of air-conditioning, power-supply system and lighting system emerges (Ni, 2006; Li et al., 2006). For instance, Liu (2006) puts emphasis on mobile stations' air-conditioning energy saving by controlling environment and air-conditioning equipment with the new technology and management. Sun (2006) proposes a set of comprehensive solutions to energy saving in communications equipment room. Wang (2008) describes the application significance of energy saving technology measures of lights used in mobile communication buildings. In recent years, much attention is paid to the technical advance in telecommunications network. Li (2010) discusses the optimization issue of existing networks and the new design of the networks by technological measures. At present, telecom operators mainly undertake the energy saving work by means of network progress, technical reform and management (Zhang and Zhao, 2011). And some scholars try to evaluate the performance of the energy saving and emission reduction work of telecom operators using some evaluation model (Duan et al., 2011). But most research above on energy efficiency improvement in the telecom industry focuses on energy saving amount comparison among different technologies. Yang et al. (2011b) find that all the energy saved by technical measures accounts for only a small part of the total energy saved of productions and develop the segment model of the energy saved of productions by telecom operators. Besides technical measures or technical reform, they also propose other segments of the total saved energy, i.e., energy saved by technical advance, management control measures and even marketing, whereas the energy saved by control measures is estimated indirectly, and the energy saving brought by technical advance is just given in a whole without detailed elaboration. However, the calculating principle for each category of technical measures in technical advance or equipment updates may be different, since the classification of the technical equipment is clear. Therefore, in order to obtain an accurate estimation of energy saving potential of telecom operators in China, the methodologies should be extended.

To make up for the lack of current related studies, the energy saving potential of Chinese telecom operators is estimated from a technical perspective by developing a model with empirical case, and each segment of energy saving is estimated in detail on the basis of the emissions reduction calculating methodologies mentioned above (i.e., the project–based methodology). And some policy suggestions, based on the energy policies in China's twelfth Five-Year Plan (Li and Wang, 2012), are put forward to telecom operators of China.

3. Methodologies and data definitions

3.1 Model framework and assumptions

As telecom operators are taking managing and technological measures to save energy, we define energy saving of telecom operators as that by management and that by technology. For further estimation, energy saved by management is divided into that by control measures and by marketing. And energy saved by technology is made up of technical advance and technical reform. The framework of segment model for total saved energy of telecom operators is shown in Fig. 1.

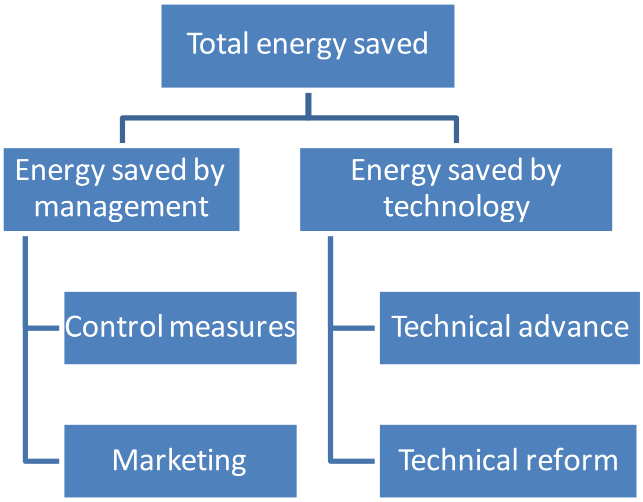

Fig. 1. The framework of segment model of total saved energy for telecom operators

It should be noted that in the following sections, we focus on electricity saving instead of energy saving, as electricity accounts for about 80%-90% of the total energy consumed by telecom industry (AQSIQ and SAC, 2008). This is further because here we aims to study the energy-saving mechanism of the operating process of telecom operators, and in this process, the equipment in operation mainly consumes electricity. As for other energy sources, such as coal, natural gas, oil and so on, they are used to support the living facilities of telecom operators, like cafeteria, but not for the operating process. Even in some situation, these kinds of facilities are often outsourced to others and energy consumption is not calculated in the total energy consumption of telecom operators. Besides, some diesel oil and gasoline may be used as the fuel of generators when the public electricity system accidentally fails. Overall, this part of energy consumption proves fairly limited, which almost may be ignored. Therefore here we only take into account the electricity consumption so as to obtain an accurate estimation of energy saving potential for telecom operators in China.

Nowadays, various kinds of technological measures for energy saving are widely applied in telecom industry, most of which have achieved good effect in energy saving. So the energy saved by technology is defined as the reduction of energy consumption per unit of product by the development and renewal of the equipment. For telecom operators, the power consumption of the communication equipment accounts for about 45% of the total power consumption. Besides, with the reduction of energy consumed by communication equipment, the air conditioning and the power supply equipment may at the same time have good energy saving potential.

In this model, we divide energy saved by technology into that by technical advance and technical reform. And technical advance represents development of telecommunication technologies and the optimization of existing networks by updating and replacing the communications equipment, such as the application of the distributed base station and Multi Carrier Power Amplifier (MCPA) in the wireless network. Upgraded equipment usually has much more communication capability and computing capacity, while its power consumption basically maintains invariable or increases very slightly. Although energy saving is not the original intension of technical advance in telecom industry, it will indeed save a large amount of energy with telecom traffic increasing steadily. Meanwhile, technical reform means the energy saving technological measures used mainly in air conditioning environment and power supply system, such as the power module dormancy and the smart ventilation system which may reduce air conditioning usage. Usually, technical advance is considered as a result of social technology progress, not a part of energy saving work of telecom operators. But we take it into account since it actually brings energy saving indirectly to telecom operators.

Besides, energy saving management has become more and more important for telecom operators. It involves developing standards for energy saving work, establishing statistical monitoring system, forming proper organization structure and formulating assessment indicators etc. What’s more, cultivating the idea of energy saving in daily work should be attached great attention too. For example, we may strengthen the awareness of controlling the set temperature of air conditioning in the specified range whether in the office or in the communication equipment room. Lighting control and lighting retrofits are also included. We define control measures as the measures mentioned above and they are quite diverse. Aside from control measures, the other segment of energy saved by management is that by marketing. Marketing brings the increase of telecom traffic volume and utilization rate of wireless devices in a short time, and in turn energy consumption per data traffic (KWh/MB) may decrease, which produces energy saving according to the GB/T 13234-2009. So energy saved by marketing should be reckoned with in calculating the total saved energy, and it is distinctive from other industries’ energy saving problem.

3.2 Model specification

Energy saving is determined by comparing measured energy use before and after implementation of an energy saving program (EVO, 2002). In general, it can be estimated by the following equation:

$$SE = BEU - PREU \pm Adj = ABEU - PREU \qquad (1)$$

where:

SE: the saved energy;

BEU: base year energy use;

PREU: post-retrofit statistic year energy use;

ABEU: adjusted base year energy use;

It should be noted that the *Adj* term in the equation means adjustments, which brings energy use in the two time periods to the same set of conditions. Adjustments are commonly made to restate base year energy use under post-retrofit conditions, in order to make them comparable to each other.

In this calculating model, we assume that other uncontrolled elements are almost the constant before and after the implementation of management or technological measures. And we call this assumption as ‘under comparable conditions’. Calculating the energy saving under two comparable conditions is consistent with the idea in other reports, such as The GHG Protocol for Project Accounting (WBCSD and WRI, 2005) and Methods for Calculating and Evaluating the Economic Value of Electricity Saving Measures GB/T13471-2008 (AQSIQ and SAC, 2008). As variable uncontrolled elements exist, e.g. the fluctuations of the outside temperature and the actual load fluctuations of communications equipment, the actual energy saving may be more than or less than the energy saving estimated by this calculating model. That means it produces calculation errors. But in the ideal situation, if the changes of these uncontrolled elements are random and of no trend, the means of random errors approach to zero. So we only divide the total energy saved into two categories, i.e., the energy saved by management and that by technology.

The estimating models for marketing and technical reform almost remain the same as Yang et al. (2011b) proposed, but this paper modifies the models to estimate energy saved by control measures and technical advance, which are shown in detail as follows.

3.2.1 Control measures

For telecom operators, we divide the power consumption scenes into four parts, i.e., base station, communications room, office building and business hall (*j*=1, 2, 3, 4). And considering the management measures used in each scene, three main measures are taken into account: increasing the indoor set temperature of air conditioning, lighting retrofit (replacing ordinary fluorescent lights with T5) and intelligent illumination control (*i*=1, 2, 3). In this way, the energy saved by control measures can be estimated as follows:

$$ESCM = \sum_{i=1}^{3} ESCM_i \quad (2)$$

$$ESCM_i = \sum_{j=1}^{4} pes_j \times pp_j \times (\mathrm{N}_{rs}/N_s) \times r \quad (3)$$

where:

ESCM: the total energy (electricity) saving for control measures;

pes_j: power consumption of the scene *j*;

pp_j: the proportion of power consumption of air-conditioning or illumination in the scene *j*;

r: energy saving rate of certain control measures applied in air-conditioning or illumination;

N_{rs}: the number of retrofitted equipments (air-conditioners or illumination equipments) in the scene *j*;

N_s: the total number of the equipments in the scene *j*.

The detailed data of the three main relevant energy-saving activities are summarized in Table A.1 in Appendix A.

3.2.2 Marketing

Because of marketing, the telecommunication traffic increases rapidly. Before the workload of telecommunication equipment reaches its warning line, the capacity of equipment does not need expansion. During that stage (maybe a few years) the utilization rate of wireless devices may increase, and the energy assumption almost remains the same meanwhile. Then it brings the energy efficiency improvement; put another way, it brings energy saving indirectly according to the calculation method of “energy saved of productions” (AQSIQ and SAC, 2009). Therefore, the model to estimate energy saving for marketing (*ESM*) is defined as:

$$ESM = ABEUM - PREUM = \Delta TV \times \frac{1}{r_0} \times ppf \times T - \Delta TV \times \frac{1}{r_1} \times ppf \times T \qquad (4)$$

$$\Delta TV = (N_{f1} \cdot r_1) - (N_{f0} \cdot r_0) \qquad (5)$$

where *ΔTV* represents net increased telecom volume in unit of frequency carrier number between base year and the next (static) year; N_f represents the average number of frequency carriers in one year while N_{f0} and N_{f1} represent the average number of frequency carriers in the base year and the next (static) year respectively; r_0 and r_1 denote the average utilization rate of wireless devices in the base year and the next (static) year respectively; *ppf* represents average power per unit of frequency carrier; *T* represents the working time of the frequency carrier in a year, i.e., 24hour*365days. And the detailed data of the relevant energy-saving activity are summarized in Table A.2 in Appendix A.

3.2.3 Technical advance

Technical advance for telecom operators refers to the communication network evolution, which usually brings about a large number of equipment replacements. And new equipment always has much more communication capacity per kilowatt (such as more bandwidth) than the old one. So the gradual replacement of energy-wasteful old equipment with energy-efficient new ones will bring potential energy saving right now and in the future. According to the function of the equipment and technologies in wireless communication network, the equipment is classified into five categories: switching equipment, transmission equipment, wireless access equipment, mobile service platform servers and other IT supporting systems. Switching equipment and transmission equipment function together, and compose the basic core network of telecommunication to switch and transfer signals. Then voice services and data services are processed by their mobile service platform servers connecting to the core network, and are conveyed to subscribers by wireless access equipment. During all these processes, IT supporting systems provide supporting and auxiliary function separately in the network operation and management of telecom operators. In this paper, energy savings brought by each equipment category's technical advance are modeled. The basic model for energy saving by technical advance can be written as:

$$ESTA = ABEUTA - PREUTA \quad (6)$$

$$ABEUTA = \left(\frac{nec \times N}{oec}\right) \times oep \times T \quad (7)$$

$$PREUTA = N \times nep \times T \quad (8)$$

where:

ESTA: energy saved by technical advance;

ABEUTA: adjusted base year energy use by technical advance;

PREUTA: post-retrofit energy use by technical advance;

nec: the communication capacity per new equipment;

oec: the communication capacity per old equipment;

N: the number of new equipment;

oep: the power of old equipment;

nep: the power of new equipment;

T: the working time of the new equipment in a year.

It should be noted that the workload of updated communication equipment may not reach the saturation point in a short time. In fact it usually needs a couple of years. In this paper we assume that after *n* years the workload of updated equipment may arrive at the maximum capacity level. So before the saturation point, the saved energy each year is supposed to be the *ESTA* being divided by *n*. Thus the annual average energy saved by technical advance (*AESTA*) should be specified as follows.

$$AESTA = ESTA / n \quad (9)$$

It should be noted that the specific technical advances and resulting replacement of equipment in each equipment category are described in detail in Appendix A. And the actual data we present for technical advance in the remainder are collected from the largest provincial company of China Mobile, namely A company, in the following sections; in particular, there are a number of parameters from its developing plan from 2011 to 2014. And sorted relevant energy-saving activities and detailed data of this category are summarized in Table A.3-A.8 in Appendix A.

3.2.4 Technical reform

We divide the technological reform or measures into three categories, i.e., main telecommunication equipment measures, air conditioning system and power supply system measures, based on the research and pilot programs on energy-saving technologies conducted by telecom operators. For example, intelligent self-turn-off carrier frequency is applied in main telecommunication equipment; in air-conditioning system, cooling system optimization is used in base station, such as frequency conversion compressor etc. And free cooling is applied in equipment rooms. In power supply system, there are new types of battery, constant temperature battery pit, high voltage DC power supply, power module dormancy and so on. And we add up the saved energy for each measure to ensure the accuracy in computation, while the calculating method almost remains the same as Yang et al. (2011b). Sorted relevant energy-saving activities and detailed data of this category are summarized in Table A.9 in Appendix A.

3.3 Model verification

Furthermore, we calculate an indicator named power consumption per unit of telecommunications traffic (PPT) based on the total saved energy estimated above. The equation is written as follows:

$$PPT_t = PPT_{t-1} - \frac{SE_t}{TT_t} \tag{10}$$

where:

PPT_t : the PPT in year t; *PPT* is power consumption per unit of telecommunications traffic.

SE_t : the total saved energy in year t;

TT_t : the total telecommunications traffic in year t.

The indicator *PPT* is used to verify the accuracy of the energy saving segment model, we compare the indicator *PPT* calculated by the segment model with the *PPT* predicted by the rolling plan of A company in next Section. The energy saving rolling plan of A company is made according to the historical relationship between the application range of various energy saving measures and the decrease of electricity consumption per unit of telecommunications traffic. It is the experience curve which can reflect the actual and future situation to some extent. So we choose this indicator to verify our model.

3.4 Data definitions

China Mobile has the world's largest mobile subscriber base, with nearly a billion subscribers, so this paper considers the case of China Mobile. And although the energy saving work of the provincial branches of China Mobile differs from one province to province, considering the data availability and the effectiveness of energy saving work of each province, we choose the largest provincial branch companies of China Mobile as the sample for empirical study, noted as A company hereafter.

Then we collect data for energy saving potential estimation. It should be noted that our basic data relies on the development plan of the sample company, namely A company, from 2011 to 2014, but its development plan only provides the information about its business development forecast, network and device development plans, without any information about energy consumption of various devices. Therefore, we have to calculate the energy saving volume based on the planed information of A company and methodologies above, and then we send the calculating template to the managers and energy saving specialists in the company, and communicate the results with them via email, telephone and face-to-face interview to ensure the quality of the data collection and results. And the basic data we collected for energy saving potential estimation for A company is displayed in detail in Appendix A.

4. Empirical results and discussions

4.1 The overall results of energy saving potential

Based on the methodologies of energy saving potential estimation above and basic data collected from A company, we obtain the overall energy saving potential for A company from 2011 to 2014 (see Table 1). Meanwhile, we also presents the carbon emissions reduction due to the energy saving. Specifically, the total energy saving of A company from 2011 to 2014 may reach 204-288 GWh. And it accordingly reduces 203-287 thousand tons of CO_2e emissions.

Table 1

Energy saving potential for A company from 2011 to 2014.

Year	Energy saved (GWh)	CO_2e reductions (thousand ton)
2011	203.76	203.15
2012	283.85	282.99
2013	268.13	267.33
2014	287.73	286.86

Besides, the proportions of each kind of energy saving segment across years are displayed in Fig. 2. As is shown in the Figure, technical advance brings the largest proportion of energy saving, about 70% to 80%. It is quite clear that the energy saving brought by technical advance needs more attention. Then technical reform brings about 20% to 30% of the total energy saving. However, the proportions of energy saving brought by marketing and control measures appear relatively smaller, about 0% to 3%. With the fierce competition among China's three telecom operators, i.e., China Mobile, China Unicom and China Telecom, the traffic volume of China Mobile grows relatively slowly and may even go down sometimes. As a result, marketing brings little energy saving, even from 2011 to 2013, it may increase energy consumption. And control measures also contribute very limited to the total energy saving, since the temperature control and the lighting retrofit measures are already universally implemented in office buildings and business halls of China Mobile.

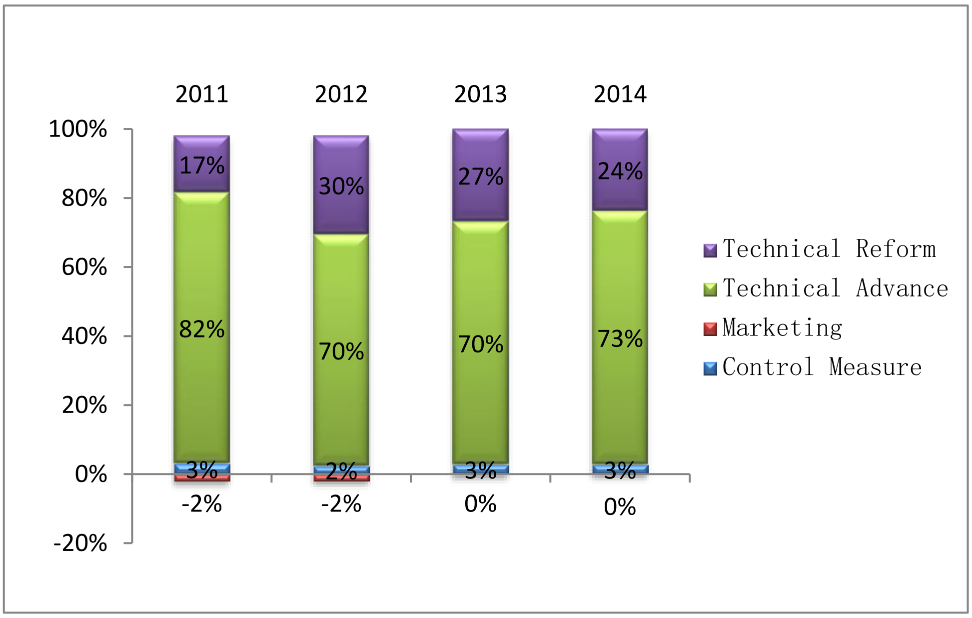

Fig. 2. The proportion of each segment of energy saving in A company

Furthermore, we also compare the indicator PPT, i.e., power consumption per unit of telecommunications traffic according to the segment model in Equation (10) with the *PPT* predicted by the rolling plan of A company in Fig. 3. We can see that the deviation of these two results each year is less than 7% of the estimated power consumption in the rolling plan and can be acceptable. However, the deviation becomes larger across the time, due to the increasing uncertainties in the future years.

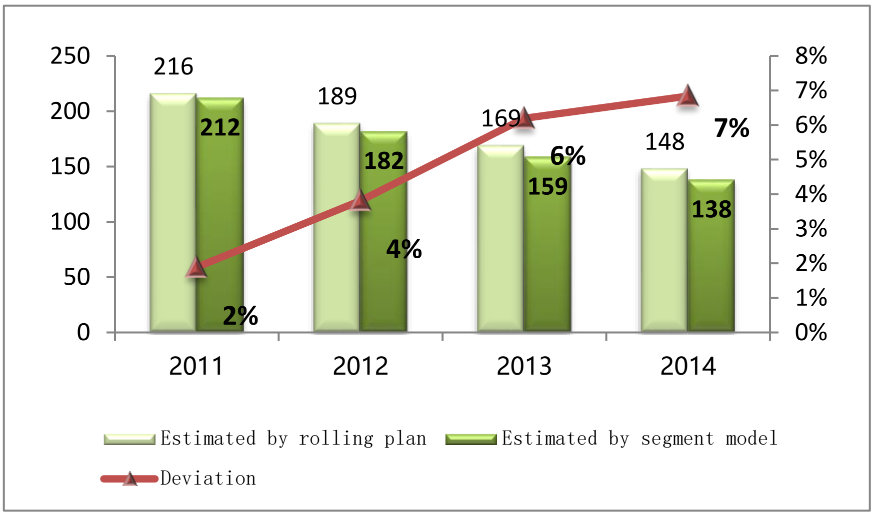

Fig. 3. The electricity consumption per unit of telecommunications traffic in A company

Besides, we calculate the energy saving by technology and management measures under comparable conditions, which assumes that other uncontrolled elements remained the same before and after the implement, so the actual energy saving is different from that estimated for the impact of the actual fluctuations of random uncontrollable elements. To check the accuracy of the model we also apply this model to two other province branches of China Mobile. First we estimate the total energy saved in 2011 by the model. Then we forecast the total energy consumption (TEC) under the condition of no energy-saving measures according to the percentage of newly added network nodes in 2011 and the total energy consumption in the previous year. So the expected energy consumption in 2011 should be obtained by subtracting the total energy saved from the total energy consumption (TEC). We find that the deviations between the expected energy consumption and the actual energy consumption of the three in 2011 are all less than 15%.

Therefore, overall, the estimating result of the segment model for energy saving potential estimation here is reasonable to a large extent and it is almost enough to meet the needs of strategic development and management.

4.2 The energy saving potential in each segment

Based on the methodologies above, the detailed estimating results of energy saving potential in each segment of A company are shown as follows.

(1)The energy saving potential from control measures

As shown in Table 2, A company has three main control measures, i.e., temperature control of air-conditioning, lighting retrofit and intelligent illumination control. And energy saved by lighting retrofit accounts for the dominant part, over 60% of the total. And temperature control of air-conditioning follows, less than 30%. This is because A company is located in the southern part of China with higher temperature across the year and its temperature control measure has already been extensively taken in base stations. Besides, the energy saving potential from intelligent illumination control measure appears less than other two, about 10% of the total.

Table 2

Energy saving potential proportion for control measures.

	2011	2012	2013	2014
Temperature control of air-conditioning	26.3%	27.1%	28.1%	29.4%
Lighting retrofit	63.1%	62.5%	61.6%	60.5%
Intelligent illumination control	10.5%	10.4%	10.3%	10.1%

(2) The energy saving potential from marketing

The energy saving potential from marketing is put forward in Table 3. Because the utilization rate of wireless devices decreases from 2011 to 2013, the energy saved by this measure is negative, which means that in these years, marketing basically may not save energy, and until 2014, it is projected to bring a little energy saving. Therefore, we may say currently the energy saving potential from marketing proves quite limited for telecom operators in China.

Table 3

Energy saving potential from marketing (GWh).

	2011	2012	2013	2014
Energy saved	-4.2713	-5.7250	-0.1205	0.1569

(3) The energy saving potential from technical advance

The empirical results have shown that technical advance has become the focus of energy saving work of telecom operators. But the energy saving potential may vary from different equipment or measures. For A company, as is shown in Table 4, energy saving mainly comes from the development of the measures applied in wireless access and transmission categories. In particular for the wireless access category, the energy saving potential proportion of wireless access equipment to the whole energy saving potential of technical advance experiences a continuous increase across the years and reaches 73% in 2014.

Table 4

Energy saving potential proportion for technical advance.

Technical Advance	2011	2012	2013	2014
Transmission Category	33.20%	28.10%	17.20%	17.80%
Switching Category	0.5%	0.8%	0.8%	0.8%
Mobile Service Platform	2.62%	1.30%	1.24%	1.46%
IT Supporting System	14.0%	12.5%	9.5%	6.7%
Wireless Access Category	49.7%	57.3%	71.2%	73.3%

(4) The energy saving potential from technical reform

As can be seen from Table 5, technological measures taken in main equipment may often save more energy than air conditioning system and power supply system in A company. Specifically, the energy saving potential caused by technical reform of main equipment may account for over 80% of the total, while the proportion of power supply system proves relatively smaller, less than 10%, though it increases gradually across the years.

Table 5

Energy saving potential proportion for technical reform.

	2011	2012	2013	2014
Main equipment	85.5%	89.7%	86.9%	84.2%
Air conditioning system	14.4%	5.6%	7.0%	8.1%
Power supply system	0.1%	4.7%	6.2%	7.7%

5. Conclusions and policy implications

In this paper, we attempt to investigate the energy saving potential of China's telecom operators. For this purpose, we develop the segment model of energy saving for telecom operators in China. The total energy saving consists of two main sources; one is from management measures and the other is from technology innovation. Moreover, management measures can be further divided into control measures and marketing, while technological innovation can be further divided into technical reform and technical advance; so four segments of energy saving are proposed.

The empirical results indicate that the four segments occupy different proportions of energy saving. Specifically, we find that among the four segments, technical advance and technical reform bring the two largest part of energy saving for telecom operators, on average accounting for about 74% and 24% of the total energy saving from 2011 to 2014 in A company respectively; while marketing and control measures contribute little to the energy saving work of telecom operators. Therefore, great efforts should be made to promote the technology development and application as far as energy saving in telecom operators is concerned.

Besides, as for each segment of energy saving of A company, we find they have their own distinctive features. First, as for the energy saving by control measures, lighting retrofit brings most of the energy saving. Second, marketing does not bring much energy saving, even its energy saving effect is negative. Third, as for the energy saving by technical advance, the optimization of the equipment in wireless access category possesses the biggest energy saving potential. And due to some well applied technical measures, the contribution of technical advance to energy saving may keep increasing in the near future. At last, as for the energy saving by technical reform, the transformation in main equipment may have desirable energy saving effect for the most part.

In the light of the estimation of energy saved by the four segments, some policy implications may be provided for policy makers. For one thing, since the utilization rate of wireless equipment has reached a high level in some provinces of China, energy saving potential for China's telecom operators in these provinces comes mainly from technical advance and technical reform. Technical advance can bring a large amount of "natural" energy saving, which means energy saving is a non-ignorable byproduct of telecom network evolution and it may be quite large. But the attention paid to it is not enough currently. Therefore, telecom operators should seize the opportunity of the revolution of communications network techniques to create an advanced network with lower energy consumption. Meanwhile, technical reform is also a basic and traditional way to obtain energy saving. And telecom operators should evaluate the energy saving effect and feasibility of the equipment updates, and promote the successful pilot technology.

For another, as for control measures, although it accounts for a small proportion of the total energy saving, the supervision work still needs enough concern. Otherwise, technical advance or technical reform may not achieve the desirable results.

Therefore, we suggest China's telecom operators should strengthen the awareness of energy saving, set energy saving regulations and train energy saving behaviors in daily work. Moreover, telecom operators should combine energy saving technology and scientific management system within the enterprises, and provide a large number of advanced ICT low-carbon technologies for the whole industry and society, so as to achieve low-carbon socio-economic development in harmony with the environment.

Appendix A

1. Control Measures

According to the four power consumption scenes, e.g. base station, communications room, office building and business hall, three main control measures (of management) are taken into account: increasing indoor set temperature of air-conditioning, lighting retrofit (replacing ordinary fluorescent lamps with T5) and intelligent illumination control. Specific data collected for the energy saving potential estimation of control measures for A company are shown in Table A.1.

Table A.1

Data collected for control measures for A company.

Type of Measures		2011	2012	2013	2014	pp_j	$(N_{rs}/N_s)_j$	r_j
		pes_j(GWh)						
Increasing indoor set temperature of AC	j=1	1113.72	1220.00	1400.00	1600.00	40%	3%	3%
	j=2	360.94	411.25	446.66	476.21	30%	10%	3%
	j=3	114.23	111.59	118.28	123.75	40%	10%	3%
	j=4	49.54	43.59	42.64	41.87	40%	10%	3%
lighting retrofit	j=2	360.94	411.25	446.66	476.21	10%	30%	20%
	j=3	114.23	111.59	118.28	123.75	20%	30%	20%
	j=4	49.54	43.59	42.64	41.87	20%	30%	20%
intelligent illumination control	j=2	360.94	411.25	446.66	476.21	10%	5%	20%
	j=3	114.23	111.59	118.28	123.75	20%	5%	20%
	j=4	49.54	43.59	42.64	41.87	20%	5%	20%

Note: j=1 to 4 respectively denotes scene base station, communications room, office building and business hall.

2. Marketing

The marketing activities may also improve the energy efficiency of telecommunications network, because the data traffic increase while the energy consumption of equipment nearly remain unchanged, i.e., using less equipment to support more communication needs. Specific data collected for the energy saving potential estimation of marketing for A company are shown in Table A.2.

Table A.2

Data collected for marketing for A company.

Marketing	2010	2011	2012	2013	2014
ppf(w)	100	100	100	100	100
r	80.8%	78.8%	75.0%	74.9%	75.0%
N_f	882874	1102495	1293098	1401331	1497462

3. Technical Advance

Specific categories of equipment for technical advance and the data definitions and methodologies of its energy saving potential estimation for A company are stated as follows.

(1)Transmission Equipment

In transmission equipment category, advanced equipment or technology is taking place of the old to provide better carrier for transferring and processing information. Since the extent of the new equipment capacity increase is much higher than that of its power consumption increase compared to the old, it may bring potential energy saving effect. Take the replacement of 2.5GB (bandwidth) Synchronous Digital Hierarchy (SDH) with 10GB (bandwidth) Packet Transport Network (PTN) for example, the capacity obviously increases from 2.5GB to 10GB, about 4 times larger, while the power consumption of 10GB PTN is only 2.13 times larger than that of 2.5GB SDH. So the power consumption per capacity decreases evidently when the technology advances, i.e., the average energy efficiency level of the equipment is improved. And then energy saving effect appears when new and old equipment operates at full capacity with the same given workload.

In order to estimate the energy saved by technical advance of transmission category, we investigate the actual situation of the sample company of China Mobile, namely A company, to record the main updates according to the 80/20 principle which may have energy saving effect in transmission network. Given the data availability, two kinds of transmission equipment, transmission link and terminal equipment are considered. In transmission link, PTN is gradually replacing SDH, as PTN proves better in data processing which can flexibly adapt to packet switching and the increasing of data traffic. And Optical Transport Network (OTN), which is able to provide functionality of transport, multiplexing and switching of optical channels, is advancing to become the next-generation main transmission link and their power consumption per communication capacity drops dramatically. For terminal equipment, the demand is growing for integrated, high capacity, high rate and high density equipment. After analyzing the energy saving principle in this category and gathering the data needed, the estimation of energy saving potential is stated below.

According to the Equations (4)-(9), the estimation model for transmission category is as follows:

$$AESTA=\left[\left(\frac{nec\times N}{oec}\right)\times oep\times T\text{-}N\times nep\times T\right]\Big/\mathrm{n} \quad \text{(A.1)}$$

In this model, limited to the data collected, the updated equipment is assumed to achieve the maximum capacity in two years for A company, i.e., n=2. Table A.3 shows the type of updated equipment which brings energy saving in transmission category. And the working time (*T*) of the equipment in each category is assumed to be the same, i.e., 24 hours every day all year round.

Table A.3
Data collected for transmission network for A company.

Type of equipment			*nep* (kW)	*nec* (GB)	*oep* (kW)	*oec* (GB)	*N*			
							2011	**2012**	**2013**	**2014**
Transmission Link	PTN(10G)	SDH(10G)	2.56	10	2.6	10	692	564	334	312
	PTN(10G)	SDH(2.5G)	2.56	10	1.2	2.5	692	564	334	312
	PTN(1G)	SDH(155M)	0.19	1	0.1	0.2	16202	13519	8009	7482
	OTN(40G)	OTN(10G)	5.44	1600	3.2	400	0	0	60	105
	OTN(40G)	OTN(2.5G)	3.2	400	2.0	100	484	808	348	600
Terminal Equipment	Integrated equipment	Single equipment	12	2400	5	480	2	2	0	0
	High capacity equipment(20G)	Low capacity equipment(10G)	5	320	5	160	36	0	0	0
	High rate interface card(10G)	Low rate interface card(2.5G)	0.2	10	0.2	2.5	48	64	36	28
	High rate interface card(10G)	Low rate interface card(1G)	0.2	10	0.2	1	486	584	412	368

	High density interface card	Low density interface card	0.2	20	0.2	10	32	36	52	18

(2) Mobile Service Platform Servers and IT Supporting Systems

For these two categories, the energy saving comes both from the development of the equipment applied in the platform or the supporting system, since new equipment generally has a higher energy efficiency than the old. For instance, the power of per unit capacity of new equipment in WAP platform of A company in 2011 is 29 w/requests/s, and 32 w/requests/s for the old equipment. Obviously the energy efficiency of the equipment in these two categories for A company is improved gradually.

Mobile service platforms are network servers for voice value-added services and data value-added services. A company we investigate provides eight service platforms and the power data of per unit capacity of the new and old equipment. They are Coloring Ring Back Tone (CRBT), Short Message Service (SMS), Wireless Application Protocol (WAP), Multimedia Messaging Service (MMS), and China Mobile Net (CMNET) and so on, as shown in Table A.4.

Table A.4

Data collected in mobile service platform and IT supporting systems of A company.

Type of measure		2011			2012			2013			2014		
		ncp	***ocp***	N_c	***ncp***	***ocp***	N_c	***ncp***	***ocp***	N_c	***ncp***	***ocp***	N_c
I	WAP	29(W/requests/s)	32(W/requests/s)	38647	29(W/requests/s)	32(W/requests/s)	20034	27(W/requests/s)	29(W/requests/s)	23846	25(W/requests/s)	27(W/requests/s)	60136
	SMS	1.4(W/number of SMS)	1.4(W/number of SMS)	0	1.2(W/number of SMS)	1.4(W/number of SMS)	31511	1.1(W/number of SMS)	1.2(W/number of SMS)	19938	1(W/number of SMS)	1.1(W/number of SMS)	12104
	CRBT	38 (W/CAPS)	42(W/CAPS)	683	38(W/CAPS)	42(W/CAPS)	972	36(W/CAPS)	38(W/CAPS)	1110	33(W/CAPS)	36(W/CAPS)	1046
	MMS	27(W/number of MMS)	30(W/number of MMS)	388	27(W/number of MMS)	30(W/number of MMS)	498	25(W/number of MMS)	27(W/number of MMS)	747	23(W/number of MMS)	25(W/number of MMS)	747
	Centrex	1.8(W/CAPS)	2(W/CAPS)	18109	1.8(W/CAPS)	2(W/CAPS)	34987	1.6(W/CAPS)	1.8(W/CAPS)	14538	1.5(W/CAPS)	1.6(W/CAPS)	12466
	OCG	2.3(W/CAPS)	2.5(W/CAPS)	10416	2.3(W/CAPS)	2.5(W/CAPS)	23100	2.1(W/CAPS)	2.3(W/CAPS)	6300	2(W/CAPS)	2.1(W/CAPS)	1890
	Data Service	27.8 (W/ten thousand TPMC)	57.03(W/ten thousand TPMC)	755	19.03(W/ten thousand TPMC)	48.03(W/ten thousand TPMC)	900	13.8(W/ten thousand TPMC)	42.03(W/ten thousand TPMC)	1200	11.9(W/ten thousand TPMC)	41.2(W/ten thousand TPMC)	1400
	CMNET	27.8(W/ten thousand TPMC)	57.03(W/ten thousand TPMC)	12000	19.03(W/ten thousand TPMC)	42.23(W/ten thousand TPMC)	8000	13.91(W/ten thousand TPMC)	31.43(W/ten thousand TPMC)	10000	8.03(W/ten thousand TPMC)	24.63(W/ten thousand TPMC)	11000
II	MSS:TPMC	25.8(W/ten thousand TPMC)	52.03(W/ten thousand TPMC)	28905	14.8(W/ten thousand TPMC)	48.03(W/ten thousand TPMC)	24905	13.8(W/ten thousand TPMC)	42.03(W/ten thousand TPMC)	23605	11.8(W/ten thousand TPMC)	41.03(W/ten thousand TPMC)	24605
	MSS:TB	43(W/TB)	82.06(W/TB)	600	35(W/TB)	74.06(W/TB)	500	33(W/TB)	63.06(W/TB)	400	32(W/TB)	62.06(W/TB)	350
	BSS:TPMC	27.8(W/ten thousand TPMC)	57.03(W/ten thousand TPMC)	60599	19.03(W/ten thousand TPMC)	47.23(W/ten thousand TPMC)	65661	13.91(W/ten thousand TPMC)	31.43(W/ten thousand TPMC)	71392	8.03(W/ten thousand TPMC)	24.63(W/ten thousand TPMC)	50118
	BSS:TB	46(W/TB)	89.06(W/TB)	2268	37(W/TB)	80.66(W/TB)	2974	29(W/TB)	65.83(W/TB)	3102	29(W/TB)	43.22(W/TB)	2981
	OSS:TPMC	9(W/ten thousand TPMC)	39(W/ten thousand TPMC)	180	9(W/ten thousand TPMC)	39(W/ten thousand TPMC)	180	9(W/ten thousand TPMC)	39(W/ten thousand TPMC)	180	9(W/ten thousand TPMC)	39(W/ten thousand TPMC)	180
	OSS:TB	91 (W/TB)	125(W/TB)	32	91(W/TB)	125(W/TB)	20	91(W/TB)	125(W/TB)	20	91(W/TB)	125(W/TB)	20

Note: I and II denote mobile service platform and IT supporting systems respectively.

It should be noted that the IT supporting system for telecom operators is an indispensable means to support the network operation and management of the business. Supporting system consists of three parts, i.e., Business Support System (BSS), Management Support Systems (MSS) and Operation support system (OSS). In Table A.4, the equipment upgraded data in these three systems is recorded with processing capacity unit TPMC and data storage unit TB.

On the basis of the common features of equipment being replaced in these two equipment categories, we propose the calculating Equation (A.2).

$$ESTA = N_c \times (ocp\text{-}ncp) \times T \quad \text{(A.2)}$$

where:

N_c: the number of new capacity;

ocp: the power per unit capacity of old equipment;

ncp: the power per unit capacity of new equipment;

The updated equipment of these two categories is found to reach the maximum capacity mainly in one year for A company. Equation (A.2) is in fact the transformation of Equations (4)-(9), while calculating AESTA in Equation (9) with n=1.

(3) Switching Equipment

Switching equipment and technologies provide link connection or signal orientation to establish signal path in communication network. The main advanced technologies, which can bring energy saving in switching category, include soft switch, POOL networking, and distributive Home Location Register (HLR). These three technical measures obtain energy saving effect in a different way. Specifically, a soft switch is the central device in a telecommunications network which connects telephone calls from one phone line to another, typically via the Internet, entirely by means of software running on a general-purpose computer system. When the technology for soft switch develops, the capacity of the equipment increases, but the power consumption does not increase so much. Therefore, it indirectly brings energy saving. The POOL networking includes MSC Pool and SGSN Pool technologies. POOL networking technology reduces the total capacity need of the switching equipment by centralized and integrated configuration of several distributed minor switching equipment from different areas whose phone call demand is negatively related, unrelated or weakly positively related. By setting up a POOL, capacity saved by this measure is used to describe the energy saving effect. For example, one MSC POOL can save about five thousand erls (telephone traffic unit) of switching equipment capacity according to the experience from CMCC. Distributive HLR separates independent front-end equipment (FE) and back-end equipment (BE), which enhances the capacity and the integration of the interface capability. Moreover, it uses the carrier-class IT platform as the hardware platform, so the cost of per user and the power consumption are reduced. The energy saving rate for this technology collected by A company is about 60%.

As the technologies explained above, we use two models to estimate the energy saved by soft switch and the other measures, and Table A.5, Table A.6 and Table A.7 display corresponding basic data of A company. It should be noted that the estimating model for soft switch is the same as Equation (8), while the estimating model for Distributive HLR is as follows:

$$ESTA_{HLR} = N_{u\&t} \times pp \times r_{HLR} \times T \quad \text{(A.3)}$$

where:

$N_{u\&t}$: the number of users of distributive HLR;

pp: the traditional HLR power of per user;

r_{HLR}: the energy saving rate of distributive HLR compared with traditional one;

T: the time the equipment runs, i.e., 24h*365day.

As for the POOL networking, the estimate model is specified as follows:

$$ESTA_{POOL} = N_{POOL} \times scp \times ppl \times T \quad \text{(A.4)}$$

where:

$ESTA_{POOL}$: ESTA for POOLs;

N_{POOL}: the number of POOLs built that year;

scp: the capacity saved by setting up one POOL under the current technology level, which is measured by ten thousand users for SGSN POOL or ten thousand erls for MSC POOL. And it should be noted that *scp* for one SGSN POOL or one MSC POOL is 150 thousand users or 5 thousand erls from the experience of CMCC.

ppl: power per capacity;

T: the time POOLs run, i.e., 24h*365days.

Table A.5

Data collected for soft switch of A company.

Type of equipment		*nep(KW)*	*nec(*ten thousand erls)	*Oep (KW)*	*oec(*ten thousand erls*)*	$N_{u\&t}$			
						2011	2012	2013	2014
Switching Category	Soft switch	6	3	4	1	33	33	23	22

Table A.6

Data collected for Distributive HLR of A company.

Type of measure		*pp(*KW/ten thousand users*)*	*r*	$N_{u\&t}$ *(*ten thousand users*)*			
				2011	2012	2013	2014
Switching Category	Distributive HLR	0.006	60%	0	3684.4	8518.6	12595.7

Table A.7

Data collected for POOL networking of A company.

Type of measure		*ppl*	*scp*	N_{POOL}			
				2011	2012	2013	2014
Switching Category	SGSN POOL	0.05(KW/ten thousand users)	15(ten thousand users)	0	16	16	16
	MSC POOL	3(KW/ten thousand erls)	0.5(ten thousand erls)	0	42	43	44

(4) Wireless Access Equipment

Wireless access equipment connects the users of cell phones to the core communication network. In this category, A company proposes two significant technical measures for energy saving, i.e., the Multi-Carrier Power Amplifier (MCPA) and distributive base station. MCPA can greatly increase the integration of wireless devices, so as to support far more communication capabilities under the same power consumption condition. Compared with ordinary base stations, the new ones that apply the MCPA may achieve a much better energy saving effect. And the distributive base station is the station where the base band Unit (BBU) and remote radio unit (RRU) are separated, so the outdoor RRUs do not need cooling any longer. And by connecting the two units with optical fiber, the line loss decreases. So it results in a significant reduction in power consumption. Besides, the distributive base stations use some other improving technologies, such as the high efficiency power amplifier. For these two technical measures, energy saving rate is used to describe the energy saving effect, and the relevant data is shown in Table A.8 for A company. It should be noted that the estimating model of these two measures is as follows:

$$ESTA=N_f \times ppf \times r \times T \quad \text{(A.5)}$$

where:

N_f: the number of frequency carriers;

ppf: the power per frequency carrier and the unit for *ppf* is KW/frequency carrier;

r: the energy saving rate here compared with ordinary base station;

T: the time the equipment runs, i.e., 24h*365day.

Table A.8

Data need for estimation in wireless access category of A company.

Type of measure	2011			2012			2013			2014		
	N_f	*ppf*	*r*	N_f	*ppf*	*r*	N_f	*ppf*	*r*	N_f	*ppf*	*r*
MCPA	134474	75	0.25	272462	75	0.25	365606	75	0.25	454958	75	0.25
Distributive base station	462213	75	0.2	524121	75	0.2	567545	75	0.2	610007	75	0.2

Note: the unit of *ppf* is KW per frequency carrier.

4. Technical Reform

Main energy-saving activities for technical reform are divided into three categories, main telecommunication equipment improvement, air conditioning system improvement and power supply system improvement. For example, intelligent self-turn-off carrier frequency which would automatically shut down when the load is low, the solution of base station without envelope, the distributed cooling which reduces the cooling waste on the indoor environment, the heat pipe exchanger that saves the compressor, free cooling, power saver of air conditioning, dedicated air conditioner for BTS, precision air conditioning for computer rooms, new types of battery (lithium iron phosphate battery), solar or wind energy, efficient UPS, power modular dormancy, constant temperature battery pit, high voltage DC power supply and harmonic wave treatment for power supply and so on. The basic calculating method is displayed in Equation (A.6). Specific data collected for the energy saving potential estimation of technical reform for A company are shown in Table A.9.

$$ESTR = esp_{tr} * N \quad \text{(A.6)}$$

where:

esp_{tr}: the energy saving per unit of reformed equipment in a year;

N: the number of reformed equipment.

Table A.9

Data need for technical reform for A company.

Type of measures		esp_{tr}(KWh)	N			
			2011	2012	2013	2014
Main Telecommunication Equipment	intelligent self-turn-off carrier frequency	3359	8600	21243	16808	15748
	solution of base station without envelope	3650	219	1175	1613	1230
	distributed cooling	3000	400	225	250	250
	the heat pipe exchanger	4500	180	40	30	20
Air-conditioning System	dedicated AC for BTS	3000	0	100	250	450
	power saver of AC	1500	400	1000	800	600
	precision air conditioning	3000	800	690	720	800
power supply system	harmonic wave treatment for power supply	30000	0	2	3	4
	wind energy	10000	4	5	6	7
	efficient UPS	3000	0	12	12	15
	power modular dormancy	3000	0	12	12	15
	lithium iron phosphate battery	5475	0	487	500	500
	constant temperature battery pit	7300	0	20	50	80
	high voltage DC power supply	730	0	16	25	46
	Integrated cabinets	3650	0	274	300	450

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[i] In order to achieve the national energy saving target and restrain the energy consumption of large enterprises, China’s SASAC set three layers for all enterprises regulated by the central government, i.e., Key enterprise, Focused enterprise, and General enterprise according to their roles in energy consumption.