Standard for district heating systems consumption in northern China: guide for heating companies and policy-makers

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SUMMARY

In China, buildings consume about 20% of total energy, of which District Heating system in northern China accounts for 1/4. Last year Ministry of Housing and Urban-Rural Development of China (MOHURD) issued <Standard for Energy Consumption of Building (SECB)> GB/T 51161-2016 (national standard), which is the first standard restraining the building energy intensity in China. It provides detailed standard for DH system. There is little study focused on the heating system code specially, and the relationship between standard and consumption was overlooked. So is the measures and achievement of local policy-maker about heating consumption. With the implementation of SECB, this study expounds how the standard values about heating were determined and how to apply them. Then how to save energy and improve profit for thermal companies with SECB are analysed. Finally, for policy-makers, how to promote SECB and ensure the control of heating consumption are discussed.

INTRODUCTION

Building energy consumption is one of the largest proportion of final energy consumption in society, except industry and transportation. In China, building consumed 864 million tons of coal equivalent (tce,1kgce=29.307MJ) in 2015, which accounted for 20% of total social energy consumption. The District Heating (DH) system in northern China consumed 191 million tce, along with area of 13.2 billion m² and intensity of 14.1 kgce/m² (BERC 2017).

From 1980s, several building codes with respect to energy consumption of all kinds of buildings were issued successively. According to Climatic Regionalization for Architecture in China, DH consumption is mainly considered in cold and severe cold region. These two regions roughly located in the north of the Qinling Mountains-Huaihe River Line, where centralized heating dominates compared to separate heating. So the leading policy about DH is mandatory building energy code there, including 3 design codes of buildings (JGJ26-1986, JGJ26-1995 and JGJ26-2010). These 3 codes correspond to purpose of 30%, 50% and 65% reduction of heating consumption respectively. But these codes only set limit for K-values (heat transfer coefficient) for envelope and window glass performance on design and construction stages (Lang 2004).

On Apr, 2016, Ministry of Housing and Urban-Rural Development of China (MOHURD) issued <Standard for Energy Consumption of Building (SECB)> GB/T 51161-2016, which started to be implemented on heating season from 2016 (MOHURD 2016). Policy about actual energy consumption of DH system in northern China is omitted until SECB. It was the first time that Chinese government put forward a restriction on the building operational energy consumption as national standard. The energy consumption level of DH systems in cold and severe cold region is explicitly stipulated in SECB.

For example, the constraint value and guided value of DH system in Beijing are 7.6 kgce/(m²a ) and 4.5 kgce/(m²a ), respectively.

However, building energy regulation development, implementation and compliance in developing countries are usually far behind compared to those in developed countries (Joseph and Abraham 2010). Indeed, there are few literatures discussing the policy of DH system in China, particularly on the design, enforcement and supervision of heating policy. Taking opportunity of the publication of SECB, this study analyses the heating part of it and discusses how to use the standard for stakeholders and policy makers.

DEVELOPMENT OF BUILDING ENERGY STANDARD FOR DH IN CHINA

Design code for buildings in cold and severe cold region

These 3 series of design codes for buildings in China were carried out for different objective of energy-saving percentage. There are 2 features and notable regulation about DH among these codes.

Firstly, the concept of energy-saving percentage set in Chinese building energy codes has been used for 30 years, which misleading the energy-saving progress of DH in some degree. Misunderstanding about the scope and baseline has caused many barriers during promotion (Yang et al. 2011). In fact, the baseline of energy-saving percentage is the energy consumption of typical buildings in 1980s in China. Not only stricter demand on building envelope contributes to the consumption reduction, but also the improvement of system operation efficiency should be taken into account. As for the heating energy consumption, the scope of the code is systematic heating for residential buildings while the type is centralized rather than other wrong understand in some local governments in China.

Secondly, the codes only give the regulation on building during construction. The primary K-value in different code is shown in Table 1. However, the actual performance of DH system is neglected. Little annual energy consumption of DH system annually was issued around China due to no consumption standard. Even the relevant official statistic is not detailed, resulting in the opacity of the direction for energy saving in heating system.

<table>
<thead>
<tr>
<th>Window</th>
<th>6.4</th>
<th>6.4</th>
<th>4.7</th>
<th>3.1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roof</td>
<td>1.26</td>
<td>0.91</td>
<td>0.8</td>
<td>0.45</td>
</tr>
</tbody>
</table>

Table 1. Limited values of building envelope heat-transfer coefficients in different design standard in China
There is no doubt that the mandatory codes contribute a lot to achievement for reduction of building energy use intensity (EU). But it’s hard to evaluate the quantitative effect or find energy-saving potential inside DH system without metered data. The consumption standard is definitely the key of heating policy in the next stage.

Analysis to regulation on DH in GB/T 51161-2016

Firstly, the scope of regulation on DH in SECB is clear. The standard value is set for typical heating system in cold and severe cold region in northern China. Heating systems in south China and rural region are not considered in this regulation. By the way, though the feature of heating EU in public buildings is different from general system in northern China, the standard is also suitable for public buildings from the calculation verification.

Secondly, the standard contains two kinds of requirement, given by the constraint value (CV) and guided value (GV). The two standard values mean different limitation, which got from different building codes when drafting. The CV is like the bottom line of performance for DH system, while the GV signifies high performance when the system is qualified.

Thirdly, the content of standard for DH consists of two parts. One is the direct assessment for entire DH system. The other one is the detailed requirement in each process during heating, including actual heating demand of buildings, the performance of distribution system in DH and thermal efficiency of heat source (like boiler or combined heat and power system). Some standard values are given for different cities, allowing for the variation of meteorological parameter. The constitution is given in Table 2, as an illustration. SECB could be used for evaluation of the system and diagnosis of the part with energy-saving potential as well.

Table 2. Regulation on DH in GB/T 51161-2016 (Values in Beijing)

<table>
<thead>
<tr>
<th>Category</th>
<th>Unit</th>
<th>Constraint Value</th>
<th>Guided Value</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total heating energy consumption</td>
<td>District heating</td>
<td>kgc/m²</td>
<td>7.6</td>
<td>4.5</td>
</tr>
<tr>
<td></td>
<td>Community heating</td>
<td>kgc/m²</td>
<td>13.7</td>
<td>8.7</td>
</tr>
<tr>
<td>Actual heating demand of buildings</td>
<td>GJ/m²</td>
<td>0.26</td>
<td>0.19</td>
<td>q_{di}</td>
</tr>
<tr>
<td>Performance of distribution system</td>
<td>Power Consumption</td>
<td>kWh/m²</td>
<td>1</td>
<td>1.7</td>
</tr>
<tr>
<td></td>
<td>Heat loss</td>
<td></td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>District heating</td>
<td>%</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Community heating</td>
<td>%</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Thermal efficiency of heat source</td>
<td>District heating</td>
<td>kgc/GJ</td>
<td>22</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>Community heating</td>
<td>kgc/GJ</td>
<td>43</td>
<td>38</td>
</tr>
</tbody>
</table>

Each category is computed with the following equation:

\[ E_{th} = (q_{di} + e_{di} \times c_{j}) \beta \]  

(1)

where \( q_{di} \) is energy consumption metered in heat source and \( e_{di} \) is power consumption of the distribution system, \( c_{j} \) is the average coal or natural gas consumption of thermal power plant in China and \( \beta \) is the meteorological correction parameter.

\[ q_{b} = \gamma \times Q_{b} \times \left( \frac{1}{1 + \alpha} \right) \times \beta \]  

(2)

where \( Q_{b} \) is energy consumption metered in heat user and \( A_{b} \) is the heating area, \( \alpha \) is the rate of excessive heating in secondary pipe network in DH and \( \gamma \) is the transport efficiency of secondary pipe network.

\[ e_{di} = \frac{E_{di}}{A_{b}} \]  

(3)

where \( E_{di} \) is the power consumption of all circulating pump in the entire heating system.

\[ \alpha_{w} = \frac{Q_{pl}}{Q_{bo}} \]  

(4)

where \( Q_{pl} \) is the total heat loss in the distribution system and \( Q_{bo} \) is the sum of actual heating consumption of all buildings.

\[ C_{t} = \sum C_{ij} \times \left( \frac{\lambda \cdot Q_{ij}}{E_{w,i} + \lambda \cdot Q_{ij}} \right) + E_{m,i} \times c_{j} \]  

(5)

where \( C_{ij} \) is the consumption of fuel in heat source and \( Q_{ij} \) is the sum of heating energy metered in outlet of heat source during a whole heating season, \( E_{out,i} \) is the net energy output from CHP and \( E_{m,i} \) is the power consumption of heat source like boiler and heat pump, \( \lambda \) is the convert coefficient of exergy for hot water.

Finally, some regulations are distinguished by district and community. It is because that the energy efficiency of DH system changes with the heating scales. Large heating areas are simulated to adopt centralized heating equipment with huge installed capacity like combined heat and power system (CHP). So the standard value for large heating areas is much stricter. Boilers are more common but they are only eligible in heating for community in China.

GUIDE FOR HEATING COMPANY

The heating companies play a leading role in energy-saving of DH systems in China. Though the regulation on DH in SECB are related to various stakeholder in heating, the heating companies seems to bear major pressure.

Combined with the current situation of statistic and regime about heating, the Chinese heating companies are trapped. The actual heating demand of buildings is the duty of building developer and owner. But the restraint is invalid as the statistical data in Chinese DH system is not detailed to get the proof at present. What's worse, CHP system is usually owned by power plant, and the consumption data is not overt for heating companies. Chinese heating company is always the weak side when information asymmetry occurs. As a result, the assessment of thermal efficiency of heat source faces difficulties. The urgent affair of heating companies in China is the completion of data collection from every part of DH. It is also necessary to ask for clear rights and duties for each stakeholder in heating process with thorough consumption data.

In accordance with collected data and SECB, a detailed target systems during operation for each company could be made. The SECB is the basic principle for every Chinese heating companies. Companies also could diagnose and find energy-saving potential in owned systems with the help of SECB. The
In fact, there is a shortcut for statistic of Chinese DH system at the moment. The heat metering is an important policy for energy saving of heating in China in last decade. The building area with heat metering in China has reached over 1 billion m². The first step could be the collection and publishment of metered data.

**New policy system on actual energy consumption**

The study of policy system is still lacking for heating in China, as heating is half-welfare in northern area. As shown in Figure 2., most procedure of general policy control is lacking in Chinese energy policy about heating, leading to barriers of the enforcement and adjustment.

With the implementation of SECB, a new policy system on actual energy consumption should be established. Besides the consumption should be used for providing energy conservation measurement, metered data must appear on work report in governments in every level. The energy-efficient buildings should be also certificated with actual EUI rather than energy-saving percentage from better construction. In addition, the energy plan is supposed to centre on consumption standard, apart from design standard.

**More attention to policy diffusion**

Policy diffusion is the key process to ensure that the policy would be executed as expected. For SECB, the diffusion process could be divided into two major part between MOHURD and local government, local government and heating company. As shown in Figure 3., the local government should set up consumption standard according to meteorological parameter, situation of system and operation. Local standards should be applied as guidelines, the highest standards for heating systems around the regions. It could be also used as engineering evaluation indicators and heating energy-saving planning reference, too.

In line with local standards, companies should focus on the formulation of internal application index system, for further refinement of different indicators. Taking the power consumption of distribution system as an example, parameter such as water flow, pressure drop range in the system, pump operation efficiency, frequency conversion mode could be added in the index system under layer of power consumption unit area.

**GUIDE FOR POLICY MAKER**

**Improvement of data statistics**

The official statistic is now obviously incomplete for heating. There is only gross of heating energy consumption counted in China Statistical Yearbook annually. The scope and more detail in heating system still have extensible space. As section 3 states, the government and statistical should be heating company-oriented. The use of SECB and saving heating energy consumption both need systematic, standardized, normalized statistic.

**Figure 1.** gives an example of use of standard value and operation data in Qianxi county, Hebei province in China.

Figure 1. Actual heating demand of buildings and circulating water flow in heating stations in Qianxi county (2015~2016 heating season)

The water temperature difference line is given to judge whether the flow of DH is suitable as reference. And the energy-efficient buildings mean the new construction or existing buildings with energy-saving renovation.

From the Figure 1., some information could be seen directly:

a) There is only one heating station meeting the constraint requirement on actual heating demand of buildings of SECB.

b) The stations that heating for building in zone IV and V are above average. To sum up the building types in IV and V, there are 18 nonenergy-efficient buildings, accounting for 72%. So for the high-energy consumption stations in IV and V, renovation is the key point.

c) There are many stations heating for energy-efficient buildings in zone III, where most of them are below the constraint water temperature. Their actual heating demand is still higher than 0.23GJ/m². It is obvious that most of stations there are below the constraint water temperature difference (Δt < 6°C). It means the system work on the mode of "large flow, small temperature difference", which causes excessive heating, seriously. Excessive heating is common in China because the large-scale heating stations are popular in central heating area. Thus for stations in III, the chief assignment to reduce heating consumption is the regulation of thermal equilibrium in system.

Through such an analysis, we can have a preliminary understanding of the status of heating energy consumption in a county. What are the problems inside the DH system and which is corresponding areas could be also known briefly, bringing of great help to deep diagnosis of energy saving.

**Figure 2.** General policy control procedure

**Figure 3.** Policy diffusion process of SECB

**Figure 1.** gives an example of use of standard value and operation data in Qianxi county, Hebei province in China.
CONCLUSIONS
This study clarifies the energy standard for district heating in China and gives guidance for both heating companies and policy-makers about the application of SECB. The status quo of energy consumption and heating policy is described as well. So the key steps to saving energy in Chinese heating systems on regulation are summarized below:

1) SECB is the first national standard based on the actual energy consumption in China, which is a great supplement for Chinese building energy policy system. Therefore, more attention need to be paid for the enforcement and diffusion of the standard. After all, the heating area in China is too vast.

2) As for heating companies, the standard could help them to reduce energy consumption in each part of heating system, which means cost reduction. What is more significant is to distinguish the duty between other stakeholders according to metered data.

3) In terms of policy-maker and government, the cooperation with heating companies seems to be especially important. Effective promotion, supervision and control are still on the way to perfection in heating policy.

Above all, SECB is a breakthrough in building energy research in China in some degree. How to make the full use of the standard should be discussed more. And the energy consumption data collection is always top priorities.

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REFERENCES
Joseph I. and Abraham M. 2010. A review of building energy regulation and policy for energy conservation in developing countries. 38 (12), 7744-7755