

# **Building performance simulation optimization in carbon trading: a comparative case study**

Yao Nie, Borong Lin\* and Yiwei Lin

Department of Building Science, School of Architecture, Tsinghua University, Beijing, 100084, China

## **ABSTRACT**

With the improvement and popularity of building performance simulation software, building performance simulation has become the major method to establish the baseline and estimate the emission reduction in building carbon trading programs. Through the method of case study, comparative analysis and real case simulation, this research investigated the application of building performance simulation in building CDM (Clean Development Mechanism) projects and analyzed some of the potential problems, which has targeted guiding significance to the methodology making of Beijing carbon trading mechanism in building sector.

## **KEYWORDS**

Building performance simulation, carbon trade, CDM, methodology, case study

## **INTRODUCTION**

In order to mitigate global warming, UNFCCC (United Nations Framework Convention on Climate Change) has established an important greenhouse gas emission trading mechanism——CDM. Multiple numbers of urban and regional carbon trading markets have been developed in mainland China, to reduce the carbon intensity (CO<sub>2</sub> per unit of GDP) in 2020 by 40%-45% compared with the level of 2005. The building energy consumption accounts for 30%-40% of the total energy consumption globally, therefore the GHG (greenhouse gas) emission in building area has enormous reduction potential. The building sector consumes about 27.5% of total energy consumption in China, and the building GHG emission is over 15.6 hundred million tons annually.

With the improvement and popularity of building performance simulation software, building performance simulation plays a more and more important role in both global and regional building carbon trading projects. However, it's hard to find deep analysis on the current application of building performance simulation in carbon trading projects. This research investigated the application of building performance simulation in building CDM projects and analyzed some of the potential problems, which has

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\* Corresponding author email: linbr@mail.tsinghua.edu.cn

targeted guiding significance to the methodology making of Beijing carbon trading mechanism in building sector.

## RESEARCH METHODS

In the first and second section of discussion, the method of comparative analysis is adopted. While in the last section of discussion, the method of real case simulation is adopted.

## RESULTS AND DISCUSSION

### 1. Comparison of CDM methodologies on provisions of the building performance simulation

There are 5 methodologies approved under the UNFCCC which are applicable to whole buildings. Their basic information is as follows.

*Table 1. The basic information of the five building CDM methodologies*

Methodology ID	Name of Methodology	Scale	Effective Date
AMS.II.E	Energy efficiency and fuel switching measures for buildings	Small	Oct, 2002
AMS.III.AE	Energy efficiency and renewable energy measures in new residential buildings	Small	Jul, 2009
AM0091	Energy efficiency technologies and fuel switching in new and existing buildings	Large	Mar, 2010
AMS.II.Q	Energy efficiency and/or energy supply projects in commercial buildings	Small	Jul, 2012
AMS.II.R	Energy efficiency space heating measures for residential buildings	Small	May, 2013

Description: If the aggregate energy savings of a single energy efficiency project does not exceed the equivalent of 60 GWh per year, the project is categorized into small scale. If not, the project is categorized into large scale.

Generally, a CDM methodology contains sections of source, definition and applicability, baseline methodology procedure and monitoring methodology. Building performance simulation is mainly adopted to establish the baseline and estimate the emission reduction in building carbon trading programs. After investigation of the registered building CDM projects, we find all of them are under the methodology AMS.II.E. And after investigation of the 5 CDM methodologies, we find only AMS.II.Q has explicit regulations on how to carry out building performance simulation. Therefore, these two methodologies are most worthy of analysis.

#### 1.1. AMS.II.E: Energy efficiency and fuel switching measures for buildings

This methodology can apply to both public buildings and commercial buildings, and to both construction scenario and retrofitting scenario. The regulation for baseline establishment is “The energy baseline consists of the energy use of the existing equipment that is replaced in the case of retrofit measures and of the facility that would

otherwise be built in the case of a new facility”. The rules for emission reduction calculation is also very general, having no detailed clauses and requiring project participants to propose appropriate ways based on the actual situation. Therefore, AMS.II.E has a wide range of applications.

## **1.2. AMS.II.Q: Energy efficiency and/or energy supply projects in commercial buildings**

This methodology is applicable to on-site building energy supply and whole building energy efficiency projects whose associated emission reductions can be determined with a whole building computerized simulation tool. The detailed simulation process requirements of ex ante and ex post emission reduction calculations are demonstrated as follows:

### **The ex ante methodology**

The ex ante baseline emissions scenario shall be based on the characteristics and operation of the existing building(s) (Retrofit) or the building(s), which would have been constructed in the absence of the CDM project activity (New Construction). The baseline energy consumption  $E_{BA}$  is get from energy bills (Retrofit), the local legally mandated building code requirement or a related database (New Construction). Then the building performance simulation model for project scenario is built. The input data set for physical building characteristics shall reflect all the measures planned for energy savings or greenhouse gas avoidance in the project activity. The input data set for weather and tenancy/occupancy should match the conditions in the baseline case (Retrofit) or should be in accordance with the project scenario (New Construction). The energy consumption by project building in baseline scenario  $E_{PA}$  is simulated by the model. Then the ex ante energy reduction is calculated as the difference between  $E_{BA}$  and  $E_{PA}$ .

### **The ex post methodology**

The model of the project building is based on the actual weather data, tenancy/occupancy data and other real performance data in the crediting period. The model should be calibrated with the real energy consumption until the simulated energy consumption  $E_{pm}$  meets the whole building calibration requirements of the ASHRAE Guideline. The reference baseline building model is built using the actual weather and tenancy/occupancy data in the project activity, and the input data set for other building features shall be based on the characteristics and the operation of the existing building(s) (Retrofit) or the building(s), which would have been constructed in the absence of the CDM project activity (New Construction). Then baseline energy consumption  $E_{bp}$  is simulated. Should activities associated with the project activity (for example if major modifications to the building are the primary activity taking place) require compliance with a legally mandated and enforced energy performance code and/or equipment standard(s), the baseline emissions scenario shall be based on minimum energy requirements in the building code and/or equipment performance standard(s) for the subject building type(s) or classification(s) in the same climate zone (e.g. in

kWh/m<sup>2</sup>/year). The avoided GHG emissions between the baseline and the project activity is calculated as the difference between  $E_{pm}$  and  $E_{bp}$ .

Besides, only building performance simulation softwares that have a current empirical validation requirements as defined in the International Energy Agency's BESTEST protocol can be used with this methodology. Project participants must demonstrate that the building energy simulations (and related calibrations) have been performed by skilled operator(s) as demonstrated by having at least three years of relevant experience and professional education and/or training.

In conclusion, only the methodology AMS.II.Q has clear and definite rules for the use of building performance simulation. Will the vague regulations of the other 4 methodologies cause any application problems? The answer is yes and it'll be discussed in the next section.

## **2. Case study on the application of building performance simulation on registered building CDM projects**

There are approximately 55 building carbon trading programs requesting registration under the CDM, among which 10 are already registered and 8 are rejected. The 10 registered projects mainly locate in India, Moldova, Brazil and South Africa, and all use methodology AMS.II.E.

Among the above registered projects, the building type of the South Africa project is residential building and the building type of the other 9 projects is public building, including office building, school, gymnasium, hotel, commercial building and mixed property. The predicted amount of reductions of the 9 registered projects is between 544 tCO<sub>2</sub> and 17888 tCO<sub>2</sub>, which is far below the upper limit of the small scale projects. The main low-carbon technologies adopted are improving the thermal performance of building envelop, using chillers with high COP, reducing the energy loss of distribution system and reforming the lighting system. A few projects adopt the method of optimizing building energy management system, switching fuel or waste heat recovery.

In the above cases of retrofit measures, the baseline emission is mainly predicted with historical data. In the case of new construction, the baseline emission is mainly predicted with building performance simulation. The baseline building is based either on the ASHRAE standard rules or on the typical building constructed in the proposed district.

In the analysis of the above cases, we found some issues worth to be noticed:

### **2.1. Is the adopted building performance simulation software authorized?**

The case 0079(reference number of CDM projects) uses QUICK Ver 3.0 thermal performance modeling software to calculate the baseline heating energy consumption. However, the certification of the IEA BESTEST program is found neither in the project design materials the project participant uploaded nor on the official website of the software. Thus, the reliability of the software is doubtful.

The case 1794 and 6777 also uses building performance simulation software. But the names of the software is not mentioned in the project design materials, let alone the

proofs of authoritativeness.

## 2.2. The absence of some key parameters

In the 6 registered projects adopting building performance simulation, only project 0079 has separate simulation report. Many project participants didn't provide some of the simulation key parameters, such as the floor area, the indoor air temperature and humidity settings, the occupancy settings, the rated power and control strategy of devices and so on. The absence of the key parameters makes it complicated for audit agencies to validate the accuracy of the simulation result.

To sum up, because the methodology AMS.II.E does not give explicit requirements on how to carry out building performance simulation, the simulation processes and results of most registered projects have the accuracy problem more or less. Therefore, when making the methodology of Chinese regional carbon trading market, we should learn from the methodology AMS.II.Q, providing clear and definite rules for the use of building performance simulation and easing the burden of audit agencies.

## 3. Real case simulation: analyzing the difference between the baseline emissions established by building performance simulation and regional building energy consumption standards or databases

In the 6 registered projects adopting building performance simulation, 5 projects haven't provide monitoring reports of real emission reductions. Only one submitted the report, but it didn't pass the audit. Only issued emission reductions can be traded through CDM, so none of the 6 projects participates in the trading market of CDM. Given all the above facts, to some extent, CDM does not strongly promote the emission reduction in building area. As described in the first part of results and discussion, the principles of baseline establishment is very complex and conservative. It is a question to be analyzed whether the baseline emission calculated by building performance simulation is too low which leads to no real emission reduction measured afterwards. Therefore, following the clauses of the methodology AMS.II.E and imitating the way the 6 projects establish baselines, we simulate the baseline building energy consumption of a new constructed building in Beijing and compare the simulation result with Chinese Standard for Energy Consumption Quota of Buildings (Discussion Draft) and the limited value of building energy consumption in the Tsinghua database.

The new constructed building we selected locates in Dongzhimen District, Beijing. It is LEED certified gold-rated and its floor area is 200838 m<sup>2</sup>.

Half of the 6 registered projects adopting building performance simulation use the regulations of ASHRAE/ IESNA 90.1-2004 and local standard to establish baselines. In our analysis, we also follow this routine and simulate two baseline building models, one of which follows the regulations of ASHRAE/ IESNA 90.1-2004 and another follows the regulations of Beijing Public Building Energy Efficiency Design Standard DB11 / 687-2009.

The specific modeling parameters are as follows:

**Table 2.** Basic set parameters of the two baseline building models

Set Parameters		ASHARE Standard	Beijing Standard
Envelop(W/(m <sup>2</sup> k))	U-value of Exterior Walls	0.479	0.8
	U-value of Roofs	0.496	0.5
	SHGC of Exterior Windows	0.3	0.45
Window-wall Ratio	East	0.4	0.62
	South	0.4	0.64
	West	0.4	0.65
	North	0.4	0.63
Lighting Power Density(W/m <sup>2</sup> )	Office	11	11
	Public Spaces	14	11
Equipment Power Density(W/m <sup>2</sup> )	Office	25	Identical with the actual usage
	Public spaces	7.5	
COP of Chilled Water System		5.55	5.1

eQUEST is the software used here to simulate the baseline building energy consumption. After the initial simulation, the model of ASHRAE standard is rotated 90, 180 and 270 degrees and the baseline building performance is taken as the average of these results. The simulation results, the standard quota and the limited value from Tsinghua database is shown below.

**Table 3. Baseline energy consumptions by different establish methods**

Items	Simulation of ASHARE standard	Simulation of Beijing standard	Chinese Standard (Discussion Draft)	Tsinghua database
Electricity consumption (kwh/(m <sup>2</sup> a))	101.1	73.4	70	88
Heat consumption (GJ/(m <sup>2</sup> a))	0.27	0.37	-	0.18

Description: In Chinese Standard for Energy Consumption Quota of Buildings (Discussion Draft), the demand for Heat consumption per m<sup>2</sup> is below 9.8 kgce/(m<sup>2</sup>•a). The heat sources of Beijing heat supply network are various and there's no authoritative conversion factor. So the baseline heat consumption of Chinese Standard (Discussion Draft) is not listed above.

The table shows that the baseline electricity consumption value obtained from Chinese Standard (Discussion Draft) is smaller than that obtained from simulation and the baseline heat consumption value obtained from Tsinghua database is smaller than that obtained from simulation. With regard to this case simulation, the baseline establishment by building performance simulation won't lower the emission reduction, compared with the baseline establishment by Chinese Standard for Energy Consumption Quota of Buildings (Discussion Draft) or the Tsinghua database.

## CONCLUSION AND IMPLICATIONS

Through the method of case study, comparative analysis and real case simulation, this research investigated the application of building performance simulation in building CDM projects and analyzed some of the potential problems, which has targeted guiding significance to the methodology making of Beijing carbon trading mechanism in building sector. Firstly, based on the investigation of existing CDM methodologies, the differences in regulations on building performance simulation are analyzed. Then, on the basis of case studies of the registered building CDM projects, two major problems are found in the application of building performance simulations, which are the adoption of non-standard simulation software and the absence of key parameters. These two problems above comes from the lack of explicit requirements in the methodologies the projects selected. Last but not least, the difference between baseline energy consumptions obtained by simulation, standard and database is discussed in a real case.

In order to better imply the building performance simulation to carbon trading projects, suggestions are given as follows:

- 1) The building performance simulation is technical and should be carried out in accordance with the standards by professional operators. It's necessary to have clear and definite rules of the simulation process, data records, report writing and relevant certificates, and have connections with local or regional standards in building carbon trading methodologies, which will improve the reliability of the result and reduce the burden on reviewers.
- 2) The baseline establishing method of building performance simulation won't necessarily lead to a lower emission reduction. As one of the major methods to establish the baseline and estimate the emission reduction, building performance simulation can play a greater role in building carbon trading programs.

## PROSPECT

Since 2013, multiple numbers of urban and regional carbon trading markets have been developed in mainland China. In future studies, continuous and large scale investigation of methodologies and real projects can be carried out to improve the adoption of building performance simulation in the carbon trading programs.

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