Application of McKinsey Curve in Building Emission Reduction Technology

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Abstract: In order to promote the application of McKinsey energy reduction cost curves in buildings, This paper introduces the concept of McKinsey abatement cost curves, the current application status of building abatement measures and abatement cost data, makes an analysis for the economic characteristics of different energy efficiency measures in retrofit projects, and presents the retrofit measures, annual energy savings and investment costs used in retrofit programs by taking the example of energy efficiency retrofits in office and commercial buildings in the past 2 years, discloses the data changes in abatement costs for some energy-saving retrofit technologies contrastingly, and suggests that dates should be iterated based on McKinsey abatement cost curves. The McKinsey abatement cost curve is useful for guiding the selection of building energy efficiency measures. The curve is economical and visualized compatibly and is a good reference for making abatement decisions through timely updating the data of retrofit technologies and influencing factors.

1. Introduction

In September 2020, Chinese government proposed to the United Nations General Assembly the "double carbon" goal of "striving to reach peak of CO_2 emissions by 2030 and achieving carbon neutrality by 2060". To achieve these goals, the Ministry of Housing and Urban-Rural Development has proposed in the 14th Five-Year Plan for the Development of Building Energy Efficiency and Green Buildings to strengthen the energy-saving and green renovation level of existing buildings and improve the energy-saving level of new buildings, and to complete the energy-saving renovation of existing buildings with an area of more than 350 million square meters by 2025, and to construct ultra-low energy consumption and near-zero energy consumption buildings with an area of more than 50 million square meters by 2022[1]. In November 2022, the State Administration, the National Development and Reform Commission, the Ministry of Finance, and the Ministry of Ecology and Environment issued the "Implementation Plan for conducting Green and Low-Carbon Leading Actions for Public Institutions in-depth to Promote Carbon Peaking", which clearly proposes that by 2025, the energy use structure of public institutions nationwide will be continuously optimized, energy efficiency will be continuously improved, energy consumption per unit floor space will be reduced by 5% and carbon emissions will be reduced by 7% on the basis of the 2020 level, areas with the necessary conditions will reach public institutions carbon peak by 2025, and the total carbon emissions of public institutions nationwide will reach the peak as early as 2030. In the context of "double carbon", the coordinated development of economy and environment, the economics, feasibility and implementation cycle of energy-saving renovation technology in the process of building emission reduction have become the issues that need to be considered in order to steadily improve building energy use efficiency, gradually optimize building energy use structure and reduce building energy consumption[2].

2. McKinsey Abatement Curve and the original intention of drawing it

When conducting a regional analysis of potential capacity for energy saving and emission reduction, we are facing with dozens choices of energy saving and emission reduction technologies .If there's a set of clear and intuitive expressions can be used to enable decision makers in energy saving and emission reduction planning to scientifically select the available technologies and understand the corresponding implementation costs so as to propose practical energy saving and emission reduction targets, which will become the main use of drawing energy saving and emission reduction cost curves.

As shown in Figure 1, in 2010, the Shanghai Energy Conservation Supervision Center was commissioned by the Changning District Government, under the guidance of WB experts, to conduct extensive research and statistics on a large number of individual retrofitting of large public buildings in the central area of Shanghai, for including adopted technology's frequency, distribution

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characteristics, project cycle, energy savings, economic parameters, ease of implementation, ease of maintenance, potential risks , etc. to establish a comprehensive database[3]. Using the McKinsey Abatement Curve Drawing Tool of AHP analysis method and score weighting combined multi-index as the main tool, we successfully compiled the energy saving and emission reduction cost curves for the Changning Hongqiao area[4], which provided an important reference basis for the district government to set the low-carbon development goals.

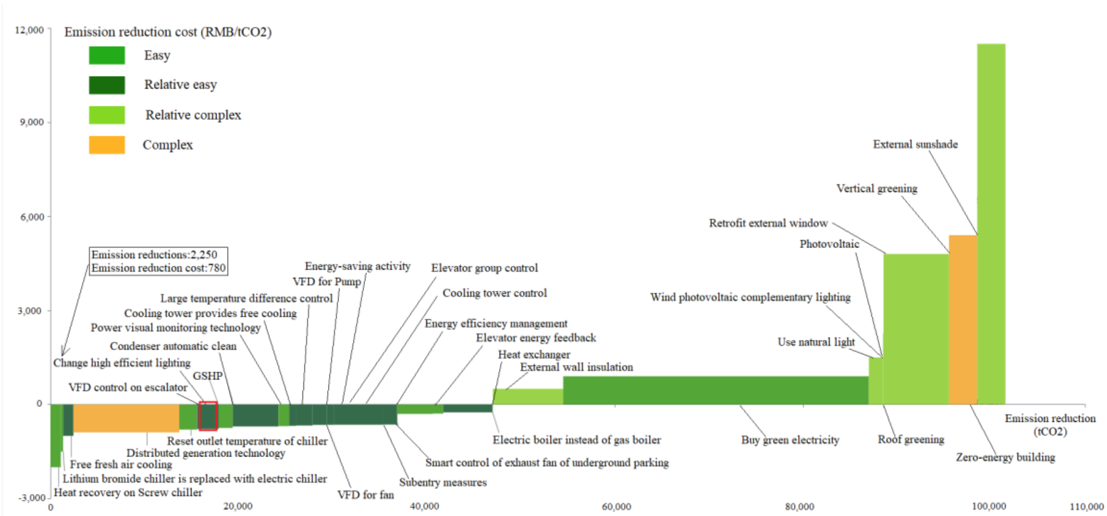

Figure 1 McKinsey Abatement Curve

3. Interpreting the McKinsey Abatement Curve

The cost curve not only covers spatial characteristics, but also implies a temporal characteristic, which refers to the expected year of potential capacity for energy saving and emission reduction. In different expected years, The technologies included in the corresponding curves, the amount of emission reduction for each technology will vary, the cost of abatement for each technology also changes somewhat, Figure 1 shows the data of expected year 2020.

The most important elements in the cost curve are the bar boxes, each of which represents a project (corresponding to a technology or product). The horizontal (X-axis) width of the bar indicates the size of the project's emission reductions, the height of the bar (Y-axis direction) indicates the amount of the unit abatement cost of the project (using NPV dynamic costing). Emission reductions can be measured in tons of carbon dioxide or tons of carbon dioxide equivalent (in the presence of other GHG emissions), and unit abatement costs can be measured in ($/ton of carbon dioxide) or ($/ton of carbon dioxide equivalent). There are usually two calibers of emission reductions: one is the annual emission reductions for the expected year, and the other is the sum of annual emission reductions for the expected year. The first caliber is process independent and the second caliber is process related, the earlier the technology is implemented, the greater the total amount of emission reductions, but for some technologies the unit abatement cost may be higher. Figure 1 shows the caliber X, All bar boxes are arranged from lowest to highest cost (from left to right) by according to per unit abatement. The tops of the bars form a horizontal S shape, which is the reason for the "curve" name. The cost curve provides key information for decision makers, including:

（1）The applicable abatement technologies in the region and the magnitude of the abatement capacity of each technology.

（2）Maximized abatement capacity (potential technical capacity), which would be the limit of the abatement target, and different low-carbon scenario analysis based on regional energy savings or potential abatement capacity curves can be used to analyze energy savings and low-carbon targets under different models.

（3）For Verifying the likelihood of implementation of emission reduction targets set through top-down approaches, generally the emission reduction achieved through technological progress can be calculated based on the emission reduction target. If the emission reduction target is on the left side of the zero point of the unit abatement cost, the target is likely to be achieved through market mechanisms. If on the right side, it indicates that the target requires additional push from the government to be achieved, the abatement cost of the technology corresponding to that target can be considered as the cost to the government in the additional push.

（4）The difficulty of implementing the project gives more information for decision making at the time of implementation. Some energy efficiency and emission reduction technologies have some important but unquantifiable benefits as a side effect, but the decision from cost can cause some bias. The difficulty of implementation will provide important information for scientific decision making, and can be analyzed for energy efficiency measures implementation decisions. Special attention can be paid to techniques that are not too difficult to implement above the X-axis of the curve.

（5）Corresponding curves have a corresponding a comprehensive database involving a large amount of information, concerning basic data such as investment cost, operation cost, lifetime, energy saving rate and energy efficiency changes related to each technology, and more valuable information can be obtained through in-depth analysis of this comprehensive database[5].

（6）As shown in Figure 1,as for the column box of "More efficient lighting"[6], which indicates that the emission reduction of this technology is 2250 tons of carbon dioxide, and the emission reduction cost is 780 yuan/ton of carbon dioxide.

Ninety-three projects using the same technology were used as the basic data to calculate the economy of the energy-saving transformation technology, and the period was set for 10 years. Calculate the total cost and total emission reduction of the projects to obtain the emission reduction cost curve data.

4. Application in energy-saving renovation examples

Table 1 shows the technical and economic analysis of the energy-saving renovation of Project A. Project A was put into operation in 2007 with a building area of 35,000 square meters. It is business type, and the following renovation was completed in 2021.

Table 1 Technical and economic analysis of project A energy-saving renovation

Project-A	Emission reduction cost (RMB/tCO2)	Emission reduction (tCO2)	Energy saving cost (RMB /tce)	Energy saving (tce)
Lighting system energy saving	129	50	278	11.56
Air conditioning refrigeration and cooling pump replacement	142	51	492	14.62
Cooling tower replacement	622	52	13263	2.43
Fresh air volume control (automatic control)	270	53	363	39.26
Refrigeration Station Group Control	102	54	2023	2.72
Air-cooled heat pumps replace electric boilers	3102	55	1183	143.65

Table 2 shows the technical and economic analysis of the energy-saving renovation of Project B. Project B was put into operation in 2005 with a building area of 25,000 m^2. It is business type, and the following renovation was completed in 2012.

Table 2 Technical and economic analysis of project B energy-saving renovation

Project-B	Emission reduction cost (RMB/tCO2)	Annual Emission Reduction (tCO2)	Energy saving cost (RMB/tce)	Annual Festival Energy (tce)
Window Film	686	50	960	36
Air-cooled heat pump with wind-pulling cover	3527	5	4938	3
Roof exterior windows to aluminum louvers	496	3	694	2
Air-cooled heat pump condensing fin spray	947	15	1325	11
Air-cooled heat pump to water-cooled screw	3237	42	4532	30
Energy saving in public area lighting systems	1341	47	1877	33
Energy saving in tenant area lighting system	2571	63	3600	45
Fresh air unit inverter	893	3	1250	2
Operation Management	551	38	772	27

Compared with the McKinsey reduction curve, adopting the same energy-saving technology[7]:

（1）Annual energy savings are mainly related to the base energy consumption of the project and the scale of the renovation.

（2）Annual emission reductions are mainly related to the project’s base energy consumption, the scale of the renovation, and the emission reduction factors.

（3）The annual cost of energy saving and emission reduction, in addition to the above factors, is also related to the cost of equipment and operating life cycle.

A single item common to the McKinsey abatement cost curve in the retrofit example of Project A and Project B was selected for analysis, as shown in Table 3, What can be seen:

（1）For the same technology, the annual emission reduction is mainly related to the basic energy consumption of the building and the scale of renovation. The larger the individual energy consumption corresponding to the technical measures and the larger the scale of renovation, the larger the annual emission reduction .

（2）The abatement cost of energy-saving renovation technology directly affects the frequency of adoption of this technology. Comparing the energy-saving cost curve table with the economic data of renovation cost of A and B projects, it can be seen that in terms of building renovation technology, the economic trend of energy-saving technical renovation measures has not changed, and lighting renovation and inverter renovation of pumps and fans are still the measures with lower abatement cost and are the preferred measures for energy-saving renovation projects.

（3）The abatement costs of measures such as group control of refrigeration stations and operation and management are beginning to fall, and their energy-saving effects will become increasingly evident during the digital construction of buildings in the context of the 3060 double carbon.

（4）Exterior windows and other envelope retrofit measures continue to be poorly economized.

（5）Lighting energy-saving retrofit measures, in the case of lighting product updates and upgrades iterations faster, the price of the product itself decreases, coupled with the new product life extension so that the frequency of product replacement decreases, the cost of emission reduction of this technology significantly decreased.

（6）Water pump and fan frequency conversion transformation measures[8], single unit transformation effect varies greatly because in the building energy-saving transformation measures, the price of the equipment itself does not change significantly, the basic energy consumption and the difficulty of transformation caused by the cost and emission reduction fluctuations of the influencing factors, so the regional emission reduction cost of the technology may be relatively lower than the emission reduction cost of a single building, but for the building itself energy-saving technology selection, energy-saving potential still occupies an indispensable advantage.

（7）Energy-saving renovation measures such as envelope structure, the amount of renovation monomer is small, the renovation target and the products used vary greatly, and the referenceability of the economic cost curve is low.

Table 3 Benchmark analysis between energy saving retrofit example and McKinsey curve

Project（McKinsey）	Emission reduction costs (RMB/tCO_2)	Project-A	Emission reduction costs (RMB /tCO_2)	Project-B	Emission reduction costs (yuan/tCO_2)
Lighting system energy saving	780	Lighting system energy saving	129		
Refrigeration Station Group Control	670	Refrigeration Station Group Control	102		
Air conditioning pump inverter	648			Air conditioning pump inverter	1031
Fan Frequency Conversion	650			Fresh air unit inverter	893
Public building exterior window renovation	4800			Exterior window film	686
Energy saving operation management	645			Operation Management	551

5. Development and suggestions

McKinsey reduction cost curve data are based on energy-saving renovation cases in hot summer and cold winter low areas.The data comes from "Changning Energy Consumption Monitoring and carbon emission Comprehensive Management Platform"[9].The curve has guiding significance for the selection of energy saving measures for large public buildings over 20,000 square meters.At present, the case data does not relate to residential buildings.

In the dual carbon strategy studies of applying abatement cost curves [10], the plotting of cost curves contains two types of parameters, one belonging to the set parameters and the other belonging to the input parameters. The set parameters involved, such as: life cycle of a single technology, carbon emission factor, standard coal conversion factor, subsidy cost, electricity tariff, etc., need to be updated timely according to the latest documents; the input parameters involved, such as: single project cost, discount rate, etc., are the factors that mainly affect the cost of carbon emission.

When new products, new technologies and new specifications appear, the relevant impact factors should be iteratively upgraded and managed. Generally speaking, it is necessary to iterate the cost of products in 3~5 years, iterate the innovative application of technology in 5~10 years, and iterate the parameters such as emission reduction factors and discount rates every year. The project database needs to be supplemented and increased in a timely manner so that the cost data can be iterated in a timely manner and the latest parameter data can be obtained to further improve the accuracy of abatement costs and provide a reliable basis for making decisions on abatement strategies.

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