# EVALUATION STUDY ON ENERGY CONSUMPTION AND CARBON DIOXIDE EMISSIONS IN JIANGSU PROVINCE

BY

MA YANING

A dissertation submitted in fulfilment of the requirement for the degree of Master of Science (Asset and Facilities Management)

Kulliyyah of Architecture and Environmental Design
International Islamic University Malaysia

FEBRUARY 2021

# ABSTRACT

This research divides the building life cycle into five stages: building materials production, building materials transportation, construction, operation and use, and demolition. At the same time, this study collected data from 262 cases of buildings under construction and completed in Zhejiang Province, established a database of building life cycle energy consumption and CO2 emissions inventory in Jiangsu Province, and finally evaluated the system framework to discuss the energy consumption and CO2 of different types of buildings at different stages. Emission characteristics. The main contents are as follows: 1. Establish a material emission inventory for each stage of the construction life cycle in Jiangsu Province Review the previous research and sort out the emissions of 27 main materials (basic inventory data of energy consumption and emissions in the five stages of building materials production, building materials transportation, construction, operation and use, and demolition and disposal) on this basis. 2. Analyze the characteristics of building energy consumption and CO2 emissions in Jiangsu Province Collected lists of 44 building materials used in Nanjing and used energy consumption lists of 262 residential buildings. Through data analysis, we can understand the energy consumption and CO2 emission characteristics of different types of buildings at different stages. 3. Establish an evaluation system for LCA energy consumption and CO2 emissions in Jiangsu Province Based on the summary of the material emission inventory and the emission characteristics of buildings in Jiangsu Province, this study established an LCA evaluation system framework suitable for buildings in Jiangsu Province, and gave calculation methods with different accuracy according to the level of detail of different inventory data. Finally, this research selects Chenggong Middle School as a case for method practice.

# خلاصة البحث

يقسم هذا البحث دورة حياة المبنى إلى خمس مراحل: إنتاج مواد البناء ، ونقل مواد البناء ، والتشييد ، والتشغيل والاستخدام ، والهدم. في الوقت نفسه ، جمعت هذه الدراسة بيانات من 262 حالة من المباني قيد الإنشاء واكتملت في مقاطعة تشجيانغ ، وأنشأت قاعدة بيانات لاستهلاك الطاقة لدورة حياة المبنى وجرد انبعاثات ثاني أكسيد الكربون في مقاطعة جيانغسو ، وقامت أخيرًا بتقييم إطار عمل النظام لمناقشة استهلاك الطاقة وثاني أكسيد الكربون لأنواع مختلفة من المباني في مراحل مختلفة. خصائص الانبعاث. المحتويات الرئيسية هي كما يلي: 1. إنشاء جرد انبعاثات المواد لكل مرحلة من دورة حياة البناء في مقاطعة جيانغسو مراجعة البحث السابق ، وفرز انبعاثات 27 مادة رئيسية (بيانات الجرد الأساسية لاستهلاك الطاقة والانبعاثات في المراحل الخمس لإنتاج مواد البناء ونقل مواد البناء والتشييد والتشغيل والاستخدام والهدم والتخلص) على هذا الأساس . 2. تحليل خصائص بناء استهلاك الطاقة وانبعاثات ثاني أكسيد الكربون في مقاطعة جيانغسو قوائم مجمعة من 44 مادة بناء مستخدمة في نانجينغ وقوائم استهلاك الطاقة المستخدمة لـ 262 مبنى سكني. من خلال تحليل البيانات ، يمكننا فهم استهلاك الطاقة وخصائص انبعاثات ثاني أكسيد الكربون لأنواع مختلفة من المباني في مراحل مختلفة. 3. إنشاء نظام تقييم لاستهلاك الطاقة LCA وانبعاثات ثاني أكسيد الكربون في مقاطعة جيانغسو استنادًا إلى ملخص جرد انبعاثات المواد وخصائص الانبعاث للمباني في مقاطعة جيانغسو ، أنشأت هذه الدراسة إطارًا لنظام تقييم LCA مناسبًا للمباني في مقاطعة جيانغسو ، وأعطت طرق حساب بدقة مختلفة وفقًا لمستوى تفاصيل المخزون المختلفة البيانات. أخيرًا ، حدد هذا البحث مدرسة مدرسة Chenggong المتوسطة كحالة لممارسة الأسلوب.

# APPROVAL PAGE

I certify that I have supervised and read this study and that in my opinion, it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Master of Science (Asset and Facilities Management).

…………………………………..
Khairusy Syakirin Has-Yun Hashim
Supervisor

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Master of Science (Asset and Facilities Management).

…………………………………..
Mohd Sharifuddin Ibrahim
Examiner

This dissertation was submitted to the Department of Quantity Surveying and is accepted as a fulfillment of the requirement for the degree of Master of Science (Asset and Facilities Management).

…………………………………..
Azrin Mohd Din
Head, Department of Quantity Surveying

This dissertation was submitted to the Kulliyyah of Architecture and Environmental Design and is accepted as a fulfillment of the requirement for the degree of Master of Science (Asset and Facilities Management).

…………………………………..
Abdul Razak Sapian
Dean, Kulliyyah of Architecture and Environmental Design

# DECLARATION

I hereby declare that this dissertation is the result of my own investigations, except where otherwise stated. I also declare that it has not been previously or concurrently submitted as a whole for any other degrees at IIUM or other institutions.

Ma Yaning

Signature ........................................................... Date .........................................

## INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA

## DECLARATION OF COPYRIGHT AND AFFIRMATION OF FAIR USE OF UNPUBLISHED RESEARCH

## EVALUATION STUDY ON ENERGY CONSUMPTION AND CARBON DIOXIDE EMISSIONS IN JIANGSU PROVINCE

I declare that the copyright holders of this dissertation are jointly owned by the student and IIUM.

Copyright © 2021 Ma Yaning and International Islamic University Malaysia. All rights reserved.

No part of this unpublished research may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording or otherwise without prior written permission of the copyright holder except as provided below

1. Any material contained in or derived from this unpublished research may only be used by others in their writing with due acknowledgement.

2. IIUM or its library will have the right to make and transmit copies (print or electronic) for institutional and academic purposes.

3. The IIUM library will have the right to make, store in a retrieved system and supply copies of this unpublished research if requested by other universities and research libraries.

By signing this form, I acknowledged that I have read and understand the IIUM Intellectual Property Right and Commercialization policy.

Affirmed by Ma Yaning

……..……………………..        ………………………..
Signature        Date

*This dissertation is dedicated to my dear parents*

ACKNOWLEDGEMENTS

First and for most, I would like to offer my sincere gratitude to Almighty Allah for his grace and mercy that has seen me through the process of this master's program.

Secondly, a special thanks goes to my supervisor Asst. Prof. Dr. Khairusy Syakirin Has-Yun Hashim for his continuous support, encouragement, and leadership, and for that, I will be forever grateful.

Last and but not the least, I would also like to dedicate this work to my dear parents, who granted me the gift of their patience and constant encourage as well as support to accomplish this work. Besides that, I would also like to express my appreciation and thanks to those who provided their time, effort and support for my research work.

# TABLE OF CONTENTS

# LIST OF TABLES

# LIST OF FIGURES

# LIST OF ABBREVIATIONS

| | |
|---|---|
| $CO_2$ | Carbon dioxide |
| GDP | Gross Domestic Product |
| LCA | Life Cycle Assessment |

# CHAPTER ONE

# INTRODUCTION

## 1.1 RESEARCH BACKGROUND

China is relatively rich in total energy resources and has relatively rich fossil energy resources. Among them, coal occupies a leading position. However, China's per capital energy resources are relatively low, coal and hydro-power resources are equivalent to 50% of the world average, and oil and gas resources are only about 1/15 of the world average. In addition, China's energy resources are unevenly distributed (Dong Huizhong, 2015). Large-scale, long-distance north-to-south coal transportation, north-to-oil transportation, west-to-east gas transmission, and west-to-east power transmission are the distinctive characteristics of China's energy flow and the basic pattern of energy transportation (Shen Yongping, Wang Guoya, 2015). Furthermore, China's energy resources development is more difficult.

### 1.1.1 Current Status of China's Energy Consumption and $CO_2$ Emissions

China's energy situation is tense, but its energy consumption is among the highest in the world. At present, China has become the world's second largest energy consumer, with total energy consumption accounting for 11% of the world's total energy consumption. Energy consumption is mainly domestic supply and the energy self-sufficiency rate is 94% (Dong Huizhong, 2015). From the perspective of energy efficiency, from 1980 to 2015, China's energy consumption per unit of GDP continued to decline, from 4.02 tons of standard coal per 10,000 yuan GDP in 1980 to 1.43 tons of standard coal per 10,000 yuan GDP. but this level was still far behind the world average. In 2015, the world's energy consumption intensity was 2.5 tons of oil equivalent per 10,000 US dollars of GDP, China was 8.77 tons of oil equivalent per 10,000 US dollars of GDP, 3.5 times the world average, 4.7 times the United States, and 6.8 times France Times, Germany's 7.3 times. It can be seen that saving energy and improving energy efficiency are the necessary development directions of China (Weimin Wang, Hugues Rivard, 2017).

The massive development and utilization of energy is one of the main causes of environmental pollution and climate change. China is a developing country in the early stages of industrialization, and its cumulative emissions are low. From 1950 to 2015, China's fossil fuel $CO_2$ emissions accounted for only 9.3% of world emissions over the same period, and per capita carbon dioxide emissions ranked 92nd in the world (Dong Huizhong, 2015).

However, China is a developing country, and its total emissions are still considerable. Therefore, comprehensive control of greenhouse gas emissions has always been one of China's development guidelines (Shen Yongping, Wang Guoya. 2015). Actively play the role of energy conservation and optimization of energy structure in mitigating climate change, and strive to reduce fossil energy consumption, improve energy efficiency, and reduce greenhouse gas emissions.

### 1.1.2 Building Energy Consumption and $CO_2$ Emissions

The destruction of the environment by the construction industry is beyond imagination. According to estimation by the European Institute of Architects, global construction-related industries consume 50% of the earth's energy, 50% of water resources, 40% of raw materials, and 80% of agricultural land losses, while producing 50% of air pollution, 42% Greenhouse gases, 50% water pollution, 48% solid waste, and 50% fluorochloro compounds (Weimin Wang, Hugues Rivard, 2017), it can be said that the construction industry is one of the protagonists of the global environmental crisis.

According to the study of the United Nations Intergovernmental Panel on Climate Change IPGC, in industrialized countries, buildings consume 40% of society’s energy consumption and produce 36% of $CO_2$ gas related to energy use; research by the US Energy Information Data Research Institute shows that the construction industry consumes 30.8% of the world’s total energy; in the European Union and the United States (Weimin Wang, Hugues Rivard, 2017), building energy consumption even exceeds industrial manufacturing and transportation energy consumption.

In the past, the efficiency of the construction industry was low (Song Hailin, 2013). Sometimes, the energy consumption density of buildings of the same size can differ by several or even tens of times. It shows that building energy saving has great potential, and it is incomparable with the energy saving efficiency of machinery, combustion, vehicles and other industries, because the energy consumption efficiency of other industries has reached the limit. It is very difficult to continue to save energy by 30% -40%. But if the building energy-saving design is good, it can easily achieve 50% to 60% energy saving effect (Song Hailin, 2013).

The construction industry also bears a considerable proportion of CO2 gas emissions that have a direct impact on global warming. The current CO2 emissions from construction in various countries account for 38% of the country’s total emissions; the United States is approximately 38% (2018); Canada is approximately 30% (2018), Japan is approximately 36% (2018), and Taiwan is approximately 28.8% (2018), mainland China is about 30.0% (Dong Huizhong, 2015). Therefore, it can be inferred that the implementation of energy-saving emission reduction in buildings not only relieves the crisis of energy exhaustion, but also has a huge effect on reducing greenhouse gas emissions.

## 1.2 STATEMENT OF PROBLEM

### 1.2.1 China’s Urban Construction and Building Development

From the perspective of the entire life cycle of a building, the first link is the building material production industry (Tang Min, Zhang Pengwei, Bian Chunlin, 2016), which is one of the industries that consumes the most natural resources and energy resources, destroys the land the most. And building material production industry has the most serious air pollution, and it is dependent on non-renewable resources. In very high industries, most of the raw materials for construction materials come from non-renewable natural mineral raw materials, and some come from industrial waste. Currently, China consumes 40%, 45% and 35% of the world's annual consumption of cement (Dong Huizhong, 2015)., glass and steel respectively due to construction. The energy used for production and construction of building materials accounts for 25% of the national energy consumption.

In the operational stage of buildings, China's current urban buildings consume 23% to 26% of the country's energy (Chen Fei, 2011). As the degree of urbanization continues to increase, the proportion of tertiary industry as a percentage of GDP and the adjustment of manufacturing structure, this part of construction energy consumption will continue to increase, and eventually approach the level of developed countries, reaching one-third of China's total domestic energy consumption. In addition, due to the poor thermal insulation performance of China's building envelopes and the low energy efficiency of air conditioners and other equipment, operating energy consumption is significantly wasted compared to developed countries, exacerbating energy tension (Dou Zhi, Zhao Min, 2011).

During the demolition and abandonment of buildings, the current recycling rate of abandoned building materials is extremely low. How to deal with and discharge construction waste has become a difficult problem that China's construction industry must face for sustainable development. Over 10 billion square meters, according to the standard of 500-600 tons of construction waste generated per 10,000 square meters of construction, at least 500 million tons of construction waste have been generated (Dou Zhi, Zhao Min, 2011).. Most of these construction wastes are treated by landfill. This method not only consumes a large amount of land expropriated, causing serious environmental pollution, but also wasting resources. It is estimated that from 2007 to 2020, China will also add about 30 billion square meters of new construction area, which will generate at least 1.5 billion tons of construction waste (Song Hailin, 2013).

In summary, China ’s urban construction and building development are extensive and inefficient, and to some extent at the cost of the health and safety of natural systems, this development model is facing energy consumption, resource consumption and the environment three challenges of pollution.

At present, governments at all levels of the central government vigorously promote building energy conservation and develop green buildings. The concept of green building is to save resources to the maximum extent (energy saving, land saving, water saving, material saving), protect the environment and reduce pollution, and provide people with healthy, suitable and efficient use of space during the entire life cycle of the building (Dong Huizhong, 2015). A building that lives in harmony with nature. To develop green buildings, the whole life cycle perspective is one of the principles that must be adhered to.

### 1.2.2 The gap of research

Life Cycle Assessment (LCA) is a new type of environmental impact assessment technology and method system. It is a quantitative assessment method for resource consumption and environmental impact issues involved in the entire construction process. Specifically, LCA is a quantitative analysis of the environmental load from the various stages of raw material mining and acquisition, processing and preparation, operation and use to waste dismantling.

At present, China's research on building energy efficiency is mainly focused on the building operation stage, that is, building energy consumption and emissions in a narrow sense. In the national standard guidelines such as green building evaluation standards, the energy consumption of air conditioning, heating, and lighting is also considered. It is true that the building has a long-life cycle, and the energy consumption in the operation stage accounts for the largest proportion in the entire life cycle (Dong Huizhong, 2015). However, throughout the life cycle, the energy consumption and emissions of the construction material production, transportation, and construction process are also parts that cannot be ignored. The evaluation of green building materials and green construction is also very important. There are now pseudo-green buildings known as "green buildings". Through high-energy-consuming technology investment, for example, large-area photovoltaic panels, smart shading systems, wind power generation and other advanced technologies are cold-squashed in a building to achieve zero energy consumption (Shen Yongping, Wang Guoya, 2015). It is the transfer of huge energy consumption and pollution to the early construction parts and construction stage. Therefore, it is of great significance to comprehensively study the energy consumption and emissions of each stage of the building from the full life cycle of the building.

### 1.2.3 Statement of Jiangsu Province

Jiangsu Province is an economic province with few resources and lack of energy. According to the China Statistical Yearbook, the province’s GDP in 2018 was 228.2 billion yuan, an increase of 8.9% over the previous year, and the added value of the construction industry for the whole year was 138.6 billion yuan, over the previous year. an increase of 15.3% (Weimin Wang, Hugues Rivard, 2017). In 2018, Jiangsu Province's housing construction area was 374 million square meters, ranking seventh in the country, and housing construction completed area was 926 million square meters, ranking ninth in the country. The contradiction between development and environment facing Jiangsu Province is particularly prominent.

In recent years, with the economic growth of Jiangsu Province, heating and cooling equipment to regulate indoor temperature and humidity has also begun to increase. Energy consumption thus rises sharply during the operation stage of buildings, which will affect social and economic development (Dong Huizhong, 2015).

According to the actual situation, the "Standards for Energy-Saving Design of Residential Buildings" has established prescribed indicators, and requires that building thermal engineering, HVAC, electrical, water supply and drainage of residential buildings in Jiangsu Province must adopt energy-saving measures, on the premise of ensuring indoor thermal environment Next, further reduce building energy consumption, so that the total energy consumption of newly built, renovated and expanded residential buildings this year will be reduced by 50% compared with residential buildings that have not taken energy saving measures.

The “Public Building Energy-Saving Design Standards” divide public buildings into three categories according to scale, and stipulate that the total annual heating, ventilation, air conditioning, and lighting energy of public buildings in the province should be reduced by 50% compared with no energy saving measures.

As an economic center, Jiangsu Province is ranked at the forefront of building energy-saving work in the country, and the set standard is slightly higher than the national unified standard. However, the current energy-saving design standards are based on the insulation and thermal insulation performance of building envelopes. The window-to-wall ratio, body shape coefficient, and energy efficiency ratio of heating, ventilation, air-conditioning and other equipment systems are specified. For a building that does not meet the standards, in order to relax the constraints on architectural design creativity, dynamic energy calculation can be weighed as required. Compared with the buildings designed and built in the early 1980s (J S Cooper, James A Fava, 2008), if it is less than its energy consumption, it is considered to be up to standard. In other words, the standard only stipulates the upper limit of energy consumption in the operation stage of the building, and does not give energy consumption requirements in other stages of the building life cycle. This will easily lead to some buildings meeting the standard requirements or even the so-called "high energy saving rate", Using some excellent thermal performance envelope materials and advanced heating and cooling equipment, thereby ignoring the energy consumed by its early investment.

It is undeniable that the energy consumption and $CO_2$ emissions of most buildings in the operation stage account for 60% to 80% of the entire life cycle. However, with the pursuit of energy efficiency, the use of some high-end technologies has reduced At the same time, it also increases the proportion of energy consumption $CO_2$ emissions in other stages of the life cycle (Shen Yongping, Wang Guoya, 2015)..

Taking the building material production stage as an example, according to Lin Xiande's research, the carbon dioxide emissions of building materials used in middlerise residential buildings are about 300kg/$m^2$. Based on 116$m^2$ per household, the $CO_2$ emissions per household are approximately 34000kg, which are equivalent It takes 40 years of photosynthesis in a tree to be absorbed (Shen Yongping, Wang Guoya, 2015). That is to say, every household on the earth must continue to plant an arbor in order to balance the destruction of residential buildings on the earth's climate.

In addition, the construction materials production and transportation, building construction, building demolition and other fortifications are very regional, and different process levels and construction methods cause large differences in energy consumption and emissions. In view of the uneven distribution of energy in China and the uneven economic development in different regions, Jiangsu Province, a city with a large population and a highly developed economy, urgently needs to have its own basic database to evaluate the real energy consumption and CO2 emissions of buildings.

At present, Jiangsu Province does not have its own basic database on the environmental impact of the building life cycle, which has caused great difficulties for current and future research on green building energy conservation and emission reduction. The aim of this research is to establish a relatively complete basic database, we can quantitatively understand the energy consumption and environmental pollution levels of Jiangsu Province's building materials production, building material transportation, building construction, building use, building demolition and other stages, which will find suitable energy saving and emission reduction.