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The Economic Efficiency Of Market-Based Green Building Policy Instruments In China

A case study of the Chenghuaxinyuan Housing Scheme in Shanghai

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Abstract

In order to curb emissions and resulting environmental problems caused by the rapidly growing energy use of its building sector, China has implemented a number of policy instruments to promote Green Building practices, including market-based instruments for energy efficiency in buildings. This thesis aims to evaluate the economic efficiency of these policy measures, using the Four-High Award of Shanghai and its application and impact on the Chenghuaxinyuan housing scheme as a case study.

A cost-benefit analysis (CBA) was performed on the case to assess its economic efficiency from society's perspective, complemented by a cost-revenue analysis from the residents' and the developers' perspective, respectively. Conservative estimates were used for all variables. All three analyses were subjected to sensitivity analyses. Data was collected from peer-reviewed literature, and interviews conducted with building market stakeholders in Shanghai.

Results suggest that the Green Building policy measures as such are not economically efficient: costs outweigh benefits. Higher electricity prices combined with tougher energy standards could change this. However, the price premium represents an added value for which some customers are willing to pay, which explains why the project was realised, and why it is in fact benefial to society as well as developer: the residents pay many times over for the developer's incremental investment, which in turn generates socio-environmental benefits to society.

To residents, the incremental investment for living in a Green Building does not pay off in pure economic terms. Environmental and status regards appear more important than price to customers in this market segment. To the developer, however, results suggest that Green Buildings are very profitable, thanks to the vast price premium paid by customers.

Interviews indicate that financial policy incentives are only a minor driver behind developers' Green Building decisions. Good relations to government, and branding, are the two critical aspects driving Green Building in Shanghai.

Keywords: Economic Efficiency, Green Building Policy, Market-based policy instruments, China

Executive Summary

China's steadily increasing greenhouse gas emissions are intimately linked with the growing energy need of the Chinese economy. While national energy use grew from 47 exajoules in 2002 to 90 exajoules in 2009, annual CO_2 emissions grew from 1454.65 Mtons in 1980 to 7706.83 Mtons in 2009, with most of the increase occurring after 2002. China is now the biggest carbon emitter in the world, producing a quarter of all energy related CO_2 emissions globally in 2010. The building sector is a major energy user. In 2010, it accounted for 30% of China's total energy consumption. Thus energy efficiency in buildings is one key factor to curbing China's contribution to global warming.

The Chinese government has taken a number of policy measures to promote Green Building practices, including financial incentives for energy efficiency in buildings. Ex-post evalutation is key to any policy-making process, and while policy expectations are high on what Green Building can do for the economy, health, environment and climate, there has been little evaluation and few empirical studies of the actual impacts of the new Chinese Green Building economic incentives.

To address this knowledge gap, this thesis examines the economic efficiency of Chinese Green Building being driven by market-based instruments, using the Four-High Community Award of Shanghai and its application and impact on the Chenghuaxinyuan housing scheme as a case study. Chenghuaxinyuan was built by the leading real-estate developer company Vanke, with some ambitious Green Building features such as solar water heaters, green roofs, low-emission insulating glass windows and exterior walls with a better-than-average U-value. It achieved a 3-star rating in the Chinese Green Building Label system. The Four-High Award is granted by city of Shanghai to housing projects that represent planning with a high ambition starting point, high design level, high quality construction, and high-level management. It was granted to Chenghuaxinyuan in 2011.

Data availability was critical for the choice of case study policy and project. Data collection methods included a critical literature review of scientific journal papers, and semistructured interviews conducted on site in Shanghai with relevant stakeholders (e.g. architects, engineers, consultants and academics).

The main method for data analysis was a Cost-Benefit Analysis (CBA), which is the operational and pragmatic form to approach 'Potential Pareto Improvements'. Investment, administration and transaction costs were estimated and compared to economic, environmental and social benefits generated. In addition, a Cost-Revenue Analysis was performed to investigate the financial feasibility of the Green Building measures from the developer's and the residents' point of view respectively. Indicators produced by the analysis were net present value, internal rate of return, benefit-cost ratio and payback period. Different discount rates were used. Each analysis was subjected to a sensitivity analysis, modifying key variables to determine their influence on the result, thereby getting an approximation of the degree of uncertainty of the overall outcome.

The main findings of this research can be summarised as follows. CBA results are highly dependent on a number of key assumptions and choices, data quality and availability and resulting estimates. The most critical aspects are the estimation of energy savings achieved and the estimation of external socio-environmental benefits. Conservative estimates were used for all variables. With a "base case" set of conservative assumptions, the benefit-cost ratio of the Four-High Award for Chenghuaxinyuan and the Green Building measures it is promoting is 0,71; the internal rate of return is 3,1%, and the net present value is -24,97 million yuan. With

these results, the measures must be considered economically inefficient from society's point of view: socio-environmental benefits are outweighed by incremental investment costs.

However, as long as the costs are instead covered by the price premium paid by customers, the Green Building measures are still economically viable, which is why a "neutral" CBA approach disreagarding the price premium paid by customers and pointing to a loss to society is somewhat misleading. In reality no party really loses. The expenses of the government are by far recouped by the socio-environmental benefits, the while the developer's incremental costs is covered many times over by the price premium, which in turn represents an added value, i.e. a benefit in the form of sustainable, high-status living for which customers in a certain market segment are willing to pay. Having said that, it is still a main finding that with current policy design, socio-environmental benefits do not outweigh costs by themselves.

The sensitivity analysis confirms the high dependency on the key assumptions mentioned above, especially the estimation of externalities and the discount rate, indicating an overall midrange uncertainty of the results. Most importantly it indicates that a rise in electricity price or greater energy savings, or a combination of those, could change the outcome into an economically beneficial one from society's point of view.

The cost-revenue analysis indicates a very poor deal from the residents' perspective, financially speaking. The internal rate of return for the residents "investment in Green living" is -14,6%, and the net present value is -6137,6 yuan/m^2. Payback time never occurs. This points to other factors, such as environmental and status regards, as being more important than price to real-estate customers in this market segment. To the developer, the extra investment for producing a Green Building is extremely profitable thanks to the vast price premium paid by customers. The internal rate of is return of 2361,8% and the net present value over 1,9 billion yuan.

Interview findings indicate that fiscal policy incentives such as subsidies and awards are less important factors when Chinese real-estate developers consider Green Building. The desire and need for good relations to local government appears to be much more important. Another major driver is branding regards: major real-estate developers want to claim leadership in Sustainable Architecture to the market.

To improve the efficiency of Green Building policy, tougher building codes, higher energy performance standards, reduced energy price distortions (including the internalization of negative externalities and subsidy removal) are recommended. The Four High Community Award as a policy instrument itself could be sharpened by setting specific maximum energy use caps for buildings eligible for the Award.

Serving as a signal of the government's intentions and a financial incentive for improvement, the Award potentially spurs and inpires energy savings in projects across the market. If those energy savings were estimated and taken into account, the Award might in fact turn out to be very cost-effective, as a way to influence all developers by rewarding one. A more extensive and complex CBA might determine this. Hence further research is suggested on the economic efficiency of a single award considering its marked-wide influence in the analysis. Further research is also recommended to obtain higher quality input data (including co-benefits of increased energy efficiency), which would enable a more detailed and reliable analysis of the economic efficiency of market-based Green Building instruments.

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Abbreviations

ADB	African Development Bank
CBA	Cost-Benefit Analysis
CRA	Cost-Revenue Analysis
CGBL	China Green Building Label
FYP	Five-Year Plan
GB	Green Building
GW	Giga-Watt
IRR	Internal Rate of Return
kWh/m^2a	kilowatt-hours per square meter and year
LEED	Leadership in Energy and Environmental Design
MBI	Market-Based Instrument
MOHURD	Ministry of Housing and Urban and Rural Development
MWh	Mega-Watt hours
NDRC	National Development and Reform Commission
NPV	Net Present Value
OAT	On-At-A-Time (sensitivity analysis)
PRC	the People's Republic of China

1 Introduction

China's steadily increasing greenhouse gas emissions are intimately linked with the growing energy need of the Chinese economy, where the building sector is a major energy user. In order to cope with the accelerating stress on climate, nature, society and human health caused by the energy consumption of the building sector, China has taken a number of policy measures to promote Green Building practices, including financial incentives for energy efficiency in buildings. This paper examines the economic efficiency of those measures. The question is, simply put: if government pays companies to build energy efficient buildings, how much energy and cost savings does society get for the money? Does it pay off?

1.1 Background: growth, energy, climate, buildings and policy

China's economy has expanded rapidly ever since the early 1990s, with double-digit growth rates some of the years, particularly between 2003 and 2007. As a result of this booming economic activity – production and consumption - national energy use has seen an unprecedented increase – almost doubling in the seven years from 2002 to 2009, from 47 to 90 exajoules. (Kahrl, Roland-Holst, & Zilberman, 2013). As China's energy sector is heavily coal-power based, this in turn has led to a steep rise in CO_2 emissions. Annual CO_2 emissions grew from 1454.65 Mtons in 1980 to 7706.83 Mtons in 2009, with most of the increase occurring after 2002 (X. Liu, 2012, p. 2). China is now the biggest carbon emitter in the world, producing a quarter of all energy related CO_2 emissions globally in 2010 (Lu, Stegman, & Cai, n.d.).

In 2010, the building sector accounted for 30% of China's total energy consumption (Y. Liu, 2012). As urbanisation continues, hundreds of millions of people move from simple, low-comfort countryside homes with negligible energy consumption to modern high-comfort urban dwellings with high demand for heating, cooling and appliances powering energy. Current floor area growth rate in China is around one billion m^2 per year, predominantly added in urban areas where per capita energy use is 3,5 times higher than in the countryside (Y. Liu, 2012). Again, from a global climate perspective, this rise in building related energy demand and the resulting increase in coal-fired power production is a critical problem. Thus energy efficiency in buildings is one key factor to curbing China's contribution to global warming.

China's government is increasingly recognising and reacting to this challenge. The new energy plan of the National Development and Reform Commission (NDRC), the top authority in energy matters, specifies energy efficiency targets for the building sector among others, a decision that has repercussions in the policies of other authorities down the political line of command. According to the 12th Five-Year Plan for Energy Development, released on January 1 2013, the overall energy efficiency of the economy should increase by 38% to 2015 compared to 2010 levels ("China Releases 12th Five-Year Plan for Energy Development," 2013). For the building sector this ambition is reflected in policy measures on the different administrative levels to promote Green Building practices, i.e. construction of energy efficient new buildings and energy efficiency improvement measures in existing ones. On the national level, the goal is that 30% of all new buildings built between 2012 and 2020 be Green Buildings (Lu-Hill & Chen, 2013).

Many policy measures addressing building resource efficiency were introduced long before the Green Building concept was known in China. In 1986 a "mandatory energy-saving rate" for new buildings was established: 30% compared to a baseline level, which was in turn based on the energy demand of a typical residential building in the cold-winter-hot-summer climate zone in 1980-1981. The rate has been gradually raised and is now 65% in Shanghai and

Beijing. This is a design standard, i.e. it applies to the pre-construction design of the building rather than the actual built result – there is no follow-up on whether the energy savings intended by design are actually achieved. (W. l. Lee & Chen, 2008)(Y. Liu, 2012)(Cai, 2010).

Since then a host of policy measures of different types has been introduced on various levels, see table 2-1 below. A number of Green Building policy measures have also been introduced and then withdrawn again. The tax reduction on fixed asset investment in Green Building property is one example (Fan, Zhu, & Wang, 2013, p. 811). Environmental policy reversal ocurred chiefly in the late ninetees due to concerns that such policy might restrain economic growth (Qian, Chan, & Xu, 2011, p. 5).

The China Green Building Label (CGBL, a.k.a. 3Star), listed under Informative Instruments in table 2-1, is a voluntary Green Building certification system, the second biggest one in China, the biggest being the American LEED label. CGBL was introduced by the Ministry of Housing and Urban and Rural Development (MOHURD) in 2006 in order to establish a voluntary domestic evaluation standard tailored for Chinese conditions. In Green Building certification systems, buildings are assessed and awarded credits for their performance in aspects such as energy efficiency, sustainable materials, site/land use, etc., resulting in an overall rating for the project, e.g. Silver, Gold or Platinum in LEED, or one, two or three stars in CGBL (Voynas, 2013). According to the Chinese website Green Building Map ("China green building - green building map - gbmap.org," n.d.), there were 1995 buildings in China certified to either CGBL, LEED or other labels on August 16, 2013. Already by 2014 all new state-owned low-income residential buildings *must* be certified to the Chinese Green Building Label (Lu-Hill & Chen, 2013).

However, it is the market-based instruments, MBIs, also known as fiscal instruments or financial incentives, that are the subject of this thesis. Market-based policy instruments typically use market mechanisms such as demand and supply, pricing, etc. to create economic incentives for companies to behave in a certain way, e.g. more environmentally responsibly, in difference to regulatory ("command-and-control") instruments, which simply demand a certain conduct by companies. When MBIs work as intended, they drive market actors to accomplish the result desired by society in the most cost-efficient way. Tradable permits and certificates, subsidies and taxes are all used in various MBIs. (Kete, 1994)(Stavins, 2003).

1.2 Problem definition

The Chinese government has high expectations on Green Buildings; for saving energy, reducing CO_2 emissions, improving indoor comfort and air quality, stimulating the domestic clean-tech industry, among other things. The policy instruments presented in section 2.3 represent a concerted effort on behalf of the government to promote Green Building practices in China, many of them being part of the "Green Economic Stimulus Packages" of the last two Five Year Plans.

Ex-post evalutation is key to any policy-making process. In order to point out, diagnose and analyse problems and challenges in the performance of a policy, and suggest improvements in its design so as to work better, a systematic outsider assessment employing academic research methods to attain the highest possible objectivity is indispensable. Without proper ex-post evaluation, there is the risk of a policy doing more harm than good, and continuing to do so.

For MBIs, economic efficiency is of particular interest, as a proxy for how well they are working and what value society gets for its money spent. There has been little evaluation and few empirical studies of the actual impacts of the new Chinese Green Building economic incentives and MBIs (Fan et al., 2013, p. 7), and more research is needed (Qian & Chan, 2009, p. 19)(Qian et al., 2011, p. 14).

Despite an extensive scholar literature search, no peer-reviewed papers on this specific problem in the Chinese Green Building context were found. Dhakal (2009) does an in-depth examination of the energy and carbon aspects of big cities and urbanisation in China, looking into policy options, but not their economic efficiency. L. Li et al. (2010) make a projection of the future emissions of Shanghai based on current and planned energy policies, estimating their effectiveness, but not their economic efficiency. Jia Li et al. (2004) model the health benefits of curbing air pollution in Shanghai and perform cost-benefit analysis on the economic efficiency of pollution abatement strategies, but the focus is on industry and power production sources rather Green Building. Price et al. (2011) conduct a broad assessment of the performance of chosen programmes across the entire national array of energy-saving policies in China, pointing at progresses and challenges, but without calculating their economic efficiency. D. Liu, Wang, Zhou, & Zhang (1997) investigate the cost-effectiveness of demand-side management of energy use in Shanghai, performing a cost-benefit analysis, but not on Green Building policies. Gielen & Changhong (2001) look into the benefits of emission reduction, assessing fiscal policy instruments, but not Green Building related ones. Zhong et al. (2009) present an interesting mathematical model for the feasibility of government financial support to energy effiecency retrofit projects in northern China as a function of the relationship between energy price, social and environmental externalities, and government- and company-borne project cost respectively, but it is a theoretical ex-ante model and does not produce a benefit-cost ratio of an actual policy measure (Zhong, Cai, Wu, & Ren, 2009).

The interviews and literature review (see section 2.1) also yielded very little specific information on MBI related support to building projects for energy-saving measures, or estimations of amounts of energy saved. This further reinforced the justification for the research itself. The only project-specific data of that kind was found in the MSc. thesis "Green Building development in China - a policy-oriented research with a case study of Shanghai" by Yujun Liu (Y. Liu, 2012). Hence that paper is the primary source of numeric data for the cost-benefit analysis, supplemented with additional data from other sources, including some presentations on the same building project, and assumptions based on or deducted from interview findings and literature review findings.

Hence it is concluded that there is a knowledge gap regarding the economic efficiency of Green Building MBIs in China, due to a lack of ex-post evaluation studies.

1.3 Research objective and research questions

The objective of this thesis is to assess the economic perfomance of Chinese market-based Green Building policy instruments from a societal cost-benefit point of view, by conducting an economic efficiency analysis, using a specific policy applied on a specific project as a case study. Policy programme costs, such as administration, regulation, investment and transaction costs, will be identified/estimated and compared to the resulting economic, environmental and social benefits, both private and public. The study also aims to investigate the financial implications of the policy for building energy end-users, i.e. residents, and building producers, i.e. real-estate developers.

To that end, the study takes the "Four high Community Award" building intiative in Shanghai, and its application in the Chenghuaxinyuan housing project, as a case study. See section 2.3 for details.

The research questions of the study are:

- What is the economic efficiency of the Four High Community Award as a market-based policy instrument for Green Buildings in Shanghai?

- What are the financial net benefits (if any) for end-users (residents)?

- What are the financial net benefits (if any) for real-estate developers?

1.4 Scope and limitations

The topic of the thesis is the economic efficiency of market-based instruments addressing building energy efficiency, and their investment risk implications. This is further scoped down to focus on one specific instrument. The scope is as follows:

- Geographic: China/Shanghai
- Sector: Residential
- Policy instrument: Four High Community Award (Green Building financial incentive)
- Technology: Energy Efficiency
- Project: Chenghuaxinyuan housing scheme by Vanke Ltd., Shanghai

A limitation to the research is the fact the author does not speak or read Chinese, while a lot of the literature on the subject and the vast majority of project/policy specific data available from companies and authorities is in Chinese. Moreover, given the importancce of *guanxí*, - interpersonal relationships or social contact networks – to many activities within Chinese society (Guo, 2001), the author's lack of said *guanxí* may further hamper attempts to establish contact with and gather data from companies and authories.

1.5 Target audience

The thesis is aimed at an audience that may be interested in Chinese Green Building policy efficiency, primarily:

- Chinese policy makers
- Housing companies
- Real estate developers
- Construction business
- Researchers in the field
- Green Building consultants

1.6 Thesis outline

Chapter 1, Introduction, presents the background of the study, elaborating on the relationship between economic growth, energy use, climate change, the building sector and Green Building policy. It also defines the research problem of the study, states research objective and research questions, defines the scope of thesis, mentions limitations, identifies the target audience and outlines the content of the paper.

Chapter 2, Research methodology and case study introduction, presents the methods used for data collection, and briefly explains the theory and practice of cost-benefit analysis, cost-revenue analysis, sensitivity analysis and discounting. It also gives a brief overview of Chinese and

Shanghai Green Building policy instruments, and then introduces the policy instrument and the project to be studied.

Chapter 3, Findings and analysis, presents and analyses the interview findings and the results of the cost-benefit analysis, the two cost-revenue analyses, and sensitivity analysis of all three.

Chapter 4, Discussion, reviews the reliability and the meaning of the results in a wider perspective, in turn discussing housing price premium and incremental cost, Green Building policies and drivers, and the uncertainty of the input data and the results.

Chapter 5, Conclusions, policy recommendations and further research, presents the conclusions drawn from the results, and proposes certain improvements to existing Green Building policies in China. It concludes by pointing out relevant scopes for further studies on the topic.

2 Research methodology and case study introduction

This chapter aims to lay the methodological foundations for this thesis. It presents the design of the research methodology, serving as a logical approach to get from 'research questions' to 'findings and conclusions'. It elaborates on the methods used for data collection and analysis. It also introduces the chosen Green Building policy to be assessed and the housing project used for the case study.

2.1 Methods for data collection

Data collection commenced with a critical *literature review* of scientific journal papers on the subject, searching for data on Chinese Green Building projects, in order to identify a study case project and relevant stakeholders. Lund University's eLibrary was searched for peer-reviewed journal articles on the costs and benefits of market-based policy instruments targeting building energy efficiency in China.

Semistructured interviews were conducted on site in Shanghai in July (15-19) 2013 with relevant stakeholders such as sustainable construction architects, engineers, consultants and academics. See Appendix I for the interview protocol employed. The purpose of the interviews was to gather data on specific projects where fiscal Green Building policy incentives had been applied and the energy savings achieved there, but also on the Green Building policy situation in general. After the field trip e-mail correspondence continued with some of the interviewees[1].

2.2 Methods for data analysis

2.2.1 Cost-Benefit Analysis

Cost-Benefit Analysis, CBA, is mathematic method designed to support decision-making processes, often applied in policymaking. When faced with market failures, such as environmental degradation due to economic activity, and considering its options for intervention, government may employ CBA in order to compare the costs of policy options with the benefits that they are expected to generate, to be able to decide which measure is likely to maximize the net benefits for the society as a whole (Boardman, Greenberg, Vining, & Weimer, 1998). CBA is the operational form to approach economic efficiency (i.e. Pareto improvements) (Tietenberg, 2006).

According to a number of authors, CBA is the approach normally applied in economic efficiency assessments (see e.g. Rossi (1999), Stavins (2004), and Tietenberg (2006). It is often considered a realistic approach to identifying whether an efficient outcome (or ´Potential Pareto Improvement), delivers the maximisation of social welfare (i.e. maximise the difference between total social benefits and costs). Note that there is a consensus in the literature about how ambitious and challenging—or sometimes impracticable—it is to perform a CBA in policy evaluation (Harrington, Morgenstern, & Sterner, 2004; Sterner, 2003; Tietenberg, 2006).

CBA has been criticised because of, for instance, it provides no accountability for distributional effects, it brings up the problematic practice of discounting, and it assumes that governments are social-profit maximisers. The technique also becomes controversial when specific monetary values are attached non-market impacts (Tietenberg, 1996).

For a policy measure or an investment to be feasible, benefits should outweigh costs. In an environmental policymaking context CBA, all costs and benefits that can be identified are

[1] Efforts were also made to reach policymakers, authorities and real-estate developers, in order to be able to interview them as

considered, public and private. Costs may be government expenses for e.g. subsidies, companies' investments or loss of revenues, increased living costs to citizens, transaction and administrative costs, etc. Benefits may be financial savings due to lower resource consumption, but usually also include the reduction of external social and environmental cost, so-called externalities, i.e. costs caused onto society by a certain market activity but not paid for by the market actors involved. Socio-environmental externalities are usually in themselves non-monetary, i.e. health problems, while they do bring monetary costs along as well, i.e. healthcare costs. In order to capture the significance of non-monetary externalities in a CBA, their monetary value is estimated using a valuation method of choice, e.g. the contingent valuation method, the hedonic pricing method, the travel cost method, or other. .

Based on the widely accepted idea in economics that it is generally preferred to have a given amount of money sooner rather than later, i.e. that it is attributed a higher value at present than in the future, costs and benefits that are projected to be incurred in the future are *discounted,* cut, by a certain percentage, *discount rate*. The discount rate reflects time preference, the subjective appraisal of how much more significant a present cost or benefit is to be regarded than one incurred e.g. in five years.

After discounting all projected future costs and benefits, they are added and subtracted respectively together with the initial costs of the project, yielding a *net present value* for the whole project. A policy measure CBA that yields a positive net present value, considering internal, external, monetary and (monetised) non-monetary costs, indicates that the policy measure is feasible from a societal-economic point of view.

Another output of CBA is *benefit-cost ratio*. This is simply the ratio between benefits and costs, i.e. the sum of discounted benefits divided by the sum of discounted and initial costs. A benefit-cost ratio above 1,0 indicates that the project or measure is feasible, while any ratio below that indicates the opposite.

The mathematical formulation of the CBA rule is defined as:

$$\sum_{t=0}^{T} (B_t - C_t \pm E_t) * (1 + d)^{-t} > 0$$

where the index t refers to time, B_t is the benefits taking place a time period t, C_t are the costs also at time period t, E_t refers to the value of the environmental change, and d is the discount rate. Both B and C are aggregated across society. The decision rule is that the sum of the benefits less costs plus or minus the value of environmental change must be positive; all discounted to present value.

If comparing multiple policy options, the one with the highest net present value, or benefit-cost ratio, is to be preferred.

A third output that can be calculated from the aggregate of costs and benefits, though strictly speaking not part of the CBA procedure as such, is the internal rate of return, IRR, i.e. the interest rate yielded by the investment in the project or policy measure. This is a more ambiguous figure that should not be used as the sole indicator of a project's feasibility.

In order to determine how sensitive the outcome is to changes in the input variables, and thereby to what extent each input variable influences the overall outcome, a *sensitivity analysis* should be performed. The sensitivity analysis ultimately gives an approximation of the reliability and uncertainty of the CBA results. There are a number of complex methods for this, but the most basic and commonly used is the One-At-a-Time (OAT) method, by which the CBA procedure is simply repeated number of times, each time changing the value of one of the input variables, while all other variables are kept at their original values. Any resulting changes in the output will then be due to that variable. The proportion between the change in the variable and the change in the output will reflect the significance of that variable for the overall result: the bigger the change in output per change in input, the more important the variable. This in turn indicates to what extent the certainty or data quality of the single variable affects the reliability of the CBA results. If the value of a variable is a mere assumption with a high degree of uncertainty, and that variable is found to have a major impact on the CBA result, then the CBA results themselves will also be highly uncertain.

In the CBA of this study, the costs are the increase in the investment cost of the project developer due to Green Building measures, the public expense for the Four-High Award, and administrative and transaction costs borne by the developer and the city of Shanghai. In addition, the increase in price paid by residents may or may not be regarded as a cost in this context, see Chapter 4, Discussion. All costs are added into one total, initial cost, incurred at the beginning of the project ("year 0"), thus there is no need to discount them.

The benefits are the energy-cost savings achieved and the avoided social and environmental externalities of coal-based energy production. These benefits are calculated and discounted for each year of the lifetime of the Green Building measure (in other words the lifetime of the housing scheme), yielding a series of diminishing annual net benefits. Together with the initial cost, they yield a benefit-cost ratio, a net present value and an internal rate of return. A sensitivity analysis is then conducted varying a number of variables to investigate the sensitivity and reliability of the result.

A summary of the main assumptions and input data used and the sensitivity analysis conducted is presented in the Findings chapter. For a detailed description of the CBA procedure used in this paper, see Appendix II.

2.2.2 Cost-Revenue Analysis

A Cost-Revenue Analysis, CRA, works much in the same way as a CBA. The main difference is that instead of considering all types of costs and benefits to all stakeholders in society as a whole, it it focuses exclusively on financial aspects from one stakeholder's point of view: it is financial analysis tool that focuses on *private* costs and benefits.

In this study a CRA was conducted to investigate the financial feasibility of the Green Building measures from the developer's and the residents' point of view respectively. From the developer's perspective, the cost is the incremental investment/technology purchase cost, and the revenue is the increase in the price paid by the residents. The residents' point of view is the opposite; the increase of price is the cost and the revenue is the energy cost savings. As the energy costs are ultimately paid by residents, they do not affect the CRA for the developer.

As in a CBA, future costs and revenues are discounted (discount rate 6% in the base case, 3% in the sensitivity analysis) and added together, and together with the initial investment cost they yield a an internal rate of return and a net present value, which indicate whether the measures make financial sense.

2.3 Case study: policy and project

Below is a table summarising the Green Building policy instruments in China. As can be seen there, there are a number of market-based instruments from which to choose for the study.

The most widespread fiscal Green Building policy instrument in China is subsidies (Zhiming, 2013). On the national level, a policy adopted in May 2012 provides a 45 yuan/m^2 subsidy for building projects achieving a CGBL two-star rating, and 80 yuan/m^2 for three-star projects. So far, however, this subsidy has not yet been paid to any project – applications are still being processed.

Table 2-1. Green Building policy instruments in the People's Republic of China (PRC)

Category	**Instrument**	**Adopted year**	**Comment**
National Laws	Water Law of PRC	1988	
	Environmental Protection Law of PRC	1989	
	Urban Real Estate Management Law of PRC	1994	
	Law of PRC on the Prevention and Control of Environmental Pollution by Solid Waste	1995	
	Energy Law of PRC	1997	
	Energy Conservation Law of PRC	1997	
	Law of PRC on Protecting Against and Mitigating Earthquake Disasters	1997	
	Construction Law of PRC	1998	This is the principal law regulating construction, including Green Building, i.e. the building code.
	Environmental Impact Assessment Law of PRC	2002	
	Renewable Energy Law of PRC	2005	
	Urban and Rural Planning Law of PRC	2008	
Regulatory Instruments	Mandatory minimum designing energy saving rate for newly-built buildings	1986	Originally 30% and only in the North, later applied nationwide. Raised to 50% in 2005 and 65% in 2009 for Beijing and Shanghai.
	Regulations on wall material production	1991	Latest revision in 1997.
	Standards on building envelope design, construction material and appliance	2002	
	Acceptance standards on indoor decoration	2003	
	Mandatory labeling and certification programs for electrical appliances	2005	
	Regulations on project inspection of energy-efficient building envelope	2005	
	Regulations on construction supervision especially of energy-efficient projects	2006	
	Designing Standard for Energy Conservation in Civil Building	2006	
	Mandatory use of water-saving appliances in fully-furnished apartments	2011	
Category	**Instrument**	**Adopted year**	**Comment**
Informative instruments	Local Five Year Plan (FYP)	(2001)	Local FYP:s have been used as informative

			instruments on energy since the 10th FYP in 2001.
	National Green Building Innovation Award	2004	
	China Green Building Label	2006	A.k.a. 3Star. See below.
	Local green building certification systems	2008	
	Demonstration programs on garbage classification, renewable energy application, green building, etc.	n.d.	
	Awareness raising, education, information campaigns about green building	n.d.	
Market based instruments	Tax reduction on new green construction material	2003	
	The "Four-high" community award	2007	Granted by the city of Shanghai to residential housing schemes for various sustainability aspects.
	Tax reduction for companies conducting energy/water conservation and environmental protection projects	2007 (national level)	
	Local special fund and soft loans for energy conservation and renewable energy programs	2008	
	Local subsidies on renewable energy and energy efficient products	2009	
	National subsidy for CGBL 2- and 3-star rated buildings.	2012	Not yet disbursed.
	"Shanghai City Building Energy Saving Projects Special Support Measures"	2012	Subsidies for various Green Building aspects of Shanghai projects.

Sources: (Cai, 2010)(Y. Liu, 2012)(Lu-Hill & Chen, 2013)

On the provincial level, the city of Shanghai (being its own province) introduced the "Shanghai City Building Energy Saving Projects Special Support Measures" ("**上海市建筑节能项目专项扶持办 法**") in September 2012. The policy provides a host of different subsidies for different types of buildings, summarised in table 2-2 below. The subsidies may be recieved in addition to national government subsidies.

Table 2-2. Summary, Shanghai Green Building subsidies.

Category	General requirements	Floor area requirements	Technical requirements	Subsidy
1. CGBL certified building projects	Two Star rating	Residential: ≥ 25 000 m²	For public buildings: Energy consumption sub-metering, monitoring, and reporting to the Municipal Government Building Bureau.	60 yuan/m² (Max. 6 million yuan)
		Individual public/commercial: ≥ 10 000 m²		
	Three Star rating	Residential: ≥ 10 000 m²		
		Individual public/comm.: ≥ 5 000 m²		
Category	**General requirements**	**Floor area requirements**	**Technical requirements**	**Subsidy**
2. Prefabricated building projects	The building must be at least 15% prefabricated.	≥ 25 000 m²		15%-25% prefabricated: 60 yuan/m²

				(max. 10 million yuan)
				≥ 25% prefabricated: 100 yuan/m^2 (max. 10 million yuan)
3. New buildings with high energy efficiency	Residential or public building. Energy demand 70% lower than the baseline of the mandatory energy-saving rate.	Individual residential buildings: ≥ 50 000 m^2	Design integrated exterior window shading. For public buildings; same as for category 1.	60 yuan/m^2 (max. 6 million yuan)
		Individual public buildings: ≥ 20 000 m^2		
4. Existing buildings with high energy efficiency	Energy-saving retrofitting of an existing building. Achieving an energy demand 50% lower than the baseline of the mandatory energy-saving rate.	Residential: ≥ 10 000 m^2	For public buildings; same as for category 1.	60 yuan/m^2 (max. 6 million yuan)
		Individual public buildings: ≥ 20 000 m^2		
5. Exterior window or window shading renovations of existing buildings	Existing building. Exterior window or window shading renovation project.	Residential: ≥ 5 000 m^2	Compliance with applicable design standards (DGJ08-205 and DGJ08-107 or JGJ237.) For public buildings; same as for category 1.	Window OR shading renovation: 150 yuan/m^2 window area.
		Ind. public buildings: ≥ 10 000 m^2		Window AND shading renovation: 250 yuan/m^2 window area
6. Onsite renewable energy	Building project with onsite renewable energy sources, e.g. photovoltaics, solar heating or ground-source heatpump.	One renewable energy source only; residential buildings: ≥ 50 000 m^2 public buildings: ≥ 20 000 m^2	For public buildings; same as for category 1.	Solar heating or ground-source heatpump: 60 yuan/m^2 benefitted area
		Two or more renewable energy sources; residential buildings: ≥ 40 000 m^2 public buildings: ≥ 15 000 m^2		Photovoltaics: 5 yuan/Watt installed
7. Green roofs and walls	Public buildings located in key areas of Shanghai. Green (vegetation) roof and walls.		Green roof area ≥ 1000 m^2 *or* "general" type green wall area ≥ 1000 m^2 *or* "special" type green wall area ≥ 500 m^2	Lawn roof: up to 50 yuan/m^2
				Plant roof: up to 200 yuan/m^2
				Combined lawn/plant roof: up to 100 yuan/m^2
				"General" type green wall: up to 30 yuan/m^2
				"Special" type green wall: up to 200 yuan/m^2
8. Building energy management and services	Existing government office buildings, large public buildings. Energy sub-metering, energy audits and building services system projects.			Government will assist/support project.

Source: (Lu-Hill & Chen, 2013)("Shanghai City Building Energy Saving Projects Special Support Measures," 2012)

For this study, the Four-High Community Award (listed under market-based instruments in table 2-1) was chosen, as it was the one policy instrument on which sufficient numeric data related to a specific project could be found. It is a financial incentive for "communities" (housing development) intended to spur developers to move forward with Green Building, as well as to create publicity and spread awareness. The name "Four High" refers to the prerequisites of the award: the rewarded community should represent planning with a high ambition starting point, high design level, high quality construction, and high level management.

The residential scheme Chenghuaxinyuan received the Four High Community Award in 2011 from the City of Shanghai. For Chenghuaxinyuan, the Award was 4,25 million yuan, granted for great Green Building design, with particular emphasis on the energy efficiency acheivements (Y. Liu, 2012). Situated on the outskirts of Shanghai, Chenghuaxinyuan was developed by Vanke, China's biggest real estate developer in the residential sector. It is a gated community in a park environment with extensive gardening and water features, mid-rise slab blocks built in what the company proudly markets as "Art Deco style". Stage 1 of the development comprises 365 764 m^2 (Y. Liu, 2012). It achieved a three star rating, the highest in the China Green Building Label system.("www.lvdichan.com," n.d.)

The Green Building design features include a better insulated building envelope than in typical residential construction (a U-value between 0,79 and 0,94 W/m^2K which is lower (i.e. better) than business-as-usual, yet notably higher (worse) than in e.g. Swedish standard (non-Green Building) constructions), low-emission insulating glass windows, sedum green roofs, permeable garden grounds, and a selection of building services systems and appliances of generally higher-than-standard efficiency. ("wenku.baidu.com: 万科城花新园_百度文库," n.d.)

Table 2-3. Chenghuaxinyuan, general information

Item	Data	Source/comment
Name	Chenghuaxinyuan	Means "New Park City Flowers".
Address	Minhang District Dongchun Road, Shanghai	("http://thape.com," n.d.)
Construction year	2009	("http://thape.com," n.d.)
Developer	Shanghai Dongyuanmeiye Real Estate Ltd., for Vanke	("http://thape.com," n.d.)
Total investment	1 billion yuan	("www.lvdichan.com," n.d.) Obviously an approximation.
Land area	55 353,6 m^2	("www.lvdichan.com," n.d.)
Construction area	365 764 m^2	(Y. Liu, 2012) Stage 1.
Buildings	18 buildings: "Nine multi-layer, three high-level and six small high-rise residential buildings"	("www.lvdichan.com," n.d.) Difficult to interpret, but of little importance to the study.
Certification	3 star rating in CGBL	(Y. Liu, 2012) The highest rating within CGBL.
Tenure	Condominium.	(J Li, n.d.)(Y. Liu, 2012) Interpretation/assumption. Residents "buy" their homes, and extensive services are provided by Vanke.
Main Green Building features	• naturally lit underground parking space • building envelope designed to meet energy-saving rate of 65% of the standard requirements • solar hot water system for 62,6% of residents • collection and storeage of rainwater, local infiltration and utilization • prefabricated concrete element structure for more efficient and less disturbing construction • sedum green roofs • low-emission insulating glass windows • self-balanced ventilation system • conventient waste recycling system	(J Li, n.d.) ("www.lvdichan.com," n.d.) Note that only a few of the measures are directly related to energy consumption.
Exterior wall U-value	0,79 - 0,94 W/m^2K	(J Li, n.d.)

For detailed Green Building related cost data etc., see table 3-1.

3 Findings and analysis

The purpose of this chapter is to summarise the main findings and analysis of the study. In accordance with the research objective, methods applied, key observations and conclusions are elaborated. Throughout the chapter, explanations are also provided regarding the relationships between the different findings and how they build on one another.

3.1 Market-based policy instruments as a driver for Green Building

A somewhat unexpected outcome of the interviews conducted on site in Shanghai was the recurring assertion from interviewees that fiscal policy incentives such as subsidies and grants play only a minor role for the motivation of developers that choose to carry out their projects as Green Buildings. The primary driver appears to be the desire and need for good relations to local government. (E. Lee, 2013)

According to professor Che Xueya, deputy chief architect at Tongji Architectural Design Co. Ltd. and board member of the Shanghai Green Building Council, the drivers and motives for Green Building developers are a mix of political pressure and persuation, branding considerations, energy cost-saving, and subsidies. Subsidies are small compared to other costs and benefits in real estate projects, and so play more of a psychological role to persuade developers into building green. Once the benefits of energy efficient construction become generally known and accepted by the market, subsidies will be phased out, professor Xueya believes. (Xueya, 2013)

However, subsidies also serve to indicate the government's intentions, which are observed with greater attention in China than in most other countries. For a Chinese real estate developer that wants to grow and prosper, a good relationship to local government is crucial (Zhang & Zhang, 2013). The fact that various Green Building measures are being subsidised may make companies consider those measures, not so much for the money as for their political value.

The secondary motivation is often branding, according to interviewees. The bigger developers are competing to be the leader in 'Sustainable Architecture', which is now a high status business. The fact that the government is a major opinion-former in China, and that it is pointing the market in the direction of Green Building, further increases the prestige of such projects, as well as the prestige of living in a Green Building. This is reflected by the fact that Vanke are able to add a price premium (compared to the average price for newly built housing in Shanghai) to the residents of Chenghuaxinyuan 29 times the incremental investment cost of the actual Green Building measures (Y. Liu, 2012).

3.2 Cost-Benefit Analysis

3.2.1 Data input and key assumptions, base case

The CBA scenario presented whose data input and key assumptions are presented in this section, and whose results are presented in section 3.2.2, is hereafter referred to as the "base case", as opposed to the various alternative cases that the sensitivity analysis gives rise to. The assumptions for the base case are generally rather conservative.

The economic efficiency of the financial support to Green Building measures in the Chenghuaxinyuan housing scheme is highly dependent on what assumptions are made. Since the increase in price for residents, the so-called price premium, is almost thirty-fold the incremental investment cost of the developer, it may be discussed whether it is wholly attributable to the Green Building measures, and therefore a Green Building related cost, or not. However, since the very same price premium is a benefit to the developer, and not a cost, it is neither from society's point of view: it is merely an internal transaction, and therefore it is disregarded in the CBA. In the CRA, on the other hand, it is major factor. See section 3.3.

The same is true for the prize sum of the Award itself, which is merely transferred from one party to another. Y. Liu (2012) reports "Administrative costs borne by developer (certification)" of 47 247 yuan, which is the fee for having the project registered and evaluated for CGBL, but this too is an internal transaction. Thus neither is considered a cost in the CBA. However, there may be other truly administrative costs occurring on behalf of developer as well as authorities. This issue is considered in the sensitivity analysis.

One important assumption concerns the energy savings. No specific numbers on energy consumption could be found for Chenghuaxinyuan, only details on parts of the climate system and building envelope. However the granting of Award requires achieving energy savings of 65% compared to the national baseline, i.e. meeting the new Shanghai standard (which few buildings do so far). Other buildings that achieve this (on which data was found) have an energy consumption of around 40 kWh/m^{2}a (Connelly, 2012), i.e. about 25 kWh/m^{2}a lower than the typical energy use of a modern Chinese residential building (Zhang & Zhang, 2013). Thus an energy saving of 25 kWh/m^{2}a adhering to the awarded Green Building measures was assumed in the calculus. Heating and cooling is assumed to be done by air-to-air heat pump ventilators, based on presentations on the housing scheme (J Li, n.d.). Then the question whether the assumed 40 kWh/m^{2}a are a heating/cooling *demand* or an energy *consumption* for heating and cooling gets important, as a modern air-to-air heat pump with a coefficient of performance of 200% would satisfy a demand of 40 kWh/m^{2}a by consuming only 20 kWh/m^{2}a. However, considering the U-value and other specs of the building envelope, it is unlikely with an energy demand that low, and hence 40 kWh/m^{2}a is assumed to be the energy *consumption*. Energy demand is a relative concept, as it depends on what indoor temperature residents are willing to accept, which in turn depends on cultural and economic context (see Cai, 2010, pp. 10–13). Energy consumption, on the other hand, can be readily measured.

In any case the fuel is electricity, and externalities of energy consumption should be calculated on typical Chinese marginal electricity production, i.e. coal power. The assumption is based on the Greenpeace report "The true cost of coal in China" (Yushi et al., 2008), that investigates the socio-environmental external costs from Chinese coal power production, including mining. The report's estimate of 698 yuan/ton coal (Yushi et al., 2008, p. 60) is multiplied by the average domestic coal consumption for power supply in 2011, 0,33 ton/Mwh (Yinbiao, 2013), yielding a total external cost of 230 yuan/MWh. For data quality discussion, see section 3.2.3 Sensitivity analysis and Chapter 4, Discussion.

Table 3-1. Main assumptions, Cost-Benefit Analysis

Item	**Value**	**Source / comment**
Floor area	365 764 m^2	(Y. Liu, 2012)
Discount rate	6%	Based on Mundaca & Neij (2009); official social discount rate. 3% also tested in sensitivity analysis.
Lifespan	40 years	Assumption. Actual building lifespan impossible to predict, 40 years assumed maximum time perspective for customers.
Energy savings due to Green Building measures	25 kWh/m^{2}a, totally 9 144 MWh/a	Assumption based on (Connelly, 2012) and (Zhang & Zhang, 2013), for explanation see 3.2, paragraph 2.

Item	Value	Source / comment
Electricity cost	470 yuan/MWh	("Smart Grid Insights by Zpryme," 2012) Avoided electricity cost equals a benefit. Cost is here assumed to correnspond to a flat electricity price. See sensitivity analysis for a test of electricity price increases corresponding to 2% and 5% annually.
Socio-environmental externalities	230 yuan/MWH	Based on Greenpeace "The true cost of coal in China" (Yushi et al., 2008) and (Yinbiao, 2013) Avoided externalities equal benefits.
Incremental cost borne by developer	82 304 578 yuan	(Y. Liu, 2012)
Transaction costs borne by developer	10 205 390 yuan	(Y. Liu, 2012)

3.2.2 CBA Results

Using the assumptions and values listed above, the outcome of the benefit-cost ratio calculus procedure (see Appendix I) can be summarized as

$$\frac{\Sigma(B_t * (1+d)^{-t})}{\Sigma C} = \frac{66{,}1}{92{,}6} = 0{,}71$$

where B is the total benefits a given year (avoided energy cost and socio-environmental externalities) in million yuan, $\sum$C is the total project cost in million yuan, and d the discount rate (6%).

Thus in the base case, the benefit-cost ratio of the Four-High Award for Chenghuaxinyuan and the Green Building measures it is promoting is 0,71, which means that for every yuan invested, only 0,71 yuan were generated. The internal rate of return is 3,1%, which is below any normal investment return target. The net present value is -24,97 million yuan, i.e. society *loses* this value due to the policy measure. The payback time for society as a whole is far past the assumed lifetime of the housing scheme or the planning horizon of residents, see Figure 3-1. In this case, the measures must be considered economically inefficient from society's point of view.

Table 3-2. Cost-Benefit Analysis, results

Indicator	Result
Benefit-cost ratio	0,71
Internal rate of return	3,1%
Net present value	-24,97 million yuan

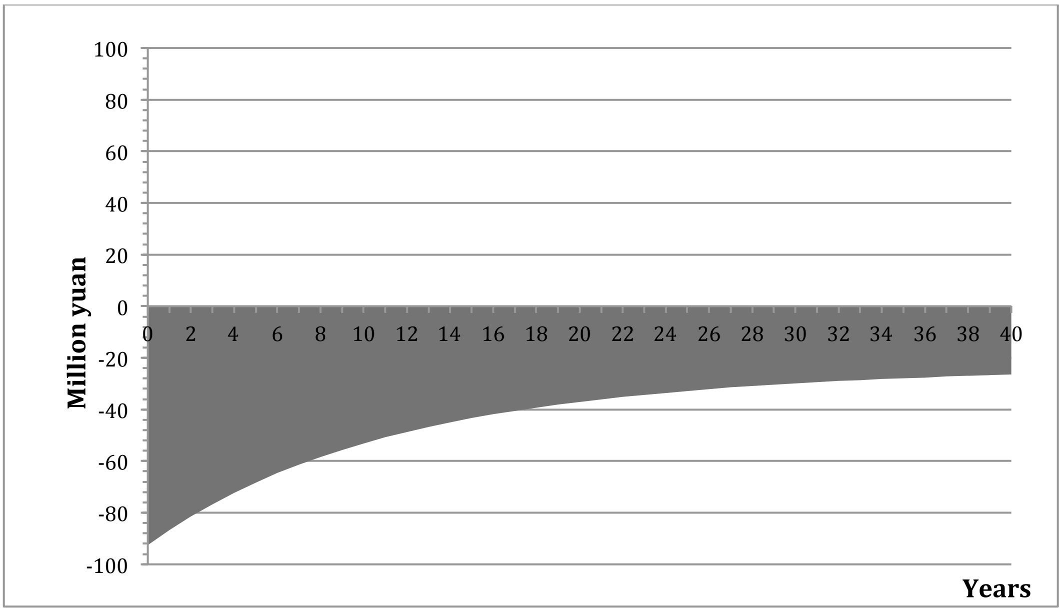


Figure 3-1. Cumulative discounted cost/benefits, Four High Award - Chenghuaxinyuan Green Building measures (discount rate 6%)

3.2.3 Sensitivity Analysis

Using the OTA method for sensitivity analysis, the calculus was run a number of times varying certain key values each time, in order to determine the significance of the specific value for the result, and thus be able to judge the reliability of the outcome. Values that were varied were

- external socio-environmental benefits
- electricity price
- discount rate

Also, two new costs were tested:

- administrative cost borne by authorities
- administrative cost borne by the developer

While the administrative cost of authorities and developer indicated by Liu (2012) is identical with the sum of the Award and the registration fee for CGBL respectively, both internal transactions and thus disregarded, one may suspect that further administrative cost may occur on behalf of authorities as well as developer. Therefore an additional 20% administrative cost is tested here for both. Both are found to have minimal impact on IRR, NVP and benefit-cost ratio.

All the more critical is the valuation of socio-environmental externalities. While the Greenpeace report that the baseline case figure of 230 yuan/MWh is based on is relatively new (2008), written by expert academics such professor Mao Yushu of the Unirule Institute of Economics and Dr. Yang Fuqiang of the Energy Foundation, and has indeed been peer-review by members of various Chinese scientific institutions and political bodies including the Ministry of Finance, it was not produced within the context of peer-reviewed academic-scientific publications – it was produced by an environmental organisation whose objectivity is sometimes questioned.

Figures from a peer-review scientific journal article was found in Hirschberg et al. (2004, pp. 167–168), who investigated the socio-environmental external costs from coal power production in the Shandong province (not Shanghai, but close) in 1998. An external cost of 950 yuan/MWh can be deducted from this article, resulting in a total avoided external cost of 8,69 million yuan per year for the project. The data quality problem here is the age of the data; the efficiency of combustion and the abatement of emissions in Chinese coal power plants is likely to have improved since then. However, if using this figure, the CBA changes dramatically. The Four-High Award for Chenghuaxinyuan, and the Green Building measures it is promoting, are then altogether feasible from a socioeconomic point of view. With all other assumptions as presented in table 3-1 and not regarding increased housing price as a cost, the benefit-cost ratio of the measures is 1,78; the internal rate of return 12,3%, and the net present value 68,63 million yuan. The payback time for society as a whole is about eleven and a half years, see Figure 3-2. The measures must be considered economically efficient, if only moderately. A lower discount rate improves economic efficiency further.

If we, on the contrary, assume that Greenpeace is exaggerating the externalities, and cut their figure by 50%, then the NPV too is cut by 50%, and the IRR by four fifths, while the benefit-cost ratio only falls to 0,54. An in-between assumption of 460 yuan/MWh, twice the Greenpeace figure, but still less than half of that of Hirschberg et al., duplicates the NPV and more than duplicates the IRR, with a more moderate increase of benefit-cost ratio. In short, IRR is the most influenced by changes in externalities, NPV almost as strongly, and benefit-cost ratio moderately so.

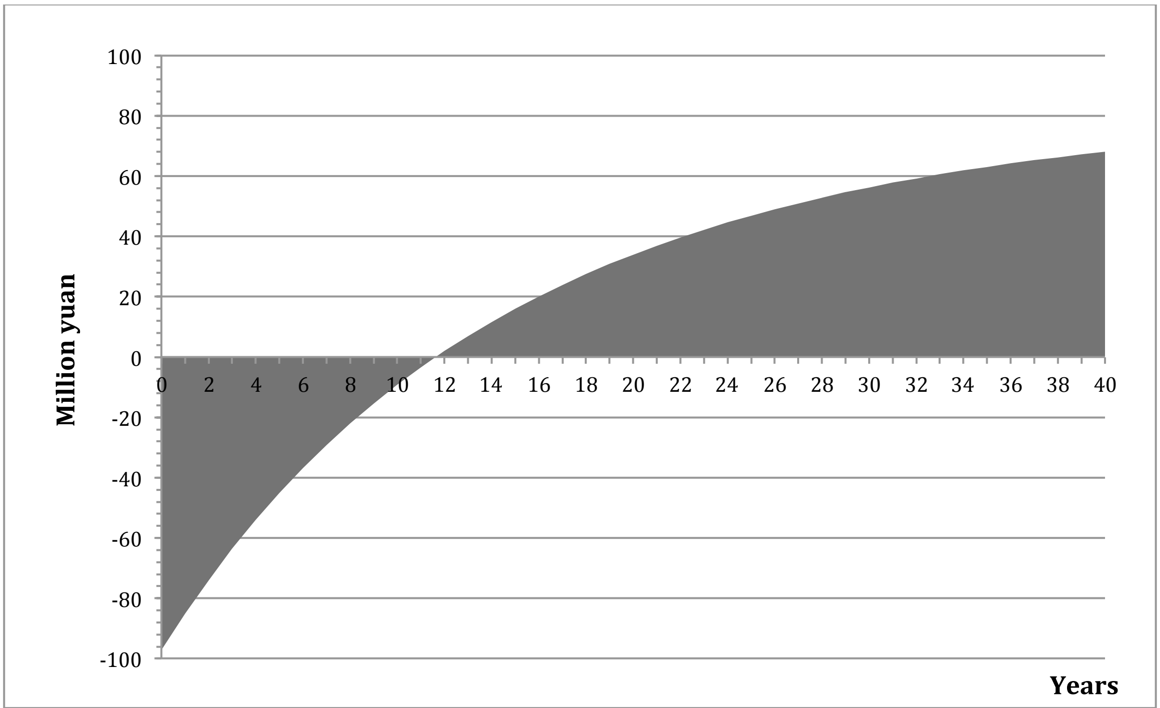


Figure 3-2. Cumulative discounted costs/benefits, Four High Award - Chenghuaxinyuan Green Building measures – externalities assumption based on Hirschberg et al. (2004). Discount rate 6%.

Conclusively the valuation of externalities is important for the outcome of the CBA. However, given the serious research approach of the Greenpeace report, authored and peer-reviewed by distinguished academics at renowned institutions respectively, the level of uncertainty of the externalities estimate can be regarded as tolerable, and thus so can the uncertainty that it exerts onto the CBA result.

Changes in electricity price have limited impact on IRR but a tangible impact on NPV. A duplication of the electricity price in the calculus corresponds to an annual electricity price increase of almost 5% for 40 years. This would increase the NPV by about 50%. Benefit-cost ratio is somewhat less affected. As electricity price is only likely to rise in the future, this increases the uncertainty of the CBA result towards the profitable side, increasing the likeliness of a more beneficial outcome.

If only 20 kWh/m^{2}a of energy savings are achieved, i.e. 20% lower than estimated, then it reduces IRR and NPV tangibly further, and benefit-cost ratio somewhat less. If on the other 40% greater savings were to be achieved than estimated, it would improve economic efficiency greatly, yielding a clearly positive NPV, IRR and benefit-cost ratio. Although this is less likely, it is an important finding pointing to policy improvement opportunity. On the other hand, greater energy savings would also entail greater incremental investment cost, which would again worsen the figures. Addressing the question of how much would require a separate study.

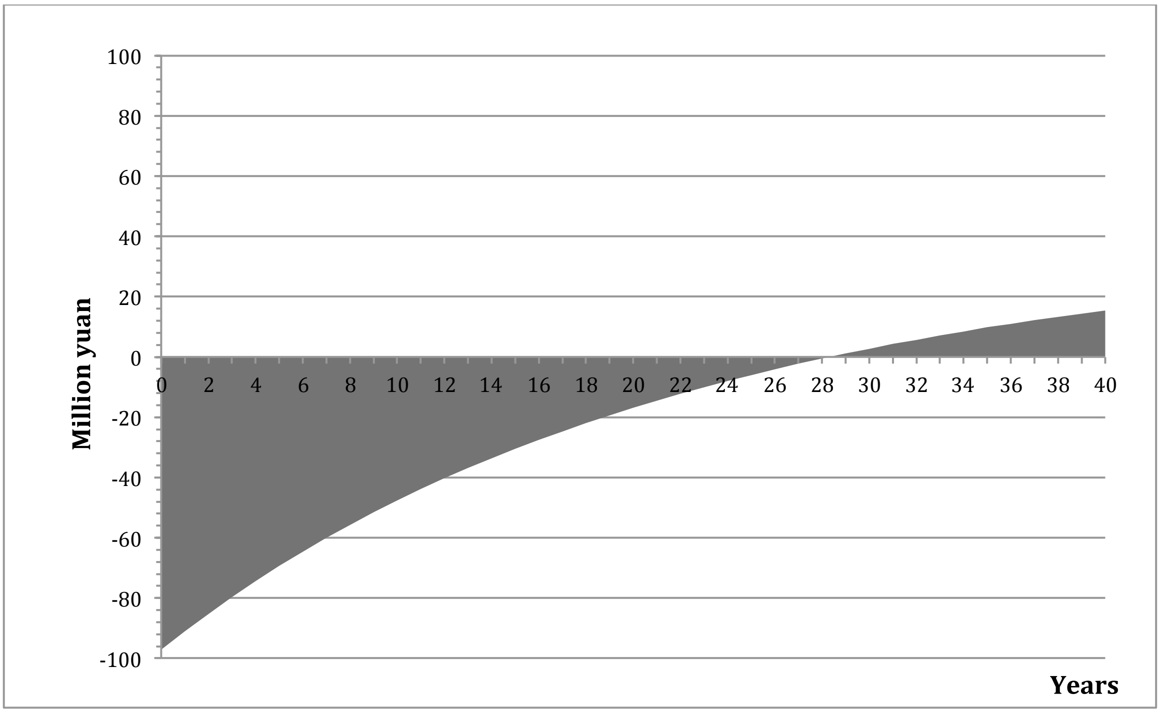


Figure 3-3. Cumulative discounted costs/benefits, Four High Award - Chenghuaxinyuan Green Building measures – assuming 5% annual increase in electricity price. Discount rate 6%.

The discount rate, finally, influences NPV and benefit-cost ratio even more. While IRR is not nearly as much affected, a halving of the discount rate more than duplicates NPV, and improves benefit-cost ratio almost as strongly. To conclude, the result of the CBA is very sensitive to changes in (the valuation of) the socio-environmental externalities of energy consumption and discount rate, and moderately sensitive to changes in electricity price, while administrative costs have litte impact. Better data on socio-environmental externalities would increase certainty significantly.

Table 3-3. Sensitivity Analysis, CBA

Variable	New Value (Old Value)	Variable Change (%)	IRR	IRR change (percentage points)	NPV (million yuan)	NPV change (million yuan)	Benefit-cost ratio
Administrative cost borne by authorities (million yuan)	0,9 (0)	n.a.	3,0% (3,1%)	-0,1	-25,82 (-24,97)	-0,85	0,71 (0,71)
Administrative cost borne by developer (million yuan)	0,009 (0)	n.a.	3,1%	(negligible)	-24,97	(negligible)	0,71
External socio-environmental benefits (M yuan/year)	8,69 (2,10)	+314%	12,3%	+9,2	68,53	+93,5	1,78
	4,21	+100%	6,5%	+3,4	4,93	+29,9	1,06
	1,05	-50%	0,9%	-2,16	-39,92	-14,95	0,54
Electricity price (yuan/kWh)	610 (470)	+30%[2]	4,2%	+1,1	-15,29	+9,68	0,82
	940	+100%[3]	6,9%	+3,8	7,52	+32,49	1,09
Energy savings (kWh/m^2a)	20 (25)	-20%	1,5%	-1,6	-37,44	-12,47	0,57
	40	+60%	7,4%	+4,3	12,44	+37,41	1,14
Discount rate	10% (6%)	+66,7%	1,66%	-1,10	-50,96	-21,72	0,42
	9%	+50%	1,88%	-0,88	-47,36	-18,12	0,47
	8%	+33,3%	2,13%	-0,63	-42,80	-13,56	0,52
	7%	+16,7%	2,43%	-0,34	-36,93	-7,69	0,59
	5%	-16,7%	3,15%	+0,38	-18,96	+10,28	0,79
	4%	-33,3%	3,59%	+0,82	-4,87	+24,37	0,95
	3%	-50%	4,08%	+1,32	15,02	+44,26	1,16
	2%	-66,7%	4,64%	+1,87	44,13	+73,37	1,46
	1%	-83,3%	5,26%	+2,49	88,45	+117,69	1,92
	0%	-100%	5,94%	+3,17	158,96	188,20	2,64

3.2.4 Benevolent scenario

The base case CBA is based on rather conservative estimates. Drawing on the results of the sensitivity analysis, it is interesting from a policy-making point of view to examine how the negative CBA outcome might be affected by a combination of more favorable, but still not unreasonable assumptions for some of the key variables. Such a hypothetical "benevolent scenario" may serve as an indication of policy design opportunities.

Central bank discount rates, including in China, have been kept low lately in order to stimulate the market. Thus a 3% discount rate may not be less reasonable than a 6% one. Energy

[2] An immediate 30% increase corresponds to an annual real price increase of approximately 2% for 40 years.

[3] An immediate 100% increase corresponds to an annual real price increase of almost 5% for 40 years.

savings could possibly be 35 rather than 25 kWh/m^{2}a, considering the poor energy efficiency standard of business-as-usual construction (the absolute energy consumption figure is less important here). And the electricity price for residential mid- and high-income users might rise by 30% in not too distant a future.

Combining these three individually fully feasible assumptions in a "benevolent scenario" brings a much more beneficial result: an IRR of 8,72%, an NPV of 84,62 million yuan, and a benefit-cost ratio of 1,90. The payback time for society is just above twelve years. Price premium is disregarded, i.e. the socio-environmental benefits alone outweigh the costs.

Table 3-4. Benevolent scenario CBA. Altered input data variables and results.

Item	**Value**	**Change compared to base case CBA**
Discount rate	3%	-50%
Electricity price	610 yuan/MWh	+30%
Energy savings	35 kWh/m^{2}a	+40%
Benefit-cost ratio	**1,99**	+1,28
IRR	**9,3%**	+6,2 percentage points
NPV	**89,01 million yuan**	+113,98 million yuan

(All other input and assumptions as in table 3.1.)

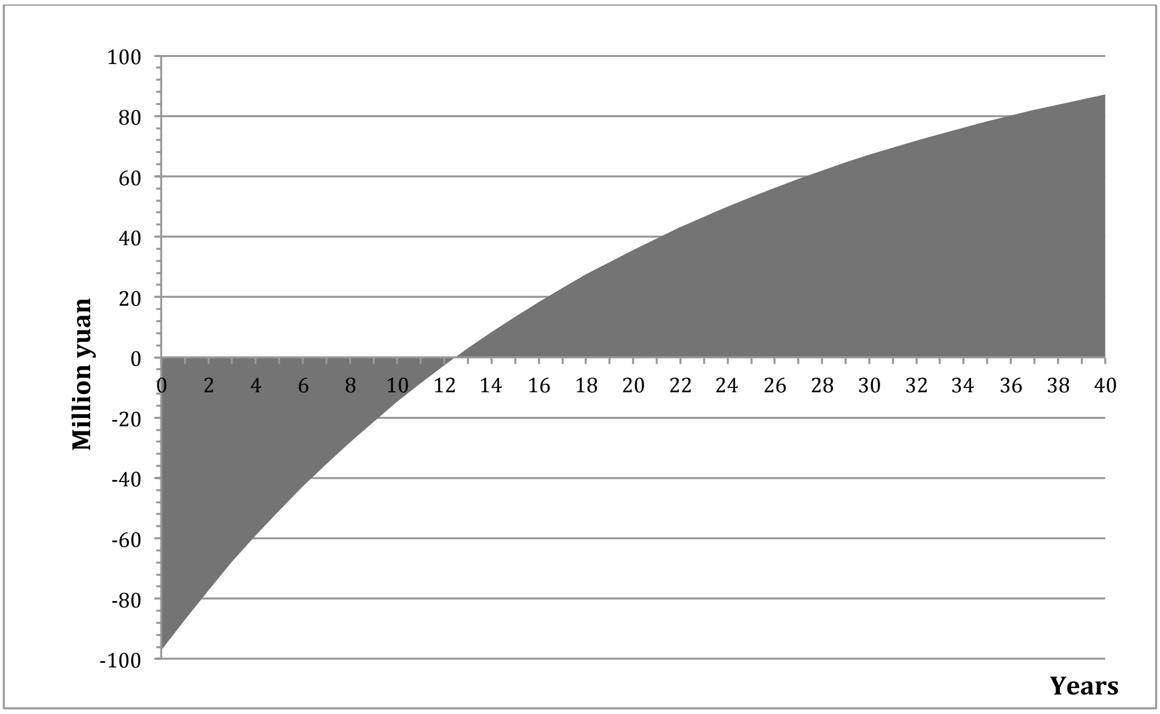


Figure 3-4. Benevolent Scenario CBA, cumulative discounted costs/benefits, Four-High Award/Chenghuaxinyuan Green Building measures. Input data, see table 3.4.

3.3 Cost-Revenue Analysis

The Cost-Revenue Analysis points to a very poor deal from the residents' perspective, financially speaking. The internal rate of return for the residents "investment in Green living" is -14,6%, and the net present value is -6137,6 yuan/m^2. The energy-cost savings of a maximum 11,1 yuan/m^2a (the first year, thereafter discounted by 6% each year) do in no way recoup the residents' increase in housing price of 6600 yuan/m^2 (compared to the average for newly built residential buildings at the same time in Shanghai (Y. Liu, 2012, p. 68)), not even when assuming a "building lifetime" residency of 40 years. Payback time is "never" from a private-economic perspective.

One possible conclusion is that energy cost savings simply are not an important factor when Shanghai real-estate customers make their choices right now.

Table 3-5 Cost-Revenue Analysis, residents' incremental investment

Item	**Value**	**Source/comment**
Price increase attributable to G.B. measures	6600 yuan/m^2	(Y. Liu, 2012)
Annual energy savings	25 kWh/m^2	Assumption based on (Connelly, 2012) and (Zhang & Zhang, 2013), for explanation see 3.2, paragraph 2.
Electricity price	0,47 yuan/kWh	[Internet search]
Discount rate	6%	Based on Mundaca & Neij (2009)
Internal rate of return	-14,6%	
Net present value	-6138 yuan/m^2	

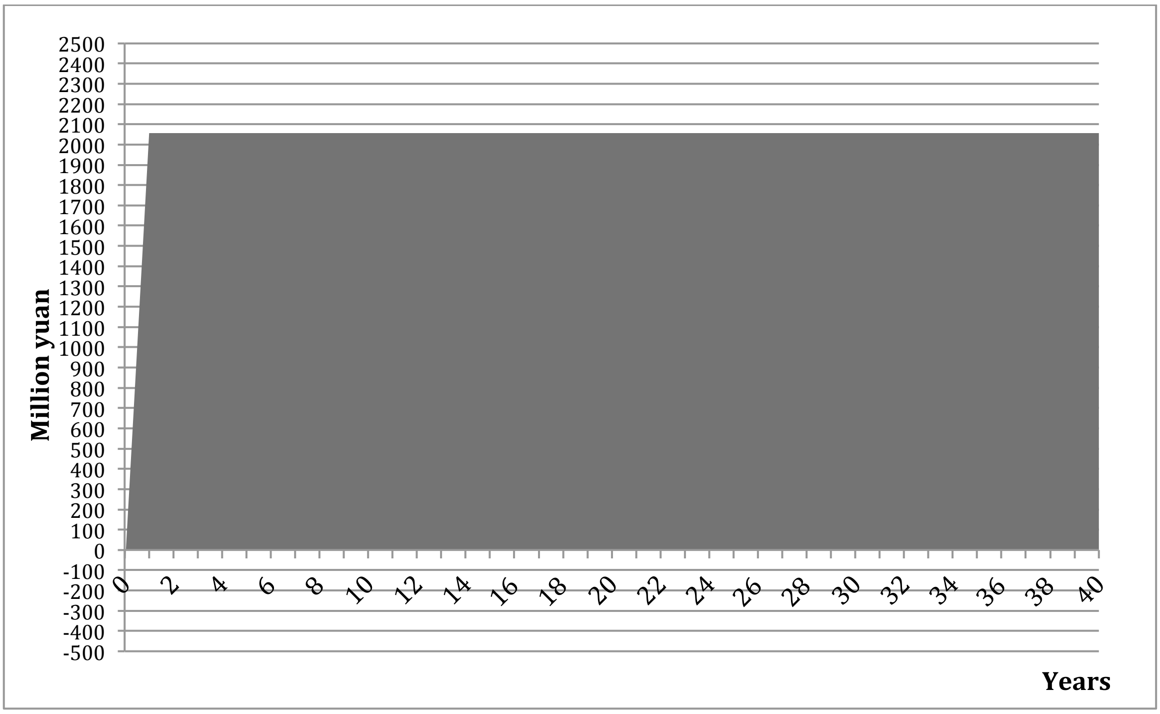
Figure 3-5. Cumulative discounted cashflow for residents due to Green Building Measures.

From the developers point of view, on the other hand, the result is quite the contrary. The CRA shows an IRR of 2509,5%, and a NPV of 2,061 billion yuan for the Green Building measures. The extreme result is due to revenues – increased housing price - being about 26 times as high as costs. Energy savings are not part of this calculus, as energy costs are paid by the residents.

Table 3-6. Cost-Revenue Analysis, developer's investment in Green Building measures

Item	**Value**	**Source/comment**
Increased housing price revenues	2,414 billion yuan (6600 yuan/m^2)	(Y. Liu, 2012) Assuming all apartments are sold year 1.
Incremental investment	92,5 million yuan	(Y. Liu, 2012)
Discount rate	6%	Based on Mundaca & Neij (2009)
Internal rate of return	2361,8%	
Net present value	1939,6 million yuan	

Figure 3-6. Cumulative discounted cashflow for the developer due to Green Building Measures.



3.3.1 CRA Sensitivity Analysis

The OTA method was used for the sensitivity analysis of the CRA. As with the CBA, the probably most critical variable is the increase in housing price paid by Vanke's customers due to the increase in ecological and energy standard, and its significance for the CRA result, due to its uncertainty: it is disputable whether this increase is due to the Green Building measures only.

First the sensitivity analysis for the residents' investment in a low-energy home. If we assume that only half of it is attributable to the Green Building measures (3300 yuan/m^2 instead of

6600), then the net present value of the residents' "investment" in Green living is still negative, but the loss is nearly cut in half. Reducing the Green Building related price increase to a sixth reduces the loss almost proportionally. The internal rate of return is less affected, but not insignificantly.

Another uncertain variable is the amount of annual energy savings, as it is an assumption based on low quality data. Yet its influence on the result appears to be limited. Assuming 50% bigger savings affects NPV and IRR rather insignificantly. Not even a 100% increase of the energy savings – not very likely - makes any substantial difference to the NPV- it rises by 88,3 yuan/m^2 only – while the IRR is somewhat more affected.

Naturally, the same relative changes to the other variable in the energy-cost savings equation, the electricity price, affect the result in exactly the same way. A doubling of electricity price yields the same IRR and NPV as a doubling of the energy savings. In other words, the two factors are equally (in)significant for the outcome, perhaps with the reservation that a future higher electricity price is much more likely than the energy savings being much bigger than assumed.

Reducing the discount rate by 50%, from 6% to 3%, actually affects the IRR more than a halving of the G.B. related incremental housing cost does, raising it by 2,5 percentage points to -12,1%. However the net present value is far less affected, rising merely 28,3 yuan/m^2 to negative 6093,2 yuan/m^2.

Conclusively, the incremental housing cost is the totally dominating factor for the outcome of the CRA. Hence the question of the reliability of the results becomes a question of interpretation. There is little uncertainty about the price increase amount as such, the question remains how much of it is due to the Green Building measures. A different appraisal of this changes the outcome greatly. However the price increase is so large compared to energy cost savings that not even an 83% discount would make it pay off financially for the residents.

Table 3-7. Sensitivity Analysis, CRA, residents' contribution

Variable	**New Value (Old Value)**	**Item Change** (%)	**IRR**	**IRR change** (percentage points)	**NPV** (yuan/m^2)	**NPV change** (yuan/m^2)
Price increase attributable to G.B. measures (yuan/m^2)	3300 (6600)	-50%	-12,7% (-14,6%)	+1,9	-3123,2 (6137)	+3014,4
	1100	-83%	-9,1%	+5,5	-923,2	+5214,4
Annual energy savings (kWh/m^{2}a)	37,5 (25)	+50%	-13,5%	+1,1	-6093,2	+44,4
	50	+100%	-12,7%	+1,9	-6048,7	+88,3
Electricity price	0,61 yuan/kWh (0,47 yuan/kWh)	+30%	-13,9%	+0,7	-6110,9	+26,1
	0,94 yuan/kWh	+100%	-12,7%	+1,9	-6048,7	+88,3
Discount rate (%)	3% (6%)	-50%	-12,1%	+2,5	-6109,3	+28,3

For the developer, a change in the increased housing-price-related revenues does have significant, almost proportional, impact on the result. Thus the uncertainty about its attributability to Green Building measures *is* a source of uncertainty for the CRA as a whole, just as with the CRA from residents' point of view. From a business point of view, on the other hand, even when cutting the incremental revenue by five sixths to 410,4 million yuan, the IRR is still an extraordinary 318,5% and the NPV a reassuring 257,3 million yuan.

For the incremental investment cost, a higher value is unlikely, since the project is finished and the data source is ex-post. However, if increasing it by 25% anyway, the effect on the IRR is almost reversely proportional, reducing it by about a fifth. The effect on the NPV is very slight. The same is true when assuming a 50% *lower* incremental investment, a less unlikely assumption in the sense that the entire incremental investment may actually not be due to the Green Building measures only.

Variations in the discount rate has very little effect on the result since it is only used once, on the one time revenue post incurred in year 1.

Table 3-8. Sensitivity Analysis, CRA, developer's investment in Green Building measures

Variable	**New Value (Old Value)**	**Item Change** (%)	**IRR**	**IRR change** (percentage points)	**NPV** (million yuan)	**NPV change** (million yuan)
Increased revenues (million yuan)	1207,0 (2414,0)	-50%	1130,9% (2361,8%)	-1230	926,1 (1939,6)	-1013,5
	410,4	-83%	318,5%	-2043,3	257,3	-1682,3
Incremental investment (million yuan)	115,6 (92,5)	+25%	1870,1%	-491,7	1917,8	-21,8
	46,3	-50%	4818,8%	+2457,0	1983,2	+43,6
Discount rate (%)	3% (6%)	-50%	2433,8%	+72,0	1998,7	+59,0

4 Discussion

This chapter discusses the findings, their meaning and credibility, their implications for the research problem, the assumptions and the data sources behind them, and the conditions of the research and analysis as such.

4.1 Price premium and incremental cost

A "neutral" CBA, i.e. one that disregards the price premium paid by customers because it is an internal transaction within society, yields a clearly negative result, pointing to the policy as being inefficient.

All in all, however, this appears to be something of a pseudo-problem. The CBA conveys a loss to society, but this is an illusion: in reality no one really loses. Society gets socio-environmental benefits that by far outweigh the government's own expenses, the developer gets great return on investment, and the customers get the sustainable, high-status living that they are willing to pay for. Since customers are willing to pay the price premium, developers have an incentive to produce Green Buildings, which in turn does generate socio-environmental benefits to society. The fact that costs are bigger than socio-environmental benefits is less important as long as they are covered by the price premium paid by customers.

A "neutral" CBA that disregards the price premium is misleading in that it compares the costs carried by two parties – public society (including government) and companies – to the benefits enjoyed by only one of the parties – public society. It considers companies' costs but leaves out the benefits that are the companies' main reason for investment: the price premium. If the price premium is considered a benefit instead of being left out or treated as a cost, then the CBA outcome is extremely beneficial.

Then again, the price premium cannot really be treated as a benefit to society either, because of the residents, who are also part of society and to whom it is clearly a cost and not a benefit.

There is no unequivocal explanation to the price premium. There are a number of factors for which at least a certain market segment of customers are willing to pay more. Part of the price premium represents a value added by the Green Building measures, which in today's China are becoming a status factor among some groups. Other status qualities of the buildings, their architecture and location, which do not have anything to do with the Green Building measures, are another driver. Finally the expectations on continued price increases play a major role on the real-estate market, in China more than in most other places, and can be assumed to add substantially to the price premium for an above-average housing scheme like Chenghuaxinyuan. Hence the most radical assumption in the sensitivity analysis of the CRA for residents and developer respectively, about only 17% of the price premium being attributable to Green Building measures (item change -83%), may very well be the closest to the truth.

Bearing this dilemma in mind, the CBA is still useful in that it illustrates the relationships between government costs, developers' costs, socio-environmental benefits, price premium, and economic efficiency. As demonstrated by the Benevolent Scenario, it also points to policy design options that might enable socio-environmental benefits to outweigh costs by themselves, with or without price premium.

4.2 Green Building policies and project realisation

For the developer the increase in rent revenues by far recoups the cost of going 3-star Green Building, as indicated by the CRA. The incremental cost for Green Building achievements is passed on to the residents many times over. The fact that this is feasible reflects the branding value of Green Building to companies and the emerging status of sustainable living in China.

The interview findings indicate a weak causality in general between Chinese financial policy incentives and Green Building project realisation. This raises the question of whether it is even meaningful to talk of economic efficiency: if the same energy savings would have occurred without any public spending, or with twice the current public spending, what's the efficiency?

In the particular case of Chenghuaxinyuan and the Four High award, the causality between the reward and the choice to go for Green Building standard can also be questioned, as that choice had already made when the project was rewarded. However, interview findings indicate that there is considerable negotiation between developers and local government for every major building scheme, where the issue of Green Building is being pushed by government, thus it cannot be ruled out that the Award has played a part as an incentive in this process, be it financial or brand-related.

Most of all, financial incentives such as the Four-High Award are granted as a reward and a sign of government's approval of a company's environmental conduct. It should be viewed in a wider context than just the bilateral relationship between the government and the single developer: it is a signal to the market as a whole, an indication of the government's intention. As such, it functions as an informative policy instrument as much as a market-based one. And the government's intention, in turn, *is* a strong driver for *all* developers. Seen this way, the Award might in fact be very cost-efficient, as a way to influence all developers by rewarding one. Analysing its economic efficiency from this perspective would require a more complex model than the simple CBA used in this paper.

4.3 Uncertainty: data and results

The study has generally been suffering from data quality problems. Since none of the authorities or developers that were contacted replied, no first-hand figures on Green Building projects, subsidies received or energy savings achieved could be obtained. The data on Chenghuaxinyuan retrieved from the MSc. thesis of Liu (2012) has been hard to verify, although some of it is supported by the presentations of the scheme that were found. On the other hand it is properly referenced and does not contain any particular outliers that would give grounds for questioning its credibility.

The assumption of 25% energy savings compared to contemporary business-as-usual residential construction is a difficult one. The general standard of living is rising tremendously, thus so is the total energy consumption. People are going from very low energy living to high energy living, and so it is hard to establish a baseline against which to measure savings. This is one of the key task currently engaging the Tongji Architectural Design Institute as well as the Shanghai Green Building Council: trying to establish a new acceptable baseline against which energy savings can be measured (Xueya, 2013).

Another problematic piece of data is the economic benefit of avoided socio-environmental externalities. The outcome of the CBA changes completely depending on which figure is used, as the sensitivity analysis shows. Greenpeace is an environmental organisation, not a university or research institute, and it publishes its own reports, which reduces the reliability of data. On the other hand, the figures of Hirschberg et al. (2004) on the effects of coal power production in the Shandong province in 1998 are 15 years old. The most reasonable assumption appears to be that Greenpeace's figures are acceptably reliable, and if biased then biased towards overstating external cost, which in that case further reinforces the conclusion that the Green Building measures taken in the Chenghuaxinyuan project are not beneficial enough from a societal point of view, and thus that the Four-High Award promoting them is an economically inefficient market-based policy instrument under current conditions. Then again, as also shown in the sensitivity analysis, this could change with a sharp rise in electricity price, which is not too unlikely an event ("Smart Grid Insights by Zpryme," 2012).

5 Conclusions, recommendations and further research

5.1 Conclusions

The economic efficiency of the Four High Community Award as a market-based policy instrument for Green Buildings in Shanghai, applied on the Chenghuaxinyuan housing scheme, is low. The benefit-cost ratio is 0,71, i.e. clearly unbeneficial, the internal rate of return is 3,1%, i.e. below any normal investment return target, and the net present value is -24,97 million yuan, i.e. a clearly negative result. If increased housing price is included as a cost the results are many times worse. See table 3.2.

The main reason for this is that the energy-related cost savings and avoided socio-environmental externalities considered in the study (i.e. in the specific housing project) are too small compared to the developer's incremental investment cost. This in turn depends firstly on the electricity price being too low, secondly on energy-saving measures not being far-reaching enough - the building envelope in Chenghuaxinyuan could still not be considered a low-energy construction by European standards – and thirdly on the system boundaries of the study. The Benevolent Scenario CBA indicates that a combination of somewhat bigger energy savings than assumed in the base case, combined with a 30% rise in electricity price, would improve economic efficiency tangibly, especially if a lower discount rate is used.

However, while socio-environmental benefits cannot yet pay for the incremental project costs of Green Building, some customers can. This explains why the project was realised, and why it is in fact benefial to society as well as developer: the residents pay many times over for the developer's incremental investment, which in turn generates socio-environmental benefits to society.

Also, if the impact of the Award on the market as a whole were to be considered, the outcome might be quite different. Serving as a signal of the government's intentions and a financial incentive for improvement, adressing all developers at the same time but only paying one per year, the Award possibly contributes to energy savings and emissions reductions in many projects, not just Chenghuaxinyuan. The economic efficiency of the policy instrument is then potentially much higher. A more extensive and complex CBA might determine this.

The net benefits to the residents of paying the extra price of a greener living by buying a home in Chenghuaxinyuan are none from a purely economic point of view: in fact they are negative. The cost-revenue analysis points to a loss of 6137,6 yuan per square meter and an internal rate of return of -14,6%. This in turn points to other considerations being more important than the strictly economic ones for the market segment targeted by the developer for this type of housing schemes, such as status and environmental concerns.

To the developer the net benefits of the extra investment resulting in a CGBL 3-star-rated houing scheme are tremendous. If the entire price premium related increase in revenues is attributed to it, the CRA points to a fantastic return on investment: a top net present value of 1939,6 million yuan and an internal rate of return of 2361,8%. Attributing a smaller portion of the price premium to the Green Building measures still leaves the with very large net benefits.

Interview findings indicate that fiscal policy incentives such as subsidies and awards are less important factors when Chinese real-estate developers consider Green Building. The desire and need for good relations to local government appears to be much more important. Hence, as stated above, the Four-High Award may be functioning as an informative instrument, conveying government intentions, as much as a fiscal one. Another major driver is branding regards: major developers want to claim leadership in Sustainable Architecture to the market.

5.2 Policy recommendations

The finding that increased energy savings might have achieved socio-economic feasibility in the case of Chenghuaxinyuan points to the possibility that tougher specific energy-saving requirements might enhance the economic efficiency of market-based Green Building policy instruments.

For example, if the Four-High energy award were conditional upon a maximum energy use of 30 or 25 kWh/m^{2}a, it might spur a race towards energy-efficient construction comparable to that in Europe. Given the generally much lower cost of construction in China (Zhang & Zhang, 2013), this should not be impossible.

Judging by the CBA, the economic efficiency of Green Building policies would be further improved if the suggested energy requirements were combined with raised electricity prices (see section 3.2.4, Benevolent Scenario), or a tax on fossil-fuel produced electricity coupled with a subsidy on renewable. In fact such a policy is already underway and to be introduced on September 25 2013 for some sectors, albeit not for residential housing ("China.org.cn," 2013).

The practice of basing energy efficiency requirements and standards on comparison to a baseline energy consumption, as is being done in the "Mandatory minimum design energy saving rate for newly-built buildings" regulation as well as in CGBL, is complicated, especially in a country where standards of living is changing so fast. The question of what is a reasonable baseline is currently putting some of the country's best experts to work. Why demand the extra calculation work of comparing with obsolete construction techniques? It would appear more practical and straightforward to set absolute requirements instead of relative ones, prescribing an actual maximum level of energy consumption for maintaining a given indoor temperature in each building category, as is the practice in most European countries. These levels - or the temperatures or both – might then be adjusted with the progress of development.

Today's Chinese construction regulation documents, design standards and guidelines are lengthy and complicated. A simplification would probably save time and money and enhance the penetration power of Green Building policies.

Finally, it is concluded that more transparency and better accessibility to authorities' and institutions' data and officials would strongly benefit research, development and Green Building progress in China.

5.3 Further research

The research questions of this study could well be investigated again just as they are and applying the same basic CBA and CRA methodology, given access to better data, preferrably first-hand information, on one or more housing schemes. Establishing good communication with "insider" stakeholders such as real-estate developers and housing, environment and energy authorities is a prerequisite for a more reliable result.

Better and more detailed data would also allow the use of finer analysis tools. For example, with detailed information on building service systems and their performance etc., the RET Screen software, issued by the Canadian government, could be used to conduct an investment risk analysis to complement the findings with another perspective.

As soon as the national and municipal subsidies for CGBL 2- and 3-Star rated buildings have been disbursed for some time, a similar study could be performed on their economic efficiency, to investigate the relationship between amount of support given and amount of energy saved, and any other patterns in their use and impact.

The economic efficiency of policy instruments such as the Four-High Award and the National Green Building Innovation Award could also be studied in a wider perspective, investigating and attempting to quantify its influence on Green Building practices on the market in general. If awards do in fact spur Green Building project decisions across the market, then the energy savings achieved there might be estimated and compared to costs, which might result in a very different conclusion regarding economic efficiency than the one in this study.

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Appendix I – Questionnaire

Energy efficiency measures and financial incentives in building projects
For the MSc. Thesis
"The Economic Efficiency Of Market-Based Green Building Policy Instruments In China"
by Albert Orrling, architect, MSc. candidate, Environmental Management and Policy.
International Institute of Industrial Environmental Economics, Lund, Sweden, www.iiiee.lu.se

1. General data on specific project

1.1 Name of the project:

1.2 Developer, owner:

1.3 Architect:

1.4 Contractor:

1.5 Type of project (retrofit/new construction, residential/commercial/public):

1.6 Project size (m^2):

1.7 Total investment cost:

1.8 Project start date:

1.9 Project completion date:

1.10 General description / other relevant information on the project:

2. Energy properties of the project

2.1 What is the (estimated) energy demand of the building(s)? (kWh/m^2a)

2.2 What heating and cooling technologies are applied in the project?

2.3 What are the power sources/fuels of those heating and cooling systems?

2.4 Approximate price of these energy sources/fuels in Shanghai today?

2.5 Environmental/energy rating or certification of the project (China Green Building Label/3Star, LEED, etc.)

3. Energy - incentives and measures:

3.1 Are any public financial energy efficiency incentives being applied in the project?

3.2 If so, which ones?

3.3 What energy savings measures are realized in the project due/related to these incentives? (extra insulation, better windows, HRV, heat pumps, district cooling, etc.)

3.4 Amount of financial support for each type of energy efficiency measure?

3.5 How much energy is (estimated to be) saved thanks to each (type of) measure?

4. Information on responding company

1.1 Name:

1.2 Established year:

1.3 Based in (city):

1.4 Operating in (cities, countries):

1.5 Business focus area (residential/commercial/public, retrofit/new construction/other):

1.6 Main business model (contractor / build and sell / build, own and let / other):

1.7 Number of employees:

1.8 Turnover:

1.9 Other relevant information:

Appendix II – CBA method

For the Cost-Benefit Analysis on MBIs, an Excel-based calculation tool was employed which was developed by Luis Mundaca and used in a study of the economic efficiency of Tradable White Certificates (an energy efficiency trading scheme) in the UK (Mundaca & Neij, 2009).

The tool calculates the economic efficiency of a policy programme comprising a bundle of energy saving measures, that adress various domestic uses of heat and electricity for space and water heating, lighting and appliances. From input data on annual energy savings per measure unit, number of units, measure lifetime and discount rate, the total annual energy savings per measure are calculated and discounted, yielding a series of slowly diminishing annual energy savings. These are multiplied with the price (user input, assumption) of the energy type in question for the specific measure, yielding an annual financial saving per measure.

The financial savings of all measures are added together for each year, yielding the total energy costs savings achieved by the policy programme in that specific year. The monetized value of total avoided socioenvironmental external costs is calculated by multiplying energy savings with assumed socioenvironmental external cost per energy unit consumed (user input), yielding the Net Benefit of the programme for each year.

The cost of the policy programme is calculated as an initial, one-time expense, comprising the sum of the investment costs of the obliged parties of the programme with added transaction and administrative costs, investment costs for other entities, customer investment cost, and the administrative costs for the policymaking authority itself. Investment costs are entered as input by the user, as is the authority's administrative cost, while obliged parties' transaction and administrative costs are calculated as percentages of their investment costs. The result is the Total Cost of the policy programme.

The total cost is inserted as the first in a series of annual payments, the following payments being the net benefit (of energy savings) of each subsequent year. From this payments series, the economic efficiency of the programme, as internal rate of return, net present value and benefit-cost ratio, is calculated by standard formulae, in the latter two cases using a discount rate set by the user.

The tool also calculates the cumulative cashflow and the cumulative discounted costs and benefits of the programme, using the same series of annual payments.