Energy-Efficient Buildings – a Business Case for India?

An analysis of the incremental costs of four building projects for the *Energy-Efficient Homes* Programme

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Executive Summary

Globally, energy needs are continually on the rise. With decreasing amounts of fossil fuels and their negative environmental impacts, energy conservation has become a central aspect of the transition towards a sustainable global economy. In most countries, the building sector is one of the largest consumers of energy. Not only have industrialised countries become aware of the importance and potential of energy-efficient building design, but more and more, developing and emerging economies are seeing the need for more energy conservation in the building sector. India is making efforts to incorporate energy-efficient building design into newly constructed building stock. However, the belief still exists among stakeholders that energy-efficient buildings are more expensive than conventional buildings, which adversely affects the "greening" of the building sector.

This report argues that energy-efficient buildings are not more expensive than conventional buildings when considering the costs of the entire life cycle of the building. On the contrary, the life-cycle-cost analyses conducted in the study prove that incorporating energy conservation measures into the building design even creates a cost benefit.

The study compared construction and life-cycle costs of energy-efficient residential multi-family buildings (actual cases) that were constructed under the *Energy-Efficient Homes* Programme with those of reference buildings with the same parameters. The analysis is based on results of the En-Eff:ResBuild energy performance assessment tool. Within the actual buildings, several passive and active energy conservation measures were implemented, such as insulated walls, double glazing, efficient air conditioners and solar water heaters.

The main findings of the study show that,

- **The EE buildings achieve energy savings of up to 36% compared to the reference buildings, resulting in energy-cost savings of up to 7.48 million Rs. (ca. € 100,000 / $ 120,000) over a time span of 15 years**
- **Incremental construction costs for the energy-efficient buildings analysed are, with 0.8 – 2.8%, only marginally higher than those for conventional buildings;**
- **The life-cycle costs for all the energy-efficient buildings analysed are substantially lower than those of conventional buildings (up to 1.6% of investment costs).**
- **Most of the passive energy conservation measures focusing on the envelope have only minimally higher incremental costs, except for more efficient glazing, which is substantially more expensive;**
- **Active energy conservation measures (appliances) such as air conditioners and solar water heaters are quite cost intensive;**

Acknowledgements

The initial study underlying this publication has been developed under the Promotional Programme for New Energy-Efficient Residential Buildings in India, funded by the German Federal Ministry for Economic Cooperation and Development and commissioned by the KfW development Bank in 2010. KfW is assisting the National Housing Bank of India (NHB) in the establishment of the *Energy-Efficient Homes* Programme, under which NHB will refinance loans for energy-efficient buildings. This publication is a distillation of the findings from the research on the incremental costs of four building projects constructed in India under the *Energy-Efficient Homes* Programme.

We would like to extend our sincere thanks to our project partner Environmental Design Solutions for their cooperation over recent years. Moreover, we are very grateful to NHB for the their input into this study, which helped immensely in shaping this publication.

Last but not least, we would like to thank KfW Development Bank and the Federal Ministry for Economic Cooperation and Development for funding the *Energy-Efficient Homes* Programme and thus enabling us to gather data for this study.

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List of Abbreviations

AAC	Autoclaved aerated concrete
AC	Air conditioner
BOQ	Bill of quantities
CO2	Carbon dioxide
CPWD	Central Public Works Department
DPP	Discounted payback period
ECM	Energy-conserving measures
EDS	Environmental Design Solutions
EE	Energy efficiency
EER	Energy-efficiency ratio
EPI	Energy-Performance Index
EUR	Euro
IT	Information technology
KfW	Deutsche Kreditbank für Wiederaufbau
kWh	Kilowatt hour
LCC	Life-cycle cost
LCCA	Life-cycle cost analysis
mm	Millimetres
NHB	National Housing Bank of India
OM&R	Operational, maintenance and repair
PV	Present value
Rs	Rupees
SHGC	Solar heat gain coefficient
Sqm	Square meter
SWH	Solar water heater
TERI	The Energy and Resources Institute
VRF	Variable refrigerant flow
W	Watt

1 Introduction

Buildings account for 35% of total final energy consumption in India and building energy use is growing at a rate of 8% annually (Yu et al., 2014). Residential buildings make up for 75% of the entire construction market in India (EIU 2013) and were responsible for 20.4% of India's total electricity consumption in 2012. Rising population and increasing urbanisation, together with scarcity of land in urban areas, has resulted in an increasing demand for newly-constructed multi-story buildings in India. Consequently, projections show that by 2032 the total electricity consumption of the residential building sector will increase to 36.4% (BEE 2014). Thus energy efficiency (EE) in the residential building sector has become an increasingly important issue and an imperative one in India.

Notwithstanding its importance, the issue of energy efficiency specifically in residential buildings is still considered sceptically by many of the relevant stakeholders in India. Energy-efficient buildings are considered as being more expensive than conventional buildings and the level of awareness of the benefits of energy efficiency is still low. Moreover, in other countries the perception that energy-efficient buildings are much more expensive is one of the major barriers to build more energy-efficient buildings (Hunt 2008). Conversely, as a wide range of studies have shown, energy-efficient and even low-energy buildings can be constructed at little or no extra costs (Harvey 2009; Hunt 2008).

Extra costs for EE buildings are commonly referred to as "incremental costs" and consist of the differences in costs that occur when constructing an energy-efficient building instead of a non-efficient reference building. It has to be noted that incremental costs strongly depend on the country's situation. In some countries energy-efficiency technology is well advanced and prices have decreased, whereas in other countries the technologies are not locally available and prices are still high. Another factor that has a substantial influence on incremental costs is subsidies. This includes subsidies for technologies, e.g. tax benefits, which have a positive effect on the incremental costs. Energy subsidies on the other hand, which are common in many developing countries, have a negative effect on incremental costs as they reduce and distort the energy prices and make energy-efficiency measures less profitable.

The issue of the incremental costs of energy-efficiency measures in buildings is one that has been thoroughly discussed among energy experts and construction practitioners. While some argue that the premium on ECMs is not being recovered by the financial benefits of the energy savings, others claim that investing in ECMs not only has a positive impact on the environment but also saves the homeowner a substantial amount of money in the long run. Several studies identified cost premiums of 1% to 7% for low-energy buildings, in which most cases had a cost premium of lower than 4% (Hunt 2008). Studies also showed that conventional energy-efficiency measures are sufficient to reduce energy use by 20-30% on average (Kneifel 2010). While more ambitious energy-efficiency measures have higher incremental costs, as Tolkin, Blake et al. (2008) concluded, they generally yield higher energy savings and thus cost benefits. However, it is crucial not only to look at the initial incremental costs for the construction of buildings but also to consider the costs and cost benefits of ECMs over the entire life cycle of a building. Even the more advanced and expensive technologies are apparently more likely to be cost effective if calculated over the entire life cycle of the building. The longer the time horizons are, the more ECMs turn out to be cost effective, since much of the future cost benefits of a building are overlooked in short time horizons (Kneifel 2010).

Given the highly-disputed issue of cost effectiveness of energy-efficiency measures, adelphi and TERI undertook an analysis of the incremental costs of several of the building projects certified under the NHB KfW *Energy-Efficient Homes* Programme (see figure 1 below). The aim was to assess the economic feasibility of energy-efficient buildings under the programme. The cost effectiveness of EE measures in the Indian context where conditions are not generally comparable to those in the developed world was analysed.

Knowing incremental costs of energy-efficient buildings is important from two perspectives:

(1) Costs for EE measures occurring at the construction stage are particularly relevant for the investors of buildings, since their overall goal is to build in a cost-efficient way and construction developers bear the extra costs for EE measures.

(2) From the apartment owners/users and also from a macroeconomic point of view, it is more relevant not only to know about the incremental costs in the construction phase, but also to look at the incremental costs over the entire life cycle of the building. Future streams of benefits arising from energy savings need to be included in the assessment of life-cycle costs of buildings in order to evaluate the economic viability of investments made towards improving the energy performance of buildings.

Given these two perspectives on incremental costs from different stakeholders, the study tries to answer the following key questions:

a) How high are the incremental costs for energy-efficiency measures at the construction phase in the four selected building projects, compared to a business-as-usual baseline case?

b) Are the EE measures cost effective over the life cycle of the buildings?

Figure 1: The Energy-Efficient Homes Programme

The *Energy Efficient Homes* Programme

On behalf of the German Ministry of Economic Development and Cooperation, the *KfW Entwicklungsbank* provided a line of credit of EUR 50 million to the *National Housing Bank of India (NHB)* to promote energy efficiency in the residential building sector in India. This credit line was used by NHB for refinancing individual homebuyer loans for new energy-efficient residential housing under the *Energy-Efficient Homes* Programme. Apartments eligible for refinancing had to meet a minimum standard of 30% improvement in energy efficiency compared to benchmark buildings. Projects meeting the target received an official certificate under the programme.

At the end of 2013 the full amount of the credit line had been disbursed for refinancing of more than 1,900 individual home loans. 15 Indian construction projects, including 443 individual buildings, were evaluated and optimised in terms of their energy requirements. With the continuous reliance on coal-based power generation in India, these 15 projects save up to 37,000 tons of CO2 emissions annually.

adelphi was commissioned, together with two Indian partners, The Energy and Resources Institute (TERI) and Environmental Design Solutions (EDS), to provide technical assistance in implementing the line of credit.

Structure of study

The study addresses both of the above-mentioned key questions, using the following structure:

Section 2 illustrates the methodology of this study. The reference case and the energy efficient case are described and general assumptions are stated. Furthermore, the different parameters, data sources and the formulas used for calculations are illustrated.

In section 3, the results of the analysis are presented. First, the incremental costs of EE building construction are illustrated for the four selected building projects, including their different incremental costs for various energy-conserving measures (ECMs). Secondly, the life-cycle costs for the certified buildings and their reference cases are illustrated and compared. This comparison allows for the calculation of payback periods of the EE investments that are presented.

The summary and outlook in section 4 summarises the key results and findings of this study.

2 Methodology

General Approach

This study analyses four building projects certified under the *EE Homes* Programme and having integrated different ECM. These projects and the implemented ECMs are presented in table 1 below:

Table 1: ECMs used in the projects that added to the incremental capital investments

Building A (Moderate climate)	• Use of autoclaved aerated concrete (AAC) block instead of brick masonry for walls • Roof insulation and reflective paints on the roof • Use of 6 mm reflective glass
Building B (Composite climate)	• Use of AAC block instead of brick masonry for walls • Roof insulation and reflective paints on the roof • Use of 6 mm reflective glass • Provision of solar hot water systems • Provision of 4-star AC
Building C (Warm & humid)	• Use of AAC block instead of brick masonry for walls • Roof insulation and reflective paints on the roof • Use of 6 mm reflective glass • Provision of solar hot water systems • Provision of 4-star AC
Building D (Composite climate)	• Use of AAC block instead of brick masonry for walls • Roof insulation and reflective paints on the roof • Use of 6 mm reflective glass

In order to calculate the incremental /additional costs for constructing an EE building, the overall costs for the actually constructed energy-efficient buildings, i.e. the actual case, were compared to the costs of the benchmark buildings, i.e. the "reference" case. Both the costs of the construction itself and the costs taken over the entire life cycle of the building were assessed. For the calculation of the costs taken over the entire life cycle of a building, a life-cycle cost analysis (LCCA) was applied. An LCCA considers all costs (construction costs, energy costs, operating and maintenance costs) that occur over the life cycle of a building and subtracts the residual value of the building at the end of the life cycle.

For this study 15 years were assumed for the life cycle, which is a very conservative assumption, since the usual life cycle of a building is closer to 25-50 years.

Estimation of energy savings for the life-cycle analysis

For the life-cycle analysis, the energy consumption and thus the associated costs of the energy efficient building were compared with those of the reference case. Hence the amount of energy saved through the ECMs during a life cycle (15 years) of the building had to be estimated. To estimate the energy consumption of both the EE and the reference case and thus calculate the savings, an assessment approach was applied using specific software developed for the *Energy-Efficiency Homes* Programme. More information regarding the software IT toolkit can be found in figure 2. The software allows the user to enter data and the parameters of the building construction and the energy conservation measures, and hence to calculate the energy demand of the building and compare it to a reference building. The parameters of the reference buildings (as of the IT Toolkit) can be found in the Annex.

Figure 2: The Fraunhofer/TERI IT toolkit

The Fraunhofer/TERI IT Toolkit

In 2010 KfW initiated a collaboration between the Fraunhofer Institute for Building Physics and The Energy and Resources Institute (TERI) in New Delhi to adapt an existing German calculation model for the energy assessment of buildings to the conditions in India. The result of the collaboration was an IT toolkit that is used to evaluate the energy performance of buildings within the *Energy-Efficient Homes* Programme in the certification process. The Fraunhofer Institute and TERI IT toolkit calculates the energy need of a building as a whole and the potential savings offered by active and passive energy-efficiency measures based on the building design. The IT toolkit allows the user to enter data for the parameters of the building project being assessed, key features of the building envelope such as geometry, orientation and building materials, and data on the technologies used for space cooling, heating, lighting and hot water. The tool thus allows assessment of the impact of various energy-efficiency measures on the energy performance of the building.

Besides information on the national benchmark for energy use in the residential sector in India, the toolkit includes case studies on energy-efficient residential buildings and provides information on selected energy-efficiency technologies.

Data source

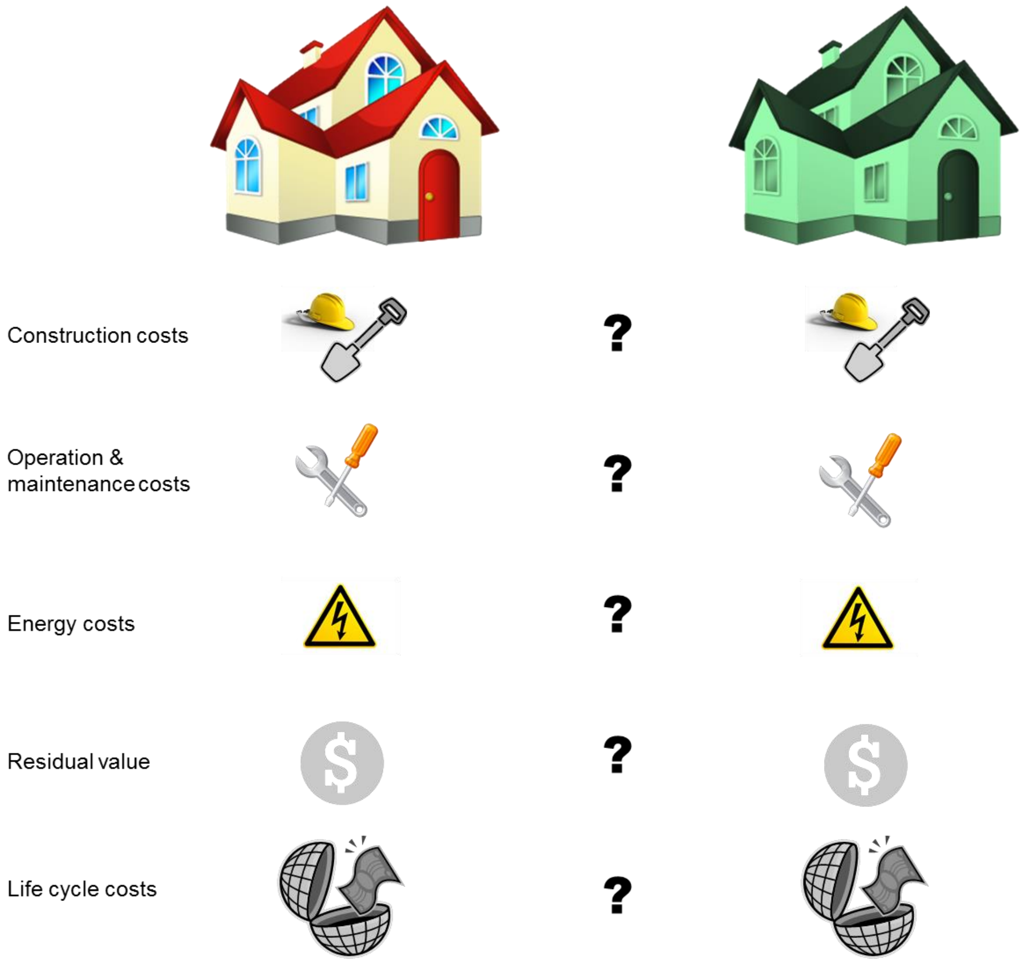
For the calculation of the life-cycle costs, four different types of costs are considered, i.e. (1) construction/ investment costs, (2) energy costs, (3) operating, maintenance and repair costs, and (4) residual costs, which are derived from specific data sources. Table 2 provides a summary of the data of these four different cost categories:

Table 2: Data specification of different types of costs

	Energy efficient case/ Reference case
Construction costs / investment costs	Central Public Works Department (CPWD) plinth-area rates and schedule of rates, market rates for components such as SWH and AC.
Energy costs	Average tariff rates for the domestic sector.
Operating, maintenance, repair costs	Assumed to be 2% of the capital costs per year (based on discussions with experts from the sector).
Residual costs	Residual costs describe the remaining (discounted) value of the initial investment cost (excluding the land cost) at the end of 15 years. It is assumed to be 6% of the initial investment cost, which increases by about 8% per year.[1]

[1] This information was provided by financial experts.

Figure 3: Costs of energy efficient and reference buildings compared in the study



3 Results – Incremental and Life-Cycle Costs

3.1 Incremental costs for construction of EE buildings

The results of the assessment of the incremental construction costs of the four projects are presented in table 3. Besides the initial incremental construction costs of the four EE buildings, the table indicates the combined energy savings achieved through the implemented ECMs, as well as the energy consumption per square meter per year.

Table 3: Results of incremental cost analysis

Building name	Cases	EPI (kWh/m2/yr)	Energy Savings	Construction costs in million Rs.	Incremental construction costs
Building A	Reference case	71	-	Rs 123.74	-
	Energy efficient case	55	23%	Rs 124.77	0.9%
Building B	Reference case	69	-	Rs 184.89	-
	Energy efficient case	44	36%	Rs 188.50	2%
Building C	Reference case	95	-	Rs 123.94	-
	Energy efficient case	65	32%	Rs 127.27	2.8%
Building D	Reference case	102	-	Rs 231.95	-
	Energy efficient case	82	20%	Rs 233.75	0.8%

The implementation of the ECMs in the projects resulted in energy savings of 20% to 36%. Energy savings for all four projects were achieved by implementing measures that lead to only slightly higher construction costs. It should be noted that the buildings B and C caused the highest incremental investment costs – with 2% and 2.8% respectively – but at the same time also achieved the greatest energy savings (36% and 32% respectively).

The following table (table 4) gives a detailed overview of the incremental costs for each energy conservation measure implemented in the projects studied (compared to the reference case). When added up, they constitute the total incremental construction costs for each project.

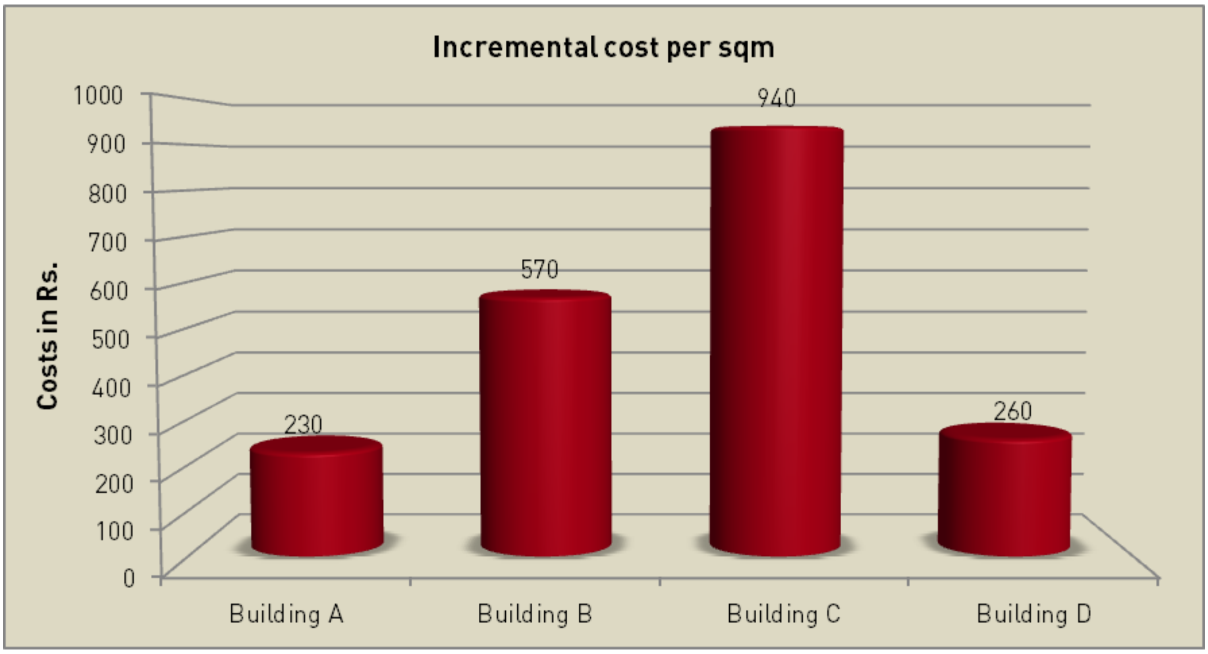
Table 4: Overview of incremental costs of ECMs in the studied building projects

	ECM	Building A	Building B	Building C	Building D
Wall	**Incremental costs for better insulation through AACs**	Rs. 79,454 (1.13 %)	Rs. 37,952 (1.13 %)	Rs. 83,256 (1.13 %)	Rs. 56,217 (1.13 %)
Roof	**Insulation of roof**	Rs. 31,703	Rs. 49,882	Rs. 36,580	Rs. 57,105
	Reflective paint	Rs. 44,997	Rs. 70,800	Rs. 51,920	Rs. 81,052
Glazing	**Incremental costs for better glazing**	Rs. 1,134,784 (131.6 %)	Rs. 833,208 (131.6 %)	Rs. 1,635,424 (131.6 %)	Rs. 833,065 (131.6 %)
Solar water heaters	**Costs for SWH**	Rs. 638,000	Rs. 660,000	-	-
ACs	**Incremental costs for ACs better than 1 star**	Rs. 1,680,000 (28 %)	Rs. 1,680,000 (28 %)	-	-
Overall in-cremental costs	**Total**	Rs. 3,608,938	Rs. 3,331,842	Rs. 1,807,180	Rs. 1,027,438

It can be observed that the incremental costs for using energy-efficient AAC blocks are very low. Incremental costs of roughly just 1% have to be invested when using AAC instead of conventional blocks. Costs for improving the EE of the roof and using reflective paint are also quite small, whereas costs for more energy-efficient glazing are rather substantial. Providing solar water heaters and energy-efficient ACs is also quite cost intensive.

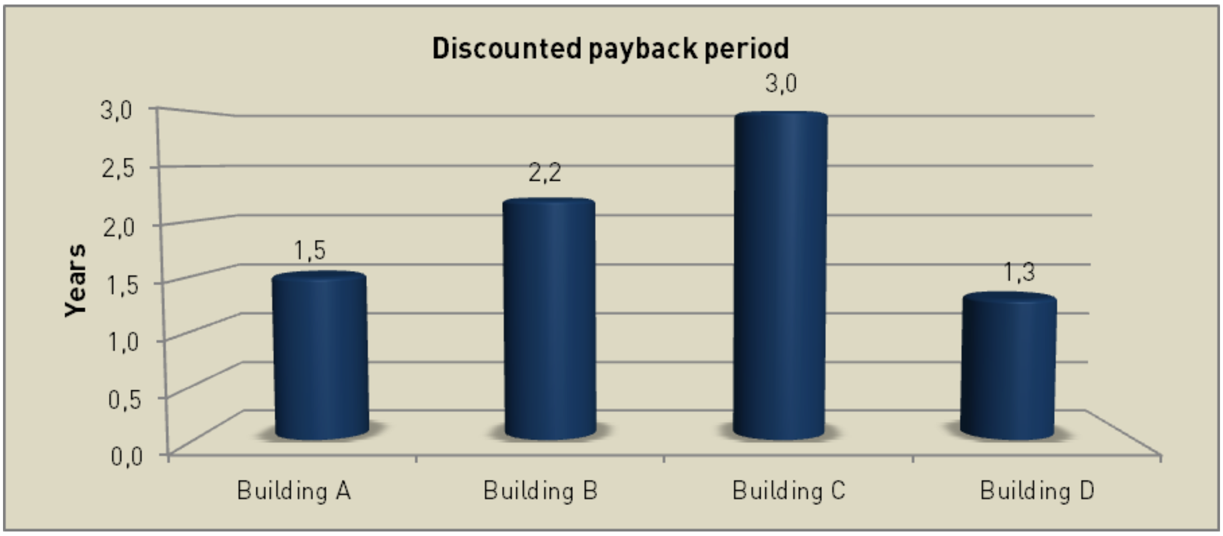
If further analysis is conducted regarding the incremental capital costs incurred per square meter (sqm) in the case of an energy-efficient building versus a conventionally built building, it can be observed that the incremental costs per sqm range between Rs. 230 and Rs. 940 in these four projects studied (please see figure 4). The average selling price of residential apartments in Class 1 towns and cities (more than 100,000 citizens) in India is 55,000 Rs/sqm. Hence, the incremental costs compared to the selling price are negligibly low.

Figure 4: Incremental costs of the different studied buildings



In addition, the discounted payback periods (DPPs) for the ECM per building project were calculated. The DPP refers to the time required to recover the initial incremental investment through the discounted future savings (of all the ECMs implemented in the building) while considering the value of money over time. To calculate the DPP, the present values of annual savings are accumulated until they equal the initial incremental investment. When using DPPs as an assessment criterion, an investment is profitable if its discounted payback period is shorter than the life of the product. The following figure shows that all the four cases have a DPP between 1.3 to 3 years.

Figure 5: Discounted payback period of studied projects



3.2 Life-cycle cost analysis for EE buildings

While the initial incremental costs of the construction provide only a momentary picture of the cost analysis of energy-efficiency measures, a life-cycle cost analysis of the incremental costs considers the monetary benefits of energy savings over the lifetime of the building. The following table (table 5) gives an overview of the life-cycle costs of the energy efficient case and the reference case, breaking down the life-cycle cost into the four types of costs defined earlier.

Table 5: Overview of different costs and overall LCC of the four projects in million Rs.

Building name	Case	Investment costs	Energy costs over life cycle	O&M and repair costs over life cycle	Residual value at the end of life cycle	Overall LCC
Building A	Reference case	Rs. 123.74	Rs. 15.06	Rs. 20.04	Rs. 6.54	Rs. 152.30
	Energy efficient case	Rs. 124.77	Rs. 11.66	Rs. 20.21	Rs. 6.59	Rs. 150.05
Building B	Reference case	Rs. 184.89	Rs. 20.64	Rs. 27.22	Rs. 7.78	Rs. 224.96
	Energy efficient case	Rs. 188.50	Rs. 13.16	Rs. 27.75	Rs. 7.94	Rs. 221.47
Building C	Reference case	Rs. 123.94	Rs. 16.01	Rs. 18.24	Rs. 5.22	Rs. 152.98
	Energy efficient case	Rs. 127,27	Rs. 10,96	Rs. 18,73	Rs. 5,36	Rs. 151,60
Building D	Reference case	Rs. 231,95	Rs. 33,32	Rs. 34,14	Rs. 9,76	Rs. 289,65
	Energy efficient case	Rs. 233,75	Rs. 26,79	Rs. 34,41	Rs. 9,84	Rs. 285,11

In all cases it can be observed that the LCC of the energy-efficient building is lower than the LCC of the same building built with conventional construction practices. The overall savings realised in the four energy-efficient buildings more than compensate for the initial incremental costs incurred by incorporating ECMs in the buildings' construction, as can be seen in figure 6 below.

Figure 6: Comparison of overall savings and initial incremental costs

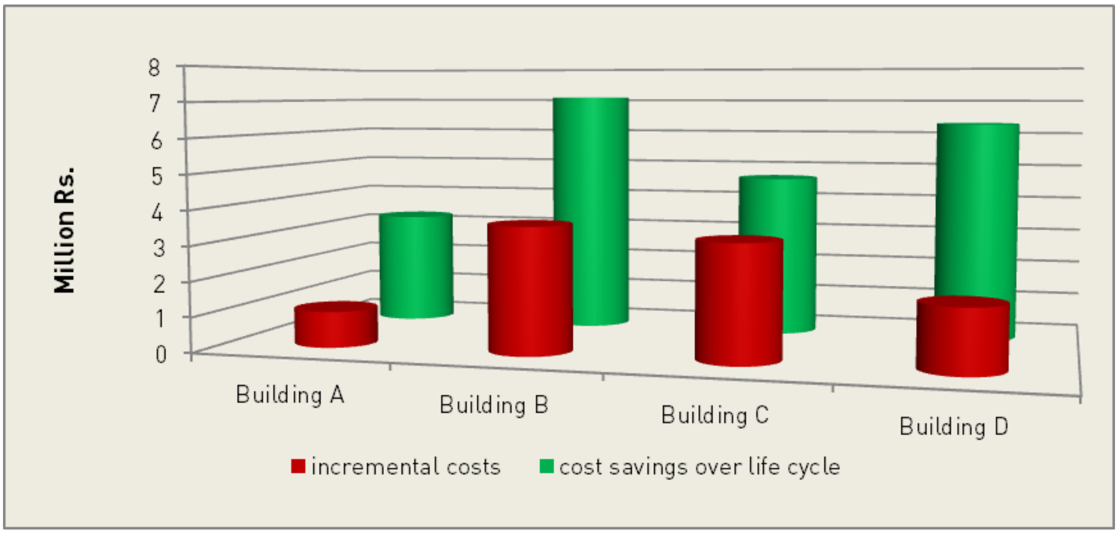
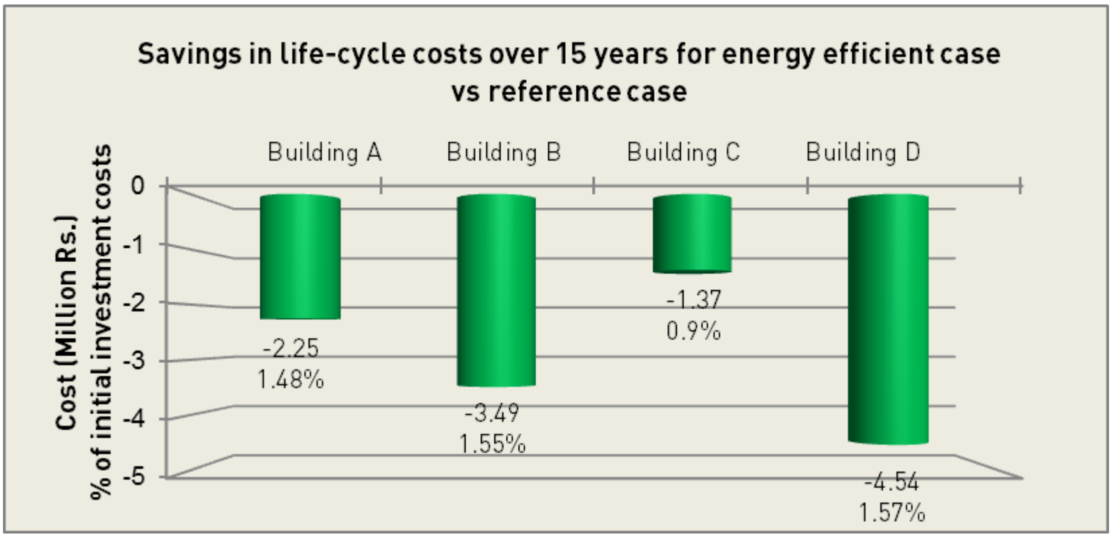


Figure 7 summarises the comparison between energy-efficient cases and their respective reference cases with regards to LCCs for the four case studies, both in terms of overall Rupees as well as in percentage related to investment/construction costs.

Figure 7: Savings in life-cycle costs for EE vs reference case



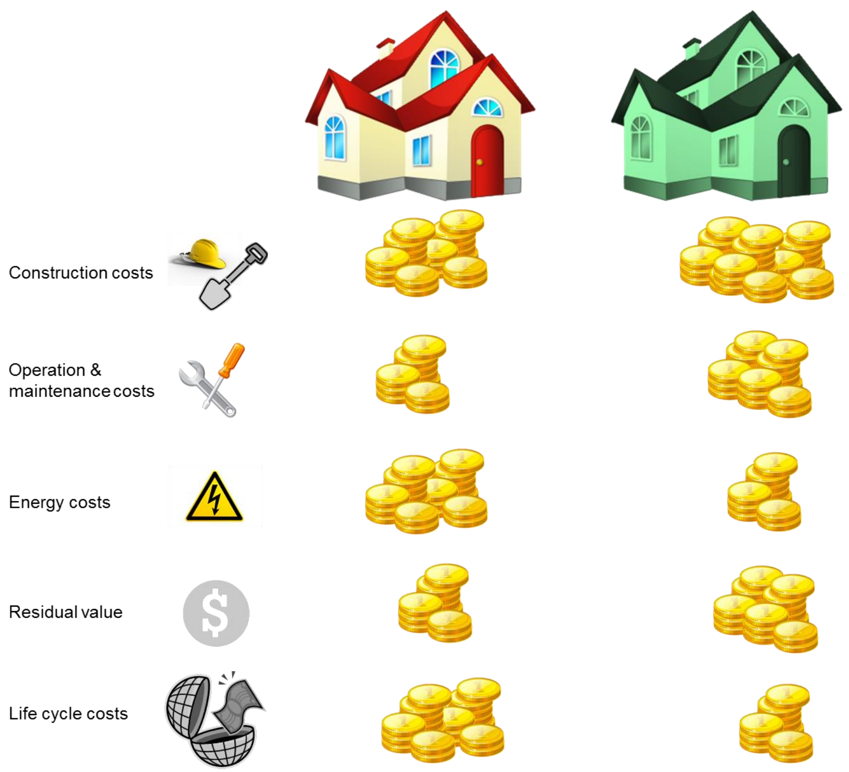
4 Summary and Outlook

The results of this study show that investing in EE buildings is a profitable venture. With the financial analysis tools used for evaluating the economic feasibility of the selected four projects, all the energy-efficient buildings have proved to be financially attractive over their life cycle.

The analysis of the initial incremental costs of the four energy efficient cases showed that although the construction costs are more expensive, the cost premiums for the ECMs are only in the range of 0.8 and 2.8% compared to the reference cases. These cost premiums are at the lower end of the international cost calculations stated in different literature. The incremental costs for applying more energy-efficient insulation with AAC blocks for walls, using reflective paint and improving the insulation of the roofs are relatively small, while EE glazing is much more expensive. Similarly, solar water heaters and efficient ACs are quite cost intensive. However, the total incremental investment costs of the EE case over the reference case are in the range of 230-940 Rs/sqm, which is very low, compared to an average selling price of 55,000 Rs/sqm. With incremental costs ranging between 0.8 % and 2.8 % of the initial capital investment, the discounted payback periods are notably attractive, ranging between 1.3 and 3 years.

Considering the incremental costs over the entire life cycle of the building (15 years was used for the calculations), the ECMs result in surpluses in all four cases. Savings of up to 1.6% of the initial investment costs of the reference case are possible. That translates into savings of up to Rs. 4.5 million (~50,000 EUR). This is due to the substantially reduced energy consumption in the EE buildings. Cash savings accrued from the energy-efficient apartments over 15 years not only compensate for the initial cost increments but provide benefits to the owners throughout the lifetime of the building. Thus, over the lifespan of 15 years an energy-efficient building turns out to be significantly cheaper than a conventionally constructed building. Moreover, it should be mentioned that the energy consumption of the EE buildings was only estimated for the LCCA. Monitoring, however, has shown that the real energy savings of the actual (EE) cases are even higher than the estimates of the IT toolkit.

Figure 8: Summary of results



Also, the life-cycle period (15 years) is quite conservative[2]. Hence the savings over the actual life cycle might in fact be even larger.

Nevertheless, in the developer-driven (residential) market, there is the added issue of split incentives, in that the developer bears the incremental construction costs but the dividends gained through conserved energy are reaped by the home owners/tenants. Based on the assumption that homebuyers are aware of the benefits of EE buildings, developers could charge a premium for the higher costs of constructing an energy-efficient building and thus forward the initial incremental costs to the buyer who eventually benefits from the energy-cost savings. However, apartment buyers are often times not aware of the benefits of energy-conservation measures and are thus also not willing to pay the premium for the more energy-efficient buildings or apartments.

The fact is, however, that both developers and homebuyers need to accept the initial higher costs for ECMs, which for different reasons both sides are still reluctant to do in many cases, particularly in India. This remains one of the key barriers in the energy efficient construction market. However, this obstacle can be overcome with enhanced awareness, incentive schemes, policy support, and other measures for promoting energy efficiency among the buyers and the general public. It is crucial to create an enabling environment for energy efficiency in buildings that encourages the dissemination of efficient construction practices in India. One possible way of creating awareness for EE in buildings is the introduction of labels that inform potential buyers of apartments and buildings about the energy-efficiency level of that real estate. This could at the same time create an incentive for developers to construct more efficient buildings, as it improves their reputation and publicity.

[2] Please remember that the actual life span of a building is closer to 25-50 years, but 15 years was used for the calculations in this study.

Bibliography

Economist Intelligence Unit (EIU) (2013): *Achieving scale in energy-efficient buildings in India: A view from the construction and real estate sectors*. Commissioned by the Global Building Performance Network. August 2013

Harvey, L. D. (2009): Reducing energy use in the buildings sector: measures, costs and examples. *Energy Efficiency* 2 (2), p. 139-163.

Hunt, W. D. (2008): *Literature Review of Data on the Incremental Costs to Design and Build Low-Energy Buildings*. Pacific Northwest National Laboratory (PNNL). May 2008.

Kneifel, Joshua (2010): Life-cycle carbon and cost analysis of energy-efficient measures in new commercial buildings. *Energy and Buildings* 42 (3), p. 333-340

Tolkin, Betty M.; Blake, William; Bonanno, Stephan; Conant, Dorothy; Mauldin, Thomas; Hoefgen, Lynn (2008): *How Much More Does It Cost to Build an ENERGY STAR® Home? Incremental Cost Estimation Process*. Summer Study on Energy Efficiency in Buildings.

Yu, Sha; Evans, Meredydd; Delgado, Alison (2014): *EE.* Pacific Northwest National Laboratory (PNNL). March 2014

Bureau of Energy Efficiency (BEE) (2014): Design Guidelines For Energy-Efficient Multi-Story Residential Buildings. New Delhi. August 2014

Annex: Reference-building parameters

For the reference case, the tool includes pre-defined values for the building envelope and systems that represent the common building practice for urban residential housing construction. In order to calculate and certify an actual "energy-efficient building", the assessment-tool user enters all active and passive energy-efficiency measures applied in the building. Through the tool, the energy consumption of the reference case and of the actual energy-efficient building are simultaneously calculated and compared.

The reference case in the tool, against which the actual building is assessed, is currently defined as:

Building Envelope

- External wall
  - Conventional external wall
  - U-value 1.57 W/(sqm K)
- Roof
  - Flat roof (conventional roof)
  - U-value 1.77 W/(sqm K)
- Floor (floor of the lowermost apartment)
  - Lowest level apartment floor
  - U-value 2.03 W/(sqm K)
- Glazing
  - Single clear
  - U-value 6.17 W/(sqm K)
  - SHGC (solar heat gain coefficient) 0.81
- Window frame
  - Aluminium without thermal break
  - U-value 13.51 W/(sqm K)
- Shading by overhangs and fins
  - SHGC (solar heat gain coefficient) 0.9

Lighting

Lighting power density for the general lighting scheme will be taken as 7.5 W/sqm for the apartment area, 6.5 W/sqm for common-area lighting and 2.2 W/m² for parking-area lighting.

No occupancy/ daylight controls

Lighting operation schedule – 06:00-09:00 in the morning, 17:30-23:00 in the evening, 60 % diversity

Space Cooling

The base case cooling system will be a BEE 1-star-rated product, having a minimum

EER of 2.5 W/W for decentralised cooling systems.

A central (VRF) system will have an EER of 3.9, as a star rating is not yet available.

Cooling operation schedule - 8 hrs/day, 70 % diversity, 1st May - 15th October

Cooling set point temperature - 25°C

Space Heating

There is no difference in space heating in the reference building.

Hot Water System

The hot water systems have been left as they are, except for the electric geyser, which will have a BEE 1 star rating.

If the actual building has a SWH, it will be removed in the reference building.