

**A DECISION TOOL AND GUIDELINES  
FOR ENERGY RETROFIT OF EXISTING  
BUILDING ENVELOPE**

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**DEPARTMENT OF CIVIL ENGINEERING  
INDIAN INSTITUTE OF TECHNOLOGY DELHI  
OCTOBER 2018**

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FOR ENERGY RETROFIT OF EXISTING  
BUILDING ENVELOPE**

by

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(DEPARTMENT OF CIVIL ENGINEERING)

Submitted

In Fulfilment of the requirements of the Degree of Doctor of Philosophy  
to the



**INDIAN INSTITUTE OF TECHNOLOGY DELHI**

**OCTOBER 2018**

## **CERTIFICATE**

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This is to certify that the thesis titled “**A DECISION TOOL AND GUIDELINES FOR ENERGY RETROFIT OF EXISTING BUILDING ENVELOPE**” by **Ms. Bandana Jha**, to the Indian Institute of Technology, Delhi for the award of the Degree of the “**Doctor of Philosophy**” is a record of bona fide research work carried by her under my guidance and supervision. The research material and the results contained in the present form of the thesis have not been submitted in part or full to any other University or Institute for the award of any other Degree or Diploma to the best of my knowledge.

Dated: 23<sup>rd</sup> October, 2018

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## **ACKNOWLEDGEMENTS**

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I express my deep gratitude to my supervisor, **Prof. B. Bhattacharjee**, Department of Civil Engineering, IIT Delhi for his keen interest, dynamic supervision and constructive guidance during the course of this thesis. The technical input provided by faculty Prof. K.G.Sharma, Prof. Shashank Bisnoi and Prof. Sanjeev Jain during the thesis is also duly acknowledged. I am also indebted to Director, IIT Delhi and Head of the Department, Civil Engineering for providing necessary facilities in completing this work. I wish to thank the IIT Delhi Library, Central Computer Services, Computation lab in charge JTS. Mr. Amit Bundela and Office in charge Rajeev Agarwal for their resource support. I extend my sincere thanks to my colleagues Dr. Kaustav Sarkar, Dr. K.K.Jain, Dr. Meenakshi Sahu, Dr. Seema Devgan, Mr. S.K.Dhawan, Mr. Ravinder Tewatia, Ms. Shraddha Deshpande, Mr. Nabeel Khan, Ms.Vandana Padmanabham and Mr.Suresh Padala for their motivation and technical inputs. Special thanks to my husband Mr. Rajiv Mishra for being patient and providing me with all the support to carry on with the thesis work. I'm also very grateful to my Mother Mrs. Manju Jha, my Father Ar. Suresh Jha and Sisters Ar. Manisha Jha and Ar. Puja Jha for their inspiration and strong encouragement. I'm also thankful to my children Capt. Surabhi Mishra and Vikramaaditya Mishra for being my strength. Finally, and most importantly, I express my gratitude to God for inspiring me to take up this Research to facilitate Mankind.

**Bandana Jha**

23<sup>rd</sup> October 2018, New Delhi

## **ABSTRACT**

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This thesis attempts to develop a Decision Tool and Guidelines for Retrofitting of Existing Building Envelope for energy efficiency. The Tool has been developed on the commonly available MS-Excel spread-sheet platform where, CIBSE Admittance Method has been used to calculate cooling loads. Presently, for the purpose of this tool development the weather conditions of three major climatic zones of India, i.e. Hot and Dry, Warm and Humid and Composite climatic zones have only been considered.

The thermal properties of envelope systems of existing buildings in combination with retrofitting options and their costs are the most important constraints for decision making.

Basic building information like climatic location, occupancy type, age, area, dimensions, and envelope construction types are input / selected from drop down menus, data for which is pre-fed in the tool. Initial, Maintenance and life cycle cost analysis along with their Net Present Value based on energy savings for all viable options are automatically calculated and best solution in each category suggested to the user as the tool Output. The Tool has been demonstrated on three buildings as trial case run in the three climatic zones of India using the weather data of Delhi, Mumbai and Jodhpur. The Tool Results of the Energy Retrofit solution for Trial Project-1 a Five Star Hotel in Delhi have been validated using eQUEST an established energy simulation software.

Furthermore, Regression Models have been developed based on tool results, involving energy saving as a function of decremented  $U$ ,  $\alpha$  and SHGC Values which will enable the users to choose the starting  $U$ ,  $\alpha$  and SHGC Values for various envelope retrofitting options. For Technically oriented users these models could also provide a Generic Guideline for Predicting Reduction in Heat Ingress while choosing Envelope Energy Retrofit Materials. The Goal of this Tool is to Promote Energy Saving Retrofits.

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## सार

यह थीसिस ऊर्जा दक्षता के लिए मौजूदा बिल्डिंग लिफाफा के पुनर्निर्माण के लिए एक निर्णय उपकरण और दिशानिर्देश विकसित करने का प्रयास करता है। टूल को सामान्य रूप से उपलब्ध एमएस-एक्सेल स्प्रेड-शीट प्लेटफॉर्म पर विकसित किया गया है, जहां सीआईबीएसई एडमिटेंस विधि का उपयोग शीतलन भार की गणना के लिए किया गया है। वर्तमान में, इस उपकरण के विकास के उद्देश्य से भारत के तीन प्रमुख जलवायु क्षेत्रों की मौसम की स्थिति, यानी गर्म और सूखी, गर्म और आर्द्र और समग्र जलवायु क्षेत्रों पर विचार किया गया है।

मौजूदा इमारतों के लिफाफे सिस्टम के थर्मल गुणों को रेट्रोफिटिंग विकल्पों और उनकी लागत के साथ संयोजन में निर्णय लेने के लिए सबसे महत्वपूर्ण बाधाएं हैं।

जलवायु स्थान, अधिभोग प्रकार, आयु, क्षेत्र, आयाम, और लिफाफा निर्माण प्रकार जैसी मूलभूत इमारत जानकारी ड्रॉप डाउन मेनू से इनपुट / चयनित होती है, जिसके लिए उपकरण में प्री-फेड किया जाता है। शुरुआती, रखरखाव और जीवन चक्र लागत विश्लेषण सभी व्यवहार्य विकल्पों के लिए ऊर्जा बचत के आधार पर उनके नेट वर्तमान मूल्य के साथ स्वचालित रूप से गणना की जाती है और उपकरण आउटपुट के रूप में उपयोगकर्ता को सुझाए गए प्रत्येक श्रेणी में सर्वोत्तम समाधान की गणना की जाती है। यह उपकरण दिल्ली, मुंबई और जोधपुर के मौसम डेटा का उपयोग करके भारत के तीन जलवायु क्षेत्रों में परीक्षण मामले के रूप में तीन भवनों पर प्रदर्शित किया गया है। ट्रायल प्रोजेक्ट -1 के लिए ऊर्जा रेट्रोफिट समाधान के उपकरण परिणाम दिल्ली में पांच सितारा होटल को एक स्थापित ऊर्जा सिमुलेशन सॉफ्टवेयर का उपयोग करके सत्यापित किया गया है।

इसके अलावा, रीग्रेशन मॉडल को उपकरण परिणामों के आधार पर विकसित किया गया है, जिसमें कमी हुई यू,  $\alpha$  और एसएचजीसी वैल्यू के एक समारोह के रूप में ऊर्जा की बचत शामिल है जो उपयोगकर्ताओं को विभिन्न लिफाफा रीट्रोफिटिंग विकल्पों के लिए शुरुआती यू,  $\alpha$  और एसएचजीसी मूल्यों को चुनने में सक्षम बनाता है। तकनीकी रूप से उन्मुख उपयोगकर्ताओं के लिए ये मॉडल लिफाफा एनर्जी रेट्रोफिट सामग्री चुनते समय हीट इन्वैस में कटौती की भविष्यवाणी के लिए जेनेरिक दिशानिर्देश भी प्रदान कर सकते हैं। इस उपकरण का लक्ष्य ऊर्जा बचत रेट्रोफिट को बढ़ावा देना है।

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## **ABBREVIATION**

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ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BEE	Bureau of Energy Efficiency, Government of India
CBERD	Centre for Building Energy Research and Development
CIBSE	Chartered Institution of Building Services Engineers
CPL	Cement Plaster
CPWD	Central Public Works Department, Government of India
DDA	Delhi Development Authority
DSR	Delhi Schedule of Rates
ECM	Energy Conservation Measures
EE	Energy Efficiency
EER	Energy Efficiency Ratio
EERM	Envelope Energy Retrofit Measures
EIA	U.S. Energy Information Administration
EPS	Expanded Polystyrene
ERM	Energy Retrofit Measures
FAR	Floor Area Ratio
GRIHA	Green Rating for Integrated Habitat Assessment
HDD	Heating Degree-Days
HVAC	Heating, Ventilating, and Air-Conditioning
IAQ	Indoor Air Quality
IES/IESNA	Illuminating Engineering Society of North America
IGBC	Indian Green Building Council
kW	Kilowatt
kWh	Kilowatt-Hour

LBNL	Lawrence Berkeley National Laboratory
LCC	Life-Cycle Cost
LEED	Leadership in Energy and Environmental Design
LPW	Lumens per Watt
MNRE	Ministry of New and Renewable Energy, Government of India
N/A	Not Applicable
NPV	Net Present Value
OA	Outdoor Air
O&M	Operation and Maintenance
OPR	Owner's Project Requirements
PNNL	Pacific Northwest National Laboratory
PUF	Polyurethane Foam
PV	Photovoltaic
QA	Quality Assurance
R	Thermal Resistance
RCC	Reinforced Cement Concrete
ROI	Return on Investment
SHGC	Solar Heat Gain Coefficient
SRI	Solar Reflectance Index
U	Thermal Transmittance
USGBC	U.S. Green Building Council
VT	Visible Transmittance
W	Watt
XPS	Extruded Polystyrene