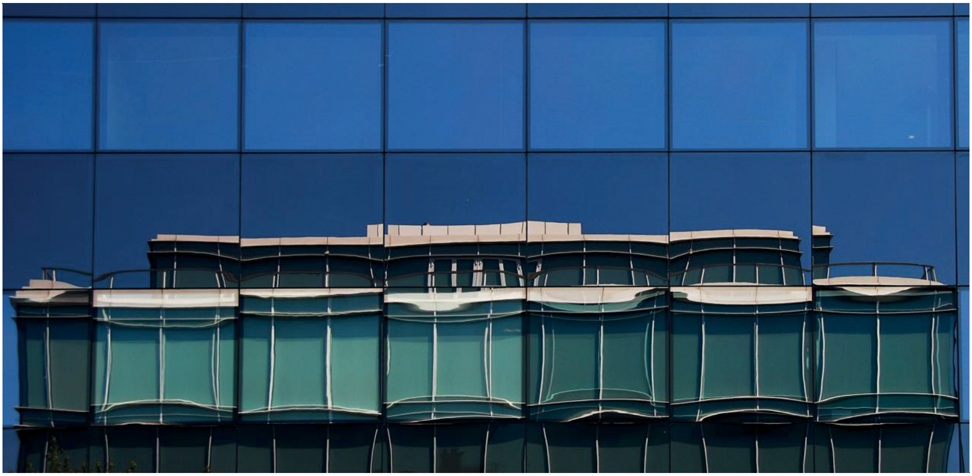
Bauwirtschaft und Baubetrieb. Mitteilungen Band 49

Shritu Shrestha

Comparison of Energy Efficient and Green Buildings

Technological and Policy Aspects with Case Studies from Europe, the USA, India and Nepal



Universitätsverlag der TU Berlin

Technische Universität Berlin

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Die Mitteilungen des Fachgebietes Baubetrieb und Baumaschinen an der Technischen Universität Berlin wurden von 1980 bis 1988 von o. Prof. Dr.-Ing. Hanskarl Gutsche und Prof. Dipl.-Ing. Horst Becker herausgegeben. Univ.-Prof. Dr.-Ing. Bernd Kochendörfer setzt die Herausgabe fort.

Das Fachgebiet und die Schriftenreihe haben im Jahr 2001 eine Umbenennung erfahren (Bauwirtschaft und Baubetrieb). Außerdem erfolgte in diesem Zusammenhang eine Veränderung des äußeren Erscheinungsbildes der Schriftenreihe.
Univ.-Prof. Dr.-Ing. Bernd Kochendörfer, Jahrgang 1947, wurde zum 1. Juli 1995 an das Fachgebiet für Baubetrieb und Baumaschinen an der Technischen Universität Berlin berufen. Nach seinem Studium des Bauingenieurwesens an der Universität Stuttgart war er als Bauleiter auf Baustellen des Wasserbaus und des Ingenieurbaus tätig und promovierte 1977 während seiner Assistenztätigkeit am Institut für Baubetriebslehre der Universität Stuttgart. Seit 1978 war er als beratender Ingenieur im Bereich Objektüberwachung und Projektmanagement freiberuflich tätig.

Shritu Shrestha, Jahrgang 1981 aus Kathmandu, Nepal, studierte ihren Bachelor in Architektur (2000–2004) an der Tribhuvan University, Nepal und Master of Science (M.Sc.) in Technologie- und Ressourcenmanagement in den Tropen und Subtropen (mit Schwerpunkt Integriertes Planen und Bauen in den Tropen und Subtropen) an der Fachhochschule Köln (2007–2009). Von 2010–2014 war sie als Doktorandin im Wuppertal Institut für Klima, Umwelt und Energie und an der Technischen Universität Berlin beschäftigt. Seit Mai 2014 ist sie als wissenschaftliche Mitarbeiterin in Wuppertal Institut angestellt. Sie forscht in europäischen und internationalen Projekten mit dem Schwerpunkt Energie- und Ressourceneffizienz von Gebäuden, nachhaltige Städte, sozio-ökonomische Bewertung und Klimaschutz.

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Bibliografische Information der Deutschen Nationalbibliothek
Die Deutsche Nationalbibliothek verzeichnet diese Publikation in der Deutschen Nationalbibliografie; detaillierte bibliografische Daten sind im Internet über http://dnb.dnb.de abrufbar.

Universitätsverlag der TU Berlin, 2016
http://verlag.tu-berlin.de/

Fasanenstr. 88, 10623 Berlin
Tel.: +49 (0)30 314 76131 / Fax: -76133
E-Mail: publikationen@ub.tu-berlin.de

Zugl.: Berlin, Techn. Univ., Diss., 2015
1. Gutachter: Prof. Dr. Bernd Kochendörfer
2. Gutachter: Prof. Dr. Peter Hennicke
Die Arbeit wurde am 25. März 2015 an der Fakultät VI unter Vorsitz von Prof. Dr.-Ing. Frank U. Vogdt erfolgreich verteidigt.

Druck: docupoint GmbH
Satz/Layout: Shritu Shrestha

ISBN 978-3-7983-2791-7 (print)
ISBN 978-3-7983-2792-4 (online)

ISSN 1610-0158 (print)
ISSN 2364-2009 (online)

Online veröffentlicht auf dem institutionellen Repositorium der Technischen Universität Berlin:
DOI 10.14279/depositonce-4948
http://dx.doi.org/10.14279/depositonce-4948

Kurzfassung

Nachteilige Umweltwirkungen und Lock-in-Risiken eines ineffizienten Bausektors nehmen zu, wenn Maßnahmen zur Reduktion des Energie- und Ressourcenbedarfs in Form stringenter Gebäudepolitiken und effizienter Technologie nicht umgesetzt werden. Dies trifft auf Industrieländer, insbesondere aber auch auf Entwicklungsländer zu. Um einen ganzheitlichen Ansatz zur Reduktion des Energie- und Ressourcenbedarfs von Gebäuden abzubilden, werden energieeffiziente und grüne Gebäude hinsichtlich technologischer Aspekte und ihres Politikkontextes in Industrie- und Entwicklungsländern verglichen. Die Analysen beziehen sich hauptsächlich auf Europa, die USA und Indien und werden ergänzt um Empfehlungen für ein Maßnahmenpaket für Nepal. Ein Review unterschiedlicher Literaturquellen, unterstützt durch diverse Expertenmeinungen, stellt die methodische Grundlage für diese detaillierte Analyse dar.

Energieeffiziente und grüne Gebäude bieten einen ökologischen, sozialen und ökonomischen Nutzen, wesentliche Umsetzungshürden bestehen aber in einem fehlenden Bewusstsein und Marktversagen auf Grund gegenläufiger Verhaltensanreize (Investor-Nutzer-Dilemma). Integriertes Politik-Design adressiert diese Barrieren. Politikinstrumente wie Bauvorschriften und –standards, freiwillige Label, Informationsinstrumente und finanzielle Anreize bilden die effektivste Kombination für die Einleitung einer Markttransformation, die schließlich zu einem höheren Anteil energieeffizienter und grüner Gebäude führt. Gute Beispiele einer höheren Beachtung von Gebäudeenergiestandards und deren Weiterentwicklung existieren in verschiedenen Industrieländern, wie z.B. in Deutschland.

Der Ausgangspunkt zur Minimierung von Energie- und Ressourcenbedarf von Gebäuden besteht darin, zunächst einen Fokus auf Suffizienz und Energieeffizienz mittels passiver Designstrategien zu legen und schließlich effiziente aktive Technologien (einschließlich erneuerbarer Energien) zu integrieren. Unter Berücksichtigung des Lebenszyklus

von Gebäuden ist es nicht ausreichend, nur die Reduktion des Energieverbrauchs in der Nutzungsphase der Gebäude zu beachten, weil diese den Einsatz von Materialien mit hohem Energieverbrauch in der Herstellung bedeuten kann. Grüne Anforderungen sind essenziell für Gebäude. Dies muss in der zukünftigen (Weiter-)Entwicklung von Gebäudeenergiestandards und -labels berücksichtigt werden, insbesondere in Industrieländern. Einige dieser Länder verfügen zwar über ökonomische und technologische Stärke und strenge Vorschriften in Bereichen wie Energie, Wasser und Transport, haben aber bislang keine verpflichtende grüne Bauausführung eingeführt. Die Zertifizierung grüner Gebäude wird auch effektiver werden, wenn Energiestandards verschärft werden und wenn vollständige Gebäude-Ökobilanzen berücksichtigt werden (wie in den aktuellsten Versionen von LEED US und BREEAM).

Basierend auf der Bedeutung, die verschiedene Länder der Schonung energetischer und stofflicher Ressourcen beimessen, unterscheiden sich die jeweiligen Systeme zur Zertifizierung grüner Gebäude hinsichtlich ihrer Bewertung verschiedener Kriterien. Zudem werden die Systeme auch an lokale Gegebenheiten angepasst, wenn sie von einem Land auf ein anderes übertragen werden (z.B. von LEED US zu LEED Indien). Auf Grund steigender Knappheit von Energie und Ressourcen sind viele Entwicklungsländer gezwungen, sich der Notwendigkeit grüner Gebäude zu stellen. Freiwillige Label für grüne Gebäude in Indien, wie GRIHA und LEED Indien, sind gute Beispiele für die Förderung grüner Gebäude in Entwicklungsländern, in denen Gebäudeenergiestandards noch nicht für alle Gebäudetypen verpflichtend sind. Obwohl das Niveau von Mindeststandards unterhalb dessen der meisten entwickelten Ländern liegt und die finanzielle Unterstützung gering ist, sind die schrittweise Verschärfung der Standards und die Einbeziehung der weiteren Perspektive der Ressourcenschonung positive Entwicklungen. Um erfolgreich zu sein, müssen bestehende Strategien umfasst werden, an die Schaffung eines geeigneten Förderrahmens, die politische Bekenntnis zu Energie- und Ressourceneffizienz und eine starke Regierungsvision für einen langfristigen und nachhaltigen Bausektor. Die Herausforderungen, mit denen Nepal konfrontiert wird, sind noch umfangreicher. Sie resultieren aus einem schnellen urbanen Wachstum und dem Fehlen von energie- und ressourceneffizienten Gebäudepolitiken. Die Erforderlichkeit eines effektiven Maßnahmenpakets für Nepal wird hierdurch unterstrichen.

Insgesamt wird hierdurch der Zusammenhang zwischen energieeffizienten und grünen Gebäuden aufgezeigt. Die verstärkte Berücksichtigung von Energieeffizienz in grünen Gebäuden sowie von Nachhaltigkeitsanforderungen in energieeffizienten Gebäude sind Sprungbretter für die verbesserte Energie- und Ressourceneffizienz von Gebäuden. Eine solche Entwicklung wird durch ein geeignetes Maßnahmenpaket unterstützt.

Abstract

The adverse environmental impacts and lock-in risks from inefficient building construction increase if measures to reduce energy and resource use, through stringent building policies and efficient technology, are not implemented in developed and developing countries - although the negative impacts are greater in developing countries. To illustrate a holistic approach to reducing buildings' energy and resources, the comparison of energy efficient and green buildings in terms of their technological aspects and their policy context in developed and developing countries, mainly in Europe, the USA and India, is presented together with a policy package recommendation for Nepal. A quality review of multiple literature sources, supported by various expert opinions, were the methods used for this in-depth analysis.

Environmental, social and economic benefits for energy efficient and green buildings do exist, but major barriers are a lack of awareness and market failure due to split incentives. Integrated policy design addresses these barriers. Policy instruments such as mandatory building standards, voluntary labels, information instruments and financial incentives are the most effective combination for the shift towards market transformation, which ultimately results in a higher share of energy efficient and green buildings. Good examples of higher compliance with, and enforcement of, building energy standards can be seen in developed countries (e.g. Germany).

The initial approach to minimise energy and resource use in buildings is to focus on sufficiency, energy efficiency with passive design strategies and then to incorporate efficient active technologies including renewable energy. Looking at a building's life cycle perspective, it is not sufficient to focus solely on operational energy reduction in higher energy efficient buildings as this is achieved by the increased use of energy intensive materials. Green requirements are vital for such buildings and this must be considered in the future development/updating of building energy standards and labels, particularly for developed countries. Some developed countries, despite being economically and technologically strong and having strict building regulations for aspects such as energy, water and transport, have not yet made green building construction mandatory. Green building certification will also become more effective when the stringency of energy standards is higher and when the whole building life cycle assessment is considered (as in the latest versions of LEED US and BREEAM).

Based on a country's priority for energy and resource saving, green building certification systems vary in how they rate different criteria, and the systems are also modified to local conditions when transferred to another country (e.g. LEED US to LEED India). Due to the increasing scarcity of energy and resources, many developing countries are forced to face up to the need for holistic green buildings. Voluntary green building labels in India, such as GRIHA and LEED India, are good examples of ways of promoting green buildings in developing countries, where building energy standards are still not mandatory for all building types. Although baseline standards are not as high as in most developed countries and national financial support is low, the gradual move towards making the standards more stringent and incorporating the wider scope of resource saving are positive developments. However, to achieve significant success, strategies must include the establishment of a suitable funding environment, a political commitment to energy and resource efficiency and a strong government vision for long term and sustainable building construction. The challenges faced by Nepal are even greater due to the fast pace of urban growth and the absence of energy and resource efficient buildings policies, highlighting the need for an effective policy package.

Overall, this demonstrates how energy efficient and green buildings are interlinked. Green buildings reinforced with higher levels of energy efficiency and energy efficient buildings incorporating green requirements are stepping-stones for achieving greater building energy and resource efficiencies. And a suitable policy package fosters its development.

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List of abbreviations

2DS	Institut für Mess- und Regelungstechnik
2DS	2° Scenario
AIA	American Institute of Architects
AIRR	Adjusted Internal Rate of Return
AP	Acidification Potential
ASHRAE	American Society of Heating, Refrigerating and Air-conditioning Engineers
BAC	Budget Allocation Chart
BAT	Best Available Technologies
BEE	Bureau of Energy Efficiency in India
BEES	Buildings for Energy and Environmental Sustainability
bigEE	bridging the information gap in Energy Efficiency
BREEAM	Building Research Establishment Environmental Assessment Methodology
BTKs	Bull Trench Kilns
DENA	German Energy Agency/Deutsche Energie-Agentur
CBS	Central Bureau of Statistics
CDD	Cooling degree days
CDM	Clean development mechanism
CFCs	chlorofluorocarbons
CFLs	compact fluorescent lamps
CO_2	Carbon di Oxide
CSEB	Compressed Stabilised Earth Block
CSL	Center for Sustainable Landscapes
dBA	Decibel (A)
DD	Degree days
DF	Dalylight Factor
DGNB	Deutsche Gesellschaft für Nachhalttiges Bauen
e.g.	*exempli gratia*
EC Act	Energy Conservation Act
ECBC	Energy Conservation Building Code
ECEEE	European Council for an Energy Efficient Economy
EEO	Energy Efficiency Obligation
EH	Efficiency House
EIO	Economic input and outpot
EJ	Energy Joule

EMS	Environmental management system
EnEV	Energieeinsparverordnung/Energy saving ordinance
EP	Eutrophication Potential
EPBD	Energy Performance of Buildings Directive
EPC	Energy Performance Certificates/Energieausweis
EPI	Energy Performance Index
ESCO	Energy Service Company
Etc.	*et cetera*
ETP	Energy Technology Perspective
EU	European Union
EU27	European Union (EU) comprises 27 member state
FEAHP	Fuzzy extended analytical hierarchy process
GBPN	Global Building Performance Network
GDP	Gross domestic product
GER	Gross Energy Requirement (MJ)
GHG	Greenhouse Gases
Gt.	Gigatonnes
GRIHA	Green Buildings Rating System India
GRIHA SVA	GRIHA Simple Versatile Affordable
$GtCO_2$-eq/yr	Gigatonnes carbon-di oxide equivalent per year
GWH	Gigawatt hours
GWP	Global Warming Potential
GWP 100	Global Warming Potential, 100 year time horizon ($kgCO_2eq.$)
HCFCs	Hydrofluorocarbons
HDD	Heating degree days
HERS	Home Energy Rating System
HPWES	Home Performance with Energy Star
HVAC	Heating, ventilation and air-conditioning
ICC	International Code Council
IEA	International Energy Agency
IECC	International Energy Conservation Code
IESNA	Illuminating Engineering Society of North America
ILO	International Labour Organization
INR	Indian Rupee
IPCC	Intergovernmental Panel on Climate Change
IRR	Internal Rate of Return
ISO	International Organization for Standardization
IWMI	International Water management Institute
JI	Joint Implementation

Kd	Kelvin days
KfW	Kreditanstalt für Wiederaufbau/ Reconstruction Credit Institute
kVA	kilovolt-ampere
kW	kilowatt
kWh	Kilowatt hour
LBNL	Lawrence Berkeley National Laboratory
LCA	Life Cycle Assessment
LCC	life Cycle Cost
LCCA	Life Cycle Cost Analysis
LCEA	Life Cycle Energy Analysis
LCI	Life Cycle Inventory
LEB	Low-Energy Buildings
LEED	Leadership in Energy & Environmental Design
MEPS	Minimum Energy Performance Standards
MJ	megajoule
MMC	Modern methods of construction
MNRE	Ministry of New and Renewable Energy
MURE	Mesures d'Utilisation Rationelle de l'Energie
n.d.	no data
NAMA	Nationally Appropriate Mitigation Actions
NPV	Net Present Value
NRE	Non renewable Energy (MJ)
NZEB	Nearly Zero-Energy-Buildings
ODS	Ozone-Depleting Substances
OECD	Organization for Economic Co-operation
PACE	Property Assessed Clean Energy Financing
PH	Passive House
PHI	Passive House Institute
PV	Photovoltaic
R&D	Research and development
RD&D	Research and development activities, as well as demonstration
ROW	Rest of the World
RWH	Rain Water Harvesting Systems
TERI	The Energy and Resource Institute
Tn	Neutrality temperature
$T_{o.av}$	Mean temperature of the month
UK	United Kingdom
ULE	Ultra-Low-Energy Buildings

UNDP	United Nations Development Program
UNEP	United Nations Environmental Programme
UNEP SBCI	UNEP Sustainable Buildings and Climate Initiative
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCC	United Nations Framework Convention on Climate Change
US-EPA	US Environmental Protection Agency
USA	United States of America
USGBC	United States Green Building Council
UVB	Ultraviolet B
Vas	Voluntary Agreements
VOC	Volatile Organic Compounds
VSBK	Vertical Shaft Brick Kiln
WBCSD	World Business Council for Sustainable Development
WEC	World Energy Council
WGBC	World Green Building Council

Foreword

One should read this excellent PhD thesis by Dr. Shritu Shrestha, a y-oung researcher and architect from Nepal! It is an outstanding resource book on the complex interlinkages between green and efficient buildings worldwide.

This PhD thesis (presented to the Faculty of Planning-Building-Environment at TU Berlin in 25.03.2015) was timely published, shortly after the adoption of the UN "2030 Agenda for Sustainable Development" (SDGs /September 2015) and the "Paris Agreement" of COP 21 (December 2015). Scientific impulses, such as this thesis, are needed for the following up of these processes and for conceptualising implementation strategies. Scaling, speeding and tightening up are the necessary dynamics e.g. to stay below the 2 degree target.

Sound databases on the building sector for international cooperation are key. Efforts are often concentrated on the restructuring of the power sector by gradually substituting nuclear and fossil fuels with renewable energies. But all sectors and energy markets, power, heat and mobility, will be more interconnected in the future. Strategies for the green transformation of the building sector, which will aid this interconnection, are however lagging behind.

This PhD-thesis has compiled and structured an impressive literature as an important step towards closing the implementation gap for energy-efficient and green buildings.

Buildings not only account for 40% of global energy use, but also for about 40% of the solid waste flow in developed countries. The embedded energy in building materials and the amount of land used for the built environment is, at present, far too great to be sustainable and must be decoupled from GDP and population growth. It depends on an integrated planning whether the sites for buildings are connected with more or less transportation needs or more or less use of water. Thus a combined strategy to raise energy and resource efficiency is necessary.

In other words: energy-efficient buildings should be green as well as vice versa. What might look theoretically self-evident is not at all straightforward when it comes to implementation and building policies. On the contrary: The building sector is so complex concerning types of use, building standards, climate zones and country specific development stages that a systematic framing of the topic "energy-efficient vs. green buildings" was urgently needed. For example different development stages of countries do require quite different priorities and policy packages for buildings. Whereas deep renovation of the building stock is a key strategy in developed countries, in developing and emerging countries the step wise introduction of more ambitious Minimum Energy Performance Standards (MEPS) for new buildings is one important policy.

It is a highly ambitious effort and it puts a huge challenge on writing a PHD thesis to systemize the tremendous amount of literature on green and energy-efficient buildings in a user friendly way. Shritu Shrestha´s PhD thesis managed this task in an extraordinary and reader friendly way.

Thus the well-structured presentation of the research material in this thesis could, on the one hand, lay the ground for more informed decisions by policy makers and managers in the building industry . On the other, hand it can be highly recommended as an interdisciplinary source book for all faculties connected with the built environment e.g. architects, engineers, planners and economists.

Prof. Dr. Peter Hennicke
Former President of the Wuppertal Institute
Full Member of the Club of Rome

Preface of the Publisher

Throughout the world, efforts are made on containing the continuously raising consumption of resources – fossil fuels in particular – and on reducing environmental pressure. For both aspects, buildings and especially residential buildings, are the significant "drivers". Going along with broadening the mind of consideration to life cycle issues of physical structures, various programs were developed and initialized in different countries. Those programs follow the vision of energy-efficient buildings – so-called "Green Buildings" – and resulted in certification programs like LEED, BREEM, DGNB or BNB.

Due to disparities in a county's level of development regarding the economic standard as well as the sociopolitical system, a comparatively wide spectrum of targets emerged. This also applies on the rigor of implementing the programs, which come along with substantial investments in national and private areas.

The paper on hand focuses on these variegated differences and frames the superior question: which strategies and criteria are available for energy-efficient and sustainable buildings? Also, which social and economic consequences can be expected as a result of implementing and using the buildings? In this context, the different certification systems will be evaluated according to their degree of target achievement. Furthermore, their transferability from high developed countries to other nations will be analyzed.

Because of the fundamental relevance of the results and because of the commendable as well as comprehensive research, a prompt dissemination of this work is aspired.

Berlin, May 2015 Univ.-Prof. Dr.-Ing. Bernd Köchendörfer

Preface by the Author

It is evident that levels of energy and resource consumption, as well as adverse environmental impacts from the building sector, are increasing. In order to reverse this trend, a global effort to understand and incorporate energy efficient and green aspects into buildings is required. The adoption of energy efficient and green building varies in developed and developing countries according to a country's need to reduce energy and resource use, and the reduction potential further depends on the technologies and materials used. Therefore, this dissertation compares these two building concepts based on a building life cycle perspective and building policies that are currently incorporated, or need to be incorporated, in developed and developing countries, mainly in Europe, the USA and India. The qualitative review of a considerable volume of literature on the subject, together with the collection of various expert opinions, has resulted in an extensive analysis of the topic. Recognising the need for energy and resource efficient buildings in developing countries, I have also attempted to recommend a suitable policy package for my home country – Nepal – together with an overview of technological options. Overall, this study provides good guidance on building regulation development and its supportive policies and it will prove useful for policy makers, developers and architects.

This dissertation would not have been possible without the encouragement and support of numerous people. Firstly, I would like to express my deepest appreciation and gratitude to my supervisors: Prof. Dr. Peter Hennicke, who has been a tremendous mentor to me, and Prof. Dr. Bernd Kochendörfer. Their continuous motivation, excellent guidance and persistent help have been invaluable for the completion of this dissertation. My sincerest thanks also to Dr. Stefan Thomas and his team members from the Wuppertal Institute's bigEE project (bridging the information gap on Energy Efficiency in buildings) for all their support.

I would also like to thank Prof. Dr. Rodolf Schäfer from TU Berlin for his help during the initial phase. My appreciation and gratitude goes to the experts, namely Dr. Christine Lemaitre from DGNB, Dr. James McMahon from LBNL, Prof. Dr. Volker Hartkopf from CMU, Dr. Yamina Saheb from IEA, Ms. Maggie Comstock from LEED US, Dr. Sushil Bajracharya from IOE Nepal, Dr. Peter Mösle from Dress & Sommer and architects and lecturers Mr. Gyanendra Shakya and Mrs. Prativa Shakya from Nepal, for providing their opinions, which were vital to my thesis. My special thanks to architect Mr. Wolfgang Korn for his critical and constructive comments and valuable discussions. I am also grateful to my colleagues Susanne Fischer, Kain Glensor, Bernhard Brand, Christopher Moore and Kristina Wagner for their help whenever I needed it. Many thanks to my other friends and colleagues who supported and backed me from start to finish in carrying out the research and writing this dissertation.

Finally, and most importantly, my profound gratitude goes to my beloved parents, parents-in-law, sisters, brothers-in-law, sister-in-law, nephews and niece. Their faith in me, support and motivation throughout this dissertation writing period and beyond has always been invaluable. Last but not least, a heartfelt thank you to my husband Fidel Devkota for his love, care and never-ending support both during the ups and downs I experienced while writing this dissertation and in my life in general.

1 Introduction

Our environment is deteriorating, our limited natural resources are on the verge of depletion and our ecosystem is being progressively destroyed. Current building construction techniques account for significant adverse environmental impacts, due to their major energy and resource consumption: global energy use (40%), global GHG emissions (38%), global potable water use (12%) and solid waste streams (40%). Nevertheless, through the careful design of *energy efficient* and *green buildings* in developed and developing countries[1], buildings can achieve huge reductions in energy use (30%-50%), GHG emissions (35%), water use (40%) and waste outputs (70%) (Comstock, Garrigan, Pouffary, de Feraudy, Halcomb & Hartke, 2012). Research undertaken by Hong, Chiang, Shapiro and Clifford (2007) showed that energy efficient buildings are a cost-effective option for addressing energy and environmental challenges. This can be achieved through the application of measures such as passive design and natural lighting, energy efficient lighting, efficient heating and cooling systems and the use of renewable energy sources (Attmann, 2010). Likewise, from the broader perspective of environmental protection and resources such as water, materials and land efficiency, green buildings – which include the efficient use of energy – reduce the environmental footprint of buildings. This dissertation compares these two environmentally friendly building concepts in terms of their technological aspects (based on their life cycle perspective) and their policy context in developed and developing countries. The main studies are conducted in Europe, the USA, India and Nepal, as well as some smaller studies in other developed and developing countries. This dissertation uses the qualitative research method - basically literature-based, in which expert opinion is sought to clarify certain issues raised (see chapter 4).

In terms of the technological aspects, this dissertation discusses a number of criteria that have to be considered in the construction of

[1] Developed and developing/emerging countries refer to the countries listed according to the International Monetary Fund (IMF 2012)

energy efficient and green buildings, in which two main strategies are applied – passive and active (see chapter 5). The building life cycle perspective shows how energy efficient and green buildings *interlink* in terms of overall energy and resource reduction, and also identifies the environmental effects of the construction materials used throughout the building's life cycle (see chapter 8).

The environmental benefits resulting from these buildings are discussed in chapter 6. The benefits are not limited to environmental protection, but also include socio-economic benefits that outweigh upfront costs and help to foster a global green economy (see chapter 7). Although environmental and socio-economic benefits are possible, barriers (such as a lack of awareness and split incentives) exist, which influence the share of energy efficient and green buildings. An integrated policy is required to address those barriers. The combination of various policy instruments – regulatory (standards and codes), information (labels) and financial incentives – is the most effective approach (see chapter 9) to increasing the share of efficient buildings in a country. An examination of the adoption and development of these policy instruments in developed and developing countries, mainly in Europe, the USA and India, illustrates the difference between the measures taken to reduce the negative environmental impact of buildings. Developed countries, which are obliged to reduce CO_2 emissions and decrease energy use due to strict climate mitigation targets, focus on the stepwise adoption of mandatory energy standards towards achieving ultra-low energy buildings. Currently, the main focus is on existing efficient buildings. Developing countries on the other hand (especially those in southern Asia), which have a growing number of new buildings and face the challenge of energy and resource scarcity, require energy security, lower construction costs, resource saving strategies and better living conditions for sustainable development. These developments can be achieved by taking steps towards adopting energy and resource efficient buildings or green buildings. Following the examination of the relationship between the countries' contexts and their building policy development, the dissertation discusses how construction standards and labels need to be strengthened in order to achieve a major reduction in the use of energy and resources by buildings. This is particularly relevant in terms of greater stringency for energy efficiency in green buildings and green requirements in higher energy efficient buildings (see chapter 10). After the approaches and lessons learnt from developed and developing countries have been presented, this dissertation recommends an integrated policy package for Nepal, where energy and resource efficient buildings do not yet feature in the country's policies and practice, despite the need for such buildings (see chapter 11).

2 Rationale of the research and objectives

2.1 Rationale of the research

2.1.1 Buildings' adverse environmental impacts and lock-in effect

The growing number of conventional buildings is having an increasingly adverse impact on the environment and if measures are not taken to reverse this trend a significant *lock-in effect* will be seen.

Buildings and CO_2 emissions

CO_2 emissions from conventional buildings increased by 2.2% per year between 1995 and 2007. During the same period growth in commercial and residential buildings was 3.1% and 1.5% per year respectively. From 1997 to 2007, although the share of commercial buildings increased from 32% to 35% and the share of residential buildings decreased from 63% to 57%, the levels of CO_2 emissions from residential buildings (around 4.7 gigatonnes (Gt) CO_2) were higher than those from commercial buildings (around 2.9 Gt CO_2) (International Energy Agency [IEA], 2010). Taking as a starting point the Baseline Scenario level of the IEA[2] (2010), CO_2 emissions from all buildings (commercial and residential) are projected to increase by 87% between 2007 and 2050. In residential and commercial[3] buildings, CO_2 emissions will increase by 88% and 85% respectively between 2007 and 2050, with electricity consumption increasing at the highest rate across all buildings by 2.1% a year, CO_2 emissions from gas increasing by 1.1% a year, from purchased heat by 0.8% a year and from oil by 0.7% a year; but CO_2 emissions from coal remain virtually unchanged between 2007 and 2050. An alternative scenario, the study by the United Nations Environment Programme [UNEP] (2009), also showed that the rate of

[2] Baseline Scenario Level of the IEA assumes that global CO_2 emissions grow rapidly, oil and gas prices are high and energy security concerns increase as imports rise, resulting in energy related CO_2 emissions in 2050 being twice the level they were in 2007 (IEA 2010).
[3] 'service sector' - name used for 'commercial buildings' in IEA (2010)

electricity use will grow by 2.5% and 1.7% per year for commercial and residential buildings respectively.

Buildings and energy consumption

Likewise, a study by the IEA (2010) illustrated that the total energy consumption in buildings grew by 1.6% per year between 1971 and 2007. In the years between 1990 and 2007, the energy consumption in commercial buildings grew by 2.2% per year (i.e. 658 Mtoe, 46% higher in 2007 than in 1990), while the growth in energy consumption in residential buildings was 1.4% a year (i.e. 1,941 Mtoe, 28% increase between 1990 and 2007). In the case of residential buildings, the increase in non-OECD countries (i.e. developing countries) was 34%, which was higher than in OECD (developed) countries (17%)). According to the study by the World Business Council for Sustainable Development [WBCSD] (2009)[4], the residential sub-sectors (single-family and multi-family buildings) use significantly more energy than commercial buildings, in which the single-family home subsector is the largest by number of buildings, area per person, energy consumption and CO_2 emissions (this sector accounts for over two-thirds of the overall residential energy use). Multi-family housing, despite consuming less energy than single-family housing globally, is significant in densely populated areas as this type of housing makes the best use of limited space (especially in the urban areas of developing countries, which are the areas that account for the bulk of the growth in new residential buildings).

Buildings' lock-in effect

Due to the long lifespan of buildings, there is a significant risk of *locking-in* energy inefficiencies, resulting in substantial levels of emissions (UNEP, 2012). Ürge-Vorsatz, Petrichenko, Antal, Staniec, Ozden and Labzina (2012) introduced three scenarios to examine the potential for reducing buildings' thermal energy (final energy use for space heating and cooling and water heating) from 2005 to 2050: *frozen* (a scenario

[4] WBCSD study regions – Brazil, China, Europe, India, Japan and the USA

whereby the energy performance of buildings does not improve from 2005 onwards), *moderate* (a scenario whereby building policy development continues at the same rate as 2005) and *deep* (a scenario whereby ambitious and appropriate policies for energy efficient and green buildings are rapidly adopted as part of an integrated package). The study illustrates that, globally, buildings' thermal energy will increase in the frozen and the moderate scenarios by 111% and 48% respectively, while it decreases by 29% in the deep scenario (see Table 1). Thermal energy use in the deep scenario differs between the EU27, the USA and India. The reduction potential for final energy use for space heating and cooling and water heating in the EU27 and the USA by 2050 is 65% and 61% respectively (taking the 2005 level as a reference), i.e. from 15.7EJ and 16EJ in 2005 to 5.4EJ and 6.2EJ in 2050 respectively, due to the proliferation of state-of-the-art building solutions and stringent building energy standards (see Table 1). Overall, this results in a *lock-in* effect of 15% and 85% respectively (compared to the moderate scenario) (see Table 2). Energy consumption in India, on the other hand, could increase by as much as 131% (i.e. from 2.6EJ in 2005 to 5.9EJ in 2050, due to an almost fivefold increase in new construction in comparison to 2005, higher living standards and a fast growing economy) even in deep scenario (see Table 1). This would result in a lock-in effect of 508% (compared to the moderate scenario) (see Table 1). The deep scenario in the model also illustrates that the potential reduction of global CO_2 emissions in 2050 (taking the 2005 level as a reference) could be 38%, of which the EU27 and the USA account for a reduction of 66% and 63% respectively, while Indian CO_2 emissions could increase by 200% (Ürge-Vorsatz et al., 2012) (see Table 3). India displays the highest levels of energy consumption and CO_2 emissions, as well as the greatest lock-in risk, indicating the need for the development of appropriate and stringent building policies in order to halt the current trend of constructing inefficient conventional buildings.

Table 1. Final energy use for space heating and cooling and water heating for all regions for all scenarios

Region	Baseline	Deep Efficiency		Moderate Efficiency		Frozen Efficiency	
	EJ 2005	EJ 2050	Δ% to 2005	EJ 2050	Δ% to 2050	EJ 2050	Δ% to 2005
US	16.0	6.2	-61%	13.7	-14%	17.9	12%
EU27	15.7	5.4	-65%	6.6	-58%	16.5	5%
China	8.6	8.6	-1%	15.5	80%	22.3	158%
India	2.6	5.9	131%	15.2	491%	20.6	701%
Rest of the World	23.9	21.3	-11%	47.8	100%	63.6	166%
World	66.7	47.3	-29%	98.7	48%	141.0	111%

Source: Ürge-Vorsatz et al., 2012

Table 2. 'Lock-in effect' in all the regions

Region	Space Heating and Cooling	Water Heating	Space Heating & Cooling and Water Heating
US	53%	32%	85%
EU27	10%	4%	15%
China	63%	83%	146%
India	414%	94%	508%
Rest of the World	130%	55%	184%
World	80%	48%	74%

Source: Ürge-Vorsatz et al., 2012

Table 3. CO_2 emissions from space heating and cooling and water heating for all regions for all scenarios

Region	Baseline	Deep Efficiency		Moderate Efficiency		Frozen Efficiency	
	$GtCO_2$ 2005	$GtCO_2$ 2050	Δ% to 2005	$GtCO_2$ 2050	Δ% to 2050	$GtCO_2$ 2050	Δ% to 2005
US	2.8	1.0	-63%	2.3	-17%	3.1	11%
EU27	2.0	0.7	-66%	0.8	-61%	2.1	4%
China	0.6	0.7	11%	1.2	90%	1.6	164%
India	0.2	0.6	200%	1.4	564%	1.7	701%
Rest of the World	2.8	2.3	-18%	4.8	73%	6.0	118%
World	8.3	5.1	-38%	9.9	20%	14.0	68%

Source: Ürge-Vorsatz et al., 2012

2.1.2 Building construction types in developed and developing countries

The focus on the building construction type - both new and retrofitted - differs in developed and developing countries. In developed countries (e.g. in Europe), a significant share (more than half) of the building (residential) stock was built before 1970 and these buildings reach the end of their lifespan at a very gradual rate (as low as 0.1% a year) (IEA, 2010). Therefore, the main opportunities for greening the building sector come from retrofitting existing buildings to render them more environmentally efficient by reducing energy demand and using renewable energy sources (UNEP, 2011). However, in most developing countries or emerging economies (e.g. India), which have a significant housing deficit in relation to rapid demographic growth, retrofitting and new construction both have compelling cases but the potential for energy and resource efficient new construction is much greater than retrofitting (UNEP, 2011). In addition, developing countries tend to have *higher* building (residential) stock *turnover* rates, with average lifespans often in the range of 25 to 35 years (IEA, 2010). Therefore, the way that buildings are currently constructed in developing countries is critical and these countries need strong policies and measures to ensure the construction of energy and resource efficient buildings.

2.1.3 Tranformation of building construction trends

Technologies to reduce impact

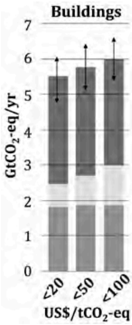
Fortunately, as Levine et al. (2007) in the IPCC report illustrate, buildings also hold the greatest potential to reduce GHG emissions. They highlight the potential for reductions of approximately 29% and 31%[5] against the projected baseline[6] emissions by 2020 and 2030 respectively, at low cost and using existing technologies, where the baseline considered was 11.1Gt and 14.3Gt of emissions of CO_2 in 2020 and 2030 respectively. This can be achieved by improving energy efficiency in new and existing commercial and residential buildings, through operational and embodied energy reduction and by incorporating a higher share of renewable energy. For 2020, an additional 3% or 4% of emissions could be avoided at a cost of up to 20US$/t$CO_2$ and 100US$/t$CO_2$ respectively, representing a reduction of approximately 3.2, 3.6 and 4.0 billion tonnes of CO_2 equivalent based on costs of zero, 20US$/t$CO_2$ and 100US$/t$CO_2$ respectively. While for 2030, an additional 4% or 5% of emissions could be avoided at a cost of up to 20US$/t$CO_2$ and 100US$/t$CO_2$ respectively, representing a reduction of

[5] From the survey of the literature (80 studies from 36 countries and 11 country groups) in Levine et al. (2007)

[6] Baseline was derived based on the literature, resulting in emissions between the B2 and A1B SRES scenarios (Levine et al. 2007)

approximately 4.5, 5.0 and 5.6 billion tonnes of CO_2 equivalent based on costs of zero, 20US$/t$CO_2$ and 100US$/t$CO_2$ respectively. Figure 1 shows the building's economic mitigation potential of using technologies and practices expected to be available by 2030, at various costs. Based on the assumption that a cost per tCO_2-eq is no more than US$ 100, the global economic mitigation potential ranges between 5.3 and 6.7 GtCO_2-eq/yr by 2030 (UNEP, 2011).

Moreover, McKinsey (2007) also identified the building sector as the most cost-effective option for CO_2 abatement and asserted that reducing buildings' CO_2 emissions can be achieved at low or even negative cost. Referring to McKinsey, UNEP (2011) estimated that a reduction of 3.5GtCO_2 emissions by 2030 would be possible by investing in green buildings at an average abatement cost of minus US$35 per tonne.



	Economic potential <100 US$/t$CO_2$-eq		Economic potential in difference cost categories		
	Cost at US$/t$CO_2$-eq		<0	0-20	20-100
	Low	High	<0US$/tC	0-73 US$/tC	73-367US$/tC
Non-OECD/EIT	2.7	3.3	2.7	0.15	0.10
EIT	0.9	1.1	0.45	0.15	0.35
OECD	1.8	2.3	1.8	0.15	0.15
Global	5.4	6.7	5.0	0.50	0.6

Source: IPCC, 2007 (synthesis report), p. 59 and Barker, et al., 2007, p. 632

Figure 1. IPCC projections of CO_2 mitigation potential in 2030

Likewise the IEA Blue Map Scenario[7] (2010), in which the most of the energy savings are assumed to result from the decarbonisation of electricity used in the buildings (6.8GtCO_2), from energy efficiency and from the shift to low and zero carbon technologies (5.8GtCO_2), also shows that buildings can play an important role in securing a more sustainable energy future. In this scenario, the energy consumption in

[7] Blue Map Scenario IEA (2010) has the goal of halving global energy-related CO_2 emissions by 2050 compared to 2005 levels, or reducing buildings' CO_2 emissions to 83% lower than in the baseline scenario and two-thirds lower than 2007 levels by 2050.

the buildings is reduced by around one-third of the baseline scenario level in 2050. Energy consumption in 2050 is only 5% higher than in 2007, despite an increase in floor area in residential and commercial buildings of 67% and 195% respectively over that period. The level of energy savings and the percentage reduction below the baseline vary by country and region.

Policies to reduce impact

In order to achieve cost-effective CO_2 emission reductions, it is essential to implement stringent, long term and sector specific policies at global and national level (UNEP, 2011), which are achievable using currently available efficient technological options. Likewise, the Blue Map Scenario IEA (2010) is also based on the large-scale deployment of a number of technological options for buildings, which include stricter building standards and codes for new residential and commercial buildings; large scale refurbishment of residential buildings in the OECD (developed) countries; highly efficient heating, cooling and ventilation systems; improved lighting and appliance efficiency; and the widespread deployment of CO_2 free technologies (e.g. heat pumps, solar thermal etc.). With the rapid development of energy (and resource) efficiency options and by incorporating suitable policy packages, the Blue Map Scenario for buildings could be achieved (IEA, 2010).

Building policies (i.e. standards and labels) are more effective when they are mandatory than when they are voluntary. The approaches to standards and labelling differ in developed countries (mostly mandatory) and developing countries (mostly voluntary or merely recommended). With the development of climate mitigation policies, developed countries (e.g. Germany) moved towards mandatory building energy standards, increasingly strict on a step-by-step basis, in order to reach national CO_2 reduction targets. In the past, these policies were perceived as only being part of a *burden sharing* regime and the economic benefits and many positive side effects connected with climate mitigation technologies and strategies were overlooked. But driving new and existing buildings in the direction of energy and resource efficiency reduces resource costs (e.g. energy and water) and import dependency (e.g. oil and gas) and increases green business sectors and new jobs in the national economies (Schade et al., 2009, Edenhofer et al., 2009). This illustrates that even without the issue of climate change, it makes sense to foster investment in energy efficient and green buildings. The mandatory standards in developed countries are now driven by macroeconomic considerations (Hennicke, Shrestha & Schleicher, 2011) and from an appreciation of the various health benefits resulting from such buildings. However, the characteristics of the building stock and the policies and institutions that promote efforts to reduce energy use in buildings differ even between developed regions (e.g. between the United States and the European Union) (Global Buildings Performance Network [GBPN] and Lawrence Berkeley National Laboratory [LBNL], 2012).

Most developing countries do not yet have mandatory building energy standards. The global negotiation process and discussions on the *common but differentiated responsibilities* (Kyoto Protocol) to reach the 2°C aim by 2050 have currently stalled. To date, climate mitigation as a burden sharing regime has been a view even more firmly held by emerging/developing than by developed countries. As a result, mandatory building standards could be perceived to be the responsibility of Annex-I countries with binding reduction obligations. However, putting climate change to one side, energy and resource efficiency standards are an important element on the path to a sustainable economy everywhere and may be – in the long term – even more important in the rapidly developing South than in the North. Although in-depth macroeconomic analyses of the building sector are mostly focused on Europe and the USA, the positive effects, such as reducing the dependency on imports and lowering costs for energy and resources, increasing the security of supply and participating in the development of green *lead markets,* are of at least equal importance to developing countries (Hennicke et al., 2011). Additionally, in the long term, the heavy burden of lock-in effects and *lost opportunities* could be avoided by emerging countries, such as India, which have rapidly growing economies and building sectors (Hennicke et al., 2011).

For these reasons, studying the building policies in developed and developing countries is necessary to understand and analyse their variance according to regional requirements. This further guides the necessary steps to take to decrease buildings' overall energy and resource use, which help to avoid lock-in effects.

2.2 Objectives

This dissertation compares energy efficient and green buildings to understand (a) how they differ technologically; (b) their policy development in developed and developing countries; and (c) how these two environmentally friendly building concepts interlink with each other to achieve a reduction in the overall energy and resource use of buildings. The focus of the research is:

1. To analyse the effect of decreased demand for operational energy in higher energy efficient buildings achieved by the increased use of energy intensive materials, through a building's life cycle perspective on environmental and economic aspects (i.e. *Life Cycle Analysis* (LCA), *Life Cycle Energy Analysis* (LCEA) and *Life Cycle Cost Analysis* (LCCA)).

2. To examine how regional requirements for energy and resources determine the incorporation of energy efficient and green buildings in developed and developing countries: looking at the policies of Europe, the USA and India on building energy codes/standards and labels, green building labels and financial incentives.

3. To understand how green buildings perform related to variations in the stringency of energy efficiency policies.

4. To determine the need for energy and resource efficient buildings in developing countries and recommend a possible policy package (specifically for Nepal).

3 Hypothesis and research questions

3.1 General hypothesis

Energy Efficient Building design primarily focuses on the reduction or elimination of operational energy, achieved by means of passive and active technologies. In contrast, in *Green Building* design, the reduction of energy (operational and embodied) is prioritised over other aspects, although other environmental aspects related to the built environment are also considered. Taken from a building's life cycle perspective, energy efficient and green buildings present various *interlinkages* on environmental and economic aspects. In terms of building policies, the priorities for energy efficient and green buildings differ between developed and developing countries.

Developed countries, which are obliged to meet strict climate mitigation targets, are focusing, sometimes aggressively, on higher energy efficient buildings as a route towards ultra-low energy buildings, introducing increasingly stringent mandatory building standards/codes on a step-by-step basis (e.g. in the EU with the Energy Performance of Buildings Directive (EPBD)/recast EPBD). However, greater energy efficiency in the operational phase is not enough on its own to respond to the issues of alarming resource scarcity and GHG mitigation, so further steps are required, i.e. the consideration of the building's life cycle, including embodied energy and resource efficiency. On the other hand, most emerging/developing countries, with their rapid demographic growth and an associated boom in the construction of conventional (inefficient) buildings, resulting in unprecedented energy consumption, have even scarcer resources (such as water and land) especially in urban areas and also face economic and technological limitations. In addition, the construction of energy and resource efficient buildings in these countries is in a nascent phase. For these countries, the emphasis on energy efficiency is important but is not enough on its own. Therefore, they need to look more widely and consider green buildings, which can help to overcome rapid inefficient building construction, improve quality of life and achieve sustainable development. The certification of green buildings has already started on a voluntary basis in developed and developing countries, with relevant criteria suited to the individual country/region. Emerging/developing countries need to adopt these standards (perhaps initially on a voluntary basis) and later move forward to make these standards and codes mandatory, which will improve their effectiveness.

Policy packages, i.e. a suitable combination of policies, help to support the growth in construction of energy efficient and green buildings by removing the possible barriers (e.g. technological and economic limitations). Lastly, a good policy package for the construction of new energy and resource efficient buildings can help to protect the environment, improve socio-economic development and support overall sustainable development in developing countries.

3.2 Specific research questions

This dissertation essentially seeks the answers to the following questions:

1. What are the strategies and criteria for energy efficient and green buildings?

2. What social and economic co-benefits of energy efficient and green buildings exist?

3. Why is it necessary to consider embodied energy in higher energy efficient buildings?

4. Are the costs (environmental and economic) for energy efficient and green buildings higher than for conventional buildings?

5. Which driving forces influence the development of energy efficient and green buildings in developed and developing countries and what are the barriers?

6. Are green requirements vital for future building energy standards and labels? If yes, which ones?

7. Does the variation in the rating of various criteria (e.g. energy, water and material) in green building certification determine the country's priority for energy and resource saving?

8. Energy efficiency is an important criterion for green buildings. Do all certified green buildings have (or are required to have) higher energy efficiency? Should the energy efficiency requirement for green buildings be tightened?

9. How can different green building certification systems be evaluated? Are the rating levels of various certification systems (e.g. LEED, DGNB and GRIHA) comparable in equal ratio?

10. How effective are the financial incentives for energy efficient and green buildings in different countries?

11. What are the steps that are required to deliver effective energy and resource efficient building standards and codes in developing countries?

12. How can a successful policy package for developing countries be designed?

4 Methodology

4.1 Methods used

This dissertation uses a qualitative research method, i.e. a quality review of the available literature on the subject together with in-depth analyses. In order to gain insights when relevant information could not be extracted from either printed or digital material, questionnaires were used to collect the opinions of researchers, scholars and practitioners (Onwuegbuzie, Leech & Collins, 2012).

Literature review

As this is a literature-based dissertation, literature review is the main research tool. The quality review of the literature carefully distinguishes what research has been carried out and what needs to be undertaken by examining multiple sources of literature, identifying: variables that are related to the topic; links between theory/concepts and practice; exemplary study; the main research methodologies and designs that have been used; contradictions and inconsistencies; and strengths and weaknesses of the various research approaches that have been used (Onwuegbuzie et al., 2012). The multiple literature sources include not only classic scientific literature, such as scientific journals, reference books, text books, government practice, policy statements, and other materials on the theory, practice and results of scientific inquiry that are produced by individuals or groups in universities, foundations and other organisations (Garrard, 2011), but also encompass research articles, dissertations, internet websites and company reports. These sources of literature have been evaluated in order to assess their trustworthiness, dependability, credibility, legitimacy, validity, plausibility, applicability, consistency, neutrality, reliability, objectivity, authenticity and/or transferability (Onwuegbuzie et al., 2012), (Denzin & Lincoln, 2003 in Bowen, 2005). As explained by Greene, Caracelli & Graham (1989), the sources are *represented* in the dissertation in four major ways: between-source *triangulation* (seeking convergence and corroboration of information from different source types); between-source *complementarity* (looking for elaboration, enhancement, illustration and clarification of the information from one source type with information from another source type); between-source *development* (using the data from one source type to help inform data from another source type); and between-source *expansion* (seeking to expand the breadth and range of information by using different source types for different pieces of information).

Broadly, the dissertation's framework for analysing and interpreting literature involves both *a within-study literature analysis* (analysing the contents of a specific work) and *a between-study literature analysis* (comparing and contrasting information from two or more sources of literature) (Onwuegbuzie et al., 2012). Among various qualitative data analysis techniques, the ones used for this study are: constant comparison analysis (i.e. taking one piece of data and comparing it to all other pieces of data that are either similar or different (RANGAHAU, n.d.), qualitative comparative analysis (i.e. systematically analysing similarities and differences across sources, typically used as a theory-building approach, allowing the reviewer to make connections between previously expounded theories, as well as to test and to develop the theories further), text mining (i.e. analysing naturally occurring text within multiple sources in order to discover and capture semantic information) and secondary-data analysis (i.e. analysing pre-existing sources) (Onwuegbuzie et al., 2012).

Expert opinion questionnaires

Experts' opinions were sought for their in-depth knowledge on certain issues and on the key questions raised in the dissertation. These were obtained by sending questionnaires to the experts via email, together with further discussion (e.g. via electronic communication, telephone or face-to-face). The experts are from a number of renowned organisations/universities that work in the building efficiency (energy and resource) sectors such as UNEP, IEA, USGBC and DGNB etc. Their opinions were analysed based on text mining data analysis. The expert opinion questionnaires and the list of experts are in Annex 1. The names of the experts are kept anonymous in this dissertation report; the terms Expert 1, Expert 2 etc. are used.

4.2 Structure of the report

Table 4 gives an overview of the content of this dissertation. It shows the scope and methodology of the research. It also refers the topics to related research questions and chapter numbers.

Table 4. Structure of the report

Chapter	Scope of the research	Research questions addressed	Methodology
2	**Building types: commercial and residential**		**Literature review**
5	**Technological aspects: strategies and criteria**	**1. Passive and active strategies and criteria for energy efficient and green buildings**	
6 and 7	**Environmental, social and economic aspects**	**2. Environmental, social and economic co-benefits of energy efficient and green buildings**	
8	**Building life cycle perspective: LCA, LCEA and LCCA**	**3. The need to consider embodied energy in higher efficiency buildings**	
		4. Environmental and economic costs of energy efficient and green buildings	
9	**Policy instruments**	**5. Driving forces that influence the development of energy efficient and green buildings, and the barriers**	**Literature review, expert opinion questionnaires (analysis)**
10	**Codes/standards, labels and financial incentives: examples from Europe, the USA and India**	**6. Green requirements for building standards and labels** **7. How variations in the rating of different criteria in the green building determine the country's priority in terms of energy and resource saving** **8. Tightening energy efficiency requirements in green buildings** **9. Evaluation of green building certification systems** **10. Effectiveness of financial incentives**	
11	**Policy package: recommendation for developing countries (specifically for Nepal)**	**11. Steps to deliver effective energy and resource efficient building standards and codes** **12. Design of a successful policy package**	**Literature review (analysis)**

5 Background: basic strategies and criteria

This chapter gives an overview on the strategies and criteria used for designing energy efficient and green buildings, examining also climate zones and thermal comfort. A design that responds to climate zones and thermal comfort helps to reduce energy and resource use from the outset.

5.1 Climate zones and thermal comfort

The perfect building design for one country or location may not suit another country or location. A building design and its incorporated elements (envelope, roof etc.) must vary according to the location, based on climate need (and the function of spaces in the building) and thermal comfort conditions. Defining good indoor thermal comfort (at the early design stage) is important to the success of an energy efficient building in order to guarantee the comfort of its occupants without wasting energy (Nicol & Humphreys, 2002).

Climate zones

Climate zones are grouped areas with specific climates, based on different climatic elements such as temperature, humidity, air movement, precipitation, cloud cover, sunshine duration and solar radiation (Szokolay, 2008). Temperature variations that depend on numbers of degree days also determine climate zones. Degree days (DD or Kd, Kelvin-days), a climatic concept, are the cumulative temperature deficit below a set base temperature (heating degree days or HDD) (Szokolay, 2008) or excess above a set base temperature (cooling degree days CDD). HDD and CDD are calculated by adding the temperature difference between the indoor temperature demand and outdoor temperature for each day over heating and cooling periods respectively (United Nations Environment Programme - Sustainable Buildings and Climate Initiative [UNEP SBCI], 2007). Based on climatic elements and degree days, climate zones can be classified into four basic types – cold; temperate; hot and dry; and hot and humid. The type of building design required to maintain human thermal comfort conditions varies between these climate zones.

Cold climates

Cold climates lack sufficient heating (i.e. face underheating), or experience excessive heat dissipation for all or most of the year (Szokolay, 2008). Therefore, these climates have a high heating demand for all or part of the year and no or little cooling demand, i.e. Heating Degree Days18°C ≥ 1000, Cooling Degree Days10°C < 1000 (bigEE, 2014).

Temperate (moderate) climates

Temperate (moderate) climates experience seasonal variation between underheating and overheating, but neither is very extreme (Szokolay, 2008). Likewise, they have both a heating and cooling demand for all or most of the year i.e. Heating Degree Days18°C ≥ 1000, Cooling Degree Days10 °C ≥ 1000 (bigEE, 2014).

Hot and dry climates

Hot and dry climates are characterised by overheating and dry air, so evaporative cooling mechanisms are required. They also have a large diurnal (day-night) temperature variation (Szokolay, 2008). Therefore, these climates have a cooling demand but no heating demand, as well as low relative humidity levels throughout the year i.e. Heating Degree Days 18°C <1000, Cooling Degree Days 10°C ≥ 1000 (bigEE, 2014).

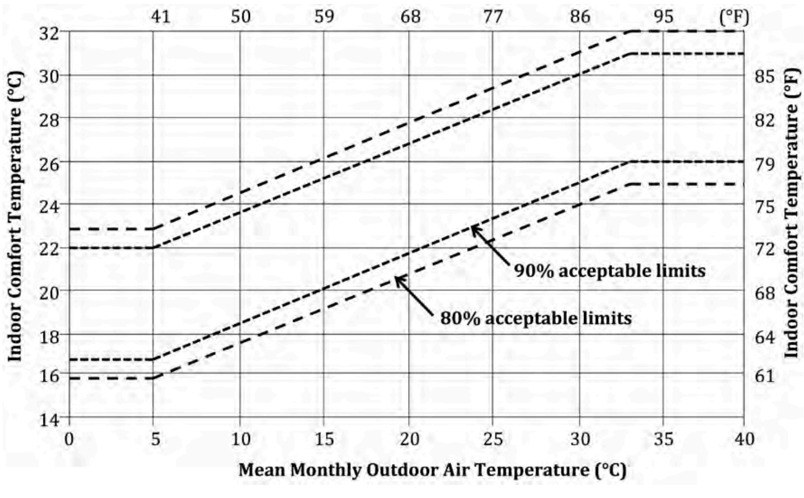
Hot and humid climates

Hot and humid climates are characterised by overheating, but not to such an extreme level as in hot and dry areas, and are aggravated by high humidity that restricts evaporation potential. The variation in diurnal temperature is small (Szokolay, 2008). Therefore, they have a cooling demand but no heating demand, as well as high humidity levels throughout the year, with a humidity level of over 50% in the hottest month i.e. Heating Degree Days18°C <1000, Cooling Degree Days10°C ≥ 1000 (bigEE, 2014).

Thermal comfort

The human comfort condition depends on different environmental parameters such as air, mean radiant temperature, humidity and air movement; on personal parameters such as metabolic rate or activity and clothing; and also on psychological factors such as expectation (Harvey, 2010). A suitably comfortable indoor environment is achieved by combining all the parameters. Therefore, the range of comfort conditions within which 80% to 90% of people feel comfortable is called the (thermal) comfort zone (Koenigsberger, Ingersoll, Mayhew & Szokolay, 1975). Defining a thermal comfort zone is a basic requirement for designing energy efficient and green buildings.

In terms of feeling comfortable, it should be noted that the acceptable comfort limit changes depending on the outdoor conditions. Rather than a fixed standard temperature, slightly warmer interior temperature on hot days and slightly colder interior temperature on cold days are acceptable. This reduces the thermal shock when entering or leaving a building. People also have the natural tendency to adapt to changing conditions or react to uncomfortable conditions as a means of restoring their personal comfort environment, known as adaptive thermal comfort (Nicol & Humphreys, 2002). Extensive studies by Szokolay (2008) showed that the neutrality temperature (Tn) (the median of many people's preferences for the optimum state of thermal comfort) varies according to the mean temperature of the month ($T_{o.av}$), as Tn = 17.8 + 0.31 x $T_{o.av}$. For 90% of people, the acceptable lower comfort limit is (Tn – 2.5)°C and the acceptable upper comfort limit (Tn + 2.5)°C (Szokolay, 2008). Figure 2 shows a range of standard acceptable indoor temperatures in relation to outdoor temperatures, including the comfort limits that are acceptable to 80% and 90% of the population. This variation in temperature is important in air conditioned buildings in order to avoid energy wastage and also provides psychological comfort. A study showed that reducing indoor temperature by 1°C can reduce energy consumption by up to 10% (European Commission, 1999). In naturally ventilated buildings, the range of the comfort limit widens and uses an 'adaptive opportunity' i.e. it allows for the opening of a window, the drawing of a blind, the use of a fan and also includes dress code working practices and other factors that influence the interaction between occupants and buildings (Nicol & Humphreys, 2002). Compared to the adaptive approach, the heat balance approach (i.e. an approach based on experiments in controlled environments) fails to provide the range of temperatures that people find comfortable in buildings taking into account the variable indoor temperatures characteristic of naturally ventilated buildings (Nicol, 2011). A psychometric chart can be a helpful tool for establishing comfort limits, showing the suitable temperature limits and the relative positioning of environmental parameters, and also recommending the measures to take to achieve thermal comfort.



Source: Brager & de Dear, 2000

Figure 2. Acceptable comfort limits that take into account psychological adaptation to different outdoor temperatures

5.2 What are energy efficient and green buildings?

Energy efficient buildings

Energy efficient building, an environmentally friendly building technique, focuses on the reduction of the building's operational energy use (i.e. energy for cooling, heating, ventilation and hot water). The strategies for saving or reducing energy in buildings can be passive and/or active (see section 5.3). The higher the building energy reduction potential, the more energy efficient the building. Low-Energy Buildings (LEB) can be a good target to aim for initially, but ultimately the target needs to be for Ultra-Low-Energy Buildings (ULEB) and Nearly Zero-Energy-Buildings (NZEB).

Schüwer, Klostermann, Moore & Thomas (2012) show that improving buildings' energy efficiency to LEB levels can result in a reduction in primary energy consumption for cooling, heating, ventilation and domestic hot water by between 40% and 60%[8] compared to conventional new buildings. It is an Easy Efficiency Approach that uses mainly passive strategies and a few efficient active technologies. The energy reduction can be up to 90%[8] in an ULEB, an Advanced Efficiency Approach that uses passive strategies and most of the available energy efficient active technologies and uses renewable energies in part to meet energy consumption. A 100%[8] net reduction in energy consumption, or even a positive energy balance, can be achieved in a NZEB or Plus-Energy-Building (i.e. an ULEB with on-site energy generation from renewable energy sources).

The concept of the NZEB implies that the renewable technologies installed in, on or near the building convert energy from renewable sources to generate at least as much primary energy as the building uses over the course of the year. At peak demand periods, when the home system cannot satisfy the demand, electricity is purchased from

[8] With the assumption that conventional new residential buildings in temperate, cold, hot and arid, and hot and humid climates consume on average about 120 to 260 kWhPE/m^2, 70 to 170 kWhPE/m^2, 140 to 160 kWhPE/m^2 and 260 to 400 kWhPE/m^2 respectively (Schüwer et al., 2012)

the utility grid; electricity is sold back to the grid when the building produces excess electricity (Leckner & Zmeureanu, 2011).

NZEB options can be determined by the potential for using renewable technologies and efficiency measures i.e. demand–site options (reduce site energy use through energy efficiency and demand-side renewable technologies), on-site supply options (renewable energy generated within the building footprint or within the building's land boundary) and off-site supply options (off-site renewable energy used to generate energy on site or the purchase and installation of renewable energy generated off-site) (Pless & Torcellini, 2010) (see Table 25 in Annex 3 for further details). The source of the renewable energy used in NZEBs can be net zero site energy, net zero source energy, net zero energy costs and/or net zero energy emissions. A site NZEB produces at least as much renewable energy as it uses in a year within the site. A source NZEB produces (or purchases) at least as much renewable energy as it uses in a year within the source. A cost NZEB refers to the situation where the amount of money the utility pays the building's owner for the renewable energy that the building exports to the grid is equal to the amount the owner pays the utility company for the energy services and energy used over the year. Lastly, the emissions NZEB produces (or purchases) enough emission-free renewable energy to offset emissions from all the energy used in the building in a year (Pless & Torcellini, 2010). Regardless of which NZEB is chosen, the drop in the cost of renewable energy makes it a more cost-effective option to meet (the increased) energy use in buildings. Between 2000 and 2012 the price of fossil fuels in Germany increased (e.g. fuel oil from 40.82 cents/litre to 88.1 cents/litre, electricity from 14.92 cents/kWh to 25.89 cents/kWh and petroleum gas from 3.94 cents/kWh to 6.95 cents/kWh) and, simultaneously, the price for renewable energy systems decreased (e.g. photovoltaic from 50.62 cents/kWh to 17.45 cents/kWh and wind energy from 9.1 cents/kWh to 8.83 cents/kWh), encouraging the greater use of renewable energies in buildings (Krischer, n.d.).

Green buildings

Green buildings increase building efficiency using a broader approach (energy and resources) and minimise adverse effects on the environment both within the buildings and in their surroundings. According to the U.S. Office of the Federal Environmental Executive (2003), green building design increases the efficient use of energy, water and materials and, as a result, reduces buildings' impacts on human health and the environment, through better siting, design, construction, operation, maintenance and removal i.e. throughout the complete life cycle of the building. It requires an integrated design approach and when these efficiency measures are applied throughout the life cycle of the building (from design and construction to renovation and demolition), a green building conserves and restores natural resources (such as energy, water and materials), improves water and air quality, reduces waste and ensures its proper disposal. The overall effect is to reduce adverse impacts on the natural environment.

Green buildings integrate all the components associated with buildings and the environment, such as best building design (form, orientation, envelope etc.), as passive and active strategies. The aims are to optimise energy use and to incorporate renewable energies, save water and ensure its reuse/recycle, use efficient means of transport and reduce distances, undertake site planning and biodiversity conservation, improve indoor environmental quality and occupants' health, reuse and recycle materials and manage waste effectively.

5.3 Strategies and criteria for energy efficient and green buildings

The criteria are the options for reducing the use of energy and resources in the construction of energy efficient and green buildings, and the strategies, which can be both passive and active, are the ways of implementing these criteria.

5.3.1 Strategies for energy efficient and green buildings

Passive strategies are an easy approach to energy efficiency and are initially considered as part of the building design process. These strategies take advantages of natural sources of heating and cooling, such as the sun and the wind, to provide a comfortable indoor environment. The design responds to the climate, site conditions and the human (thermal) comfort level. The long term effect is that for minimal cost at the outset, significantly lower amounts of energy and resources are used. For example, in an average Australian home, passive design reduces the need for extra heating or cooling by 40% (or much more in some climates) (McGee, 2013). Active strategies, on the other hand, use systems and technologies to achieve comfort. In energy efficient and green buildings, efficient active systems or technologies such as efficient air-conditioning and renewable energy are used to save or reduce energy use and resources (see Table 5).

5.3.2 Criteria for energy efficient and green buildings

The criteria for energy efficient and green buildings are the options for selecting efficient technologies and systems that reduce the environmental impacts of the buildings. They are energy efficiency, atmosphere, water efficiency, site/location/transport efficiency, indoor environmental quality and material efficiency. These criteria include various sub-criteria and they are classified into passive and active strategies. The selection of the technologies and systems in the criteria/sub-criteria determine the stringency level of the energy efficient and green buildings, which varies according to the climate and country. The criteria and sub-criteria for energy efficient and green buildings are listed in Table 5.

Table 5. Criteria and strategies for energy efficient and green buildings

Criteria	Passive Strategies		Active Strategies	
Energy efficiency				
Energy optimisation (passive design)	■	▒		
Energy optimisation (active system)			■	▒
Renewable energy (including solar energy for domestic hot water)			■	▒
Atmosphere				
Environmental impact reduction			■	▒
Water efficiency				
Water reuse/recycling	■			
Water conservation			■	
Water quality	■			
Site/Location/Transport				
Site selection	■	▒		
Community connectivity	■	▩		
Eco-friendly transportation	■	▩		
Soil protection/conservation	■			
Heat island effect (microclimate)	■	▒		
Stormwater control	■			
Waste water treatment	■			
Light pollution			■	▒
Indoor environmental quality				
Air quality (natural ventilation)	■	▒		
Air quality (mechanical ventilation)			■	▒
Visual comfort (daylight)	■	▒		
Visual comfort (artificial lighting)			■	▒
Thermal comfort (natural)	■	▒		
Thermal comfort (mechanical)			■	▒
Acoustic comfort	■			
Smoke control	■			
Hygiene/Chemical control	■			
Material efficiency				
Resource efficiency	■	▩		
Material reuse/recycle	■	▩		
Waste management	■			

■ **Green buildings**

▒ **Energy efficient buildings**

▩ **Green requirement in Energy efficient buildings**

5.3.2.1 Energy efficiency

Energy efficiency is one the most important criteria for both green and energy efficient buildings. Energy is used in buildings for heating, cooling, ventilation, lighting and hot water for sanitary requirements. In most conventional buildings, the main source of energy is from non-renewable sources (e.g. fossil fuels), which do not only have a negative effect on the environment (e.g. harmful emissions including NOx, SOx, particulates, and CO_2) and on health, but are also expensive due to the rise in energy prices and increase in energy scarcity. Therefore, increasing energy efficiency is a significant step for addressing the challenges faced by energy (price and scarcity) and the environment (Hong et al., 2007), through the application of measures such as developing strategies for passive design and natural lighting, energy efficient lighting, heating and cooling systems, and by considering the use of renewable energy sources (Attmann, 2010). The energy reductions achieved through the design and construction of green buildings reduce pollution and lower the environmental impact of conventional power generation (Lovins et al., 2002). Energy efficiency in green and energy efficient buildings is achieved by energy optimisation (passive and active) and by the use of renewable technologies. The codes, standards and labels in a country help to achieve energy optimisation (see chapter 10 for details).

Energy optimisation (passive design)

Energy optimisation with passive design refers to the minimisation of operational energy use in buildings (space heating and cooling energy consumption) by designing suitable climate zones (as outlined in section 5.1) and by the proper selection of building form, orientation and building envelope technologies. It can be achieved by incorporating passive heating and cooling methods that help to maintain indoor thermal comfort. Buildings are heated passively by absorbing solar energy on the building envelope, which is stored and then dispersed within the building's rooms. Solar energy can be collected through proper building orientation (equator facing), building tilt with respect to the angle of the sun, size of the openings and use of heat retaining materials in the external walls. Passive heat storage and heat retention within the building depends on the thermal properties (e.g. U values) and thickness of the external walls and roof materials (depending on their heat storage capacity), and on the selection of efficient glazing for the windows. The lower the U value, the higher the level of insulation. In the case of windows, double and triple glazed are preferable to single glazed due to their low thermal transmittance. The variations in the thermal performance of different window types and insulating materials are shown in Figure 56 and Table 26 respectively in Annex 3. In order to distribute heat properly and maintain a comfortable room temperature, heat loss through air leakage (i.e. to ensure low air infiltration rate) and through thermal bridges should be minimised. Likewise, cooling the building passively includes controlling the heat gained externally by taking measures such as shading the doors/windows, siting the building so that it is shaded by neighbouring structures, topography and vegetation, using proper insulation in the walls, using special glazing materials and incorporating a textured or light coloured external wall surface into the building design. Regarding shading options for the doors/windows, curtains result in less heat loss while horizontal and suspended blinds account for high levels of heat loss (Kukreja, 1978). Table 27 in Annex 3 gives examples of the properties of some shading devices. Cooling by means of adequate natural ventilation (see also section 5.3.2.5) increases the air circulation in the building.

Energy optimisation (active system)

Energy optimisation in the active system refers to the minimisation or limiting of the amount of (useful and primary) energy required in the building's operational phase in order to reduce the use of non-renewable energy. Useful energy use refers to the use of energy without it being lost as heat. Primary energy use refers to the direct use of energy at source, or supplying users with crude energy i.e. that which has not been subjected to any conversion or transformation process (IEA, 2013c). Building design approaches intended to reduce or limit non-renewable energy in buildings through active systems include efficient HVAC, lighting and the use of building automated systems (in higher efficiency buildings such as ULEBs and NZEBs). With regard to thermal comfort, the use of active systems increases when comfort levels are not achieved from the passive design.

Renewable energy

The use of renewable energy, in addition to energy optimisation, in energy efficient buildings helps to further increase the efficiency level of a building and potentially achieve NZEB. It is gained by balancing the energy needs that can be met by renewable energy technologies (Pless & Torcellini, 2010) (see also section 5.2). Renewable energy technologies include PV, solar heated water, wind turbines, hydroelectricity and biofuels etc. In some efficient buildings (homes), heating water typically consumes more energy than space heating (Environment Agency, 2007). Solar water heating can be a good alternative and also represents huge energy savings. In the case of (domestic) solar water heating systems e.g. flat plate collectors (mostly used in developing countries), a pump is employed to transfer the solar thermal energy to storage tanks, which are operated by means of a differential thermostat. An auxiliary system is connected to this system; this can be an electrical, diesel or hybrid system, resulting in different emission levels. The environmental impact is significant: a solar water heating system with electrical backup reduces GHG emissions by 79%, a system with both electrical and diesel backup reduces GHG emissions by 74.2% and a system with diesel backup by 80% (Kalogirou, 2004). Behavioural change by the building's occupants (e.g. taking shorter showers, choosing a shower rather than a bath and lowering water heater temperature settings) can also reduce water heating energy consumption (IEA, 2012).

5.3.2.2 Atmosphere

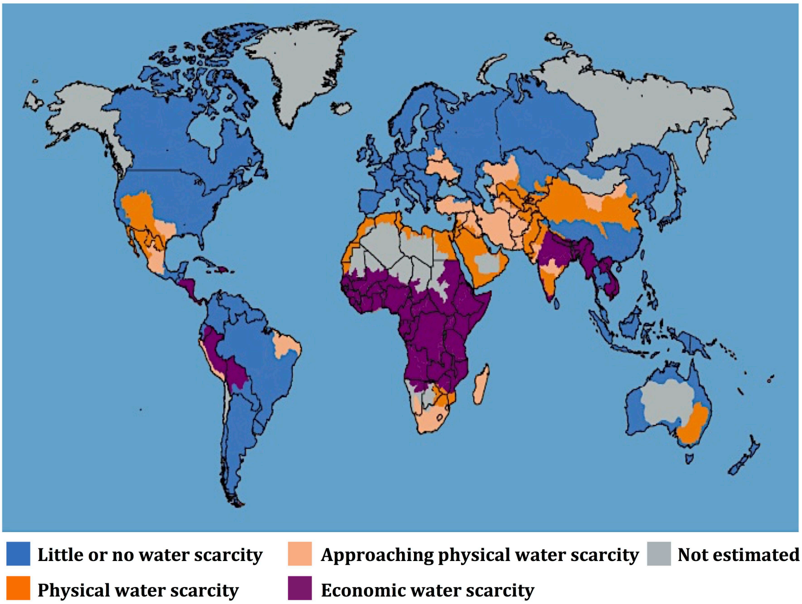
One of the major environmental impacts of buildings is the use of ozone depleting refrigeration substances such as chlorofluorocarbons (CFCs) in Heating Ventilation and Air-conditioning systems (HVAC) and other building elements. Energy efficient and green buildings reduce or do not use CFC based refrigerants and protect ozone depletion via reduced emissions from the resultant improved efficiency in the areas of refrigeration and air-conditioning.

Depleting the ozone layer causes higher levels of UVB reaching the earth's surface, which increases the risks to health and bio-diversity (plants, marine life etc.) (United States Environmental Protection Agency [US-EPA], 2010). The most widely used Ozone-Depleting Substances (ODS) (related to buildings) are chlorofluorocarbons (CFCs), which are used as coolants in refrigerators, freezers and air conditioners and also in some insulating materials (e.g. extruded polystyrene foam boards). Hydrofluorocarbons (HCFCs) can be used in place of CFCs, and these are less harmful to the stratospheric ozone than CFCs but, nevertheless, can cause some ozone destruction and are potent greenhouse gases (B.C. Air Quality, 2013). The design and use of refrigeration and air-conditioning equipment with reduced HCFC emissions and with improved energy efficiency reduces CO_2 emissions (Bivens, 2000). Likewise, global warming potential (GWP) quantifies the amount of ODSs or chemicals that contribute to global warming over a given period of time compared to the same mass of CO_2 (GWP of CO_2 is 1.0) (US-EPA, 2014).

5.3.2.3 Water efficiency

Many regions around the world face severe water scarcity due to a combination of factors such as population increase, higher incomes and changing lifestyles, pollution and climate change (Klop, Rodgers, Vos & Hansen, 2008). Scarce water supply can be due to physical or economic factors. Physical water scarcity refers to shortages that arise when water resource development approaches or exceeds sustainable limits. In these regions 75% of river flow is used for agricultural, industrial and domestic purposes (even accounting for the water that is recycled back into the rivers), resulting in severe environmental degradation, declining groundwater and a shortage of water for other purposes. In some areas more than 60% of river flow is withdrawn, and these areas are classified as 'approaching' physical water scarcity. Likewise, economic water scarcity refers to shortages that arise when humans, institutions and finances limit access to water. In these scenarios less than 25% of river water is withdrawn, even though locally there is sufficient water naturally available to meet human demand

(Klop et al., 2008 and International Water Management Institute [IWMI], 2007) (see Figure 3). Moreover, the lack of safe and clean water has hit hardest in the majority of developing countries, making it difficult for people (the poor and those of average means) to carry out daily activities and, in addition, making them more susceptible to illness.



Source: IWMI, 2007, p.11

Figure 3. Types of water scarcity in the world

Water efficiency, or the securing of water resources, is essential and it could be achieved in green building by recycling/reclaiming water use, capturing greywater for use in landscape/irrigation, by the efficient use of drinking water through better design and technology and by capturing on-site stormwater for use or groundwater recharge (Kats 2003). These water efficiency options are discussed below.

Water reuse/recycling

The ways of reusing and recycling water in a building are through the reuse of greywater and the harvesting (recycling) of rainwater. Greywater refers to all household wastewater (such as baths, showers and washbasins), except wastewater from the toilet. The treated greywater can be used for washing clothes, flushing toilets and watering the garden. But if rainwater (which requires no further treatment) is correctly collected and stored, it can also be used for those purposes. In areas of water scarcity (especially in developing countries), rainwater harvesting can be a solution to the problem of an intermittent municipal water supply. The assumption is that 60% of rainwater that falls on a building's roof could be collected and reused (Environment Agency, 2007). Table 6A shows the amount of water that can be collected according to different roof areas and rainfall volumes and Table 6B shows the drainage factor of different types of roof. The drainage factor indicates the proportion of water falling on the roof that will reach the gutter e.g. a factor of 0.5 indicates that half the rain falling on the roof will reach the gutter (Environment Agency, 2007). Likewise, as rainfall can be sporadic, its storage is needed. In general, the size of the tank can be designed to hold 18 days' worth of demand or 5% of the annual yield; the formula to calculate the optimum tank size for a rainwater harvesting system is (roof area (m^2) x drainage factor x filter efficiency x annual rainfall (mm) x 5% of annual yield (0.05)) (Environment Agency, 2007).

Table 6. Approximate annual yield of rainwater for roof size and drainage factors of different roof types

A. Approximate annual yield of rainwater in cubic metres per year for a range of roof sizes with varying rainfall

	Plan roof area m^2	50	75	100	125	150
mm rain/year	500	15	22.5	30	37.5	45
	1000	30	45	60	75	90
	1500	45	67.5	90	112.5	135
	2000	60	90	120	150	180

B. Drainage factors of different roof types

Roof type	Drainage factor
Pitched roof tiles	0.75 - 09
Flat roof smooth tiles	0.5
Flat roof with gravel layer	0.4 - 0.5

Source: Environment Agency, 2007

Water conservation

In buildings water can be conserved (i.e. less water can be used for the same purpose) by installing water saving technologies (for toilets, showers, domestic appliances and gardening) and by using water wisely to meet our needs and the needs of the environment (Environment Agency, 2007). To reduce water volume in toilets, dual flush toilets of 6/4 litres (effective flush 5 litres) and 4/3 litres (effective flush 3.5 litres) can be installed (Water Efficiency in Buildings Network, 2013), instead of conventional single full flush toilets of 6 litres. Compost or other dry toilets that do not need any water can be a good solution for sites without a reliable water supply or drainage. Urinals that operate using a timer to match the hours of use, or that are fitted with a motion sensor to detect the presence of people, save a lot of water in comparison to constant uncontrolled urinal flushing. Aerated showerheads can be an effective option for reducing water flow, and tapered and peanut shaped baths use less water yet can provide more space for bathing. Domestic appliances, such as efficient dishwashers and washing machines, also significantly reduce the volume of water used. Dishwashers use between 12 and 18 litres to wash 12 place settings, whereas washing the same crockery by hand would require 40 litres of water, and efficient washing machines use less than 40 to 50 litres of water per 6kg wash. Spray taps at the basin or sink save about 80% water (and energy) for hand washing. Gardening with added organic matter, home compost, composted bark or rotted manure at about a bucketful per square metre can boost the amount of water the soil retains, which decreases the need for additional watering. Selecting appropriate plants for the soil type and site can also be beneficial as these plants will grow roots that can search out moisture. Additionally, using the correct sized pipes and optimising the layout of piping (e.g. by minimising the length of (hot) water pipes by grouping all water fittings closely around the water source) reduces the amount of water that has to be drawn every time a tap or shower is used (Environment Agency, 2007).

Water quality

Treated surface water, as well as untreated but uncontaminated water from sources such as natural springs and the ground, is considered to be safe for fulfilling the metabolic, hygienic and domestic needs of a person (The World Bank Group, 2001). A water supplier might deliver safe drinking water but the water quality could deteriorate inside the building (in drinking water pipes and systems) by the leaching of materials, bacterial development or cross contamination with other water sources – well water or rainwater etc. Green buildings ensure the quality of drinking water and water for other purposes. Building installation can increase the likelihood of water contamination due to corrosion or the leaching of heavy metals such as lead or other harmful substances from pipes and other plumbing materials. As heated water has a higher ability to dissolve traces of plumbing materials such as copper and lead, it is not considered to be suitable as drinking water. In addition, the presence of hot water pipes near to cold water pipes might increase the temperature of the cold water in the pipes, which can increase the risks of contamination in the cold water system (GCI-UICP, 2006). Green buildings give careful consideration to the optimum design and maintenance of the water supply.

5.3.2.4 Site/Location/Transport

This criterion deals with the impact of the site (during and after the construction of the building) to the environment and the relationship between the site location and the means of transport to and from the building. The location of the building and the site on which it is built strongly determine the resource use and its environmental and ecological effects. The selection of an appropriate site reduces a building's water demand, transportation and energy impacts, minimises disturbances to the ecosystem and also lowers the project cost. In other words, a sustainable site refers to a site that operates the best management practices in terms of its activities outside the buildings, such as construction techniques that protect undeveloped land and open spaces, contaminated site remediation, traffic reduction (alternative transport), and stormwater minimisation and treatment (Harrison & Noll, 2008). The ways of minimising the building site impacts are discussed below.

Site selection

Careful selection of the site can reduce environmental impacts and preserve the ecosystem and biodiversity. Constructing a building on vacant brownfield land is less damaging to the environment and less costly than constructing it on undisturbed virgin land. The impact lessens even further when the area already benefits from infrastructure such as existing roads, public transportation facilities, utility lines and sewer lines. Construction on environmentally sensitive sites should be avoided; such sites include prime agricultural areas, wetland areas, aquifer recharge areas, floodplains, steep slopes, soil that is highly prone to erosion, geologically sensitive areas, scenic vistas, habitats for rare and endangered species, historical areas and recreational areas etc. (US-EPA, 2012).

Community connectivity and eco-friendly transport

Site circulation efficiency can be achieved by creating a close neighbourhood within an easy walking distance to goods and services such as grocery stores, retail shopping, community facilities and recreational opportunities (US-EPA, 2012). Streets with pedestrian-friendly paths, including cycle lanes and safe crossings, and parking facilities for bicycles and fuel efficient vehicles facilitate these healthier modes of transport, as well as reducing or eradicating pollution levels.

Soil protection/soil conservation

Soil protection during the building construction phase refers to the act of preventing further soil degradation (including harm to the topsoil and existing vegetation) and preserving its functions, as well as restoring the degraded soil to its intended use. Construction works can also cause or increase pollution by soil erosion, waterway sedimentation and airborne dust generation, which should be reduced. The disturbance of onsite ecology and the impact on biodiversity should be avoided/minimised during construction and, instead, the focus should be on maintaining and enhancing the ecological value of the site by replanting onsite trees in the ratio of 3:1, replanting other forms of vegetation and by consulting an ecologist before beginning the onsite construction works (CDM Smith, 2013).

Heat island effect

Heat island effects are experienced more in urban areas due to the change in the landscape i.e. the replacement of open land and vegetation with (concrete) buildings, (paved) roads and other infrastructure, which form an 'island' of higher temperature in the area. During hot sunny (summer) days the air temperature rises on the exposed urban surfaces, such as roofs and pavements, affecting the community's environment and the quality of life (while the shaded and moist surfaces can remain cooler). This rise in temperature can increase energy consumption (due to the cooling demand that generally results in emissions of air pollutants and greenhouse gases), negatively affect human health and comfort (e.g. induce respiratory difficulties, heat cramps and exhaustion etc.) and impair water quality (as the excess heat from hot pavements and exposed building surfaces is transferred to stormwater that drains into storm sewers and raises the water temperature as it is released into streams, river, ponds, and lakes) (US-EPA, 2013). The heat island effect can be minimised or prevented by reducing hard paving on site (using instead interlocking blocks or vegetative covers), providing shaded hard surfaces (with trees or other structures), incorporating 'non-roof' areas into the design (i.e. shading exposed areas on site with landscape features and using highly reflective materials for hardscape) and reducing heat absorption on roofs (by installing high albedo and vegetated roofs).

Stormwater control

The (untreated) surface runoff flows from rain and snowmelt over land and impervious surfaces (such as paved streets, parking lots and buildings' rooftops) accumulates debris, chemicals (such as oil, sediment and toxic chemicals from vehicles, pesticides and nutrients from lawns and gardens (US-EPA, 2014)) and other pollutants (such as heavy metals from roof shingle and vehicles (US-EPA, 2014)) that can adversely affect the water quality (US EPA 2012a). Stormwater pollution can be controlled by designing the site with pervious cover that allows for rain and snow melt to soak into the ground, and by managing stormwater runoff by limiting the pollution of natural water flows.

Light pollution

Light pollution refers to disturbing, harmful and wasteful lighting due to the over-illumination of commercial buildings (interior spaces), light trespassing and light cluttering from unmanaged street lighting and lighting from buildings. It not only contributes to global warming by wasting energy, but also disrupts ecosystems. Some harmful lighting (e.g. in offices) can endanger wildlife (e.g. create confusion for birds and cause their deaths especially during migration time) (Transcontinental Media G.P., 2013). Light pollution can be controlled by minimising light trespass from the building and site, increasing night sky access by reducing excess sky glow and concentrating external lighting in the appropriate areas (e.g. minimise upward lighting).

5.3.2.5 Indoor Environmental Quality

The indoor environmental quality of a building determines the occupants' health, comfort and work productivity. People spend most of the time indoors and the concentration of indoor pollution can be higher than outdoors if the indoor environmental quality is ignored. This can be improved in a building by providing thermal comfort with a higher degree of personal control over temperature and airflow, and by supplying the required levels of ventilation and outside air to ensure indoor air quality. The prevention of airborne bacteria, mould and other fungi is also necessary and this can be achieved by installing HVAC systems that adjust indoor humidity and prevent the build-up of moisture. The use of highly pollutant materials (with volatile organic compounds (VOCs) or toxins) should be avoided. Indoor acoustic privacy and comfort is also required and this can be achieved through the use of sound proofing material and equipment isolation. Unwanted odours should be controlled through contaminant isolation and the careful selection of cleaning products. Lastly, a well-lit indoor environment can be created through the careful integration of natural and artificial light sources (Whole Building Design Guide [WBDG], 2013). Ways to improve or maintain indoor environmental quality in energy efficient and green buildings are discussed below.

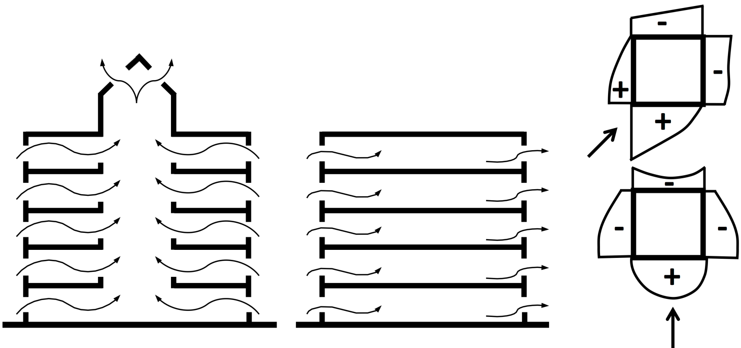
Air quality

Indoor air quality (in terms of adequate ventilation) refers to the provision of clean outdoor (natural) air and a suitably conditioned (mechanical) air supply to the occupants of the building (Dols, Persily & Nabinger, 1996) to ensure a healthy indoor environment. Absence of adequate air flow can create unwanted odours, poor air quality and mould build-up, which should be removed.

Air quality (natural ventilation)

Natural ventilation allows for fresh air and convective cooling using air movement, which removes stale and contaminated air in a room/building. Proper air movement within a building can be achieved through optimising the pressure gradient across the building, either by using the temperature gradient effect or the wind effect (Givoni, 1976). The temperature gradient effect or stack effect is due to the density difference between indoor and outdoor air. It occurs through openings (i.e. windows, doors, vents etc.) when warmer and lighter indoor air flows out at the top, and cooler and denser air from outside flows in from the bottom (see Figure 4A). Building ventilation due to the wind pressure effect depends on the direction and speed of the wind and the shape of the building (Krishan, Baker, Yannas & Szokolay, 2001). Air movement inside the room is created when wind blows against the building, which forms a high-pressure zone of increased velocity on the windward side and a low-pressure zone of lower velocity on the leeward side (see Figure 4B). Building orientation or window placement according to wind direction enhances the air movement inside a room. The perpendicular wind direction creates pressure on the frontal side only with the other three sides under suction, while oblique wind direction creates two upwind sides with the other sides under suction (Givoni, 1976) (see Figure 4C). The amount of air movement also depends on the size of the openings.

Natural ventilation allows the user to control on opening and lowers the costs (both initial costs and ongoing maintenance costs) of energy for cooling. However, this method is useful for limited to low occupant densities, but is insufficient for extreme hot climates where mechanical ventilation systems are required.



A. Temperature gradient effect of ventilation
Source: Krishan et al., 2001

B. Wind pressure effect of ventilation
Source: Krishan et al., 2001

C. Distribution of pressure around a building
Source: Givoni, 1976

Figure 4. Effect of ventilation and distribution of pressure around a building

Air quality (mechanical ventilation)

When good indoor air quality through natural ventilation is not achieved, mechanical ventilation (HVAC) is used. This uses outside air to dilute and exhaust indoor air contaminants. The appropriate ventilation rate for the HVAC should be determined, as failure to introduce sufficient ventilation can reduce indoor air quality, while powering excess ventilation will result in additional energy costs. However, care should be taken with the location of the outside air inlets as, if they are located near polluted areas such as heavily congested streets, rubbish bins etc., the outside air introduced into the building could contain contaminants. In addition, the indoor air quality from HVAC also depends on the type of air filter used; this should be chosen according to the contaminants present in the building's outdoor surroundings and should also take the indoor activities and processes into account. Sometimes during condensation, which occurs due to cooling and dehumidifying the warm air, mould growth can occur. This can be eliminated by sloping the cooling coil drain pan towards the drain and by properly trapping the drain. Careful consideration of possible leakages in the ductwork is also necessary, as this can reduce the amount of conditioned air reaching the occupied space and leaks in the return ducks can pick up contaminants as they pass through the unconditioned spaces of the building. It is also important to use proper diffuser types and locate these effectively in order to achieve proper air distribution (VentDepot, 1996).

Visual comfort

Visual comfort refers to balancing the light levels in a room through the proper size, shape and positioning of openings to allow sufficient daylight (avoiding glare and overshadowing from other buildings), combined with sufficient artificial lights that can be individually adjusted.

Visual comfort (Daylight)

The height of the window determines the depth of daylight penetration and the width affects the sideways spread of daylight (Szokolay, 2008) which, in turn, affects the distribution of light. The higher the position of the window in a room, the further the daylight penetrates into the room. A window at a height of 2m to 3m has a maximum Daylight Factor (DF) of about 5.5%; minimum 2%. Likewise, a window at a height of 1m to 2m or 3m has a maximum DF of over 10%; minimum DF is

2.5% and 3% respectively (Eicker, 2001) (for further illustration, see Figure 57A in Annex 3).

When the neighbouring buildings are too close, overshadowing affects the amount of daylight inside a room. This can be minimised by planning taller buildings and high-density development to the pole-facing side of the site, and lower rise and low-density development to the equator-facing side. Moreover, a room will benefit from good daylight levels if none of the obstructing buildings creates an angle to the horizontal (at the 2 metres reference height) greater than 25° (for further illustration, see Figure 57B in Annex 3). Likewise, glare from windows and other openings can be reduced by using low-transmittance glass or by installing blinds, or by using external protective devices (these are similar to shading devices but should not be white or bright metallic devices) (Szokolay, 2008).

Visual Comfort (Artificial lighting)

Lights with acceptable illumination (lux) levels (for different activities) inside buildings provide visual comfort. In order to establish the type of artificial lighting required, the type of activity that will take place in the room/building, the precision required to carry out the activity and the amount of work must all be analysed (Hernández Calleja & Ramos Pérez, 2011), as illustrated in Figure 58 in Annex 3, based on the lists from European norms CENTC 169).

Thermal comfort

Thermal comfort, as explained in section 5.1, is a prerequisite for energy efficient and green buildings. Undesirable thermal conditions can lead to occupants becoming dissatisfied, which has an adverse impact on their health, productivity and performance (Budaiwi, 2007). An appropriate thermal comfort level can be achieved naturally (as is the case in climate responsive design), while in extreme climate conditions a mechanical system (HVAC) is used for thermal control.

Thermal comfort (natural)

In addition to the occupants' adaptive approach to thermal comfort (i.e. the occupants' own control over the indoor environment through their choice of clothing and the actions they take, such as opening windows, blinds and using fans etc. (Nicol & Humphreys, 2002)), climatic design approach, i.e. building design that takes into account site conditions (orientation), wind speed and direction (for natural ventilation), climate zone and other environmental conditions, helps to achieve thermal comfort naturally. The right selection of building materials for the envelope provides a proper time lag for the thermal transmittance between indoor and outdoor conditions, creating good interior thermal ambiance.

Thermal comfort (mechanical)

In extreme climatic and outdoor conditions (i.e. when thermal comfort is unattainable via natural ventilation or building control approaches), indoor thermal comfort is achieved by HVAC components and device control strategies (for heat and moisture) (Vakiloroaya, Su & Ha, 2011). The seasonal setpoints must be defined (i.e. different indoor setpoints relating to the outdoor temperature for 'summer' and 'winter') based on assumptions made about clothing insulation and metabolic rate (Nicol & Humphreys, 2002), but without reference (or making little reference) to other controls such as windows etc. for ventilation. Higher thermal comfort and lower energy consumption (e.g. up to 12.8% energy saving for a commercial building in a hot and dry climate) has been achieved by the integration of both HVAC controls and building control approaches using simulations (Vakiloroaya et al., 2011).

Acoustic comfort

An acoustically uncomfortable condition within a building arises when the occupants are exposed to noise beyond their acceptable outdoor and indoor noise level (30-55 dBA) over an extended period of time. This noise can be controlled by the selection of suitable building materials (sound proofing or insulation) and by designing in accordance with the specific noise protection standards of the given country (in some countries, such standards might not exist).

Smoke Control

Indoor smoke can be controlled by prohibiting smoking (cigarettes etc.) in buildings. A designated smoking area away from the entrance is advisable, as well as the siting of buildings away from external smoke-producing areas in order to avoid outdoor smoke entering the building.

Hygiene/Chemical control

Materials that emit Volatile Organic Compounds (VOCs, especially formaldehyde and urea formaldehyde etc.) used in new building materials, products and furnishings (such as paints, adhesives and sealants) have a negative effect on human health and their use should be avoided or minimised in buildings.

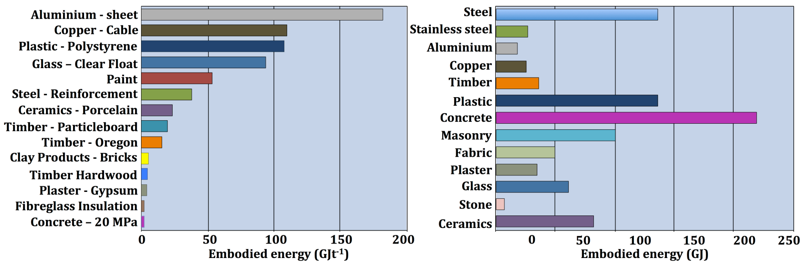
5.3.2.6 Material efficiency

The efficient use of building materials conserves non-renewable resources and reduces the environmental impacts of a building througout its life cycle. Once materials are assigned to a building, the building's energy (embodied energy) value differs according to the energy used (i) to extract, transport and process the raw materials; (ii) to change them into manufactured products and components; (iii) to transport them to the construction site; and (iv) to incorporate them into a building (WBCSD, 2007). For this reason, green building materials are a good choice over conventional energy consuming materials in terms of their lower negative impacts over the life of the product (Spiegel & Meadows, 1999). Additionally, the material efficiency of a building can be increased by the efficient use of materials, i.e. by minimising waste (reuse and recycle) and reducing GHG emissions. This illustrates that the sub-criteria that should be considered in the 'material' criterion are as follows:

Resource efficiency/Low embodied energy

On one hand, a focus on shifting towards higher energy efficiency buildings reduces operational energy, while on the other hand there are opportunities to reduce the embodied energy of a building. The embodied energy of conventional buildings comprises 10% to 15% of the whole life cycle energy (Adalberth 1997a; Sartori and Hestnes 2007; Yohanis and Norton 2002; Zhong 2005 in Gong, Nie, Wang, Cui, Gao & Zuo, 2012) and can even represent around 40% of the life cycle energy in ultra-low energy buildings (e.g. Passive House standard buildings in Belgium) due to the huge amount of insulation needed to achieve high operational efficiencies (Stephan, Crawford & de Myttenaere, 2013). Therefore, the careful selection of building materials with low embodied energy (e.g. certified wood, fly ash etc.), in terms of both the individual embodied energy of building materials and the total embodied energy of building materials in a building (Harrison, 2006), can minimise the adverse effect on the environment. For example, metallic material such as aluminium (depending on whether it is used as primary or secondary material) has a high embodied energy level at around 180 Gj/t (Harrison, 2006) due to its energy-intensive production process despite its good performance in terms of lifespan, maintenance, reuse and recyclability (UNEP, 2011), while its total embodied energy as a construction material in a building can be low compared to concrete at around 2 Gj/t (Harrison, 2006). Similarly, although concrete possesses relatively low embodied energy, its use makes a huge contribution to the total embodied energy of a building due to the enormous volume used in construction (see Figure 5A and Figure 5B). A study by Asif, Muneer & Kelley (2007) also shows that concrete was found to account for over 60% of the total embodied energy in residential building materials in Scotland, when comparing the production of five commonly used construction materials (wood, aluminium, glass, concrete and ceramic tiles) from the standpoint of energy use and air emissions produced.

However, some examples in Zürich, Switzerland show that the potential for reusing/ recycling concrete can be, on average, as high as 72% (Gugerli, 2011). And according to an Australian study (Lawson, 1996), 95% of the embodied energy that would go to waste can be saved by the reuse of building materials; the savings range from 95% for aluminium to only 20% for glass. More details about the Life Cycle Assessment (LCA) and Life Cycle Energy Analysis (LCEA) of building materials are discussed in chapter 8.



A. The embodied energy of individual building materials

Source: Harrison, 2006

B. The total embodied energy of building materials

Source: Harrison, 2006

Figure 5. The embodied energy of building materials

Material reuse/recycle

Buildings can decrease their burden on the environment and avoid the unnecessary use of natural resources by maximising most building materials through their reuse and recycle (rather than simply disposing of them at the end of life stage). Building materials such as windows and doors, metal structures and wall panels etc. can be recycled or reused. Moreover the use of recycled materials (e.g. recycled aggregates) also reduces the demand for virgin materials. For this to be effective, proper separation, collection and storage points for recycling are important.

Waste management

Managing the building waste is an important aspect of green building. Construction waste can be segregated so that it can be recovered and not diverted to landfill or other disposal areas. Careful waste management can be economically beneficial and can create value through the return of waste back into the manufacturing process, by promoting and seeking out opportunities to incorporate recycled materials into products, and by emphasising the minimisation of building-related waste through efficient job generation. Waste management includes eliminating waste where possible, minimising waste where feasible and reusing materials that might otherwise become waste (Napier, 2012). For example, during concrete construction, durable modular metal form systems, which are readily demounted and reused on other projects, eliminate wood waste related to formwork fabricated from plywood and dimensional lumber. Likewise, the selection of construction products on the basis that they are designed and manufactured to be shipped with minimal packaging, the selection of recyclable materials and products (Napier, 2012) and the optimisation of building dimensions based on standard sized materials all minimise waste. On the construction site, containers for recycling materials must be available and clearly labelled, as well as being monitored periodically to prevent waste mixing (Sustainable Sources, 2014).

6 Environmental aspects

The construction of energy efficient and green buildings provides many environmental benefits. Research by McGraw-Hill Construction (2013) gives a good overview on the environmental reasons for different firms (globally) choosing green buildings over conventional buildings. The responses from different firms confirm that the main environmental reasons for selecting green buildings are to reduce energy consumption (72%), to minimise GHG emissions (27%), to protect natural resources (27%), to reduce water consumption (25%) and to improve indoor air quality (17%). However, these reasons differ according to the country. In most developed countries (such as Germany, Norway, the UK and the other European Nations), reducing energy consumption and lowering GHG emissions are the most critical environmental reasons for selecting efficient (energy efficient and green) buildings as the EU has stringent targets to meet in terms of reducing carbon use and emissions. The second most important reason is natural resource conservation (e.g. Germany 38%) (McGraw Hill Construction, 2013). In Asian countries energy savings are also the most critical environmental reason (based on the 93% and 73% responses from Singaporean and other Asian firms respectively), while reduced water consumption (32% response from 9 Asian firms) and natural resource conservation (24% response from Singaporean firms) are the second most important reason for selecting energy efficient and green buildings (McGraw Hill Construction, 2013).

A study (Fowler, Rauch, Henderson & Kora, 2011) showed that in green buildings, energy use, water consumption and GHG emissions are 25%, 11% and 34% lower respectively than comparable baselines (taking as the example LEED Gold buildings in the US General Services Administration's portfolio compared with the average commercial buildings). The following section discusses some of the environmental benefits of energy efficient and green buildings.

6.1 Energy saving

Energy saving in terms of buildings can include operational energy saving and/or embodied energy saving. The levels of operational energy savings increase as the building becomes highly energy efficient (through the use of efficient building technologies and equipment). Green buildings with higher operational energy efficiency and lower embodied energy consumption (i.e. the use of natural materials combined with energy efficient technologies) produce more energy savings overall.

Records show that green buildings save energy; for example, LEED buildings saved 0.17 quads of energy (~49.8 billion KWh) and 8.29 million tonnes of coal (1 tonne of coal = 8141 KWh) in 2011 (Watson, 2011). Likewise, by improving conventional buildings through using energy efficient technologies (such as efficient building envelopes), a huge amount of energy can be saved in the long term. The 2DS scenario[9] IEA (2013d) illustrates that energy savings for envelope improvement could amount to between 4.3EJ and 5.8EJ in residential buildings and 1.5EJ in commercial buildings by 2050 (i.e. equivalent to almost 20% of the overall savings in the buildings sector). Energy saving due to building energy efficiency can be influential at various levels – individual, sectoral, national and international (which can further trickle through to generate wider socio-economic benefits) (Ryan & Campbell, 2012).

6.2 Greenhouse gas (GHG) emission reduction

Buildings are responsible for GHG emissions from the onsite combustion of fuels and from the end use of electricity for heating, cooling and

[9] The 2°C Scenario (2DS), as described in Energy Technology Perspective (ETP) 2012 (IEA, 2012a), considers that energy-related CO_2 emissions are halved by 2050 which help to limit the global average temperature rise to no more than 2°C. It explains how energy technologies in all sectors could be transformed by 2050 to achieve the global goal of reducing annual CO_2 emission levels to half of those in 2009 (IEA, 2013d). Likewise ETP 2014 (IEA, 2014) explains that energy efficiency makes the largest contribution to global emissions reduction in the 2DS, but requires to be combined with other technologies to achieve long term targets.

power provision. Energy efficient and green buildings can minimise emissions by reducing energy consumption, which can be achieved by better building design incorporating energy efficiency approaches (C2ES, 2009) and by using renewable energy technologies. The location efficient LEED building with sustainable site design (located in or near areas served by mass transit and alternative forms of transport) avoided 2.5 million tonnes of CO_2 emissions in 2011 and the incorporation of renewable energy in LEED buildings avoided 7.6 million tonnes of CO_2 annually in 2011. Likewise, LEED buildings avoided 0.35% of the total US CO_2 emissions in 2011 (Watson, 2011). A report prepared for the City of Santa Rosa in the USA by Wanless (2007) showed that the higher the green building certification level (gold or silver LEED rather than just certified or non-certified), the higher the GHG reduction potential and concluded that the city needs to take steps to construct new buildings above the baseline certification in order to ensure greater GHG reductions (The Maryland Department of the Environment, 2013).

6.3 Natural resource management/protection

Energy and resource efficient buildings alleviate pressure on scarce natural resources (e.g. by reducing fossil fuel extraction) (Ryan & Campbell, 2012). Green buildings encourage the use of natural building materials (or certified building products) with the further reuse and recycling of materials to help protect the environment and ecology. Green buildings also promote the careful use of scarce water, the proper treatment of waste (water) and the responsible use of land (to avoid causing further damage). In 2011, the LEED buildings avoided or treated over 2 billion gallons (~7.5 billion litres) of toxic flush through stormwater prevention and treatment, preserved ~10.3 million tonnes of topsoil from erosion control, redeveloped 36,947 acres (~149.5 million sq.m.) of brownfield sites and reduced embodied energy equivalent to 25.7 million barrels of oil (~4 million m3) (in which the area of reused buildings amounted to 183 million sq.ft. (~17 million sq.m.)) (Watson, 2011).

6.4 Water saving

Green buildings allow for water saving through measures such as reusing water (e.g. rain water harvesting and grey water reusing) and reductions in water use (low flow fixtures and waterless urinals etc.) (see also chapter 5, section 5.3.2.3). The study by Watson (2011) showed that in 2011 LEED buildings saved 48.74 billions of gallons (~184.5 billion litres) of water through efficient plumbing, landscaping and the installation of a cooling tower. In the same period, LEED buildings also reduced 9.176 billion gallons (~34.7 billion litres) of wastewater through efficient sanitary fixtures (Watson, 2011).

6.5 Pollution control

Green buildings control outdoor air pollution through proper site and transportation management (encouraging the use of public and cleaner methods of transport, which reduces the number of inefficient vehicles on the road), and reduce indoor air pollution through managing indoor air quality (discouraging chemical emissions produced by indoor equipment and technologies). Likewise, significant water pollution is controlled in green buildings through the incorporation of stormwater control (e.g. by using green roofs) and wastewater management.

7 Social and Economic aspects

As well as huge environmental benefits (as explained in chapter 6), green and energy efficient buildings provide a number of economic and social benefits. In general, energy efficiency programmes are basically evaluated on the delivery of energy savings, meaning that the full value of energy efficiency improvements in both national and global economies may be underestimated (Ryan & Campbell, 2012) and most developers do not construct environmentally friendly buildings (CB Richard Ellis, 2009). One of the reasons is the intangible nature of their socio-economic benefits, which are difficult to quantify by different stakeholders and are generally overlooked or poorly understood. As a result, energy efficient and green buildings are under-appreciated and attract poor levels of investment, meaning that the full range of opportunities and benefits are missed (Ryan & Campbell, 2012). It is crucial to understand the socio-economic aspects of energy efficient and green buildings in order to realise and appreciate the missed opportunities in terms of benefits and boost to the green economy.

The financial benefits of green buildings, resulting from lower energy use, efficient waste disposal, lower water costs, lower environmental and emissions costs, lower operating and maintenance costs, and savings from increased productivity and health, are significant (Kats, 2003a). They include investment payback (with varying payback periods), higher rent, higher building values and job creation. Research by WBCSD (2009) showed that there is the potential for investment in energy efficient buildings of US$150 billion per year, which would reduce related energy use and the corresponding carbon footprint in the range of 40% and would produce 5 year discounted payback periods for the owners (at an energy price proportionate to oil at US$60 per barrel and depending on the local context). Likewise, the study by McGraw Hill Construction (2013) showed that from 2012 to 2015 a number of firms were anticipating that 60% of their work would be in green buildings (this equates to a threefold increase in South Africa, a twofold increase in Germany, Norway and Brazil, and an increase of between 33% and 68% in the United States, Singapore, the United Kingdom, the United Arab Emirates and Australia). The main reason for this growth is the business opportunity it represents in an increasingly competitive global marketplace. Moreover, constructing green buildings contributes significantly to social benefits such as health, quality of life and increased productivity of workers/occupants, which can result in considerable additional economic benefits (UNEP, 2011).

Research from McGraw Hill Construction (2013) illustrates the most important social factors for constructing green (and energy efficient) buildings based on responses from different firms. These factors include: promoting greater health and well-being; encouraging sustainable business practices; increasing worker productivity; supporting the domestic economy; and the appreciation of aesthetic values. Similarly, the same research explains the business reasons for constructing green and energy efficient buildings based on responses from different firms. These reasons include: the belief that constructing green buildings is 'the right thing to do'; the need to respond to market transformation; the requirement of the business to fulfil environmental regulations; and opportunities to brand the building, lower the operating costs and increase business values.

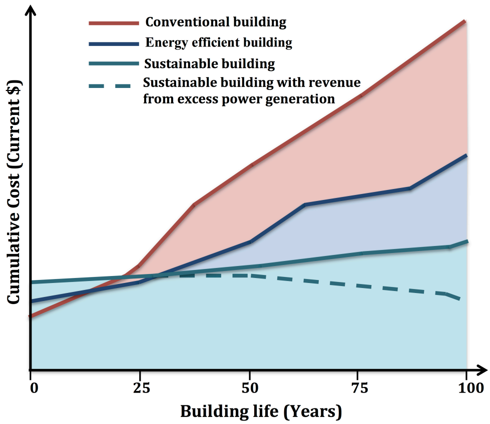
7.1 Co-benefits of energy efficient and green buildings

7.1.1 Micro benefits

Energy efficient and green buildings are perceived to have higher upfront costs. Various empirical studies of commercial green buildings in the USA and other countries illustrate that they are likely to have higher upfront costs compared to conventional buildings; ranging between 2% and 7% higher depending on the green building rating level in the USA (LEED) and UK (BREEAM), but with respect to building the zero carbon scheme the upfront cost could raise around 12.5% (CB Richard Ellis, 2009). That means that the costs for LEED Gold certified buildings are higher than LEED Silver but, when the performance level is taken into account, LEED Gold may be the most cost-effective design objective for green buildings (Kats, 2003a). On the other hand, the green cost premium depends also to a great extent on the skill of the designers and builders in incorporating green factors into the design (UNEP, 2011). In India the cost premium for green buildings is in the range of 6% to 18%, depending on the certification level. This is mainly due to a lack of technical knowledge, the immaturity of the market and a lack of resources (Roy & Gupta, 2008). Whatever the upfront cost for energy efficient and green buildings, developers (in both developed and developing countries) will receive certain rewards for this increased investment in the form of higher rental values, which reflect the lower operating costs of such buildings (CB Richard Ellis, 2009), improved health and/or increased productivity of occupants/workers (UNEP, 2011) and an increase to the building's value and reputation. Weighing (additional) upfront costs against reduced life cycle costs and (soft) benefits from green buildings (e.g. image and reputation deriving from the decision to invest) also appears to depend on the ownership of the building, combined with the potential to split incentives between the developer and the owner. These micro benefits are described below.

7.1.1.1 Cost saving

The higher initial cost for energy efficient and green buildings proves to be economically beneficial when analysed in the context of the building's life cycle. In Figure 6, a comparison of conventional buildings with energy efficient buildings, sustainable (green) buildings and sustainable buildings with revenue from excess power generation, shows that investing in sustainable buildings with solar and other power generation technologies results in cumulative life cycle costs falling below the original construction costs (assuming that energy costs will escalate over the next century) (Ted, n.d.).



Source: Ted, n.d.

Figure 6. Life Cycle Cost Relationships between Building Alternatives

The incremental investments in green buildings are paid back from reduced life cycle costs. The payback period depends on the level of certification of the green building, e.g. for LEED Platinum it is more than 10 years, while for LEED Gold it is 5 to 10 years (Enermodel Engineering, 2012). A study (Kats, 2010 in UNEP, 2011) suggests that green buildings are often believed to be more expensive than they actually are. Data from 170 green buildings in the USA showed that it costs, on average, only 1.5% more to construct green buildings than to construct conventional buildings, while public perception was that the cost would be approximately 17% more. Additionally, these premium costs are recovered through lower energy bills and increased employee productivity (Kats, 2010 in UNEP, 2011). Similarly, when considering energy efficient buildings in different European countries, the discounted payback time for ultra-low energy buildings (e.g. Passive Houses) varies from 4 to 19 years for the different countries (Passive-On Project, 2007, p.31). Operational energy costs account for nearly 10% of total costs in commercial buildings in the USA (Eichholtz, Kok & Quigley, 2010a) and anecdotal evidence shows that LEED-certified buildings use 30% less energy on average than conventional buildings (Kats, 2003b). They also benefit from cost savings for potable water supply through water efficiency from rain water harvesting, the use of pervious paving for groundwater recharge and waterless urinals (UNEP, 2011). The net present value of 20 years of water savings in a typical green building in the USA ranges from US$5.40 to US$21.50 per square metre (Kats, 2010). Similarly, material cost savings in green buildings are achieved through lowering the embodied energy in the building materials by recycling and reusing the products as mentioned above (life cycle cost). These cost savings from green buildings again translate into premium rents for developers.

7.1.1.2 Health/employee productivity

Energy efficient and green buildings impact positively on public health and associated social aspects, due to their improved heating and cooling systems (thermal comfort) and good air quality. A variety of illnesses are associated with cold indoor temperatures and damp and mould in (conventional) housing; particularly respiratory illness and asthma in children (Ryan & Campbell, 2012). Likewise, employee sick leave is also higher in thermally uncomfortable (conventional) offices. Green buildings and improved energy efficiency in buildings can result in appreciable benefits for the health of residential occupants, office employees and other stakeholders (as well as for the whole population) (Ryan & Campbell, 2012).

A green building with a better and healthier indoor environmental quality results in higher employee productivity, together with increased satisfaction of the (indoor) working conditions (Eichholtz et al., 2010a; Miller & Pogue, 2009). Although the financial impact of healthier and more comfortable green buildings is difficult to assess (Eichholtz, Kok & Quigley, 2010b), by taking into account its indirect potential to reduce sick leave and increase productivity (Eichholtz et al., 2010a) tenants (who are dependent on high levels of human capital (Eichholtz et al., 2010a)) may be willing to pay a higher rent for buildings with better indoor environmental quality (Eichholtz et al., 2010b). For the average office, employee costs are a major share of total expenditure and the potential financial benefits from improved productivity are substantial – even greater than the direct cost savings gained from lower energy consumption (Edwards, 2006; Nelson, 2007).

7.1.1.3 Reputation

Green building developers use green spaces to give an impression to stakeholders and customers that the firm has a long term commitment to the natural environment. In a Finnish study (Newsec, 2012 in Heincke & Olsson, 2012), 150 large northern European companies were asked about environmental responsibility. 80% of the companies considered that environmentally adapted buildings (energy efficient and green buildings) strengthened a company's reputation. Likewise, firms in the finance, insurance, real estate and service sectors rent green offices, preferring higher building quality to conventional office space (Eichholtz et al., 2010a). Tenants who lease space in green buildings send a strong public signal about their social awareness and the superior social responsibility of the occupants (Eichholtz et al., 2010b). Leasing office space in green buildings also helps to offset a negative environmental corporate image for firms who operate in environmentally 'unfriendly' industries or environmentally sensitive industries, such as mining and oil (Eichholtz et al., 2010a). This can help to attract a better quality work force and improve the company's reputation, providing indirect economic benefits. However, the added value gained from owning green buildings is difficult to assess in solely financial terms (Heincke & Olsson, 2012).

7.1.1.4 Higher rental value

Developers receive economic benefits from green and energy efficient buildings by attracting higher rents from tenants, who are prepared to pay more in view of the socio-economic (and environmental) benefits. The rent premium varies slightly (this is shown in various research). Research (Wiley, Benefield & Johnson, 2010) on office buildings in the USA shows that green and energy efficient certified buildings achieve rents that are between 15.2% and 17.3% higher (in the case of LEED buildings) and 7.3% to 8.6% higher for Energy Star buildings (data collected from the CoStar Properties within the CoStar Group examining class A office leasing activities in 46 markets across the USA with a total of 7,308 properties using a hedonic pricing approach. Class A office space tends to be highly responsive to changes in design technologies). Likewise, another study in the USA (Eichholtz, Kok & Quigley, 2010c) was carried out for Energy Star and LEED (office) buildings to examine the changes in rental or investment returns between 2007 and 2009 for buildings that were already certified in 2007 in comparison to non-certified buildings. The research illustrated that the downturn in the property market from 2007 to 2009 did not have a significant negative effect on the financial performance of certified (green and energy efficient) buildings in the USA (8182 commercial office buildings were analysed in the study) and that the rental premiums were 5.8% higher for LEED certified buildings and 2.1% higher for Energy Star certified buildings. Likewise, another study (Fuerst & McAllister, 2011) showed a rental premium of approximately 5% for LEED buildings and 4% for Energy Star buildings. (This study analysed 1900 certified buildings, of which 626 were LEED buildings and 1282 were Energy Star. The researchers considered 9806 transaction prices and 18519 asking prices for rentals; the transaction prices were observed over a period of 10 years from 1999 to 2008 and all the rent observation are of Q4 2008). Wiley et al. (2010), Eichholtz et al. (2010c) and Fuerst and McAllister (2011) indicated that green buildings (LEED certified office buildings) attract a higher rental premium than energy efficient buildings (Energy Star office buildings). According to CB Richard Ellis (2009), the amount of the rental increase depends on the rating level of the green building certification.

Eichholtz et al. (2010c) also showed that energy efficiency has a significant effect on rents, with a US$1 saving in energy costs translating into a US$0.95 increase in (net) rent. Moreover, market studies have also shown that buyers or tenants will pay higher prices or higher rents for ultra-low energy buildings (Passive Houses) and green buildings, particularly in view of predictions about the likely future increases in energy costs (Ernst & Young, 2008). In a study examining high-rise commercial green buildings in the USA, the higher rental values decreased slightly for the storeys above 20 (Eichholtz et al., 2010b).

7.1.1.5 High sales value

As well as attracting higher rental values, the improved energy performance and resource efficiency of green buildings also translates into higher selling prices for investors. As energy is the highest single operating cost in most offices, the net present value of future energy savings can be added to the resale value (Ryan & Campbell, 2012). A study (Wiley et al., 2010) of office buildings in the USA shows that green and energy efficient certified buildings receive significant sales premiums, such as US$129/sq.ft. for LEED buildings and US$30/sq.ft. for Energy Star buildings (US$1/sq.ft. = approx. US$10.80/sq.m.). This data was collected by CoStar COMPS within the CoStar Group, examining class A offices (as class A office space tends to be highly responsive to changes in design technologies) and identifying 25 office markets with sales information – a total of 1151 observations. Likewise, according to Eichholtz et al. (2010c) the transaction price (sales premium) for LEED buildings is 11.1% higher compared to conventional buildings. A study by Fuerst & McAllister (2011) showed that sales premiums of 25% for LEED buildings and 26% for Energy Star buildings (based on survey results for 559 Energy Star and 127 LEED certified buildings).

Similarly, other studies (Bounen & Kok, 2009; Griffin et al., 2009; ADEME, 2011; Salvi et al., 2008-2010 and Kaufman, 2011 in Heincke & Olsson, 2012) on housing in France, the Netherlands, Switzerland and the USA show that market values for certified buildings increase by between 3% and 9%. In addition, certified buildings sell faster than uncertified ones (Bounen & Kok, 2009 in Heincke & Olsson, 2012). Due to the high demand for green buildings by tenants, it is predicted that green buildings could have longer economic lives than conventional buildings. This implies a lower volatility in market value, reduced risk premiums and higher valuations. Moreover, the buildings' value is related to their energy efficiency level. A 10% decrease in energy consumption leads to an increase in value of about 1% in the USA, over and above the rent and value premium for a certified building (Eichholtz et al., 2010b). In addition to this, US-EPA states that for every US$1 investment in energy performance improvement, a commercial building owner can generate US$2 to US$3 of incremental asset value (US-EPA, 2003 in Ryan & Campbell, 2012; FYP 2012).

7.1.2 Micro benefits

Energy efficient and green buildings also provide macro-economic benefits through the creation of new green jobs, securing energy and resources within a country and raising a country's economic situation.

7.1.2.1 Job creation

The emerging industry for the construction of energy efficient and green buildings has a big influence on the creation, substitution, elimination (in certain cases) and transformation of conventional jobs (UNEP, 2011) to green jobs, and also provides a boost to the green economy. Green construction has the potential to transform resource-consuming (conventional) buildings into partial producers of resources such as water, energy and materials, or even green space, as new jobs are generated to respond to new and stringent standards for water heating and energy efficient equipment (Comstock et al., 2012). The current demand for green buildings has increased the production of resource efficient materials, products and components, and has furthered the expansion of renewable energy sources including recycling and waste management (UNEP, 2011) in both developed and developing countries. A study by the International Labor Organization [ILO] (2009) in UNEP (2012) on the green building industry in Brazil shows that the share of jobs in the construction, commercialisation, maintenance and use of buildings increased from 6.3% of total jobs in 2006 to 7.3% in 2008. According to a study by Booz Allen, the US green building sector supported over 2.4 million jobs (from 2000 to 2008) across occupations ranging from construction managers and carpenters to truck drivers and cost estimators (United States Green Building Council [US-GBC], n.d.). UNEP (2012) also indicated that investment in energy and resource efficient buildings and products generates a net gain, citing the example that an investment of US$1 million would generate a net gain of 16.4 job-years over 20 years.

7.1.2.2 Energy/Resource security

By improving energy efficiency and reducing energy demand, a country can improve the security of its energy systems across the four dimensions of risk i.e. fuel availability (geological), accessibility (geopolitical), affordability (economic) and acceptability (environmental and social) (APERC, 2007; Kruyt et al., 2009 in Ryan & Campbell, 2012).

7.1.2.3 Country's economic growth

The positive macroeconomic impacts of efficient (energy efficient and green) buildings include the growth in GDP and the collective benefits of an improved trade balance (for fuel importing countries), national competitiveness and employment support. These are basically the result of the indirect effects of increased consumer spending and economy-wide investment in energy efficiency, as well as of lower expenditure on energy (Ryan & Campbell, 2012). Green and energy efficient buildings provide benefits for green growth[10] (or the green economy) and for sustainable development. Governments achieve the benefits of green growth through cost-effectiveness, positive societal and individual welfare benefits and environmental advantages – while simultaneously contributing to economic development and growth (Ryan & Campbell, 2012). Additionally, green growth contributes to public budgets by reducing expenditure on energy and using fewer resources in the public sector. For example, fuel-importing countries benefit from positive impacts on their currency reserves, while energy exporting countries free up more fuel for export. For countries with energy consumption subsidies, reduced consumption means lower government budgetary outlays to finance these subsidies (Ryan & Campbell, 2012).

[10] Green growth is the growth that ensures 'natural assets continue to provide the resources and environmental services on which our well-being relies' (OECD 2011).

The green economy is even more important in developing countries. It improves human well-being and social equality, while significantly reducing environmental risks and ecological scarcities (UNEP, 2011) and maintaining the balance of environmental and economic aspects with social elements (European Environment Agency, n.d.). For developed countries, the green economy accelerates the achievement of climate mitigation strategies and helps to fulfil the target of achieving NZEB (by 2020). For developing countries (such as India) the green economy represents a mechanism for dealing with unprecedented urbanisation, for stopping the growth of the inefficient building sector and for improving people's livelihoods. Ramesh, an Indian Minister for the Environment and the Forest, said in 2011 that the importance of the green economy in India is a matter of livelihood, not just a matter of lifestyle. Unless people's livelihoods are protected and improved, it is hard to make economic growth inclusive. In developing countries, significant levels of new construction are expected to provide adequate housing for over 500 million people, while access to electricity is to be provided for over 1.5 billion people. Therefore, taking into account sustainable or energy efficient and green building strategies at the design and construction stage makes good economic sense (UNEP, 2011).

The interrelationship between co-benefits of energy efficient and green buildings

One benefit of energy efficient and green buildings may impact, or increase the impact, of another benefit, thereby increasing the overall social and economic value of the buildings. The impacts can be direct or indirect. For example, when a building is cost-effective or has a low life cycle cost, it has the direct impact of attracting a high sale and rental value and the indirect impact of increasing the reputation of the owner, developer, construction company or tenant. Likewise, a building with a healthy environment that consequently improves employee productivity can have the direct impact of increasing the company's reputation, the building's rent and sale value, and the indirect impact of saving costs (due to the reduced number of employee absences and improved productivity). Table 7 shows the impacts of such co-benefits in an assessment matrix. From left to right, the table shows whether one benefit impacts on another *directly (D), indirectly (I) or has no effect (N).*

Table 7. An assessment matrix of co-benefits of energy efficient and green buildings

	Micro benefits					Macro benefits		
	Cost saving	Health	Reputation	Higher rent	High sales	Job	Energy security	Economic growth
Cost saving	------	N	I	D	D	I	D	D
Health	D	------	D	D	D	I	N	D
Reputation	N	N	------	D	D	I	N	N
Higher rent	N	N	N	------	D	N	N	N
High sales	N	N	N	D	------	N	N	N
Job	D	N	N	N	I	-----	D	D
Energy security	D	N	N	D	D	D	------	D
Economic growth	N	I	I	D, I	D, I	D	I	------

7.2 Market driving factors in energy efficient and green buildings

Although the various benefits of energy efficient and green buildings may drive/encourage stakeholders to build energy efficient and green buildings, their market driving factors and energy and resource saving potentials depend to some extent on stakeholders' perspectives (in terms of investment payback periods, awareness, their willingness to pay and economic situation (ability to pay)), location, and energy price dynamic.

7.2.1 Stakeholders' perspective

In view of the economic (as well as the environmental and social) benefits of energy efficient and green buildings, a variety of different stakeholders should feel incentivised to construct such buildings. But the stakeholders are confronted with general barriers that prevent the large-scale transformation of the market, including a lack of awareness of energy and resource efficient technologies and options, uncertainty about the related financial and other benefits (e.g. variations in payback periods), a lack of motivation due to other priorities (willingness to pay) and capital constraints and risk aversion (ability to pay) (Sorrell, O'Malley, Schleich & Scott, 2004 in Höfele & Thomas, 2011). Sometimes when the users of the buildings are not aware of the environmental effects of the savings, a *rebound effect* occurs.

7.2.2 Payback periods

Some corporate organisations look for the social and marketing advantages of occupying green buildings, while investors and developers only adopt green practices when they make good commercial sense (CB Richard Ellis, 2009). This relates to the intended payback period of the higher initial investment cost. Many building owners who intend to sell or lease consider a four-year payback period acceptable, as this can be factored into a sale or letting price without making a loss. Depending on the period of the lease, some tenants may consider payback periods of up to 10 years, and astute owner-occupiers may consider payback periods of up to 25 years (Brophy & Lewis, 2011).

7.2.3 Stakeholder awareness

The increase in the levels of construction of green and energy efficient buildings depends on the awareness of stakeholders, especially of investors. If property investors are unaware of the potentials for premium rental values and the value creation of green buildings, as well as their environmental benefits, few such buildings will be constructed. There is currently a problem due to the lack of available information, for example, on actual energy consumption. Sometimes building owners, developers and tenants are unable to make well-informed decisions on their environmental management if a baseline measurement of energy use is not established. For example, if investors are not able to directly measure the energy savings of efficient lighting or heating systems, then they are not likely to install energy efficient lighting or an advanced environmental management system (EMS). Therefore, demonstration through the use of smart metering or smart building software can be useful to measure precisely the source of an energy saving. Added to this, the slow progress made in introducing the construction of green buildings to the real estate sector in developing countries (South and Southeast Asia) is due to the growing risk of energy insecurity, water scarcity and climate change (as also mentioned in Kok, Bauer, Eichholtz & Quigley (2010)). The connections between these (environmental) benefits and financial gains are not well understood by analysts, investors, companies and governments in the (Asian) region.

7.2.4 Willingness to pay

For investors who need to offset their higher initial investment in green buildings, the economic benefits of green buildings are reflected in tenants' willingness to pay net rent premiums for green spaces and in the fact that risk premiums are lower for green buildings (Eichholtz et al., 2010b). The willingness of developers to pay for green buildings improves with the understanding that the increased costs may be offset (to some extent) by higher rents (CB Richard Ellis, 2009). Tenants, for their part, are incentivised to pay higher rents as they will benefit from reduced energy costs.

7.2.5 Economic situation/ability to pay/country context

The ability to pay for green buildings is higher in metropolitan areas where income levels are higher, and it can relate to the positive association between income and willingness to pay for environmental goods (Kok, McGraw & Quigley, 2012). However, the opposite is true in poor areas where people already face major economic barriers to affording conventional buildings. However, making buildings greener can be a major strategy for improving access to basic services and reducing vulnerability and, more broadly, for contributing to better living conditions for the poor (UNEP, 2011). To support this, India has incorporated 3 approaches – vernacular architecture, the Indian green building rating system (GRIHA) and energy efficient buildings (UNEP, 2011).

7.2.6 Rebound effect

A range of potential benefits related to energy (and resource) efficiency through key energy (and resource) savings do exist, but these are often not realised because improved efficiency gains are undermined and counterbalanced by increased consumption and expenditure. This is known as the rebound effect (Ryan & Campbell, 2012). As an effect of energy or cost savings, individuals or industries increase the size, number, features and use of energy-consuming equipment (Janda, 2011, p.16) (see Table 8 for examples of different rebound effects). This has a negative effect, leading to lower reductions in energy and resource demand than anticipated, although it is sometimes justified in terms of providing welfare gains to the individual and society. This effect is an important issue for OECD countries, and even more pertinent for emerging economies looking to improve the quality of life of its citizens (Ryan & Campbell, 2012).

Behavioural change and awareness of occupants is key in unlocking sources of energy savings that cannot be achieved from architectural and technical strategies alone (Shama, 1983 in Janda, 2011, p.17). Janda (2011) also points out that architects play an important role in improving buildings and should look for ways of integrating user involvement into building performance to fully succeed. This approach can reduce the rebound effect.

Table 8. Examples of three different rebound effects

Rebound Effects	Consumer		Producer	
	Income	Substitution	Output	Substitution
Direct	Turning up the heat, using more appliances	Buying a bigger house	Increasing production	More energy use relative to other factors
Indirect	Taking a holiday		Lower cost appliances lead to more energy consumption	
Macro-economic	Lower prices for energy services boost demand for all goods and services economywide; increased employment		Increased productivity, higher profits/dividends implies investment in the economy	

Adapted from: Ryan & Campbell, 2012, p.24

7.2.7 Location

One study (Eichholtz et al., 2010b) on the economics of green commercial buildings in the USA found that the premium is negatively related to the location of the building. A green building that is located in a lower cost region or in a less expensive part of a metropolitan area can achieve a higher rental or sales value than a conventional building in the same location. However, in the most desirable (popular) locations, the levels of increased rental and market value documented for green buildings are lower (Eichholtz et al., 2010a).

7.2.8 Energy price dynamic

The economic benefit of green buildings also depends on the differences in energy usage and running costs. If the oil price falls, the scale of the cost saving will also be reduced. However, some evidence suggests that for any given level of oil price, the energy savings in energy efficient buildings, relative to inefficient buildings, remain significant and, depending on the level of efficiencies, these savings can exceed between 10% and 50% (CB Richard Ellis, 2009). Likewise, the study by McKinsey (2009a) estimated that an increase in the price of oil from US$50 per barrel to US$200 per barrel could decrease the overall growth in energy demand for commercial buildings from 1.8% to 1.6% and for residential buildings from 2.1% to 2.0% between 2006 and 2020. However, overall, buildings are much less sensitive to oil prices than other sectors (e.g. transport) (McKinsey, 2009a).

8 Life cycle perspective of energy efficient and green buildings

Compared to conventional buildings, energy efficient and green buildings provide many environmental and economic benefits, as shown in chapters 6 and 7. However, by examining the technologies and materials used in the buildings' life cycle more closely, it becomes clear that the environmental and economic impacts vary. A building life cycle perspective shows how the greater reduction of operational energy in the higher energy efficient buildings can contain significant levels of embodied energy and also shows how the higher upfront costs for energy efficient and green buildings turn out to be beneficial in the long run. Therefore, to achieve energy efficient as well as resource efficient buildings, the life cycle perspective of energy efficient and green buildings must be taken into account. This chapter shows the interlinkages of energy efficient and green buildings on the overall reduction of energy and resources and also illustrates the effect of conventional technologies in comparison with the environmentally friendly alternatives in a building.

Life Cycle Assessment (LCA), Life Cycle Energy Analysis (LCEA) and Life Cycle Cost Analysis (LCCA) are the environmental evaluation methods used in this study to analyse a building's products or processes over its life cycle. Various reviews of the literature dealing with background information on this subject, together with case studies of energy and resource efficient buildings and technologies, are discussed in this section.

8.1 Background: LCA, LCEA and LCCA

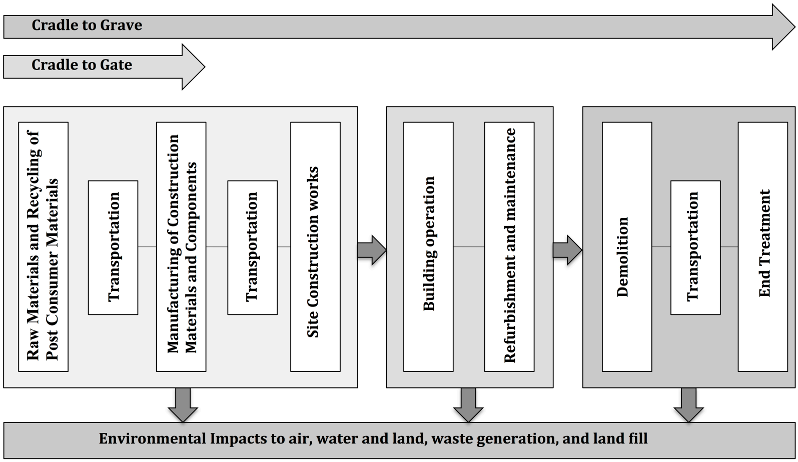
8.1.1 Life Cycle Assessment (LCA)

Life Cycle Assessment (LCA) is a method of systematically analysing the environmental performance of products and processes over their entire life cycle (Cabeza, Rincón, Vilariño, Pérez & Castell, 2014). The Code of Practice by the Society of Environmental Toxicology and Chemistry (Consoli et al., 1993) describes LCA as a process for evaluating the environmental impacts related to a product, process or activity by identifying and quantifying the energy and materials used and wastes released into the environment; for assessing the impacts of the energy and materials used and wastes released to the environment; and for identifying and evaluating opportunities to improve the environment. A complete LCA evaluates the entire process, from the raw material extraction to the final disposal of the product or its eventual recycling or reuse, which shows the environmental impacts at different stages of the product's life cycle. In order to determine the environmental impacts, the inputs (quantities of raw materials, energy use and water consumption) needed for a process and the resulting outputs (atmospheric emissions, waterborne and solid wastes, by-products and other releases) are considered for each life cycle stage (Curran, 1993, 1996 in Stephan, 2013).

Types of Building LCAs

In order to evaluate buildings' environmental impacts, LCA can be applied from cradle to grave or from cradle to gate (see Figure 7). In general, building LCA can be divided into 3 types – conventional life cycle assessment, comparative life cycle assessment and streamlined life cycle assessment (Stephan, 2013).

Conventional life cycle assessment is a whole life cycle assessment (from cradle to grave), which evaluates individual processes or products across the different stages of the life cycle to improve their environmental profile (in the identified areas). Likewise, *comparative life cycle assessment* compares the environmental impacts of two or more products or processes with the same function to identify the product with the better environmental profile. *Streamlined life cycle assessment*, on the other hand, considers only some environmental impacts and/or some stages of the life cycle of a product or process (cradle to gate) (Stephan, 2013). Some of the factors for streamlined life cycle assessment are due to a building's longer life span (more than 50 years), which makes it difficult to predict the whole life cycle (cradle to grave) and possible changes in a building's form and function during its life-span, which makes it difficult to predict the change from the original form.



Source: Khasreen, Banfill & Menzies, 2009

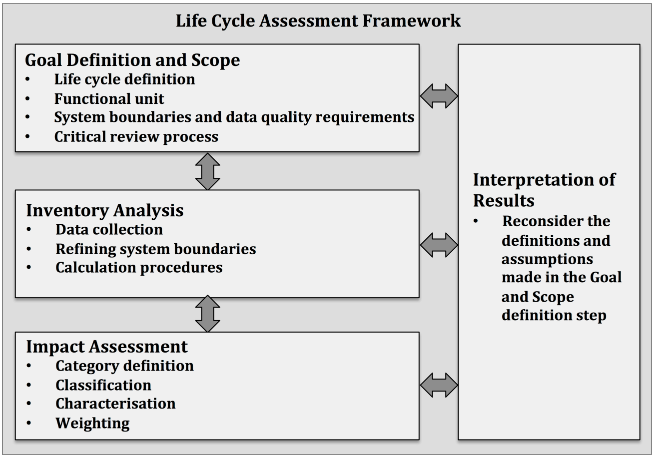
Figure 7. Cradle to grave and cradle to gate in building LCA

In addition to these types of assessment, Cradle to Cradle (McDonough & Braungart, 2002) is an ideal way to mimic nature in the form of an endless cycle of materials with a no-waste nutrient cycle. It encourages the use of harmless materials only and, if possible, compostable (biological nutrients) and non-compostable or toxic (technical nutrients) materials should be segregated so that a product can be disassembled and the two kinds of materials can be disposed of or reused separately. This material stream generates nourishing waste or no waste at all instead of depleting resources (Cool Climate Network, n.d.).

Building LCA framework

According to ISO 14040, the building LCA framework incorporates 4 steps (see Figure 8):

- Step 1: Goal and Scope Definition
- Step 2: Inventory Analysis (Life Cycle Inventory Analysis)
- Step 3: Impact Assessment (Life Cycle Impact Analysis)
- Step 4: Interpretation (Life Cycle Assessment)

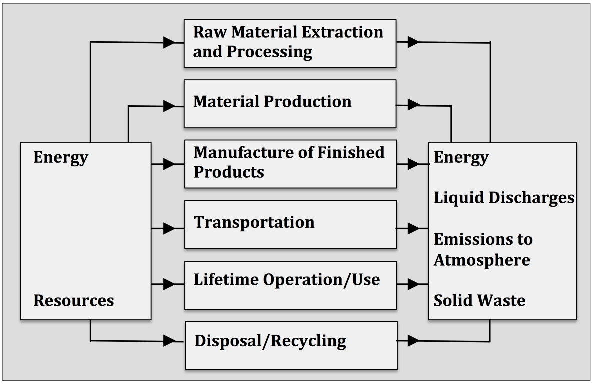


Source: AIA, 2010, p. 25 and Canada Mortgage and Housing Corporation, 2004, p.3

Figure 8. Building LCA framework

Step 1: Goal and Scope Definition deals with defining the products and services to be assessed (AIA, 2010) in a building's life cycle. This process of definition incorporates assumptions about, or estimations of, the building's functional service life time, scenarios for use and maintenance, repair and replacement of components, major renovations, demolition and recycling. *The functional unit* is also established, which serves as a basis for comparison and for normalisation reference for the input and output flows. Likewise, system boundaries (that identify the extent to which specific processes are included or excluded) and *data quality requirements* (that address aspects such as time, geographical and technology-related coverage of the included data) are also defined. To ensure the quality of the study, a critical review process is carried out consulting a reviewer or review panel (Canada Mortgage and Housing Corporation, 2004).

Step 2: Inventory Analysis involves the collection of data and the refining of system boundaries (Canada Mortgage and Housing Corporation, 2004) (see Figure 9). The energy and raw materials used and their emissions into the atmosphere, water and soil for each step in the process are quantified, and then combined in the process flow chart and related back to the functional unit. This step also involves the preparation of an inventory of all the *inputs and outputs to and from the production systems*. Using Life Cycle Inventory (LCI) results, products and processes can be compared and evaluated. Software tools and databases are critical in this step (AIA, 2010) (see also section 8.1.4).



Source: British Royal Chemistry Society in AIA, 2010

Figure 9. Life Cycle Inventory Analysis steps

Step 3: Impact Assessment involves *category definition*, which provides guidance on selecting and defining the environmental categories addressed by the study. These are then classified and inventory inputs and outputs are assigned to the impact categories. The *characterisation factor* is used, in which the relative importance of the contributing substances is modelled and quantified for each of the impact categories. Lastly, the *impact categories are ranked* according to their relative importance to each other and numerical values are assigned to show their relative levels of significance (Canada Mortgage and Housing Corporation, 2004). The impact categories of building LCA differ according to the system used. Impact is given as a ratio of the quantity of the impact per functional unit of product produced. Each impact category is an indicator of the contribution of a product to a specific environmental problem (AIA, 2010). See Table 9 for various impact categories.

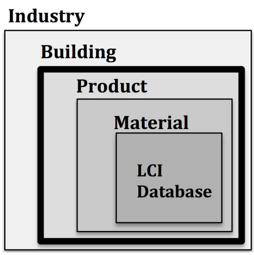
Table 9. Impact categories used in LCA

Impact categories	Short description	Unit
Global warming Potential (GWP)	Characterise the change in the greenhouse effect due to emissions and absorptions attributable to humans (AIA 2010) and measure the increase in the earth's average temperature (Crawford, 2011, p.55 in Stephan, 2013)	Gram equivalent to CO_2 per functional unit of product (note: impact not an emission)
Acidification Potential (AP)	Emission of acidifying substances (principally sulphur and nitrogen) to air and water (Crawford, 2011, p.55 in Stephan, 2013)	Grams of hydrogen ions per functional unit of product
Eutrophication Potential (EP)	Increased concentration of chemical nutrients (such as nitrogen and phosphorus) in water and on land (Crawford, 2011, p.55 in Stephan 2013) that results in undesirable shifts of species in ecosystems and a reduction in ecodiversity (AIA, 2010)	Grams of nitrogen per functional unit of product
Fossil Fuel Depletion	Consumption of non-renewable energy or material resources (Crawford, 2011, p.55 in Stephan 2013) and the depletion aspects (AIA, 2010)	Megajoule (MJ) of fossil-based energy per functional unit of the product
Smog Formation Potential	Emissions (from industry and fossil fuel powered transportation) of substances (volatile organic compounds, nitrogen oxides) to air (Crawford, 2011, p.55 in Stephan, 2013)	grams of nitrogen oxide per functional unit of product
Ozone Depletion Potential	Increase of stratospheric ozone breakdown (Crawford, 2011:55 in Stephan, 2013) that protects the earth from certain parts of the solar radiation spectrum (AIA, 2010)	CFC-11 per functional unit of the product
Ecological toxicity	Emissions of organic substances and chemicals to air, water and land (Crawford, 2011, p.55 in Stephan, 2013) that harm terrestrial and aquatic ecosystems	Grams of 2, 4-dichlorophenoxy-acetic acid per functional unit of product
Water use	Consumption of water	litres per functional unit

Source: adapted from AIA, 2010 and Crawford, 2011 in Stephan, 2013

Step 4: Interpretation of LCA results incorporates the identification of important environmental issues, an evaluation of the fundamental study and the resulting information. This leads to conclusions and recommendations from both the life cycle inventory analysis and the life cycle impact assessment (Canada Mortgage and Housing Corporation, 2004).

In addition to these steps, LCA can be carried out at one of four levels: material, product, building or industry, as in Figure 10. At material level, the material information is calculated by chemical engineers and associated specialists and submitted for inclusion in different LCI databases. At product level/product LCA, the product information (on the source and quantities of materials and the manufacturing processes) is calculated as a collection of materials, which are assembled into a final product. At building level, whole-building LCA is carried out (where the product is the building). Lastly, at industry level/building industry scale LCA, the Economic Input-Output (EIO) LCA is used to quantify the impacts of material production (e.g. cement and steel), suburban sprawl, urban densification and land use changes (AIA, 2010).

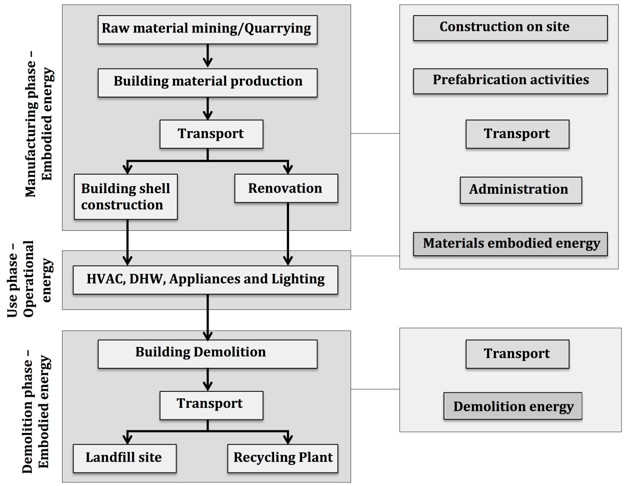


Source: AIA, 2010

Figure 10. Building LCA on four levels

8.1.2 Life Cycle Energy Analysis (LCEA)

Life Cycle Energy Analysis (LCEA) accounts for all the energy inputs in a building's life cycle, including energy use for building manufacture, use and demolition. During the manufacture phase, energy is used for the manufacturing and transportation of building materials and technical installations; this is also known as embodied energy. Energy is mainly used in the operational phase for heating and cooling to maintain the thermal comfort condition, to heat water and to power appliances; this is known as operational energy. The third energy type in this cycle is demolition energy; i.e. energy used at the end of the buildings' service life to destruct it and to transport the dismantled materials to landfill sites or recycling plants (Ramesh, Prakash & Shukla, 2010) (see Figure 11).



Source: Cabeza et al., 2014

Figure 11. Life cycle energy of a building

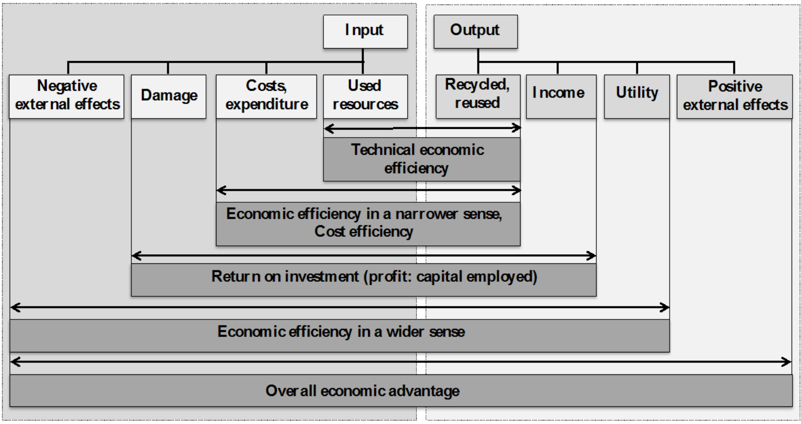
8.1.3 Life Cycle Cost Analysis (LCCA)

Life Cycle Costing or Life Cycle Cost Analysis (LCCA) is a method of systematically calculating and evaluating a building's cost over its complete life cycle or a defined period of observation (König, Kohler, Kreissig & Lützkendorf, 2010). Building LCCA, a valuable tool for rational decision-making in many building economic matters, enables the client (investor) to assess the financial return of investments including energy savings or other resource-conserving measures over the lifetime of a building (Brophy & Lewis, 2011). LCCA helps in the selection of cost-effective options and in making a final decision in the light of a LCA carried out on those options. Therefore, LCCA and LCA can either be used alongside each other in a broad evaluation or either process can form an input into the other (Davis Langdon, 2007). LCCA needs input variables for its calculations, such as building use, type and location, period of observation, type and scope of cost types, discount rate, assumptions for determination and price of building costs, energy costs and water costs, and price increases (König et al., 2010).

LCCA determines the cost inputs for calculating the costs for different phases of the building's life (Davis Langdon, 2007) and shows the economic efficiency of the building (König et al., 2010). The cost variables are categorised into groups under ISO 15686-5 (an international standard for life cycle costing), which helps the decision making process for investment and management accounting. ISO 15686-5 also offers significant scope for interpretation in the selection and consideration of cost types in life cycle costing (both in the wider and narrower sense of life cycle costing), which can be combined in a manner appropriate to the particular application and circumstances (König et al., 2010). The types and components of LCCA are discussed in the following sections.

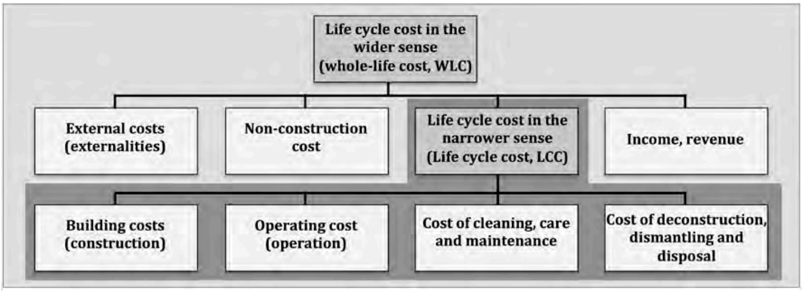
Types and components of LCCA

LCCA depends on the assessment of economic efficiency, which is the part of the process of investment decision. In a narrower sense, the assessment of economic efficiency considers monetary values, while in a wider sense it investigates the advantages of measuring monetary and non-monetary values (e.g. externalities) (König et al., 2010). Figure 12 gives an overview of ways of comparing expenditure and utility and illustrates economic efficiency from different viewpoints. Figure 13 shows the difference between life cycle costing (LCCA) in the narrower sense and in the wider sense according to ISO 15686-5 (König et al., 2010). The wider LCCA (whole life cycle) includes the narrower LCCA (Business LCC or Traditional LCC), external costs/externalities (Environmental LCC), income and revenue, and other non-constructional costs.



Source: König et al., 2010

Figure 12. Economic efficiency from different viewpoints



Source: König et al., 2010

Figure 13. Difference between life cycle costing in the narrower sense and in the wider sense according to ISO 15686-5

Method of calculating LCCA

There are various cost types in the whole life cycle, but the method of calculating the most applicable LCCAs – Business LCC and Environmental LCC – are discussed below.

Business LCC

Business LCC is the most commonly used cost analysis to support procurement and investment business decisions (Testa, Iraldo, Frey & O'Connor, 2011). Using a dynamic process to calculate the LCCA, the methods of calculating the LCCA are Net Present Value, equivalent annuity and internal rate of return (König et al., 2010).

<u>Net Present Value (NPV)</u>

In the Net Present Value analysis, all payments in and out are related to their cash or present value at the time of the original investment. Investments with positive NPV or alternatives with higher NPV are selected. The NPV is also taken as the capital growth or loss at the time of investment. In calculating NPV, payments that will take place at a later date are not entered as their nominal amount, but as the sum which would have to be set aside at the present time in order to yield the actual later amount through the application of a pre-set interest rate. All payments are discounted to the time of the beginning of the investment and are assessed in the calculation as their cash or present values. Furthermore, if a future payment is made and the interest rate is higher, the present cash value lowers (König et al., 2010). The NPV also illustrates the sum of the cash values of all the payments. Using a discount factor (present value of annuity factor), the cash value of a constant series of payments (e.g. from rental income) can be calculated (König et al., 2010).

<u>Equivalent Annuity</u>

With the annuity method, the level of regular income that will be obtained from the investment can be determined. This method helps to assess investments by comparing an initial payment at the beginning of a project with future regular income or savings. It also shows a one-off expense balanced by a regular yield in the form of energy cost savings due to the improved energy performance of the building or other environmental measures. This helps the owner-occupier to see the yield in the rent. Those products with a positive annuity, or alternatives with the highest annuity, are selected. The calculation of the annuity is carried out by converting the one-off payment at the beginning into a regularly recurring payment over the period. For this the one-off payment is multiplied by the annuity factor, the reciprocal of the discount factor (the present value of the annuity factor) (König et al., 2010).

<u>Internal Rate of Return and Adjusted Internal Rate of Return</u>

Internal rate of return (IRR) is the discount rate for which the estimated NPV of the total benefits equals the present value of costs (or NPV as an investment equal to zero). When its IRR exceeds the chosen discount rate, the project is accepted (Davis Langdon, 2007). Adjusted internal rate of return (AIRR) is the annual percentage yield from an investment over the study period (Davis Langdon, 2007), which assumes that savings gained by a project can be reinvested at the discount rate for the remainder of the study period (Fuller & Petersen, 1996). The AIRR is required to be greater than the discount rate and is used for ranking projects (Davis Langdon, 2007). However, the alternatives with the highest AIRR are not usually the alternatives with the lowest LCC (Fuller & Petersen, 1996, pp. 6-7).

Environmental LCC

The costs relating to adverse environmental impacts caused by a building are considered as externalities (included in the wider sense LCA). They are generally not used as a tool for procurement decisions or control (Testa et al., 2011) and are also not reflected in the market price; hence they do not directly affect investment decisions and can sometimes lead to distortion in the comparison of variants. Undesirable impacts on the environment caused by a building (negative externalities) can be analysed in terms of costs (e.g. pollution, avoidance, evasion or costs to cover long term risks) (König et al., 2010). The environmental LCC is integrated into the LCA. Some of the approaches for estimating external costs are described below.

Equivalent energy price

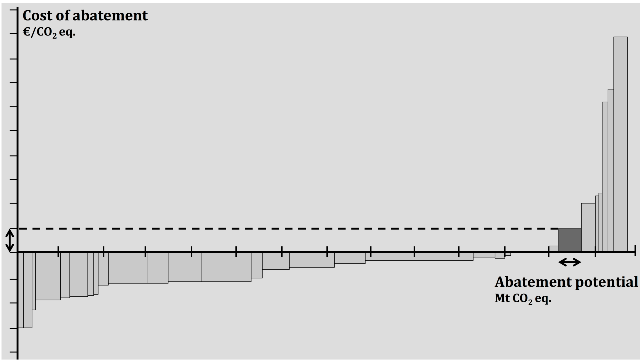
The equivalent energy price (or cost per kWh energy saved) is calculated based on the useful energy (for heating requirement) or final energy (energy requirement or demand on end energy carriers), taking into account the conversion chain. The energy savings are expressed in kWh/year so that the measure related costs can be distributed over the service life or use period and expressed in Euros (or any other currency) per year. The annual charge is compared with the annual saving of the annual useful or end energy demand in energy units (as kWh/year) resulting from the measures. Measures that are put in place at the outset are considered advantageous as their saving potential is available for longer time (König et al., 2010). The calculated result of the equivalent energy price is independent of the energy carrier, energy tariff and efficiency of energy conservation (only the actual investment costs and interest terms go into the calculation). The equivalent energy price is compared with average or specific costs of provision of useful or end energy incorporating the actual energy carrier and conversion information together with, if relevant, supplements to take into account any external costs. When the expenditure for achieving a saving of a unit of energy is smaller than the cost of its creation or provision, the measure is considered advantageous (König et al., 2010).

Energy/ecology amortisation period

This calculation considers the resources (energy) that will be used and/or the environmental impacts caused (emission of pollutants/depletion of raw materials). Initially the primary energy or environmental impact (CO_2 emissions) invested or caused by the manufacture, realisation, commissioning and, if needed, maintenance of the improvement measures are determined. Then the payback period, after which the energy saved or environmental impact resulting from the measures will have covered the investment, is calculated (König et al., 2010).

CO_2 avoidance costs

CO_2 avoidance costs depend on the net cost of emissions reduction. These costs may have positive (additional) or negative (reduced cost) values. Negative net costs or reduced costs for emissions reduction occur if the additional costs for measures are less than the cost reductions resulting from this measure with other, similarly considered costs of the same system. The Budget Allocation Chart (BAC) (Figure 14) shows one way of calculating and interpreting CO_2 avoidance costs (the net avoidance cost approach) represented in bars. Each bar represents one option. The X-axis shows the CO_2 avoidance potential through various options in which the width of the bar represents the amount of CO_2 eq. that can be reduced annually by means of the option, and the height represents the average cost of avoiding 1 tonne CO_2 eq. by using that option. The Y-axis shows the net costs of CO_2 saved, in which the negative cost (below the horizontal axis) shows a net benefit or saving to the economy over the life cycle of the option, while the positive cost (above the axis) shows that the option would incur incremental life cycle costs versus the reference case (adapted from McKinsey, 2007).



Source: McKinsey, 2007

Figure 14. Budget Allocation Chart

Budget Allocation Charts (BAC) help policy makers/decision makers and end users (or other stakeholders) by providing information to identify priorities, unearth best options and define policy strategies. They show the additional energy savings (or greenhouse gas emissions) and net costs of several different technologies/options (from the societal perspective). They help to identify the energy potential and cost effectiveness of several options and rank those options according to increasing net costs (Durand, 2010).

8.1.4 Database and tools

Database

The databases developed by various LCA tool developers include elementary flows (inputs and outputs) for each unit process for a product system. They vary according to specific countries and regions within countries (as the energy fuel mix and methods of production often vary from region to region) and also according to industry averages or specific suppliers. The databases generally account for raw material extraction, transportation to the manufacturing unit, the manufacturing process and packaging and distribution (AIA, 2010). The accurate impacts of LCA depend on: the data quality; data reliability (is the data based on measurements or assumptions?); completeness (is the data from a sufficient sample of sites over an adequate period or is it from a smaller number of sites over a shorter period?); temporal correlation (is the data less than 3 years old or less than 15 years old?); geographical correlation (is the data from the area of study or is it from an area with similar production conditions?); and technological correlation (is the data from the material under study or is it on related material but the same technology?) (Khasreen et al., 2009).

LCA tools

LCA tools are environmental modelling software designed to develop and illustrate life cycle inventory (LCI) and life cycle impact assessment (LCIA) results through a rigorous analytical process that closely follows relevant ISO standards and other accepted LCA guidelines.

Based on their application, they can be classified into building product tools, building assembly tools and whole building LCA tools (AIA, 2010). Building product tools evaluate and compare competing building products and are based on underlying material data (AIA, 2010), e.g. BEES and SimaPro. Building assembly tools evaluate complete assemblies for their environmental footprint by considering the combined effects of all materials and products (AIA, 2010), e.g. Athena Eco-Calculator and Envest. Whole building LCA tools assess the environmental impacts of the combined systems and assemblies and are generally capable of comparing several design options, which is helpful during the initial design phase (AIA, 2010), e.g. Athena impact estimator, LEGEP and BRE environmental assessment method.

8.2 Impact of building materials and technologies

Building materials contain different levels of embodied energy and make different environmental impacts, depending on the way the materials are produced and how much is used in a building. This section compares different building materials to understand their embodied energy and discusses why the right selection of materials is necessary to reduce overall energy consumption in a building.

8.2.1 Environmental impact of building materials

Examining the environmental impact of building materials is equally as important as ensuring their stability and functional use. This section gives an overview of the environmental impacts of some of the building materials considered in the building life cycle.

Regarding flooring, a study in Sweden by Jönsson, Tillman, & Svensson (1997) compares the environmental impacts of the production of three materials (linoleum, vinyl flooring and solid wood flooring), using data on production, resource use, energy use, emission to air and water, and waste generation. From this cradle to grave impact assessment, solid wood flooring was shown to be environmentally preferable over linoleum and vinyl options, due to negative net energy consumption and lower global warming potential (Taylor & Langenberg, 2003) Another study with comparative LCA for the environmental performance of various floor covering materials by Bowyer (2009) also shows that bio-based materials (e.g. wood, cork and linoleum) have lower environmental impacts than terrazzo, stone, vinyl, ceramic tile and carpets. The study was carried out with the Building for Energy and Environmental Sustainability (BEES) programme of the National Institute of Standards and Technology (NIST). A comparative LCA between marble and ceramic tile, carried out in Italy (Nicoletti, Notarnicola & Tassielli, 2002), showed that ceramic tiles have twice the level of negative impacts of marble tiles. The impact categories of the life cycle of the two systems are global warming, human toxicity and acidification.

The LCA of traditional brick production in India (using software SIMA-PRO 7.3.3 with the scope cradle to gate), discovers that brick is very energy intensive and responsible for huge levels of emissions (due to the combustion of coal in the kilns and diesel combustion during transportation). The main pollutants include particulates and sulphur oxides. Those pollutants can be minimised by the complete combustion of the coal, which will increase the coal efficiency and reduce emissions (Kumbhar, Kulkarni, Rao & Rao, 2014). A similar study of brick production in Greece by Koroneos & Dompros, 2007 (with the scope cradle to grave) also showed that the environmental burdens that arise from the operation of a conventional brick industry are mainly due to air emissions derived from the use of fossil fuel. The study, therefore, recommended the use of low sulphur fuels to reduce such impacts.

Regarding insulating material, a comparative LCA of acoustic and thermal insulating materials carried out by Asdrubali, Schiavoni & Horoshenkov, 2012 showed that the production of natural materials (hemp, kenaf, coco fibre, sheep wool, wood wool, cork, cellulose and flax) and recycled materials (rubber, plastic, textile fibres) has a lower environmental and health impact than the production of traditional materials (glass wool, rock wool and expanded polystyrene).

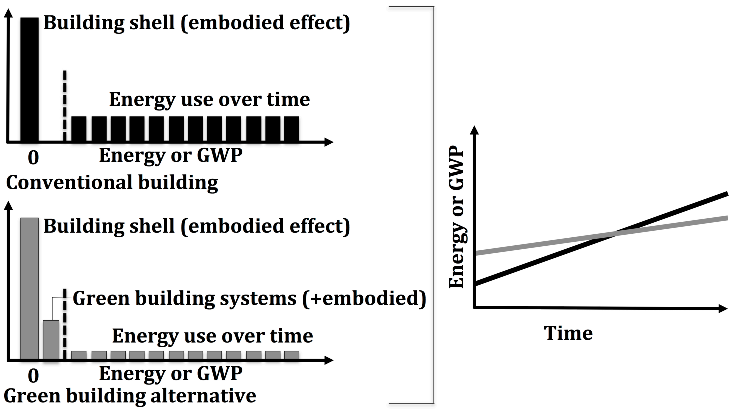
A case study by Thiel, Campion, Landis, Jones, Schaefer & Bilec (2013) in the USA on the comparison of the Center for Sustainable Landscapes

(CSL) building (a net zero energy and water building) with a standard commercial building on the production of building materials only showed the CSL building to have a 10% higher global warming potential and almost equal embodied energy per square foot, largely due to the CSL's PV system. The CSL is an office building attempting to meet Living Building Challenge v1.3, LEED Platinum and SITES certification for landscapes. The study considered the production of the building materials (concrete, structural steel, PV panels, inverters, and gravel) and used materials databases from Franklin USA, ecoinvent and others.

The highest environmental impacts of the CSL building materials come from the foundations and excavation or structural categories. Concrete contributes an average of 73% of the environmental impact for the excavation and foundations of the building, which is 11% to 65% of the building's total GWP and 7% to 28% of the total embodied energy. Likewise, steel contributes an average of 59% of the environmental impact for the structural system of the CSL, which is 17% to 38% of the building's total GWP and 12% to 42% of the total embodied energy. Regarding human health, eutrophication and water intake categories, the electrical system (PV panels and inverters) and the plumbing system represent high environmental impacts. PV panels account for approximately 16% of the total GWP and 49% of the total embodied energy (due to their high water intake category and the fact that the inverters required to utilise PV panels are associated with a high level of toxicity risk) and the geothermal wells account for 5% of the total GWP and 4% of the total embodied energy for the CSL. Therefore, the study shows that the contributions of concrete, steel, and glass to GWP and embodied energy are comparable between the CSL and standard commercial structures. However, the addition of green energy features such as the PV system and geothermal wells increases the CSL's global warming potential and embodied energy by nearly 30% and 50% respectively (Thiel et al., 2013).

As a solution, CSL used fly ash to replace 40% of the cement in the concrete, instead of using 100% Portland cement. This reduced the concrete's overall GWP contribution by 39%. Likewise, the use of 100% recycled content in the production of the stainless steel would reduce CO_2 emissions by 85,000kg and the total GWP by 8%. PV panels have a high impact in the material phase; however, PV panels as a renewable and non-fossil based fuel source reduce the total environmental impacts of the CSL when allocated over the building's lifetime (Thiel et al., 2013).

Moreover, Figure 15 also illustrates that in two buildings i.e. in a conventional/baseline building (blue bars) and a green building (green bars), the baseline building has the lowest embodied energy but uses more energy over time. Although efficient green building does include additional embodied energy, over time the energy embodied in the green build system is paid back and the overall impact of the green building becomes lower than the baseline building, thereby reducing global warming potential (GWP) (AIA, 2010).

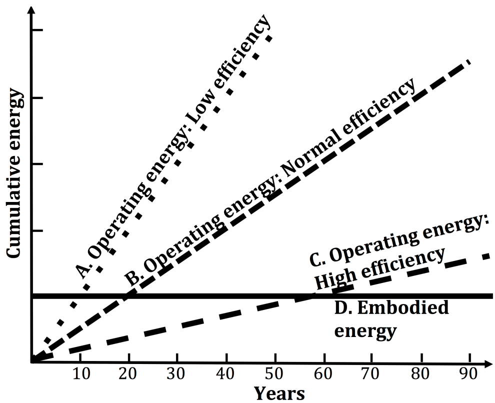


Source: AIA, 2010

Figure 15. Embodied energy effect in conventional and green buildings

8.2.2 Operational and embodied energy in energy efficient buildings

In a conventional building (e.g. relatively energy inefficient building), operational energy might be more important than embodied energy due to the need for more energy to maintain comfort conditions. However, for energy efficient buildings, the lifetime operational energy consumption is much lower compared with conventional new buildings (e.g. a passive house, a type of low energy building, can achieve a factor three in total energy reduction and even a factor four for an improved design (Sartori & Hestnes, 2007), while the share of embodied energy is higher due to additional sophisticated construction materials, energy production and recovery systems (Dutil, Rousse & Quesada, 2011), along with the use of renewable technologies. Therefore, in highly efficient or even plus energy buildings – the buildings of the future – where the operational phase is characterised by very low energy costs or even a positive energy balance, embodied energy plays an increasingly important role in reducing the environmental impact (Dutil et al., 2011). In Figure 16 below, the lines A, B and C show cumulative energy consumption over almost 100 years for different efficient buildings and line D is embodied energy. The lines (A, B and C) clearly show that as buildings become more efficient, the energy required in their operational phase decreases, while the embodied energy becomes relatively more important. For a building of normal efficiency (line B), the amount of energy required to construct the building equals the amount of operating energy required for about the first 20 years. Likewise, the highly efficient building (line C) shows very low cumulative operating energy in which the embodied energy will be many times more than the cumulative operating energy for the first 20 years (i.e. at only around 60 years does the operating energy equal the embodied energy) (Stauffer, 2009).



Source: Stauffer, 2009

Figure 16. The changing relationship between embodied and operational energy consumption over time in buildings

It is also argued in various studies (Sartori and Hestnes, 2007, Leckner and Zmeureanu, 2011 and Berggren, Hall & Wall, 2013) that the reduction in operating energy in energy efficient buildings (mainly in higher energy efficient buildings) has increased the relative share of embodied energy in buildings' LCEA. As discussed in Berggren et al. (2013), Minergie-A[11] buildings account for roughly 45% of energy demand, due to plug loads and lighting, and 35% of embodied energy. The remaining energy loads are for heating, hot water and HVAC systems. The embodied energy is roughly 60% for structural elements, 20% due to HVAC systems and 20% due to ST collectors and PV. The overall assessment shows that the LCEA of a NZEB is about 60% lower compared to the LCEA of a low energy building. Therefore, the study concluded that future considerations on the stages towards the reduction of embodied energy in structural elements, such as choosing insulation materials with low EE instead of conventional ones, is necessary to achieve an overall lower life cycle energy demand. Similarly, a study of single-family residences in Australia by Fay, Treloar & Iyer-Raniga,

[11] A Minergie-A building has a heating demand ≤ 90% of the allowed heating demand according to Swiss building regulations

(2000) also found that the addition of higher levels of conventional insulation to reduce operating energy consumption could cause higher levels of overall energy consumption. The use of insulation had a payback period of 12 years for the initial embodied energy in life cycle energy. However, the saving represented less than 6% of the total embodied and operational energy of the building over a 100 year life span. This indicates the necessity of prioritising energy efficient and other environmental strategies for building materials on a life cycle basis.

In another case study for NZEB in Montreal, Leckner and Zmeureanu (2011) asserted that the NZEB is environmentally superior to the conventional building due to its large reduction in LCEA, but that this depends where the energy comes from. It is important to take into account that when the house is supplied with a relatively clean form of electricity, such as hydroelectricity, this may improve the building's environmental credentials, but if the extra embodied energy in the NZEB materials comes mainly from environmentally harmful energy sources, such as petroleum and coal, then the overall negative environmental impact (GHGs, air pollution etc.) from the NZEB could be worse. The study further suggests that achieving the goal of NZEB, based on the operating energy of the building, is the initial step in creating a more sustainable and lower impact building. The next step is to transform the NZEB into a Net Zero LCEA, which would not only produce as much energy as it used in the operational phase, but would also offset all the life cycle embodied energy. Therefore, on one hand, taking the first step and investing in embodied energy in the NZEB (i.e. making a house more energy efficient with changes to items such as insulation, appliances and using domestic hot water saving devices) and installing a solar combisystem would save energy with the financial benefit of a relatively quick energy payback period of between 8 and 11 years, and an energy payback ratio of 3.6-4.8. But, on the other hand, LCCA shows that with the current solar technology and low electricity price in Montreal, homeowners would be more reluctant to accept the additional expenses for the construction of a NZEB.

8.2.3 Material selection to reduce embodied energy and environmental impact

Increasing the use of natural materials in construction ultimately decreases embodied energy and environmental impact. A case study by Shukla, Tiwari & Sodha (2009) of an adobe house, using low energy intensive materials, measured the total embodied energy as 475-552GJ/100m^2, which is much lower than the embodied energy in conventional buildings (720GJ/100m^2). Using low energy intensive materials such as soil, burnt brick, sand, cow dung etc. resulted in the mitigation of 101 tonnes CO_2 per annum. The energy payback period for the house was only 1.54 years. If adobe materials are not commonly used in the present context, finding alternative materials with a similar potential for reducing the embodied energy in a building's life cycle is necessary.

In order to reduce the embodied energy of building elements, their efficiency during their life cycle, mainly during the manufacture, transport and building construction phases, must be addressed. In the course of building material manufacture, waste output also increases embodied energy. It has been suggested that between 2% and 36% of a conventional building's lifetime energy demand in the UK results from the manufacture, transport and construction of primary materials (Sartori & Hestnes, 2007 in Monahan & Powell, 2011). For a low energy house, this range increases to between 9% and 46% (Monahan & Powell, 2011). As an alternative way of identifying areas that could deliver reductions in embodied carbon, a study by Monahan & Powell, 2011 compared a conventional house with three building elements for modern methods of construction (MMC) and identified areas that could deliver reductions in embodied carbon. These are MMC timber frame larch cladding (low energy offsite modular construction), MMC timber frame brick cladding (replacing larch cladding with brick cladding) and conventional masonry cavity walls. The LCA scope is cradle to site with process based LCA methodology (bottom up) rather than an input-output (top-down) methodology. The study showed that the embodied carbon for the conventional house was 4.6 tonnes CO_2 for a

3 bedroom semi-detached house, i.e. 405 kg CO_2 per m^2 of useable floor area. The house with the timber frame larch cladding had an embodied carbon level of 12%, but the embodied carbon and embodied energy increased by 32% and 35% respectively in the house with the timber frame brick cladding compared to the house with the timber frame larch cladding. For the house with a conventional masonry cavity wall, the embodied carbon and embodied energy increased by even more, up to 51% and 35% respectively compared to the house with the timber frame larch cladding. Lastly, the study found that the MMC house with the timber frame larch cladding resulted in a 34% reduction in embodied carbon compared to the conventional one. Although timber is the predominant structural and cladding material, concrete is the most significant material (by proportion) in embodied carbon terms, responsible for 36% of materials related to embodied carbon (Monahan & Powell, 2011).

Annually, cement production is responsible for between 5% and 7% of worldwide CO_2 emissions. Various research has been conducted in order to find solutions to reduce its impact. One of these is 'green cement', the environmentally compatible cement Celitement (developed by the Karlsruhe Institute of Technology, Karlsruhe, Germany), which halves CO_2 emissions and is characterised by the low consumption of resources. Compared to conventional Portland cement, only one third of the amount of limestone is required and it can be produced without gypsum being added. As well as that, its production process requires a much lower temperature, about 200°C instead of 1,450°C (Econsense, 2012). Other lower embodied carbon alternatives for cement include ground granulated blast furnace slag, fly ash and other pozzolanic materials or lime based materials, and also the implementation of strategies designed to reduce the volumes of cement required for foundations and other areas (Monahan & Powell, 2011). Moreover, as an alternative to conventional bricks and local clay, renewable constituents such as straw produce lower environmental impacts. In insulating materials, replacing synthetic insulating materials (such as polyurethane rigid foam and EPS (expanded polystyrene)) with natural insulation materials (such as cork, wood fibre and sheep's wool) can also reduce environmental impacts (European Commission, 2011).

The use of recycled materials and reusable/recyclable materials also provides an opportunity to reduce the embodied energy (Thormark, 2002). By using recycled materials, the energy saved in material production ranges from between 12% and 40% (depending on recycling rates and material composition) (UNEP, 2011). A study (in Sweden) illustrated that recycling nationally-produced building waste can save about 50% of the embodied energy (Thormark 2001 in Thormark 2002) and that reusing materials in a one-family building can decrease embodied energy by about 45% (Thormark, 2000 in Thormark, 2002). In developing countries such as India, recycled building components are economical, environmentally friendly, participatory and aesthetically pleasing options, all of which can be of benefit to the urban poor. This was demonstrated in the Manav Sadhna Activity Center (an educational building) in Ahmedabad, India, which used various environmentally friendly materials and techniques for the walls (cement bonded fly ash bricks, mould-compressed bricks made from landfill site waste residue, stabilised soil blocks, recycled glass bottles, recycled plastic bottles filled with ash and waste residue and vegetable crate wood panelling in the inner partition walls) and on the floor and roof slab (filler slab with glass bottles, plastic bottles and brick slab, cement bonded particle board with clay tile cover, and light conduit pipe truss with galvanised iron sheet and clay tile roof) (UNEP SBCI, 2010). The rate of recycling for different building materials varies, e.g. 54% for copper, 35% for aluminium, 59% for lead, 90% for steel and 20%-25% for cobalt (Econsense, 2012).

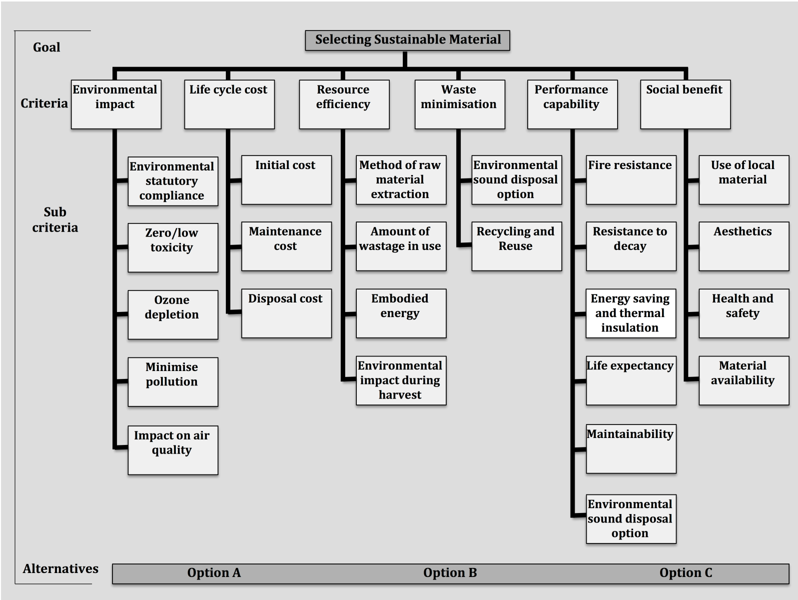
Another case study (Proietti, Sdringola, Desideri, Zepparelli, Masciarelli & Castellani, 2013) on LCA modelling of a Passive House standard sustainable building in Perugia, Italy also showed that an integrated approach during the design phase can result in the significant decrease in the embodied energy and provide a positive environmental outcome. The building used a mix of advanced technological solutions in its envelope, incorporating recycled materials, reuse of rainwater, reduced energy consumption, renewable energy utilisation and an intelligent use of insulation. The model used the whole life cycle of the building product through a cradle to cradle approach, according to ISO 14040-14044, for 70 years of lifespan. SimaPro software with the ecoinvent database was used in the model. The analysis includes all the life cycle phases: raw material extraction, production, transportation, building process, occupation/use, selective and controlled deconstruction, and waste handling and treatment. Cement, steel and wood are the main construction materials. As the building is located in a seismic temperate zone, the amount of concrete and cement use was 20% more than in a typical building to reinforce the structure against earthquakes. As a result, the impact of the concrete basement accounts for 27% of total GER and represents a 70% increase of GWP100, while the subsystems made of timber and wood fibre (for insulation) reduce their relative contributions, because 78% of their energy load is covered by renewable sources. Taking into account the use of recycled materials for the building construction (pre-utilisation phase): polypropylene moulds (for under ground-floor space), cement sealing matrix (for paving), crushed stone, polyester fibre (insulation) and polyurethane (insulation), equating to 1.7% of the total weight, produce a reduction in global impacts of 9% in terms of NRE. Likewise, the heating and ventilation in the utilisation phase contribute 21% of GER and 25% of GWP100, while the maintenance phase accounts for 16% and 12% respectively. The careful selection and controlled de-construction allows for the efficient reuse and recycling of 95% of the materials; this causes a huge reduction in impacts in comparison to 100% being sent to landfill: a reduction of 90% of GER and 87% of GWP100. Regarding the environmental impact of the PV system in its end of life phase, its contribution resulted in a GER reduction greater than 80% and GWP100 reduction greater than 70%. Recycling and reuse after careful deconstruction reduces the impacts by between 5% and 20%, while renewable sources of electricity further decrease the impacts by between 50% and 65%. Even the exclusion of PV energy production in the building during the utilisation phase causes an overall impact of only 20% to 25% (unlike in a traditional building where the percentage is between 80% and 90%), maintenance phase 10% to 18%, building envelope 45% to 52%, plants 3% to 9%, transportation 4% to 5% and construction process 2% to 5%.

Therefore, the whole discussion revolves around the selection of environmentally friendly materials to reduce embodied energy in a building's life cycle. Sustainable material selection is an important strategy in building design. As well as the environmental aspects of building material selection, the technical, social and economic aspects must be simultaneously considered. Table 10 shows the environmental, social and technical criteria for sustainable material selection. Material selection can also have hierarchy of four levels, which involve six major criteria (environmental impacts, life cycle cost, resource efficiency, waste minimisation, performance capability and social benefits) (see Figure 17) based on the fuzzy extended analytical hierarchy process (FEAHP) technique (Akadiri, Olomolaiye & Chinyio, 2013).

Table 10. Sustainable assessment criteria for building material selection

Environmental criteria	Social-economic criteria	Technical criteria
• Potential for recycling and reuse • Availability of environmentally sound disposal options • Impact of material on air quality • Ozone depletion potential • Environmental impact during material harvest • Zero or low toxicity • Environmental statutory compliance • Minimize pollution –e.g. air, land • Amount of likely wastage in use of material • Method of raw material extraction • Embodied energy within material	• Disposal cost • Health and safety • Maintenance cost • Esthetics • Use of local material • Initial-acquisition cost • Labor availability	• Maintainability • Ease of construction • Resistance to decay • Fire resistance • Life expectancy of material (e.g. strength, durability etc.) • Energy saving and thermal insulation

Source: Akadiri et al., 2013



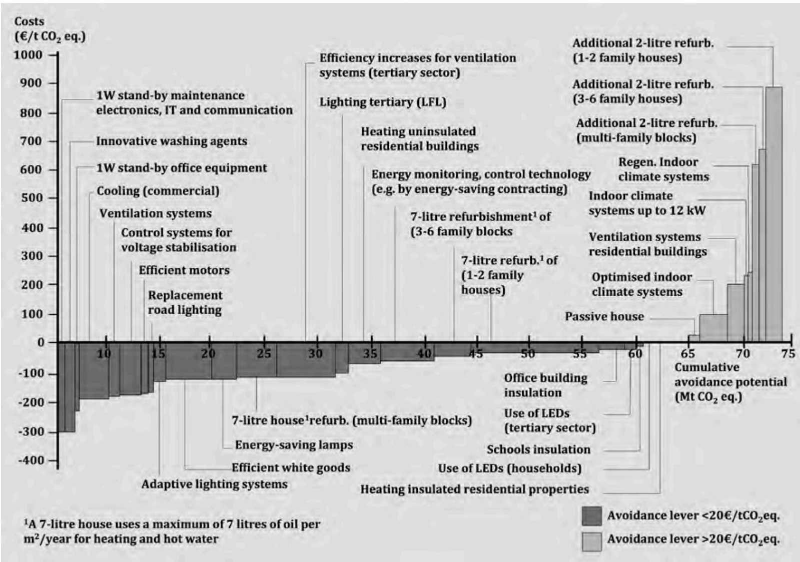
Source: Akadiri et al., 2013

Figure 17. Hierarchy of the decision problem for selecting sustainable materials

8.2.4 Building technologies and environmental cost

The rapid reduction of CO_2 emissions from buildings (in the short term) can be achieved by taking action on appliances, fittings and systems. Electronics and appliances are changed or updated quite frequently in buildings. Heating, ventilation and air-conditioning (HVAC) systems are generally changed every 15 to 20 years. Roofs, facades and windows are renovated periodically. Office equipment is changed after three to five years. Household appliances are changed around every 5 to 15 years. Consumables, such as light bulbs, are changed in much shorter periods of time. The selection of the best available technology (BAT) at the time of renovation or purchase is important in reducing the energy demand in buildings, and this also has an impact on the costs and benefits associated with energy savings (IEA, 2010).

As previously discussed, BAC assists in the selection of building technologies based on environmental costs throughout the building's life cycle. Figure 18 is an example of BAC for the avoidance costs of GHG emissions in the German building sector. The bars for the technologies and appliances below the horizontal axis indicate negative costs, i.e. they are the beneficial options over the life cycle with a GHG avoidance lever of <20Euro/tCO_2eq. However, it is necessary to notice the width and height of the options in order to make the appropriate selection. Likewise, the bars above the horizontal axis are positive costs, i.e. these options provide long term benefits with some additional costs and have an avoidance lever of >20Euro/tCO_2eq. (König et al., 2010).



Source: Mckinsey, 2009 in König et al., 2010

Figure 18. Avoidance costs for GHG emissions in the German building sector

8.3 Energy saving related to transportation and urban density

In a wider perspective LCEA, a total energy reduction calculation for a low energy building must take into consideration not only operational energy but also embodied and transportation energy. Stephan et al. (2013) argue that Passive House (PH) standard buildings do not always provide net energy savings and can have total energy needs similar to new standard buildings. This is discussed in the case study (Stephan et al., 2013) of a Belgian PH in which the total energy requirement over 100 years increases due to the location (suburban as opposed to in the city) and urban density (the life cycle energy demand per capita in a house in the suburb compared to an apartment in a city). The LCEA or the embodied energy assessment was carried out using the comprehensive input-output hybrid technique developed by Treloar, based on a database containing Australian process data and European data.

The base case PH is a detached 3-storey 330m^2 gross floor area family house for 4 people, in a suburban location. It has a steel structural frame on concrete slabs, a façade of glued brick with polyurethane insulation, triple glazed, argon filled timber framed windows and a roof with terracotta tiles with polyurethane insulation. The household owns 2 cars and does not use public transport, as the nearest train station is 13.6km away. The results for the base case PH show that the embodied, operational and transportation energy requirements represent 40%, 32.8% and 27.2% of the total respectively (in which the highest single energy consumption comes from the steel structure). This means that the operational energy demand, which is the main focus of most certification systems and directives, represents less than 40% of the total energy consumption of the house, while the embodied energy demand represents the highest share of energy consumption in the PH. The transportation energy requirements (9804 GJ over 100 years), make up an important part of the total, and embodied energy and transportation energy together represent 67.2% of the overall life cycle energy consumption (Stephan et al., 2013).

As a first alternative, the base case PH is compared with a best case PH, which sees changes implemented such as a reinforced concrete and timber framed structure, fibreglass insulation and other improved technologies. The best case PH also has reduced operational energy (due to the use of solar panels), has occupants who use public transport and has more occupants. The life cycle energy demand of the best case PH is 30.8% lower than the base case PH, which includes a 31% reduction in the transport energy demand (an 8.4% reduction in life cycle energy consumption). Increasing the occupants to 5 and 7 had the effect of reducing the overall energy demand per capita by 16.9% and 30% respectively (Stephan et al., 2013).

As a second alternative, the base case PH is compared with a retrofitted apartment in Brussels to verify whether net energy savings do occur. The apartment is 80m^2, has 2 occupants and is located next to public transport links. The comparison of the base case PH with an apartment is important because 75% of the dwellings in Brussels are apartments and 84% of those have a floor area smaller than 105m^2. The changes implemented in the retrofit are from single-glazed to double-glazed windows (which cover 94% of the façade) and the adjacent brick veneer walls etc. (Stephan et al., 2013). The total embodied energy requirements of the apartment are lower than the base case PH and are as much as 23.4% lower than the best case PH. The unit of measurement, energy efficiency per m^2 and energy efficiency per capita, can result in the distortion of the findings due to different perceptions of energy reduction. While the energy demand per m^2 of the apartment is much higher than the best case PH (74% higher), its life cycle energy consumption per capita is lower by 15.2% (Stephan et al., 2013).

8.4 Cost-effectiveness with respect to payback and study periods

In order to estimate life cycle (operational) energy savings, carbon emission reductions and the cost-effectiveness of conventional energy efficiency technologies in new (commercial) buildings, a study by Kneifel (2010) was reviewed. Twelve building types in the USA (including residences, hotels, apartments, schools, offices, retail stores and restaurants), ranging in size from 465m^2 to 41,806m^2, were evaluated. For each building type, energy simulations were run with the base case, ASHRAE 90.1-2004. The base case was compared with two alternatives – the ASHRAE 90.1-2007 design and the higher efficiency Low Energy Case (LEC) – in four analysis period lengths: 1 year, 10 years, 25 years and 40 years.

The results show that conventional energy efficiency technologies can decrease energy use in new commercial buildings by 20% to 30% on average and even more than 40% for some building types and locations (mainly comparing the ASHRAE 90.1-2004 building with the LEC). Regarding life cycle costs, an increase in the study period length increases the cost saving. For 10 year, 25 year and 40 year study periods, the LEC is the cost-effective option for 69%, 88% and 93% of the buildings respectively, and the cost-effectiveness increases even more with the adoption of the most energy efficient building design alternatives (not overlooking the future costs of operating and maintaining the building). The investments in energy efficiency also reduce the carbon footprint of the building by as much as 32% over a 10 year study period: the largest carbon (and energy) reductions occur in states that rely heavily on coal-fired electricity generation, while states with the largest amounts of alternative energy use benefit from much smaller reductions. Similarly, the introduction of a charge for carbon increases the rate of return on energy efficiency investments in all building types, resulting in the LEC being the most cost-effective option (with greater incentives for states that use the most electricity from coal-fired generation) (Kneifel, 2010).

Likewise, a LCCA study of Indian green building, carried out by TERI (2010), also showed that investing in green buildings can be a profitable venture. Seven certified/ registered green buildings were compared with conventional buildings and analysed based on primary data, i.e. general information about the building, its envelope system, lighting system, electrical system and HVAC system. The results showed that the high initial costs (4% to 32% higher than for conventional buildings) are paid back in just 1 to 3 years from an adjusted rate of returns of 19 to 30 (TERI, 2010).

8.5 Water saving options

The results of LCA and LCCA studies for various water saving options, such as efficient fixtures and appliances and rain water harvesting, are positive. Arpke & Hutzler (2005) studied the use of water in multi-occupant buildings in various cities of the USA, using the Building for Environment and Economic sustainability (BEES) tool, Version 3.0. The study period was 25 years, in which an operational life cycle for plumbing fixtures and water-consuming appliances for four different multi-occupant buildings (an apartment, a college residence, a motel and an office building) were carried out. The results illustrated that efficient fixtures and appliances are environmentally and economically justifiable when compared with conventional fixtures and appliances. Using natural gas instead of electricity for water heating can save $80,000 over the 25 year period. The main life cycle cost component for efficient water fixtures and appliances is their maintenance, repair and replacement. For long term building owners, such as universities, the results of this study can be especially beneficial as operational costs savings can be realised (Arpke & Hutzler, 2005).

Regarding the sustainability of Rain Water Harvesting Systems (RWHS), a case study by Rahman, Dbais & Imteaz (2010) from Australia was reviewed. The study was carried out in (hypothetical) multi-storey residential buildings in Sydney under different scenarios, such as varying roof areas, number of floors in the building, water price and interest rate, in order to identify suitable conditions for sustainable

RWHS. It was found that buildings with larger roof areas are better suited to water collection and consequently benefit financially. The main life cycle cost component for RWHS was capital (in the form of plumbing) and regular maintenance. Lower interest and increased water price regimes could enhance the financial viability of RWHS. In the case study, it was found to be possible to achieve a payback representing a benefit/cost ratio of 1.39 under the following conditions: a RWHS for a roof area of 1,600m^2, 5% nominal discount rate, Aus$1.634 per kL water price with an inflation rate of 4.5% p.a. for the water price. The financial viability of the rainwater tank harvesting system depends on the use of the rainwater, i.e. to maximise the benefit, the rainwater needs to be drawn as much as possible from the tank on a regular basis so that the tank is empty at the beginning of the next rainfall event. Also, at the current water price and under high interest rate regimes, the financial profitability of RWHS could be achieved by individual apartment owners, when the current level of subsidy provided by the Australian government for rainwater harvesting system for multistorey buildings is increased to reduce the burden on households and to enhance the sustainability of rainwater harvesting systems (Rahman, Dbais & Imteaz, 2010). Water-efficient appliances in Germany, such as rainwater harvesting systems and grey water re-use systems, also illustrate how setting a price for water creates variation in the level of savings (i.e. higher prices = larger savings and lower prices = smaller savings) (UNESCO, 2001 in UNEP, 2011).

9 Policies for energy efficient and green buildings

Good policies trigger the development of energy and resource efficient buildings in both developed and developing countries. Various driving forces from governmental and private sectors exist but, at the same time, numerous barriers hinder efficient building construction. Good policies/policy instruments (and also the combination of good policy instruments) tackle the barriers and create a good environment for fostering such buildings. These are discussed in the following sections.

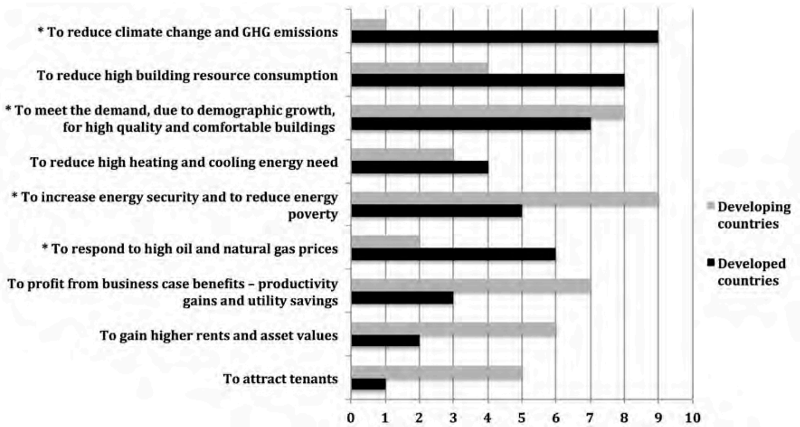
9.1 Driving forces for energy efficient and green buildings

The study by IEA (2010b) shows that the driving forces for governmental energy policies are energy security, economic development, the need to respond to climate change, economic competitiveness and the desire to improve public health (see Table 11). Some of the drivers for governments around the world, as well as for decision makers in both public and private sectors, to foster energy efficient and green buildings are resource conservation, job creation, improved occupant health, long term resilience and quality of life (World Green Building Council [WGBC] 2013). Likewise, Yudelson (2008) lists the major drivers for green buildings (LEED in the USA) (see Table 11) (this also relates to the governmental energy policies). However, how the driving forces are prioritised differs according to regional need (WGBC, 2013) and the differences, according to the expert opinion consulted for this dissertation, are shown in Figure 19.

Table 11. Drivers of governmental energy efficiency policies

Drivers of governmental energy efficiency policies		Drivers for green buildings in the USA
Drivers	**Typical objectives**	**Drivers**
Energy security	• Reduce imported energy	
	• Reduce domestic demand to maximise energy security	• Movement back into the cities • Changes in cultural patterns, to favour more environmentally-friendly lifestyles
	• Increase reliability	
	• Control growth in energy demand	• Higher oil and natural gas prices • Local government incentives and mandates for green buildings
Economic development and competitiveness	• Reduce energy intensity	
	• Improve industrial competitiveness	• More commercial and institutional green projects
		• More green homes on the marketplace, leading to growth in demand • Slowdown in homebuilding market causes builders to "build green" for competitive reasons
	• Reduce production costs	• Growing evidence of the business case for benefits of green buildings
	• More affordable energy costs for consumers	• New local government, utility and state government tax incentives for green buildings and renewable energy
Climate change	• Contribute to global mitigation and adaptation efforts	• Growing awareness of the role played by buildings on carbon dioxide emissions
	• Meet international obligations under the United Nations Framework Convention of Climate Change (UNFCCC)	• Growing pressure on companies to conduct sustainable operations
	• Meet supra-national (e.g. European Union) accession requirements or directives	• Energy Policy Act of 2005 (assuming extension past 2012)
Public health	• Reduce indoor and local pollution	

Source: IEA 2010b Source: Yudelson 2008



Note: '*' means suitable for public sector and others for private sector

Figure 19. Priorities of driving forces for energy efficient and green buildings (regional and sectoral basis)

9.2 Barriers to fostering energy efficient and green buildings

Although various environmental, social and economic benefits exist for energy efficient and green buildings, some barriers hinder their development in both developed and developing countries. The barriers can create an efficiency gap and prevent actors from making cost-effective investments in energy (and resource) efficiency (Managan, Layke, Araya & Nesler, 2012). McGraw Hill Construction (2013) lists some of the barriers, or challenges, to the acceleration of the construction of green buildings (according to respondents in different countries). These are: higher initial costs, lack of political support/incentives, challenges due to the split between capital expenditure and operating cost savings, lack of market demand, affordability, lack of public awareness and lack of trained green building professionals. These can be categorised into economic/financial barriers, hidden costs and benefits, market failures, behavioural and organisational constraints, and political, structural and information limitations (UNEP SBCI, 2007). Their importance varies according to the region. For example, information and technical barriers play a major role in developing countries (where energy and resource efficient markets are less developed), whereas market and financial barriers are a bigger challenge in developed countries (where markets that have more pursuing energy efficiency opportunities) (Managan et al., 2012). Based on the expert opinion consulted in this study, awareness/information (i.e. lack of knowledge on economic benefits) is considered a prime barrier, followed by market failure and political and structural limitations (see Figure 20). One of the experts consulted also emphasised the lack of policy drivers in a country as a major barrier. The selection of proper policy instruments can overcome these barriers. Some of the barriers, together with possible solutions due to the implementation of certain policy instruments, are discussed in Table 12 below. Each policy instrument is described in the section below.

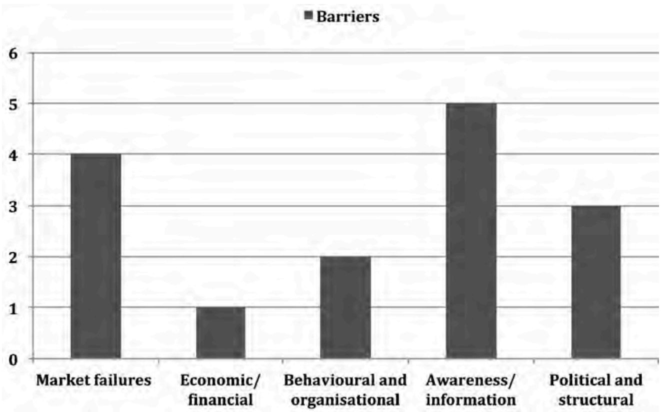


Figure 20. Level of barriers in fostering energy efficient and green buildings

Table 12. Barriers to fostering energy efficient and green buildings

Barriers	Definition	Examples	Countries	Policy instruments (see section 9.3)
Econom-ic/financial barriers	Ratio of invest-ment cost to value of energy and resources	• Higher up-front costs for more efficient equipment • Lack of access to financing (for financial institutions, small transactions may require the bundling of buildings or improvement measures to make them suitable for finance) • Energy subsidies • Lack of internalisation of environmental, health and other external costs (for building owners)	Especially developing countries, but also developed countries	• Regulatory norma-tive and informa-tive • Economic instru-ments • Fiscal instruments
Hidden costs/benefi ts	Costs or risks - not considered directly in financial flows	• Costs and risks due to potential incompatibilities, performance risks, transac-tion costs etc. • Poor power quality, particularly in some developing countries	All coun-tries	• Regulatory-normative • Economic instru-ments
Market failures	Market struc-tures and con-straints that prevent a con-sistent trade-off between specific energy and resource effi-cient investment and energy and resource saving benefits	• Limitations of the conventional building design process • Fragmented market structure (price distortions of a product that prevent consumers and investors from valuing energy and resource efficiency) • Landlord/tenant split and misplaced incentives (transactions where the economic benefits of energy savings do not benefit those who invest in ener-gy and resource efficiency, e.g. when building owners invest in energy and resource efficiency, but occupants benefit from the reduced bills) • Administrative and regulatory barriers (e.g. in the incorporation of distribut-ed generation technologies) • Imperfect information • Unavailability of energy efficiency equipment locally (sometimes resulting high transaction costs) • Not pricing externalities associated with fossil fuel consumption resulting in imperfect competition • Energy tariffs (that discourage energy efficient investments) • Failed to address market conditions (on consumer preferences) (IEA 2013)	All coun-tries	• Regulatory norma-tive and informa-tive • Economic instru-ments • Fiscal instruments • Support, infor-mation and volun-tary action

Behavioural and organisational barriers	Behavioural characteristics of individuals and companies that hinder energy efficiency technologies and practices	• Tendency to ignore small energy saving opportunities • Organisational failures (e.g. internal split incentives) • Non-payment and electricity theft • Tradition, behaviour and lifestyle; corruption • Transition in energy expertise: loss of traditional knowledge and non-suitability of Western techniques	Developed countries Developing countries	• Support, information and voluntary action
Information barriers	Lack of information provided on energy and resource saving potentials	• Lacking of awareness amongst consumers, building managers, construction companies, politicians • Lack of sufficient information and understanding for consumers, tenants and building owners to make rational consumption and investment decisions • Lack of information about the performance of buildings • Lack of energy information (by end users, energy providers, or other implementing agencies)	Especially developing countries, but also developed countries	• Support, information and voluntary action • Voluntary action
Political and structural barriers	Structural characteristics of the political, and economic energy system, which make energy efficiency investment difficult	• Slow process for drafting local legislation • Gaps between regions at different economic levels • Insufficient enforcement of standards • Lack of detailed guidelines, tools and experts • Lack of incentives for energy and resource efficient investments • Lack of governance leadership(due to the limited technical capacity to design and implement energy efficiency policies and programmes) • Lack of equipment testing/certification • Inadequate energy service levels (insufficient capacity to identify, develop, implement and maintain energy and resource efficiency investments) • Limited inter-agency coordination to ensure policy coherence (at different levels of government, between various energy policy goals, or across scattered energy efficiency initiatives) • Lack of partnership between government and the private sector (to tackle energy efficiency in a collaborative manner) • Lack of affordable energy efficiency technologies suitable to local conditions • Lack of firms that can aggregate multiple projects; lack of implementation firms than can deliver cost optimal energy and resource efficient projects	Most developing countries (and in some developed countries)	• Support, information and voluntary action • (Public leadership programmes)

Source: adapted from UNEP SBCI, 2007

9.3 Background: policy instruments

Reducing energy and resource demand needs the deployment of effective policies (BPIE, 2011), which also help to increase investment in green buildings (UNEP, 2011). Policy instruments are designed to target the key barriers to increasing energy and resource efficiency in any given market (as mentioned above), bridging the efficiency gap formed by the barriers and opening up the opportunity for greater investment in energy and resource efficiency. Today many cities, states and countries have designed policies to improve energy and resource efficiency in buildings and they are at different stages of implementation (Managan et al., 2012). These policy instruments are grouped in four categories that include control and regulatory instruments such as building codes (energy efficiency standards for buildings); economic and market-based instruments such as cooperative procurement; fiscal instruments and incentives such as energy taxes and subsidies; and support, information and voluntary action such as the voluntary labelling of appliances (UNEP SBCI, 2007) (see Table 13). However, the effectiveness of these policy measures in terms of reaching goals differs, mainly depending on the country's situation and the selection of policy instruments (UNEP SBCI, 2007). Each country has to choose a suitable policy package that can transform the built environment in a way that fits the local circumstances (Managan et al., 2012).

Table 13. Classification of policy instruments

Control and regulatory instruments		**Economic and market-based instruments**	**Fiscal instruments and incentives**	**Support, information and voluntary action**
• Appliance standards • Building codes • Procurement regulations • Energy efficiency obligations and quotas	• Mandatory audits • Utility demand-side management programmes • Mandatory labelling and certification programmes	• Energy performance contracting • Cooperative procurement • Energy efficiency certificate schemes • Kyoto flexibility mechanisms	• Taxation • Tax exemptions • Public benefit charges • Capital subsidies, grants, subsidised loans	• Voluntary labelling • Voluntary and negotiated agreements • Public leadership programmes • Awareness raising, education and information campaigns • Detailed billing and disclosure programmes

Source: UNEP SBCI, 2007

9.3.1 Regulatory and control instruments

If applied well, regulatory and control instruments are the most common and highly effective instruments in the building sector. They can provide strict standards for certain products (regulatory normative) or stipulate the provision of voluntary information by the user (regulatory informative). To maintain their effectiveness, they have to be monitored, evaluated and updated periodically based on technological developments and market trends. The main problems of these instruments are their lack of enforcement and the rebound effect. However, most of these policy instruments achieve high savings at low cost, even at negative cost to society, and overcome many barriers in the building sector such as financial/economic barriers, hidden costs and market failures (UNEP SBCI, 2007).

Regulatory - normative instruments

These include *appliance standards*, which set minimum energy efficiency levels that are required to be fulfilled by the producer to improve the energy efficiency of appliances (lighting, heating and cooling equipment) used in commercial and residential buildings. Likewise, *building codes* set minimum standards for the energy use of an entire building or building system, such as heating or air-conditioning. To initiate energy and resource efficiency in public building sectors, *procurement regulations* are very helpful as the public sector accounts for a large share of buildings in many countries. Moreover, *energy efficiency obligations* help to define legal obligations for electricity and gas suppliers to achieve targets for the promotion of improvements in energy efficiency, for instance in households (UNEP SBCI, 2007).

Regulatory - informative instruments

These include *mandatory certification and labelling*, which provide information to end users on the energy performance of energy using appliances (such as Energy star in the USA) or whole buildings (such as the Energy Performance Certificate in Europe). These approaches can also begin as voluntary labelling programmes that can achieve the desired market transformation. *Mandatory audit programmes* are carried out to measure and record the energy performance of industrial and large commercial consumers (rarely used in the residential sector), in order to illustrate their energy consumption over time and motivate urgent energy savings to restrict excessive use. Likewise, *utility demand-side management programmes* plan, implement and monitor the activities of energy efficiency programmes carried out by utility companies, which are highly effective in the commercial sector (rather than in the residential sector) (UNEP SBCI, 2007).

9.3.2 Economic and market-based instruments

Economic and market-based instruments are often promoted by regulatory incentives that usually contain elements of voluntary action or participation. These include *Energy Performance Contracting (EPC)*, in which an Energy Service Company (ESCO) is the implementing agent. The ESCO guarantees certain energy savings for a location over a period of time, implements improvements and is paid out of the cost savings made by reducing energy use. ESCOs need support from legal, financial and business environments, and can only function well in an environment that does not provide subsidies for energy that give out the wrong price signals (UNEP, 2011). Likewise, the voluntary tool of *cooperative/technology procurement* helps customers (in the private or public sector) who procure large quantities of energy consuming appliances to cooperate in order to influence the market by creating a demand for more efficient products. It can also trigger market transformation. Moreover, *energy efficiency certificate/white certificate schemes* are tradable certificates for energy savings, which consist of a savings obligation that can be fulfilled through trading with savings certificates. These certificates are issued by independent certifying bodies confirming the claims made by market actors in terms of their energy savings, as a result of applying energy end use efficiency measures (UNEP SBCI, 2007). On the other hand, *Kyoto flexibility mechanisms* (i.e. Joint Implementation (JI) and Clean Development Mechanisms (CDM)) are less attractive in the building sector due to "the fragmentation of the building market with few baselines and reference cases that could be used to determine additionality" (UNEP, 2011). Recommendations for improvement could underline the need for using performance based indicators (such as energy use per square metres) together with technology based indicators, as well as the need for common baselines and national building energy efficiency standards (UNEP, 2011). *NAMA* (Nationally Appropriate Mitigation Actions) credit can be useful in building sectors that give emission reduction credits to developing countries. This action is undertaken by developing countries in the context of sustainable development, supported and enabled by technology, financing and capacity building, in a measurable, reportable and verifiable manner (UNFCCC, 2008, p.3).

9.3.3 Fiscal instruments and incentives

These instruments influence energy prices either by imposing Pigouvian tax (to correct negative externalities of market activity) or by providing financial support, if initial cost barriers are addressed, to equalise compliance costs. On one hand, they include *energy or carbon taxes* imposed by governments, which can increase the end user price for units of energy purchased, resulting in a reduction in demand. On the other hand, they also offer governments the opportunity of investing tax revenues into energy and resource efficiency improvements (UNEP SBCI, 2007). These taxes can reinforce other instruments, such as standards and subsidies, affecting the whole building life cycle and making energy and resource efficiency more profitable (UNEP, 2011). Likewise, *tax exemptions and reductions*, which are granted in the form of tax credits, stimulate the introduction and initial sales of energy and resource efficient technologies, appliances and whole buildings and provide signals promoting their investment to end users. *Public benefits charges* are a special form of energy tax (raising funds from the operation of the electricity and energy market) whose revenues are invested in efficiency improvements (UNEP, 2011). *Capital subsidies, grants, subsidised loans and rebates*, which are mostly common in residential buildings as an incentive, provide financial support for purchasing or investing in energy and resource efficient appliances or buildings (UNEP SBCI, 2007). Grants and subsidies provide direct capital, rather than access to capital, particularly helping low-income households (UNEP SBCI, 2007) to purchase equipment that has a longer payback period but high efficiency gains (e.g. renewables, co-generations) (World Energy Council [WEC], 2008). Preferential loans, more appropriate for middle and upper income households who wish to carry out energy and resource efficiency improvements, can be granted through public-private partnerships in which governments give fiscal incentives to banks, who in turn establish low interest rates for their customers (e.g. the case of KfW, a German development bank) (UNEP, 2011).

9.3.4 Capacity support, information and voluntary action

These instruments help to overcome barriers such as information and political/structural limitations by providing the necessary information on a voluntary basis to end users on energy and resource efficient buildings. *Voluntary certification and labelling programmes* give the opportunity for innovation, resulting in appliances and buildings that are more energy and resource efficient than conventional ones. As a result, stakeholders are influenced in the choices they make, resulting in higher environmental and market benefits. LEED from the USA, DGNB from Germany and GRIHA from India are successful voluntary green building certification systems. Energy star from the USA and Passive House from Germany are some of the renowned voluntary labelling programmes. *Voluntary and negotiated agreements* help to "reduce costs in the public sector and provide demonstration of new technologies that can be followed by the private sector" (UNEP, 2011). These voluntary agreements are made between a responsible government body and an organisation, stating that the organisation will undertake specific actions to increase the energy and resource efficiency of its products in the buildings (UNEP SBCI, 2007). Likewise, as the government and the public sectors together account for a large share of a country's energy and resource consumption, *public leadership programmes* (energy and resource efficiency programmes in public authorities) can demonstrate projects to show the private sector that savings and technologies are possible and to provide an incentive to the private sector to follow the example of the public sector (UNEP SBCI, 2007). *Awareness-raising, education and information campaigns*, initiated by government agencies, help to change individual behaviour, values or knowledge in terms of energy and resource efficiency in buildings, which in turn helps to reduce the rebound effect (UNEP SBCI, 2007). Education and training can support the upskilling of professionals, which is required for the green transformation of the building sector (especially in developing countries) (UNEP, 2011). For those who are not aware of how much energy they consume, *detailed billing and disclosure programmes* display detailed information on energy consumption to the user either on their bill or directly on the appliance or meter (e.g. smart meter) (UNEP SBCI, 2007), motivating the user to reduce their energy use.

When these four major policy instruments are compared[12], regulatory and control measures are the most effective and cost-effective in developing countries (achieving a rating of high or medium) (UNEP SBCI, 2007) and can play a major role in developing policies for fostering energy and resource efficiency in these countries. Detailed comparison is in Table 28 in Annex 3. The normative legislative instruments, such as mandatory minimum standards for buildings or appliances, are more effective than informative legislative instruments such as labelling or mandatory audits, as their effectiveness depends on their enforcement – especially in developing countries (UNEP SBCI, 2007).

Energy performance contracting and cooperative procurement are promising economic instruments. Due to the absence of a suitable methodology adapted to the building sector, Kyoto Flexibility Mechanisms are not currently effective. In terms of fiscal instruments, tax exemption, loans and subsidies are effective and can achieve higher savings than taxation (which increases the energy price). Voluntary instruments can be a good starting point for countries that are just introducing building energy efficiency policies or when mandatory measures

[12] Comparison is based on MURE (Mesures d'Utilisation Rationelle de l'Energie) database from UNEP SBCI (2007) report.

are not possible. Information instruments can be effective when they are specially tailored to the target group (UNEP SBCI, 2007).

9.4 Combination of policy instruments

In some cases policy instruments are more effective when they are combined within an integral policy package, which can also remove barriers to individual policy instruments (e.g. covering the upfront costs for the implementation of energy standards will not be easy without financial incentives). Generally, a combination of sticks (regulations) and carrots (incentives) with tambourines (information), creates the best potential for reducing GHG emissions (Warren, 2007 in UNEP SBCI, 2007) and increasing building efficiency. Table 14 gives an overview of the possible combination of policy instruments. Some of the combinations of policy instruments are discussed in following section.

Table 14. Possible policy instrument packages

Measures	Regulatory instruments	Information instruments	Financial/Fiscal Incentives	Voluntary Agreements
Regulatory instruments	Building codes and standards for building equipment	Standards and information programmes	Building codes and subsidies	Voluntary agreements with a threat of regulation
Information instruments	Appliance standards and labeling	Labelling, campaigns, and retailer training	Labelling and subsidies	Voluntary MEPS and labeling
Financial/Fiscal Incentives	Appliance standards and subsidies	Energy audits and subsidies Labelling and tax exemptions	Taxes and subsidies	Technology procurement and subsidies
Voluntary Agreements	Voluntary agreements with a threat of regulation	Industrial agreements and energy audits	Industrial agreements and tax exemptions	

Source: UNEP SBCI, 2007

Some examples of the combinations of policy instruments are:

9.4.1 Regulatory and information programmes

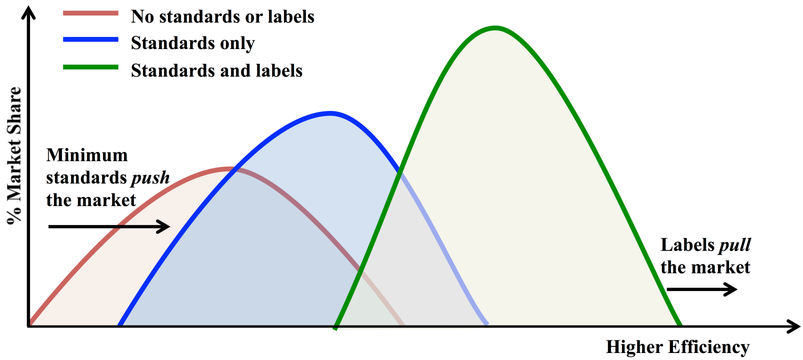
Barriers to regulatory and control instruments, such as the rebound effect and lack of compliance/enforcement, can be removed by using information programmes (such as awareness-raising, information campaigns and training). Sometimes energy efficient techniques are not adopted due to a lack of public awareness (owner/designer), technical incapability/knowledge (designer) and a misconception about the higher upfront costs (developers). Therefore, information about the financial benefits (payback periods) and the environmental and health benefits should also be disseminated in order to convince owners, developers and designers. This is particularly important issue in developing countries where the adoption of energy and resource efficient techniques is at an early stage. One study (McGraw Hill Construction, 2013) shows that internet, conferences and magazines etc. are the most useful resources for the exchange of information (based on the respondents in the survey).

9.4.2 Public leadership programmes and energy performance contracting

Public leadership programmes, which help to improve efficiency in the public sector, face budgetary constraints in both developing and developed countries. But when this instrument is used together with energy performance contracting, the barrier can be overcome. Executive orders, which oblige public authorities to reduce their energy and resource consumption, have boosted the ESCO industry (UNEP SBCI, 2007).

9.4.3 Mandatory regulations (codes and standards), voluntary labels and financial incentives

The combination of policy instruments can also play a major role in market transformation, i.e. a change in the structure and function of the market for energy (and resource) consuming products/technologies (UNEP SBCI, 2007) and inefficient buildings. Market transformation is an integrated and strategic process that aims to produce a permanent change in the efficiency of the whole market using proper regulations, incentives and information (Decade 1995). The combined effect of mandatory regulations (codes and standards), voluntary labels and financial incentives increases the market share of efficient buildings, as shown in Figure 21 and briefly explained below.



Source: Tholen and Thomas 2011

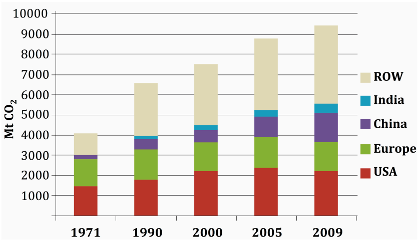
Figure 21. Combination of standards and labels

The curved red line shows the market distribution of building stock without any intervention. As mandatory codes and standards are binding instruments (e.g. EnEV in Germany) and all buildings must comply with the limits set for energy and resource use, the enforcement of mandatory standards cuts the dirty end of inefficient appliances/buildings from the market (World Energy Council, 2008), pushing the curved line towards the right and forming the blue bell shaped distribution curve. This illustrates how the market is moving towards higher efficiency. However, it is critical at the outset for mandatory standards to insist on compliance and focus on enforcement, in order to produce more energy and resource efficient buildings and to integrate energy and resource efficiency requirements into standard practices (Liu, Meyer & Hogan, 2010). The additional introduction of voluntary labelling (e.g. Passive House standards in Germany and LEED) pulls the market towards more energy and resource efficient buildings and accelerates the competition between manufacturers/developers. Likewise, financial incentives such as subsidised loans/interest rates and tax credits help to overcome upfront costs and further encourage customers to build more efficient buildings and buy efficient appliances. The combined effect of labels and financial incentives form a steep green curve that increases the share of efficient buildings. To enhance the effectiveness of financial incentives, the labelling of buildings and products ensures that only the most efficient categories of buildings and appliances are financially supported.

Chapter 10 describes some of the good practice case studies of building codes/standards, labelling and financial incentives for energy efficient and green buildings. As described in WBCSD (2009), in addition to codes/standards, labelling and financial incentives, the market transformation of higher energy efficient and green buildings can be further accelerated by: encouraging developers to integrate efficient design approaches and innovations; further research and development to introduce advanced and efficient technologies; developing workforce capacity to produce more energy efficient and green building design professionals; and by raising awareness among all stakeholders through campaigns and demonstration projects. The whole process is basically supplemented by government actions, together with the support of all stakeholders (see chapter 11, section 11.1.3 for detailed steps and explanation).

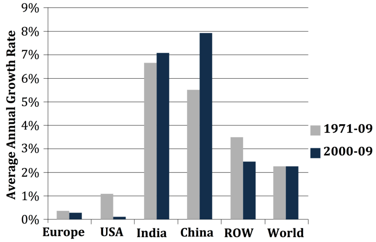
10 Policy case studies from Europe, the USA and India

Buildings in developed countries (e.g. Europe and the USA) contribute higher levels of CO_2 emissions than India (and China) due to the *lock-in effect* of inefficient existing buildings (see Figure 22A), but Figure 22B shows that the current trend of the construction of (inefficient) new buildings in developing countries (e.g. India) is contributing to a higher annual growth rate of CO_2 emissions for energy (and resource) use in buildings. This chapter gives examples of policies from Europe, the USA and India, showing how these countries are reacting to the need to reduce adverse environmental impacts from buildings through designing effective policies (codes/standards, labels and financial incentives) to promote energy efficient and green buildings and to stimulate market transformation. These are good practice examples and are selected on the basis of success factors in terms of energy saving, effective administration, high enforcement and compliance rates and cost-effectiveness. The policies are analysed in terms of the establishment of the codes/standards, the development of the methods and how the focus differs for energy efficient and green buildings according to the country's circumstances. Financial incentives for the selected countries are discussed to see how they have helped to trigger market transformation.



Source: IEA, 2011a and de la Rue du can and Price 2008 in GBPN and LBNL, 2012

A. Building CO_2 emissions for various countries



Source: GBPN and LBNL, 2012

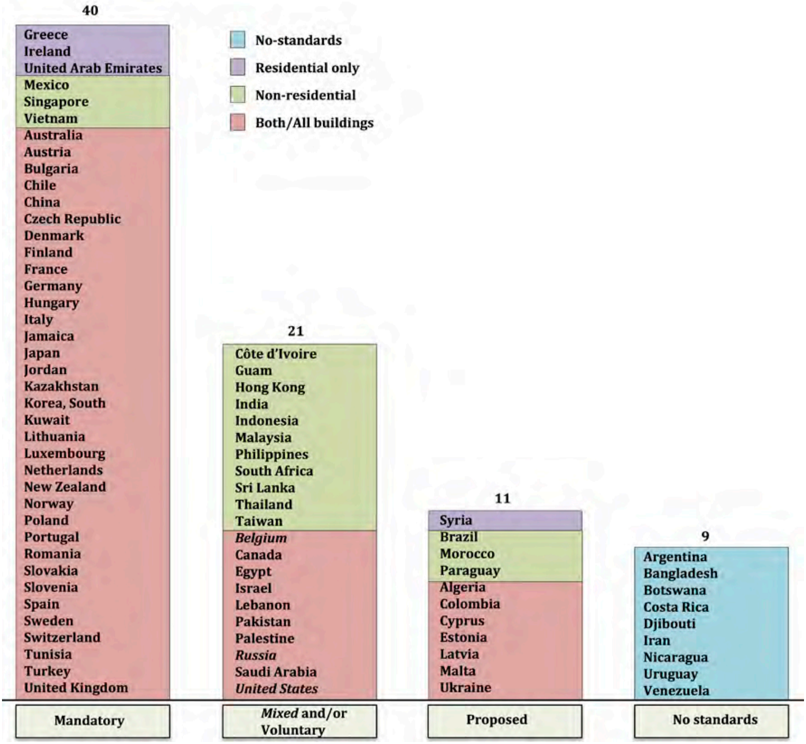
B. Annual growth rate of building CO_2 emissions from energy use for various countries

Figure 22. Building CO_2 emissions and its annual growth rate for the USA, the EU27, China, India and the rest of the world

10.1 Energy codes and standards

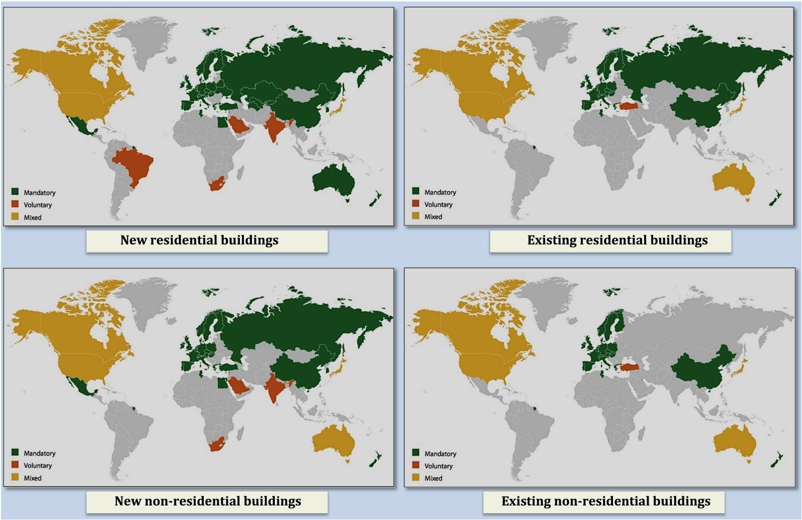
Building codes are an enforceable body of rules that govern the design, construction, maintenance and repair of buildings. Buildings standards outline a series of options for the performance of building systems and their construction. They are often referenced by codes but are not enforceable, unless adopted as part of a code (as mandatory). Energy code and standards play an important role by setting minimum requirements for energy efficient design and construction, for both new and existing buildings (AIA, 2010). Energy codes stipulate how buildings must be constructed or perform to minimise energy demand, and are written in mandatory, enforceable language. The codes are adopted and enforced by a country or state or local government for their jurisdiction. Energy standards, however, describe how buildings should be constructed in order to save energy cost-effectively. Energy standards are not mandatory, but serve as national recommendations with regional climate variations and are published by national organisations such as ASHRAE in the USA. States and local governments frequently use energy standards as the technical basis for developing their energy codes. Some energy standards are written in mandatory, enforceable language to make it easy for jurisdictions to incorporate the provisions of the energy standards directly into their laws or regulations (Bartlett et al., 2003). Most developed countries are early developers of building energy codes. For a list of the chronology of the building energy codes in various countries, see Figure 59 in Annex 3.

The present energy standards range from voluntary guidelines to mandatory requirements and may apply to various building types (Janda, 2009) (see Figure 23 and Figure 24). These standards are more successful when mandatory (UNEP, 2009). In most developed countries, the energy standards are mandatory, but their effective enforcement is key to producing the projected levels of energy savings. There is little international data on evaluated impacts of the standards and it is not always possible to compare data. For example, in the USA (taking a study up to 2004 with baseline in 2000), the energy saved through buildings was 15% to 16% (Nadel, 2004). In the EU the energy saved by new residential buildings was as much as 60% compared to the average building stock built before the first oil shock (WEC 2008), due to the mandatory energy standards in European countries. A further study (International Energy Agency [IEA] and United Nations Development Programme [UNDP], 2013) states that building energy codes have reduced annual energy consumption per dwelling by 22% (e.g. in the Netherlands and Germany) and by 6% (e.g. in Southern European countries). The variation in energy savings is due to the difference in the stringency of energy requirements and the approach used in the design of building energy codes (IEA and UNDP, 2013) However, in most developing countries, the energy standards are in a voluntary or proposing phase and their effectiveness may be comparatively low due to difficulties with enforcement and corruption (Koeppel and Ürge-Vorsatz 2007). Even in developed countries, ensuring complete compliance with mandatory standards still remains a challenge.



Source: Janda, 2009

Figure 23. Status of energy standards in 2009



Source: IEA and UNDP, 2013

Figure 24. Status of building energy codes

Building energy codes and standards are designed mainly with two approaches (the prescriptive and performance approaches). In the prescriptive approach, minimum energy requirements are set for each building component (window, wall, roof etc.) and for the heating and cooling equipment. Two compliance paths are possible within this approach: (i) each building component has to meet strict minimum energy performance requirements and (ii) trade-offs are allowed between the energy performance needs of different components (IEA and UNDP, 2013) (e.g. the energy requirement can be balanced by using, for example, a stringent requirement for insulation and a lower requirement for lighting (IEA, 2013c)). However, this approach does not allow for synergies from the interaction of different components. Likewise in the performance approach, an integrated design based on a holistic assessment of the building's energy performance is required, in which energy requirements are set for a building's overall energy consumption and equipment. This approach optimises the savings by considering the interaction of different building components. Two compliance paths are possible within this approach: (i) a model building approach that considers minimum energy performance requirements, which vary depending on the size of the building (comparing the building with a reference building calculation), and (ii) the overall performance approach with a standard energy performance requirement (primary energy consumption or CO_2 emission reductions) for all building sizes (differing according to climate zones) (IEA and UNDP, 2013). Therefore, the overall performance code is wider and more advanced than the prescriptive approach for minimising energy use in buildings. Looking at the trend of the development of energy codes (as explained in the webinar for modernising building codes (IEA and UNDP 2013)), prescriptive codes were developed in the early phase of energy code development (1970s). Later, in the 1990s, model code under performance code was developed and then, in 2000, overall performance code was introduced.

10.1.1 Energy codes and standards in Europe

Building code: mandaroty Energy Performance Buildings Directive (EPBD)

Most European countries introduced building codes/standards in the 1970s and have updated and tightened them over the course of time (Liu et al., 2010). The EU provides a mandatory framework directive with the obligation for its member states to set minimum energy performance standards (MEPS) to achieve significant reductions in the energy consumption of buildings. The first European building directive on energy efficiency went into force in 2002: The Energy Performance of Buildings Directive (EPBD 2002). During the following years the member countries started to implement energy efficiency standards. The EPBD required all member states to adopt the following by January 2006: methodologies for integrated building energy performance standards (Article 3), minimum energy performance requirements on the basis of those methodologies for all new buildings and those >1000 m2 with major refurbishment (Articles 4-6), certification schemes for all buildings (Article 7), inspection and assessment of boilers and air-conditioning installations (Articles 8 & 9) (Liu et al., 2010). The features of EPBD are shortly described below.

EPBD
Energy Performance Buildings Directive

Building scope
It includes new and existing residential and commercial buildings with a particular focus on reducing heating demand.

Development
EU

Implementation
EU Member countries

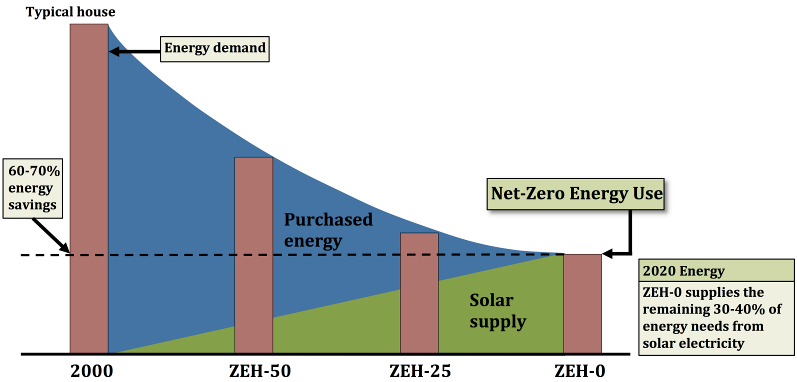
Energy saving target
In 2007, the European Union committed to the 20-20-20 targets to be achieved by 2020 as the EU's climate protection goal (reduction of GHG emissions by 20% below 1990 levels, a 20% share of renewables in the energy mix and reduction of primary energy use by 20% compared with projected levels through improved energy efficiency) (Liu et al., 2010) and also committed to 80%-95% GHG reduction by 2050. Therefore, all the EU member states need to tighten their building energy regulations and to introduce energy certification schemes for buildings (EPBD-CA 2011, p. II-1). Moreover EU member states must implement buildings-related certification systems, inspections, information and communication campaigns and minimum energy performance standards for new and existing buildings (bigEE, 2012).

Compliance
An important driver for the European buildings market is the fact that some countries in Northern Europe (e.g. Sweden and Denmark), and later Germany, strengthened their performance standards stepwise. As a result, European markets for new buildings have already been pushed towards a better energy performance over the last 20 years. However, as there is a substantial lack of effective control mechanisms, compliance is one of the most important implementation issues (Hennicke, Shrestha, & Schleicher, 2011).

Enforcement
The ways of enforcing EPBD in Europe vary significantly and depend largely on the procedures applicable for the building sector. All member countries require building permits before beginning construction. However, for some minor alterations, permit-free construction is allowed. Most member countries require inspection during construction, approval for use and a completion certificate (Liu et al., 2010). Violation of the rules incurs penalties such as fines, demolition, refusal of building permit and imprisonment.

Recast EPBD

Recast EPBD or a revision of the EPBD was proposed by the EU Commission in 2008, approved by the European Parliament with considerable changes and approved by the European Parliament in May 2010. It was agreed that the member states should implement the recast directive within two years and an evaluation of the directive would take place in 2017 (Liu et al., 2010). Its key characteristics are that new public buildings have to be NZEB by 2018 and all new residential and commercial buildings by 2020. However, the definition within the directive only states that such buildings must have a "very high energy performance and the nearly zero or very low amount of energy required should to a very significant level be covered by energy from renewable sources including renewable sources onsite or nearby" (Article 2, Dir. 2010/31/EU). This, therefore, is the European conceptual approach to describe nearly zero energy buildings (see Laustsen, 2008; European Council for an Energy Efficient Economy [ECEEE], 2011). Although an exact definition must be developed by the EU in future years (regarding on-site balance and grid-based balance of energy demand and supply), Figure 25 shows that the energy demand for a NZEB will be targeted stepwise over the next few years (2000, ZEH 50, ZEH-25, ZEH 0) until the net zero energy line is reached. Simultaneously, the residual energy demand, as stated in the EPBD definition, should be covered by renewable energy systems.



Sources: Laustsen, 2008, ECEEE 2011

Figure 25. Progression to Full Zero Energy Houses

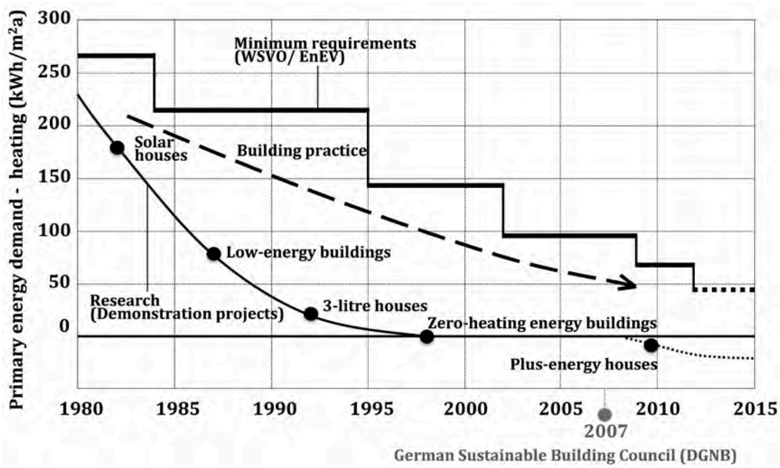
The second key characteristic of the EU approach is that optimising the costs for implementing the energy performance standards must be verified by each member country using a given framework methodology. A net present value method provided by an amendment to the recast EPBD by the end of June 2011 has to be used by each country's authorities to check the cost-optimality of the current standards. In the case of deviation, e.g. the standards being too lax, the member countries must justify this within their annual report to the commission.

The EU, therefore, does not set standards itself, but forces the member countries to set cost-optimal energy efficiency standards (ECEEE 2011). To illustrate how these can translate into national law – also under the cost-optimality criteria – the development of the German standards is outlined in the following section.

10.1.2 Energy codes and standards in Germany

Building code: Energy saving ordinance (EnEV)

Germany implements Energy saving ordinance (Energieeinsparverordnung or EnEV) as Minimum Energy Performance Standards (MEPS). The code came into effect in 2002 and replaced earlier MEPS (from 1977). Since 2009, the heating and cooling requirement of buildings must be in line with the EnEV 2009 (bigEE, 2012). Figure 26 shows the development of MEPS for new buildings in Germany. The features of EnEV are shortly described below.



Source: Erhorn and Erhorn-Klutting, 2009

Figure 26. Development of MEPS for new buildings in Germany

EnEV
Energieeinsparverordnung (Energy saving ordinance)

Building scope
It includes new and existing residential and commercial buildings, which are heated or cooled using energy. It covers heating, cooling domestic hot water and, for non-residential buildings only, lighting and ventilation.

Development
Federal Ministry of Transport, Building and Urban Development; Federal Ministry of Economics and Technology

Implementation
Federal States

Energy saving target
EPBD, under the EU, does not set standards itself but forces member countries to set cost-optimal energy efficiency standards (ECEEE, 2011). To show how these can translate into national law - also under the cost-optimality criteria - the development of the German standards is outlined. Figure 26 shows how MEPS have been developed in Germany over the past 30 years (from 2002 under the EPBD).
Since the introduction of MEPS in 1977, the minimum energy requirement for the primary energy demand for heating was strengthened stepwise in Germany. The first EnEV requirement in 2001 pushed the requirements under the 100 $kWh/m^2/yr$ threshold; the latest recast in the year 2009 to 70 $kWh/m^2/yr$ followed by a further tightening of 30% in 2012. The energy saved through the more stringent EnEV 2009 standard, compared to EnEV 2007, is around 30%. The calculation of the maximum allowable level of primary energy consumption was carried out with comparison to a reference building and depends on the surface-to-volume ratio, and the maximum allowable level of heating energy consumption is around 70 $kWh/m^2/yr$ for a typical dwelling (see Figure 26 and bigEE,

2012). Further tightening of 12.5% is planned in 2014 followed by another 12.5% in 2016.
The latest German MEPS for new buildings require a) the building envelope for new buildings to be 30% more energy efficient than the previous level; b) the selection of energy sources with a lower environmental impact instead of traditional sources such as oil; and c) the issuing of Energy Performance Certificates (Energieausweis) by state-certified energy advisors (Power and Zulauf 2011, p. 7 in bigEE, 2012). For existing buildings, EnEV must be complied with if the change to the exterior elements of the building due to renovation is more than 10% (Tuschinski, 2011, p. 21 in bigEE, 2012).

Compliance

Compliance control is provided by local authorities and is carried out at the time of issuing the building permit for new buildings (there is no compliance control for renovation) (bigEE, 2012).

Enforcement

Building control authority (local level). Violation of the rules incurs penalties such as demolition and refusal of the building permit.

10.1.3 Energy codes and standards in the USA

The share of primary energy and electricity consumption of buildings (residential and commercial) in the USA amounted to 41% and 74% respectively in 2011 (US-DoE, 2012). CO_2 emissions for US buildings in 2010 (attributable to lighting, heating, cooling, cooking, refrigeration, water heating and other building services) came to a total of 2,268 million metric tonnes, which is 40% of the US total and 7.4% of the global total (US-DoE, 2012). More stringent building energy codes are part of the energy solution.

Building codes and standards

Two national codes are available in the USA – the International Code Council’s (ICC) International Energy Conservation Code (IECC) and the American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE)/Illuminating Engineering Society of North America’s (IESNA) Standard 90.1. These are adopted by many states and local authorities (Liu et al., 2010). The features of IECC and ASHRAE are shortly described below.

IECC and ASHRAE International Energy Conservation Code and the American Society of Heating, Refrigerating, and Air-conditioning Engineers.
Building scope IECC and ASHRAE/ IESNA Standard 90.1 provide minimum energy efficiency requirements covering the building envelope, HVAC, service water heating systems, electric equipment and systems, lighting and other motors. The IECC includes all residential and commercial buildings, while ASHRAE/IESNA standard 90.1 includes all building types except residential buildings with three or four storeys (but includes commercial buildings with high-rise multifamily residential buildings) (Liu et al., 2010).
Development IECC is developed with the support of ICC using a government consensus process and updated every three years (US-DoE, 2010). ASHRAE 90.1 is developed with the support of the American Society of Heating, Refrigerating and Air-conditioning Engineers using the ANSI consensus process (US-DoE, 2010) and updated every three years.
Implementation State and local governments. Before the adoption of the IECC (and ASHRAE 90.1), state and local governments often made changes to the suitability of regional building practices, or state-specific energy-efficiency goals (US-DoE, 2010).
Energy saved Several generations of the US energy codes and standards since the mid-1970s have resulted in estimated energy efficiency improvements of about 60% (Liu et al., 2010).
Compliance Both codes (IECC and ASHRAE) take into account eight climate zones and have two compliance paths - prescriptive/component performance for the individual building systems and total building performance method or energy cost budget method (Liu et al., 2010).
Enforcement States or jurisdictions are responsible for enforcing the building energy codes and the responsibility for complying with the building energy code falls to developers, designers and contractors. The enforcement strategies vary according to a state or local government's regulatory authority, resources and manpower and may include all or some of the following activities: review of plans; review of products, materials and equipment specifications; review of tests, certification reports and product listings; review of supporting calculations; inspection of the building and its systems during construction; evaluation of materials substituted in the field; inspection immediately prior to occupancy (US-DoE, 2010). The other approaches of the enforcement of building energy codes are local enforcement (performed by municipality or county officials), third party enforcement (an independent entity, trained in energy efficiency and approved by the local building department or relevant state agency) and self-certification (requiring the builder to provide certificates of compliance to a local or state agency) (Liu et al., 2010).

10.1.4 Energy standards to India

The development of energy standards in India only goes back to 2001, when the Energy Conservation Act (EC Act) was introduced. The EC Act came in force in March 2002 with the establishment of the Bureau of Energy Efficiency (BEE) under the Ministry of Power, Government of India. Its primary objective is to reduce the energy intensity of the Indian economy by setting a minimum energy performance standard for buildings in India. In May 2007, BEE developed the Energy Conservation Building Code (ECBC) on a voluntary basis to set minimum energy efficiency standards for the design and construction of new commercial buildings with a connected load of 500 kilowatt (kW) or contract demand of 600 kilovolt-ampere (kVA). Since 2010, ECBC has also included smaller offices and high rise residential buildings with a connected load of 100kW or contract demand of 120kVA (Shankar n.d.) (Figure 27 for a roadmap). This code demonstrates an initial and early effort by India to address the issue of rapidly increasing energy use in commercial buildings (GBPN and LBNL, 2012). The ECBC is planned to become mandatory soon. The features of ECBC are shortly described below.

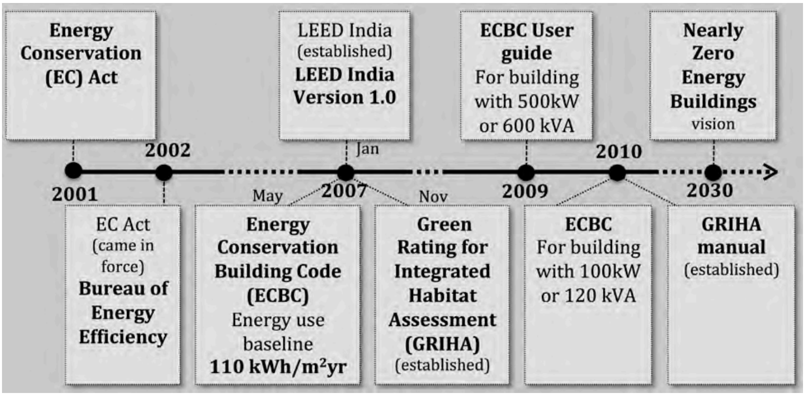


Figure 27. Roadmap for the development of Energy Standards and Green Building certification in India

ECBC
Energy Conservation Building Code

Building scope
ECBC has provisions for building envelopes (except for unconditioned storage spaces or warehouses), mechanical systems and equipment (including heating, ventilation and air-conditioning), service hot water heating, interior and exterior lighting, and electrical power and motors (BEE 2009).

Development
Bureau of Energy Efficiency (BEE), Ministry of Power, Government of India with support from USAID ECO II project.

Implementation
Bureau of Energy Efficiency (BEE), Ministry of Power, Government of India with support from USAID ECO II project.

Energy saving target
ECBC set the building energy consumption requirement at 110kWh/m^2/year, while the national benchmark is 180kWh/m^2/year (Shankar n.d.). Some of the case studies of ECBC compliant buildings show even smaller levels of energy consumption, as shown in Figure 60 in Annex 3.

Compliance
Several state and central agencies are in the process of incorporating the code into guidelines and requirements for public buildings (GBPN and LBNL, 2012).

Enforcement
Bureau of Energy Efficiency (BEE), Ministry of Power, Government of India with support from USAID ECO II project. The implementation of ECBC at state level and the incorporation of ECBC provisions in building design pose several challenges (Kumar et al., 2010), as the measures to support enforcement, commissioning requirements and mandatory computer modelling are needed. New Delhi has adopted it and made it mandatory for government buildings (Liu et al., 2010). The penalties for non-compliance with the code include refusal of permission to occupy and refusal of permission to construct (GBPN, 2013).

Energy saved
39% calculated energy savings against national benchmark building (Liu et al., 2010)

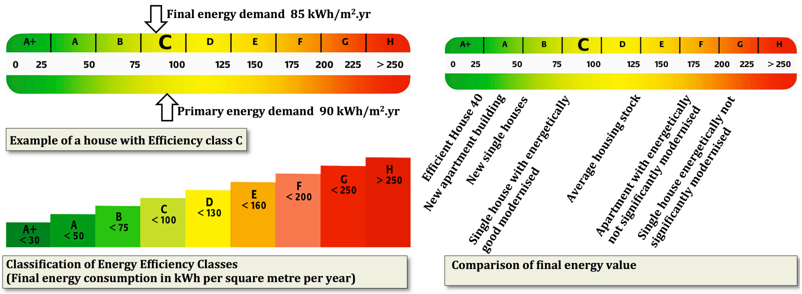
10.2 Energy labelling

Labelling (also called certification or rating) aims to achieve environmental goals above and beyond the codes by setting criteria for construction and performance. These are not written in enforceable language (AIA, 2010).

10.2.1 Energy labels in Germany

Energy Performance Certificates

In EU member countries, Energy Performance Certificates (EPC) (*Energieausweis* in German) provide reliable information on energy efficient buildings, giving advice about realistic energy saving potentials and offering recommendations for modernisation (DENA 2009). In Germany, EPCs supplement EnEV. EPC has been compulsory for new buildings since 2002. Since January 2009 (for residential buildings) and since July 2009 (for non-residential buildings), there has been a legal obligation for a building to have an EPC before being leased or sold. The EPC has two variants; a requirement certificate (or *Bedarfsausweis* in German), based on a technical analysis of the building and a consumption certificate (or *Verbrauchsausweis* in German), showing the actual building energy consumption for hot water and heating over the last three years. The colour scale in an EPC shows at a glance the performance of a building in terms of its energy consumption. The 'green' area denotes very good, while 'yellow' indicates potential for modernisation and 'red' indicates significant energy saving potentials. Additionally, it provides information on the quality of the building envelope (e.g. windows, ceilings and exterior walls), the heating system, the energy medium (e.g. heating oil, natural gas or electricity) and ventilation and CO_2 emissions (DENA, 2009). Figure 28 shows the scaling of EPC in Germany.



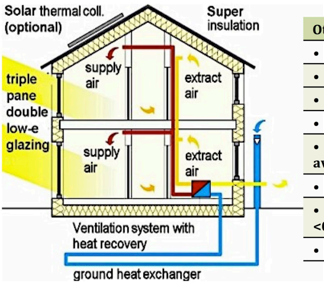
Source: DENA, 2013

Figure 28. Scaling of the EPC for Germany showing final energy demand and primary energy demand

Passive House (PH) concept

The Passive House (PH) concept, developed by the Passive House Institute (PHI) in Darmstadt, moves towards ultra-low energy buildings, which provide the opportunity for energy savings of at least 80% to 90% higher (overall) than conventional buildings (EIA 2009). The basic idea of a PH is to provide high-energy efficiency/performance by using good insulation, an airtight construction and mechanical ventilation to achieve high indoor thermal comfort conditions (ISO 7730) at a low building cost (Janson, 2008).

Although the features of a PH depend on the climatic conditions, its main energy use criteria (for a European cold climate) are a specific heating/cooling demand of ≤15kWh/m^2/year and a total primary energy demand of 120kWh/m²/year including lighting and all household appliances (Passive House Institute, Tuohy, n.d.) Basic principles and other features of PH (for European cold climates) are shown in Figure 29. See also Figure 30 for different scope, calculation methods and norms for low energy and PH in selected countries) indicating primary and final energy use.



Source: Janson, 2008

Other features of PH for European cold climates
• Highly efficient systems, appliances and lights
• Heating load (≤10W/m2)
• Insulation material with very low conductivities (λ < 0.035 W/m.K)
• Low life cycle cost through high energy savings
• High efficiency ventilation for air quality – air changes (≤0.6 /h), average ventilation volume (20-30 m3/h/ person)
• Excellent insulation (U<0.15 W/m2.K)
• Excellent construction – no unintended air leakage (AC/H <0.6@50Pa), no thermal bridges (Psl<0.01 W/m.k ext)
• Excellent glazing (U<0.8 W/m2.K)

Source: PH Institute, Tuohy, n.d.

PH with high indoor thermal comfort conditions (ISO 7730) at a low building cost

Figure 29. Basic principles and other features of PH

Danish low energy class 1	The Swiss Minergie	French Effinergie	German Passive House	German Passive House	
<35+1100/A kWh/m².yr = energy consumption for heating, cooling, ventilation and hot water	<42 kWh/m².yr = energy consumption for heating, cooling, ventilation and hot water	<50 kWh/ m².yr = energy consumption for heating, cooling, ventilation and hot water + Lighting	<120 kWh/m².yr = energy consumption for heating, cooling, ventilation and hot water + electrical domestic appliances &	<15 kWh/ m².yr =energy need for heating	
2.5	2.0	2.58	2.70	2.70	Ratio primary energy/final energy for electricity
Primary energy	Primary energy	Primary energy	Primary energy	Final energy	

Source: Thomsen, Wittchen & EuroACE, 2008 in EC 2009

Figure 30. Primary energy and final energy consideration in PH and other low energy buildings in different countries

10.2.2 Energy labels in the USA

Energy labels include more rigorous requirements than minimum energy codes and address additional issues not covered in energy codes (US-DoE, 2010). Most building energy labels in the USA use IECC and/or ASHRAE 90.1 as a baseline, together with additional requirements. There are many voluntary energy labels in the USA and these vary in terms of scope, method, stringency and region covered (US-DoE, 2010). Some of the energy labels are listed and described in Table 15. These energy labels can, over time, become acceptable as typical practice and are often submitted to the ICC or ASHRAE processes as code changing proposals (US-DoE, 2010).

Table 15. Some of the building energy labels in the USA

Home Energy Rating System (HERS)	
Building scope	Energy efficiency at home
Method	Involves analysis of the home's construction plans and at least one onsite inspection. Used to estimate the home's annual energy costs and gives the home an index between 0 and 100. The higher the score, the more efficient the home.
Used in States/County	Jurisdictions such as Boulder County, Colorado, have mandated a particular HERS index for new residential construction.
Energy Star	
Building scope	Homes and commercial buildings
Stringency	15% more energy efficient than average minimum energy codes.
Used in States/County	New York State allows local jurisdictions to adopt Energy Star as their minimum residential energy code and many, such as Brookhaven, have done so.
Developed by	U.S. Energy Protection Agency
EarthCraft House	
Building scope	Residential
Method	Point based system
Stringency	Includes Energy Star certification in its baseline.
Used in States/County	Used in Alabama, South Carolina, Tennessee, Virginia and Georgia. The city of Nashville offers incentives for EarthCraft homes.
Developed by	Southface Energy group, Inc. in partnership with the U.S. Department of Energy's (DOE) Building America

Building America	
Building scope	Designed to accelerate the development and adoption of advanced building technologies in new and existing homes.
Method	Industry based research programme.
Developed by	DOE
Collaborative for High Performance Schools	
Stringency	Mandates energy efficiency 25% above ASHRAE 90.1.2004.
Used in States/County	Originally a California standard, it is being revised to take regional factors into account and is adopted by states and school districts across the country.
Core Performance Guide	
Building scope	Commercial buildings from 10,000 to 70,000 sq. feet (~929 to 6,503 sq. metres).
Stringency	20% to 30% more efficient than ASHRAE 90.1-2004 buildings.
Used in States/County	This fee-based programme is available nationally. The State of Massachusetts recently adopted this as the commercial section of Appendix 120.A, known as the “stretch code”.
Developed by	New Buildings Institute
NAHB Green Guidelines	
Building scope	Provides guidance for builders interested in green building products and practices for residential design, development and construction.
Stringency	15% to 40% above IECC or local code.
Used in States/County	Local jurisdictions and utilities promote the programmes and provide verification, such as in Pierce County, Washington, where it is supported by Washington State Department of Ecology, Puget Sound Energy and Tacoma Power.
Developed by	First published in 2005, the National Association of Home Builders (NAHB) Model Green Home Building Guidelines were written by a group of builders, researchers, environmental experts and designers.
ASHRAE 90.1.189	
Building scope	Standard for the Design of High-Performance, Green Buildings except Low-Rise Residential Buildings. It was published in January 2010. It is applicable to new commercial buildings and major renovation projects. “It is not targeted for any building project, but rather for high performance building projects” (ASHRAE, 2010).
Method	Addresses energy efficiency, a building’s impact on the atmosphere, sustainable sites, water-use efficiency, materials and resources, and indoor environmental quality and also ‘provides minimum requirements for the siting, design, construction and plans for operation of high performance green buildings’ (ASHRAE, 2010).
Stringency	Has an energy efficiency level comparable to ASHRAE 90.1-2010 but buildings use 30% less energy than ASHRAE 90.1-2007. On water efficiency, it puts limits on the number of cycles of water through cool-

	ing towers and requires condensate collection on air-handling units above 5.5 tonnes of cooling capacity (19KW). On Indoor Environmental quality (IEQ) it requires tobacco smoke control, outdoor air monitoring, filtration/ air cleaning and the determination of the outdoor airflow rate (ASHRAE, 2010).
Developed by	Developed in collaboration between ASHRAE, the Illuminating Engineering Society of North America (IES) and USGBC for inclusion into building codes.
IECC	
Building scope	New construction and renovation to existing buildings, other than residential structures.
Method	Effectively meshes with the other ICC codes for ease of adoption with building regulations based on the ICC codes. It is performance-based and allows adopting entities to determine which provisions of the code are applicable to their needs. Issues covered are siting, materials, energy, air quality and water, not only in the design and construction phase, but through commissioning and actual operation of the building.
Developed by	Currently under development in conjunction with the American Society for Testing and Materials and the AIA.
ICC-700-2008	
Building scope	Defines green building for single and multi-family homes, residential remodelling projects and site development.
Stringency	This standard exceeds the 2006 IECC by a minimum of 15%.
Locally Developed Programmes	
Used in States/County	City of Albuquerque's 2009 Interim Energy Conservation Code (www.cabq.gov/planning/bldgsafety) and Boulder County Colorado's BuildSmart Programme.

Adapted from: US-DoE, 2010 and ASHRAE, 2010

10.2.3 Energy labels in India

In India, the BEE (Bureau of Energy Efficiency) energy star label (which supplements ECBC compliance) is for equipment, appliances and buildings. The star label for buildings is based on actual performance of the building in terms of specific energy usage (kWh/m^2/year). It rates office buildings on a 1-5 Star scale (5 Star labelled buildings being the most efficient) on the bandwidth of Energy Performance Index (EPI) in kWh/m^2/year for 3 climatic zones (warm and humid, composite and hot and dry) for air-conditioned and non-air-conditioned buildings (Bassi, n.d.) (see Table 16).

Table 16. Bandwidth of EPI for BEE star label in 3 climatic zones

Bandwidths (less than 50% air conditioning)		**Bandwidths (more than 50% air conditioning)**	
Composite		Composite	
EPI (kWh/m²/year)	Star Label	EPI (kWh/m²/year)	Star Label
80-70	1 Star	190-165	1 Star
70-60	2 Star	165-140	2 Star
60-50	3 Star	140-115	3 Star
50-40	4 Star	115-90	4 Star
Below 40	5 Star	Below 90	5 Star
Warm and Humid		Warm and Humid	
EPI (kWh/m²/year)	Star Label	EPI (kWh/m²/year)	Star Label
85-75	1 Star	200-175	1 Star
75-65	2 Star	175-150	2 Star
65-55	3 Star	150-125	3 Star
55-45	4 Star	125-100	4 Star
Below 45	5 Star	Below 100	5 Star
Hot and Dry		Hot and Dry	
EPI (kWh/m²/year)	Star Label	EPI (kWh/m²/year)	Star Label
75-65	1 Star	180-155	1 Star
65-55	2 Star	155-130	2 Star
65-45	3 Star	130-105	3 Star
45-35	4 Star	105-80	4 Star
Below 35	5 Star	Below 80	5 Star

Source: Bassi, n.d.

10.3 Conclusion and discussion on energy codes, standards and labelling

Energy codes and their stringency differ internationally

The section above shows that building energy codes, standards and labels differ from country to country; especially in terms of their level of stringency (e.g. the energy standard in Germany is higher than in India). Some variation factors are due to (i) supportive policy differences, (ii) available technological standards and availability of technology, (iii) climate (heating/cooling need) and, finally, (iii) local economic situation and acceptability (according to the collective expert opinion).

Energy codes and compliance

New buildings in developed countries (Germany and the USA) consume less energy than buildings constructed 20-50 years ago (i.e. before the adoption and more complete implementation of stringent building codes) (Liu et al., 2010) and energy labels incentivise stakeholders to go beyond the codes towards more efficient buildings. However, actual savings and emission reductions due to the building codes are, in general, lower than indicated by the codes and standards due to a certain degree of non-compliance, behavioural factors and low emphasis on measuring the energy performance of buildings after construction (Liu et al., 2010). However, the regular updating of building codes (EPBD in EU member states every seven years, energy codes for most EU member states every three to five years and the national model energy codes in the USA every three years) allows for incremental stringency improvements and for adjustments to be made that will improve implementation (Liu et al., 2010). This has helped buildings achieve higher energy efficiency.

How to achieve stringent energy standards and codes in developing countries

In the case of developing countries (e.g. India) the stringency of energy standards and labels is not as high as in developed countries. In addition, the implementation of the standards also faces various barriers and constraints, such as a lack of information about energy use and efficiency, risk perception due to a lack of confidence in the performance of new technologies, an underdeveloped materials and components market for compliance, including related testing and certification capabilities, a limited ability to internalise the incremental cost of energy efficient technologies due to low income levels, and high levels of informal building construction (Liu et al., 2010) (see also Table 12). Therefore, developing countries need to make a political commitment to energy efficiency, ensure that compliance with building codes becomes simpler, strengthen the governmental oversight of building construction, develop the enforcement and compliance infrastructure, and start with what can be complied with and enforced effectively now, expanding the scope incrementally over time (Liu et al., 2010).

Energy efficiency in a holistic approach

To target energy efficiency improvement, energy codes and standards have to move towards advanced building energy codes and standards by transforming buildings from being energy consumers to energy producers. This is achieved by moving to a comprehensive holistic approach in which (i) energy demand is reduced by energy sufficiency measures (i.e. a focus on reducing the amount of energy needed to operate and maintain a building (such as incorporating bio-climatic design and passive solutions)); (ii) energy consumption is reduced by using efficient building components and equipment to meet the energy demand; and (iii) renewable energy sources are used to generate heat and electricity (such as capturing solar heat for space or water heating, using prevailing breezes for natural ventilation or heat pumps to extract heat or cold from the ground as well as using biomass for heating; and using power-generating systems i.e. photovoltaic systems and small wind or water turbines). All these measures combined reduce a building's net energy demand (IEA and UNDP, 2013) (see Table 17).

Table 17. Modern building energy codes: energy sufficiency, energy efficiency and renewable energy

	1 Energy sufficiency	2 Energy efficiency	3 Renewable energy
Energy strategy	Reduce energy needs	Reduce energy consumption	Reduce CO_2 emissions by using renewable energy
Policy instrument	Land use policies Building energy codes	Building energy codes Standard and Labelling policies	Land use policies Building energy codes Standard and Labelling policies for equipment
Policy measure	Bioclimatic design principles Use of passive solutions	Mandatory standards and labels for: Overall building energy performance Building elements and equipment	Mandatory share of supply from renewable energy sources Mandatory standards and labels for equipment

Source: IEA and UNDP, 2013

Green requirements in energy standards

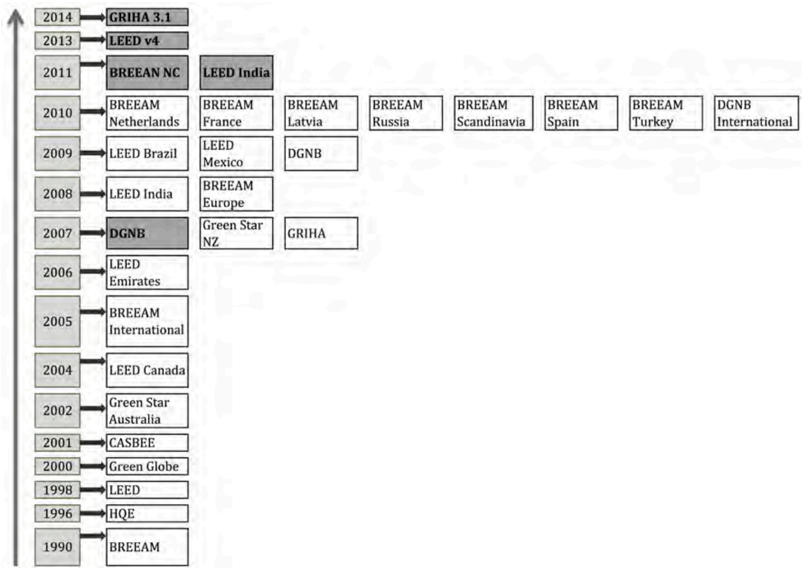
Other aspects of a building's energy consumption, such as embodied energy, should also be considered in future energy codes (IEA and UNDP, 2013) As illustrated in chapter 8, higher energy efficient buildings result in lower operational energy, but the embodied energy or resources (materials) used in the buildings can be higher due to better insulation and technologies. Therefore, the selection of sustainable energy sources and lower embodied and lower emitting materials (including recycled and reused materials) are necessary in (higher energy efficient buildings) for future building energy standards (according to the collective expert opinion).

Moreover, careful site selection and consideration of transport to and from buildings can save a lot of energy (as transport is a huge energy consumer). Some examples can be found, such as Plus energy houses, where electric vehicles can be charged from the energy produced in the building (through renewables), and buildings located close to public transport links or within walking distance of workplaces can save energy for transport. Therefore, future building energy standards should include the potential for efficient buildings to reduce their transport energy use.

10.4 Labels for green buildings: green building certification systems

Green building certification systems evaluate the green performance of a building and confirm its green building status (Nelson, Rakau & Dörrenberg, 2010) by rating and certifying it by an independent third party. Various international systems of building certification have been developed throughout the world, although their coverage varies (e.g. only rate commercial buildings or are limited to new buildings and focus on building operations or on design). However, they do set standards for green buildings and aims for builders, investors and occupants (Nelson, Rakau & Dörrenberg, 2010). To date, these systems are voluntary and have been developed through non-governmental or governmental organisations. The selected green building certification systems for analysis here are LEED (Leadership in Energy and Environmental Design) from the USA (introduced in 1998) and LEED India for India (introduced in 2007), BREEAM (Building Research Establishment's Environmental Assessment Method) from the UK (introduced in 1990), DGNB (Deutsche Gesellschaft für Nachhaltiges Bauen e.V./German Sustainable Building Council) from Germany (introduced in 2007) and GRIHA (Green Rating for Integrated Habitat Assessment) from India (introduced in 2007). The rating systems and weightings for criteria differ between these schemes and they are either limited to their country of origin or used internationally (e.g. LEED in the USA and India).

Figure 31 shows the evolution of these green building certification systems in different countries. Moreover, among different building types, most of the green building certification systems start by assessing new commercial (non-residential) buildings and then expand to cover other building types. This is because commercial buildings offer greater potential for energy and resource saving and the developers can afford to take a long term view, despite the high upfront costs (Yudelson, 2008). Therefore, the initial versions of the green building certification systems (such as BREEAM, DGNB and GRIHA) are for commercial buildings, which include offices, stores, restaurants, institutions and government buildings. The green building certification systems selected (GRIHA, LEED India, LEED, DGNB and BREEAM) are for new construction (commercial and/or residential buildings). See Table 18 for a short overview of the different certification systems, illustrating how the different schemes evolved, their environmental assessment criteria, their assumed baseline standards and certification process according to the country's need to minimise the environmental impact of buildings (taking social and economic aspects into account).



Adapted from: Ebert, Essig & Hauser, 2011

Figure 31. Evolution of green building certificates

Table 18. An overview of different green building certification systems

	GRIHA	LEED India	LEED	DGNB	BREEAM NC
Origin	India	India	US	Germany	UK
Established	Nov 2007	Jan 2007	1998	2007	1990
Responsible	TERI and MNRE	Indian Green Building Council	US Green Building Council	DGNB and BMVBS (Federal Ministry of Transport, Building and Urban Affairs)	BRE Global (under BRE Trust)
Reason for establishment /Background	Rapid urbanisation in India resulted in a tremendous increase in energy demand in urban areas and critical levels of water demand (for drinking, cooling and landscaping/agriculture). Energy efficient solar buildings or green buildings reduce energy demand and GHG emissions, while the treatment of waste water and its reuse for various applications can tackle water shortages. GRIHA focuses on agro-climatic conditions in India, in particular the preponderance of non-air-conditioned buildings (or partially air-conditioned buildings) that have extreme levels of thermal	IGBC realised in 2001 that one of the priorities for the sustainable building industry was to have a system to define and measure 'green buildings'. The objective of LEED India is to adapt the LEED rating system (internationally recognised rating system) for the Indian context. The intention of LEED India is to assist in the creation of high performance, healthy, durable, affordable and environmentally sound buildings.	USGBC realised in 1993 that the sustainable building industry needed a system to define and measure 'green buildings'. The objective is to use resources more efficiently compared to conventional buildings. LEED provides building owners and operators with a framework for identifying and implementing practical and measurable green building design, construction, operations and maintenance solutions.	Today's society faces a wide range of challenges such as climate change, resource scarcity and the financial crisis. Buildings are responsible for approximately 30% of raw material use and 40% of energy consumption and carbon emissions worldwide. Ecological, economic and socio-cultural issues are focal points in the planning, construction and operation of sustainable buildings.	Buildings need to address environmental and sustainability issues. The industry requires a straightforward scoring system that is transparent, flexible, easy to understand and supported by evidence-based science and research.

	GRIHA	LEED India	LEED	DGNB	BREEAM NC
	discomfort. Follows best practice along with national/international codes that are applicable to the green design of buildings.				
Major focus of green building criteria - country specific priority	Suitable for the current Indian context. Energy efficiency - GHG reduction, water and waste management (construction, demolition and occupants' waste) and heat island effect (urban temperature rise). Affordability: Low payback period (3-5 years). Renewable energy for power generation.	To achieve green buildings of international standard (LEED US), adapting to the country's specific circumstances (climate and building practice).	To achieve environmental, economic and social benefits.	To incorporate ecological, economic and socio-cultural issues (management).	The performance targets go beyond the minimum standard needed to satisfy Building Regulations and other legislation.
Countries that used the certification system	India	India	Argentina, Brasil, Canada, Chile, Colombia, South Korea, India, Italy, Jordan, Mexico, Norway, Poland, US, Romania. Russia, Spain, Sweden, Turkey and UAE	Germany, Austria, Bulgaria, Switzerland and Thailand (co-operation agreement) China, Brazil and Russia (on the process)	UK, Netherlands, Norway, Spain, Sweden and (other countries)
Different building types for certification	New building stock-commercial, institutional, and residential-of varied functions	LEED India for New Construction LEED India for Core & Shell	LEED for New Construction LEED for Existing Buildings: Operations and Maintenance	Existing Occupancy Profiles: New Office and Administrative Buildings New Retail Buildings	BREEAM Courts BREEAM Education BREEAM Industrial BREEAM Healthcare BREEAM Offices

	GRIHA	LEED India	LEED	DGNB	BREEAM NC
			LEED for Commercial Interiors LEED for Core & Shell LEED for Schools LEED for Retail LEED for Healthcare LEED for Homes LEED for Neighborhood Development	New Industrial Buildings New Educational Facilities New Residential Buildings New Hotels Modernization of Office and Administrative Buildings Existing Office and Administrative Buildings City Districts Future Occupancy Profiles: Branches / Tenant Interiors New Hospitals New Laboratory Buildings Design Objects Public Assembly Buildings New Industrial Complexes New Infrastructure Facilities New Sports Facilities New Parking Structures New Airport Terminals	BREEAM Retail BREEAM Prisons BREEAM Multi-residential BREEAM Data Centres International: BREEAM Europe Commercial BREEAM international Bespoke BREEAM Communities BREEAM In-Use
Assessment			US GBC	Auditor	Trained Assessors
Energy efficiency	In order to optimise energy use, GRIHA requires buildings to follow the requirements of ECBC. NBC 2005 is also followed for climate responsive building design, thermal comfort and lighting level requirements.	LEED India certification meets or exceeds the level of the ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers) standard 90.1-2007 for energy efficiency and also correlates with the national ECBC for building energy efficiency.	LEED certification meets or exceeds the level of the ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers) standard 90.1-2007 for energy efficiency. ASHRAE is the USA's energy code, which is updated every three years.	DGNB takes into account total primary energy demand and the proportion of non-renewable primary energy within the building (SWEGON AIR ACADEMY 2012) and it should fulfil the requirement up to or above the level of EnEV (Energiesparverordnung/	BREEAM bases parts of the results on carbon dioxide emissions, which means that energy is recalculated to carbon dioxide equivalents to make it possible to give points to some of the issues in the energy category (SWEGON AIR ACADEMY 2012).

	GRIHA	LEED India	LEED	DGNB	BREEAM NC
				German Energy Saving Ordinance) (latest e.g. EnEV 2014). EnEV is the minimum energy performance standard (MEPS) for Germany which has a stringent energy consumption baseline.	
Material efficiency	GRIHA encourages the reuse of recyclable and biodegradable waste to reduce the burden on landfill as per the Solid Waste management and Handling Rules, 2000 of the MoEF and the use of alternative building materials (e.g. fly ash in building structures) and low-energy materials and products.	LEED India puts emphases on building material reuse and promotes recycling; manages construction waste and uses regional environmentally friendly materials with Green Product Certifications.	LEED puts emphases on building material reuse and promotes recycling; manages construction waste and uses regional environmentally friendly materials with Green Product Certifications.	DGNB focuses on the avoidance of construction waste by designs that facilitate deconstruction, recycling and dismantling; promotes the use of environmentally friendly materials that have Green Product Certification and focuses on design alteration to save resources.	BREEAM considers the reuse of existing building façades, building structure, recycled aggregates, the minimisation of construction waste and the use of low embodied and environmentally friendly materials determined by their Green Guide Rating.
Type used in the report	GRIHA Version 3.1 (2014) for New building stock-commercial, institutional, and residential-of varied functions	LEED 2011 for India – New Construction and Major Renovation	LEED US (v2013) for New Construction and Major renovations	DGNB New Office and Administrative Buildings (2009)	BREEAM NC (2011)
Features of the one considered in the report	Criteria categorised under – Sustainable Site Planning, Health and Wellbeing, Building Planning and Construction, Building Operation and Maintenance, Innovation Points. Aims to achieve efficient	Criteria categorised under - Sustainable Sites, Water Efficiency, Energy and Atmosphere, Materials and Resources, Indoor Environmental Quality, Innovation in Design and Regional Priority.	Criteria categorised under - Sustainable Sites, Water Efficiency, Energy and Atmosphere, Materials and Resources, Indoor Environmental Quality, Innovation in Design and Regional Priority.	Criteria categorised under- Ecological Quality, Economic Quality, Socio-cultural and Functional Quality, Technical Quality, Quality of Process and Quality of Location.	Criteria categorised under – Management, Health and Wellbeing, Energy, Transport, Water, Materials, Waste, Land Use and Ecology, Pollution and Innovation. An environmental assess-

	GRIHA	LEED India	LEED	DGNB	BREEAM NC
	resource utilisation and to enhance resource efficiency and quality of life in buildings. In the case of India, local standards/codes for building services (energy, water, waste and sound) do exist but they are not normally followed. GRIHA integrates all relevant Indian codes and standards for buildings and acts as a tool to facilitate their implementation.	Enhancement in energy and water efficiency baselines, promotes naturally ventilated buildings and encourages passive technologies, adopts the latest versions of standards and codes in tune with the local regulations and standards of India.	To design and distinguish high performance buildings that have less impact on the environment, are healthier for those who work and/or live in the building and are more profitable than their conventional counterparts (environmental, economic, and occupant-oriented performance and health advantages).	To promote resource efficient, environmentally friendly and affordable construction and use of buildings, with special attention paid to the health and comfort of building users along with socio-cultural demands from the surrounding area. Optimally adapted to the German and European building environments. Includes building codes and norms, as well as long term market experience with energy efficient buildings etc.	ment method and certification scheme that can be used at the design, construction and refurbishment stages of a building's life cycle.
Ratings	1 Star (50-60 % points) 2 Star (61-70% points) 3 Star (71-80% points) 4 Star (81-90% points) 5 Star (91-100% points)	Certified (40-49 points) Silver (50-59 points) Gold (60-79 points) Platinum (80 and above)	Certified (40-49 points) Silver (50-59 points) Gold (60-79 points) Platinum (80 and above)	Bronze (50-64.9%) Silver (65-79.9%) Gold (above 80%)	Pass (≥30%) Good (≥45%) Very Good (≥55%) Excellent (≥70%) Outstanding (≥85%)
Scheme	Voluntary	Voluntary	Voluntary, consensus-based, and market driven, performance based	Voluntary	Voluntary
Local or International standards/codes taken into account	National Building Code 2005, India ECBC (Energy Conservation Building Code) 2007, the appliance labeling programme of the Bureau	ANSI/ASHRAE/IESNA standard 90.1-2007 ASHRAE Standard 62.1-2007 Chartered Institution of Building Services Engi-	ANSI/ASHRAE/IESNA standard 90.1-2007 ASHRAE Standard 62.1-2007 Chartered Institution of Building Services Engi-	EnEV 2007 DIN EN ISO 14040 DIN 4108 DIN EN 12207 FSC HOAI	EPC EU Code of Conduct on Data Centres CIBSE

	GRIHA	LEED India	LEED	DGNB	BREEAM NC
	of Energy Efficiency Other IS codes	neers (CIBSE) Applications Manual 10: 2005 ASHRAE Standard 55-2004 ANSI/SMACNA 008-2008 National Building Code 2005, India ECBC 2007, the appliance labeling programme of the Bureau of Energy Efficiency	neers (CIBSE) Applications Manual 10: 2005 ASHRAE Standard 55-2004 ANSI/SMACNA 008-2008	EPC	
Previous/latest version/revision period	1st and latest: GRIHA 2010 Guidelines/criteria may be revised every 3 years to take into account the latest scientific developments during the period.	1st: LEED India Version 1.0, 2007 Previous version: LEED 2011 for India-NC Revision period not specified.	1st : LEED v1998 2nd : LEED v2000 3rd : LEED v2002 4th : LEED v2005 5th: LEED v2009 6th: LEED v2013 Revision period generally every 3 - 4 years	1st: DGNB New Office and Administrative Buildings, version 2008 Latest: DGNB New Office and Administrative Buildings, version 2010	Latest: BREEAM 2014 New Construction Scheme - for commercial, public and multi-residential accommodation
Number of certified buildings in total	108* (registered so far) (until June 2011)	153 certified buildings 1116 registered buildings (until June 2011-including all building types)	7052 certified buildings (within US) (until June 2011-including all building types)	160 certified buildings (until June 2011-including all building types)	115,000 certified buildings 700,000 homes and buildings registered (until June 2011-including all building types)
Certified buildings (examples)	Common Wealth Games Village, New Delhi Suzlon One Earth, Pune (5 star) CESE (Centre for Environmental Sciences and Engineering) Building, Uttar Pradesh (5 star)	Yamuna- Corporate office Kirloskar Brothers Limited, Pune (LEED India NC - Platinum) TCS Technopark, Chennai (LEED India NC - Gold) Odyssey Building – GE India Technology Pvt. Ltd., Bangalore (LEED India NC – Gold)	Alberici Office Headquarters, St. Louis, MO, US (LEED NC 2.1 Platinum) CSU Academic Training Center, Fort Collins, Co, US (LEED NC 2.2 Gold) DCCCD Richland Science Building, Dallas, TX, US (LEED NC 2.2 Platinum)	E.ON Bürogebäude und Kompetenzcenter, Regensburg, Germany (New Office and Administrative Buildings, version 2008, DGNB Gold) Die neun Deutsche Bank-Türme, Frankfurt am Main, Germany (Building retrofit, version 2008, DGNB Gold)	Ceredigion County council Offices, Aberystwyth, UK (Excellent rating) Church View House, DWP Offices, Seaham, UK (excellent rating) 8-12 Sur Parc, Paris, France (Good rating)

	GRIHA	LEED India	LEED	DGNB	BREEAM NC
Certification process	Registration Submission of documentation Preliminary evaluation by AdaRSH Technical team Evaluation by panel of experts Preliminary rating with comments sent to project team Final submission of documents Final evaluation by panel of experts Approval of rating by advisory committee Award of rating	Registration CIR submission Document submitted Receipt of preliminary review Project team responses Final review Receipt of final assessment If certified rating awarded, submitting image and project case study to USGBC	Registration CIR submission Document submitted Receipt of preliminary review Project team responses Final review Receipt of final assessment If certified rating awarded, submitting image and project case study to USGBC	Registration of the property at DGNB Defining of goals for characteristics of the building according to gold, silver, or bronze Using of the pre-certification for marketing DGNB checks the planning and construction documentation	Registration Assessment reference number issue Information collection Assessment by independent BREEAM assessor Assessment report submitted Quality Assurance process Certification

10.4.1 Supporting criteria for green buildings

As well as the environmental aspects listed and discussed in Table 5 green (and energy efficient) buildings should consider social, economic and management aspects and incorporate innovative design approaches. These aspects are included in most of the green building certification systems and are briefly discussed below.

10.4.1.1 Social aspects

Buildings need to enhance their occupants' comfort and health and improve their overall quality of life. This provides safety, security, barrier-free accessibility and user flexibility. The social aspects in green buildings (and also in energy efficient buildings) add a sense of community, which is important for sustainability. Moreover, workers' safety during the construction and demolition phases is also necessary for a building to be considered as sustainable for all its stakeholders (not only for users). Therefore, the sub-criteria, which must be considered under 'Social aspects', are:

Health & Safety and functional aspects

The safety of workers during the construction phase means meeting safety measures (e.g. using belts, helmets and safety clothing) and also avoiding danger and accidents (by the use of proper scaffolding etc.). The sanitary facilities for the workers also need to meet minimum standards. For occupants, buildings need to provide security (from possible crimes) and structural safety from natural catastrophes (e.g. earthquakes, tornadoes etc.). Other social aspects, such as prevention measures (e.g. fire protection) and disabled access should also be considered.

10.4.1.2 Economic aspects

Economic aspects refer to the minimum cost of a building throughout its life cycle. A building's life cycle cost is made up of all the costs of acquiring, owning and disposing of a building or building system. These costs include the initial design and construction costs, operation, maintenance and repair costs, replacement costs, disposal costs or salvage value (WBDG, 2012). The sub-criteria for economic aspects are as follows:

Building life cycle cost saving

Building life cycle cost saving is the minimisation of a building's cost for its production, maintenance, deconstruction and disposal. It takes into the account both energy and environmental costs. The building life cycle cost can be reduced by selecting efficient materials (reused/recycled), lowering maintenance costs and using efficient technologies. These provide benefits for both the occupants and the environment.

10.4.1.3 Management

Management of a building allows for the overall performance of the building to be checked or validated (i.e. to assess whether it is designed and maintained incorporating green aspects) and ensures that its impact on environmental and human health is minimised throughout the building's lifespan. This also informs the users about resources consumed in the building through constant (regular) energy, water and air quality monitoring, prompts changes in users' behaviour if necessary (to optimise energy and resource use) and helps to resolve possible operational and maintenance issues. Highly qualified personnel are responsible for commissioning, auditing and validating building performance. The sub criteria of 'management' are:

Planning quality

An integrated design team of architects, engineers and other experts involved in building design can develop an integral concept of sustainability (reducing energy use and environmental impacts, maintaining comfort and improving economic performance). The team must be involved in the project early in the design phase to achieve the necessary quality in the building design. Asking for evidence of a commitment to sustainability and experience in the field in the tender process may help to ensure the overall building quality.

Qualified personnel

The involvement of qualified personnel, such as accredited professionals, can help achieve efficient (energy and resource) buildings.

Commissioning/Operation and maintenance

Appointing a commissioner to a building is necessary to assure the quality of the construction and to verify that the building is constructed as per the design concept. To achieve this, the commissioning authority has to be engaged early in the project design phase. In addition, regular checks and maintenance must be carried out to ensure the efficient functioning of the building's system through the regular monitoring of the building's energy and water consumption, and indoor air quality.

Energy monitoring

Energy monitoring must be carried out to ensure that all the energy and environmental systems in the buildings are functioning as per the design. The performance of the systems should be recorded and there should be the opportunity to fix any errors that occur.

Water monitoring

Water monitoring records the water consumption in a building through water metering. This helps users to take necessary steps to reduce their water usage if the records show an imbalance (i.e. overuse due to wastage). Sometimes leaky pipes or maintenance issues may cause significant water loss and regular monitoring helps to identify such problems (Environment Agency, 2007).

Air quality management

Air quality management ensures that the outdoor air quality (during the construction and demolition phases) and the indoor air quality are good for the occupants. During the building's construction or demolition, dust from materials must be controlled (e.g. by water spraying etc.) so that it does not affect the workers and pedestrians. Before occupants take up residency, a building flush out should be performed and the air contaminant levels should be tested to ensure that certain chemicals used in construction are not present in the air. Likewise, mechanical ventilation systems should be monitored to check that their performance suits the occupant's comfort requirements.

10.4.2 Comparison of green building certification systems

The study and comparison of five selected certification systems (GRIHA, LEED India, LEED US, DGNB and BREEAM) gave an overview of those aspects relating to current green building construction that are presently being considered by developed and developing countries. Table 19 presents a comparison of the latest versions (valid until March 2014) of the green building certification systems for GRIHA (GRIHA version 3.1 2014 for new building stock – commercial, institutional and residential), LEED India (LEED India 2011 for India – New Construction and Major Renovations), LEED US (LEED v4 2013 for New Construction and Major Renovations), DGNB (DGNB 2009 for New Construction of Office and Administration Buildings) and BREEAM (BREEAM NC (New Construction) 2011). This comparison aims to analyse the variation in the features (e.g. baseline stringency) and weightings of criteria; the change in the characteristics of the criteria when the certification goes international; the consideration of life cycle analysis in the certification; and whether the energy standard (and its weightings) affects the overall evaluation of the green buildings.

In addition, Table 24 in Annex 2 shows the features of the other versions of the certification systems, such as previous ones for GRIHA (GRIHA 2010), LEED US (LEED 2002 and LEED 2009) and BREEAM (BREEAM Office 2008), the latest but draft version for BREEAM (BREEAM 2014), and the simplified and affordable version for GRIHA (GRIHA SVA (Simple Versatile Affordable) 2011). These are compared with the latest versions to see how the certification systems develop and change (or strengthen) their criteria over time.

Methodology

The 1:1 comparison of certification systems is complex, as each certification system possesses its own format and method of assigning criteria and weighting (within the boundary of basic green building features). Therefore, to simplify the comparison of certification systems with varying scopes and methodology, the criteria and sub-criteria in the certification systems are again re-categorised as per the criteria listed in section 5.3 (Table 5) and section 10.4.1 in the form of matrix, and the assigned values for the sub-criteria are converted into percentages to achieve effective results. As described briefly in section 4.1, this method of comparison mainly arranged the text sources as between-source triangulation and between-source development. The criteria and sub-criteria are analysed using qualitative comparative analysis and text mining. However, certain limitations in the comparison arise due to unassigned values for some of the mandatory sub-criteria, which cannot be weighted (e.g. in LEED). For the purposes of comparing 'like for like' in terms of the certification systems, the values of certain sub-criteria within DGNB (e.g. quality of the location) have been scored, although DGNB does not actually include these scores when calculating a building's rating.

Table 19. Comparison of different green building certification systems in their criteria selection

	GRIHA v3.1 (2014)	LEED India NC (2011)	LEED US (2013)	DGNB Office (2009)	BREEAM NC (2011)
Basic information					
Origin	India	India	US	Germany	UK
Established	Nov-07	Jan-07	1998	2007	1990
Total Points	104	110	131	98.5 (includes quality of location)	144
Criteria					
			Energy		
Total points	36	30	29	5	26
Percentage	34.6	27.3	22.1	5.1	18.1
Energy Optimisation (active)	14 Optimise energy performance of building within specified comfort limits (partly mandatory) (16 points)	(EA) Minimum Energy Performance (Mandatory) (EA) Optimise Energy Performance (19 points) (IEQ) Controllability of systems – Lighting (1 point)	(EA) Minimum Energy Performance (Mandatory) (EA) Optimise Energy Performance (12 points) (EA) Demand Response (EQ) Interior Lighting (1 point)	10 Non-renewable primary energy demands (3 points)	Ene 1 Reduction of emissions (15 points) Ene 3 External lighting (1 point) Ene 6 Energy efficient transportation (2 points) Ene 8 Energy efficient equipment (2 points) Ene 9 Drying space (1 point)
Points/Percent	16/15.4%	20/18.2%	15/11.5%	3/3%	21/14.6%
Energy Optimisation (passive)	13 Optimise building design to reduce the conventional energy demand (Manda-	(IEQ) Daylight and views – Daylight (1 point)	(EA) Optimise Energy Performance (6 points) (EA) Daylight (3 points)		Ene 4 Low and zero carbon technologies (Mandatory) (1 point)

	tory) (8 points)				
Points/Percent	8/7.7%	1/0.9%	9/6.9%		1/0.7%
Renewable Energy	6 Enhance outdoor lighting system efficiency and use renewable energy system for meeting outdoor lighting requirements (1 point) 18 Renewable energy utilisation (Partly mandatory) (8 points) 19 Renewable energy-based on hot water system (3 points)	(EA) On-site Renewable Energy (7 points) (EA) Green Power (2 points)	(EA) Renewable Energy Production (3 points) (EA) Green Power and Carbon Offsets (2 points)	11 Total primary energy demands and proportion of renewable primary energy (2 points)	Ene 4 Low and zero carbon technologies (Mandatory) (4 points)
Points/Percent	12/11.5%	9/8.2%	5/3.8%	2/2%	4/2.8%
			Atmosphere		
Total points	1	2	3	6	6
Percentage	1.0	1.8	2.3	6.1	4.2
Environmental Impact	27 Minimise ozone depleting substances (Mandatory) (1 point)	(EA) Fundamental Refrigerant Management (Mandatory) (EA) Enhanced Refrigerant Management (2 points)	(EA) Fundamental Refrigerant Management (Mandatory) (EA) Enhanced Refrigerant Management (1 point) (MR) Building Product	1 Global Warming Potential (GWP) (3 points) 2 Ozone depletion potential (0.5 point) 3 Photochemical ozone creation potential (0.5 point) 4 Acidification potential	Pol 1 Impact of refrigerants (3 points) Pol 2 Nox emissions (3 points)

			Disclosure and Optimisation - Material Ingredients (2 points)	(1 point) 5 Eutrophication potential (1 point)	
Points/Percent	1/1%	2/1.8%	3/2.3%	6/6.1%	6/4.2%
Water					
Total points	15	10	10	2	9.0
Percentage	14.4	9.1	7.6	2.0	6.3
Water Reuse/Recycling	20 Wastewater treatment (2 points) 21 Water recycling and reuse (including rainwater) (5 points)	(WE) Water Efficient Landscaping (4 points) (WE) Innovative Wastewater Technologies and Reuse (2 points)		14 Potable Water Consumption and Sewage Generation (2 points)	Wat 1 Water Consumption (greywater and/or rainwater reuse) (2.5 points)
Points	7/6.7%	6/5.5%		2/2%	2.5/1.7%
Water conservation	10 Reduce landscape water requirement (3 points) 11 Reduce water use by the building (2 points) 12 Efficient water use during construction (1 point)	(WE) Water Use Reduction (Mandatory) (WE) Water Use Reduction (4 points)	(WE) Outdoor Water Use Reduction (Mandatory) (WE) Indoor Water Use Reduction (Mandatory) (WE) Outdoor Water Use Reduction (2 points) (WE) Indoor Water Use Reduction (6 points) (WE) Cooling Tower Water Use (2 points)		Wat 1 Water Consumption (efficiency in water consuming components) (2.5 points) Wat 3 Water leak detection and prevention (2 points) Wat 4 Water efficient equipment (1 point)
Points/Percent	6/5.8%	4/3.6%	10/7.6%		5.5/3.8%
Water Quality	28 Ensure water				Hea 4 Water quality

	quality (Mandatory)				(Mandatory) (1 point)
Points/Percent	2/1.9%				1/0.7%
Site/ Location/Transportation					
Total points	16	30	48	20	36.0
Percentage	15.4	27.3	36.6	20.3	25.0
Site Selection	1 Site Selection (partly mandatory) (1 point)	(SS) Site Selection (1 point) (RP) Regional Priority (4 points) (SS) Brownfield Redevelopment (1 point)	(LT) Neighbourhood Development Location (16 points) (LT) Sensitive Land Protection (2 points) (LT) High Priority Site (3 points) (SS) Site Assessment (1 point) (RP) Regional Priority (4 points)	15 Surface Area Usage (2 points) 56 Risk at the Micro location (2 points) 57 Circumstances at the micro location (2 points) 58 Image and Condition of the Location and Neighbourhood (2 points) 59 Connection to Transportation (3 points) 60 Vicinity to usage - specific facilities (2 points) 61 Adjoining Media, Infrastructure Development (2 points)	Tra 2 Proximity to amenities (1 point) LE 1 Site selection (2 points)
Points/Percent	1/1%	6/5.5%	26/19.8%	15/15.2%	3/2.1%
Community connectivity and eco-friendly transportation	7 Plan utilises efficiently and optimises onsite circulation efficiency (3 points)	(SS) Development Density and Community Connectivity (5 points) (SS) Alternative Transportation: Public Transporta-	(LT) Surrounding Density and Diverse Uses (5 points) (LT) Access to Quality Transit (6 points) (LT) Bicycle Facilities (1	29 Accessibility (2 points) 30 Bicycle Comfort (1 point)	Tra 1 Public transport accessibility (8 points) Tra 3 Cyclist facilities (2 points) Tra 4 Maximum car

		tion Access (6 points) (SS) Alternative Transportation (6 points)	point) (LT) Reduced Parking Footprint (1 point) (LT) Green Vehicles (1 point)		parking capacity (2 points) Tra 5 Travel plan (1 point)
Points/Percent	3/2.9%	17/15.5%	14/10.7%	3/3%	13/9.0%
Soil Protection / Conservation	2 Preserve and protect the land-scape during construc-tion/compensatory depository forestation (partly mandatory) (4 points) 3 Soil conserva-tion (through to post construction) (2 points) 4 Design to in-clude existing site features (4 points)	(SS) Construction Activity Pollution Prevention (Manda-tory) (SS) Site Develop-ment (2 points)	(SS) Construction Activi-ty Pollution Prevention (Mandatory) (SS) Site Development-Protect or Restore Habi-tat (2 points)	48 Construction Site/ Construction Process (0.5 point)	Man 3 Construction site impacts (5 points) LE 2 Ecological value of site and protection of ecolog-ical features (1 point) LE 3 Mitigating ecological impact (Mandatory) (2 points) LE 4 Enhancing site ecology (4 points) LE 5 Long term impact on biodiver-sity (2 points)
Points/Percent	10/9.6%	2/1.8%	2/1.5%	0.5/0.5%	14/9.7%
Heat Island Effect	5 Reduce hard paving on site and/or provide shaded hard paved surfaces	(SS) Heat island effect (2 points)	(SS) Heat Island Reduc-tion (2 points)	9 Microclimate (0.5 point) 24 Roof Design (1 point)	

	(Partly mandatory) (2 points)				
Points/Percent	2/1.9%	2/1.8%	2/1.5%	1.5/1.5%	
Stormwater Control		(SS) Stormwater Design (2 points)	(SS) Rainwater Management (3 points)		Pol 3 Surface water run off (5 points)
Points		2/1.8%	3/2.3%		5/3.5%
Light Pollution		(SS) Light pollution Reduction (1 point)	(SS) Light pollution Reduction (1 point)		Pol 4 Reduction of night time light pollution (1 point)
Points/Percent		1/0.9%	1/0.8%		1/0.7%
Indoor Environment Quality					
Total points	6	10	11	16	16.0
Percentage	5.8	9.1	8.4	16.2	11.1
Air quality		(IEQ) Minimum Indoor Air Quality (IAQ) Performance (Mandatory) (IEQ) Increased Ventilation (1 point)	(EQ) Minimum Indoor Air Quality Performance (Mandatory) (EQ) Enhanced Indoor Air Quality Strategies (2 points)		Hea 2 Indoor air quality (natural ventilation and air pollution control) (2 points)
Points/Percent		1/0.9%	2/1.5%		2/1.4%
Visual comfort		(IEQ) Daylight and views: View (1 point)	(EQ) Interior Lighting (1 point) (EQ) Quality views (2 points)	22 Visual Comfort (3 points)	Hea 1 Visual comfort (Mandatory) (5 points)
Points/Percent		1/0.9%	3/2.3%	3/3%	5/3.5%
Acoustic comfort	29 Acceptable outdoor and indoor noise level (2 points)		(EQ) Acoustic Performance (2 points)	21 Acoustic Comfort (1 point) 34 Noise Protection (2 points)	Hea 5 Acoustic Performance (4 points) Pol 5 Noise attenuation (1 point)

Points/Percent	2/1.9%		2/1.5%	3/3%	5/3.5%
Thermal Comfort		(IEQ) Controllability of systems-Thermal Comfort (1 point) (IEQ) Thermal Comfort (2 points)	(EQ) Thermal Comfort (1 point)	18 Thermal comfort: Winter (2 points) 19 Thermal comfort: Summer (3 points) 35 Energetic and Moisture-Proofing Quality of the Building's Shell (2 points)	Hea 3 Thermal Comfort (2 points)
Points/Percent		3/2.7%	1/0.8%	7/7.1%	2/1.4%
Smoke Control	30 Tobacco and smoke control (Mandatory) (1 point)	(IEQ) Environmental Tobacco Smoke (ETS) Control (Mandatory)	(EQ) Environmental Tobacco Smoke Control (Mandatory)		
Points/Percent	1/1%				
Hygiene/ Chemical Control	26 Use of low Volatile Organic Compounds (VOC) paints/ adhesives/ sealants (3 points)	(IEQ) Low Emitting Materials (4 points) (IEQ) Indoor Chemical and Pollutant Source Control (1 point)	(EQ) Low Emitting Materials (3 points)	20 Indoor Hygiene (3 points)	Hea 2 Indoor air quality (chemical control) (2 points)
Points/Percent	3/2.9%	5/4.5%	3/2.3%	3/3%	2/1.4%
Materials					
Total points	19.0	14.0	11.0	9.5	20.0
Percentage	18.3	12.7	8.4	9.6	13.9
Material Reuse/ Recycle	25 Resource recovery from waste (2 points)	(MR) Storage and Collection of Recyclables (Mandatory) (MR) Building Reuse (4 points) (MR) Material Reuse (2 points)	(MR) Storage and Collection of Recyclables (Mandatory) (MR) Building Life Cycle Impact Reduction (2 points)	42 Ease of deconstruction, recycling and dismantling (2 points)	Mat 3 Responsible Sourcing of Materials (reused and recycled) (Mandatory) (1.5 points) Wst 2 Recycled aggregates (1 point)

		(MR) Recycled Content (2 points)			
Points/Percent	2/1.9%	8/7.3%	2/1.5%	2/2%	2.5/1.7%
Waste Management	22 Reduction in waste during construction (1 point) 23 Efficient Waste Segregation (1 point) 24 Storage and disposal of waste (1 point)	(MR) Construction Waste Management (2 points)	(MR) Construction and Demolition Waste Management Planning (Mandatory) (MR) Construction and Demolition Waste Management (2 points)	48 Construction Site/ Construction Process (1.5 points)	Mat 5 Designing for Robustness (1 point) Wst 1 Construction Waste Management (Mandatory) (4 points) Wst 3 Operational Storage (Mandatory) (1 point) Wst 4 Speculative floor and ceiling finishes (1 point)
Points/Percent	3/2.9%	2/1.8%	2/1.5%	1.5/1.5%	7/4.9%
Resource Efficiency/Low Embodied Energy	15 Utilisation of fly ash in the building structure (6 points) 16 Reduce volume, weight and time of construction by adopting an efficient technology (e.g. pre-cast systems, ready-mix concrete etc.) (4 points) 17 Use low energy	(MR) Regional Materials (2 points) (MR) Rapidly Renewable Materials (2 points) (MR) Certified Wood (50% of wood based materials) (1 point)	(MR) Building Life Cycle Impact Reduction (3 points) (MR) Building Product Disclosure and Optimisation- Environmental Product Declaration (2 points) (MR) Building Product Disclosure and Optimisation - Sourcing of Raw	6 Risk for the local environment (3 points) 8 Other Impacts of the Global Environment (1 point) 17 Value Stability (2 points)	Mat 1 Life Cycle impacts (6 points) Mat 2 Hard Landscaping and Boundary Protection (1 point) Mat 3 Responsible Sourcing of Materials (sustainable source) (Mandatory) (1.5 points) Mat 4 Insulation (2

	material in the interiors (4 points)		Materials (2 points)		points)
Points/Percent	14/13.5%	4/3.6%	7/5.3%	6/6.1%	10.5/7.3%
Innovation					
Total points	4.0	5.0	5.0	4.0	10.0
Percentage	3.8	4.5	3.8	4.1	6.9
Innovation in design	34 Innovation Points (4 points)	Innovation in Design (5 points)	(IN) Innovation (5 points)	31 Assurance of the Quality of Design and Urban Development in Competition (3 points) 32 Art with Architecture (1 point)	Inn 1 Innovation (10 points)
Points/Percent	4/3.8%	5/4.5%	5/3.8%	4/4.1%	10/6.9%
Social aspects					
Total points	3	0	1	10	2
Percentage	2.9	0.0	0.8	10.2	1.4
Safety/Health and Functional aspect	8 Provide at least the minimum level of sanitation/safety facilities for construction workers (Mandatory) (2 points) 31 Provide at least the minimum level of accessibility for persons with disabilities (1 point)		(SS) Open Space (1 point)	23 User Influences (2 points) 25 Safety and Failure Risks (1 point) 26 Barrier-free Accessibility (2 points) 27 Area Efficiency (1 point) 28 Conversion Feasibility (2 points) 33 Fire Protection (2 points)	Hea 6 Safety and Security (2 points)
Points/Percent	3/2.9%		1/0.8%	10/10.2%	2/1.4%

Economical aspect					
Total points	0	0	0	5.0	3.0
Percentage	0	0	0	5.1	2.1
Life Cycle Cost Saving		(EA) Optimise Energy Performance (+)		16 Building related Life Cycle Costs (LCC) (3 points) 40 Ease of Cleaning and Maintenance of the Structure (2 points)	Man 5 Life cycle cost and service life planning (3 points)
Points/Percent				5/5.1%	3/2.1%
Management					
Total points	4.0	9.0	13.0	21.0	16.0
Percentage	3.8	8.2	9.9	21.3	11.1
Planning quality			Integrative Process (1 point)	43 Quality of the Project's Preparation (3 points) 44 Integral Planning (3 points) 45 Optimisation and Complexity of the Approach to Planning (3 points) 46 Evidence of Sustainability during Bid Invitation and Awarding (2 points) 47 Establishing Preconditions for an Optimised Use and Operation (2 points)	Man 1 Sustainable procurement (8 points) Man 2 Responsible construction practices (Mandatory) (2 points) Man 4 Stakeholder participation (Mandatory) (4 points)
Points/Percent			1/0.8%	13/13.2%	14/9.7%
Qualified personnel		LEED Accredited Professional (1 point)	(IN) LEED Accredited Professional (1 point)	49 Quality of the Executing Contractors/ Pre-Qualification (2 points)	
Points/Percent		1/0.9%	1/0.8%	2/2%	

Commission-ing/ Operation and mainte-nance	33 Operation and maintenance (Mandatory) (2 points)	(EA) Fundamental Building systems commissioning (Mandatory) (EA) Enhanced Commissioning (2 points)	(EA) Fundamental commissioning and verification (Mandato-ry) (EA) Enhanced com-missioning (6 points)	50 Quality assurance of Construction Execution (3 points) 51 Systematic Commission-ing (3 points)	
Points/Percent	2/1.9%	2/1.8%	6/4.6%	6/6.1%	
Energy moni-toring	32 Audit and Validation (Man-datory)	(EA) Measurement and Verification (3 points)	(EA) Building-Level Energy metering (Mandatory) (EA) Advanced Energy Metering (1 points)		Ene 2 Energy moni-toring (Mandatory) (1 point)
Points/Percent		3/2.7%	1/0.8%		1/0.7%
Water monitor-ing	32 Audit and Validation (Man-datory)		(WE) Building-Level Water metering (Man-datory) (WE) Water metering (1 point)		Wat 2 Water moni-toring (Mandatory) (1 point)
Points/Percent			1/0.8%		1/0.7%
Air Quality Management	9 Reduce air pollution during construction (Mandatory) (2 points)	(IEQ) Outdoor Air Delivery Monitoring (1 point) (IEQ) Construction IAQ Management Plan (2 points)	(EQ) Construction Indoor Air Quality Management Plan (1 point) (EQ) Indoor Air Quality Assessment (2 points)		
Points/Percent	2/1.9%	3/2.7%	3/2.3%		

10.4.3 Analysis of green building certification systems

Variation in weightings

The comparison of the certification systems in Figure 32 (based on the matrix in Table 19) shows that: GRIHA assigns a higher weighting for energy efficiency, DGNB for Management, and LEED US and BREEAM give priority to site and transportation, while LEED India gives equal weighting to both energy efficiency and site and transportation. DGNB puts less emphasis on energy efficiency, but comparably more on atmospheric/environmental protection, social and economic aspects, and management than other certification systems. Second to energy efficiency, GRIHA emphasises water and material efficiency. This variation in the prioritisation of the weightings for the criteria reflects how the criteria and sub-criteria are given different priorities according to their importance to the given country. However, the difference in weighting for green buildings depends upon: the country's considered standard/baseline (for energy efficiency, water efficiency, material efficiency and other country codes), technological acceptance and affordability for the population and their behaviour and local conditions (climate and infrastructure) (according to the collective expert opinion). For example: according to a survey carried out by National Geographic and Globescan (2012), consumers in developing countries are more concerned about tackling environmental challenges such as water shortages, air and water pollution and species and habitat loss (although this focus has, in general, decreased since 2010); while developed countries are more concerned about the economy and the cost of energy and fuel (this focus has increased since 2010) and meeting GHG mitigation targets.

Regarding GRIHA, the weightings in GRIHA (2010) and GRIHA version 3.1 (2014) are quite similar, although GRIHA SVA (2011) prioritises energy efficiency more but does not give any weighting to Indoor Environmental Quality (see Figure 33). Likewise, for LEED US, the emphasis on site and transportation has increased in the newer version and in BREEAM, the consideration of economic aspects has increased in the newer version (although its weighing is not significant).

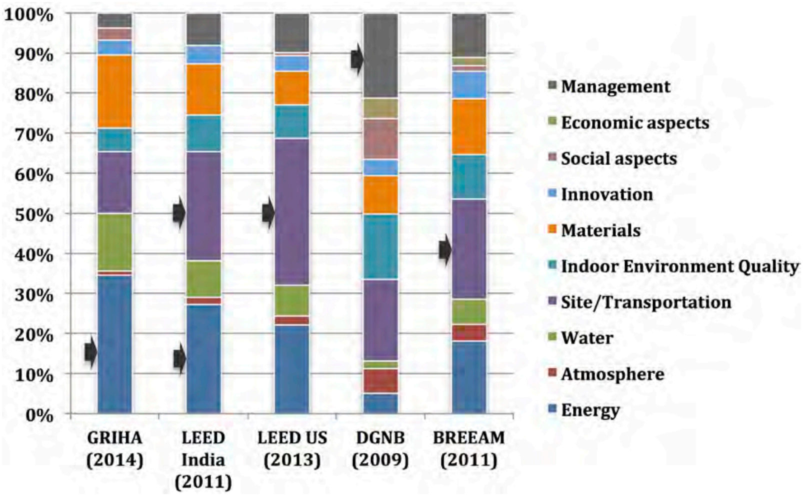


Figure 32. Weightings of the criteria in various certification systems

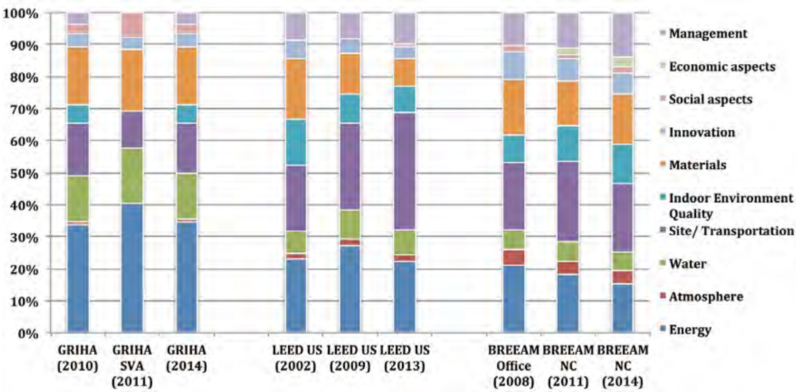


Figure 33. Weightings of the criteria in different versions of various certification systems

Comparison of criteria in different certification systems

Energy efficiency

As already mentioned, this is the most prioritised criterion, except by DGNB. Within this criterion, the sub-criterion 'energy optimisation' features strongly through the minimisation of conventional energy use and then the maximisation of renewable energy to reduce environmental impact. Climate responsive design also maximises the energy efficiency potential of green buildings. In green buildings the minimum energy performance level is set at the same level or higher than the building energy code of the respective country (Figure 34). Looking at different versions of GRIHA, GRIHA SVA gives more priority to passive design for energy optimisation than GRIHA versions 2010 and 2014. This increase in the prioritisation of passive design can also be seen in the new versions of LEED US and BREEAM, with a corresponding decrease in emphasis on active systems for energy optimisation (see Figure 46 in Annex 2).

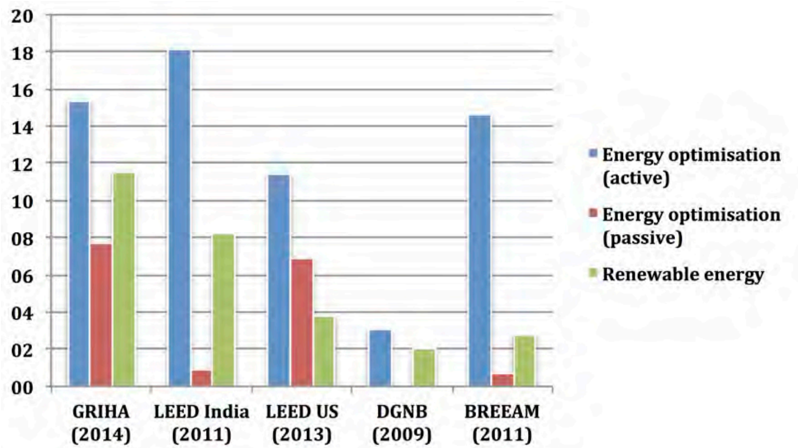


Figure 34. Weightings of energy sub-criteria in various certification systems

Atmosphere

The reduction of environmental impact through the emphasis on the minimisation of ozone depleting substances is most highly prioritised in DGNB, followed by BREEAM (see Figure 35). The increase in its priority can be seen in the newer version of LEED US, while its priority decreases in BREEAM (see Figure 47 in Annex 2).

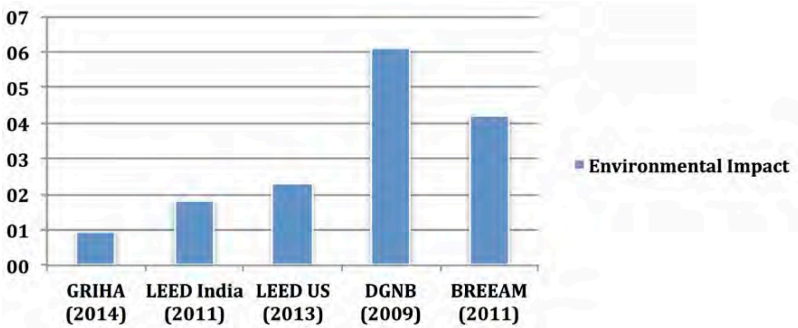


Figure 35. Weightings of atmosphere in various certification systems

Water

Water conservation through the reduction of water use is emphasised in LEED US and BREEAM, while reusing water is prioritised in GRIHA and LEED India. LEED US and DGNB do not give preference to maintaining water quality (see Figure 36). GRIHA SVA gives the highest priority to water conservation; this priority increases in the newer version of LEED US, but it decreases in the newer version of BREEAM (see Figure 48 in Annex 2).

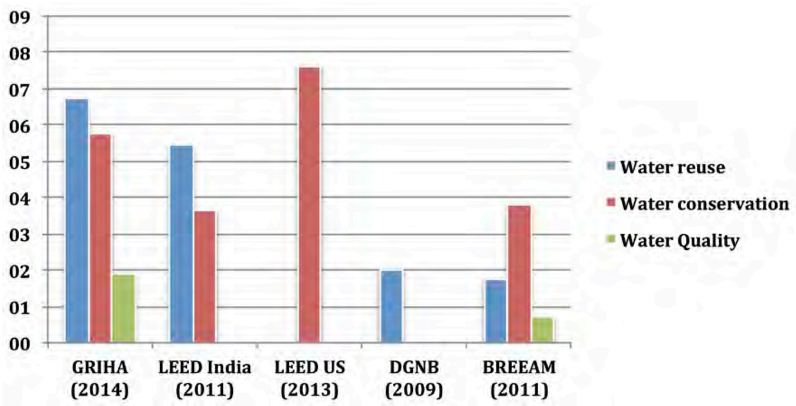


Figure 36. Weightings of water sub-criteria in various certification systems

Site, location and transportation

The selection of the site is emphasised in LEED US and DGNB, while soil protection is prioritised in GRIHA and BREEAM, and community connectivity and eco-friendly transportation in LEED India (see Figure 37). In GRIHA SVA the emphasis is on reducing the heat island effect, while its other version emphasises soil protection. The emphasis on site selection increases in newer versions of LEED US and BREEAM (between BREEAM 2011 and 2014) (see Figure 49 in Annex 2).

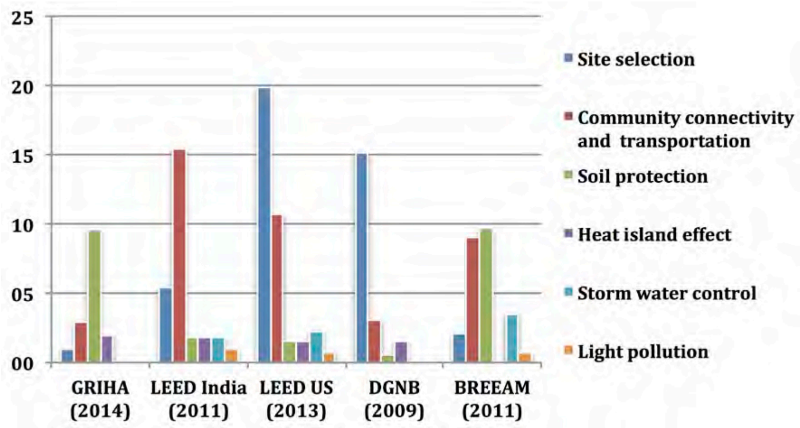


Figure 37. Weightings of site, location and transportation sub-criteria in various certification systems

Indoor Environmental Quality

GRIHA and LEED India show preference for hygiene/chemical control through the use of low Volatile Organic Compounds (VOC), which reduces indoor chemical pollutants. DGNB gives priority to thermal comfort, while BREEAM prioritises visual and acoustic control. Although no weighting is given for smoke control in LEED US and LEED India, it is mandatory in these certification systems (without weighting) (see Figure 38). However, the preference for hygiene/chemical control and thermal comfort decreases in newer versions of LEED US, while it increases in BREEAM NC (See Figure 50 in Annex 2).

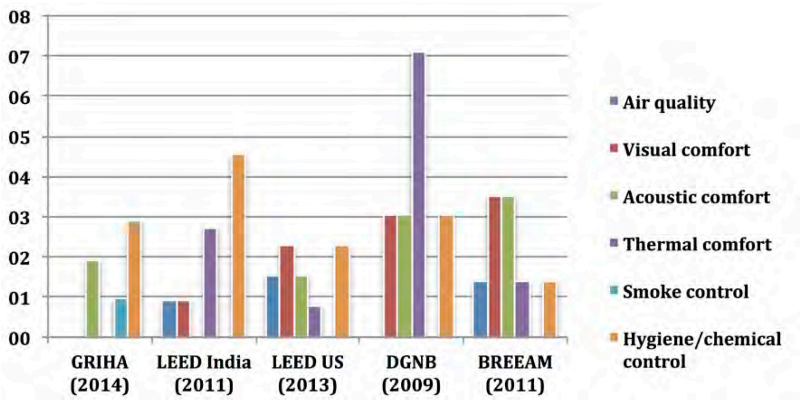


Figure 38. Weightings of indoor environmental quality sub-criteria in various certification systems

Material efficiency

Resource efficiency through the use of regional materials and the selection of low embodied materials are prioritised in all certification systems except LEED India. LEED India gives priority to material reuse and recycling (see Figure 39). In LEED US, the priority of material reuse and recycling decreases in the newer version, while resource efficiency/low embodied energy increases in its newer version (from LEED 2009 to 2014). Waste management for the proper disposal of waste is not considered in GRIHA SVA, but its emphasis remains equal in GRIHA 2010 and 2014 (see Figure 51 in Annex 2).

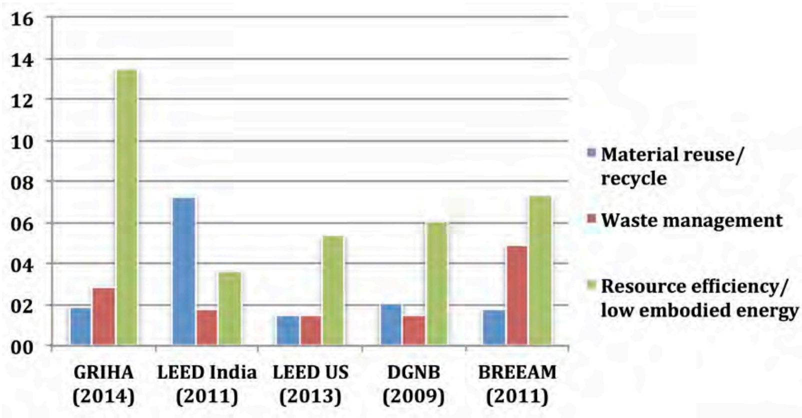


Figure 39. Weightings of material efficiency sub-criteria in various certification systems

Innovation

This criterion aims to encourage design teams to achieve exceptional performance above and beyond the conventional requirements through innovative design, and to ensure that the building system has low environmental impact combined with higher performance and human comfort levels. Of the certification systems studied, BREEAM gives innovation the highest priority (see Figure 40). Its priority decreases in newer version of LEED US and in BREEAM from BREEAM 2008 to BREEAM 2011(see Figure 52 in Annex 2).

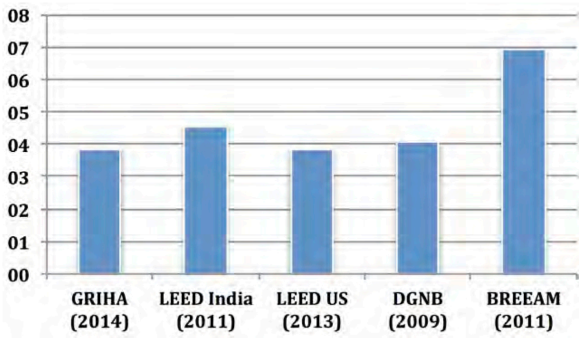


Figure 40. Weightings of innovation in various certification systems

Social Aspects

Health & Safety and functional aspects, which consider safety, security and quality of life, are emphasised in DGNB, followed by GRIHA, BREEAM and LEED US (see Figure 41). Within GRIHA, GRIHA SVA gives more priority to this criterion than other versions of GRIHA (see Figure 53 in Annex 2).

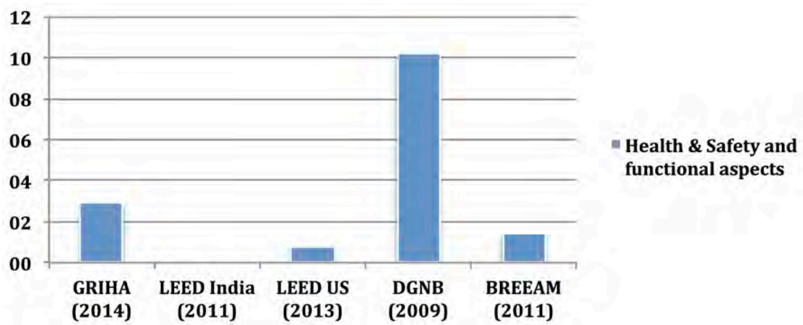


Figure 41. Weightings of social aspects in various certification systems

Economic Aspects

The minimisation of the building life cycle cost is prioritised only in DGNB and BREEAM (see Figure 42). However, it is considered in LEED and LEED India under the optimisation of energy performance. Within

BREEAM, its priority increases in newer versions (see Figure 54 in Annex 2).

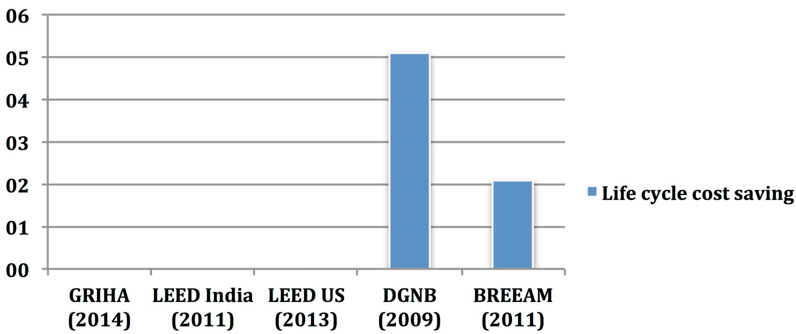


Figure 42. Weightings of economic aspects in various certification systems

Management

Planning quality prior to building construction is given preference in DGNB and BREEAM, while all other certification systems ignore this issue. Commissioning/operation and maintenance are the second most emphasised sub-criterion in DGNB but are the top priority for LEED US and GRIHA (the same weighting is given for air quality management in GRIHA). Timely energy monitoring is emphasised in LEED India (it also gives equal weighting to air quality management), but is less emphasised in LEED US and BREEAM. In GRIHA, although weighting for the sub-criteria of energy and water monitoring is not given, these are mandatory (see Figure 43). In LEED US, the trend over time shows a decrease in emphasis on air quality management and an increase in emphasis on commissioning/operation and maintenance. In BREEAM, however, the trend between older and newer versions shows a decrease in emphasis on both the planning quality (between BREEAM 2011 and 2014) and the commissioning/operation and maintenance (between BREEAM 2008 and 2014) (see Figure 55 in Annex 2).

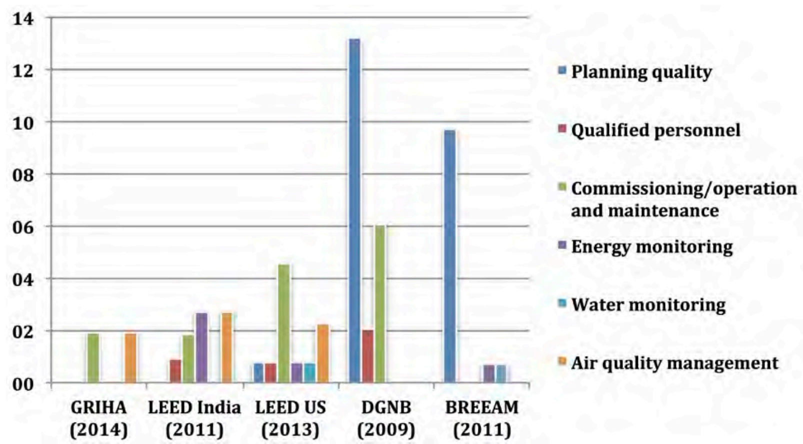


Figure 43. Weightings of management sub-criteria in various certification systems

10.5 Conclusion and discussion on green building certification systems

Green building certification goes international

When a certification system goes international (e.g. LEED US to India, Mexico, Brazil and South Korea etc.), the criteria are adapted to fit the national circumstances, rather than simply remaining the same. For example, in the case of GRIHA and LEED India, GRIHA is a national green building certification system for India whereas LEED India is the adapted form of LEED (US) to suit the Indian context. Although both these certification systems are for the same country, the weightings of the criteria are different (see Table 19 and Figure 32). Energy efficiency is a main priority in both the certification systems, while the second major criteria are site and transportation in LEED India and material efficiency in GRIHA.

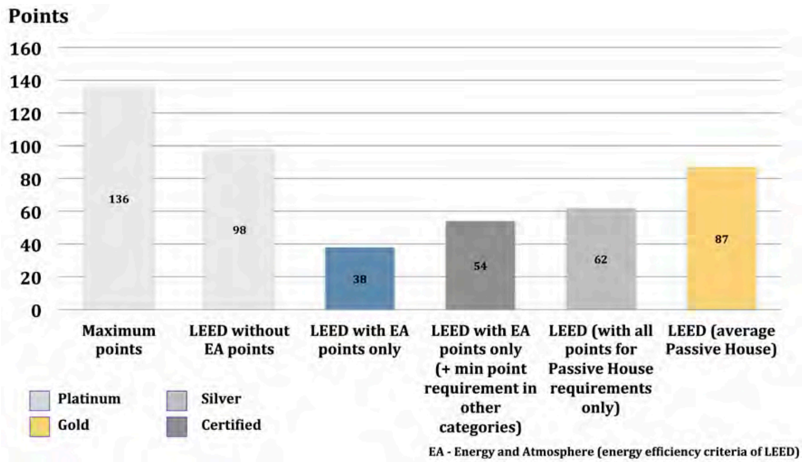
When a country has more than one certification system (e.g. GRIHA and LEED India in India), the consumer faces the challenge of how to choose which system to adhere to and confusion can arise regarding the basis of the evaluation of the certification. To overcome this problem (according to the collective expert opinion) the certification systems need to be evaluated in terms of their quality assurance in order to distinguish them for each other. Furthermore, experts 3, 4, 7 and 8 agree that the decision to select a particular certification system is often based on reasons of prestige; in such cases the internationally acclaimed system is chosen.

Life Cycle Analysis in green building certification

It should also be noted that the evaluation of green buildings in the certification systems is carried out using checklists and guidelines (e.g. LEED) and focuses mainly on the use phase of the buildings (with less emphasis on the construction and demolition phases). Therefore, most of the green building certification systems lack whole life cycle analysis (environmental and economic) and fail to assess global environmental impacts. To date, the latest versions (2013/2014) of LEED US and BREEAM UK have incorporated LCA to ensure better environmental, economic and social performance.

Stringency of energy standards within green building certification

Energy efficiency is one of the most important criteria in green building certification systems. However, as green building certification systems are basically performance based and ratings are largely awarded on overall scores (i.e. one criteria may score less than the others but this may not affect the overall rating), relatively low energy efficiency levels can be certified and even receive high ratings. For example, Figure 44 illustrates the case of a LEED Platinum building with 136 points overall (LEED for Homes 2008); in this example the building has been awarded maximum points in all other criteria except energy efficiency, but it still achieves LEED Platinum level. Furthermore, when a LEED building reaches Passive House level, it automatically gains 87 points for energy efficiency, which takes it directly to LEED Gold level. This shows that green buildings with ratings from the certification systems may not all be highly energy efficient. Newsham et al. (2009) in Kneifel (2009) also explained that the level of certification does not always reflect increased energy efficiency. They cite an example of LEED certified buildings where various building types (in general) are shown to save energy (between 18% and 39%); however between 28% and 35% of LEED buildings actually use more energy per sq. ft. than comparable non-LEED buildings. Expert opinion was sought on this issue and all the experts agreed that buildings with low energy efficiency levels can only achieve a low rating. Expert 1 added that for developing countries with limited financial and social capabilities, a low level energy efficiency rating is better than nothing. Moreover, experts 2, 3, and 4 also felt strongly that the energy efficiency stringency in green building certification systems should be increased, given the level to which energy use impacts negatively on climate, local pollution and health.



Source: Hennicke et al., 2012

Figure 44. LEED points for different energy scenarios

10.5.1 Financial incentive programmes in Europe

A number of incentive schemes are available in Europe for both residential and commercial buildings (new and existing). The mostly commonly used financial incentive programmes in European countries are grants/subsidies, as well as loans and tax incentives, together with other financial instruments (BPIE, 2012). In the largest European countries, such as Italy, France and Germany, the source of funding is the taxpayer and the most commonly used types of incentive are (in order of usage) tax credits (55%), tax credits together with subsidised loans, and grants. In the UK, the source of funding is the consumer, who pays additional tax via their Energy Provider (EP), and the most commonly used type of incentive is the Energy Efficiency Obligation (EEO) (GBPN and LBNL, 2012).

Tax credits

Tax credits are provided by governmental environmental organisations, energy ministries or other public agencies, and the percentage of the credit or deduction varies by country. Tax credits reduce the amount of tax the customer pays (i.e. they reduce the customer's taxable income). They can also reduce the sales tax on energy-efficient equipment purchases, either directly or via a refund. In Italy, the government offers tax credits that reduce the price of purchasing energy efficient equipment by 50% (e.g. window upgrades, heating system replacements and solar panel installations) and about 250,000 households have taken advantage of this measure annually since 2007 (GBPN and LBNL, 2012). In France, tax credits are available for the installation of more efficient equipment and this programme benefitted 1.5 million households (between 2005 and 2009), representing €2.6 billion in tax credits (French Environment Ministry 2011 in GBPN and LBNL, 2012) and saving 6.6 million tonnes of CO_2 equivalent (GBPN and LBNL, 2012).

Low interest loans

Low interest loans in Germany, through the government's development bank, KfW (Kreditanstalt für Wiederaufbau or Reconstruction Credit Institute) are one of the most successful incentive schemes in Europe. KfW, owned by the Federal Republic of Germany (80%) and the States of Germany (20%), does not lend directly to enterprises or individuals but it provides commercial banks with liquidity at lower rates and with long maturities i.e. loans are accessed through normal retail banks (GBPN and LBNL, 2012). The advantages of KfW include: no distortion due to competition, no need for a branch network and lower risks due to the inclusion of retail banks (Gump, 2012). A KfW loan is basically provided to improve the energy performance of the existing building stock through the incorporation of energy efficiency measures, increased deployment of building integrated renewables and connection to district heating schemes. KfW works with the federal ministry (for legal minimum requirements) and DENA or regional energy agencies (for know-how transfer) to mutually reinforce and support each other in the creation of a positive environment for improving energy efficiency in Germany (GBPN and LBNL, 2012).

The level of support from KfW depends on the energy performance level i.e. the more efficient the property after renovation, the higher the support level. For example, KfW Efficiency House 55 performs better than KfW Efficiency House (EH) 100, so the grants are (respectively) 20% and 12.5% of the total investment, with a repayment bonus of 12.5% and 5% of the loan. As a result, the KfW-EHs have saved huge amounts of energy compared to unmodernised or partially modernised houses (KfW-EH 100 achieved energy savings up to 74% higher than unmodernised properties). Interestingly, the credits provided by KfW are ultimately returned to KfW in loan repayments, and the net outgoing from KfW shows that approximately €15.50 of investment in energy saving is generated for every €1 of net cost to KfW (GBPN and LBNL, 2012). According to the Bremen evaluation of the public sector programme (carried out between 2007 and 2010), the annual energy savings delivered from an investment of €364 million were 329,000 MWh (1,184 TJ/yr), a reduction of 116,000t CO_2e per year. In 2010, KfW granted loans to 340,000 dwellings, delivering annual energy savings of 2,450,000 MWh/yr and reductions in GHG emissions of 847,000t CO_2e per year. With this success, KfW plans to increase the fund to €1.5 billion per year from 2012 to 2014 (GBPN and LBNL, 2012).

10.5.2 Financial incentive programmes in the USA

Financial incentive programmes for energy efficient buildings (residential, commercial and other types) in the USA include utility and ratepayer-funded programmes, tax incentives and other financing mechanisms (e.g. loans, on-bill financing and Property-Assessed Clean Energy Financing (PACE)) (GBPN and LBNL, 2012). Similarly, the financial incentives initiated by the government for green buildings (LEED buildings) include tax incentives, density bonuses, expedited permit reviews and grants etc. (US-GBC, 2009).

Utility Demand-Side Management programmes

Utility demand-side management programmes, or ratepayer-funded energy efficiency programmes, use funds from ratepayers who are the recipients of the lower total costs of supplying energy for the utility system. This programme has been increasing steadily in the USA from US$900 million in 1998 to US$5.5 billion in 2010 and it mainly targets residential and commercial buildings (but also operates in industrial sectors). This has resulted in higher energy savings in the USA, amounting to an estimated 112,468 gigawatt hours (GWH) of electricity and 808 million therms of natural gas in 2010 (CEE 2010 in GBPN and LBNL, 2012). This programme uses rebates to reduce the initial costs of energy efficiency investments, targeting whole building approaches (for high efficiency equipment and sophisticated construction techniques, installation and operational practices) (GBPN and LBNL, 2012).

In the new residential sector, the Energy Star (labels) for homes programme is offered by more than 100 utility companies as their basic platform for their new homes programme, offering funding ranging from less than US$1,000 to US$12,500 in California (CEE 2010 in GBPN and LBNL, 2012). For homes that qualify for Energy Star funding, utility incentives can be of four types: tiered incentives (offered to builders, with increasing value for increased efficiency), equipment incentives (applied to specific highly efficiency equipment, e.g. HVAC), rating incentives (paid to the builder or assessor covering the cost of assessment) and homeowner discounts (paying a percentage or flat-fee discount on utility bills) (US-EPA, 2011 in GBPN and LBNL, 2012). For existing residential buildings, the Home Performance with Energy Star (HPWES) programme offers cash rebates and interest rate buy-downs on project financing for energy efficient building improvements (e.g. insulating attics and crawl spaces, improving heating and cooling systems, and upgrading lighting and appliances). This has resulted in a 20% saving in home energy use (US-EPA, 2011a in GBPN and LBNL, 2012).

In the new commercial sectors many programmes incorporate LEED certification or the New Buildings Institute's Advanced Buildings protocol, and incentives can range from less than US$50,000 to more than US$450,000 (GBPN and LBNL, 2012). The savings from the programmes range from 11% to 26% of the whole energy use (through comprehensive retrofit programmes) and from 85% to 20% (through retro-commissioning and operations & maintenance improvements) (Aman and Mendelsohn 2005 in GBPN and LBNL, 2012).

Tax Incentives

Energy efficiency tax incentives were established by the Energy Policy Act of 2005 for the residential, commercial and transportation sectors to increase their market share of advanced energy efficiency products and encourage homeowners and business owners to move towards energy efficiency improvements.

Credit of US$2,000 is provided to new residential buildings that use 50% less energy for space heating and cooling than buildings built according to the 2004 IECC. In addition, a tax credit of US$1,000 is granted to the builder of a newly manufactured home, which achieves 30% heating and cooling energy savings compared to the 2004 IECC (Gold & Nadel, 2011 in GBPN and LBNL, 2012). Tax credits (at varying rates) for residential retrofits are available for upgrading building envelope components (windows and insulation etc.) and installing new energy efficient equipment (GBPN and LBNL, 2012).

For new and commercial buildings (new and retrofits), tax incentives are provided to owners and tenants for reducing HVAC and interior lighting energy use by 50%, relative to the ASHRAE standard 90.1-2001 (Gold & Nadel, 2011 in GBPN and LBNL, 2012).

Loan programmes

Loan programmes are offered in US residential and commercial sectors to cover the costs of energy efficiency upgrades. These are not used on a nationwide basis, but some states have implemented these programmes with varying degree of success (GBPN and LBNL, 2012). In California, the California Energy Commission funds US$25 million in loans for public building sectors (e.g. local authorities), offering low interest rates of 1% for local jurisdictions to invest in energy efficiency, save money, reduce GHG emissions and create new jobs and industries for the communities. The loan repayment comes from energy savings and the money is then loaned out again for energy projects. The maximum loan available is US$3 million per project, with the loan repaid in 10 years or less from the energy savings achieved (CEC 2010).

On bill financing

On bill financing (serviced by, or in partnership with, a utility company) is offered for energy efficiency improvements in which the monthly repayment by the customer is covered through energy savings. 14 states in the USA operate this programme, including California, Georgia, Hawaii, Illinois, Kentucky, Michigan, New York, Oregon and South Carolina.

Property-Assessed Clean Energy (PACE) financing

PACE financing is offered to both residential and commercial buildings, enabling property owners to finance energy efficiency and renewable energy projects. It provides long term financing through an assessment of the property tax bills for up to 20 years, and the repayment obligation transfers to the new property owner upon resale (along with the energy cost savings from the project), which eliminates the risk for an owner who is unable to recoup the investment at the time of reselling the property. 24 states in the USA and the District of Columbia operate this programme (GBPN and LBNL, 2012).

10.5.3 Financial incentive programmes in India

Financial incentives in India, mainly at national and state level, tend to be for green buildings, renewable technologies and energy efficient bulbs. The incentives are basically in the form of rebates and tax credits, but some banks also provide loans and other financing schemes for green buildings and technologies. The financial schemes for India are categorised in terms of who provides the funds.

National level incentives

The Ministry of New and Renewable Energy (MNRE) incentive scheme for GRIHA-rated buildings is one of the biggest schemes at national level for buildings under the MNRE 'Energy-Efficient Solar/Green Buildings' programme. This programme reimburses developers for 90% of the registration and rating fee for projects up to 5,000m2 with a minimum 3 star rating, and for projects larger than 5,000 m2 with a minimum 4 star rating (MNRE, 2009 in GBPN and LBNL, 2012). Architects and consultants are motivated by being awarded 250,000 INR (1 EURO = 80.8 INR) for projects up to 5,000m2 with a minimum 3 star rating and 500,000 INR for 4 star projects that are larger than 5,000m2. Inter-government assistance is available to municipal corporations (5,000,000 INR) and to other local bodies (2,500,000 INR) by offering property tax rebates for green buildings (to qualify, new government and public sector buildings must obtain a GRIHA rating and the local authorities must sign memorandum of understanding with GRIHA for the large scale promotion of green buildings in their local area). In addition, the first 200 government/public sector buildings to be certified are exempt from paying registration fees, through a combination of up-front payments and completion-based rebates (MNRE, 2011 in GBPN and LBNL, 2012).

Likewise, MNRE and many state governments provide incentives for the adoption of integrated renewable energy technologies by funding 50% of design preparation costs, up to 200,000 INR. MNRE also provide reduced interest loans for small scale renewable technologies (such as solar water heating, air heating, cooking and biomass gasification etc.) to customers of the India Regional Economic Development Agency and seven other designated banks (Nayak & Prajapati, 2006 in GBPN and LBNL, 2012). Other subsidies provide a 2% interest rate on purchases of solar water heaters (Pandit, Patankar & Prem, 2010 in GBPN and LBNL, 2012).

Nationally developed incentives also exist for energy efficient lighting. The Bachat Lamp Yojana project seeks to replace energy consuming incandescent lamps with efficient compact fluorescent lamps (CFLs) and part of the funding for the scheme comes from the largest carbon credit project under the Clean Development Mechanism (Suki, 2010 in GBPN and LBNL, 2012).

State level incentives

A good example of state level incentives in India are the tax concessions offered by the Pune Municipal Corporation (Maharashtra State) that reduce property taxes by between 10% and 50% (depending upon the rating achieved) of the total premium paid by builders for Eco-Housing rated projects (Pandit et al., 2010 in GBPN and LBNL, 2012).

Likewise, a few states and municipal bodies (e.g. Hydrabad government) offer property tax rebates (of around 10%) and other incentives for properties that install solar heating and lighting systems (Jaiswal, Vedala & Bilolikar, 2010 in GBPN and LBNL, 2012).

Financial incentives from banks

Several banks in India offer financial incentives (especially loans) for green buildings and technologies (see Table 20).

Table 20. Financial incentives from banks for green buildings and technologies in India

Bank name	Incentive Scheme Description
State Bank of India (SBI)	Green Home Loan: supports environmentally friendly projects and offers concessions. Provides loans for projects rated by the IGBC. Financial benefits include a 5% concession fee in margins, 0.25% concession in interest rates, and processing fee waivers.
State Bank of Mysore	Projects related to energy efficiency, green housing, renewable energy, and waste management are eligible for small interest concessions at this bank. Subject to limitations, the entire cost of a rainwater harvesting system for a new residential building will be incorporated into a loan with no additional interest.
Industrial Credit and Investment Corporation of India Bank	Reduced mortgage processing fees for customers who own LEED-certified buildings
Bank of Maharashtra and ING Vysya Bank	Eco-housing Mortgage products offered under the Eco-Housing Pune Program: These products offer a 0.5% rebate on prevalent interest rates, 1% interest rate subsidy on certain efficiency equipment and appliances (solar water heaters, efficiency lighting, refrigerators, and air conditioners); and either a longer repayment tenure or a 3-month moratorium on repayments. The program also appears to offer larger loan amounts for Eco-Housing projects (10% more that normal loans).

Source: GBPN and LBNL, 2012

10.6 Conclusion and discussion on financial incentive programmes

Among various financial incentives, utility demand-side management programmes in the USA and the KfW programme in Germany have proven to be successful and these mainly focus on energy efficient buildings. India has comparatively few financial incentives, except for a limited number of national and state incentives for green buildings. As well as establishing better national funding mechanisms, seeking international funding would also be helpful in India.

11 Policy package recommendation for developing countries

Before defining appropriate policies for energy efficient and green buildings in developing countries, it is necessary to review the status of the existing policies in terms of their various criteria (energy, water, materials and pollution etc.). Energy demand in developing countries is high (although per capita energy consumption can be lower than in developed countries) but, at the same time, many regions in the world do not have sufficient access to energy (IEA and the World Bank, 2013). Energy end use in buildings in developing countries (e.g. India) varies widely across income groups, building construction types/methods and climates (GEA, 2012). Therefore, in developing countries energy security and accessibility are equally as important as energy efficiency. Issues surrounding water usage are also significant in developing countries, due to physical or economic water scarcity (see Figure 3 in Chapter 5, section 5.3.2.3). Incorporating the efficient use of water into building design and securing water supply are essential. Moreover, fast demographic growth in developing countries (especially urban-rural) has caused rapid growth in the construction sector on a large scale, but the buildings constructed are inefficient, unplanned land encroachment is common and ecological damage has been sustained. Pollution is also one of the biggest issues in developing countries (outdoor air pollution from dust and harmful chemicals from industry (building related), and lower indoor air quality from VOCs from indoor equipment and technologies).

Although the above mentioned problems exist, developing countries also lack proper (stringent) policies in the individual sectors e.g. energy, water and materials etc. at national and local level. Good policies in these sectors could enhance or accelerate the stringency of policies for energy efficient and green buildings in developing countries. As the individual sectors are weak in developing countries (in comparison to developed countries), the importance of building standards/codes or labels referring to energy and all the resources (involved in buildings) and the requirement to develop a proper policy package is higher. Among all the sectors, energy efficiency (including operational and embodied energy use) in the building standards/codes or labels is the most important aspect for reducing a building's environmental impact, for securing energy supply and for lowering building costs. This indicates the need for a good policy/policy package for 'energy and resource efficient buildings' (which also includes green buildings, but with the emphasis on energy efficiency) in developing countries that could raise the quality of building construction, protect the environment and improve social and economic conditions.

As mentioned in chapter 10, India is following this approach and focusing on green buildings (although the rate of construction is lower than in developed countries) before introducing mandatory building energy standards. However, there still exist various countries (e.g. Nepal) that have neither energy efficient nor green building standards. This chapter recommends a policy package for energy and resource efficient buildings for such developing countries.

11.1 Designing a successful policy package

Before designing and implementing a policy for energy and resource efficient buildings, some of the guiding principles must be considered (based on bigEE, 2013). These include: *building confidence in stable framework conditions* (i.e. a strong credible commitment from government to the markets to energy and resource efficiency as a long term political goal); *determining priorities based on status quo analysis* (i.e. the government needs to choose priorities and set targets for energy and resource efficiency policy wisely, analysing the status quo and specific circumstances in the country*); involving the market and assessing the needs of market actors* (i.e. assess the barriers and incentives faced by each of the market actors in the current market situation and existing legislation to identify the needs of market actors and the need to improve the policy package in order to overcome the barriers and strengthen the incentives; also, relevant building stakeholders should be involved and regularly consulted in the design and implementation phase of policies and measures to ensure that policies are adequate and practically feasible and also increase the rate of compliance); *making goals, instruments and benefits transparent* (i.e. each major policy or programme should be accompanied by an information campaign about its concrete objectives, way of functioning, target groups and expected benefits*); increasing uptake through highlighting co-benefits* (i.e. highlight tangible and intangible benefits); *monitoring, evaluating and reviewing policies* (i.e. constantly monitor policies and measures and thoroughly evaluate them on a regular basis); *policy dynamics, maximising benefits and minimising negative side effects* (policies need to avoid the snap-back effect (the market falling back to lower energy and resource efficiency levels), reduce the free-rider effect (a policy that continues to support energy and resource efficiency levels that market actors would have achieved without it) and create the spill-over effect (enable the market to adopt further energy and resource saving actions through its own initiatives); and *taking the social dimension into account* (i.e. analyse social capacity and need and take national or local circumstances into account).

Following these guidelines, section 11.1.1 below discusses the elements of an overall policy package for energy and resource efficient new buildings in developing countries. As building standards and codes are the main policies for stimulating energy and resource efficient buildings, section 11.1.2 discusses steps to take towards effective energy and resource efficient building standards and codes and section 11.1.3 discusses steps showing how policy interaction can result in market transformation.

11.1.1 Overall policy package for energy and resource efficient (new) buildings in developing countries

A successful policy package design requires a supportive government framework (including policy elements such as targets and planning, infrastructure and funding and distortion elimination) and specific policy and measures (including policy elements such as regulations, transparency and information, incentives and financing, capacity building and networking, promotion of energy services and RD&D and BAT promotion). These policy package elements are based on the recommendations of bigEE (2013) (which focuses on energy efficient buildings), later adapted for new energy efficient and green buildings in developing countries.

11.1.1.1 Governance framework

Targets and planning

There must be a clear political commitment to energy and resource efficiency in buildings, demonstrated by setting ambitious yet achievable energy and resource saving targets, in order to ensure long term investment in the construction industry and building market (bigEE 2013). The targets in developing countries need to address energy efficiency and GHG reduction in buildings (including appliances, industry and transportation), water efficiency and security, land management, waste management, material efficiency and pollution control and minimisation. As large areas of new development are common in developing countries, spatial planning and urban district planning are important means of ensuring that such multiple targets are met and e.g. 'urban sprawl' is avoided. This can be effective if governments oblige local authorities to perform sustainable spatial planning and urban district planning and enforce the results, but governments also need to provide local authorities with the relevant tools, training and possibly the financial resources for staff and implementation. As Voluntary Agreements (VAs) complement regulations, the government can conduct VAs on energy and resource efficiency targets and actions with commercial and public organisations (e.g. developers, housing companies and local authorities) that accelerate the achieving of targets and increase the demand for energy and resource efficient buildings. International cooperation can help to stimulate energy and resource efficiency by providing opportunities to learn from others' experience (in the fields of technology and policy); this approach can also reduce costs associated with information gathering (bigEE, 2013), but experiences from elsewhere in the world must be adapted to suit national circumstances in accordance with the social, cultural, economic, climatic and geographical conditions.

Infrastructure and funding

This includes forming an organisation that co-ordinates policies and implements parts of the policy packages, such as the co-ordination of energy and resource efficiency projects and programmes, provision of information and initial advice, promotional activities, education, training, information dissemination, demonstration activities, network-building between market actors, awareness-raising and campaign organisation (such as the Bureau of Energy Efficiency in India (BEE) or German Energy Agency (Deutsche Energie-Agentur in Germany for energy efficiency (DENA)). Moreover, the funding for energy and resource efficiency (for information, motivation, financial incentives and/or financing, capacity building and RD&D/BAT promotion) is an important aspect in developing countries (due to the limited economic means of the majority of the population) and this should be provided by government budgets or by climate finance (Clean Development Mechanism – CDM or Nationally Appropriate Mitigation Actions – NAMAs) (bigEE, 2013).

Eliminating distortions

Distortions, such as subsidised energy prices, can be removed or reformed through full-cost pricing or the internalisation of external effects to discourage the wasteful consumption of environmental resources (and this should be the long term plan of governments in developing countries). Providing financial incentives for energy-efficient equipment and buildings will, in many cases, be more effective in reducing the energy costs of low-income households than subsidising energy prices and will, therefore, be a better use of government budgets.

The government can remove legal barriers that discourage the use of energy and resource efficient solutions and investments. In developing countries in particular, where energy demand is high and energy efficiency is more cost-effective to society than new power plants and energy supply, it is important for regulators to give an economic incentive to energy companies. The energy companies must invest in energy end-use efficiency, e.g. in buildings, rather than focus on raising their profits by investing in power plants and networks to increase energy consumption (bigEE, 2013).

11.1.1.2 Specific policies and measures

Regulations

To exclude the most (energy and resource) inefficient buildings and encourage the construction of energy and resource efficient buildings, minimum baselines for energy and resource efficiency should be set by standards and codes. As well as that, other legal requirements, such as energy and water metering, monitoring and commissioning, are also necessary.

Transparency and information

Transparency in the performance of energy and resource efficient buildings can be provided by the introduction of certification systems or labels (comparative labels or endorsement labels). Comparative labels rate a building's performance in comparison to other buildings of the same type and also against BAT (Best Available Technologies) for the building type (e.g. EPC for energy efficient buildings in Europe). Comparative labels may also rate the energy performance of single technologies (components such as windows, or units such as air conditioners). Endorsement labels, on the other hand, are awarded to buildings that have reached a specific level of building performance beyond the minimum standards (e.g. LEED). Providing information on energy and resource saving opportunities, cost savings and other benefits of energy and resource efficient buildings to investors and end users enables decision makers to select effective technological options for energy and resource saving. The instruments for the provision of information include information centres, demonstration buildings, information campaigns and websites etc. (bigEE, 2013).

Incentives and financing

These include providing financial incentives (loans, grants etc.) for energy efficient and green buildings that also help to tackle the increased up-front costs of energy efficient and green buildings (bigEE, 2013).

Capacity building and networking

Developing countries lack sufficient professional capacity to foster energy efficient and green buildings. Capacity building for the workforce in the building sector (i.e. architects, planners, developers and building contractors etc.) in order to have the knowledge and experience to design, build, operate, monitor and assess highly energy and resource efficient buildings is necessary. This also helps to provide accurate and convincing information to investors, building owners and tenants about the tangible and intangible benefits of such buildings (bigEE, 2013).

Promotion of energy services

Particularly in cases where there are budgetary constraints or a lack of expertise, or both, governments can promote and support energy services, such as energy performance contracting or third-party financing schemes (bigEE, 2013), especially for the retrofit of existing larger public or commercial buildings (e.g. India's attempts to promote EPCs for government buildings). Governments can provide targeted information and training to the potential customers of energy services and support capacity building etc. (bigEE, 2013).

RD&D and BAT promotion

In order to foster the technologies and design concepts for energy efficient and green buildings, the promotion of research and development activities, as well as demonstration (RD&D) projects, is crucial. RD&D funding can help to develop innovative ideas, accelerate the introduction to market of new technologies and reduce the incremental costs of energy and resource efficient solutions. Public sector programmes can lead by example and create first markets for energy and resource efficient building concepts and technologies, which helps to raise awareness and investor confidence in the benefits of energy and resource efficient buildings, as well as demonstrating cost-effectiveness. Moreover, competitions and awards increase stakeholders' motivation to strive to develop more efficient buildings and technologies (bigEE, 2013).

11.1.2 Steps towards effective energy and resource efficient buildings standards and codes

Having defined the overall policy package and necessary elements for energy and resource efficient buildings in developing countries in section 11.1.1, this section discusses the steps to plan the development of energy and resource efficient building standards and codes; to create a suitable environment to implement them; to keep track of compliance and enforcement through monitoring; and to evaluate the codes and standards along with possible regular updates. For developing countries at an early stage of development, or with no such standards and codes, these steps provide guidance to policy makers (and other stakeholders) on how and which policy elements are to be implemented or deployed at which stage to have an effective result on reducing buildings' demand for energy and resources. This also shows that building standards and codes are not, in effect, standalone policies, but need to be embedded within a package of measures to be effective (see Table 21 for details).

For the concept of these steps, a review of the IEA and UNDP (2013) study was undertaken. This study shows the pathway to improving buildings' energy efficiency is through the deployment of energy codes in four phases – plan, implement, monitor and evaluate, combined with further steps and actions. This concept is adapted and described as per the requirement for the successful implementation of energy and resource efficient building standards and codes for developing countries. The IEA and UNDP (2013) study also asserted that modern building energy codes have to advance and improve the path to low energy and low carbon buildings (taking into account energy sufficiency measures, energy efficiency through the use of efficient building components and equipment and the use of renewable energy resources) with a further reduction in a building's embodied energy (as well as other resources such as water and land etc.). Therefore, supporting the argument, Table 21 further explains the future development of building energy codes as energy and resource efficient building standards and codes.

Table 21. Steps for delivering a successful policy package

	Actions	Short description
Planning phase		
1. Define terms of reference		
	1.1 Define objectives	1.1.1 Set the target (for energy and resource saving), which should be ambitious yet achievable in the long term (see section 11.1.1). 1.1.2 Look at the local conditions and determine the areas with saving potentials. 1.1.3 Go through existing national codes, standards and also labels (if these exist) for energy and resources such as water, materials and land management and structural safety, and determine the areas for improvement.
	1.2 Define scope	1.2.1 Select the type of buildings on which to focus - new or existing, residential or non-residential buildings. 1.2.2 Determine the climate zones of the country and define suitable building technologies and approaches according to the climatic need.
	1.3 Define necessary norms	1.3.1 Carry out studies of international conditions such as existing energy and resource efficient standards and codes and structural safety codes and learn lessons to avoid making the same mistakes and to leapfrog if possible (as chapter 10). 1.3.2 Consider the supportive policy context (check the status of individual complementary policies in the country e.g. land use policies, water quality and standards, building appliances and components labelling e.g. windows, insulation materials, wall components etc. as well as Life Cycle Analysis (LCA) for embodied energy) and renewable energy policies; also check their status and stringency, which will depend on the country's requirements and socio-economic capacity. 1.3.3 Establish baselines and reference buildings (carry out an inventory of the existing building stock – including construction methods, construction materials and building equipment technologies).

	Actions	Short description
		1.3.4 Determine methodology, strategies and criteria: 1.3.4.1 Prescriptive or performance method - if the level of professional knowledge and skills in the building sector is sufficient, performance based minimum requirements can be applied. Otherwise start with prescriptive methods (bigEE, 2013) and then adapt performance standards as requirements strengthen (UNDP, 2010). 1.3.4.2 Passive and active strategies - adapt passive strategies first as these are an easy and climate responsive design approach and then look for possible efficient active strategies. 1.3.4.3 Minimum requirements of each criteria depend on the locational need. 1.3.5 Keep the policies and requirements as simple as possible to allow for implementation by non-professionals in the case of a high share of self-built or informally built housing and provide extra effort to develop support tools and resources (bigEE, 2013 and UNDP, 2010). 1.3.6 Write the standards or codes in clear and straightforward language. 1.3.7 Implement the building standards or codes on a mandatory basis (as a long term aim) and strengthen them over time (but if the industry's track-record does not show the capability of enforcing mandatory regimes, start first with voluntary standards and make these mandatory only after their usefulness has been tested and confirmed (UNDP, 2010 and bigEE, 2013).
2. Define modalities to support implementation and enforcement		
	2.1 Define institutional arrangements	2.1.1 Check and ensure that the implementation of the standards or codes is functioning effectively. 2.1.2 To increase their effectiveness, update the standards or codes regularly (every 5 years) by a national building bureau or other governmental authority with the responsibility for developing, implementing, compliance-tracking, monitoring and evaluation carried out by a co-ordination body.
	2.2 Define funding mechanisms to secure financial resources	2.2.1 Define a sustainable funding mechanism by the government to maintain a high compliance rate, to update the standards and codes regularly and to run the overall scheme (this is crucial in a developing country) and secure international funding and climate funding (NAMAs and CDM) can be mobilized to co-finance the development of building standards and codes). 2.2.2 Provide funding to cover indirect costs for data management, awareness-raising campaigns, RD&D and training.

	Actions	Short description
		2.2.3 Determine financing schemes (grants or loans) for energy efficient buildings based on the type of stakeholders (owner based or tenant based) and also determine suitable financial schemes with banks or responsible bodies to alleviate the high upfront costs.
	2.3 Determine compliance and evaluation methodologies and indicators	2.3.1 Determine indicators and methodologies to be used for compliance checking (compliance checking methodologies include the review of plans and calculations and on-site field inspections with compliance checklists). 2.3.2 Carry out ex-ante evaluations to project the identified energy and resource savings and cost-effectiveness (bigEE, 2013) i.e. conduct evaluations by national but also local authorities prior to the national or regional evaluation of code implementation to better understand local needs and challenges.
	2.4 Involve stakeholders and market actors	2.4.1 Organize a public hearing process before the adoption of the new building standards or codes by the regulatory body that co-ordinates the government bodies and market players and help to address the fragmentation challenges of the building sector, raise awareness of energy issues among stakeholders and prevent delays in implementation.
Implementation		
3. Raise awareness		
	3.1 Make relevant information accessible to all stakeholders (look at IEA 2010a)	3.1.1 Provide easy access to current/updated information through different media (e.g. television, websites, local authorities' offices and real estate offices) to encourage stakeholders to incorporate standards and codes. 3.1.2 Demonstrate building projects to show the energy and resource saving potentials as well as to highlight their tangible and intangible benefits.
	3.2. Organize awareness-raising campaigns directed at different market actors by local and/or regional agencies	3.2.1 Plan and conduct awareness-raising campaigns to target the industry (including architects, designers, engineers, developers, construction industry, finance experts) and the buildings' final buyers and occupiers, in order to ensure that all market actors clearly understand what building energy and resource saving standards or codes mean (i.e. the benefits) for their professions, the environment and the socio-economic context. 3.2.2 Inform market actors how to implement the standards and codes effectively and also provide information about the enforcement actions the government could take in case of non-compliance. 3.2.3 Inform buildings' end-users/owners or occupiers about the effective use of building technologies (and appliances) and about the impact of usage patterns on the buildings' energy and resource (e.g. water) consumption to help to avoid the rebound effect.

	Actions	Short description
4. Provide training or increase professional capacities		
	4.1 Assess the capabilities of existing professionals (look at IEA 2010a)	4.1.1 Conduct a review of the technical capacity in the existing construction professions. 4.1.2 Understand the necessary types of training (if informal construction practices are common, include the training of labourers as well). 4.1.3 Organize information and training sessions such as workshops, seminars, conferences at both nationally and by facilitating professional participation in international countries to exchange and share ideas and concepts on building technologies and methods.
	4.2 Develop a long term training strategy	4.2.1 Ensure that practitioners understand the implementation of building energy and resource saving codes and the performance of compliance-checking. 4.2.2 Provide technical training for architects, engineers, urban planners, builders, developers, installers, financial advisers and inspectors, and to all other parties involved in the design, construction, renovation and maintenance of buildings. 4.2.3 Also provide non-technical training for an understanding of the holistic approach and integrated design to ensure that these principles become an intrinsic part of the design and operation of buildings. 4.2.4 Include demonstration buildings in the training strategy. 4.2.5 Update university modules on energy and resource saving technologies and approaches
	4.3 Develop training materials and compliance software	4.3.1 Develop training materials, including compliance software (based on the calculation methodology), which are accredited by the government's building or energy department and make these available free of charge to all practitioners.
	4.4 Deliver training on compliance software	4.4.1 Deliver training to all public and private sector actors involved in the design and/or implementation of building standards or codes.
5. Develop necessary tools for compliance - checking and tracking and enforcement		
	5.1 Check compliance at the design and construction stage	5.1.1 Check the designed projects (this can be done either by developers using their own staff or an accredited third party to establish whether they comply with building energy and resource saving code requirements. Review plans, review test reports of construction materials, review calculation assumptions and review thermal calculation results etc). 5.1.2 Visit construction sites randomly several times most importantly during construction and upon completion to inspect whether the buildings are constructed according to the plans

	Actions	Short description
		and the code (review materials (if) substituted in the field, review test reports indicating the approval of the changes and check the proper installation of building equipment).
	5.2 Check compliance prior to occupancy of the building	5.2.1 Check whether each building system performs well and conduct comprehensive commissioning.
	5.3 Check compliance after the building is occupied	5.3.1 Check the usage patterns by metering the energy and water consumption for at least the first two years of occupancy and adjust the heating, cooling, ventilation and lighting systems as relevant; work with end-users on their behaviour.
	5.4 Enforce building standards or codes	5.4.1 Establish an enforcement body to control and oversee the inspector's work (US-DoE, 2010 in IEA and UNDP, 2013). 5.4.2 Appoint an accredited independent third party to avoid conflicts of interest. 5.4.3 Establish the provision of penalties in the case of non-compliance such as fines, demolition and refusal of building occupancy permits or imprisonment (IEA and UNDP, 2013).
	5.5 Track compliance at local level	5.5.1 Develop databases that include all the indicators pre-defined at the planning phase for compliance-tracking. 5.5.2 Use the data collected later by the national co-ordination body at the evaluation phase to ensure that results are prepared objectively and consistently, and also allow for a better understanding of training needs and progress made.
Monitoring phase		
6. Analyse compliance trends		
	6.1 Analyse compliance trends by municipalities at local level	6.1.1 Establish a process to report, aggregate and analyse the compliance rate for each building type at each stage (design, construction, prior to occupancy and when the building is occupied).
7. Communicate compliance results and enforcement actions openly		
	7.1 Communicate compliance trends openly	7.1.1 Publish compliance results and enforcement actions, giving more credibility to governments and local authorities and raising awareness. 7.1.2 Translate energy or resource savings into cost savings that help stakeholders to readily understand the benefits.
	7.2 Encourage public debate on compliance trends by governments and municipalities	7.2.1 Improve compliance trends by communicating compliance and non-compliance rates and subsequent penalties.
8. Generate different metrics and evaluate implementation gaps at national level		
	8.1 Calculate evaluation met-	8.1.1 Carry out ex-post impact evaluation to show the actual impact of the building standards or codes and their effectiveness

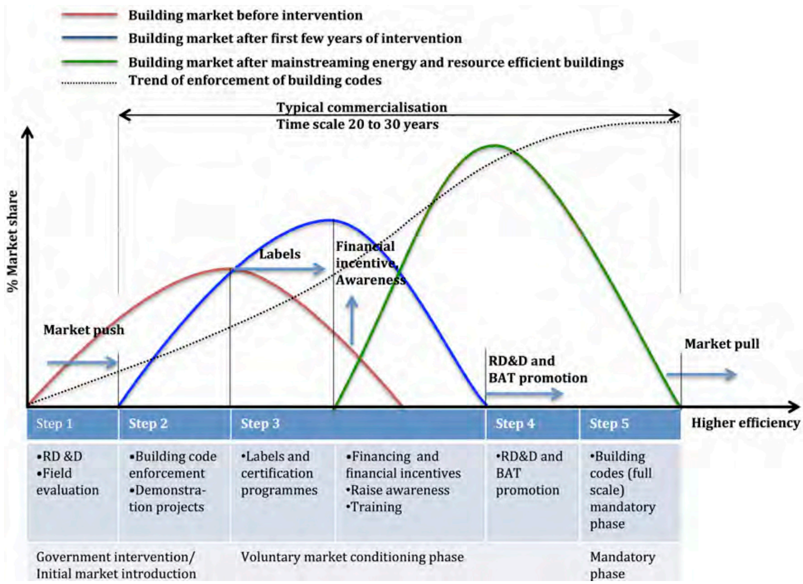
	Actions	Short description
	rics for each building type	in achieving its targets, e.g. are they as effective as anticipated in the ex-ante? (bigEE, 2013). 8.1.2 Include questionnaires and interviews with the implementers of building energy and resource saving codes, and with inspectors and practitioners in the evaluation process, to illustrate the challenges in the field. 8.1.3 Create compliance rates at national level and estimate the energy and resources saved. To achieve this, a national system of evaluation is required to check each individual building and ascertain whether or not it complies with the building codes.
9. Update building energy codes regularly based on lessons learned from the evaluation		
	9.1 Use evaluation results for the next revision of the code	9.1.1 Update building codes on a regular basis (usually every three to five years) to ensure that they are aligned with international best practices and technological developments (with RD&D development of efficient solutions).

Note: Concept for Steps and Actions are adapted from IEA and UNDP, 2013

11.1.3 Steps showing how policies interact for market transformation

After the development of building codes, full scale enforcement takes time (around 2 to 3 decades) and requires considerable effort. As explained in chapter 9 section 9.4.3, to increase the market share of energy and resource efficient buildings with mandatory code enforcement and to prevent the construction of inefficient (energy and resource consuming) buildings, supportive policies (i.e. the labelling programmes (e.g. Energy Performance Certificates or green building certification systems)) and incentives (loans and grants etc.) play a vital role. RD&D and BAT promotion help to drive towards the development of higher efficiency buildings (bigEE, 2013). Figure 45 shows the steps and the trends of enforcement of building codes, along with the effect of market transformation, due to mandatory codes, voluntary labels and other incentive policies. The concept for the steps is adapted from the following studies: bigEE (2013a), p.4 and IEA (2013), p.219. The steps described are those best suited to the market introduction and transformation of energy and resource efficient building codes in developing countries through various actions (related to the policy elements). Full-scale incorporation typically takes around 2 to 3 decades to achieve, while it can take 1 to 1.5 decades in the case of accelerated commercialisation.

In step 1, government intervention is required at the early development phase i.e. for research and development (R&D) of energy and resource efficient buildings. This includes the research of effective technologies to suit the climate and local conditions, which reduces the need to invest in cutting-edge innovative technologies. Performance validation is carried out through field evaluation to check whether the design is acceptable (environmentally, socially and economically). In step 2, prescriptive or performance based energy and resource efficient building standards or codes are formed and enforced, and these are initially introduced to the market through demonstration projects. In this phase, the market will be limited to early adopters, but they play a vital role in promoting energy and resource efficient buildings to higher levels of market penetration. The red curve in Figure 45 shows the building market before intervention. But after step 2, the curve shifts a bit towards higher efficiency buildings and cuts off the “dirty ends” of inefficient buildings (start of the blue curve).



Adapted from bigEE, 2013a and IEA, 2013, p.220

Figure 45. Interaction of policies for market transformation

Once the energy and resource efficient buildings have established a basic market presence through mandatory codes, market incentives to encourage necessary growth in market share can be enhanced by voluntary labels/certification systems. The combination of voluntary and mandatory standards in the market will enhance the development of more efficient and innovative technologies and increase the share of energy and resource efficient buildings (step 3). The introduction of other supportive policies, such as financing (supporting investors), financial incentives (loans and grants etc.) and information actions (awareness-raising, education and training for building professionals (and non-professionals)) in combination with voluntary labels and mandatory standards, increases the market share of energy and resource efficient buildings as in the blue curve in Figure 45 (which shows the trend of the building market after the first few years of intervention). After this phase, step 4, with innovation support through

R&D funding and BAT promotion (such as demonstration projects (e.g. public buildings) and award competitions), and step 5, with the full-scale incorporation of mandatory energy and resource saving building codes, increase the market share of energy and resource efficient buildings. This pushes the market conditions towards the development of higher energy and resource efficient buildings as in the green curve in Figure 45 (which shows the building market after mainstreaming energy and resource efficient buildings).

11.2 Case for a developing country- Nepal

To illustrate the case in a developing country I have chosen Nepal, which is my home country and where there is huge potential to save energy and resources in the building sector. In addition to that, the technologies and policies for such buildings are in a nascent phase (i.e. there are currently no national building standards or labels for energy and resource efficient buildings). This section aims to highlight the need to introduce technologies and policies for energy and resource efficient buildings or green buildings in Nepal, while simultaneously understanding the resource/environmental problems the country faces. Recommendations are made on technologies and policy options that could alleviate resource and environmental problems and improve the quality of both the built environment and the social and economic situation.

11.2.1 Country's background

11.2.1.1 Topography and climate variation

Nepal, located in southern Asia (between India and China) in a sub-tropical zone, covers an area of 147,181km2 (i.e. equal to 0.3% of the land area of Asia and 0.03% of the global land area). Although the average width (north to south) of Nepal is 193km and the average length (east to west) is 885km, the country has a wide variety of topography and climate, broadly corresponding to the altitudes that range from 60 metres above sea level to 8,848 metres. The northern Himalayan region has a cold climate (mean temperature <10°C), the middle hilly region has a temperate climate (mean temperature 10-20°C) and the lowland plain of the Terai region has a warm and humid climate (mean temperature >20°C) (CBS, 2011).

11.2.1.2 Population (growth) and land encroachment

According to the Population Census 2011, the total population of Nepal is 26.5 million with an annual growth rate of 1.35% per annum. The middle hilly and lowland plain regions of Nepal are the most populated, in comparison with the mountainous region. Although the rural population is higher than the urban population, urbanisation is growing at a faster rate (Central Bureau Statistics [CBS], 2011). Kathmandu, the capital city of Nepal, has the highest rate of population growth (4% per year (The World Bank Group, 2013). Looking at the Kathmandu valley, the population density in 2001 was 2,739 per sq.km. in Kathmandu, 877 per sq.km. in Lalitpur and 1,895 per sq.km. in Bhaktapur (CBS, 2011). The urban area in the valley increased from 3% in 1967 to 13% in 2000 and, correspondingly, the shrubs and forestlands decreased from 43% to 25% (Thapa & Murayama, 2009 in Shrestha, 2011). This caused the transformation of fertile agricultural land into urban land and the shrubs and forestlands into agricultural land in the surrounding rural areas (Shrestha, 2011).

The main reason for this population growth is rural to urban migration (due to pull factors – the economic development of the city relative to the countryside and the concentration of the country's political and administrative centre – and the push factor – the displacement of a large number of people due to conflicts in the rural areas) (Shrestha, 2011). This migration has created the demand for a large number of new buildings (some of which are constructed by the informal sector). In Kathmandu alone the number of new apartments in 2007 rose from 1,088 to 3,385. Due to weak governance, including ineffective planning and land management, the conditions have worsened (Shrestha, 2011).

As most of the land is in private ownership, the government has little influence except over the provision of infrastructure (which is also inadequate due to poor planning). Fertile agricultural lands in the city are 'voluntarily' converted into (sold as) new plots for building construction because of the lure of the high land price in the city, or 'forcefully' sold because of the degradation of the land due to water pollution and solid waste. This has led to the need to import a vast quantity of food (90%), which threatens food security in the city (Shrestha, 2011), and has also resulted in haphazard urban planning. Therefore, in order to stop the further degradation of (fertile/useful) land with inefficient building construction (a situation that unprecedented population growth has exacerbated), especially in the cities in the Kathmandu valley, the development of green buildings, combined with conscious land management, is a solution. This solution also reduces the over exploitation of natural resources, conserves the environment and raises the quality of the built environment.

11.2.1.3 Resource problems

Nepal faces two main environmental challenges – problems due to the pressure on natural resources (including air and water pollution) and pressure generated by climate change (CBS, 2011). The increase in the construction of (inefficient) new buildings, especially in the cities, has aggravated the effect.

Water problems (quantity and quality)

Although Nepal is rich in water resources, the country suffers from economic water scarcity (i.e. it is unable to extract or use the available water efficiently). The rivers in Nepal are not only the source of water for drinking and for other daily purposes, but are also the source of hydropower. Due to seasonal variations, the shortfall in water supply occurs more often in the dry season (in winter) than in the rainy season, resulting in power shortages and a lack of sufficient water to meet daily demand (in terms of both quantity and quality). Population increase in urban areas, especially in the Kathmandu valley, has worsened water scarcity as the municipal water supplies are inadequate for meeting the increased water demand. The surface water supply is not sufficient, therefore groundwater is extracted (over-exploited) from shallow, deep and dug wells by different users (e.g. private companies/individuals, hotels, households, government institutions and embassies etc.), which disturbs the groundwater recharge, lowers the groundwater levels and raises concern about risks of land subsidence in an area with highly compressible clay and silt layers (Pradhanang, Shrestha & Steenhuis, 2012). The quality of the urban water is mostly polluted, due to untreated municipal sewage that impacts on the shallow aquifers (Kannel, Lee, Kanel, Khan & Lee, 2007 in Pradhanang, Shrestha & Steenhuis, 2012). Building design with a focus on water efficiency strategies is required in order to address current water related problems and prevent further water scarcity.

Energy

In 2011, Nepal had a per capita energy consumption (total primary energy supply) of 14.2GJ (i.e. 0.34 toe (tonnes of oil equivalent)), which is far less than the world's average per capita (76.6 GJ (i.e. 1.88 toe)) (IEA, 2013a and K.C., Khanal, Shrestha & Lamsal, 2011). Of the total energy consumption, the share of traditional sources (fuel wood, crop residues and animal dung) accounts for 87.1% (mostly consumed in the rural sector), while the share of commercial sources (petroleum products, coal and electricity) is 12.2% (mostly consumed in the urban sector). Other renewable sources account for 0.7% (MoF 2009 in K.C. et al., 2011). This illustrates the difference in the energy consumption patterns in rural and urban areas of Nepal. With regards to the different sectors (residential, commercial, transportation, agricultural and others), the rate of their energy consumption is growing each year and the share of energy consumption in the residential buildings sector is the highest (CBS, 2011) (Table 29 in Annex 3 illustrates the increase in energy consumption in various sectors). Compared to the national average, urban residents (especially residents in the Kathmandu valley) use three times as much commercial energy per capita (i.e. seven times as much electricity per capita). The energy use for cooking in residential buildings is dominant in comparison with end use energy (for lighting and electric appliances). Despite the low share of end use energy, demand for energy (over the next 30 years) is projected to grow at 5.1% per year for lighting and 5.4% per year for electrical appliances in urban residential buildings, and about 1.5% per year each in rural residential buildings (Malla, 2013).

Nepal does not have significant reserves of fossil fuel; all petroleum products and over 75% of coal are imported from its neighbouring country, India (Malla, 2013). The growing dependency on imports, coupled with rising fuel prices on the international market, has impacted on the fragile economy of the country. Although Nepal has huge potential for using hydropower (about 83,000 Megawatts, of which 42,000 Megawatts of power generation is economically and technically achievable (Shrestha, 1966)), only 2% of this potential has been harnessed (due to political instability, lack of capital investment and lack of effective treaties among co-riparian countries for sharing the costs and benefits of large scale hydroelectricity projects) (K.C., Khanal, Shrestha & Lamsal, 2011). The electricity supply from the reservoir based hydropower plants during peak demand is minimal, resulting in load-shedding of up to 16 hours/day during the dry (winter) season. As the electricity supply is lower than the demand, it is difficult to determine the true per capita demand for electricity (although in 2010 Nepal's per capita electricity consumption was less than 4% of the world average (Malla, 2013)). Although energy security, which refers to the uninterrupted availability of energy sources at an affordable price (IEA, 2013b), is an important issue in Nepal - energy is not given significant attention in national policy debate. The government provides subsidies (directly and indirectly) for the importing of fossil fuels and this has increased the use of imported fuels rather than focusing on renewable options (K.C., Khanal, Shrestha & Lamsal, 2011).

Therefore, energy efficiency is an important issue in Nepal and efficiency in the operational energy use in the building sector can be addressed through energy optimisation (especially by incorporating passive options into building design), energy saving options and the use of renewable energy technologies. Energy from building materials can also be reduced through the selection of low embodied energy materials.

Building materials

The most common contemporary building materials in Nepal are brick, cement, concrete and timber. Brick and cement are the most commonly used construction materials and their production is considered to be one of the main industries in Nepal's construction sector. Most of the conventional building materials produced in Nepal have high embodied energy and a high emission rate due to the production process, the type of energy used and the place of import. Some new and energy efficient building materials (e.g. Vertical Shaft Brick Kiln (VSBK), hollow and solid bricks, stabilised compressed earthen blocks and solid/hollow concrete blocks) are slowly being introduced in Nepal, but they need some time, support and awareness to replace the conventional materials.

Bricks are the primary construction material in most parts of Nepal (especially in the Kathmandu valley and in the southern Terai region) and about 575 brick kilns are in operation in Nepal. Nepalese brick kilns use mainly coal (~96%), which is mostly imported from Assam in India, for production, with a small fraction of sawdust/firewood (~2%) and electricity (~2%). There are basically two types of brick industries – machine made bricks and handmade bricks. Conventional brick production is through natural draft systems or bull trench kilns (BTKs), which consume and emit high levels of energy. In comparison, the newly introduced energy efficient brick production technology – Vertical Shaft Brick Kilns (VSBKs) (a CDM project) – consumes 30% to 40% less energy and produces 30% to 40% less CO_2 emissions (EEC/FNCCi, 2014a). The conversion of all the brick kilns in Nepal to VSBK has the energy saving potential of 1.6 million tCO_2e/year in 2018 (Dhakal and Raut 2010) and would significantly reduce coal imports and the country's trade deficit with India (EEC/FNCCi 2014a). Likewise, cement is one of the main construction materials in Nepal and there are about 59 cement industries registered in the private sector. Nepalese cement industries use mainly thermal (coal) (91%) and electricity (9%) during production. The limestone based cement industry is one of the highest energy intensive industrial sectors in Nepal, followed by clinker based cement industries (EEC/FNCCi, 2014b). These cement industries do, however, have GHG reduction potentials; firstly by reducing the amount of clinker used by mixing in other substances such as fly ash and, secondly, by reducing the amount of coal by supplementing renewable energy sources such as rice husks. Some CDM projects have been suggested as ways of tackling these issues and its study report shows that the use of 10% rice husks for clinker production and blending 10% supplementary cementing materials to produce Portland Pozzolana Cement (PPC) could avoid 210,974 tCO_2e in 10 years (Dhakal & Raut, 2010).

In addition, other alternative energy efficient and environmental friendly building materials, such as Compressed Stabilised Earth Blocks (CSEB), solid/hollow concrete blocks and efficient brick bonding approaches (e.g. rattrap bonding), are slowly being introduced in Nepal. Although they hold less embodied energy, they have not gained as much popularity as clay bricks yet and their acceptance will require further awareness-raising and demonstration projects. More research is also required for the introduction of new building materials (preferably eco-friendly and cost-effective) to improve thermal comfort in the buildings. Moreover, the reuse and recycling of building materials should be practiced in Nepal.

Pollution (air pollution and river pollution)

Pollution is one of the major issues in Nepal (especially in urban areas such as in the Kathmandu valley) and it has presented serious health issues. Air pollution is triggered by the increasing number of (inefficient) vehicles/lack of transportation management (exacerbated by inadequate and poor public transport) and the poor state of (dusty) roads (worsened by the lack of greenery/parks and unmanaged road construction/maintenance). Similarly, pollution due to unmanaged waste (solid waste and sewerage) has added challenges to the urban environment. The segregation of household waste (mostly organic waste as opposed to plastics, glass and others) is still not well practiced in Nepal and municipal solid waste (mixed with medical and hazardous waste) is usually dumped in semi-aerobic landfill sites (e.g. Sisdol in the Kathmandu valley), polluting air and water (groundwater through leachate). Organic household composting, community composting and recycling has been initiated, but these practices have not yet been fully adopted. Various research has been carried out to instigate a pioneering project to generate electricity from the waste produced by the Kathmandu valley, but such a project has not yet been realised. Likewise, due to the lack of proper wastewater management in the municipalities in Nepal, serious issues are ignored, such as grey and black water being mixed together and subsequently drained into rivers and brooks, which pollutes groundwater and surface water. The use and emptying of sceptic tanks also requires proper regulation. Therefore, building design in Nepal should consider proper planning to reduce the need for large numbers of vehicles and should include waste management systems (conserve, recycle and reuse) in buildings and in their surroundings.

11.2.1.4 Climatic properties and thermal comfort of the Kathmandu Valley

Climate zone

The Kathmandu Valley, at an altitude of 1,337 metres, lies in a temperate zone that experiences all four seasons: spring, summer, autumn and winter. According to the air temperature throughout the year, the summer season in the valley is from May until July, with an average maximum temperature of 31°C. Winter lasts from November to January and has an average minimum temperature of -0.8°C. Autumn is from August until October, with an average temperature of 21.39°C and spring, from February to April, has an average temperature of 15.56°C.

Position of the sun

As the latitude of the valley is 27.7° north, the sun's angle at different times of the year are 62.3° (i.e. 90° - 27.7°) for Equinox (March 21 and September 22), 85.8° (i.e. 62.3° + 23.5°) for Summer solstice (June 22) and 38.8° (i.e. 62.3° - 23.5°) for Winter solstice (December 22) (McGee, 2013). This calculation of sun's angle helps to determine projection of horizontal shadings to allow the winter sun but block the summer sun, that allows solar heating and cooling.

Air temperature

Air temperature indicates a diurnal variation of the lowest temperature just before sunrise and the highest temperature in the afternoon (Achard and Gicquel, 1986). It helps to show whether a building requires heating or cooling based on the comfort limit of the area. The recorded maximum is 31°C and minimum is -0.8°C (SWERA, 2009), which indicates the requirement for both cooling and heating systems in the valley's buildings.

Humidity and precipitation

In the Kathmandu Valley, the maximum average relative humidity (RH) is in July, at around 80% (SWERA, 2009). Similarly, the maximum average monthly precipitation (about 403mm) occurs in July and the minimum in December (about 3.43mm) (DHM, 2009). Therefore, the buildings in the Kathmandu valley need measures to protect them from high precipitation and humidity levels.

Wind

Wind velocity statistics for the Kathmandu Valley indicate a maximum wind speed of 13.4 metres per second in May in a southeast direction. However, most wind during the year comes from westerly, northwesterly and southwesterly directions (SWERA, 2009). Building designs for the Kathmandu valley must consider these wind directions and speeds in order to control or use them for natural ventilation and passive cooling.

Degree days

Heating Degree Days (HDD) (relating to the number of days that heating is required in a building) and Cooling Degree Days (CDD) (relating to the number of days that cooling is required in a building) are 569 and 333 respectively for the Kathmandu Valley (BizEE Software, 2013) (taking 17°C as the baseline temperature, 20.5°C as the lower comfort limit with a 3.5°C internal heat gain and clothing adjustment for HDD and taking 24°C as the baseline temperature, 27.5°C as the lower comfort limit with a 3.5°C internal heat gain and clothing adjustment for CDD). Overall, the climate data for the valley shows that buildings need heating, cooling and rain protection.

Thermal comfort limit

Based on a straightforward equation according to Lippsmeier (1980), if a comfort zone decreases by 1°C per 14° increase in latitude, considering the base comfort zone for equatorial conditions to have an upper limit of 29.5°C and a lower limit of 22.5°C, the comfort zone for the Kathmandu Valley would be 27.53°C (upper limit) and 20.53°C (lower limit).

According to a study by Rijal, Yoshida & Umemiya (2010), the indoor neutral temperature in the Kathmandu valley is 25.6°C in summer and 15.2°C in winter. The study conducted research on a traditional house in Bhaktapur (one of the three municipalities in the Kathmandu valley) where the differences in summer and winter in terms of temperature, clothing insulation and wind velocity are 13.8°K, o.58clo and -0.01m/s respectively.

11.2.1.5 National building codes and emerging voluntary initiation for green buildings

Currently, Nepal only has a mandatory national building standard for designing earthquake resistant structures, which was developed by the Department of Urban Development and Building Construction under the Ministry of Physical Planning and Works. The National Building Codes of Nepal are implemented as per the ‘Building Act: 1998’ which comprises 23 volumes for Design Requirements, Material Specifications, Guidelines, Architectural, Electrical and Sanitary Requirements and Safety Requirements for new construction (the codes were introduced in 1994 and some of the volumes were updated in 2003). To date, no standards or labels exist in Nepal for energy efficient or green buildings.

Looking back to the history of building regulations in various countries, these were originally initiated in response to disasters (such as fire, epidemics and earthquakes). Therefore, the first building regulations were concerned with construction, fire safety, and occupants' health. Concern about buildings' thermal conditions was initiated in response to health problems caused by poor insulation in countries with cold climates (mostly in developed countries). Later, in response to the oil crisis and the need to reduce oil dependency (in most developed countries), building energy codes were developed to reduce the need to import energy for buildings (IEA and UNDP, 2013). In the 1990s, concerns about climate change led to the development of more stringent energy requirements for buildings (IEA and UNDP, 2013) and, in addition, moves were made to address resource scarcity and a lack of resource security through the promotion of green buildings.

Therefore, in the Nepalese context, the National Building Code of Nepal 2003 is the first and only enforced set of building regulations in Nepal. However, the thermal conditions of conventional modern buildings are generally poor, which affects the health and productivity of occupants and increases the requirement for active technologies to achieve the comfort level. Insufficient/ineffective building elements (e.g. walls: often 230mm single brick walls with cement plaster and glazing: often single glazed and lack of/ inadequate insulation) and ignorance of climate responsive design has worsened the situation. The resource problems in the country have already been mentioned in section 11.2.1.3. These exemplify the need for new building regulations in Nepal, preferably leapfrogging towards energy and resource efficient building standards/codes (rather than following the slower trend, as adopted by most countries, of first developing building regulations).

To address this, Nepal is in the process of developing building guidelines (which, in turn, will become labels or standards) that will address the problems of energy and resource scarcity in the country and will protect/reduce further damage to the environment. The building guidelines will also help to improve the country's economy (through the creation of a green economy). Some of these initiatives are being instigated by:

- The Department of Urban Development and Building Construction, Kathmandu, Nepal under the Ministry of Physical Planning and Works, with their research report on 'The Preparation of Guidelines & Norms/Standards of Green Building Technology'
- UN Habitat (in collaboration with the European Union under SWITCH Asia), with their three year project (2013-2015) 'Green Homes: the Sustainable Housing' (in cities).

Energy and resource problems are accepted as an important issue in Nepal and their devastating effects are visible in various parts of the country (e.g. major cause/effect in urban areas such as the Kathmandu valley). Energy and resource efficient buildings not only help to save the environment (or stop further degradation), but also help in the socio- economic development of the country. Developing countries (such as Nepal) can benefit from huge socio-economic benefits (see chapter 7, section 7.1) including the creation of a green economy. However, until now there has been little effort to construct such buildings and the main reasons could be the lack of public policy to stimulate energy (and resource) efficiency, limited governmental efforts to regulate the building industry and a conservative building industry (Ryghaug & Sørensen, 2009). Nepal requires the adoption of new energy and resource efficient building technologies (to replace the conventional ones) in the building industry. To achieve this, new and effective policies, better regulations and the reform of building practices in the industry will be necessary (Ryghaug & Sørensen, 2009). In the following section 11.2.2, a brief overview is given of the technological approaches to energy and resource efficient buildings in the Kathmandu valley, which could help to develop building standards or labels in Nepal.

11.2.2 Technologocal options for energy and resource efficient buildings in the Kathmandu Valley

Various BATs are available worldwide, from simple to complex systems, which can result in huge reductions in energy and resources. However, considering the background information in section 11.2.1 about Nepal and Kathmandu along with the opportunity for the country to build energy efficient and green buildings but has a relatively limited availability of building technologies in the country, an easy efficiency approach is recommended. This approach focuses on low energy buildings to provide a comfortable indoor environment, concentrating on passive strategies which take advantages of natural sources of heating and cooling such as sun and wind, and cost-effective and efficient active building technologies. The simple and easily applied technologies, which have the potential to improve both the built environment and the social conditions in the Kathmandu valley, are described in this section in tabular form (see Table 22). Chapter 5 section 5.3 listed and described the criteria for energy efficient and green buildings; these are adapted here and described in the context of the Kathmandu valley.

Table 22. Technological options for energy and resource efficient buildings in the Kathmandu valley

Criteria 1: Energy efficiency
Energy optimisation
• Use building energy simulation tools to calculate maximum heat gain options. • Use tools (e.g. bioclimatic charts, Mahoney table) to establish the comfort limits and thermal transmittance, and an effective solution.
Building form
• Calculate the optimum surface to area ratios. The larger the building surface compared to the internal space (surface to volume ratio), the greater the heat loss or gain through heat transfer (Olgyay, 1992). • Proper room planning for utilising solar insolation.

Orientation

- Design buildings so that the longer side has a south orientation (or 20° east of south) to maximize passive heating in the winter by using the westerly wind and minimize overheating on the west side.
- North side to receive fairly constant and indirect daylight.

Building envelope (technologies)

- Calculate the thermal transmittance of walls, slabs and roof to control heat exchange.
- The thermal performance of the building envelope in traditional buildings in the Kathmandu valley is better than that of conventional buildings (with indoor temperature 1-2°C warmer and cooler in winter and summer respectively due to thermal mass compared to conventional modern buildings (Bajracharya & Tiwari, 2013)). Therefore look for alternative wall material to a conventional brick wall e.g. CSEB wall).
- Green roof and façade can act as a buffer for extreme thermal conditions.
- Achieve air tightness value of 1.0h or less to minimize air infiltration (bigEE, 2014).

Passive cooling with shading (protect from excessive solar radiation)

- Study sun path diagram to design optimum shading designs.
- Horizontal shading projection can be calculated taking into consideration of sun's angle (see Position of sun in section 11.2.1.4). Sun path charts allow to create sun angle for the whole year (UO, 2008). Depending upon the height of the façade to be shaded (A) and considering a vertical shadow angle of 74° to shade summer sun on April at 1200 for the Kathmandu valley, the projection of horizontal shading device should be 0.28A to protect from strong summer rays and rain but to allow for winter sun. To prevent heat loss from the top of the openings that are shaded by the projection, the top of the openings should be placed at 30% of the height of the opening from the sill level to the shading device, which also enhances horizontal air flow (for an illustration, see Figure 61 in Annex 3
- Fixed vertical shading - with reference to the solar chart of the Kathmandu valley, suitable shading angle on east and west side is 45° horizontal angle for April conditions.
- Shade ground with trees (preferably deciduous trees).

Passive cooling with natural ventilation

- Design with temperature gradient effect (stack effect) or wind pressure effect.
- Cross-ventilation with air outlet larger than inlet for good air movement. Horizontal cross ventilation through openings in the inner walls and vertically through stack effect with openings in the inner walls and on the top of the buildings to enhance air movement.

Passive air-conditioning with earth air tunnel system

- Use undisturbed earth temperature to heat or cool the building through the tunnel (Kaushik, Lal, & Bhargava, 2013). The air temperature in the earth tunnel remains almost constant throughout the year, which helps to cool the buildings in summer and warm them in winter.

Overshadowing

- Plan the space between the buildings so there is enough space for solar gain in winter and for a cool breeze to reach openings in summer.
- Calculate the shadow length and buildings' spacing: consider the month of December with the longest shadow length so that if building height is 'x', a.m. and p.m. shadow length is '2.4x' (and the sun angle is 23.9°), and noon shadow is '1.2x' (and the sun angle is 38.8°)

Mechanical ventilation/thermal controls

- Use mechanical controls (fans, air-conditioning and heating systems) in extreme cases (when thermal comfort cannot be achieved through passive strategies).
- Select fan forced ventilations with maximum flow per given wattage.
- Select HVAC with efficient energy recovery ventilators to reduce the ventilation load on the system (bigEE, 2014), with energy efficient water-cooled condensers in place of air-cooled condensers and with intelligent building automation and controls using sensors and actuators (EEC/FNCCI, 2014).
- Set/change HVAC comfort level in relation to outdoor temperature and humidity, and according to the acceptance level of the occupant.
- Select the heating system depending on various factors such as occupancy, comfort levels, rate of heat loss, internal heat gains, how airtight the building is and the combination of heat generation, supply and distribution to avoid oversizing the system (which leads to energy wastage) (bigEE, 2014).

Artificial lighting

- Use efficient lighting systems such as compact fluorescent lamps (CFLs) or light-emitting diodes (LEDs) in place of incandescent lamps.

Design lighting requirements according to the need in the rooms to avoid unnecessary and overuse of energy.

Renewable energy (including solar energy for domestic hot water)

Renewable energy technologies

- Install solar photo-voltaic (PV) panels (possible locations are on non-shaded spaces over terraces, on balcony roofs, on the ground and on walls below window sills) with the angle of tilt equal to the geographic latitude minus 15° in winter and plus 15° in summer (to gain maximum power output).
- If possible use advanced renewable energy technologies such as small scale wind turbines with helical structures, Combined Heating Cooling and Power (CHCP) systems, biomass or biogas based energy generation.

Domestic hot water production

- Install solar water heating systems e.g. flat plate collectors on the roof for hot water, with the angle of tilt as for solar PV panels to increase the efficiency of the collectors.

Criteria 2: Atmosphere
Environmental impact reduction
Ozone depleting material • Use materials (refrigerants in HVAC and insulating materials etc.) that are free from CFCs and HCFCs (both of which are ozone depleting substances).
Criteria 3: Water efficiency
Water reuse/recycle
Grey water • Treat grey water to reuse it for toilet flushing, horticulture, floor cleaning etc. **Rainwater harvesting** • This is a good technology for tackling water scarcity in Nepal especially in the Kathmandu valley as the precipitation levels are high (maximum in June-August). • Collect rainwater from the catchment area on the roof or on the ground, sent it to storage tanks (below or above ground) and either recharge it when the ground-water table is low or use it when the groundwater table is high. • Multiple buildings on one site can have a common rainwater harvesting system.
Water conservation
Water saving technologies • Conserve excessive/unnecessary water flow through efficient dual flush toilets and urinals, showerheads and taps (through control valves and the correct pressure flow). • Use home compost (to retain water in the soil) and collect rainwater in the garden.
Water quality
Drinking water quality from supply/source • Ensure extra water filtration for the municipal water supplied to the buildings (as it is not directly drinkable) and for groundwater supply. • Carry out water quality tests and select the appropriate water treatment method e.g. water filter tanks. **Drinking water quality during storage** • Use storage tanks made of non-contaminating materials to store water supplied by the municipality or pumped from the ground (as a direct system from supply to tap is not available). • Clean the storage tank periodically.
Criteria 4: Site/Location/Transport
Site selection
Proper land use (reuse) • Avoid disturbing/damaging land with specific use such as agricultural fields, wetlands and heritage areas by constructing buildings (i.e. build under proper

planned zones citing specific use and without violating the environment).
- Select brownfield areas rather than undeveloped sites.

Utilize site features

- Select south, south easterly and south westerly slopes for the buildings' orientation (in the case of a sloping site).
- Locate/orient buildings respecting the wind direction to take advantage of natural ventilation.

Community connectivity and eco-friendly transportation

- Select sites where basic amenities (shops and community facilities etc.) are in close proximity and within walking distance for ease and to reduce transportation use.
- Develop open spaces (e.g. parks) for social interaction and recreational activities.
- Include pedestrian-friendly paths, bicycle paths and bicycle parking spaces on the site to encourage eco-friendly means of transportation (gradually these can be developed across the neighbourhood to the cityscape).
- Encourage the use of fuel efficient and non-polluting vehicles to reduce pollution from transportation.

Soil protection/ conservation

- Maintain existing trees and vegetation as much as possible or plant greenery to prevent the removal of the top fertile layer of soil (the vegetation also functions as shading and reduces excessive heat gain in summer).
- Preserve top-soil from degradation and reduce soil pollution and erosion caused by construction.

Heat island effect (microclimate)

Vegetation and paving options

- Increase vegetative areas to reduce air temperature through evapotranspiration and the shading effect.
- Reduce hard paved surfaces using interlocking blocks or pervious paving instead.

Roofs

- Design green roofs or terrace gardens.
- Design cool roofs with high solar reflectance or albedo.

Source control

- Control excess water flow through green roofs.
- Design infiltration structures to return water to the ground such as pervious pavements, dry wells and infiltration trenches.
- Design structures to store water (e.g. water butts and rainwater tanks).
- Design structures to decrease flow rates (e.g. swales and filter strips) and allow for the settlement of sediment particles.

Waste water treatment

- Install a dual plumbing system to separate grey water and black water.

Waste water treatment technologies

- Anaerobic waste treatment (for smaller sites): design septic tanks.
- Decentralized Wastewater Treatment Systems (DEWATS) (for bigger sites): provide primary, secondary and tertiary treatment for wastewater through sedimentation, anaerobic digestion, aerobic and facultative decomposition and post treatment (waste can also provide a renewable energy source for biogas) (Gutterer, Sasse, Panzerbieter & Reckerzügel, 2009).

Light pollution

- Remove discomfort due to excessive light reflection by restricting light

Criteria 5: Indoor environment quality

Air quality

- Enhance air quality naturally in buildings by increasing air movement through pressure gradient effects (temperature gradient effect and wind effect).
- Provide cross-ventilation for efficient air circulation and remove the stagnant air.
- Provide indoor comfort with good air quality through HVAC (but only if really needed after optimization of the building envelope as well as natural ventilation and passive cooling).
- Determine the appropriate ventilation rate, apply a good air filter and make timely checks on the ductwork to maintain good air quality.

Visual comfort

- Design all the rooms with appropriate daylight.
- Avoid daylight obstructing structures inside or outside the building.
- Arrange appropriate lighting levels according to the required task in the room.

Thermal comfort

- Design the building to achieve an appropriate indoor thermal comfort level on temperature and relative humidity etc. through passive design strategies (natural ventilation, proper orientation and thermal mass etc.) as far as possible.
- If and when these are needed, set the active technologies (fans and HVAC) to the comfort range according to the building type and room usage.
- Set or change the required level of HVAC according to the outdoor conditions (rather than maintaining the same level for summer and winter) to avoid temperature shock.
- Avoid temperature settings that are too low or too high, which cause discomfort to the occupants.

Acoustic comfort

- Use suitable wall materials to avoid sound nuisance within the rooms or from outside noise.

Smoke control

- Avoid smoking inside the building
- Provide a smoke ventilation system (natural/mechanical ventilation) in the

building.

- Avoid building near a smoke generating area.
- Design a good fire escape route in the building and for Nepal/the Kathmandu valley follow NBC 1994 or the latest code for 'provisional recommendations on fire safety'.

Hygiene/ Chemical control

- Select internal finishes i.e. paints and adhesives with lower or zero levels of Volatile Organic Compounds (VOCs) so that they have a less negative effect on human health.

Criteria 6: Material efficiency

Resource efficiency/low embodied energy

Material extraction and production

- Use materials that cause minimum environmental damage during extraction i.e. encourage sustainable mining.
- Use materials that are produced with low environmental impact or low embodied energy i.e. Vertical Shaft Brick Kiln (VSBK) bricks or Compressed Stabilized Earth Blocks (CSEB), rather than conventional bricks produced in inefficient kilns, for walls and use fly ash in cement production.
- Encourage the use of locally produced materials to reduce transportation energy.

Material reuse/ recycle

- Use waste glass to remanufacture glass.
- Use marble chips to manufacture terrazzo.

Waste management

Household waste

- Separate/sort bio-degradable waste, plastic, papers, hazardous waste and other waste into separate waste bins before collection, which helps to reduce landfill.
- Reuse and recycle the separated waste as far as possible.

Construction waste

- Reduce construction waste (e.g. by proper room or space sizing according to the size of the products, minimizing cutting waste), and use recyclable products as much as possible.
- Reuse construction waste (e.g. doors and windows in good condition can be used for other buildings).
- Recycle construction waste (e.g. use demolition waste for road construction).

The easy efficiency approach selected in this section is a kick-starter and a basic requirement for constructing energy and resource efficient buildings in the valley; it can be used as a guideline for introducing a standard for energy and resource efficient buildings. Additionally, in terms of the building standard, a deeper study (based on calculations) is required on (i) the definition of the baseline of the criteria and sub-criteria to the levels suitable for Nepal or the Kathmandu valley and on (ii) cost-effective buildings and technological options with lower LCCA.

11.2.3 Policy package development for Nepal

Based on the understanding of (i) designing policy packages for developing countries (section 11.1) and (ii) Nepal's context in the built environment and the need for energy and resource efficient buildings in the Kathmandu valley (sections 11.2.1 and 11.2.2), this section recommends a policy package development for Nepal – explained in a tabular form (Table 23). Looking at the current status quo of various policy elements, Table 23 indicates which of them are (i) "ongoing" (i.e. policy elements that are already being considered and are in the process of development) or (ii) "to be considered" (i.e. policy elements that have not yet been considered but should be developed in future).

Table 23. Policy package recommendation for Nepal

	Country driven actions	Status quo
1. Governance Framework		
1.1. Targets and planning		
	Government to set targets for clean environment and efficient buildings • Energy (main focus): emphasize energy security and eliminate energy poverty in a few years, as well as reducing energy imports and as IEA (2013) suggests, develop a strategy combining (i) energy sufficiency, (ii) energy efficiency and (iii) renewables. Develop a concrete target for energy efficiency in buildings (reaching NZEB) for new buildings within 20-30 years). • Water: ensure a sufficient and clean water supply along with an emphasis on water efficiency. • Materials: encourage the local production of building materials (with low GHG emissions/environmental impact). • Pollution: control air pollution through transport management (proper infrastructure) and river pollution through waste water management.	Ongoing
	Develop and strengthen the political support for resilient green buildings • Help to avoid major failure to develop and implement building energy resource codes due to the lack of indigenous technical, institu-	Ongoing

	Country driven actions	Status quo
	tional, and market capacities (Liu et al., 2010). • Form multilateral development institutions (MDis) or provide bilateral assistance to increase knowledge and awareness of the critical issues, practical solutions and cost benefit implications of promoting energy (and resource) efficiency within the country of Nepal (Liu et al., 2010). • Encourage in-depth research on cost-effective and environmentally-friendly and disaster resilient design strategies and options suitable for Nepal.	
1.2. Infrastructure and funding		
	Organization in charge • Use Department of Urban Development and Building Construction (DUDBC), a governmental organization in Nepal or form a new organization to manage suitable infrastructure to develop resilient green building i.e. to coordinate projects, provide information, advice, training and demonstration projects (starting with government/public buildings).	Ongoing
	International technical and financial support • South-South Cooperation, a key mechanism for the development agenda of countries in the south (defined broadly as the exchange of knowledge, best practices, technical support, human resources and trade and policy advice between developing countries). Government plays a major role, which involves public and private institutions, non-governmental organizations and individuals. The range of services (e.g. United Nations Environmental Programme's (UNEP's) South-South Cooperation) include specialized data support, policy advice, technical backstopping support, training and related capacity development, expert input including tools and methodologies, outreach materials and mechanisms for information sharing (UNEP 2011). South-South Cooperation presents a tremendous opportunity for Nepal to learn about and share energy and resource efficient building technologies and options with other countries.	Ongoing
	• International financing such as the Global Environmental Facility (GEF) can be an important source for the development and implementation of building codes that support national code development, pilots and demonstration projects (Liu et al., 2010).	
	• Climate finance actions such as Nationally Appropriate Mitigation Actions (NAMAs), i.e. activities intended to reduce GHG emissions, are carried out by a developing country that is not subject to mitigation commitments under the UNFCCC. It is supported by industrialized countries through financing, technology transfer and/or capacity building (de Carmen Rivero Arias et al., 2013). Currently Mexico	To be considered

	Country driven actions	Status quo
	has undertaken successful NAMAs for sustainable housing (with the objectives of extending the penetration of basic efficiency standards to the entire new housing market in Mexico and of upgrading efficiency standards to more ambitious levels) (NAMA Database, 2011). A NAMA project for energy and resource efficient buildings in Nepal could be developed to benefit from climate financing.	
1.3. Eliminate distortion		
	Remove high energy price subsidies • Although the current energy subsidies help, to some extent, to secure the energy supply to private households and commercial sectors in Nepal by providing them with economic benefits, in the long run these subsidies need to be removed (gradually/stepwise) with the simultaneous introduction and strengthening of energy efficiency.	To be considered
2. Specific policies		
2.1. Regulations		
	Establish energy and resource efficient standards or codes • Define minimum baseline levels for different criteria such as energy efficiency, water efficiency and material efficiency etc. • Start with a voluntary approach and move towards mandatory standards in the long run, and strengthen these over time (in three to five years). • Form a prescriptive standard approach at an early stage (as this is an easy and effective approach) and move towards an overall performance standard approach in the long run (once the standard matures). • Develop building standards suitable to the local conditions, with particular emphasis on passive strategies and the relevant supporting architectural designs such as appropriate building orientation, shading and natural ventilation etc., and then focus on efficient active strategies. • Look for the potential and viability of producing materials and components required to comply with the codes domestically, and develop market strategies to increase their supply and assure the quality of such products domestically or at regional level (Liu et al., 2010). • Develop suitable technological options (as discussed in Table 22 for the Kathmandu valley)	To be considered
	Effective compliance and enforcement • Simplify the building laws (formulate these in such a way that non-professionals can also follow and understand them); streamline the permit process and make it more user-friendly and predictable (e.g. India) (Liu et al., 2010).	To be considered

	Country driven actions	Status quo
	• Introduce penalties and fines in cases of non-compliance. • Involve non-governmental organizations or third party services to strengthen compliance and effective infrastructure (Liu et al., 2010).	
2.2. Transparency and information		
	Establish energy and resource efficient building labels/green building labels • Voluntary labels create competition in the building sector and provide market transformative incentives for efficient buildings. • Baseline levels should be equal to or above the minimum requirement levels of standards or codes.	To be considered
	Building energy performance disclosure • Give building owners and users information on building energy consumption, cost savings, benefits (tangible and intangible). • Collect data on energy performance through energy metering, monitoring and evaluation.	To be considered
	Information dissemination • Raise awareness about resilient green buildings through information campaigns (in conferences, workshops, on TV and on websites), using demonstration buildings as convincing examples.	Ongoing
2.3. Incentives and financing		
	Provide financial incentives • Provide financial support to promote the uptake of building technologies and appliances e.g. efficient lighting systems – CFLs, LEDs and solar photo-voltaic panels etc.	Ongoing
	• Provide loans and grants for buildings that prove to be energy and resource efficient (incentives depend on the extent of code compliance, the level of certification gained and life cycle cost-effectiveness) and structurally safe. • Target the market segment (type of buildings) where economic benefits are greatest and enforcement is most likely to succeed (e.g. commercial buildings).	To be considered
2.4. Capacity building and networking		
	Increase technical capacity (training and assistance) • National level commitment and involvement for establishing and sustaining systematic programmes to educate a new generation of architects and engineers, train professionals, inform the public, disseminate good practices and standardize procedures (through conferences, workshops and university modules) (Liu et al., 2010). • International assistance programmed into nationally orchestrated capacity building programmes is likely to have greater systematic impact and value (Liu et al., 2010), e.g. exchange programmes between professionals and university students.	Ongoing

	Country driven actions	Status quo
2.5. RD & D/ BAT promotion		
	Present demonstration projects • Start with public and government buildings e.g. a Zero Energy House in the Institute of Engineering where energy generation in the building equals the energy consumption throughout the year through Building Integrated Photovoltaic Electrification System (BIPVES), Building Energy Management and HVAC system, Earth-Air-Tunnel, Micro Hydro Power Plant, Solar Hot Water System, Solar Kitchen and Biogas Plant etc. (Center of Energy Studies, 2006) • Demonstration of efficient wall components such as Rat Trap Bonding and CSEB bricks. • Demonstrate structural seismic resistance through various methods such as earthquake shake table • Demonstrate improved comfort and net economic benefit to the relevant types of investors; for this purpose, a set of demonstration buildings covering all important regions and/or climate zones of the country will be the most effective.	Ongoing

12 Conclusions and further research

12.1 Conclusions

Buildings are responsible for considerable adverse environmental impacts. Through the careful design of buildings to incorporate energy efficiency and green aspects, significant amounts of energy and resources can be saved and lock-in effects from inefficient buildings can be avoided.

This dissertation provides an overview not only of energy efficient and green building technologies, together with their environmental, social and economic benefits, but also gives an insight into their relevant policy framework in some developed and developing countries. The main studies were conducted in Europe, the USA and India, as well as in other developed and developing countries. The comparison of energy efficient and green buildings based on the building life cycle perspective (in chapter 8) illustrates the importance of accounting for embodied energy in energy efficient buildings, as the reduction in demand for operational energy is achieved by the increased use of energy intensive materials. The study on policies aimed at increasing the number of efficient buildings in developed and developing countries (these policies being mainly building standards and labels) illustrates the importance of incorporating green aspects in energy efficient buildings and the need for increased stringency of energy efficiency in green buildings (as explained in chapter 10). Most developing countries do not yet have policies for energy and resource efficient buildings (e.g. Nepal), or they are in the nascent phase. This dissertation recommends a policy package, which will foster the planning and construction of energy and resource efficient buildings in developing countries (see chapter 11). The core messages of the dissertation are listed and described below:

1. The risk of building "lock-in" in developed and developing countries

The long lifespan of inefficient buildings results in a significant lock-in risk of high energy use (and CO_2 emissions). The risk increases if the measures to reduce buildings' energy use, such as stringent building energy policies and technology development, are not implemented, both in developed and developing countries. Developed countries, with their proliferation of state-of-the-art building solutions and stringent building energy standards, face a lower lock-in risk than developing countries. As shown in two scenarios – the deep[13] and moderate[14] scenarios of Ürge-Vorsatz et al. (2012a) – the potential reduction by 2050 in final energy use for space heating and cooling and water heating in the EU27 and the USA is 65% and 61% respectively, based on the 2005 reference level. This would reduce the lock-in effect by 15% and 85% respectively. In India, even if the highest energy efficient technologies are adopted, the final energy consumption of buildings could still increase by 131% (due to an almost fivefold increase in new building construction in relation to 2005, higher living standards and a fast growing economy). In this scenario, the much higher (508%) lock-in effect of final energy use would be avoided. This indicates the requirement for energy efficient and green building technologies and policies to replace inefficient buildings (see chapter 2, section 2.1.3).

Opportunities for incorporating energy and resource efficiency in the building sector vary widely between developed and developing countries. Developed countries, with a significant share of old building stock, have started to focus on the green retrofitting of buildings. Developing countries, on the other hand, with their growing trend for new (inefficient) construction systems to cope with rapid demographic growth, have not yet harnessed the potential for new green buildings. Countries embark on green retrofitting or new green construction because it

[13] Deep scenario: a scenario whereby ambitious and appropriate policies for energy efficient and green buildings are quickly implemented as integrated packages
[14] Moderate scenario: a scenario whereby the building policy development continues at the current rate (as of 2005)

makes economic sense to save energy and resources and to reduce GHG emissions. In developing countries in particular, building retrofits are generally more difficult to achieve than efficient new construction, due to technological and economic limitations and the lack of will of the owners. Therefore, if early actions on new green buildings, such as the development and use of technologies and policies, are not taken seriously by those concerned, the outcome for the future will be the need to retrofit a huge number of old inefficient buildings. This will present a massive challenge in developing countries.

2. Incorporate passive and then active design strategies

A building design of the right size (neither oversized nor undersized in relation to the plot; wasting no land or building space), combined with the use of efficient appliances that meet functional need, avoids the unnecessary loss of energy and resources. This describes energy and resource sufficiency. Passive design strategies for achieving energy efficiency, such as proper orientation and insulation and natural ventilation, lead to huge energy and resource savings in the long term at minimum cost. This is technically an easy but a fundamental energy and resource efficiency approach, as described in chapter 5. Additional energy and resource reductions and increased thermal comfort are further achieved through efficient active building technologies, such as solar photovoltaic panels and active ventilation systems. It is not only architects who need to consider this design approach, but also policy makers who must design building codes and standards focusing on this holistic method, with the aim of transforming buildings from being energy consumers to energy producers. The emphasis on building energy codes that focus on energy sufficiency, energy efficiency and also renewable energy is a ‘must’.

3. Green requirements in energy efficient buildings

Energy efficient buildings, as defined, primarily focus on the reduction or elimination of operational energy. Higher energy efficient buildings consume very little energy (as little as zero energy buildings or plus energy buildings). Life Cycle Energy Analyses (LCEA) for passive houses, a particular type of low-energy building, show that the total primary energy reduction can be a factor of three or four fold compared to conventional buildings over an 80 year lifespan. However, this is achieved by the use of conventional materials, which increase the share of embodied energy (Sartori and Hestnes 2007). In higher energy efficient buildings (such as zero energy buildings or plus energy buildings), the share of embodied energy is even higher; energy is embodied in the sophisticated construction materials and energy production and recovery systems required to achieve the operational savings (Dutil et al. 2011). Various case studies also demonstrate the impact of building materials and technologies on energy efficient buildings (see chapter 8, section 8.2). Consequently, energy efficient buildings need to broaden their energy considerations, i.e. to take account not only of operational energy reduction, but also embodied energy. Reductions in embodied energy are achieved through the selection of sustainable energy sources and lower embodied and lower emitting materials (including recycled and reused materials). The impact can also be lowered by considering the environmental cost of building materials and technologies (see chapter 8, section 8.2.4). Energy required for transport to and from energy efficient buildings accounts for an insignificant amount of the overall energy consumed. This can be minimised through proper site location, i.e. close to public or eco-friendly transport links (as shown in the case study in chapter 8, section 8.3). This study, therefore, stresses that green requirements are vital for energy efficient buildings and that this is an important issue to weigh up in the future development/updating of building energy standards and labels.

4. Green buildings with higher energy efficiency

In green building design, as defined, the reduction of energy (operational and embodied) is prioritised over other aspects, although all other environmental aspects related to the built environment are also considered. In some cases, despite there being an energy efficiency baseline, a higher rating awarded by a green building certification system does not indicate increased energy efficiency. As green building certification systems are an overall performance based system and offer options for adjusting points from different criteria, buildings with relatively low energy efficiency levels can achieve a high rating. For example: upto 35% LEED certified buildings actually use more energy than comparable non-LEED buildings (Newsham et al., 2009). Expert opinion agrees, however, that green buildings with low energy efficiency levels will only receive a low rating. In conclusion, green building certification will only become more effective when the stringency of energy standards is higher (as explained in chapter 10, section 10.4). Additionally, its effectiveness increases when the whole building life cycle assessment (LCA, LCEA and LCCA) is considered. To date, the latest versions (2013/2014) of LEED US and BREEAM UK have incorporated LCA to ensure better environmental, economic and social performance.

5. Green building certification systems and criteria for rating

The study of green building certification systems (in chapter 10, section 10.4) showed that the criteria and sub-criteria differ widely according to the country and its current standard/baseline; technological acceptance and affordability for the population and their behaviour; and local conditions, climate and infrastructure. Similarly, when a certification system is transferred to another country (e.g. LEED US to LEED India), the criteria must be modified to be appropriate for local conditions, rather than just replicating the original criteria. As a result, the variations in the ratings of the different criteria (e.g. energy, water and materials) in green building certification systems determine the country's priorities for energy and resource savings. The study on the present trends in the development of certification systems also shows that criteria stringency has, to some extent, increased in updated versions in some countries. Those countries at an early stage of development of green building certification systems, for example Nepal, need to set the minimum baseline for the different criteria at an appropriate level for the country's context and issue regular updates (normally every 4-5 years), making the criteria gradually more stringent.

6. When a green building certification goes international

When a certification system goes international and when a country has more than one certification system (e.g. GRIHA and LEED India in India), confusion arises regarding which one to select. An evaluation of certification systems for their quality assurance is required to distinguish them from each other, based on the stringency of the criteria, environmentally friendly factors in the given country/location and social acceptance levels. Without this kind of evaluation, people tend to select the system that they believe to be the most prestigious and internationally acclaimed, without fully analysing its suitability (as discussed in chapter 10, section 10.4).

7. Socio-economic benefits outweigh upfront costs

Despite the huge environmental benefits, stakeholders (including government authorities, investors and owners) are reluctant to invest in energy efficient and green buildings, missing their full opportunities and benefits. One of the reasons for this is the perception that upfront costs are higher in comparison with conventional buildings. Some of the studies (in chapter 7) indicate that upfront costs for certified green buildings can be even up to 7% higher and the cost increase is relative to the rating level in the USA (LEED) and the UK (BREEAM) (CB Richard Ellis, 2009) (i.e. the higher the rating, the greater the increase in costs). These upfront costs are generally due to the design, construction and application of necessary technologies and sophisticated materials. However, the numerous social and economic co-benefits (micro benefits and macro benefits) outweigh the costs. Micro benefits include: higher rental value for the owner or landlord (e.g. up to 17.3% higher for LEED certified buildings and 8.6% for Energy Star buildings in the USA (Wiley et al. 2010)) and higher sale values (e.g. energy consumption that is 10% lower equates to a 1% sale value increase in the USA (Eichholtz et al. 2010b)), as well as the guarantee of energy and resource (cost) savings, health benefits and improved reputation for tenants. Macro benefits include job creation due to the demand for efficient technologies, energy and resource security due to greater energy efficiency and the intelligent selection of building materials and technologies, and increased economic activity through the growth of the green economy.

LCCA illustrates the cost-effectiveness of energy efficient and green buildings and highlight the varying payback periods for the increased upfront costs. Some of the case studies examined in the study (in chapter 8, section 8.4) show that cost savings and reductions in a building's carbon footprint due to the incorporation of energy efficient technologies increase in relation to the life span of a building (this was observed within the given study period). The studies also demonstrate that the higher initial costs of some certified green buildings can be paid back in less than 5 years. In addition, increasingly stringent building energy codes, the inclusion of green buildings in building codes, the maturity of the supply chain for green materials/technologies and industries with greater skills for delivering efficient technologies will cause the trend of increased upfront costs to change, resulting ultimately in the reduction/eradication of these additional upfront costs (WGBC, 2013). The elimination of energy price distortions also plays a major role in cost reduction.

8. Drivers, barriers and integrated policy packages

The main driving forces for governmental energy efficiency policies should be to secure the world's energy supply for the long term future, develop a green economy, address climate change and improve social conditions. The collective expert opinion in this study highlights that the main drivers for energy efficient and green buildings in developed countries are the reduction of GHG emissions, while for developing countries the main aims are to achieve energy security and to reduce energy poverty (as explained in chapter 9, section 9.1).

As well as for other reasons, the current over-exploitation of resources and their rapid depletion result in an increase in inefficient building construction. Environmental damage, as well as social and economic losses, are also trigger points that encourage the construction of energy efficient and green buildings. A number of barriers create the energy and resource efficiency gap in different countries and impede actors (such as governments, investors and owners) from making cost-effective investments in energy and resource efficient buildings (Managan et al., 2012). The main barriers are the lack of awareness/information and market failure due to split incentives. Political commitment also plays a role (as explained in chapter 9, section 9.2). Integrated policy design addresses these barriers. Policy instruments such as building codes and standards, mandatory regulatory instruments and voluntary labels, information instruments and financial incentives are the most effective combination. These policies influence the shift towards market transformation, which ultimately results in an increase in the share of energy and resource efficient buildings. As explained in chapter 11, section 11.1.3, enforcing mandatory building codes and standards initially has the effect of preventing the construction of inefficient buildings, which cuts the dirty ends and pushes the building construction market towards higher efficiency. Voluntary labels act as market accelerators to increase competition between manufactures/developers and to stimulate advanced and efficient building systems. Along with labels, financial incentives help to overcome the barrier of upfront costs and increase the market share of higher efficiency buildings. Awareness-raising and training enhances the process and causes the increased adoption of building codes. As is evident from the past experiences of various countries (as mentioned in IEA (2013)) the full-scale enforcement of mandatory building codes takes considerable time (around 2-3 decades) and much effort. Four major steps are involved: planning (defining targets, financing and funding incentives; establishing enforcement schemes), implementation (awareness-raising and training; compliance checking), monitoring (analysing compliance trends and results) and evaluation (ex-post impact evaluation; regular updating of certification systems/building codes) (adapted from IEA and UNDP, 2013). In order to define and adapt effective energy and resource efficient building standards and codes, governments must, among other actions, initiate the framework development, show clear political commitment and long term vision to implement their selected targets in incremental steps and to a formal timetable, and eliminate distortions arising from energy price subsidies (bigEE, 2013) (as explained in chapter 11, section 11.1.2).

9. Lessons to be learnt from developed countries

Most developed countries were early adopters of the introduction and implementation of highly efficient building technologies. Although buildings built around 50 years ago consume high levels of energy, which has directly or indirectly caused environmental damage, buildings that have complied with efficiency codes consume much less energy. The early establishment of mandatory building energy codes and standards (in the 1970s in response to the global oil crisis), which were strengthened stepwise over time to become more stringent, combined with the promotion of competition between voluntary labels, strong governmental support and effective financial incentives are positive lessons to be learnt from developed countries (such as in Germany). The MEPS of European EPBD and Germany's EnEV have regularly been updated and tightened since the 1980s, which has helped to reduce energy inefficient building construction and move towards ultra-low energy buildings. ASHRAE and IECC, in the USA, also have a similar approach, but the energy reduction target is not as high as in Germany, reflecting the difference in supportive policies between the two countries. In general, compliance and enforcement are comparatively higher in developed than in developing countries. There is still a gap between compliance and enforcement in some countries and states due to a lack of knowledge, willingness and effective control mechanisms. Voluntary building energy labels (e.g. EPCs and Passive House standards in Europe and Energy Star and HERS in the USA) have demonstrated and motivated various stakeholders to construct high energy efficient buildings that go beyond the standard baseline, creating socio-economic benefits as well as environmental benefits (as explained in chapter 10, section 10.1).

In some developed countries, which are economically and technologically strong and have strict regulations for different aspects related to buildings, such as energy, water and transport, green building construction is not yet mandatory. Although various green building labels, such as BREEAM and LEED, were introduced in the 1990s (with updated versions issued every 3-7 years) green building construction is still voluntary in the USA and Europe, as well as in other countries (as explained in chapter 10, section 10.4). However, country specific green building labels are being introduced in many countries, including DGNB in Germany, which has been available since 2007. This shows that green buildings will be important in future to make the built environment sustainable. Among various financial incentives, KfW's low interest loans in Germany and the demand-side management programme in the USA, are effective and successful in supporting a growing number of energy efficient buildings in these countries (new build and retrofit) (as explained in chapter 10, section 10.5).

10. Positive steps taken by developing countries

Passive low energy strategies and climate responsive vernacular architecture were successful in old buildings as they used only local materials and the building form and design were adapted to the local need (for example in India and Nepal). However, these approaches are not/cannot be practiced widely and the features are not incorporated into many of the conventional new buildings that are 'springing up' in the rapidly growing sector, as western building styles/designs are often copied. This results in the construction of buildings that are climate unresponsive, thermally uncomfortable and with shorter lifespans. Nevertheless, recognising the increasing scarcity of energy and resources, many developing countries are forced to face up to the need for holistic green buildings. Voluntary green building labels to promote green buildings in India, such as GRIHA and LEED India, are good examples for developing countries, where building energy standards – e.g. ECBC – are still not mandatory for all building types. Although baseline standards for energy and other aspects are not as high as in most developed countries and national financial support is low, the gradual move towards making the standards more stringent and the incorporation of the wider scope of resource saving, are positive developments (as explained in chapter 10). However, to achieve significant success, strategies must be adopted to increase the pace of change.

11. Future consideration for developed and developing countries

For developed countries, broadening and implementing the scope of building energy and resource efficiency is required. This can be better achieved in principle by moving from voluntary green building labels to mandatory standards and by taking embodied energy reduction into account, rather than assessing only the operational energy. The European Commission's Resource Efficiency Roadmap has opened the door to this issue. Similarly, in developing countries, political commitment to energy and resource efficiency and to strengthening the government's vision for long term and sustainable building construction is urgently needed. The incorporation of local knowledge and efficiency technologies has been demonstrated to be effective both socially and economically. Much greater energy and resources savings can be achieved by leapfrogging the development of efficient buildings. This is possible by raising building energy efficiency baselines and creating a favourable environment for green buildings. The next step is to incorporate the higher baselines into revised building standards and provide support in terms of financial and social capacity. Although the approaches might be different in developed and developed countries, further energy and resource reductions are achieved through behavioural changes, such as developing the sufficiency concept and avoiding the rebound effect.

12. How can Nepal introduce energy and resource efficient buildings?

Nepal, similarly to other developing countries, faces the challenge of haphazard urban growth (especially in the Kathmandu Valley), poor infrastructure, scarce resources (such as energy and water) and very weak governmental support. In view of the lack of building energy (and resource) codes, the current trend for most building construction is wholly inefficient – buildings are energy intensive for heating and cooling and provide low levels of thermal comfort, which negatively affect the occupants' health. An effective policy package for energy and resource efficient buildings is essential and, in order to develop this, assistance is required to support action on a national scale and to deal with the challenges. This quote from Schumacher (1973) is true in the context of Nepal – "... [i]t's easier to help those who can help themselves than to help those who cannot help themselves". Nepal requires not only effective technologies, better social awareness/acceptance and affordable options, but also needs the government to be willing to take urgent action on a national scale. Amongst the technological options, passive strategies and cost-effective and efficient active building strategies are the recommended easy and basic approaches. The main national actions include setting a target for clean environmental and efficient buildings and developing and strengthening political support for energy and resource efficient buildings. Financial support can be sought through south-south co-operation and international environmental financing sources. Energy and resource efficient building standards must be formed as soon as possible and these must be updated periodically and gradually strengthened over time. Other necessary policy steps include effective compliance and enforcement, the establishment of competitive building labels, awareness-raising, the provision of financial incentives and the improvement of technical capacity (as explained in chapter 11, section 11.2).

In summary, this dissertation compares energy efficient and green buildings, not only in terms of their technological aspects, but also in terms of their policy context in both developed and developing countries. It concludes that the features of these two concepts should not be seen as contradictory, but rather as complementary measures for broadening energy and resource saving potential. Green buildings reinforced with higher energy efficiency and energy efficient buildings incorporating green requirements are seen as stepping-stones for reaching greater building energy and resource efficiencies. Having learnt lessons from both developed and developing countries, it is now high time to take action to achieve a sustainable built environment and to benefit from the resulting opportunities to save energy and resources.

12.2 Further research

There are two recommended areas of opportunity for further research. The first focuses on the limitations in the available literature analysed in the course of this dissertation. To 'fill in the gaps' in certain areas, further in-depth study is required. The second area of further research includes future studies to broaden the horizons for exploring this topic.

In terms of the first area of additional research, in order to gain further insight into building life cycle perspectives, software tools could be used. Two examples of buildings – one in a developed country and the other in a developing country – could be considered. By using a software tool such as LEGEP with detailed, up-to-date and accurate data, it would be possible to examine the specific effects as well as the reduction potential of embodied energy (and overall energy) in higher energy efficient buildings. In addition, in the case of Nepal, a more in-depth study on possible technologies and building design approaches, using a software tool, is required. To complement this, detailed research on appropriate guidelines for energy and resource efficient buildings in Nepal, which can later form the basis for building standards, is necessary.

The second area of further research deals with broadening the horizon of study from green buildings to integrated green urban and infrastructure planning (mainly considering the potential for an efficient transportation network to and from buildings, as well as for minimising waste and reusing materials related to building use and construction), in order to analyse the potential of the holistic approach to energy and resource reduction. Moreover, as well as examining policy case studies for India, it would be interesting to study other fast growing economies, such as China and Brazil, to understand the steps they have already taken, or need to take, and how to develop and incorporate these further in order to minimise buildings' energy and resources.

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Annex 1

Expert opinion questionnaires sample

A. Questionnaires on the general relationship between energy efficient and green buildings

1. Globally, retrofitting the building stock in developed countries and the rapid construction of new buildings in developing countries seems to be a main difference in the building construction sector/ building industry.
   1.1. Does this difference influence the priorities in the selection of constructing energy efficient and green buildings?
   Please write your opinion (below) in few sentences.

→

   1.2. What do you think are the main driving forces for public and private decisions on energy efficient and green buildings in developed and developing countries?
   Please select suitable option(s) for public and private sectors. Please write the option numbers in priority order for developed and developing countries (e.g. if options 5,1,3… are selected, this means 5 is the top priority and 1 is second and so on). Please give further opinions, if any, under 'others'.

	Driving forces	Public sector	Private sector	Developed countries	Developing countries
1	To reduce climate change and GHG emissions				
2	To reduce high building resource consumption				
3	To meet the demand, due to demographic growth, for high quality and comfortable buildings				
4	To reduce high heating and cooling energy need				
5	To increase energy security and to reduce energy poverty				
6	To respond to high oil and natural gas prices				
7	To profit from business case benefits – productivity gains and utility savings				
8	To gain higher rents and asset values				
9	To attract tenants				
	Others:				

2. In your opinion what are the most important barriers to the market deployment of energy efficient and green buildings?
Please rate following options, '1' being highly influential, '5' being low. Please give further opinions, if any, under 'others'.

Barriers		High←				→Low
		1	2	3	4	5
1	Market failures - *split incentives between owners and tenants, unavailability of efficient equipment*					
2	Economic/financial - *upfront costs, access to financing*					
3	Behavioural and organisational - *ignore saving opportunities, corruption*					
4	Awareness/information - *lack of knowledge on economic benefits*					
5	Political and structural – *difference in economic levels between countries and also people, weak government leadership*					
	Others:					

B. Questionnaires on green buildings and green building certification

3. Green building certification systems include various criteria such as energy efficiency, water efficiency, material efficiency, indoor environment quality, site selection etc.).
   3.1. What are the main reasons for the selection and ranking of those criteria in a certification?
   Please rate following options, '1' being highly influential, '5' being low. Please give further opinions, if any, under 'others'.

Reasons for the selection and ranking of the criteria		High←				→Low
		1	2	3	4	5
1	Geographical location and adaptation to local requirements					
2	Climate conditions					
3	Social or living conditions/behaviour					
4	Technological acceptance and affordability					
5	Country's standard and baseline of each criteria					
	Others:					

   3.2. In some countries baseline energy levels defined in building energy standards have low requirements. As green building certification systems offer options for adjusting points from different criteria, relatively low energy efficiency levels can be certified or receive higher ratings.
      3.2.1. What is your opinion on the value of these certification systems on the comparative evaluation of buildings (within the certification and within a developed or developing country)?

Please select suitable answer(s) and write your further opinion, if any, in 'others'.

1	Minimum requirement levels set in the criteria (e.g. meeting baselines for energy efficiency) are adequate	
2	Those buildings are given low ratings as energy efficiency is an important aspect in green buildings.	
	Others:	

3.2.2. What is your opinion on energy efficiency stringency in green building certification systems?

Please write your opinion (below) in a few sentences.

→

4. Various certification systems are available worldwide such as LEED in the USA (also in Brazil, Canada, India, Mexico, Norway and South Korea etc.), BREEAM in the UK (also in Germany, Netherlands, Norway and Spain), DGNB in Germany (also in Bulgaria, Denmark and Austria etc.) and GRIHA in India.

4.1. How do you see the necessity of the development of different certification systems for different climate zones and adapted to the countries' local conditions?

Please write your opinion (below) in a few sentences.

→

4.2. Some countries have more than one certification system (e.g. GRIHA and LEED India in India). Do you think such competition is necessary or can this create confusion?

Please select suitable answer(s) and write your further opinion, if any, in 'others'.

1	Competition stimulates future improvement in the certification systems	
2	Confusion arises about the ratings awarded by the certification systems	
3	Some buildings are certified for prestige, in which case the internationally acclaimed certification system is chosen	
4	Evaluation of certification systems for their quality assurance is required to distinguish them from each other	
	Others:	

4.3. When a certification system is applied internationally (e.g. LEED of US applied to India - LEED India) adopting local requirements that incorporate different energy standards and other requirements but use the same overall points/ rating, how can their certification level be defined or distinguished?

Please select suitable answer(s) and write your further opinion, if any, in 'others'.

1	The level of certification systems changes according to its adaptation to local requirements, hence the level has to be defined accordingly	
2	Evaluation of certification systems for their quality assurance is required to distinguish them from each other	
3	Adaptation to the local environment is the only solution and the level remains the same	
	Others:	

5. Do you think the effect/acceptance of green building certification systems is higher if it is mandatory?

Please write your opinion (below) in a few sentences.

→

C. Questionnaires on energy efficient buildings (building energy efficiency standards and labels)

6. The level of building energy efficiency standard differs according to the country (e.g. energy standards in Germany are higher than in India). What is your opinion on the reasons (factors) for their variation?

   Please rate the following options, '1' being highly influential, '5' being low. And please write your further opinion, if any, in 'others'.

Factors for variation		High ←				→Low
		1	2	3	4	5
1	Climate (heating/ cooling need)					
2	Technology availability					
3	Economic situation					
4	Local acceptability or need					
5	Overall technological standards					
6	Supportive policy differences					
	Others:					

6.1. Do you see a tendency for the development of more stringent energy standards over time? In what countries or regions?

Please write your opinion (below) in a few sentences.

→

7. In a building life cycle for higher/advanced energy efficient buildings, operational energy use is lower but embodied energy or resources (materials) used in the buildings can be higher due to better insulation and technologies. What is your opinion on considering additional green aspects in such buildings?

Please rate following options, '1' being highly influential, '5' being low. And please write your further opinion, if any, in 'others'.

Green aspects in energy efficient buildings		High←				→Low
		1	2	3	4	5
1	Low embodied energy material					
2	Recycled material					
3	Reused material					
4	Low emissions from building materials (e.g. VOCs)					
	Others:					

D. Questionnaires on the socio-economics of energy efficient and green buildings

8. Although there are numerous social and economic co-benefits of energy efficient and green buildings in their total life cycle, higher upfront costs remain one main barrier for developers. How can this problem be solved?

Please select suitable answer(s) and write your further opinion, if any, in 'others'.

1	Show life cycle cost accounting (LCCA)	
2	Show long term benefits	
3	Proper policy/policy package	
4	Awareness about the co-benefits of low energy buildings	
	Others:	

9. The higher socio-economic benefits are reasons to build energy efficient and green buildings compared to inefficient conventional buildings (with higher life cycle costs). The environmental benefits of green buildings are higher than of energy efficient buildings. How can developers (or stakeholders) be motivated to choose green buildings?

Please rate following options, '1' being highly influential, '5' being low. And please write your further opinion, if any, in 'others'.

Motivations to choose green buildings		High←				→Low
		1	2	3	4	5
1	Raise awareness					
2	Stabilise financial schemes					
3	Set up regulations/appropriate policy					
4	Incentivise by showing prestige with green certification					
5	Impose a cost for environmental and health impacts of efficiency					
	Others:					

10. Is it reasonable to assume that on average, and in the long run (20 years), energy efficient and/or green buildings with higher rents or selling prices will result in greater economic benefits in comparison to BAU (Business As Usual) building standards?

Please write your opinion (below) in a few sentences.

→

E. Questionnaires for policies for energy efficient and green buildings

11. What differences do you see in current building sector policies in developed or developing countries regarding energy efficient and green buildings?

Please rate the influence of the options in developed and developing countries, '1' being highly influential, '5' being low. And please write your further opinion, if any, in 'others'.

Policies for energy efficient and green buildings		Developed countries					Developing countries				
		1	2	3	4	5	1	2	3	4	5
1	Regulatory:										
1.1	(Mandatory) Building codes										
1.2	Energy efficiency obligations (EEOs)										
1.3	Mandatory labelling and certification programmes										
1.4	Mandatory audit programmes										
2	Economic and market based:										
2.1	Energy performance contracting (EPC)										
2.2	Kyoto flexibility mechanism										
2.3	Nationally Appropriate Mitigation Actions (NAMAs)										
3	Fiscal:										
3.1	Capital subsidies, grants, subsidised loans										
3.2	Tax exemptions and reductions										
4	Capacity support, information and voluntary action:										
4.1	Voluntary certification labelling										
4.2	Public leadership programmes										
4.3	Awareness rising, education and information										
	Others:										

12. Many of the successful policy packages can be found in developed countries (e.g. in the USA (San Francisco Green Building Ordnances) and in Germany (KfW support for credit/ loans).

    12.1. What are the decisive steps for developing a good policy for energy efficient and green buildings for emerging/developing countries (where energy efficient or green buildings are in a nascent phase)?

    Please rate the following options, '1' being highly influential, '5' being low. And please write your further opinion, if any, in 'others'.

	Decisive steps for developing a good policy in developing countries	High← 1	2	3	4	→Low 5
1	Develop infrastructure					
2	Increase technical capacity					
3	Strong governmental support					
4	Proper financial schemes					
5	Stable political situation					
6	Raise awareness					
7	Change behaviour					
8	Market transformation - first a voluntary then a mandatory scheme					
9	Show socio-economic (co-) benefits					
	Others:					

List of experts who provided their opinion:

Dr. Christine Lemaitre	Chief Executive Officer, German Sustainable Building Council – DGNB e.V. Website: www.dgnb.de
Dr. James McMahon	Lawrence Berkeley National Laboratory (LBNL), the USA
Prof. Dr. Volker Hartkopf	Professor of Architecture, Director Center for Building Performance and Diagnostics Carnegie Mellon University
Dr. Yamina Saheb	Head, Sustainable Buildings Center International Energy Agency (IEA), France
Maggie Comstock	Policy Analyst LEED- US Green Building Council, the USA
Dr. Sushil Bajracharya	Assistant professor Tribhuvan University, Nepal
Dr. Ing. Peter Mösle	Managing Director, Dress & Sommer Advance Building Technologies GmbH (Member of the presidency of the DGNB) Website: www.dreso.com
Gyanendra Shakya	Architect, Department of Urban Development and Building Construction, Nepal
Prativa Shakya	Lecturer, Khwopa Engineering College, Nepal (Managing Director of Prativa Architects and Associates, Nepal)

Annex 2

Table 24. Features of different versions of the same certification systems for GRIHA, LEED US and BREEAM

	GRIHA (2010)	GRIHA SVA 2.2 (2011)	LEED US (2002)	LEED US (2009)	BREEAM Office (2008)	BREEAM NC (2014)
Basic information						
Origin	India	India	US	US	UK	UK
Established	Nov-07	Nov-07	1998	1998	1990	1990
Total Points	101	52	68	108	115	144
Criteria						
Energy						
Total points	32	21	16	30	24	22
Percentage	31.7	40.4	23.5	27.8	20.9	15.3
Energy Optimisation	14 Optimise energy performance of building within specified comfort limits (partly mandatory) (16 points)	4 Efficient artificial lighting (2 points) 6 Use of energy efficient appliances (3 points)	(EA) Minimum Energy Performance (mandatory) (EA) Optimise Energy Performance (10 points) (EQ) Controllability of systems: Perimeter Spaces (1 point) (EQ) Controllability of systems: Non-Perimeter Spaces (1 point)	(EA) Minimum Energy Performance (mandatory) (EA) Optimise Energy Performance (19 points) (IEQ) Controllability of systems –Lighting (1 point)	Ene 1 Reduction of CO_2 Emissions (mandatory) (15 points) Ene 4 External lighting (1 point) Ene 8 Lifts (2 points) Ene 9 Escalators and travelling walkways (1 point) Hea 6 Lighting zones and controls (1 point) (12 points)	Ene 1 Reduction of energy use and carbon (Mandatory) (12 points) Ene 3 External lighting (1 point) Ene 6 Energy efficient transportation systems (3 points) Ene 8 Energy efficient equipment (2 points) Ene 9 Drying space (1 point)
Points/Percent	16/ 15%	5/9.6%	12/17%	20/18%	20/17%	19/13.2%
Energy optimization (passive design)	13 Optimise building design to reduce the conventional	2 Adopt passive architectural design strategies (4 points)		(IEQ) Daylight and views – Daylight (1 point)	Hea 1 Daylighting	Ene 4 Low carbon design (Passive design) (2 points)

	GRIHA (2010)	GRIHA SVA 2.2 (2011)	LEED US (2002)	LEED US (2009)	BREEAM Office (2008)	BREEAM NC (2014)
	energy demand (mandatory) (8 points)	3 Good fenestration design for reducing direct heat gain and glare while maximizing daylight penetration (6 points) 5 Thermal efficiency of building envelope (points)				
Points/Percent	8/7.9%	12/23.1%		1/0.9%	1/0.9%	2/1.4%
Renewable Energy	6 Enhance outdoor lighting system efficiency and use renewable energy system for meeting outdoor lighting requirement (3 points) 18 Renewable energy utilization (Partly mandatory) (5 points) 19 Renewable energy-based on hot water system (3 points)	7 Use of renewable energy on site (4 points)	(EA) Renewable Energy: 5% (1 point) (EA) Renewable Energy: 10% (1 point) (EA) Renewable Energy: 20% (1ponit) (EA) Green Power (1point)	(EA) On-site Renewable Energy (7points) (EA) Green Power (2 points)	Ene 5 Low and zero carbon technologies (Mandatory) (3 points)	Ene 4 Low carbon design (Low or zero carbon technologies) (1 point)
Points/Percent	8/7.9%	4/7.7%	4/5.9%	9/8.3%	3/2.6%	1/0.7%

	GRIHA (2010)	GRIHA SVA 2.2 (2011)	LEED US (2002)	LEED US (2009)	BREEAM Office (2008)	BREEAM NC (2014)
Atmosphere						
Total points	1	0	1	2	6	6
Percentage	1.0	0.0	1.5	1.9	5.2	4.2
Environmental Impact	27 Minimise ozone depleting substances (Mandatory) (1 point)		(EA) CFC Reduction in HVAC&R Equipment (mandatory) (EA) Ozone Depletion (1 point)	(EA) Fundamental Refrigerant Management (mandatory) (EA) Enhanced Refrigerant Management (2 points)	Pol 1 Refrigerant GWP-Building Services (1 point) Pol 2 Preventing Refrigerant Leaks (2 points) Pol 4 Nox emissions from heating sources (3 points)	Pol 1 Impact of refrigerants (3 ponits) Pol 2 Nox emissions (3 points=
Points/Percent	1/1%		1/1.5%	2/1.9%	6/5.2%	6/4.2%
Water						
Total points	15	9	5	10	7.0	8.0
Percentage	14.9	17.3	7.4	9.3	6.1	5.6
Water Reuse/ Recycling	20 Wastewater treatment (2 points) 21 Water recycle and reuse (including rainwater) (5points)	9 Rainwater harvesting (4 points)	(WE) Water Efficient Landscaping: Reduce by 50% (1 point) (WE) Water Efficient Landscaping: No Potable Use or No Irrigation (1 point) (WE) Innovation Wastewater Technologies (1 point)	(WE) Water Efficient Landscaping (4 points) (WE) Innovative Wastewater Technologies (2 points)	Wat 1 Water Consumption (greywater and/or rainwater reuse) (Mandatory) (1 point)	Wat 1 Water Consumption (greywater and/or rainwater reuse) (Mandatory) (2.5 points)
Points	7/6.9%	4/7.7%	3/4.4%	6/5.6%	1/0.9%	2.5/1.7%
Water conservation	10 Reduce landscape water requirement (3 points) 11 Reduce water use by the building (2 points)	8 Reduction in building and landscape water demand (5 points)	(WE) Water Use Reduction: 20% Reduction (1 point) (WE) Water Use Reduction: 30% Reduction (1 point)	(WE) Water Use Reduction (mandatory) (WE) Water Use Reduction (4 points)	Wat 1 Water Consumption (efficiency in water consuming components) (Mandatory) (2 points) Wat 3 Major leak Detection (1 point)	Wat 1 Water Consumption (efficiency in water consuming components) (Mandatory) (2.5 points)

	GRIHA (2010)	GRIHA SVA 2.2 (2011)	LEED US (2002)	LEED US (2009)	BREEAM Office (2008)	BREEAM NC (2014)
	12 Efficient water use during construction (1 point)				Wat 4 Sanitary Supply Shut Off (1 point)	Wat 3 Water leak detection (2 points) Wat 4 Water efficient equipment (1 point)
Points/Percent	6/5.9%	5/9.6%	2/2.9%	4/3.7%	4/3.5%	5.5/3.8%
Water Quality	28 Ensure water quality (Mandatory) (2 points)				Hea 12 Microbial Contamination (Mandatory) (1 point) Pol 6 Minimizing Watercourse Pollution (1 point)	
Points/Percent	2/2%				2/1.7%	
Site/ Location/ Transportation						
Total points	17	6	14	30	24.0	31.0
Percentage	16.8	11.5	20.6	27.8	20.9	21.5
Site Selection	1 Site Selection (partly mandatory) (1 point)		(SS) Site Selection (1 point) (SS) Brownfield Redevelopment (1 point)	(SS) Site Selection (1 point) (RP) Regional Priority (4 points) (SS) Brownfield Redevelopment (1 point)	LE 1 Reuse of Land (1 point) LE 2 Contaminated Land (1 point) Tra 1 Provision of public Transport (3 points) Tra 2 Proximity to amenities (1 point) Pol 5 Flood Risk (3 points)	LE 1 Site selection (2 points) Tra 2 Proximity to amenities (2 points)
Points	1/1%		2/2.9%	6/5.6%	9/7.8%	4/2.8%
Community connectivity and eco-friendly transportation	7 Plan utilises efficiently and optimise on site circulation efficiency (3 points)		(SS) Development Density (1 point) (SS) Alternative Transportation: Public Transportation Access (1 point)	(SS) Development Density and Community Connectivity (5 points) (SS) Alternative Transportation: Public Transportation Access (6 points)	Tra 3 Cyclist Facilities (2 points) Tra 4 Pedestrian and Cyclist Safety (1point)	Tra 1 Public transport accessibility (6 points) Tra 3 Cyclist facilities (2 points)

	GRIHA (2010)	GRIHA SVA 2.2 (2011)	LEED US (2002)	LEED US (2009)	BREEAM Office (2008)	BREEAM NC (2014)
			(SS) Alternative Transportation: Bicycle Storage & Changing Rooms (1 point) (SS) Alternative Transportation: Alternative Fuel Vehicles (1 point) (SS) Alternative Transportation: Parking Capacity (1 point)	(SS) Alternative Transportation: Bicycle Storage and Changing Rooms (1 point) (SS) Alternative Transportation: Low-Emitting and Fuel-Efficient Vehicles (3 points) (SS) Alternative Transportation: Parking Capacity (2 points)	Tra 5 Travel Plan (1point) Tra 6 Maximum Car Parking Capacity (2 points)	Tra 4 Maximum car parking capacity (2 points) Tra 5 Travel plan (1 point)
Points/Percent	3/3%		5/7.4%	17/15.7%	6/5.2%	11/7.6%
Soil Protection / Conservation	2 Preserve and protect the landscape during construction/compensatory depository forestation (partly mandatory) (5 points) 3 Soil conservation (till post construction (2 points) 4 Design to include existing site features (4 points)		(SS) Reduced Site Disturbance: Protect or Restore Open Space (1 point) (SS) Reduced Site Disturbance: Development Footprint (1 point)	(SS) Construction Activity Pollution Prevention (Mandatory) (SS) Site Development (2 points)	LE 3 Ecological Value of Site and Protection of Ecological Features (1point) LE 4 Mitigating Ecological Impact (Mandatory) (2 points) LE 5 Enhancing site ecology (3 points) LE 6 Long term impact on biodiversity (2 points)	LE 2 Ecological value of site and protection of ecological features (2 points) LE 3 Mitigating impact on existing site ecology (Mandatory) (2 points) LE 4 Enhancing site ecology (4 points) LE 5 Long term impact on biodiversity (2 points)
Points/Percent	11/10.9%		2/2.9%	2/1.9%	8/7%	10/6.9%
Heat Island Effect	5 Reduce hard paving on site and /or provide shaded hard paved surfaces (Partly mandatory) (2 points)	1 Reduce exposed hard paved surface on site and maintain native vegetation cover on site (6	(SS) Heat island effect: Non-Roof (1 point) (SS) Heat island effect: Roof (1 point)	(SS) Heat Island Effect (2 points)		

	GRIHA (2010)	GRIHA SVA 2.2 (2011)	LEED US (2002)	LEED US (2009)	BREEAM Office (2008)	BREEAM NC (2014)
		points)				
Points/Percent	2/2%	6/11.5%	2/2.9%	2/1.9%		
Stormwater Control			(SS) Erosion and Sedimentation Control (Mandatory) (SS) Storm Management: Rate and Quantity (1 point) (SS) Storm Management: Treatment (1 point)	(SS) Stormwater Design		Pol 3 Surface water run off (5 points)
Points/Percent			2/2.9%	2/1.9%		5/3.5%
Light Pollution			(SS) Light pollution Reduction (1 point)	(SS) Light pollution Reduction (1 point)	Pol 7 Reduction of Night Time Light Pollution (1 point)	Pol 4 Reduction of night time light pollution (1 point)
Points/Percent			1/1.5%	1/0.9%	1/0.9%	1/0.7%
Indoor Environment Quality						
Total points	6	0	10	10	10.0	18.0
Percentage	5.9	0.0	14.7	9.3	8.7	12.5
Air quality			(EQ) Minimum Indoor Air Quality Performance (mandatory) (EQ) Ventilation Effectiveness (1 point)	(EQ) Minimum Indoor Air Quality Performance (mandatory) (IEQ) Increased Ventilation (1 point)	Hea 7 Potential for Natural Ventilation (1 point) Hea 8 Indoor Air Quality (1 point)	Hea 2 Indoor air quality (natural ventilation and air pollution control) (3 points)
Points/Percent			1/1.5%	1/0.9%	2/1.7%	3/2.1%
Visual comfort			(EQ) Daylight and views: Daylight 75% of Spaces (1 point) (EQ) Daylight and views: Daylight 90% of Space (1 point)	(IEQ) Daylight and views – View (1 point)	Hea 2 View out (1 point) Hea 3 Glare control (1 point) Hea 5 Internal and external lighting levels (1 point)	Hea 1 Visual comfort (5 points)
Points/Percent			2/2.9%	1/0.9%	3/2.6%	5/3.5%
Acoustic comfort	29 Acceptable outdoor and				Hea 13 Acoustic Performance (1 point)	Hea 5 Acoustic Performance (4 points)

	GRIHA (2010)	GRIHA SVA 2.2 (2011)	LEED US (2002)	LEED US (2009)	BREEAM Office (2008)	BREEAM NC (2014)
	indoor noise level (2 points)				Pol 8 Noise Attenuation (1 point)	Pol 5 Reduction of noise attenuation (1 point)
Points/Percent	2/2%				2/1.7%	5/3.5%
Thermal Comfort			(EQ) Thermal Comfort: Compliance with ASHRAE 55-1992 (1 point) (EQ) Thermal Comfort: Permanent Monitoring System (1 point)	(IEQ) Controllability of systems – Thermal Comfort (1 point) (IEQ) Thermal Comfort (2 points	Hea 10 Thermal Comfort (1 point) Hea 11 Thermal zoning (1 point)	Hea 4 Thermal Comfort (3 points)
Points/Percent			2/2.9%	3/2.8%	2/1.7%	3/2.1%
Smoke Control	30 Tobacco and smoke control (Mandatory) (1 point)		(EQ) Environmental Tobacco Smoke Control (mandatory)	(EQ) Environmental Tobacco Smoke Control (mandatory)		
Points/Percent	1/1%					
Hygiene/ Chemical Control	26 Use of low Volatile Organic Compounds (VOC) paints/ adhesives/ sealants (3 points)		(EQ) Low Emitting Materials: Adhesives & Sealants (1 point) (EQ) Low Emitting Materials: Paints (1 point) (EQ) Low Emitting Materials: Carpet (1 point) (EQ) Low Emitting Materials: Composite Wood (1 point) (EQ) Indoor Chemical and Pollutant Source Control (1poiint)	(EQ) Low-Emitting Materials (4 points) (IEQ) Indoor Chemical and Pollutant Source Control (1 point)	Hea 9 Volatile Organic Compounds (1 point)	Hea 2 Indoor air quality (chemical control) (2 points)
Points/Percent	3/3%		5/7.4%	5/4.6%	1/0.9%	2/1.4%
Materials						
Total points	19	10	13	14	20.0	22.0
Percentage	18.8	19.2	19.1	13.0	17.4	15.3
Material Reuse/ Recycle	25 Resource recovery from waste (2 points)	10 Generate resource from waste (2	(MR) Storage and Collection of Recyclables (mandatory)	(MR) Storage and Collection of Recyclables (mandatory)	Mat 3 Re-Use of Façade (1 point)	Mat 3 Responsible Sourcing of Materials (reused and recycled) (Mandatory) (2

	GRIHA (2010)	GRIHA SVA 2.2 (2011)	LEED US (2002)	LEED US (2009)	BREEAM Office (2008)	BREEAM NC (2014)
		points)	(MR) Building reuse: Maintain 75% of Existing Walls, Floors and Roof (1 point) (MR) Building reuse: Maintain 100% of Existing Walls, Floors and Roof (1 point) (MR) Building reuse: Maintain 100% Shell and 50% Non-Shell (1 point) (MR) Resource Reuse: 5% (1 point) (MR) Resource Reuse: 10% (1 point) (MR) Recycled Content: 5% (post-consumer+1/2 post-industrial) (1 point) (MR) Recycled Content: 10% (post-consumer+1/2 post-industrial) (1 point)	(MR) Building reuse (4 points) (MR) Material Reuse (2 points) (MR) Recycled Content (2 points)	Mat 4 Re-Use of Structure (1 point) Wst 2 Recycled Aggregates (1 point	points) Wst 2 Recycled aggregates (1 point)
Points/Percent	2/2%	2/3.8%	7/10.3%	8/7.4%	3/2.6%	3/2.1%
Waste Management	22 Reduction in waste during construction (1 point) 23 Efficient Waste Segregation (1 point) 24 Storage and disposal of waste (1 point)		(MR) Construction Waste Management: Divert 50% From Landfill (1 point) (MR) Construction Waste Management: Divert 75% From Landfill (1 point)	(MR) Construction Waste Management (2 points)	Mat 7 Designing for Robustness (1 point) Wst 1 Construction Site Waste Management (4 points) Wst 3 Recyclable Waste Storage (1 point) Wst 6 Floor Finishes (1 point)	Mat 5 Designing for durability and resilience (1 point) Wst 1 Construction Waste Management (Mandatory) (4 points) Wst 3 Operational waste (Mandatory) (1 point) Wst 4 Speculative floor and ceiling finishes (1 point) Wst 5 Adaptation to climate change (1 point)
Points/Percent	3/3%		2/2.9%	2/1.9%	7/6.1%	8/5.6%

	GRIHA (2010)	GRIHA SVA 2.2 (2011)	LEED US (2002)	LEED US (2009)	BREEAM Office (2008)	BREEAM NC (2014)
Resource Efficiency/ Low Embodied Energy	15 Utilisation of fly ash in the building structure (6 point) 16 Reduce volume, weight, and time of construction by adopting an efficient technology (e.g. precast systems, ready-mix concrete etc) (4 point) 17 Use low energy material in the interiors (4 point)	11 Reduce embodied energy of building (4 point) 12 Use of low energy materials in interiors (4 points)	(MR) Regional Materials: 20% manufactured regionally (1 point) (MR) Regional Materials: 50% manufactured regionally (1 point) (MR) Rapidly Renewable Materials (1 point) (MR) Certified Wood (1 point)	(MR) Regional Materials (2 points) (MR) Rapidly Renewable Materials (1 point) (MR) Certified Wood (50% of wood based materials (1 point)	Mat 1 Materials Specification (Major Building Elements) (4 points) Mat 2 Hard Landscaping and Boundary Protection (1 point) Mat 5 Responsible Sourcing of Materials (3 points) Mat 6 Insulation (2 points)	Mat 1 Life cycle impacts (6 points) Mat 2 Hard Landscaping and Boundary Protection (1 point) Mat 3 Responsible Sourcing of Materials (sustainable source) (Mandatory) (2 points) Mat 4 Insulation (1 point) Mat 6 Material efficiency (1 point)
Points/Percent	14/13.9%	8/15.4%	4/5.9%	4/3.7%	10/8.7%	11/7.6%
Innovation						
Total points	4	2	4	5	10	10
Percentage	4.0	3.8	5.9	4.6	8.7	6.9
Innovation in design	34 Innovation Points	14 Innovation Points	(IN) Innovation in Design	Innovation in Design	Inn1 Innovation	Inn1 Innovation
Points						
Percentage						
Social aspect						
Total points	3	4	0	0	2	3
Percentage	3.0	7.7	0.0	0.0	1.7	2.1
Safety/ Health and Functional aspect	8 Provide at least the minimum level of sanitation/safety	13 Adoption of green Lifestyle (4 points)			Hea 4 High frequency lighting (Mandatory) (1 point) Man 8 Security (1 point)	Hea 6 Safety and Security (2 points) Wst 6 Functional adaptability (1 point)

	GRIHA (2010)	GRIHA SVA 2.2 (2011)	LEED US (2002)	LEED US (2009)	BREEAM Office (2008)	BREEAM NC (2014)
	facilities for construction workers (Mandatory) (2 points) 31 Provide at least the minimum level of accessibility for persons with disabilities (1 point)					
Points/Percent	3/3%	4/7.7%			2/1.7%	3/2.1%
Economical aspect						
Total points	0	0	0	0	0	4.0
Percentage	0	0	0	0	0	2.8
Life Cycle Cost Saving			(EA) Optimise Energy Performance (+)	(EA) Optimise Energy Performance (+)		Man 2 Life cycle cost and service life planning
Points/Percent						4/2.8%
Management						
Total points	4	0	5	7	12	20
Percentage	4.0	0.0	7.4	6.5	10.4	13.9
Planning quality						Man 1 Project brief and design (4) (Mandatory) (4 points) Man 3 Responsible construction practices (Mandatory) (6 points) Man 5 Aftercare (Mandatory) (3 points)
Points/Percent						13/9.0%
Qualified personnel			(IN) LEED Accredited Professional (1 point)	(IN) LEED Accredited Professional (1 point)	Man 2 Considerate Constructors (Mandatory) (2 points) Inn 1 Innovation (+)	

	GRIHA (2010)	GRIHA SVA 2.2 (2011)	LEED US (2002)	LEED US (2009)	BREEAM Office (2008)	BREEAM NC (2014)
Points/Percent			1/1.5%	1/0.9%	2/1.7%	
Commissioning/Operation and maintenance	33 Operation and maintenance (Mandatory) (2 points)		(EA) Fundamental commissioning and verification (mandatory) (EA) Additional Commissioning (1 point)	(EA) Fundamental commissioning and verification (mandatory) (EA) Enhanced commissioning (2 points)	Man 1 Commissioning (Mandatory) (2points) Man 3 Construction Site Impacts (4 points) Man 4 Building User Guide (Mandatory) (1 point)	Man 4 Commissioning and handover (Mandatory) (4 points)
Points/Percent	2/2%				7/6.1%	4/2.8%
Energy monitoring	32 Audit and Validation (mandatory)		(EA) Measurement and Verification	(EA) Measurement and Verification	Ene 2 Sub-metering of Substantial Energy Uses (Mandatory) (1 point) Ene 3 Sub-metering of High Energy Load and Tenancy Areas (1 point)	Ene 2 Energy monitoring (Mandatory) (2 points)
Points/Percent					2/1.7%	2/1.4%
Water monitoring	32 Audit and Validation (mandatory)				Wat 2 Water Meter (Mandatory) (1 point)	Wat 2 Water monitoring (Mandatory) (1 point)
Points/Percent					1/0.9%	1/0.7%
Air Quality Management	9 Reduce air pollution during construction (Mandatory) (2 points)		(EQ) Carbon Dioxide (CO_2) Monitoring (1 point) (EQ) Construction IAQ Management Plan: During Construction (1 point) (EQ) Construction IAQ Management Plan: During Occupancy (1 point)	(IEQ) Outdoor Air Delivery Monitoring (1 point) (IEQ) Construction IAQ Management Plan (2 points)		
Points/Percent	2/2%		3/4.4%	3/2.8%		

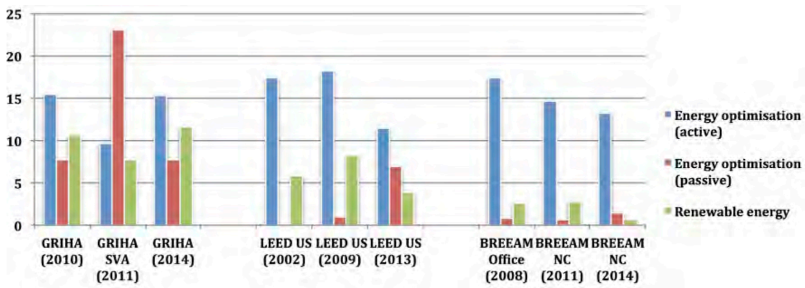


Figure 46. Weightings of energy efficiency sub-criteria in various certification systems with different versions

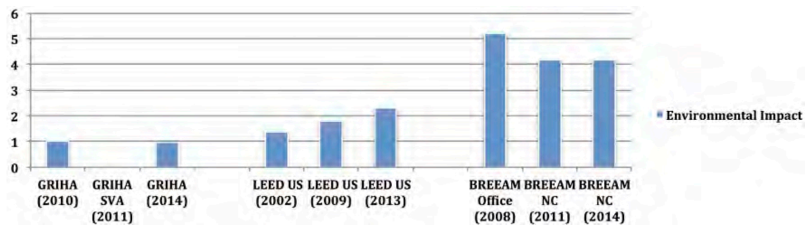


Figure 47. Weightings of atmosphere sub-criteria in various certification systems with different versions

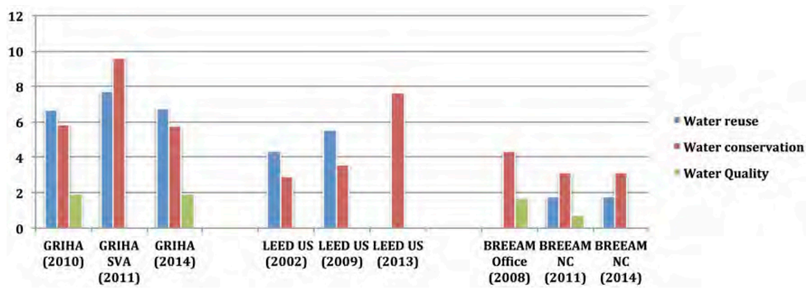


Figure 48. Weightings of water efficiency sub-criteria in various certification systems with different versions

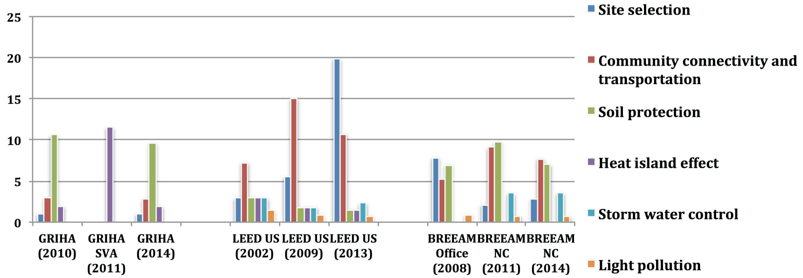


Figure 49. Weightings of site, location and transportation sub-criteria in various certification systems with different versions

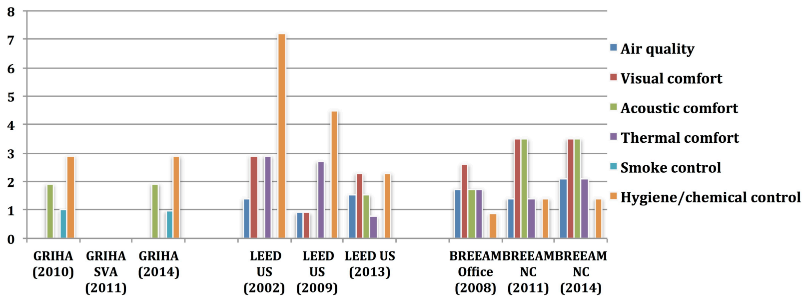


Figure 50. Weightings of indoor environmental quality sub-criteria in various certification systems with different versions

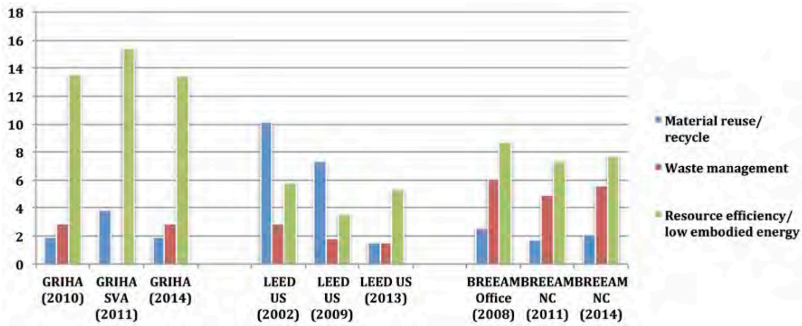


Figure 51. Weightings of material efficiency sub-criteria in various certification systems with different versions

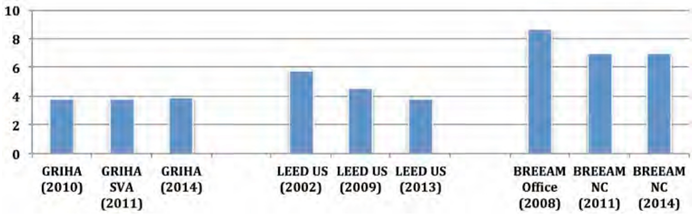


Figure 52. Weightings of innovation sub-criteria in various certification systems with different versions

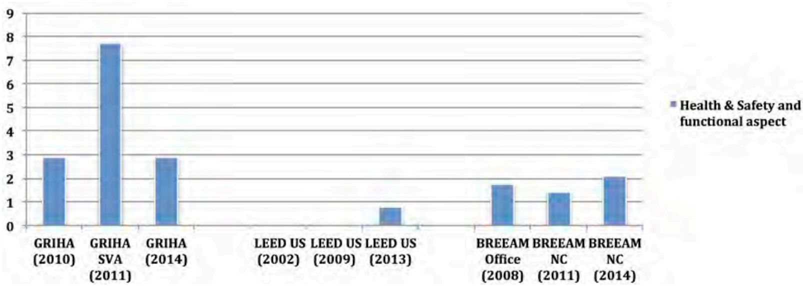


Figure 53. Weightings of social aspect sub-criteria in various certification systems with different versions

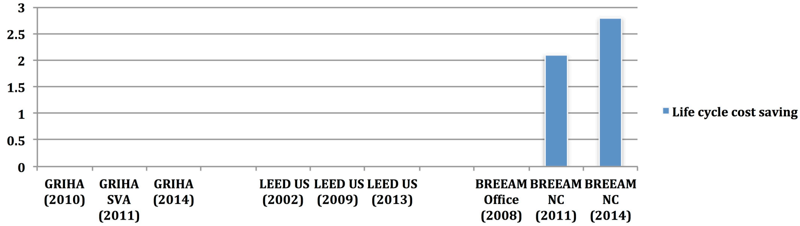


Figure 54. Weightings of economic aspect sub-criteria in various certification systems with different versions

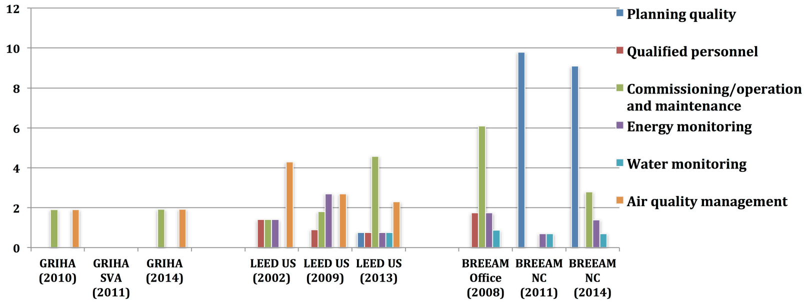


Figure 55. Weightings of management sub-criteria in various certification systems with different versions

Annex 3

Table 25. Renewable energy supply options in NZEB

Option	NZEB options	Examples
Demand-Site option		
Energy strategy	Reduce site energy use through energy efficiency and demand-side renewable building technologies	Daylighting; insulation; passive solar heating; high-efficiency heating, ventilation, and air-conditioning equipment; natural ventilation, evaporative cooling; ground-source heat pumps; ocean water cooling
On-Site options		
1 Renewable Energy generated within the building footprint	Use RE sources available within the building footprint and connected to its electricity or hot/chilled water distribution system	PV, solar hot water, and wind located on the building
2 Renewable Energy generated within the boundry of the building site	Use RE sources available at the building site and connected to its electricity or hot/chilled water distribution system	PV, solar hot water, low-impact hydro, and wind located on parking lots or adjacent open space, but not physically mounted on the building
Off-Site Supply options		
3 Off-site renewable energy used to generate energy on site	Use RE sources available off site to generate energy on site and connected to the building's electricity or hot/chilled water distribution system	Biomass, wood pellets, ethanol, or biodiesel that can be imported from off site, or collected from waste streams from on-site processes that can be used on site to generate electricity and heat
4 Purchase and install renewable energy generated off site	Purchase off-site certified RE sources. Continue to purchase the generation from this new resource to maintain NZEB status	Utility-based wind, PV, emissions credits, or other "green" purchasing options, All off-site purchases must be certified as recently added RE. A building could also negotiate with its power provider to install dedicated wind turbines or PV panels at a site with good solar or wind resources off site. In this approach, the building might own the hardware and receive credits for the power. The power company or a contractor would maintain the hardware.

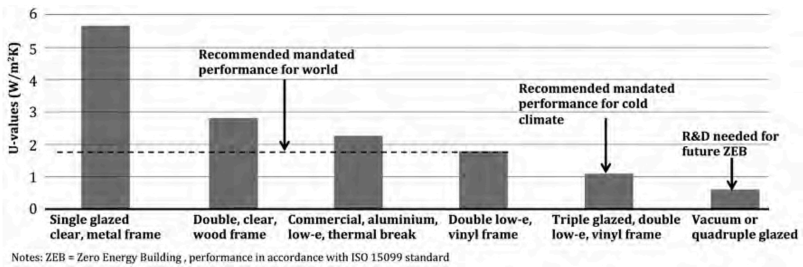


Figure 56. U values of various windows

Table 26. Insulation types, thermal conductivity and typical applications

Thermal performance level	Highest		High	Mid	Low	Application comments
Thermal conductivity	**0**	**0.01**	**0.02**	**0.03**	**0.04**	**0.05**
Vacuum insulated panel (VIP)						Research underway in EU and North America to embed VIPs in EPS or XPS as part of EIFS systems with adhesives to avoid fastener penetrations. High material cost.
Aerogel						For highly constrained space and thermal bridges, such as stud caps. Case studies underway for interior installations with wall board to reduce labor and offer lower systems level cost. High material cost.
Polyurethane boards and spray						Wide applications for value-added performance with space limitations. Roof decking, cathedral roof structures, wall cladding, SIPS, basement, slab edge, and spray foam for cavities also offers air sealing benefits, Moderate price premiums with many cost effective applications.
Extruded polystyrene (XPS)						Wide applications for value-added performance with space limitations, Roof decking, wall cladding, SIPS, basement, slab edge, and also offers air sealing benefits. Moderate price premiums with many cost effective applications.
Eypanded polystyrene (EPS)						Wall cladding and a dominant choice for EIFS, SIPS, ICFs, and interior applications. Moderate price premiums with many cost effective applications.
Glass fiber						Widely used a cavity insulation alone or with spray foam (flash and batt) to offer more affordable but sealed application. Used in attics with less space constrained applications, generally lower cost and lower performing applications.
Stone fiber						Used as cavity and it attics with less space constrained applications, generally lower cost and lower performing applications.
Cellulose						Used a cavity and in attics with less space constrained application, generally lower cost and lower performing applications. New formulations doped with PCM and passed fire rating tests but has very limited market
Wood fiber, flax, hemp, cotton, other						Variety of genrally lower cost and lower performing insulation applications

Notes: W/mK= watts per metre kelvin; EIFS= exterior insulation finish systems; SIPs= structural insulated panels; ICFs= insulated concrete forms; PCM=phase change material source: adapted from EST, 2010

Source: IEA 2013

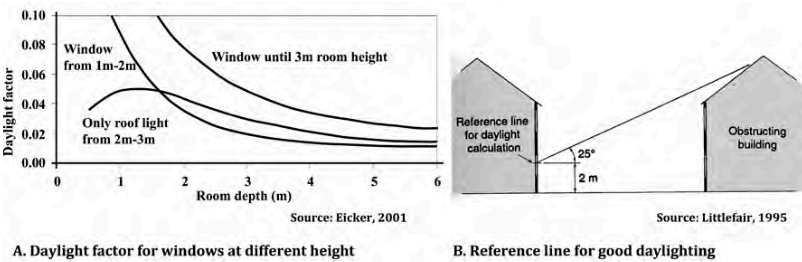
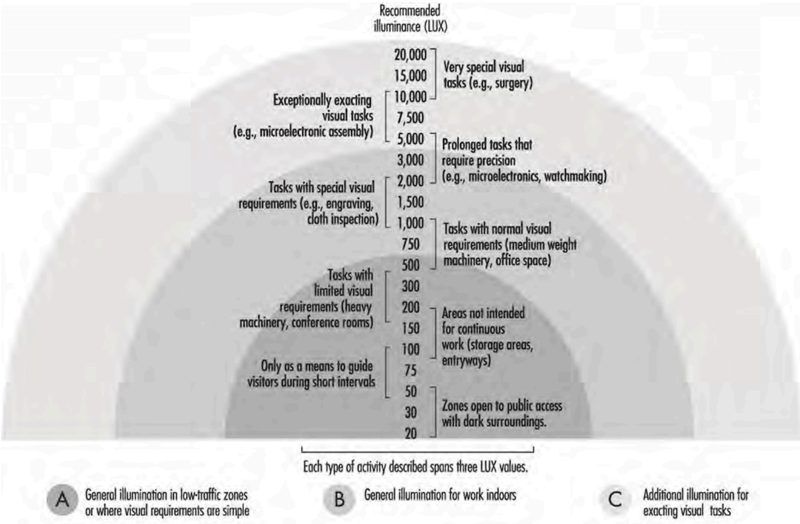


Figure 57. Daylight factor for windows and a reference line for good daylighting

Table 27. Comparison of different shading devices

Type of control	Percentage reduction in total heat gain	Percentage efficiency to ensure cross ventilation	Percentage of natural light resulting from control	Approx. average efficiency as means of control
Curtains	10-20	5-25	30-50	35
Metal venetian blinds	20-30	5-90	50-75	64
Heat resisting glass (coloured)	60	70 (presumed)	40	57
Roof or corridor overhang	75-80	80-100	40	69
Concrete hood and fins	70-80	80-100	45	70
Louvered hood	85	80-100	77	84
Vertical louvres	70-80	10-50	45-65	54
Horizontal louvres	70-80	15-50	45-70	53
Suspended louvres	80-85	80-100	70-80	82

Source: Kukerja 1978



Source: Hernández Calleja & Ramos Pérez, 2011

Figure 58. Levels of illumination as a function of tasks performed

Table 28. Comparison of policy instruments

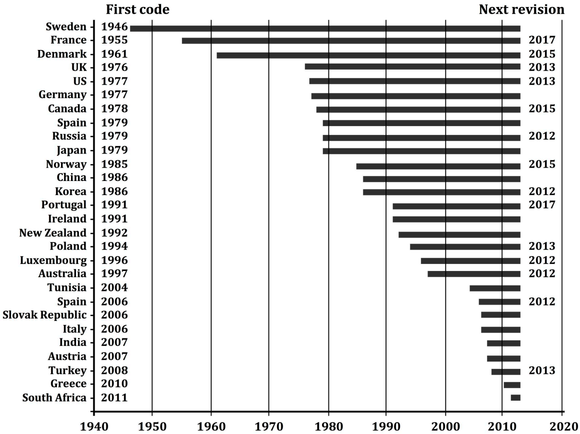
Policy instruments	Cost-effectiveness	Effectiveness	Barriers	Remedies	Advantages	Factor of success
Regulatory and Control mechanism- normative instruments						
Appliance standard	(High) US$65/$tCO_2$ in 2020 (US) US$194/$tCO_2$ in 2020 (EU)	High	No incentives for innovation Rebound effect Problem of enforcement	Combination with informative instruments	Low transaction costs Can change market	Regular update Clear communication Provide quality testing Use 'Top Runner' approach
Building codes	(Medium) US$189/$tCO_2$ to - US$5/$tCO_2$ for end users (Netherlands)	High	Lack of compliance Rebound effect	Regular inspection in combination with incentives	Lowers transaction costs Very effective	Regular update of standards Adaptation to local context Training/ Capacity building Demonstration programs
Procurement regulations	(High/ Medium) US$1 Million in purchases saves $726,000/year (Mexico)	High			Appreciated way to spend tax- payers money	Ambitious energy efficiency specification and regular update Mandatory programs are better Immediate need is positive (energy shortage, high energy prices) High-level political commitment Energy efficient labeling and testing Beginning with simple measures Supporting legal framework and reliance on other policy instruments i.e. labeling
Energy efficiency obligations (EEOs) and quotas	(High) US$139/$tCO_2$ (UK)	High	Rebound effect	Combination with information and incentives	Cheap administration No government expenditure Trigger market transformation Avoid regressive social impacts	Regular updates New energy efficiency measures Government decides on target Use "Top Runner" approach

Policy instruments	Cost-effectiveness	Effectiveness	Barriers	Remedies	Advantages	Factor of success
Regulatory and Control mechanism – informative instruments						
Mandatory certification and labeling	(High) US$30/t$CO_2$ (Australia)	High	Rebound effect Lack of compliance	Combination with other instruments Stakeholder involvement in supervisory systems	Very effective and cost-effective Lead to market transformation	Information and training Use by major economic agents as marketing tool Use as basis for reporting and specifying performance Open-ended labeling, regular revision and updates
Mandatory audit programs	(Medium/ High) US Weatherisation program BC-ration: 2.4	High but variable	No requirement to implement advice of audit Insufficient staff Complex and expensive to administer	Regular audit requirement	Can be positive for ESCOs	Correct implementation and financing Combination with financial incentives High energy price Capacity-building
Utility demand side management programs	(High) US$35/t$CO_2$ (USA) US$255/t$CO_2$ (EU)	High	Restructuring of electricity market	Mandatory charges on electricity prices	Involvement of industry More effective for commercial sector	Combination with regulatory incentives Adaptation to local needs & market research Clear objectives Focus on skills and pilot programs first Strong leadership
Economic and market-based instruments						
Cooperative/ technology procurement	(High/ Medium) US$118/t$CO_2$ saved (USA)	High	Skepticism from buyers & sellers Technical Incompatibilities Lack of funding	Strong interaction between buyers and sellers Secure sufficient Funding		Long-term market commitment and buyer-relationship, active engagement Positive publicity for winner Combination with other benefits for consumers such as noise reduction Combination with standards or labeling Choice of right products with technical and market potential

Policy instruments	Cost-effectiveness	Effectiveness	Barriers	Remedies	Advantages	Factor of success
Energy efficiency certificate/ white certificate schemes	(High/ Medium) US$0.013/kWh expected (France)	Medium	Transaction costs can be high High institutional costs	Existing green certificates schemes Certain degree of self-regulation	Benefits for employment Flexibility for cost-effective compliance	Advanced institutional structures needed Appropriates setting of baseline Good measurement and verification
Kyoto Flexibility Mechanisms	(Low) US$10/t$CO_2$ (Latvia)	Low	High transaction costs	Develop new methodology	It is the only international cooperation instrument directed at developing countries	Project bundling Information & awareness campaigns Link to programmatic CDM/ GIS
Fiscal instruments and incentives						
Energy or carbon taxes	(Low)	Low/ Medium	Low elasticity of demand in many countries	Higher rates of taxes and longer period	Can reinforce other instruments such as VAs Affects whole building life-cycle Revenues can be used for energy efficiency improvements	Levy tax as upstream as possible in supply chain
Tax exemptions and reductions	(High) Benefit/Cost ratio 1:6 for new homes (the USA)	High	Free-rider effect Small size of credits Application to old technologies	Sufficiently high level No early phase-out Apply them to new technologies	Effective for advanced technologies with high first-cost	Pay for results according to performance criteria - Flexibility who receives credit Combination with other instruments
Public benefits charges	(High in reported cases) US$53/t$CO_2$ to	Medium	Misuse of funds by government Inexperienced	Independent administration of funds to avoid	Good mechanism to raise funds for energy efficiency	Involvement of all stakeholders Regular evaluation/ monitoring and programme changes

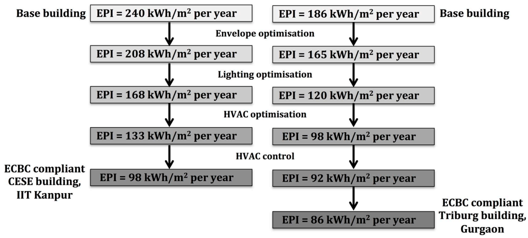
Policy instruments	Cost-effectiveness	Effectiveness	Barriers	Remedies	Advantages	Factor of success
	US$17/$tCO_2$ (the USA)		pro- gram administration Year-to-year decision- ma king	misuse for budget filling Multi-year programs		Team approach with utilities Good communication Simple and clear programme design
Capital subsidies, grants, subsidized loans, rebates	(Low sometimes high) Benefit/Cost ratio 12:1 (Brazil) -US$20/$tCO_2$ (Denmark)	High/ Medium	Risk of free-riders	Limit period of time	Good mechanism if first cost is major barrier	Not to use if penetration rate is already high Limit to short period of time & specific target group
			Lack of awareness	Information provision		
			Rebound effect	Combination with information campaigns		
			Bureaucratic procedures	Simplification of procedures		
Support, information and voluntary action						
Voluntary certification and labeling programs	(High) US$0.01-0.06 kWh (the USA)	Medium/ High	Only labeling of energy efficient models	Mandatory labeling	Good strategy if mandatory labels are not possible	Adaptation to local market Low number of manufacturers is better
			Insufficient testing mechanisms	More testing centers		
				Accepting that saved energy costs may be in- vested into better access to energy services		
Voluntary and negotiated agreements	(Medium)	Medium/ High	Results often below expectations	Combine with threat of regulation	Faster decision and implementation More flexible for companies and more cost-effective to them	Inclusion of most important manufacturers Clear targets Effective monitoring Involve all stakeholders

Policy instruments	Cost-effectiveness	Effectiveness	Barriers	Remedies	Advantages	Factor of success
					Positive for beginning	
Public leadership programs	(High/Medium) US$13.5 billion savings by 2020 (EU) -US$125/t$CO_2$ (Brazil)	Medium/ High	Budgetary constraints	Energy Performance Contracting Mandatory programmes	Tax- payers' money spent in useful way Driver for ESCO-industry	Clearly state, communicate and monitor Adequate funding and staff Involve building managers and experts
Awareness raising, education and information campaigns	(Medium/High) US$8/t$CO_2$ for Energy Trust programs (UK)	Low/ Medium	Too little correspondence between consumers and message	Better research on consumers	Can reinforce long-term effect of other measures	Deliver credible and understandable message Adaptation to audience
Detailed billing and disclosure programs	(Medium)	Medium	Imperfect information First-cost bias Uncertainty about rate of return on investment and about duration at house	Information programs Free meters (DSM programs)	Can change behavior	Regular evaluation Combination with other mechanisms Comparability with other households



Source: IEA, 2013c

Figure 59. Chronology of building energy codes



Note: EPI-Energy performance Indicator

Source: Shankar, n.d.

Figure 60. Case studies on energy saving in ECBC compliant buildings

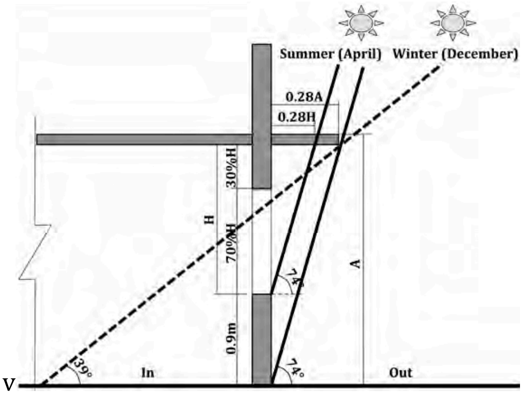
Table 29. Energy consumption by sector in Nepal for 2011/02-2010/11

Sector	**Year**									
	2001/02	**2002/03**	**2003/04**	**2004/05**	**2005/06**	**2006/07**	**2007/08**	**2008/09**	**2009/10**	**2010/11***
Residential	7381.6	7512.1	7654.5	7778.2	7921.5	8103.7	8239.7	8364.0	8568.4	5806.6
Industrial	294.1	280.8	321.8	299.4	395.1	300.1	328.2	312.2	437.6	256.9
Transport	282.1	298.0	308.1	325.9	351.5	378.0	352.8	538.6	700.1	384.7
Commercial	115.5	122.7	124.7	125.2	89.8	72.1	114.6	70.5	77.5	51.2
Agriculture	65.1	67.8	67.8	72.4	67.8	70.6	59.1	85.5	108.1	58.4
Others	10.7	11.4	12.5	14.4	14.6	16.0	17.8	17.2	19.4	13.5
Total	**8149.1**	**8292.8**	**8489.5**	**8615.5**	**8840.2**	**8940.3**	**9112.3**	**9388.1**	**9911.0**	**6571.5**

Statistics of the year 2010/11 only covers the first 8 months figure

Prepared by: Water and Energy Commission Secretariat

Source: CBS, 2011



Adapted from: McGee, 2013

Figure 61. Horizontal shading for the Kathmandu valley

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Bauwirtschaft und Baubetrieb. Mitteilungen
Hrsg.: Univ.-Prof. Dr.-Ing. Bernd Kochendörfer, Fachgebiet Bauwirtschaft und Baubetrieb, Fakultät Planen Bauen Umwelt der Technischen Universität Berlin
ISSN 1610-0158 (Druck)
ISSN 2364-2009 (Internet)

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ISBN 978-3-7983-2791-7 (print)
ISBN 978-3-7983-2792-4 (online)

ISBN 978-3-7983-2791-7

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