Toolkit:
Energy efficient design

Buildings

Buildings energy efficiency sessions in partnership with:

UCL ENERGY INSTITUTE

INDO-SWISS BUILDING ENERGY EFFICIENCY PROJECT

IEA #energyefficientworld

Energy Efficiency Training Week: Buildings programme

1. **Where to start:** Energy use in buildings
2. **Where to start:** Energy efficiency potential in buildings
3. **Toolkit:** Energy efficient building design
4. **Toolkit:** Energy efficient building technologies

   Special session. Technology demonstration

   Where do I get help? IEA's Technology Collaboration Programmes
5. **Toolkit:** Energy efficiency policies and target setting
6. **What are the steps?** Enabling investment with energy efficiency policies
7. **What are the steps?** Implementing building energy codes and standards
8. **What are the steps?** Building operations and procurement

   Special session. The multiple benefits of energy efficiency
9. **Did it work?** Evaluation and energy efficiency indicators

   Where do I get help? International and regional energy efficiency initiatives
10. **Energy efficiency quiz:** Understanding energy efficiency in buildings

3. Toolkit: Energy efficient building design

Trainers: Brian Dean and Pierre Jaboyedoff

Purpose: To teach the fundamentals of how building design can reduce energy use in buildings. This course will also describe how an integrated design process and the use of simulation tools can achieve cost effective and energy efficient buildings.

Scenario: Builders are saying that construction timelines are short and it is not possible to design more efficient buildings because it is too complicated. *What changes in building design can enable more energy efficiency in buildings?*

Integrated design process

Sufficiency, efficiency, renewables

Tiered approach to integrated design

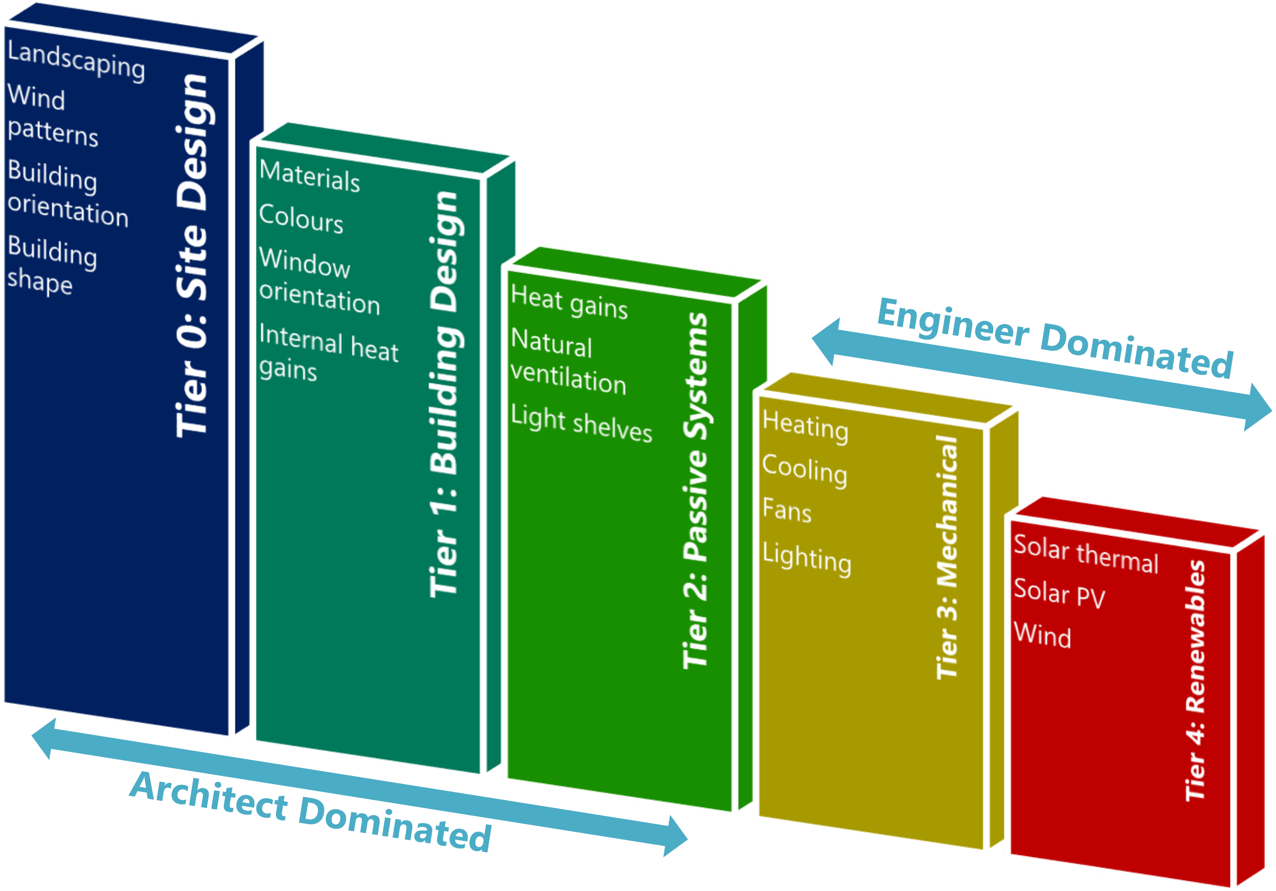
Design charrette

Path to zero emissions or net zero energy buildings

	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 S&L policies	Land-use policies Building energy codes S&L policies for equipment
Policy measure	Bioclimatic design principles Use of passive solutions	Mandatory S&L for: - overall building energy performance - building elements and equipment	Mandatory share of supply from renewable energy sources Mandatory S&L for equipment

Source: www.iea.org/publications/policypathwaysseries/

The tiered approach for the integrated design process



Integration of:

- Multiple design professionals
- Multiple aspects of building design and construction

Source: Adapted from Lechner, Norbert: Heating, Cooling, Lighting : Sustainable Design Methods for Architects

Integrated Design Process: Tier 0 – Site Design

Landscaping

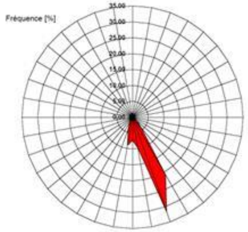
- Impact on solar gains on building
- Impact on airflow
- Seasonal variation

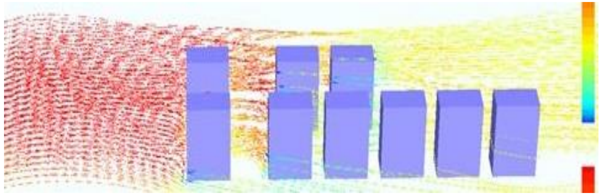
Wind patterns

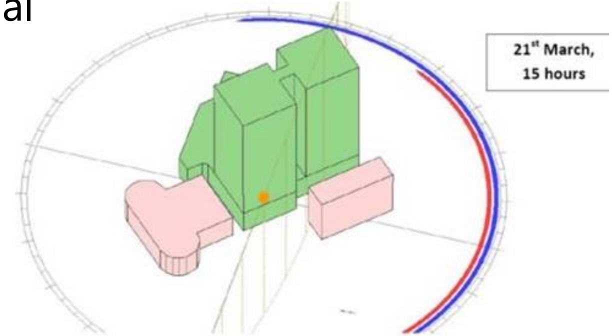
- Dominant wind direction in hot summer
- Layout of buildings for natural ventilation potential

Building orientation & building shape

- Solar gains on facades
- Optimal orientation of facades







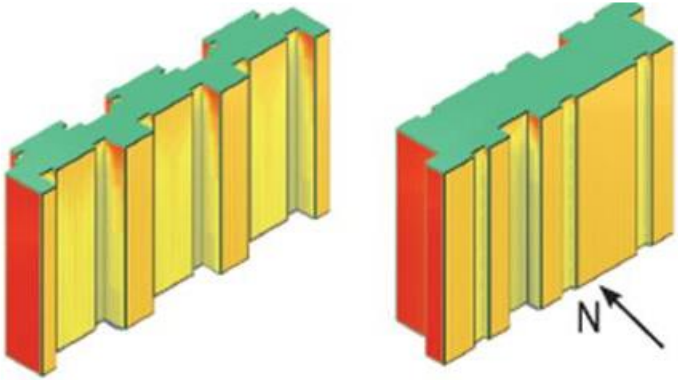
Source: Adapted from Lechner, Norbert: Heating, Cooling, Lighting : Sustainable Design Methods for Architects

Integrated Design Process: Tier 0 – Site Design

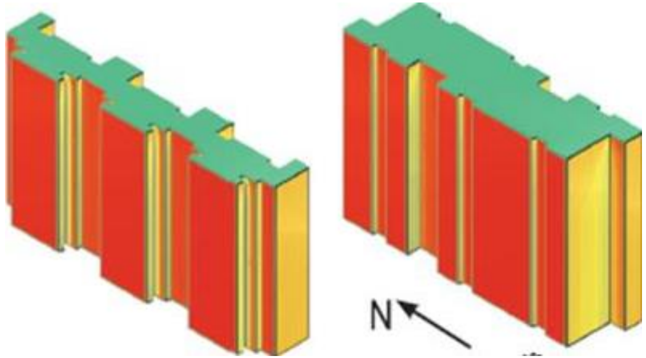
Facade orientation

- Crucial, especially for long buildings
- Account for annual solar gains by orientation

Isometric view from South West



Long facades facing South and North



Long facades facing East and West

Source: India BEEP and India BEE. Design Guidelines For Energy-Efficient Multi-Storey Residential Buildings (Composite and Hot-Dry Climates)

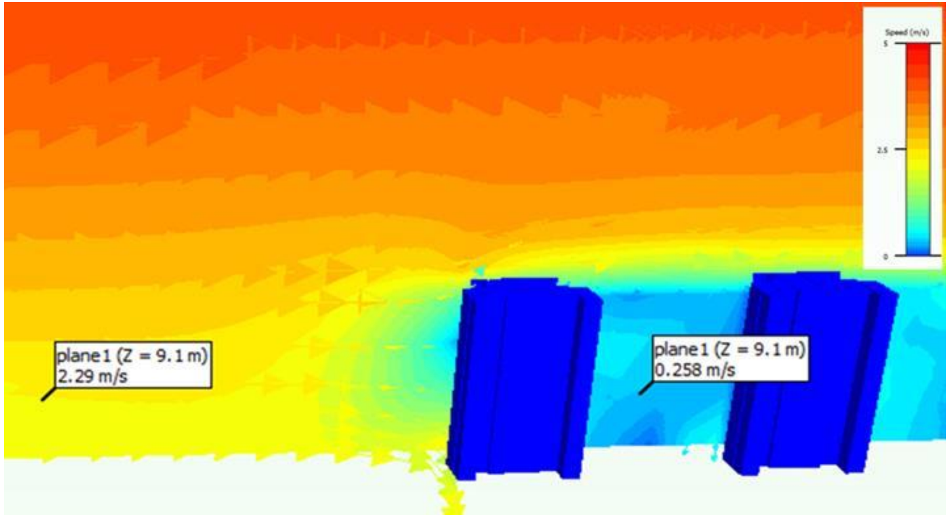
Landscaping
Wind patterns
Building orientation
Building shape

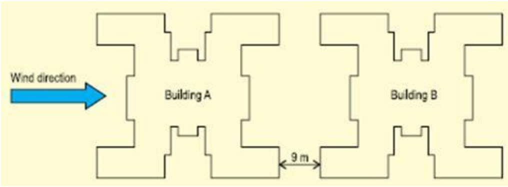
Tier 0: Site Design

Influence of buildings on wind velocity

- Building shape, size and layout all influence wind speeds

Air velocity when wind is perpendicular to building facade orientation

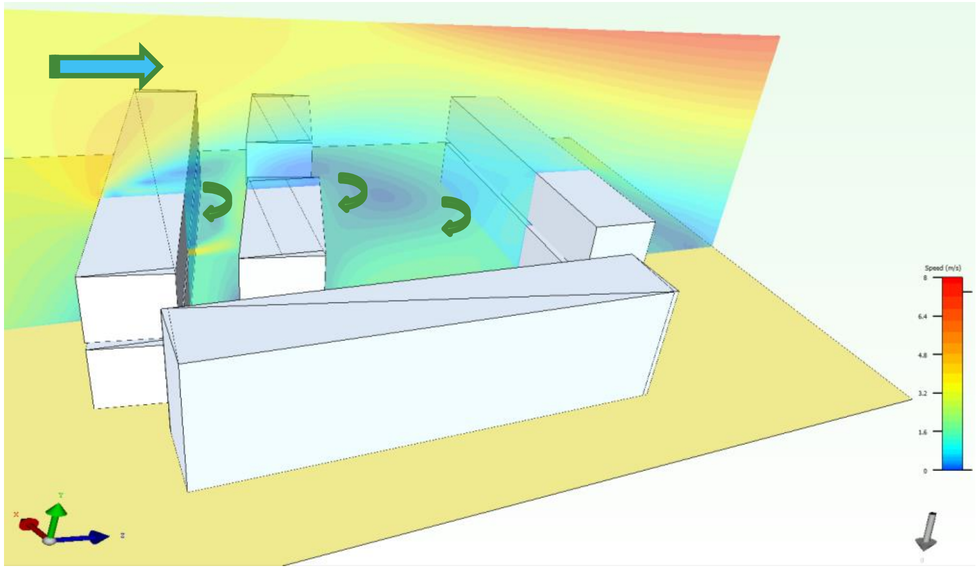




Source: India BEEP and India BEE. Design Guidelines For Energy-Efficient Multi-Storey Residential Buildings (Composite and Hot-Dry Climates)

Integrated Design Process: Tier 0 – Site Design

Example wind distribution for a project in Indore (DB Pride)



Using wind speed for natural ventilation

- **Low-density projects:** influence cross (horizontal) and stack (vertical) ventilation
- **High density projects:** there is low wind speed between buildings, but you can use wind speed on the roof to increase suction on vertical shafts for increased stack ventilation.

Source: India BEEP and India BEE. Design Guidelines For Energy-Efficient Multi-Storey Residential Buildings (Composite and Hot-Dry Climates)

Integrated Design Process: Tier 0 – Site Design

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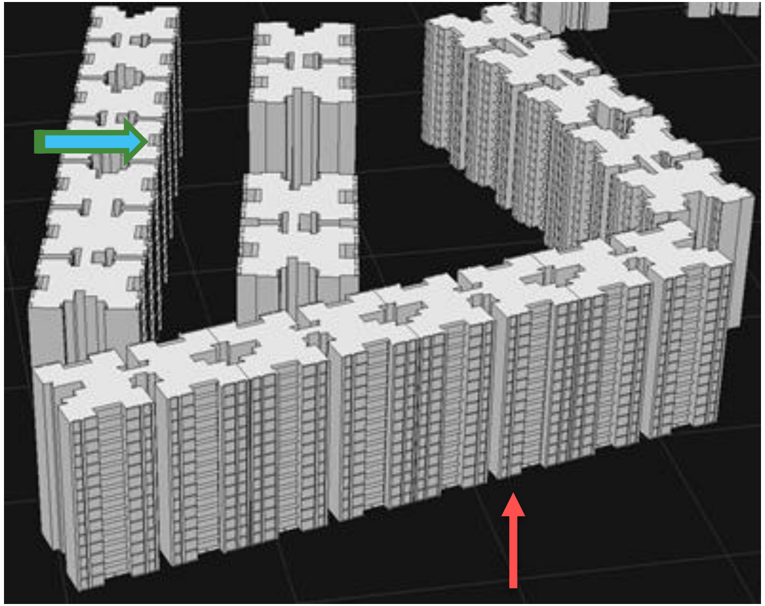


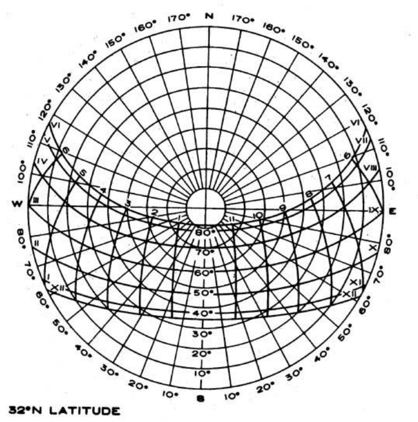
View from the South / Main wind from the West

Source: India BEEP

Walls, windows, shading and solar gains

- Wall should be designed to have insulation
- Window area should be limited to 10-30% of the wall area
- Windows should be highly efficient, particularly if more than 25% of the wall area (both thermal protection and solar protection)
- Shading with overhangs should be designed based on solar angles (i.e. typically overhangs are more effective on North and South walls)
- Shading with movable external shades can be highly effective for optimized daylighting and controlling solar gains.
    - Shutters
    - Movable blinds
- Infiltration should be controlled by better air tightness of the building.

(technologies are described in more detail in the next session)



Sun chart for designing shading devices

Source: Adapted from Lechner, Norbert: Heating, Cooling, Lighting : Sustainable Design Methods for Architects

Integrated Design Process: Tier 1 – Building Design

Building envelope is often the main source of heat gain/loss

- Walls, windows, roof, uncontrolled air infiltration
- There is a wide variation in the quality of building envelopes:

U ~ 3.5 W/m^2.K
Monolithic concrete wall

35% Windows with inadequate shading

U ~ 0.5 W/m^2.K

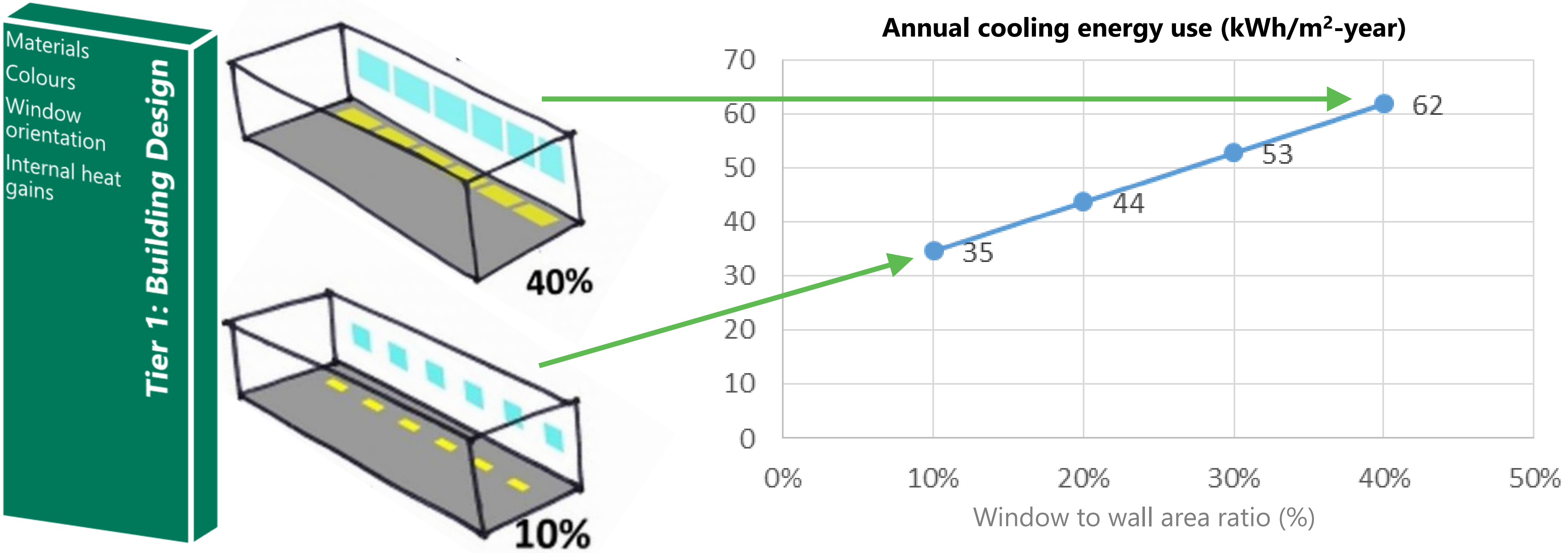
10% Windows with shading

Source: Adapted from Lechner, Norbert: Heating, Cooling, Lighting : Sustainable Design Methods for Architects

Integrated Design Process: Tier 1 – Building Design

Building envelope is often the main source of heat gain/loss

- Window area has a significant impact on cooling energy use:



Source: BEEP India

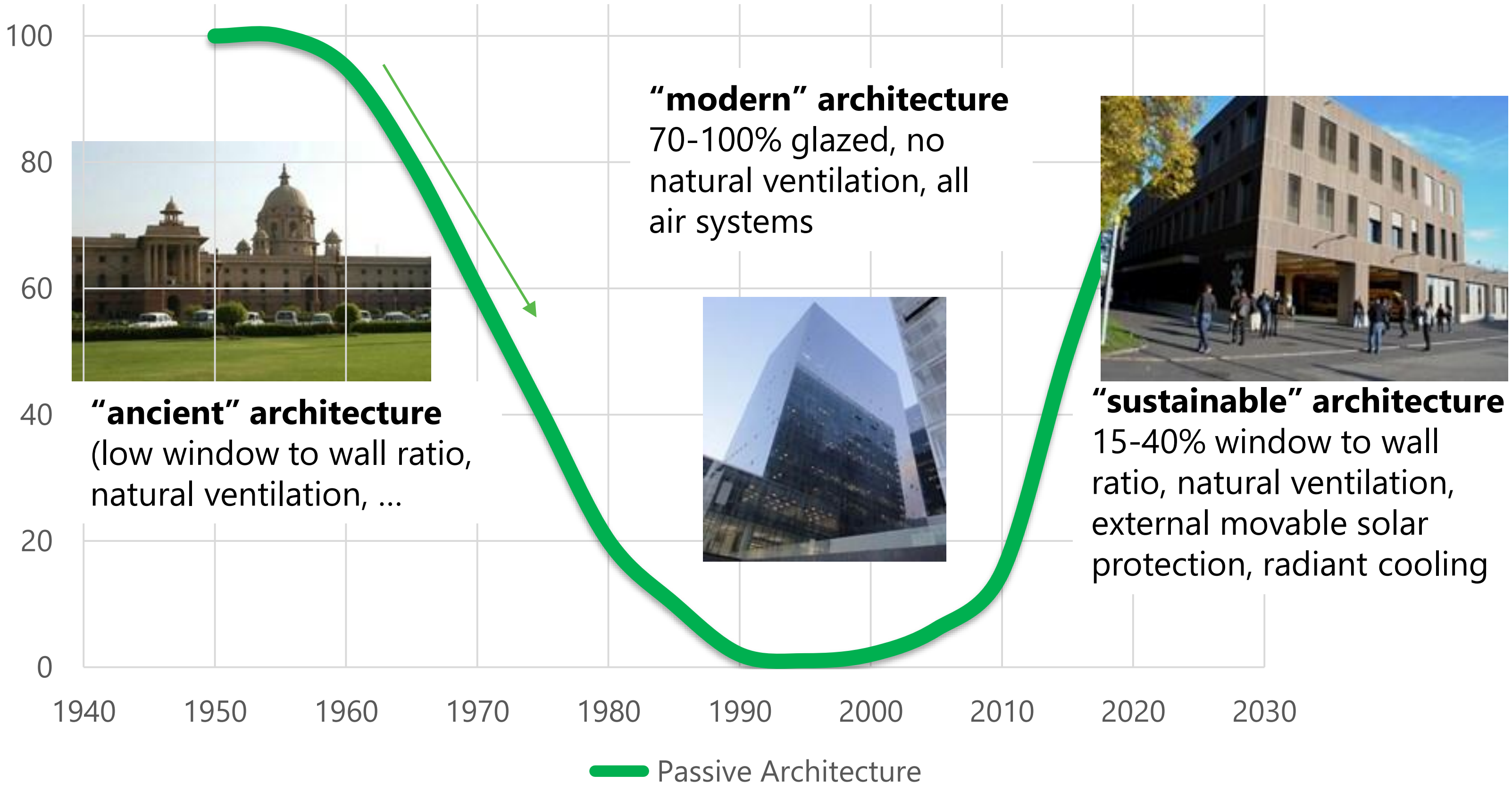
Integrated Design Process: Tier 2 – Passive Systems

Passive systems are reliant on Tier 0 (site design) and Tier 1 (building design), and include:

- Passive cooling
  - Ventilative cooling (natural ventilation)
  - Evaporative cooling (airflow and water)
  - Earth cooling (underground)
- Passive heating (trombe wall and greenhouse effect)
- Passive lighting (daylighting)

Source: Adapted from Lechner, Norbert: Heating, Cooling, Lighting : Sustainable Design Methods for Architects

Integrated Design Process: Tier 2 – Passive Systems



Source: BEEP India

Integrated Design Process: Tier 3 – Mechanical Systems

After all of the passive options are used, mechanical systems can deliver the designed comfort:

- Active heating systems
- Active cooling systems
- Fans
- Active lighting

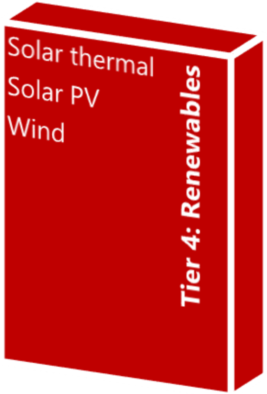
Intelligent controls
Flexibility

Source: Adapted from Lechner, Norbert: Heating, Cooling, Lighting : Sustainable Design Methods for Architects

Integrated Design Process: Tier 4 – Renewable Energy

To deliver net zero energy or emissions, renewable energy can be used to provide all on-site energy needs

- Solar thermal
    - Typically for hot water or heating
- Renewable electricity
    - Solar photovoltaic
    - Wind
    - Purchased renewable energy



Source: Adapted from Lechner, Norbert: Heating, Cooling, Lighting : Sustainable Design Methods for Architects

Design charrette

The process:

- Client
- Architect
- HVAC engineer
- Lighting engineer
- Sustainability consultant
- Commissioning agent
- Structural engineer
- Drainage engineer
- Contractor

- Working together to benefit from synergies offered between disciplines.
- Regular design charrettes throughout project.

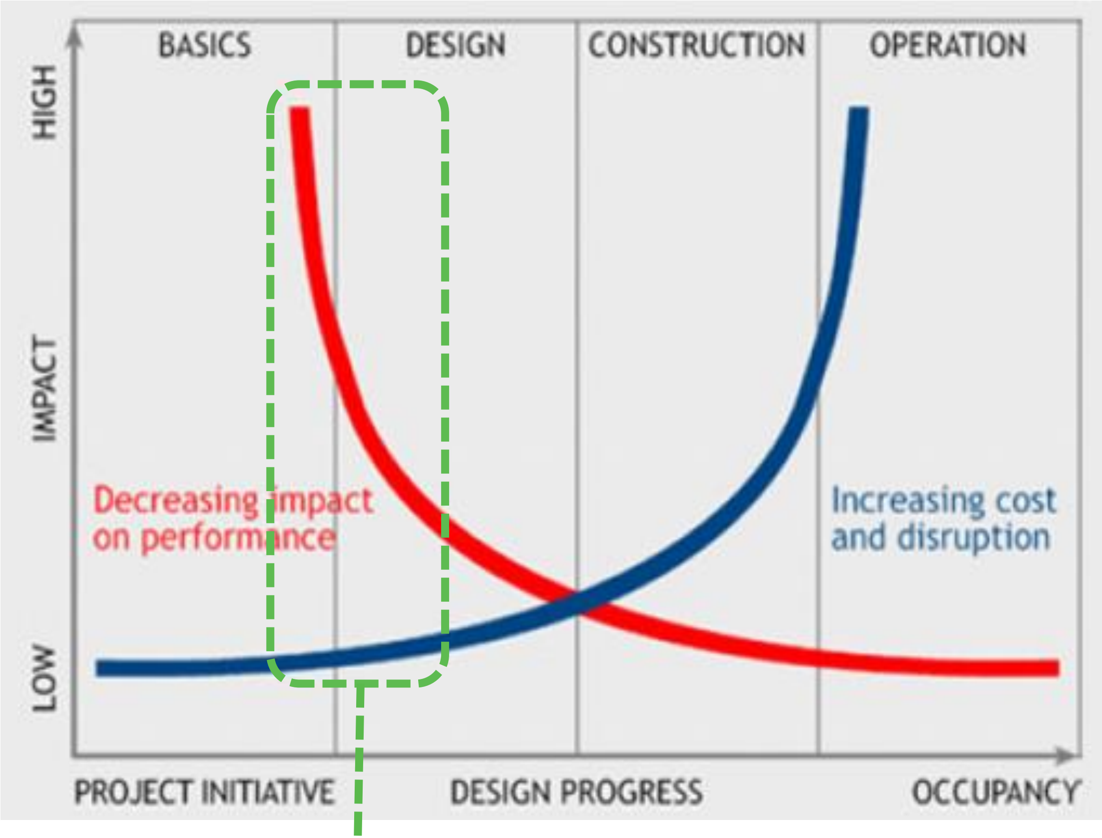
Why?

For example, by optimising the glazing area, building orientation, materials, and lighting power density, it may be possible to save on installed air conditioning capacity, or even remove the need for air conditioning altogether.

Design charrette

Experience shows:

- Cost-effective and energy efficient design (25-40% energy savings at no/ marginal cost increase) is possible if the **architect, engineer and client** work together in a design charrette/workshop during the early design phase.
- More savings are achieved when the **architects and engineers** continued to work together in the design phase.



Timing for design charrette

Source: BEEP India and IEA Task 23 Optimization of Solar Energy Use in Large Buildings, 2003

Design charrette

Case study:

Mitsidi Projetos consultancy for a hospital project in Sao Paulo, Brazil

- Integrated design process and design charrettes optimised building design identifying energy efficiency measures and ensuring coordination and integration among the design team.
- Early building simulation enabled a reduction of 24% in the installed AC capacity as compared to a baseline, reducing capital and operational costs.
- Thermal comfort guaranteed through natural ventilation in 4000m² of the building.

Source: Mitsidi Projetos, SPBR

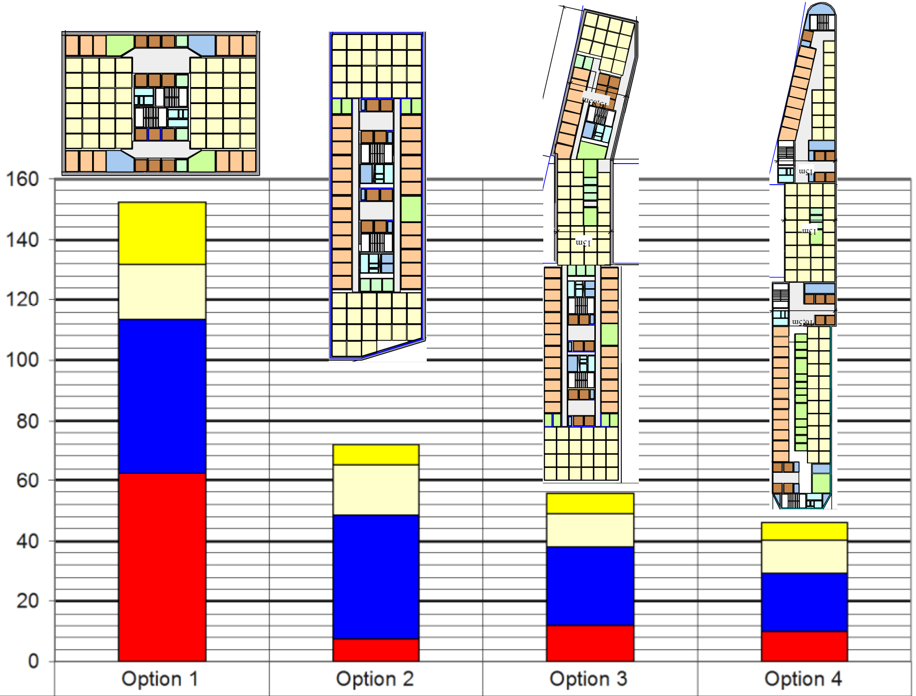
Energy efficiency measures identified:

- Reduction in the internal gains by selecting efficient lighting and appliances
- Overhangs for shading
- Increased temperature setpoint
- Reflective material finishes
- Openable windows and ventilation openings

Example: high rise office building for France Ministry of Ecology

Option 1 (reference case): Square deep floor plate, poor envelope, no dynamic solar shading, mechanical ventilation without heat recovery

Option 2 (high performance): Square shallow floor plate, good quality envelope, dynamic solar shading (SHGC=15%), mechanical ventilation with heat recovery, natural ventilation on the peripheral zones



	Option 1	Option 2	Option 3	Option 4
Specific electricity for mechanical ventilation	20.9	6.7	6.7	5.5
Specific electricity for lighting	18.1	16.7	11.1	11.1
Specific cooling requirements	51.1	40.6	25.9	19.1
Specific heating energy	62.3	7.9	12.2	10.1

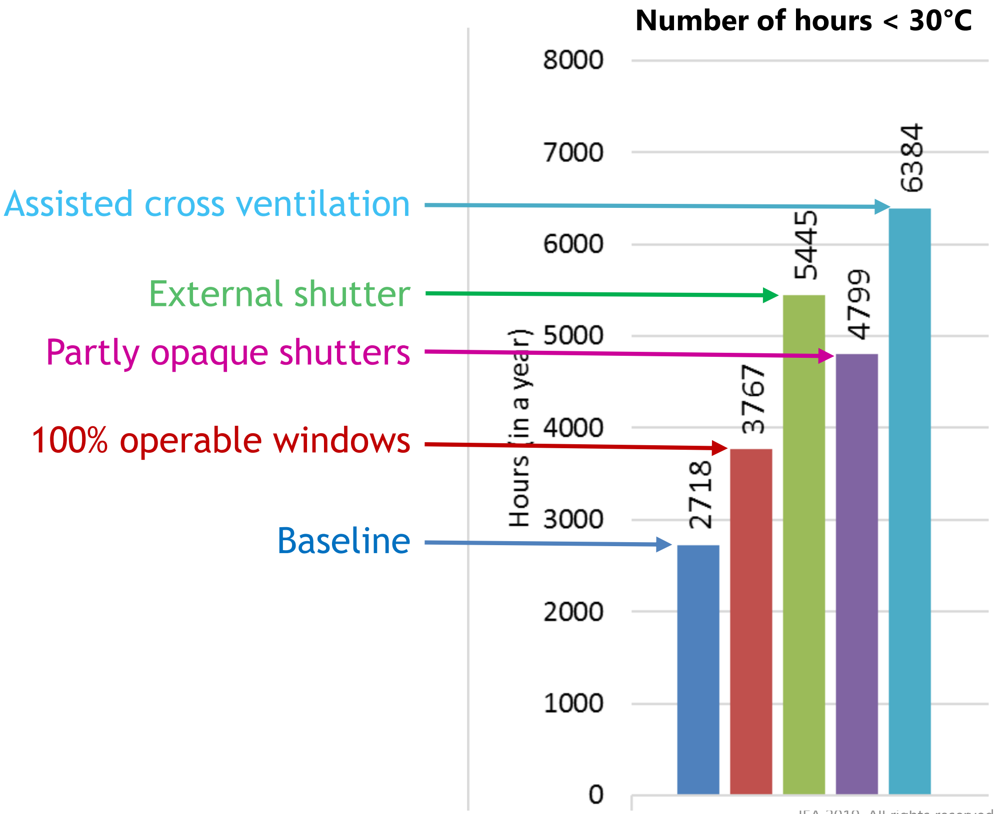
Option 3 ("bioclimatic" design): shallow floor plate (15.4 m depth) and longer building, with the same energy efficient technologies and ventilation as Option 2

Option 4 ("bioclimatic" design with cross ventilation): shallow floor plate (15.4 m depth) and longer building with increased cross ventilation for peripheral and central zones and the same energy efficient technologies and ventilation as Option 2 & 3

Source: BEEP India

Example: thermal comfort without active cooling

Low cost housing project Smart Ghar



Source: BEEP India

Supporting efficient design

Modelling tools

Certification

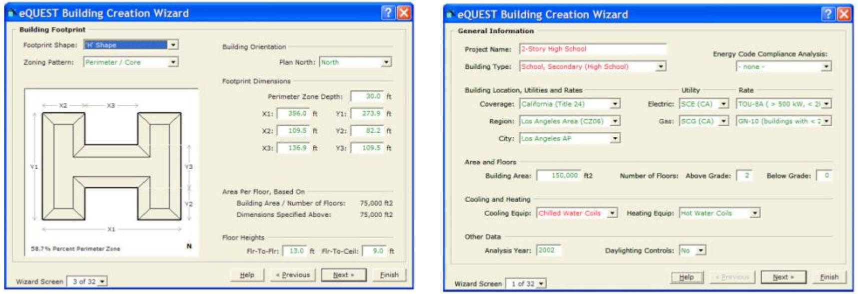
Commissioning

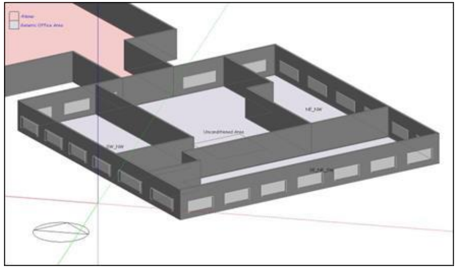
Building energy modelling

- Should be used throughout the design process from schematic design (early) to construction (end of design) to understand the impact of design decisions

- At the early design stage, use *simplified models* or *simplified modelling*:
  - **Simplified model**: such as using “wizard mode” in eQUEST that pre-fills information so that you do not have to enter in all data.
  - **Simplified modelling**: such as modelling one zone of the building

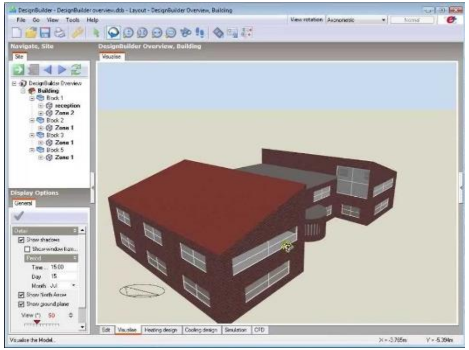
eQUEST ... the QUick Energy Simulation Tool



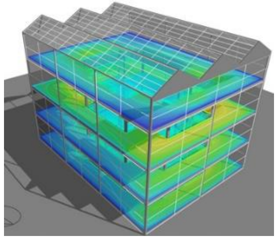


Building energy modelling

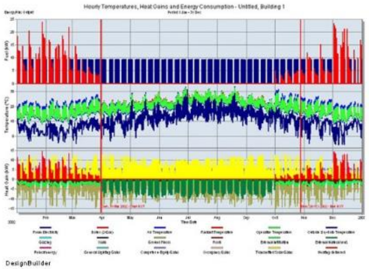
- Examples of analyses possible through modelling:



3D modelling of the building geometry



Daylight simulation of light levels



Internal and external temperatures over the course of a year

Source: DesignBuilder

- Other building energy modelling software:

EnergyPlus

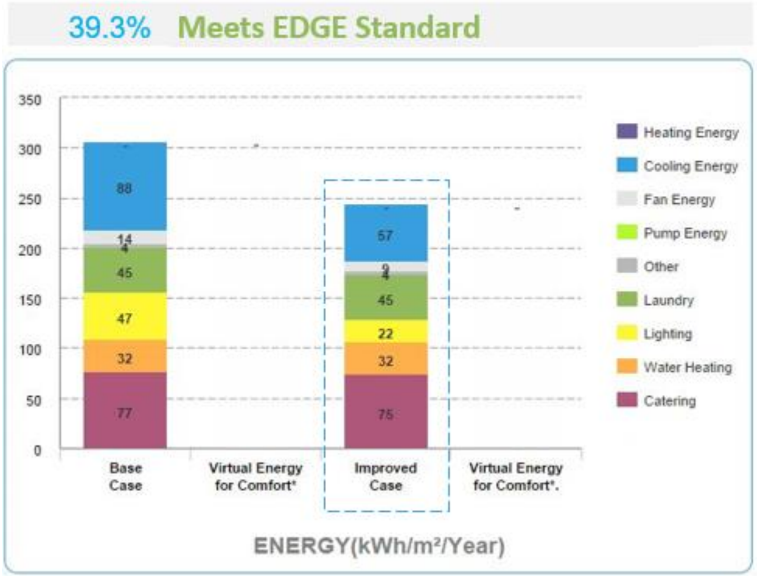
IES INTEGRATED ENVIRONMENTAL SOLUTIONS

OpenStudio

DesignBuilder SOFTWARE

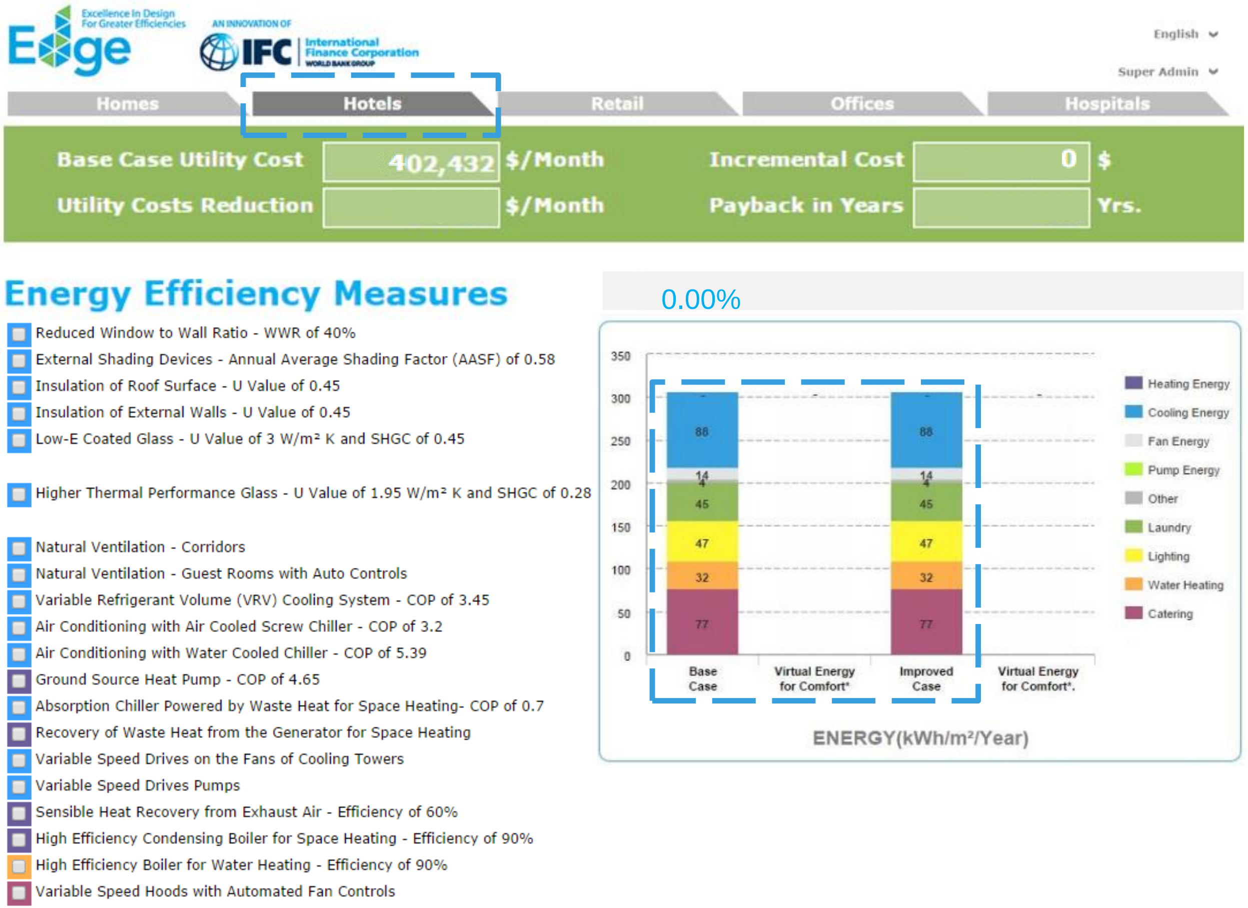
Building evaluation tools

- Tools are available to help assess the design of a building project without requiring full building energy modelling, such as:
  - **EDGE** is a free software, developed by the IFC, which *quickly* assesses the resource efficiency of a building design as compared to a baseline.
  - The software evaluates the annual energy and water consumption, as well as the embodied energy of the materials.
  - Can be used as a design tool to test the impact of different measures.
  - The EDGE standard is also a certification.
  - Accessible to not only building energy modellers, but the whole design team as well as the client.



Source: International Finance Corporation, World Bank Group

EDGE



Excellence in Design For Greater Efficiencies
Edge
AN INNOVATION OF
IFC International Finance Corporation WORLD BANK GROUP
English
Super Admin
Homes
Hotels
Retail
Offices
Hospitals
Base Case Utility Cost
402,432
$/Month
Incremental Cost
0
$
Utility Costs Reduction
$/Month
Payback in Years
Yrs.
Energy Efficiency Measures
Reduced Window to Wall Ratio - WWR of 40%
External Shading Devices - Annual Average Shading Factor (AASF) of 0.58
Insulation of Roof Surface - U Value of 0.45
Insulation of External Walls - U Value of 0.45
Low-E Coated Glass - U Value of 3 W/m² K and SHGC of 0.45
Higher Thermal Performance Glass - U Value of 1.95 W/m² K and SHGC of 0.28
Natural Ventilation - Corridors
Natural Ventilation - Guest Rooms with Auto Controls
Variable Refrigerant Volume (VRV) Cooling System - COP of 3.45
Air Conditioning with Air Cooled Screw Chiller - COP of 3.2
Air Conditioning with Water Cooled Chiller - COP of 5.39
Ground Source Heat Pump - COP of 4.65
Absorption Chiller Powered by Waste Heat for Space Heating- COP of 0.7
Recovery of Waste Heat from the Generator for Space Heating
Variable Speed Drives on the Fans of Cooling Towers
Variable Speed Drives Pumps
Sensible Heat Recovery from Exhaust Air - Efficiency of 60%
High Efficiency Condensing Boiler for Space Heating - Efficiency of 90%
High Efficiency Boiler for Water Heating - Efficiency of 90%
Variable Speed Hoods with Automated Fan Controls
0.00%
350
300
250
200
150
100
50
0
88
14
45
47
32
77
Base Case
Virtual Energy for Comfort*
Improved Case
Virtual Energy for Comfort*.
Heating Energy
Cooling Energy
Fan Energy
Pump Energy
Other
Laundry
Lighting
Water Heating
Catering
ENERGY(kWh/m²/Year)

EDGE

Edge — Excellence in Design For Greater Efficiencies — An innovation of IFC International Finance Corporation, World Bank Group

English
Super Admin

Homes | Hotels | Retail | Offices | Hospitals

Base Case Utility Cost	102,432	$/Month	Incremental Cost	915,675	$
Utility Costs Reduction	40,040	$/Month	Payback in Years	1.9	Yrs.

Energy Efficiency Measures

- [x] Reduced Window to Wall Ratio - WWR of 40%
- [x] External Shading Devices - Annual Average Shading Factor (AASF) of 0.58
- [ ] Insulation of Roof Surface - U Value of 0.45
- [ ] Insulation of External Walls - U Value of 0.45
- [ ] Low-E Coated Glass - U Value of 3 W/m² K and SHGC of 0.45
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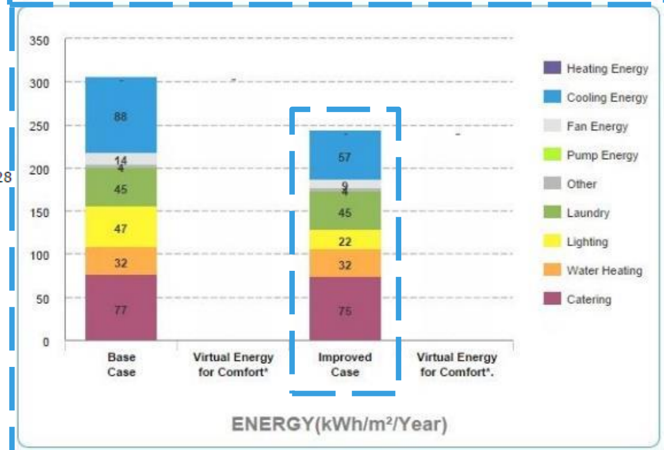
- [ ] Recovery of Waste Heat from the Generator for Space Heating
- [ ] Variable Speed Drives on the Fans of Cooling Towers
- [ ] Variable Speed Drives Pumps
- [ ] Sensible Heat Recovery from Exhaust Air - Efficiency of 60%
- [ ] High Efficiency Condensing Boiler for Space Heating - Efficiency of 90%
- [ ] High Efficiency Boiler for Water Heating - Efficiency of 90%
- [x] Variable Speed Hoods with Automated Fan Controls

39.3% Meets EDGE Standard



City Express Hotel, Mexico City

CASE STUDY
City Express Hotel Santa Fe
135 Guest Rooms ★★★
Mexico City, Mexico
Final EDGE Certification: November 2012
http://edgebuildings.com/portfolio-item/city-express-hotels/

Incremental Cost of Green Measures:

US $56,209

Payback in Years:

0.6

Utility Cost Reduction:

US $7,500/month

Savings Impact of Green Measures:

51% Lower Energy Bill

32% Lower Water Bill

44% Less Energy In Materials

Select Green Measures:

- Low-E coated glass
- Dual flush water closets
- External shading devices
- Energy-efficient lighting
- Air conditioning with water cooled chiller
- Finished concrete flooring

Source: International Finance Corporation, EDGE

Nam Long, E-Homes 5, Vietnam

Apartments feature high-performance glazing and energy-efficient lighting & controls, thermal insulation & dual-flush water closets, autoclaved aerated concrete blocks for internal & external walls.

Source: International Finance Corporation, EDGE

Imperial Homes- Batangas, The Philippines

Source: International Finance Corporation, EDGE

Commissioning

- Commissioning is the process by which it is **assured** that the systems and components of the building are **designed** and **installed** according to the requirements of the **client**.

At each project stage:
“Is the project still in line with what the client wants?”

Definition of client requirements → Concept design → Detailed design → Construction → Handover → Operation

Commissioning agent responsible for verifying that the design meets the requirements.

Design, construction and measurement standardisation

Capital gap and performance gap

Investment Ready Energy Efficiency

The energy efficiency capital gap

Projects

- Untapped market opportunity
- Healthy returns
- Established industry
- Excess capacity

Investors

- Search for yield
- Risk/return
- Growing emphasis on impact investing
- Growing interest in EE

Source: Investor Confidence Project

The performance gap

Why Don't Green Buildings Live Up to Hype on Energy Efficiency?

Analysts call it the "energy performance gap" – the difference between promised energy savings in green buildings and the actual savings delivered. The problem, researchers say, is inept modeling systems that fail to capture how buildings really work.

BY RICHARD CONNIFF · MAY 25, 2017

Not long ago in the southwest of England, a local community set out to replace a 1960s-vintage school with a new building using triple-pane windows and super-insulated walls to achieve the highest possible energy efficiency. The new school proudly opened on the same site as the old one, with the same number of students, and the same head person– and was soon burning more energy in a month than the old building had in a year.

Lack of standardisation results in:

Greater performance risk

Uncertainty limiting demand

Higher transaction costs

Difficult to build capacity

Difficult to aggregate

Source: Investor Confidence Project

What owners and investors want?

- Clear and transparent construction or renovation project plan based on industry best practices
- Evidence of the qualification of professionals
- Third-party measurement and verification
- Consistent documentation
- A project label that represents these components and can live with the project

Source: Investor Confidence Project

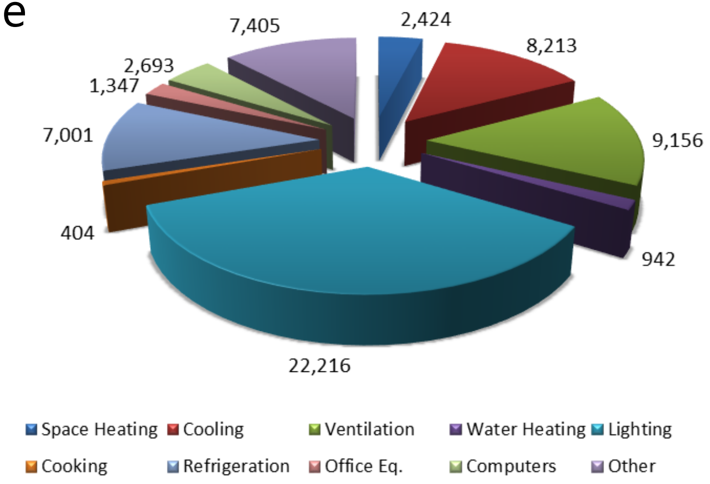
What does a standardised approach looks like?

Source: Investor Confidence Project

What does a standardised approach looks like?

Baselines provide a reference regarding energy use, allowing for prediction of energy consumption in different scenarios, and for energy savings calculations.

- Develop 12 month energy consumption baseline accounting for:
  - Weather data
  - Occupancy data
- Calculate lifecycle energy use and impacts
- Determine energy use by end-use



Source: adapted from Investor Confidence Project

What does a standardised approach looks like?

Baselining → **Savings Projections** → Design, Construction, Verification → Operations, Maintenance, Monitoring → Measurement & Verification (M&V)

Savings calculations provide important information for project valuation and for the determination of the energy efficiency measures to be implemented.

- Energy modelling
  - Certified software
  - Modeller credentials
  - Supporting model files and model calibration
  - Energy efficiency measures model variables
- Energy analysis
  - Key metric benchmarks
  - Individual and packaged energy savings results

Source: adapted from Investor Confidence Project

What does a standardised approach looks like?

Design, construction and verification are all crucial phases. Procedures and documentation of these processes is key to investor confidence.

- Inspections, spot measurements and data logging
- Commissioning
- Operational performance verification plan
- Systems manual
- Training

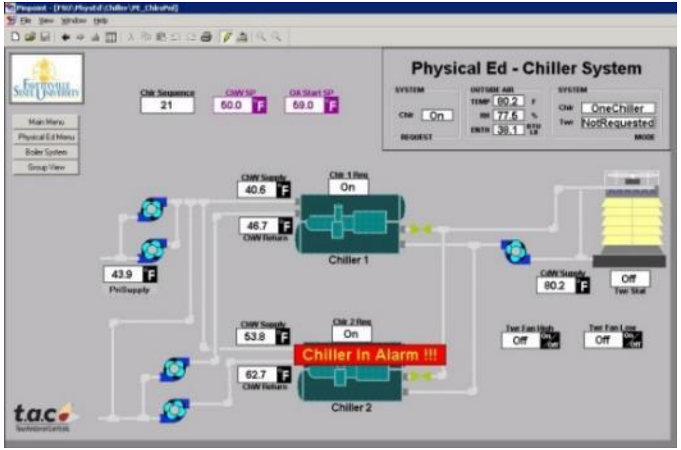
Source: adapted from Investor Confidence Project

What does a standardised approach looks like?

Baselining → Savings Projections → Design, Construction, Verification → **Operations, Maintenance, Monitoring** → Measurement & Verification (M&V)

The way that buildings are operated and maintained impact their energy performance, and monitoring this information is key to performance guarantees.

- OM&M plan and management framework
- OM&M process
  - Inspections
  - Retro commissioning
  - Ongoing commissioning
  - Monitoring-based commissioning
- Operator's manual and training

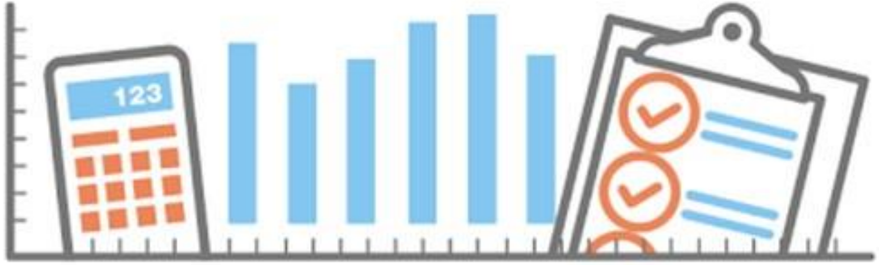


Source: adapted from Investor Confidence Project

What does a standardised approach looks like?

Proper measurement and verification procedures validate the reliability and effectiveness of predicted energy savings.

- M&V provider credentials
- M&V report
  - Whole building analysis
  - Retrofit isolation
  - Utility bill analysis



Source: adapted from Investor Confidence Project

Standardised approach

Does NOT:

- Invent new standards
- Attempt to impose national standards in another country
- Restrict engineering solutions
- Define a set level of energy savings

Does:

- Increase deal-flow in the near-term
  - Increase confidence in savings
  - Reduce transaction costs

- Reduce risk and costs in the long-term
  - Attract project finance investors
  - Reduce cost of capital

Source: Investor Confidence Project

Investor Ready Energy Efficiency (IREE)

An international framework for reducing owner and investor risk, lowering due diligence costs, increasing certainty of savings achievement and enabling aggregation.

The IREE™ certification ensures transparency, consistency and trust-worthiness through **best practice and independent verification.**

Source: Investor Confidence Project, www.eeperformance.org/iree-certification.html

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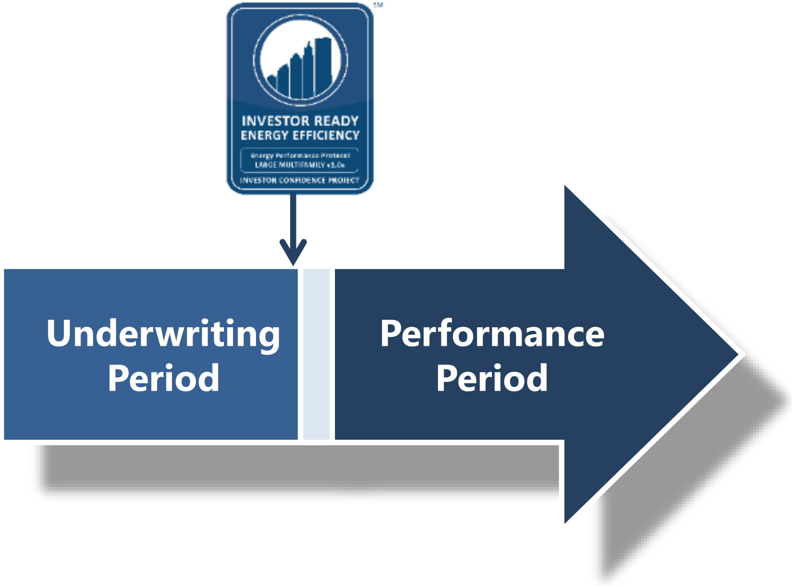

The IREE™ certification is **delivered prior to investment decision**

Source: Investor Confidence Project

Scenario:

Builders are saying that construction timelines are short and it is not possible to design more efficient buildings because it is too complicated.

What changes in building design can enable more energy efficiency in buildings?

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