



Toolkit:

Energy efficient building design

Buildings: Session 3

*Buildings energy
efficiency sessions
in partnership with:*



**INDO-SWISS BUILDING
ENERGY EFFICIENCY PROJECT**



**WORLD
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 #energyefficientworld

Energy Efficiency Training Week: Buildings Program



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
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

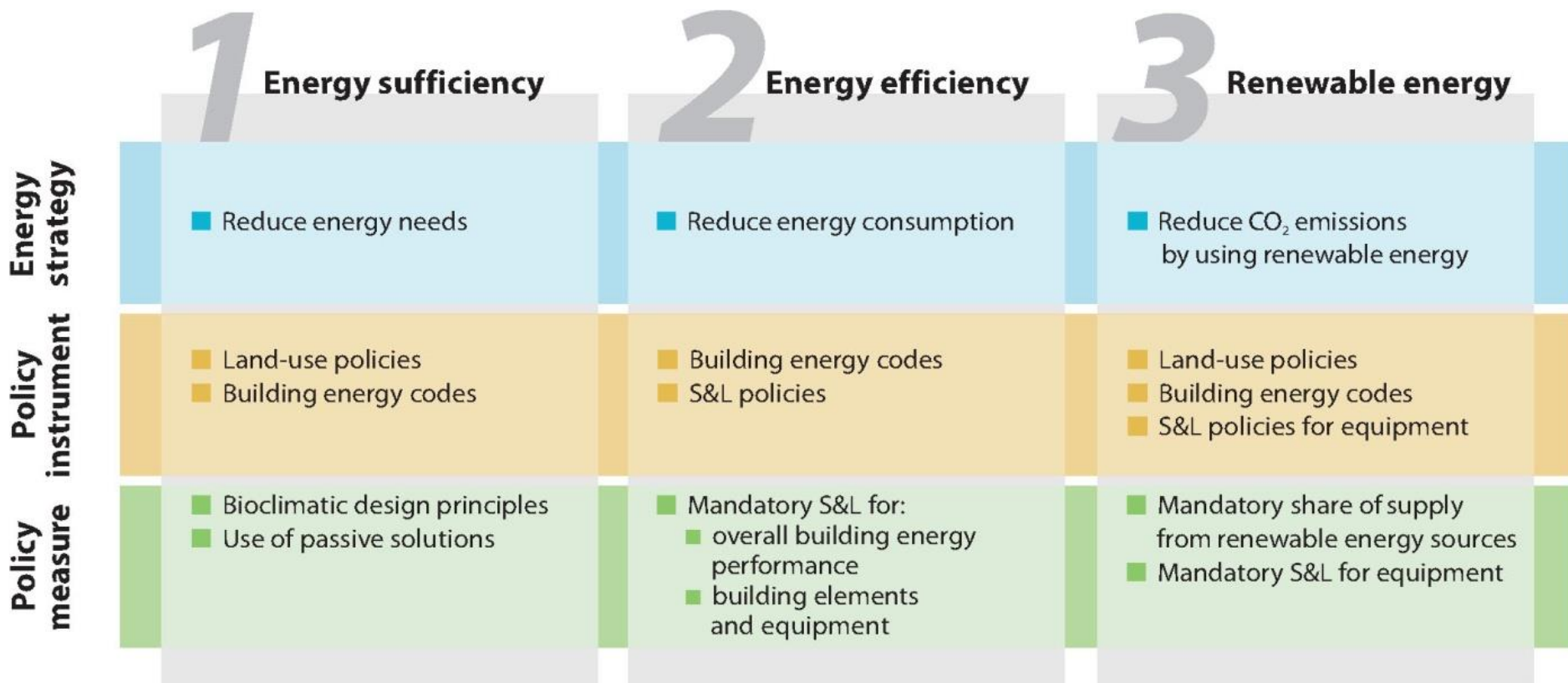
Sufficiency, efficiency, renewables

Tiered approach to integrated design

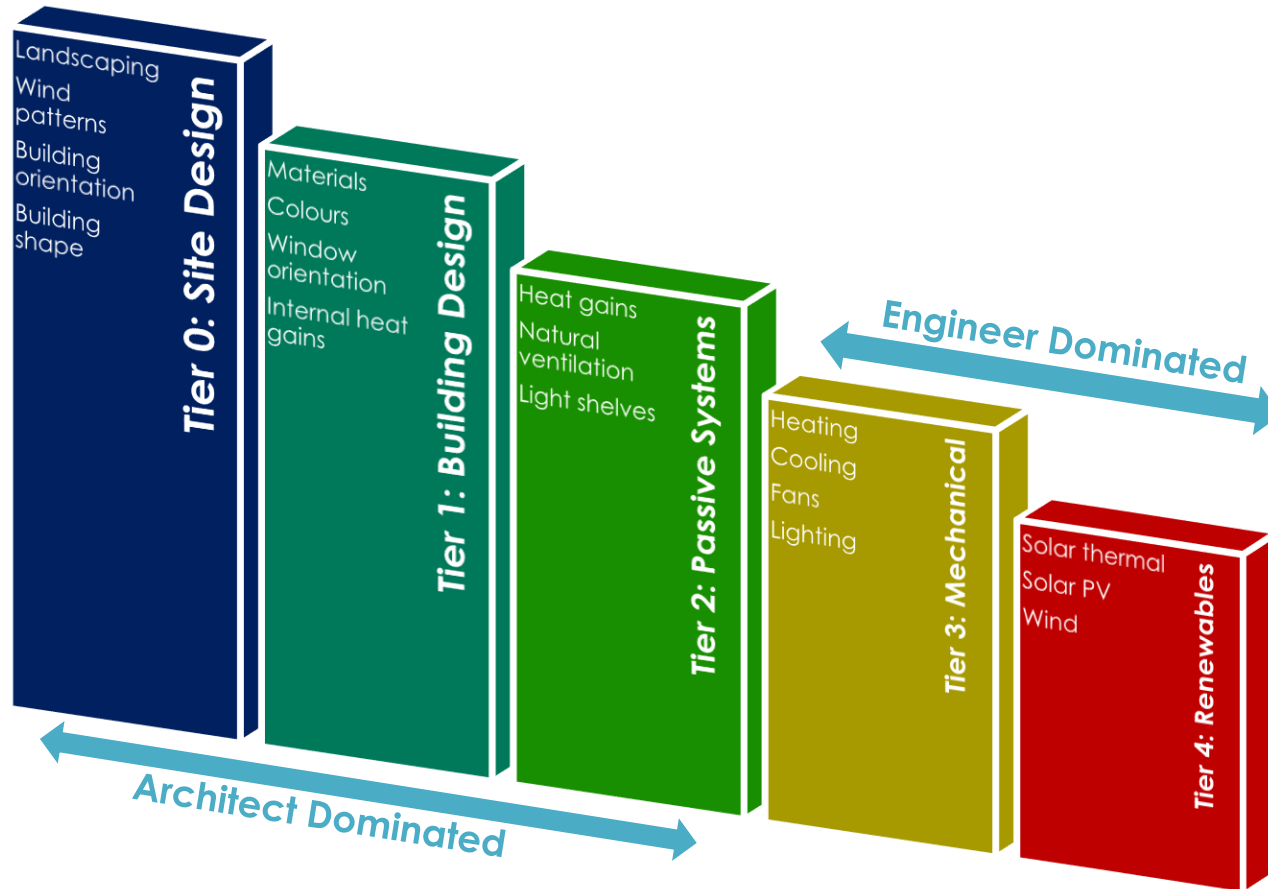
Design charrette



Path to zero emissions or net zero energy buildings



The tiered approach for the integrated design process



Integration of:

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

Landscaping

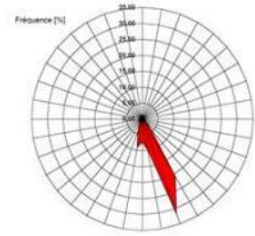
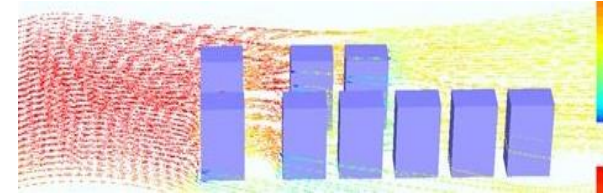
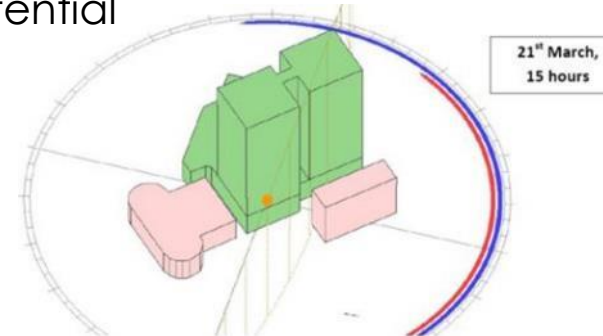
- Impact on solar gains on building
- Impact on airflow
- Seasonal variation

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

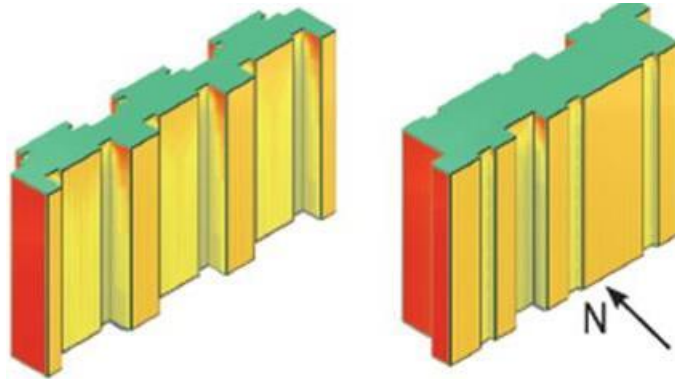


Facade orientation

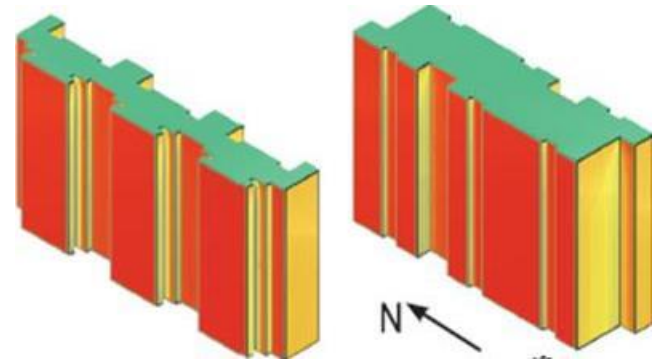
- Crucial, especially for long buildings
- Account for annual solar gains by orientation



Isometric view from South West



Long facades facing South and North

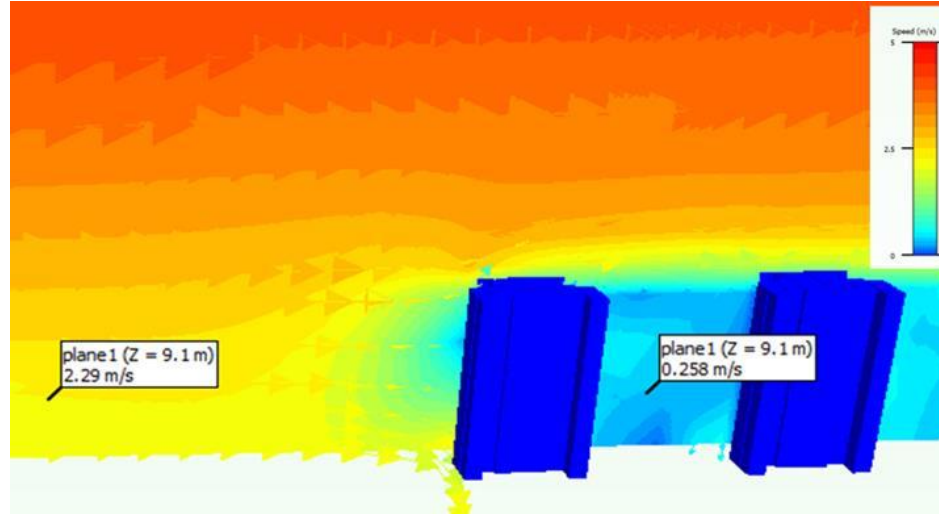
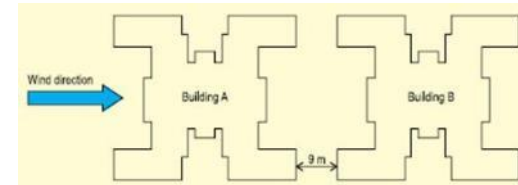


Long facades facing East and West

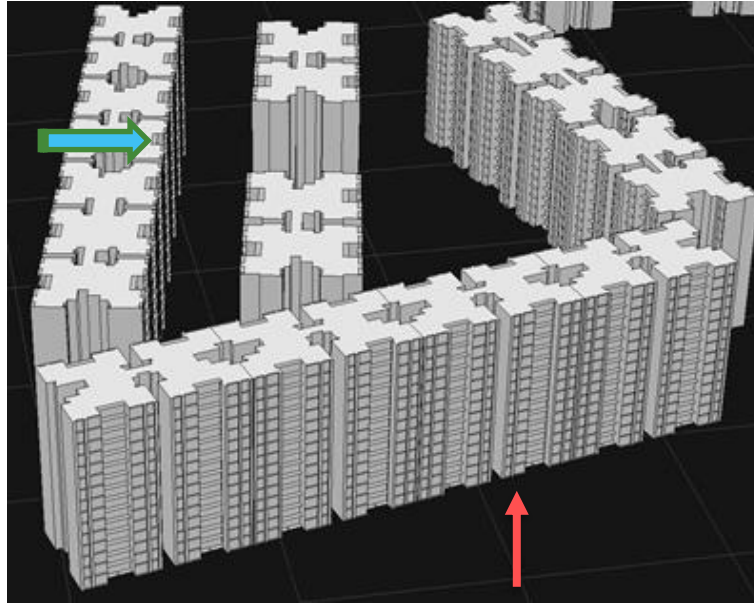
Influence of buildings on wind velocity

- Building shape, size and layout all influence wind speeds

Air velocity when wind is perpendicular to building facade orientation



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



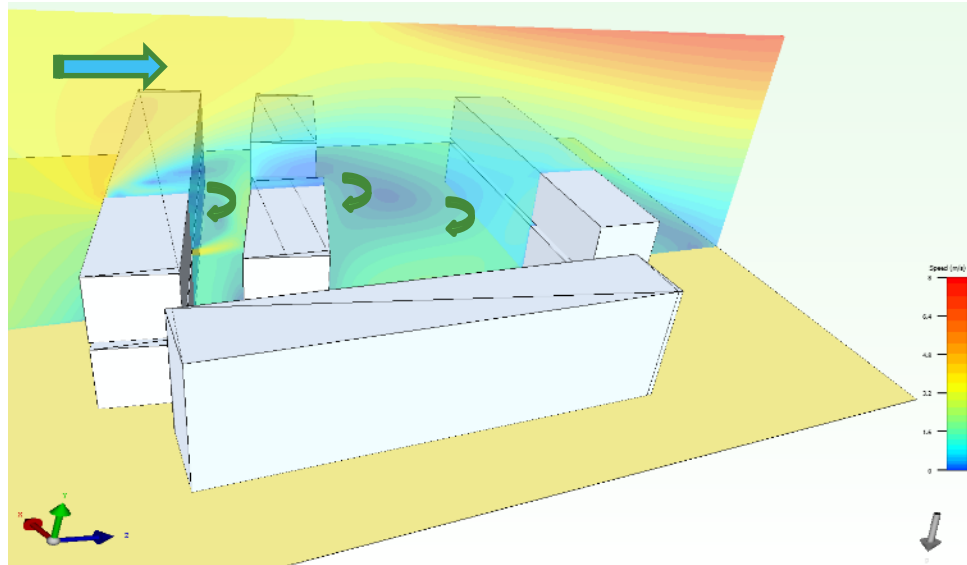
View from the South / Main wind from the West



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.



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

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



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:



$U \sim 3.5 \text{ W/m}^2\text{.K}$
Monolithic concrete wall



$U \sim 0.5 \text{ W/m}^2\text{.K}$

35%
Windows
with
inadequate
shading

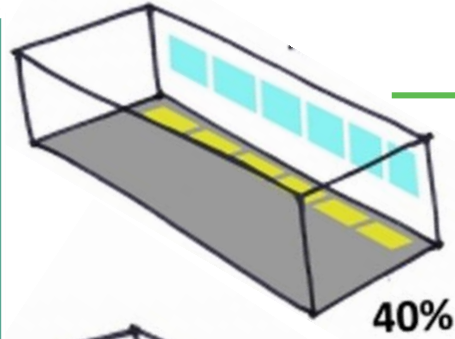
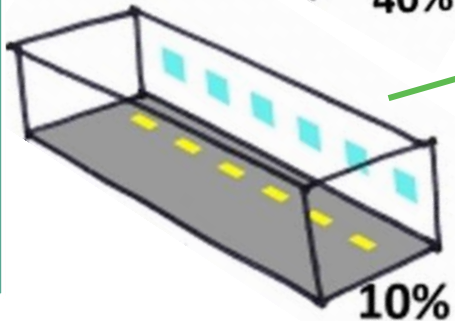


10%
Windows
with
shading

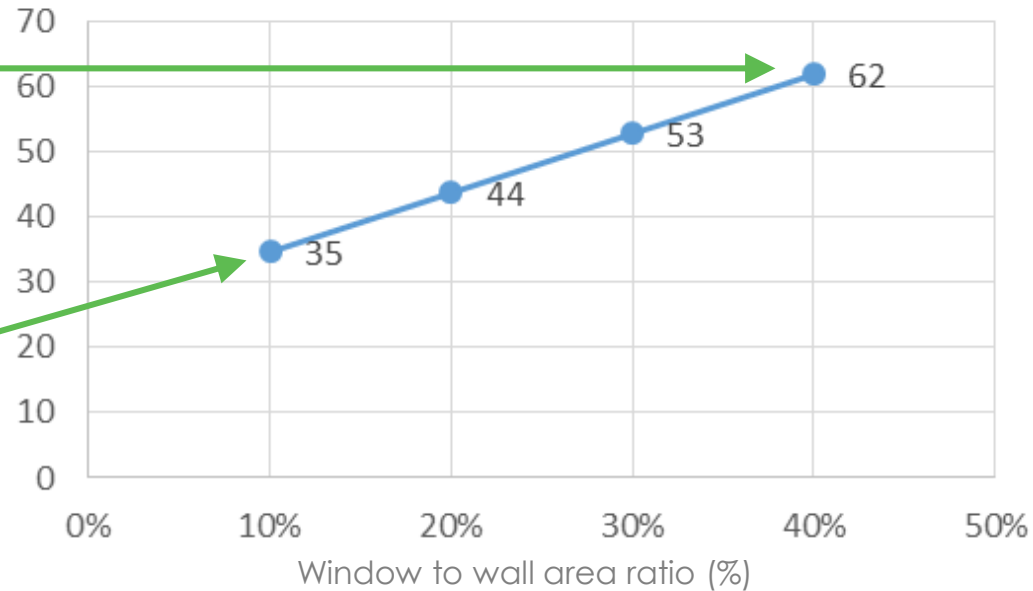


Building envelope is often the main source of heat gain/loss

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



Annual cooling energy use (kWh/m²-year)

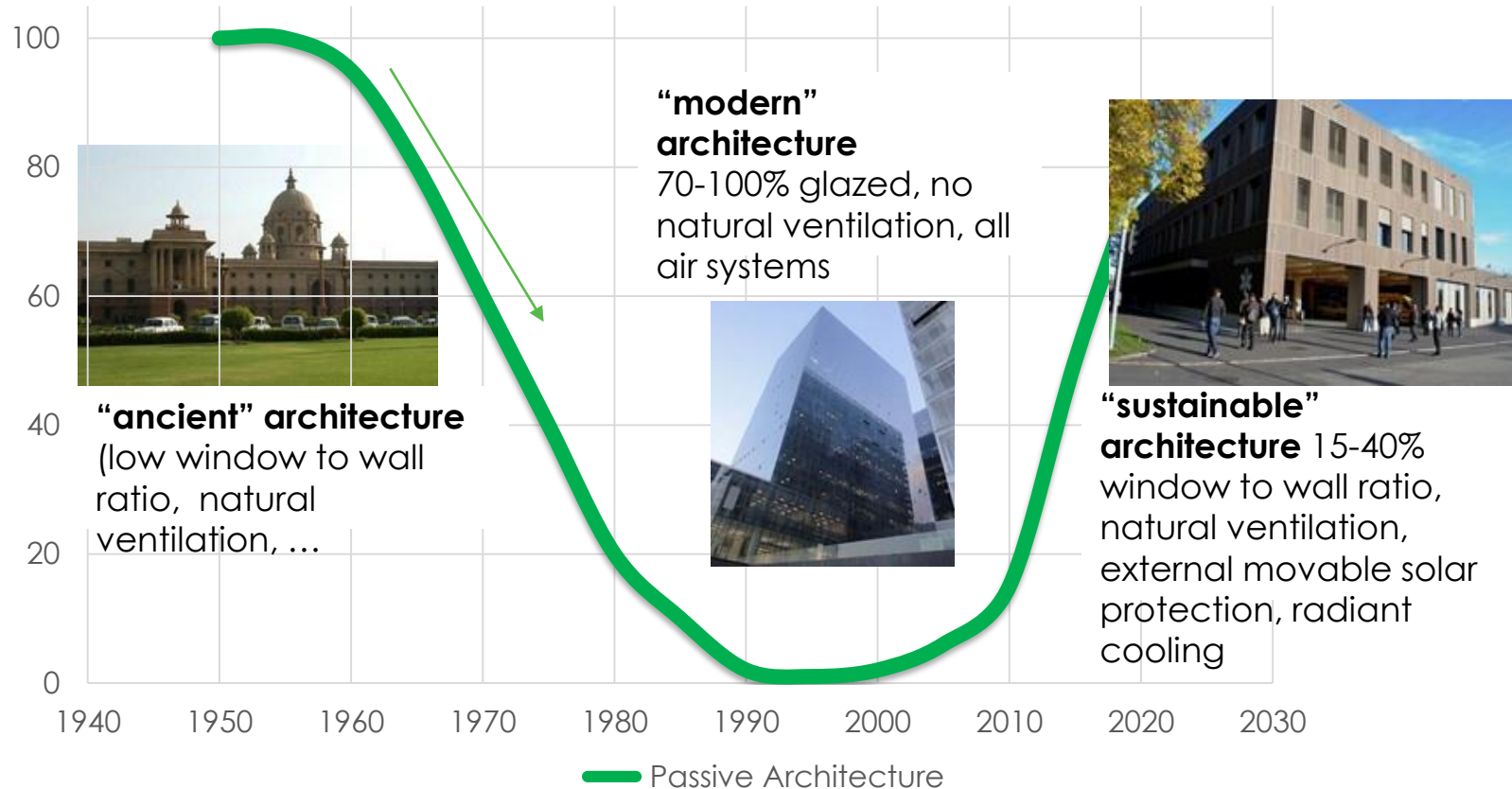


Passive systems are reliant on Tier 0 (site design) and Tier 1 (building design), and include:

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



Integrated Design Process: Tier 2 – Passive Systems



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

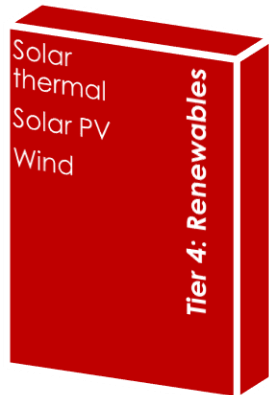
- Active heating systems
- Active cooling systems
- Fans
- Active lighting

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



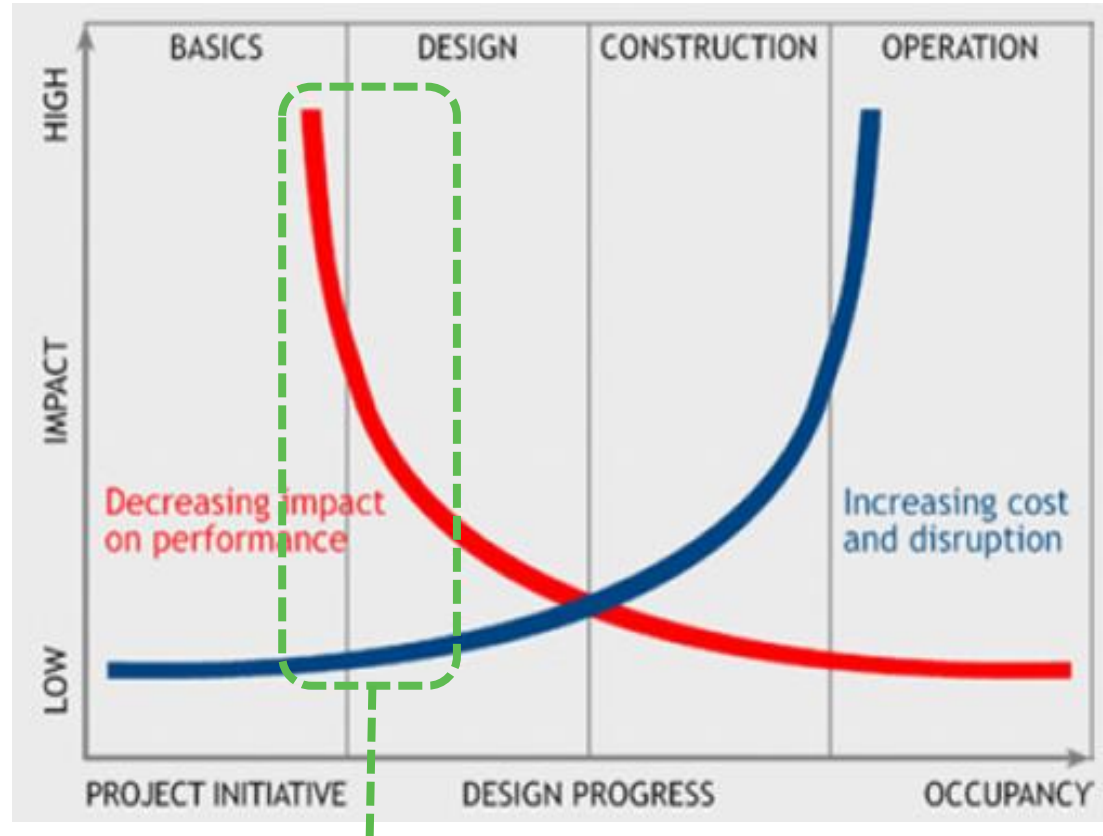
To deliver net zero energy or emissions, renewable energy can be used to provide all on-site energy needs

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



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.



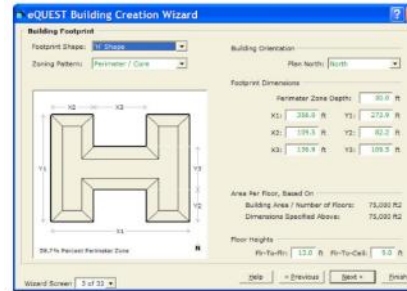
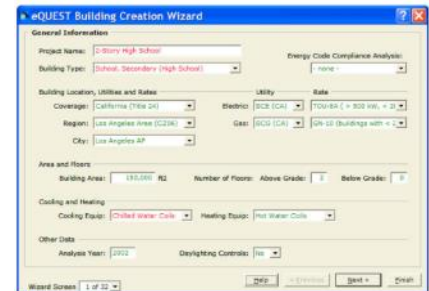
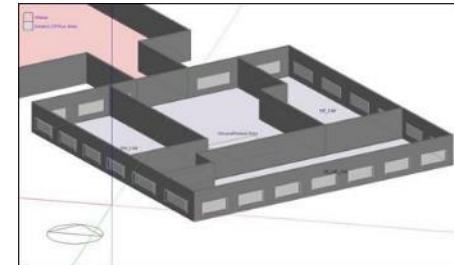
Timing for Design Charrette

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



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):

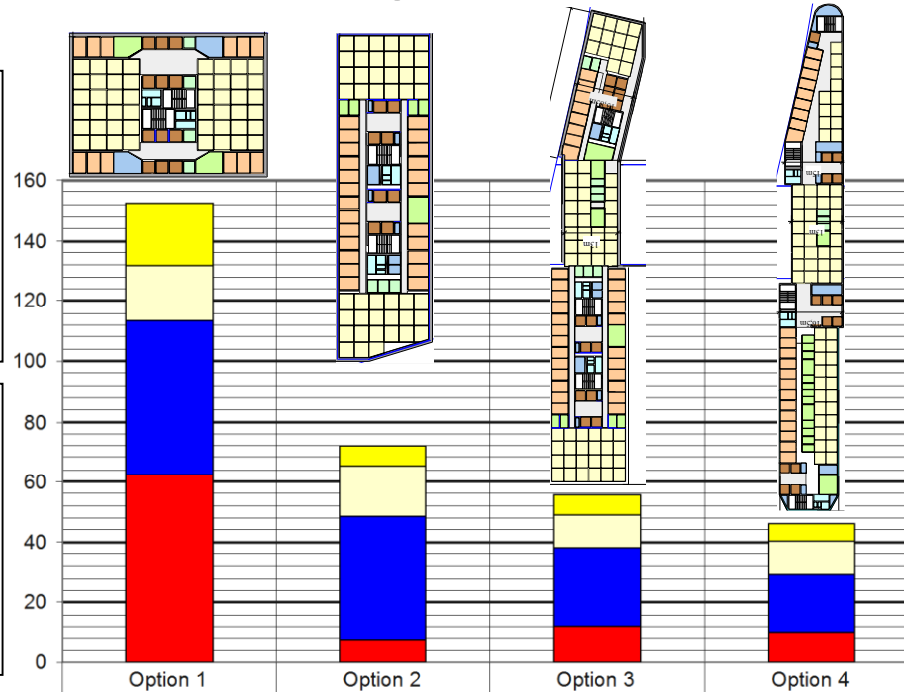
Square shallow floor plate, good quality envelope, dynamic solar shading (SHGC=15%), mechanical ventilation with heat recovery, natural ventilation on the peripheral zones

Option 3 ("bioclimatic" design):

shallow floor plate (15.4 m depth), good quality envelope, dynamic solar shading (SHGC=15%), mechanical ventilation with heat recovery, natural ventilation on the peripheral zones

Option 4 ("bioclimatic" design with cross ventilation):

shallow floor plate (15.4 m depth), good quality envelope, dynamic solar shading (SHGC=15%), mechanical ventilation with heat recovery, natural ventilation between peripheral and central zones

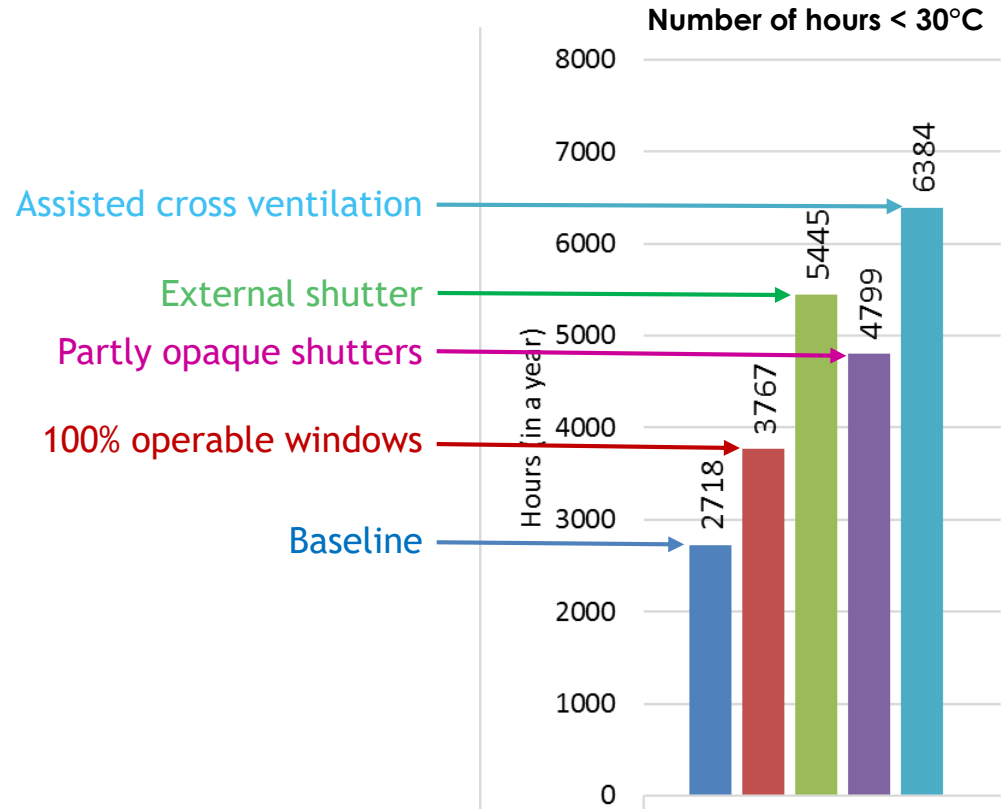


Specific electricity for mechanical ventilation	20.9	6.7	6.7	5.5
Specific electricity for lighting	18.1	16.7	11.1	11.1
Specific cooling requirements	51.1	40.6	25.9	19.1
Specific heating energy	62.3	7.9	12.2	10.1

Example: thermal comfort without active cooling



Low cost housing project Smart Ghar



Case study: Aranya Bhawan, Jaipur

- BEEP Integrated Design Charrette (December 2012)
- Monitored data (2016)



Aranya Bhawan is the new office building of the Rajasthan Forest Department in Jaipur, inaugurated in March 2015.

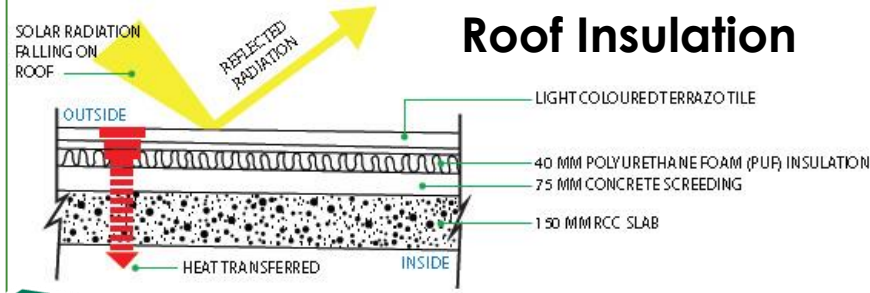
BEEP Integrated Design Charrette was held in December 2012, adopting a collaborative working approach between the client, RSRDC & the architect.

- **Client:** Rajasthan Forest Department
- **Executing Agency:** Rajasthan State Road Development and Construction Corporation Ltd. (RSRDC)
- **Architects:** Mathur, Ugam and Associates



As at the time of charrette, the orientation and building massing was already finalized; the focus was more on envelope & HVAC measures

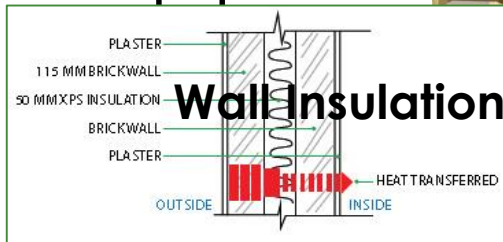
Aranya Bhawan: Passive measures



U-value: $0.6 \text{ W/m}^2.\text{K}$

Glazing: U-value:
 $1.8 \text{ W/m}^2.\text{K}$
SHGC: 0.24
VLT: 36%

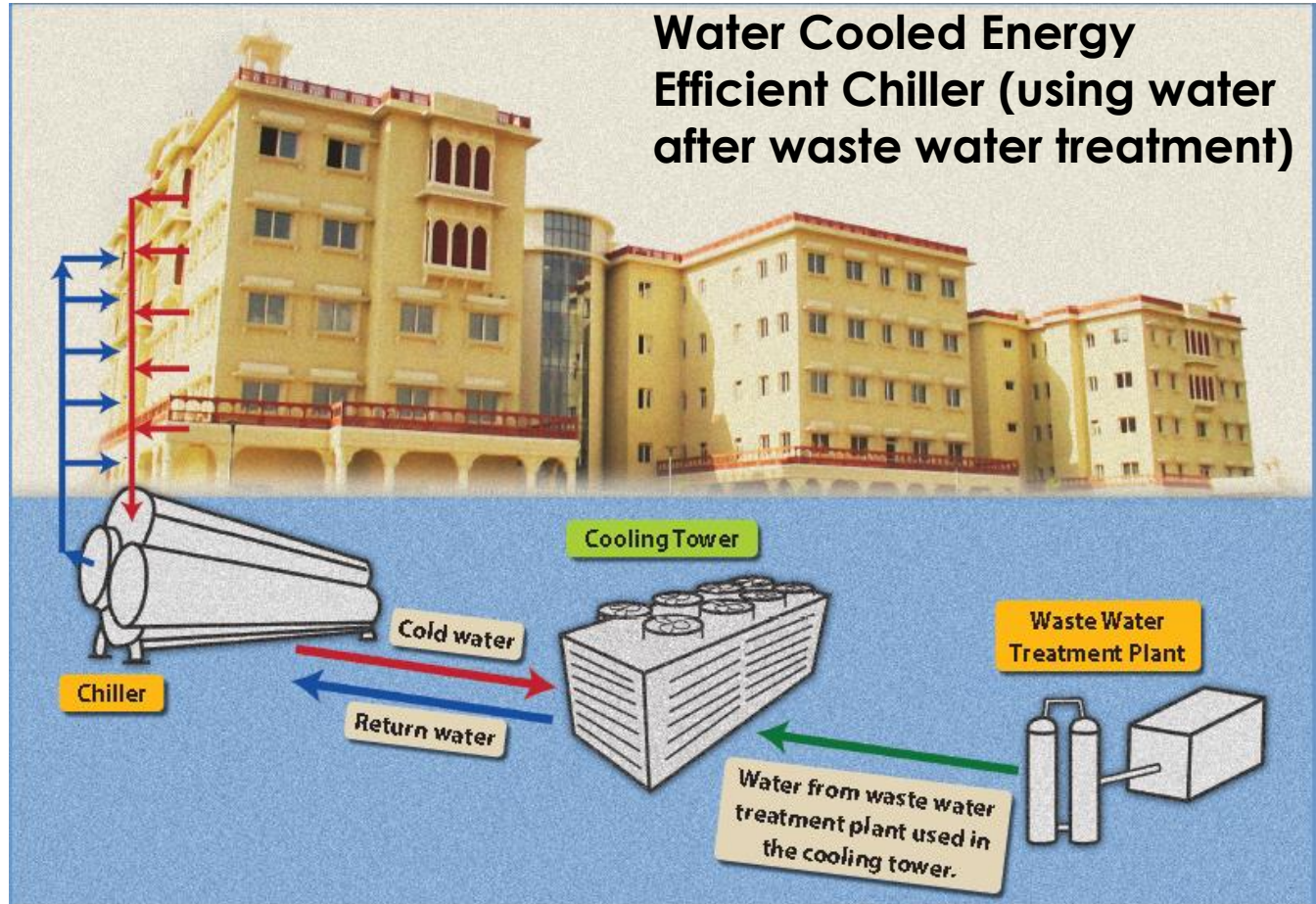
Reduction
in Glazed
Area



U-value: $0.5 \text{ W/m}^2.\text{K}$



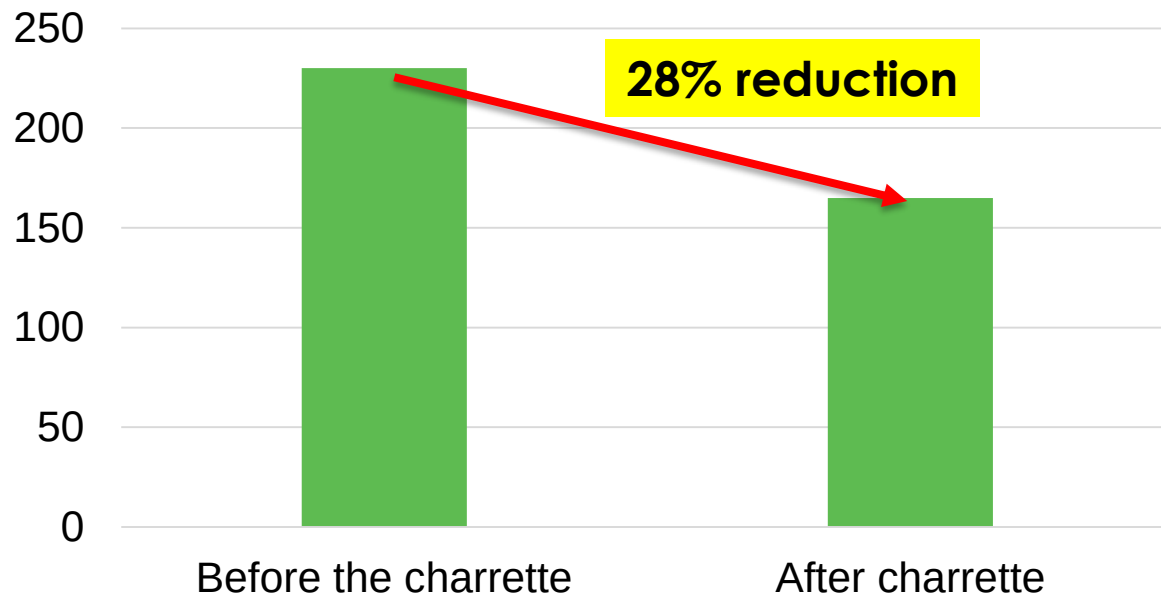
Water Cooled Energy Efficient Chiller (using water after waste water treatment)



Aranya Bhawan: Cooling system size



Cooling system size (TR)



Integrated design often allows reducing investment for HVAC systems

Aranya Bhawan: Cost benefit of energy efficiency measures



**EPI: 77
kWh/m²/year**

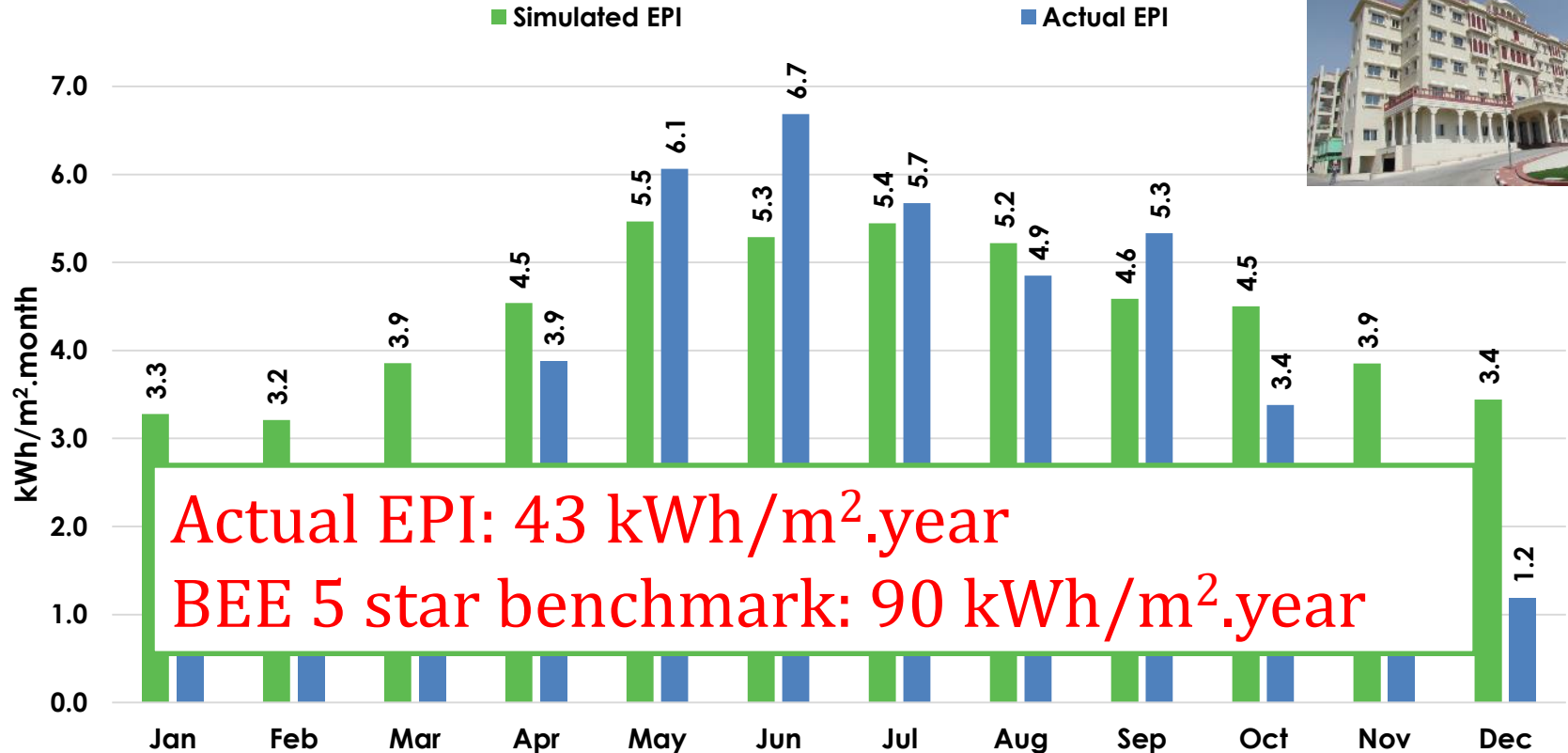
	Before Charrette	After Charrette	
Energy Performance Index (EPI)	77 kWh/m ² /year	53 kWh/m ² /year	32% energy savings
Cost of construction (not including the solar PV system)	Rs. 30 crores	Rs. 30.6 crores	2% cost increase
PAYBACK PERIOD: 3 YEARS			

**EPI: 53
kWh/m²/year**

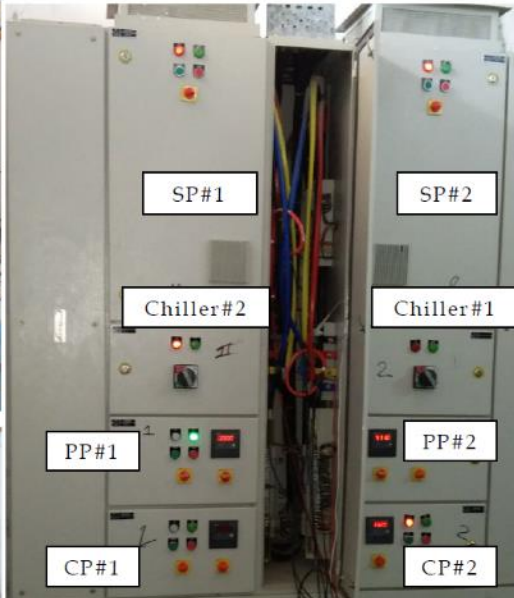
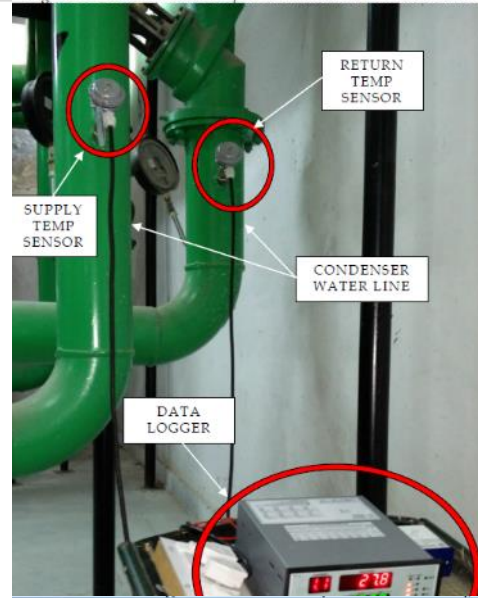
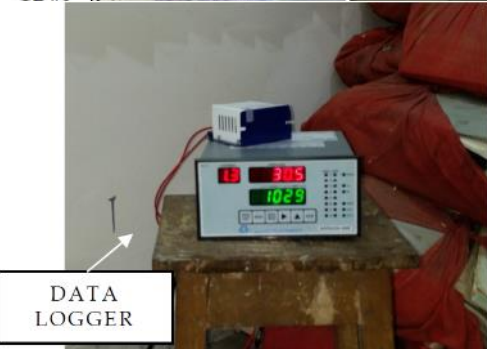


Aranya Bhawan: Electricity consumption

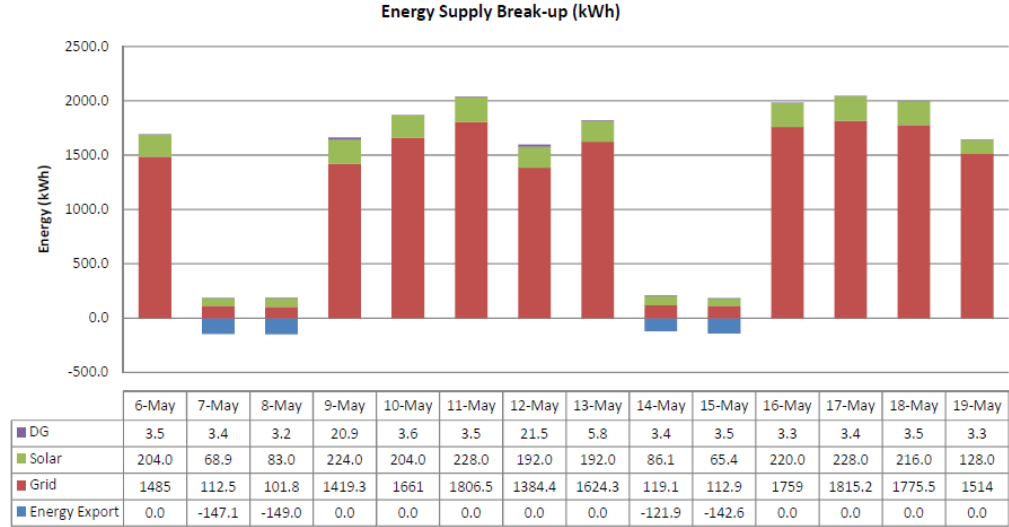
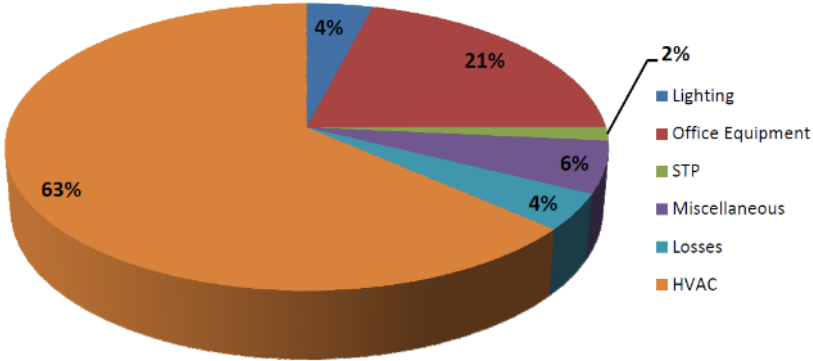
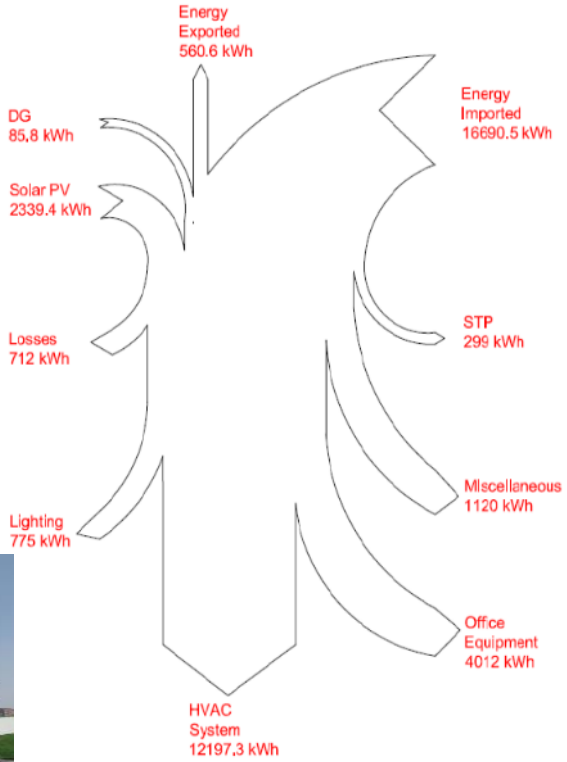
Monthly EPI Comparison: Simulated vs. Actual

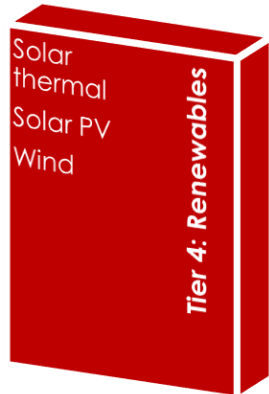


Aranya Bhawan: Energy monitoring



Aranya Bhawan: Monitoring results





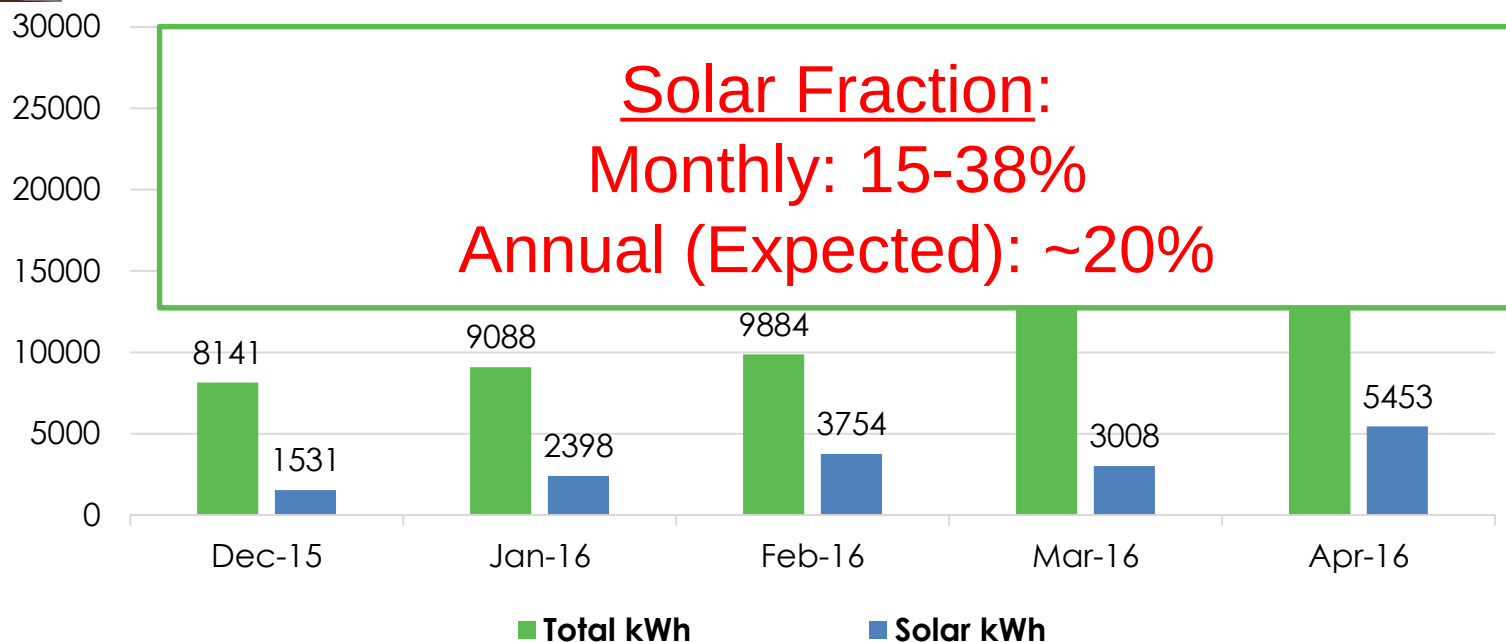
Grid connected rooftop solar PV

- Capacity: 45 kWp (annual production: ~60,000 kWh)
- Additional 100 kWp being planned

Aranya Bhawan: Rooftop solar photovoltaic system



Aranya Bhawan Energy Consumption & Solar PV Generation (kWh/month)



Design, construction and measurement standardisation

Capital gap and performance gap

Investment Ready Energy Efficiency



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



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.

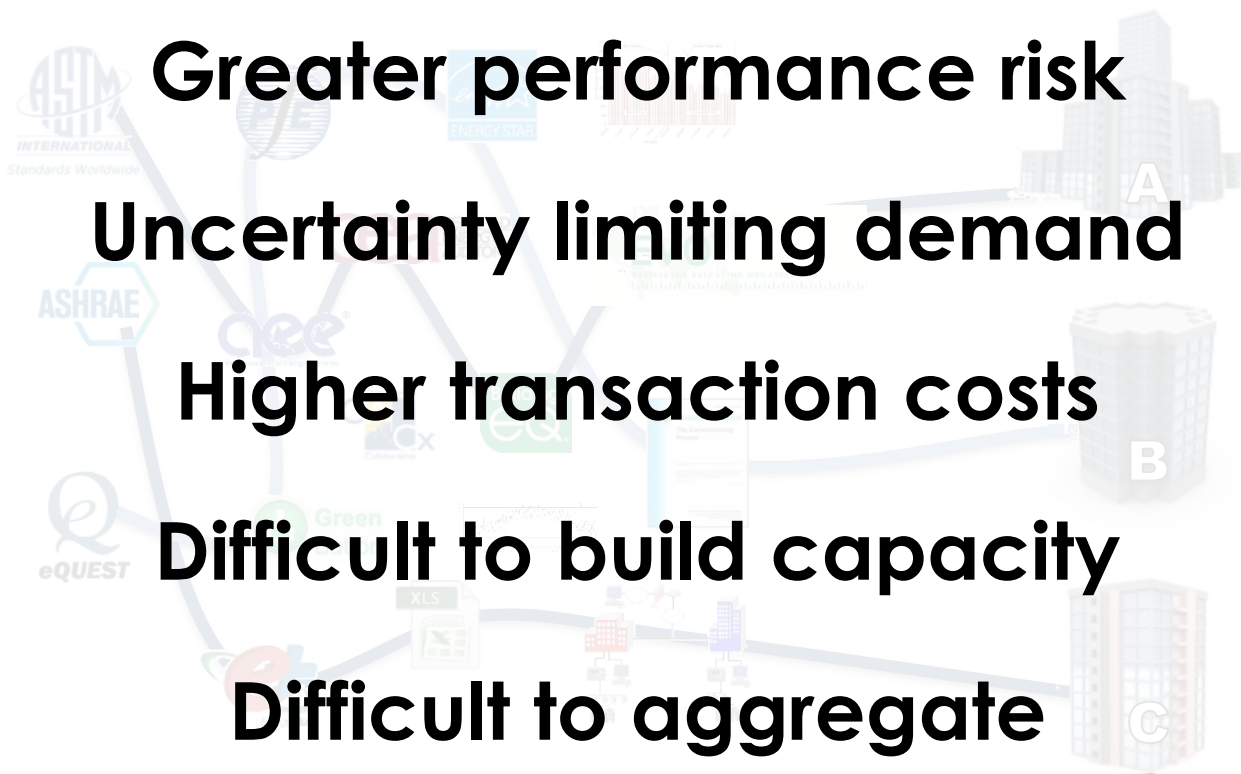
Greater performance risk

Uncertainty limiting demand

Higher transaction costs

Difficult to build capacity

Difficult to aggregate



What owners and investors want

- 
- The background of the slide features a man in a dark suit and striped tie, holding a large fan of US dollar bills in front of his face. He has large, white, feathered angel wings drawn over his shoulders. The entire image is set against a dark, textured background.
- **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**

What does a standardised approach looks like?

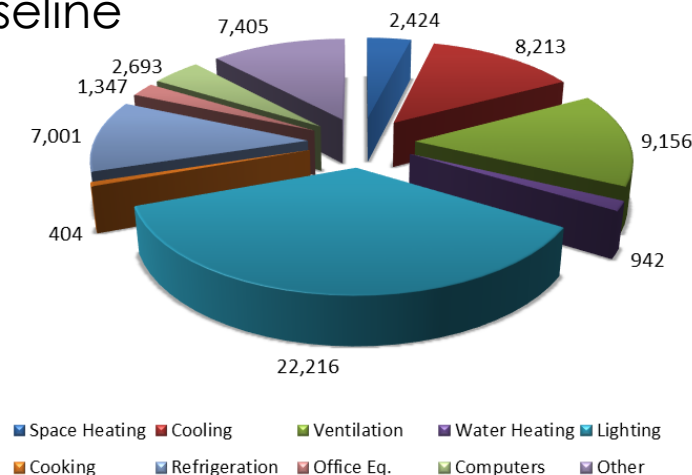


What does a standardised approach looks like?



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
- Determine energy use by end-use
- Building performance
- Weather data
- Occupancy data



What does a standardised approach looks like?



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

- Energy modeling software
- Modeler credentials
- Supporting model files and model calibration
- Key metric benchmarks
- Energy efficiency measures model variables
- Individual and packaged energy savings results



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.

- Operational performance verification plan
- Commissioning
- Inspection and spot measurements
- Data logging
- Training
- Systems manual

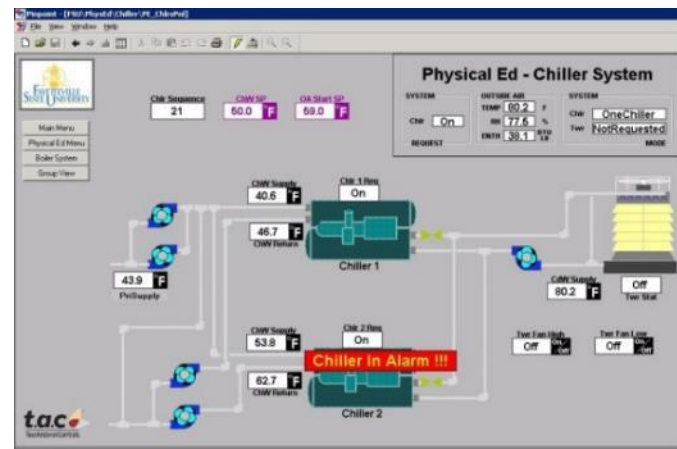


What does a standardised approach look like?



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

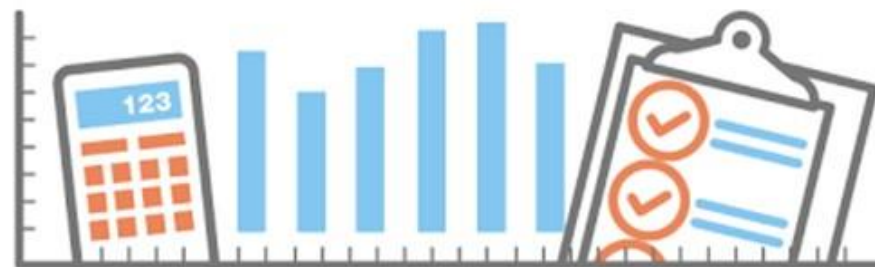


What does a standardised approach looks like?



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

- M&V provider credentials
- Options A and B: retrofit isolation
- Option C: utility bill analysis
- M&V report



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



Investor Ready Energy Efficiency (IREE)

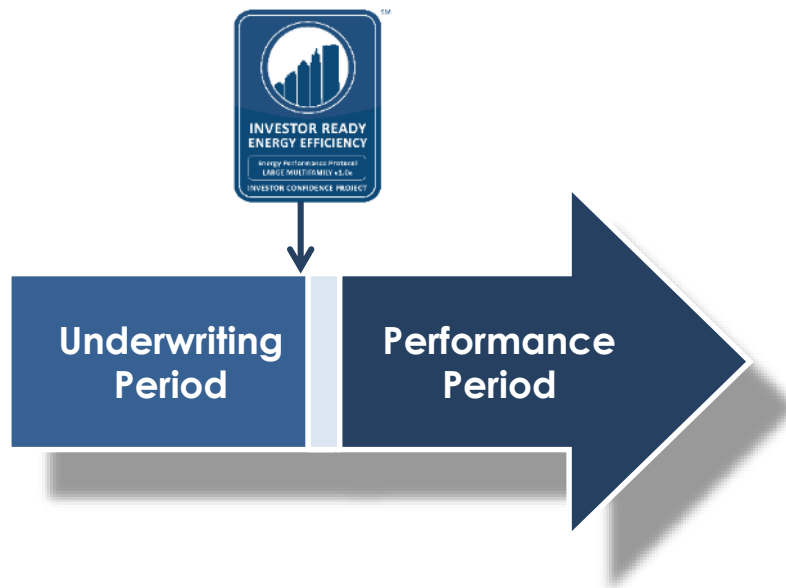
An international framework for reducing owner and investor risk, lowering due diligence costs, increasing certainty of savings achievement and enabling aggregation.



The IREE™ Certification ensures transparency, consistency and trustworthiness through **best practice and independent verification**.

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 is **delivered prior to investment decision**

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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