Energy Efficiency in buildings – day 2
Maxine Jordan, IEA, and Ian Hamilton, UCL Energy Institute
Pretoria, Tuesday 15th October 2019

Buildings energy efficiency sessions in partnership with:
UCL ENERGY INSTITUTE
Welcome back!

• Review: What we learned yesterday and questions
• Polls:

**Question 1:**
Which aspects of regional collaboration could benefit you the most?
Selezione uma ou mais respostas
- Policy exchange
- Harmonisation of policies
- Technology transfer
- Industrial networks
- Capacity building
- Other

**Question 2:**
By which year do you think that all new buildings could be mandated to be net zero energy in your country?
Selecione uma resposta:
- 2030
- 2040
- 2050
- Other
Results

Which aspects of regional collaboration could benefit you the most?

- Policy exchange: 15%
- Harmonisation of policies: 21%
- Technology transfer: 25%
- Industrial networks: 10%
- Capacity building: 27%
- Other: 2%
By which year do you think that all new buildings could be mandated to be net zero energy in your country?

- 2030: 23%
- 2040: 31%
- 2050: 35%
- Other: 12%
Toolkit: Energy efficient building design technologies

Buildings: Maxine Jordan, IEA and Ian Hamilton, UCL Energy Institute

Pretoria, Tuesday 15th October 2019

Buildings energy efficiency sessions in partnership with:

UCL ENERGY INSTITUTE
Energy Efficiency Training Week: Buildings programme

1. Where to start: Energy use in buildings
2. Where to start: Energy efficiency potential in buildings
   Special session: GlobalABC Regional Roadmaps
3. **Toolkit: Energy efficient building design technologies**
4. Toolkit: Energy efficient building system technologies
   Special session: Green Building in Africa – Elizabeth Chege, KGBS
   Special session: The GlobalABC Africa Roadmap for buildings and construction
5. What are the steps? Determining the current status of policies
6. Toolkit: Energy efficiency policies and target setting with guest speaker: Hlompho Vivian, GBC SA
7. What are the steps? Implementing codes and standards
8. What are the steps? Building operations and procurement with guest speaker: Christelle Van Vuuren, Carbon Trust
   Special session: The multiple benefits of energy efficiency
9. Did it work? Evaluation and energy efficiency indicators
   Special session: Financing energy efficiency in buildings
10. Buildings quiz
3. Toolkit: Energy efficient building design technologies
Trainers: Maxine Jordan, IEA

Purpose: To teach the fundamentals of how energy use in buildings can be reduced through design. 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 building construction timelines are short and that it is not possible to design buildings that are more efficient because it is too complicated.

Discussion question: What design feature or part of a building do you think most needs to be addressed today to support low energy buildings? Take 5 mins to write your thoughts on a post-it
- which sector
- which part of the building
- why is it the most urgent
## Path to zero emissions or net zero energy buildings

<table>
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<tr>
<th>Energy strategy</th>
<th>Energy efficiency</th>
<th>Renewable energy</th>
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<td><strong>1. Energy sufficiency</strong></td>
<td><strong>2. Energy efficiency</strong></td>
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<td>Reduce energy needs</td>
<td>Reduce energy consumption</td>
<td>Reduce CO₂ emissions by using renewable energy</td>
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<td><strong>Policy measure</strong></td>
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<td>Land-use policies</td>
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<td>Bioclimatic design principles</td>
<td>Mandatory S&amp;L for: overall building energy performance</td>
<td>S&amp;L policies for equipment</td>
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<td>Use of passive solutions</td>
<td>building elements and equipment</td>
<td>Mandatory share of supply from renewable energy sources</td>
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<td><strong>Source:</strong> <a href="http://www.iea.org/publications/policypathwaysseries/">www.iea.org/publications/policypathwaysseries/</a></td>
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Integrated design process

Sufficiency, efficiency, renewables

Tiered approach to integrated design

Design charrette
The tiered approach for the integrated design process

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

We will talk about both the strategies and the technologies themselves.

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

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Integrated Design Process: Tier 0 – Site Design

**Landscaping**
- Impact of 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
IEA 2019. All rights reserved.
Integrated Design Process: Tier 0 – Site Design

**Facade orientation**

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

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

IEA 2019. All rights reserved.
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
Integrating Design Process: Tier 1 – Building Design

Walls, windows, shading and solar gains
- Wall should be designed to have insulation: materials
- Light surface finishes reflect heat from the sun
- Window area should be limited
- 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.

Source: Adapted from Lechner, Norbert: Heating, Cooling, Lighting : Sustainable Design Methods for Architects
IEA 2019. All rights reserved.
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:

35% Windows with inadequate shading
- \( U \approx 3.5 \text{ W/m}^2\cdot\text{K} \)
- Monolithic concrete wall

10% Windows with shading
- \( U \approx 0.5 \text{ W/m}^2\cdot\text{K} \)

Source: Adapted from Lechner, Norbert: Heating, Cooling, Lighting: Sustainable Design Methods for Architects
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Building envelope technology: insulation

- Recommended average wall and roof U-values based on lifecycle cost effectiveness:

  - ≤ 0.15 W/m²°C cold climate
  - ≤ 0.35 W/m²°C hot climate

Insulation levels vary widely in the existing building stock. Efficient new buildings have increased insulation (low U-value).

Source: IEA Building Codes Policy Pathway and Transition to Sustainable Buildings
Building envelope technology: roof as a system

Insulation, air sealing, ventilation, radiant barriers, are all important factors, with the best approach depending on the type of roof (pitched, low-slope, or flat).

Source: IEA Energy Efficiency Training Week
The building envelope is often the main source of heat gain/loss

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

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

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Building envelope technology: windows

Single glazing

- **U-value**: \(~5 \text{ W/m}^2\text{K}\)

Double glazing

- **U-value**: \(~2 \text{ W/m}^2\text{K}\)

- Air gap – possible inert gas mix to reduce convection within cavity (e.g. argon, krypton)

Single glazing windows are highly inefficient in all climate types.
The majority of the world’s installed windows can be significantly improved and more work is needed to bring costs down to improve financial feasibility.
Building envelope technology: window coatings

Low emissivity films

- **Transparent metal coatings** that reflect radiant heat (long wave radiation) combined with solar selective coatings that reflect visible light and near-infrared light (heat we feel)

- **Typical savings of 30% to 40%**

- Commonly applied to new windows, but can also be installed in retrofit low-e storm panels and low-e window films when window replacement is not possible

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Low-e coatings can be a low cost and highly efficient addition to windows. Do you know the market share of low-e glass in your country?
Building envelope technology: window frames

Window low conductive frames

Outside

Advanced, warm interior in winter

Improving performance

Inside

Old, no thermal break, cold interior in winter

Source: Alcoa/Kawneer
Ancient and modern shading can be a low cost demand efficiency measure.
Internal shades still allow the solar heat gain to enter the building.

Source: BEEP India
Building envelope technology: internal vs. external shading

External shades keep out much more heat than internal shades.

Source: BEEP India

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Integrated Design Process: Tier 1 – Building Design

A high solar reflectance rejects heat from sun.

- The visible colour or the presence of near infrared reflective pigments affect the amount of heat that enters the building.

SR ~ 5% to 10%

Lighter colours or reflective pigments increase the higher solar reflectance of materials, absorbing less heat.

SR ~ 70% to 80%

Dark colours have low reflectance and absorb more heat.

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

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Million Cool Roofs Challenge

A $2 million global competition to rapidly scale up the deployment of highly solar-reflective “cool” roofs in developing countries suffering heat stress and lacking widespread access to cooling services.

Source: Kigali Cooling Efficiency Programme
Building envelope technology: reflectance impact on heat island

High density of low solar reflectance surfaces increases the heat absorption and heat islands in cities.

Source: LBNL
Building envelope technology: air sealing

• **Air sealing can account for 10-30% of heating and cooling loss.** However, air sealing can be easily applied and verified with infrared camera and air pressure tests.

Sealing the connection

Thermal image

Source: Marc LaFrance
Building envelope technology: air sealing

- **Validated air sealing** is a critical measure for building codes and renovation

- Testing of large multi-family buildings can be expensive – possible to institute **sampling and workmanship criteria to reduce cost**

- More research needed to offer more affordable testing but **many low cost and simple solutions exist today**
  - New research is occurring on a whole building air-based sealant (to seal the building envelope), by the inventors of Aeroseal (for duct sealing)

Source: Oak Ridge National Laboratory
Advanced technologies: building envelope and modelling

Examples of some of the newest technologies

• **Sealing:**
  - Aeroseal for ducts
  - Aeroseal for building envelopes

• **Insulation:**
  - Vacuum insulated panels
  - Aerogel insulation
  - Phase-change material insulation

• **Windows:**
  - Dynamic glazing (tinting)
  - Solar PV integrated clear windows

• **Data collection and energy models:**
  - Drive by image collection and satellite image collection translated to building energy models
Integrated Design Process: Tier 2 – Passive Systems

“ancient” architecture
(low window to wall ratio, natural ventilation, ...)

“modern” architecture
70-100% glazed, no natural ventilation, all air systems

“sustainable” architecture
15-40% window to wall ratio, natural ventilation, external movable solar protection, radiant cooling

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

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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
Tier 3: After all of the passive options are used, mechanical systems can deliver the designed comfort:

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

Tier 4: Meet the rest of the energy demand through renewables to get to net zero

- Renewable heat: solar thermal, waste heat, cogeneration
- Renewable electricity: solar photovoltaic, wind, purchased renewable energy

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

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How the integrated design process works in practice

The process:

- **Design charrettes**
  - 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 charrettes

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.

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

Modelling tools
Certification
Commissioning
Building energy modelling

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) 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
Building energy modelling

Example: thermal comfort without active cooling

Low cost housing project Smart Ghar, India

- Assisted cross ventilation
- External shutter
- Partly opaque shutters
- 100% operable windows

Baseline

Number of hours < 30°C

Source: BEEP India
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

Source: BEEP India

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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

• Other building energy modelling software:
  - EnergyPlus
  - IES
  - OpenStudio
  - DesignBuilder

Source: DesignBuilder
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BIM: Building Information Modelling

• **What is it?** Modelling in 3+ dimensions

• **Why is it important?**
  - Standardisation, lower cost
  - Facilitate resolving conflicts
  - Facilitates working as a cross disciplinary team
  - Modules for energy simulation, CFD, daylight modelling
  - Management over whole lifecycle of project

Source: Autodesk.com
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.
Building performance 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.

- [www.edgebuildings.com](http://www.edgebuildings.com)
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 4.05
- 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
**Energy Efficiency Measures**

Select options from the list below:

- 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 (VRF) 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
- 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

39.3% Meets EDGE Energy Standard
Energy efficient building design technologies

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

Discussion question: What design feature or part of a building do you think most needs to be addressed today to support low energy buildings?
- which sector
- which part of the building
- why is it the most urgent