Building systems and operations
Maxine Jordan and Ian Hamilton
Singapore, 16-18th July 2019
The trainers

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International Energy Agency

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UCL Energy Institute, University College London
Introductory roundtable

**Introduce yourself!**
Name, country, organisation

State one buildings policy or technology you think is the most promising for your region

State the most interesting thing you learned from the previous session or the site visit

**Over the next 3 days:**
Speak up and engage with others
Ask questions, give answers
Net Zero Building SD4 NUS
How the session will work

1. Introduction to the subtopics
2. Setting the level of ambition: what are we trying to achieve?
3. Identifying Technology Gaps
4. Identifying Policy Gaps
5. Identifying the “Enablers”
6. Identifying the Key Actions

**Fill in templates** for:
- technology timeline
- policy timeline
- key actions
Current 8 strategic priority areas:

1. **Urban planning:** use urban planning policies to enable reduced energy demand, increased renewable energy capacity and improved infrastructure resilience.

2. **New buildings:** Increase uptake of new buildings with net-zero operating emissions.

3. **Building retrofits:** Increase the rate of building energy renovation and increase the level of sustainability in existing buildings.

4. **Building operations:** Reduce the operating energy and emissions through improved energy management tools and operational capacity building.

5. **Systems:** Reduce the energy and emissions needed for equipment, appliances, lighting and cooking.

6. **Materials:** Reduce the environmental impact of materials and products in buildings and construction by taking a life-cycle and circular economy approach.

7. **Resilience:** Reduce building risks related to climate change through building design, selection of materials and improving resilience to structural, water and heat risks.

8. **Clean energy:** Increase secure, affordable and sustainable energy and reduce the carbon footprint of energy demand in buildings.
1. Introduction to the subtopics

Building systems and operations

“Buildings don’t use energy, people do”:
Building systems are **operated by people** to make people **comfortable**, and these systems use energy.

This module will cover measures to reduce the energy use of building systems during their operation.

- **Step 1**: Sufficiency
- **Step 2**: Efficiency
- **Step 3**: Renewables
Roadmap for Buildings and Construction

Set targets for:

- Urban planning
- New buildings
- Building retrofits
- Building operations
- Systems
- Materials
- Resilience
- Clean energy

Building systems improvement for:

- Efficient and low carbon heating systems
- Efficient cooling systems
- Efficient lighting systems
- Efficient large appliances and cooking
- Efficient small appliance and electronics

Achieve these through:

- Minimum energy performance standards
- Product labelling
- Testing and evaluation
- Incentives
- Technology and knowledge transfer

A collaboration of the IEA (Clean Energy Transitions and Energy Efficiency in the Emerging Economies programmes) and the Global Alliance for Buildings and Construction
Set targets for:
- Urban planning
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Existing building operations improvement:
- Improved energy management
- (Nearly) net zero operating emissions

Achieve these through:
- Energy reduction targets
- Occupant behaviour
- Energy management tools (e.g. ISO)
- Energy data collection/disclosure
- Building energy labelling and certification
- Building and system commissioning
- Building passports
- Technology and knowledge transfer

A collaboration of the IEA (Clean Energy Transitions and Energy Efficiency in the Emerging Economies programmes) and the Global Alliance for Buildings and Construction
What systems are we talking about?

For electricity consumption: prioritise water heating and appliances (residential) and lighting, cooling and appliances (non-residential). Note: AC ownership in households is growing.
What operations are we talking about?

• Building operations consist of the activities necessary to **operate, maintain, and manage** buildings. This includes maintaining the HVAC systems, plumbing, electrical, and building system configuration.

• Operation and management activities, methods, and approaches should **enable energy savings** while maintaining or enhancing **indoor environmental quality** and **equipment reliability**.

• Good operation and management practices will lead to the efficient operation of buildings rather than emphasising energy-efficient capital improvements or equipment-specific maintenance procedures. Can also lead to increased productivity of occupants, and a longer lifetime of the building and its components.

• Operation management Improvements focus on:
  - Management: goals, planning, accounting
  - Teamwork: staffing, training, outsourcing
  - Resources: documentation: tools, assessments
  - Energy-Efficient operation and maintenance: Tune-up, automated controls, scheduling, tracking, prevention
2. Setting the level of ambition: what are we trying to achieve?

**What are we trying to achieve**
- Low operational energy
- Low capital cost
- Comfortable
- Easy to maintain
- Resilient
- Low emission

**What are the factors**
- Climate
- Typology
- Choice of systems
- Operation and maintenance

**How might we measure that?**
- Annual energy consumption, EPI (kWh/m²/year)
- Efficiency of systems
- Use of procedures
Drivers of building energy use: systems

Once energy needs have been reduced through passive measures, the principle factors become:

Correctly sized and designed systems
Efficient components
Correctly maintained
Correctly operated

Responsible:
• Designer
• Manufacturer
• Facilities manager
• Operator/occupant
**Evaluation:** choosing the right metric

The right energy performance metric is crucial to understanding & tracking progress over time.

Source: IEA energy efficiency indicators database

Index: 1990=1. Data for IEA18 (Australia, Austria, Canada, Denmark, Finland, France, Germany, Ireland, Italy, Japan, Netherlands, Norway, Slovakia, Spain, Sweden, Switzerland, UK, USA). TC: Temperature Corrected.

What are these types of energy performance metrics not telling us about energy demand and efficiency progress?

- Behaviour?
- Technology?
- Efficiency?
- Income?
Energy efficiency indicators pyramid

• Residential
  - Energy per household
    - Energy for end-use (eg. Water heating, appliances) per household
  - Energy per floor area
    - Energy for end-use (eg. heating, cooling, lighting) per floor area
    - Equipment energy use per floor area and type

• Commercial
  - Energy per floor area
    - Energy by building type per floor area
    - Energy for end-use by building type per floor area

Source: IEA energy efficiency indicators
3. Technology gaps

- Let’s try and think of all the technologies that are relevant to building systems and operations in your regions.

<table>
<thead>
<tr>
<th>Residential</th>
<th>Non-residential</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cooking &amp; water heating</strong></td>
<td><strong>HVAC</strong></td>
</tr>
<tr>
<td>- More efficient fuels eg. Electricity or gas</td>
<td>- Central HVAC, pumps and fans, commissioning</td>
</tr>
<tr>
<td>- Heat pump</td>
<td>- Air cooled vs water cooled chillers</td>
</tr>
<tr>
<td>- Solar thermal</td>
<td>- Split systems, inverters, heat pumps</td>
</tr>
<tr>
<td>- District heating</td>
<td>- District systems</td>
</tr>
<tr>
<td><strong>Appliances &amp; lighting</strong></td>
<td>- Evaporative cooling, heat recovery, free cooling, hybrid cooling</td>
</tr>
<tr>
<td>- Efficient appliances with low standby power</td>
<td>- Temperature set point</td>
</tr>
<tr>
<td>- “Smart” devices</td>
<td></td>
</tr>
<tr>
<td>- LEDs</td>
<td></td>
</tr>
<tr>
<td>- Smart meters</td>
<td></td>
</tr>
<tr>
<td><strong>Space cooling</strong></td>
<td><strong>Lighting</strong></td>
</tr>
<tr>
<td>- Split systems</td>
<td>- LED</td>
</tr>
<tr>
<td>- Inverters</td>
<td>- Dimming, daylight harvesting</td>
</tr>
<tr>
<td>- Window units, portable ACs</td>
<td></td>
</tr>
<tr>
<td>- VRF, VRV</td>
<td></td>
</tr>
<tr>
<td><strong>Ventilation</strong></td>
<td><strong>Controls &amp; Energy management</strong></td>
</tr>
<tr>
<td>- Properly sized and positioned kitchen extract</td>
<td>- Variable speed drives</td>
</tr>
<tr>
<td>- Fans</td>
<td>- Smart and connected sensors</td>
</tr>
</tbody>
</table>

Think about: - which are available locally? Which are currently affordable? Expensive? Are specially skilled workers or tools required?
Setting targets

• For the roadmap, we will set targets for the key technologies in this format:

<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>List key technologies</td>
<td>Typical: X</td>
<td>Achieve: X</td>
<td>Achieve: X</td>
</tr>
<tr>
<td></td>
<td>Exceptional: X</td>
<td>Aspire: X</td>
<td>Aspire: X</td>
</tr>
</tbody>
</table>

• List the key barriers and enablers for achieving this timeline.
Technology refresher – keeping buildings cool

• **Step 1: building envelope and design**
  - Module 1

• **Step 2: lower heat gains through efficient appliances**
  - More efficient lights and appliances reduce the heat transfer to the space

• **Step 3: assisted ventilation**
  - Efficient ceiling fans with high performance brushless DC motors and improved blade designs
    - Can bring down the perceived temperature down by 2-4°C

• **Step 4: energy-efficient air conditioning**
  - Raised set point
  - High EER, seasonal efficiency, label rating
  - Water based systems
Technology refresher – reducing HVAC demand

Decrease transport energy
- VFD for pump and fans for adaptation to the demand
- Chilled Water systems instead of air systems

Decrease the cooling demand
- Free cooling
- Evaporative cooling
- Enthalpy recovery
- Gliding temperature for the chilled water production
- Select chillers on part load performance with VFDs on fans and pumps
- Run chillers on optimum point

Increase the efficiency of the cooling production

Source: BEEP
Technology refresher – energy management

- Example: energy monitoring equipment at Aranya Bhawan Office Building, Jaipur, India

Source: BEEP
Energy monitoring results – Aranya Bhawan

Energy flow (Sankey Diagram) for the Summer Monitoring

Monthly EPI Comparison: Simulated vs. Actual

Actual EPI: 43 kWh/m².year
BEE 5 star benchmark: 90 kWh/m².year

Source: BEEP
### Set targets for:

- Urban planning
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#### Heating, cooling and lighting

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<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td><strong>Space heating</strong></td>
<td>Typical: X COP</td>
<td>Achieve: X COP</td>
<td>Achieve: X COP</td>
<td>Achieve: X COP</td>
</tr>
<tr>
<td></td>
<td>Exceptional: &gt;X COP</td>
<td>Aspire: X COP</td>
<td>Aspire: X COP</td>
<td>Aspire: X COP</td>
</tr>
<tr>
<td><strong>Space cooling</strong></td>
<td>Typical: X EER and X SEER</td>
<td>Achieve: X SEER</td>
<td>Achieve: X SEER</td>
<td>Achieve: X SEER</td>
</tr>
<tr>
<td></td>
<td>Exceptional: ≥ X EER and X SEER</td>
<td>Aspire: X SEER</td>
<td>Aspire: X SEER</td>
<td>Aspire: X SEER</td>
</tr>
<tr>
<td><strong>Ventilation</strong></td>
<td>Typical: mechanical without energy recovery</td>
<td>Achieve: X% energy recovery</td>
<td>Achieve: X% energy recovery</td>
<td>Achieve: X% energy recovery</td>
</tr>
<tr>
<td></td>
<td>Exceptional: natural</td>
<td>Aspire: X% natural</td>
<td>Aspire: X% natural</td>
<td>Aspire: X% natural</td>
</tr>
<tr>
<td><strong>Water heating</strong></td>
<td>Typical: X COP</td>
<td>Achieve: X COP</td>
<td>Achieve: X COP</td>
<td>Achieve: X COP</td>
</tr>
<tr>
<td></td>
<td>Exceptional: &gt;X COP</td>
<td>Aspire: X COP</td>
<td>Aspire: X COP</td>
<td>Aspire: X COP</td>
</tr>
<tr>
<td><strong>Lighting</strong></td>
<td>Typical: &lt;100 lumens/watt</td>
<td>Achieve: X lm/w</td>
<td>Achieve: X lm/w</td>
<td>Achieve: X lm/w</td>
</tr>
<tr>
<td></td>
<td>Exceptional: &gt;200 lumens/watt</td>
<td>Aspire: X lm/w</td>
<td>Aspire: X lm/w</td>
<td>Aspire: X lm/w</td>
</tr>
</tbody>
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<tbody>
<tr>
<td>Refrigerators</td>
<td>Typical: X kWh/year/litre</td>
<td>Achieve: X kWh/year/litre</td>
<td>Aspire: X kWh/year/litre</td>
<td>Achieve: X kWh/year/litre</td>
</tr>
<tr>
<td></td>
<td>Exceptional: X kWh/year/litre</td>
<td>Achieve: X kWh/year/litre</td>
<td>Aspire: X kWh/year/litre</td>
<td>Achieve: X kWh/year/litre</td>
</tr>
<tr>
<td>Cooking</td>
<td>X% clean cooking</td>
<td>Achieve: X% clean cooking</td>
<td>Aspire: X% efficient</td>
<td>Achieve: X% clean cooking</td>
</tr>
<tr>
<td></td>
<td>Typical: &lt;X% efficient</td>
<td>Achieve: X% clean cooking</td>
<td>Aspire: X% efficient</td>
<td>Achieve: X% clean cooking</td>
</tr>
<tr>
<td>Sensors and controls</td>
<td>Typically: digital, but not smart</td>
<td>Achieve: X% smart</td>
<td>Aspire: X% smart</td>
<td>Achieve: X% smart</td>
</tr>
<tr>
<td>Management systems</td>
<td>Typical: simple or programmable</td>
<td>Achieve: X% smart</td>
<td>Aspire: X% smart</td>
<td>Achieve: X% smart</td>
</tr>
<tr>
<td></td>
<td>Exceptional: learning and fault detection</td>
<td>Achieve: X% smart</td>
<td>Aspire: X% smart</td>
<td>Achieve: X% smart</td>
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<tr>
<td></td>
<td>Exceptional: active fault detection</td>
<td>Aspire: X% active fault detection</td>
<td>Aspire: X% active fault detection</td>
<td>Aspire: X% active fault detection</td>
</tr>
<tr>
<td>Audit tools</td>
<td>Audits seldom conducted when not required</td>
<td>Achieve: X% annual audits</td>
<td>Achieve: X% annual audits</td>
<td>Achieve: X% annual audits</td>
</tr>
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<td></td>
<td></td>
<td>Aspire: X% annual audits</td>
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<td>Building management systems</td>
<td>Typical: simple or programmable</td>
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<td></td>
<td>Exceptional: learning and fault detection</td>
<td>Aspire: X% smart</td>
<td>Aspire: X% smart</td>
<td>Aspire: X% smart</td>
</tr>
<tr>
<td>Energy management systems</td>
<td>&lt;X% using ISO 50001 or equivalent</td>
<td>Achieve: X% energy managed</td>
<td>Achieve: X% energy managed</td>
<td>Achieve: X% energy managed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Aspire: X% energy managed</td>
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Setting targets

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<td>Typical: X</td>
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<td></td>
<td>Exceptional: X</td>
<td>Aspire:</td>
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</tr>
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</table>

• List the key barriers and enablers for achieving this timeline.
Coffee break
4. Policy gaps

Let’s try and think of all the **policies** that are relevant to building systems and operations in your regions.

<table>
<thead>
<tr>
<th>To remove inefficient products off the market</th>
<th>To increase the demand for efficient products:</th>
</tr>
</thead>
<tbody>
<tr>
<td>- MEPS</td>
<td>- Building certification</td>
</tr>
<tr>
<td>- Phase-out</td>
<td>- Information and awareness</td>
</tr>
<tr>
<td></td>
<td>- Incentives</td>
</tr>
<tr>
<td></td>
<td>- Bulk or EE procurement</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>To promote low energy consumption of buildings</th>
<th>To increase the efficiency of products</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Mandatory disclosure</td>
<td>- R&amp;D</td>
</tr>
<tr>
<td>- Benchmarking</td>
<td>- Incentives</td>
</tr>
<tr>
<td>- Mandatory audits</td>
<td></td>
</tr>
<tr>
<td>- Recommissioning</td>
<td></td>
</tr>
</tbody>
</table>

Some things to think about:
- Mandatory or voluntary policies? How stringent should they be? Does the resource and capacity for enforcement exist?
Setting targets

• For the roadmaps, we will set targets for the key technologies in this format:

--------------------------------|---------------------|---------------------|---------------------
List key policies
  Typical: X  
  Exceptional: X  
  Achieve:  
  Aspire:  
  Achieve: X  
  Aspire: X  
  Achieve: X  
  Aspire: X

• List the key barriers and enablers for achieving this timeline.
Policy refresher – MEPS for ACs

- Stock of ACs in ASEAN is growing, and could be 10 times as high as today in 2050.
- Almost all homes will have on average 2 ACs.
- Efficiency of small ACs needs to improve drastically to avoid catastrophic impacts on the grid capacity, security and air pollution.

Stock of Air Conditioners in ASEAN

- Million units
- Categories: Indonesia residential, rest of ASEAN residential, Indonesia non residential, rest of ASEAN non residential
Efficiency of ACs in ASEAN

If ACs are already available that are much more efficient than the current MEPS, should the MEPS be revised?

MEPS and labelling are important mechanisms to increase the average efficiency of ACs on the market.

MEPS and labels should use appropriate metrics. EER, SEER or CSPF?
Policy refresher – mandatory disclosure

• Example: mandatory disclosure for commercial buildings in Australia - NABERS
Commercial Buildings using NABERS have reported energy efficiency improvements of almost 10%. In addition to that, surveys conducted in the program framework show that lessors and sellers can obtain up to a 9% green premium on the building value, depending on their score. Accordingly, buildings with BEEC have considerably increased their ratings in the first years of the program (2010 to 2014), but now have shown steady and even slightly decreasing scores due to: increased difficulty due to higher improvements marginal costs, and the reduction of the floor area threshold in 2017-2018, leading to more and smaller, poorer performing buildings participating in the program than the previous years.

• Example: mandatory disclosure for large buildings in New York City – Energy Star
By the beginning of 2020, the Department of Buildings will assign a grade to each building, which will have to be placed near each building entrance within 30 days after receiving the score. The benchmarking and disclosure program are part of the city’s efforts to reach the goal of reducing greenhouse gas emissions by 80% in 2050.
Setting targets

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<td>Achieve: X</td>
<td>Achieve: X</td>
</tr>
<tr>
<td></td>
<td>Exceptional: X</td>
<td>Aspire: X</td>
<td>Aspire: X</td>
</tr>
</tbody>
</table>

• List the key barriers and enablers for achieving this timeline.

• Some things to think about:
  • Mandatory or voluntary policies? How stringent should they be? Does the resource and capacity exist?
5. The “enablers”

- Some “enabling” strategies

**Capacity Building**
- Government training
- Professional training
- Educational training
- Awareness and information
- Institutional coordination

**Finance**
- Urban development funds
- Infrastructure funds
- Dedicated credit lines
- Guarantees
- Green bonds
- Preferential tax, grants and rebates
- EPCs
- Procurement purchase or lease
- On-bill/ tax repayment

**Multiple benefits**
- Emissions savings, air quality
- Energy savings, energy security, energy prices
- Economic, productivity, employment, asset value
- Poverty alleviation, health and wellbeing, safety and security
**Roadmap for Buildings and Construction**

**Set targets for:**
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</thead>
<tbody>
<tr>
<td>Minimum performance standards</td>
<td>X countries have at least one minimum performance standard</td>
<td>Achieve: X% mandatory Aspire: X% mandatory</td>
<td>Achieve: X% mandatory Aspire: X% mandatory</td>
<td>Achieve: X% mandatory Aspire: X% mandatory</td>
</tr>
<tr>
<td>Information and awareness</td>
<td>Minimal consumer awareness</td>
<td>Achieve: X% labels &amp; education Aspire: X% awareness</td>
<td>Achieve: X% labels &amp; education Aspire: X% awareness</td>
<td>Achieve: X% labels &amp; education Aspire: X% awareness</td>
</tr>
<tr>
<td>Research and development</td>
<td>Mission Innovation goal of doubling investment</td>
<td>Achieve: X% more investment Aspire: X% more investment</td>
<td>Achieve: X% more investment Aspire: X% more investment</td>
<td>Achieve: X% more investment Aspire: X% more investment</td>
</tr>
<tr>
<td>Circular economy</td>
<td>Minimal circular economy decisions</td>
<td>Achieve: X% plan circular economy Aspire: X% plan circular economy</td>
<td>Achieve: X% plan circular economy Aspire: X% plan circular economy</td>
<td>Achieve: X% plan circular economy Aspire: X% plan circular economy</td>
</tr>
<tr>
<td>Procurement and phase out</td>
<td>Leading jurisdictions procure sustainably</td>
<td>Achieve: X% green procurement Aspire: X% green procurement</td>
<td>Achieve: X% green procurement Aspire: X% green procurement</td>
<td>Achieve: X% green procurement Aspire: X% green procurement</td>
</tr>
<tr>
<td>Incentives</td>
<td>Leading jurisdictions provide incentives</td>
<td>Achieve: X% non-fiscal incentives Aspire: X% fiscal and non-fiscal</td>
<td>Achieve: X% non-fiscal incentives Aspire: X% fiscal and non-fiscal</td>
<td>Achieve: X% non-fiscal incentives Aspire: X% fiscal and non-fiscal</td>
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## Roadmap for Buildings and Construction

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</thead>
<tbody>
<tr>
<td><strong>Benchmarking</strong></td>
<td>Achieve: X% benchmarking Aspire: X% benchmarking</td>
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<tr>
<td><strong>Building certification</strong></td>
<td>X countries with voluntary or mandatory certification</td>
<td>Achieve: X% mandatory Aspire: X% mandatory</td>
<td>Achieve: X% mandatory Aspire: X% mandatory</td>
<td>Achieve: X% mandatory Aspire: X% mandatory</td>
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<td><strong>Building passports</strong></td>
<td>Widespread voluntary and silo information collection</td>
<td>Achieve: X% building passports Aspire: X% building passports</td>
<td>Achieve: X% building passports Aspire: X% building passports</td>
<td>Achieve: X% building passports Aspire: X% building passports</td>
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<tr>
<td>Disclosures and inspection</td>
<td>Minimal disclosure and inspection</td>
<td>Achieve: X% disclosure Aspire: X% disclosure</td>
<td>Achieve: X% disclosure Aspire: X% disclosure</td>
<td>Achieve: X% disclosure Aspire: X% disclosure</td>
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<tr>
<td><strong>Incentives</strong></td>
<td>Leading jurisdictions provide incentives</td>
<td>Achieve: X% non-fiscal incentives Aspire: X% fiscal and non-fiscal</td>
<td>Achieve: X% non-fiscal incentives Aspire: X% fiscal and non-fiscal</td>
<td>Achieve: X% non-fiscal incentives Aspire: X% fiscal and non-fiscal</td>
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A collaboration of the IEA (Clean Energy Transitions and Energy Efficiency in the Emerging Economies programmes) and the Global Alliance for Buildings and Construction

Enable investment in clean systems. Enable increasing use of sustainable products by increasing access to and use of finance to enable private investment.

Governments lead by example. Develop policies that ensure all government buildings invest in low-emission and efficient systems.

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<tr>
<td>Less-efficient lighting, appliances and equipment</td>
<td>Achieve: X% MEPS coverage</td>
<td>Aspire: X% of current BAT</td>
<td>Achieve: X% MEPS coverage</td>
<td>Aspire: X% of current BAT</td>
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<tr>
<td>Materials</td>
<td>Achieve: X% MEPS coverage</td>
<td>Aspire: X% of current BAT</td>
<td>Achieve: X% MEPS coverage</td>
<td>Aspire: X% of current BAT</td>
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Energy management systems. Train on energy management systems and use energy management processes in all buildings, particularly non-residential buildings.

Human resources: Hire and support the capacity building of sustainability and energy managers.

Smart controls. Deploy temperature, lighting and ventilation systems controls, sensors and energy metering.

Information. Provide data and information that will improve the decision making for building operators and occupants.
Thank you!