‘Human Habitats today have become centers of energy consumption. By conserving energy with appropriate building design, reducing energy by efficient energy management and producing energy with decentralized systems that allows feeding surplus energy into the grid, we can create a shift towards energy positive habitats. Essential to this movement is the fact that humans have to change their life styles to consume less energy.’
Building Energy Auditing & Management

Brahmanand Mohanty
Visiting Faculty
Asian Institute of Technology

Auroville Green Practices 2012:
Energy Positive Habitats
30 August – 1 September 2012
Energy in buildings

- Factors influencing the growth of energy use in buildings
  - Demographic evolution
  - Socio-cultural changes (lifestyle changes)
  - Design of building and greater use of energy consuming home and office appliances
Energy use in commercial buildings

250kWh/m².year
Energy-Star Buildings

Fully air-conditioned buildings in warm and humid climate

1 star: 100 kWh/m².y
2 stars: 125 kWh/m².y
3 stars: 150 kWh/m².y
4 stars: 175 kWh/m².y
5 stars: 200 kWh/m².y
Energy-Star Buildings

Fully air-conditioned buildings in warm and humid climate

- 5-Star: <100 kWh/m².y
- 4-Star: 100-125 kWh/m².y
- 3-Star: 125-150 kWh/m².y
- 2-Star: 150-175 kWh/m².y
- 1-Star: 175-200 kWh/m².y
How to design low-energy buildings?

- Fossil Fuels
- Renewable Energy
- Energy Efficient Appliances
- Sustainable design

- Efficient transformer and high power factor
- Cogeneration
- Solar thermal (heating, and cooling, photovoltaic (electricity))
- Wind turbine
- Biomass and biogas
- Lighting (efficient lamps, fixtures, control...)
- Heating and cooling equipment
- Other appliances (refrigerator, washing machines, computers...)
- Passive solar design (orientation, solar protection, natural ventilation, daylighting, etc.)
- Building envelope (insulation of walls and roof, special glazing)
How efficient is the energy conversion chain?

Primary Energy (coal, oil, gas...)

Energy conversion facility (refinery, power plant)

Secondary energy (refined oil, electricity...)

Transmission & distribution (pipeline, grid network...)

Final energy (delivered to consumer)

End-use energy services (human comfort, food cooked, IT applications...)

Energy services (lighting, motive power, chilled water)

Energy using appliance (lamp, motor, compressor...)

The Integrated approach starts with demand management and ends with the right choice of energy supply.
Consider the simple example of lighting

Energy service delivered is a fraction of the fuel fed into a power plant

100% with incandescent lamp
100% with incandescent lamp

80% less energy by switching from incandescent to CFL

Energy supply divided by 5!
80% less energy by adopting CFL

90% less energy by adopting LED

Energy supply further divided by 2!
Further loss reduction by adopting Solar-PV energized LED
Scope for achieving Factor-4 efficiency

- The steps that yield the greatest impacts on the whole system should be performed.
- Downstream investments reduce the demand, hence lowering upstream supply-side investments and the operating costs.
- Similar to lighting, there is scope for achieving Factor-4 or more efficiency by adopting the whole-system analysis approach.
Energy efficiency versus Renewable energy

Initial energy efficiency measures (low-hanging fruits) are easy to attain; one can achieve high energy saving while investment stays low.

The more we try to reduce the energy demand, the higher the life cycle cost becomes!

At a certain point, Energy efficiency measures become more expensive than Renewable technologies. It is time to shift efforts to renewable energy investments.
Typical energy issues in buildings

1. Fed up with Power Cuts
2. Ever-rising energy bills
3. Frequent Breakdowns
4. Irregular & erratic energy supply

The starting point is an energy audit (diagnosis)
Why energy audits?

• Energy audit is the first step to reducing energy costs at your facility

• There are many ways to reduce energy costs but not all are cost-effective

• An energy audit provides focus and direction, serving as the road map to energy savings
Approach to energy auditing  (ref: ASHRAE 2011)

Preliminary Energy Use Analysis
- Energy use index
- Compare with similar buildings

Level 1: Walk-through
- Rough costs and Savings for EEMs
- Identify Capital Projects

Level 2: Energy Survey & Analysis
- End-use Breakdown
- Detailed Analysis
- Cost & Savings for EEMs
- O&M Changes

Level 3: Detailed Survey & Analysis
- Refined Analysis
- Additional Measurement
- Hourly Simulation
Energy audit: Level 1

- Analysis of utility bills, brief survey or walk-through of building and facilities
  - Qualitative analysis
  - Recommendations usually do not include costs, savings and payback information
  - But recommendations address specific building areas and systems
  - Sufficient for proposing low-cost and no-cost energy saving measures
Energy audit: **Level 2**

- Detailed analysis of utility bills, in-depth inspection of building, breakdown of energy use by facility and identification of specific end uses
  - Quantitative analysis
  - Recommendations include implementation costs, savings and payback information
  - Sufficient for developing energy performance improvement measures
    - Replacement of inefficient equipment by energy efficient alternatives
    - Lighting, air conditioning, motive power (fans, pumps, compressors, variable frequency drives)
**Steps involved in data collection**

- **Collect data**
  - Data must be complete and accurate (for analysis and goal setting)

- **Determine appropriate level of details**
  - The level and scope of data collection varies from one organization to another

- **Account for all energy sources**
  - Make inventory of all energy purchased and generated on site, on cost basis

- **Document all energy uses**
  - Gather at least 3 years monthly data (energy bills, meter readings, etc.)

- **Collect facility and operational data**
  - To normalize and benchmark, collect non-energy related data
Undertake quantitative review

Develop use profiles
- Identify energy consumption peaks and valleys and determine how they relate to operations or key events

Compare performance
- Compare the use and performance data of similar facilities in buildings

Assess the financial impacts
- Identify areas of high-cost energy use

Identify data gap
- Determine areas where more information is needed
Energy audit: Level 3

• Also known as Investment-grade audit
• Thorough field inspection of facility, professional engineering analysis of energy use and potential improvements
  ○ Recommendations include implementation costs, savings and payback, life-cycle cost analysis
  ○ If needed, provision of bid specification services
  ○ Necessary for large-scale projects where many components and major changes are being considered
    • Major HVAC upgrades, re-design and re-engineering of HVAC systems, energy management systems
    • Major alteration to the building structure
Apply whole system design approach

1. Ask the right question
2. Benchmark against the optimal system
3. Design and optimize the whole system
4. Account for all measurable impacts
5. Design and optimize subsystems at the right time and in right sequence
6. Design and optimize subsystems in a downstream to upstream sequence
7. Review the system for potential improvements
8. Model the system
9. Track technology innovation
10. Design to create future options
Life cycle cost analysis

Consider the “seen” and “unseen” costs and benefits of investments in energy systems
## Life cycle cost analysis: simple example

<table>
<thead>
<tr>
<th></th>
<th>Standard</th>
<th>Efficient</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lamp</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capacity W</td>
<td>100</td>
<td>20</td>
</tr>
<tr>
<td>Investment NRs</td>
<td>15</td>
<td>180</td>
</tr>
<tr>
<td>Economic life Hours</td>
<td>1000</td>
<td>5000</td>
</tr>
<tr>
<td>Operation hours/year</td>
<td>2,000</td>
<td>2,000</td>
</tr>
<tr>
<td>Electricity Rs/kWh</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Yearly electricity Rs/year</td>
<td>800</td>
<td>160</td>
</tr>
<tr>
<td>Lifecycle cost (5000 hours) Rs</td>
<td>2,075</td>
<td>580</td>
</tr>
<tr>
<td>Lamp depreciation cost Rs/hour</td>
<td>0.015</td>
<td>0.036</td>
</tr>
<tr>
<td>Hourly electricity Rs/hour</td>
<td>0.415</td>
<td>0.116</td>
</tr>
<tr>
<td>Hourly cost savings Rs/hour</td>
<td></td>
<td>0.299</td>
</tr>
<tr>
<td>Cost of saving electricity Rs/kWh</td>
<td></td>
<td>0.45</td>
</tr>
</tbody>
</table>
Cycling process of energy management

1. Set target & review energy
2. Adjust operation, replace equipment, improve engineering
3. Control, monitor & report
4. Analyze situation & identify problem
5. Meet the planned target

Cycle of Energy Efficiency Enhancement

*Energy Audit*
Life cycle cost analysis: a dynamic process
To sum up...

• Energy auditing & management are effective in **reducing energy costs**
  - Without affecting building’s functional requirements
  - Without compromising comfort and well-being

• **Gain compounded savings** through whole system analysis

• **Conduct life cycle cost analysis** to reap long-term benefits