# LIFE CYCLE ENERGY ANALYSIS OF A REFERENCE BUILDING


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## ABSTRACT

The lifecycle energy of a reference residential air-conditioned building of floor area of about 40 m$^2$ located at Ahmedabad, India is evaluated using EnergyPlus simulation software. The lifecycle energy comes to 536 kWh/m$^2$-year with the embodied energy being 3%. This sets a baseline from which improvements can be made to move towards low energy buildings. Air-conditioning contributes to 73% of the lifecycle energy of this building. Different components of heat gain and energy consumption are studied to look for ways to reduce energy consumption. Addition of insulation building material, overhangs, change in orientation of the building or climate can affect the lifecycle energy significantly.


## INTRODUCTION

Presently, over 40% of the Indian energy demand comes from the buildings sector. This may further increase as India faces a housing shortage of over 20 million houses, which needs to be fulfilled. However, new buildings can save up to 40% of energy with design interventions. This suggests tremendous scope for energy reduction for new buildings.

A reference building is identified which is representative of a major portion of the upcoming building stock of India and Energy Simulation is performed for different scenarios to assess ways of reducing the life cycle energy of the building, which has implications for the nation's building sector energy use.

## REFERENCE BUILDING

**Selection of a Reference building**

As the first step, a reference building is chosen for India, which represents a majority of the building stock and the improvement in its design could lead to substantial energy savings for the entire nation. About 78% of the energy consumed in the building sector for India is in the residential sector. So, a residential reference building is selected. In this sector, it has been decided to have a building for LIG and EWS with a size between 300 to 600 sq. ft. to address the housing shortage. It is to be noted that although the present EWS and LIG would improve their living standards by the time their housing needs are fulfilled but they may still not be able to afford to pay the electricity bills due to extensive use of AC. However, the emphasis here has been to set a baseline which doesn't compromise on the human thermal comfort, if their housing needs are to be met completely. This baseline, therefore, allows to analyse possibilities to reduce energy consumption such that in the ideal case, the energy consumption due to AC can be reduced to a minimum.

The building layout has been inspired by the Tata Shubh Griha project in Ahmedabad for the low cost housing segment.

## INPUT DATA

**Construction Details**

Google Sketchup version 8.0 has been used for drawing the building. There are 8 exterior sidewalls in the building as shown in Figure 1, five windows, namely, W1, W2, W3, W4 and W5 and two doors, namely, D1 and D2 as shown in Figure 2. Table 2 shows the building material properties.

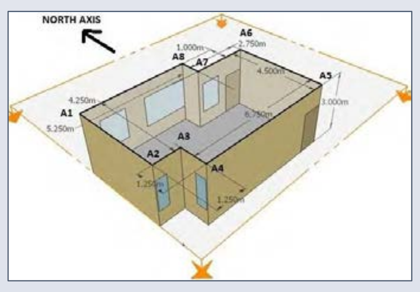

**Fig 1: Detailing of Walls**

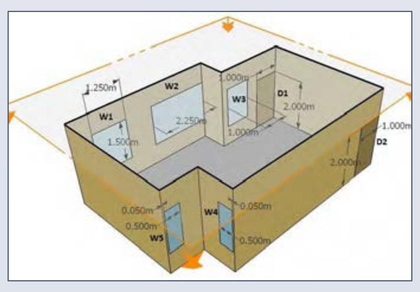

**Fig 2: Detailing of Windows and Doors**

| | |
|---|---|
| **Floor Area** | 39.7 m$^2$ |
| **Area occupied by the Windows** | 8.25 m$^2$ |
| **Area occupied by the Doors** | 4 m$^2$ |
| **Area occupied by the Internal Walls** | 60 m$^2$ |
| **Area occupied by the Furniture** | 30 m$^2$ |
| **Volume of the building** | 119.1 m$^3$ |

**Table 1: Construction Data**

| Property | Fired Clay Brick | Cement Plaster | Plywood | RCC | Cast Concrete | Mortar | Marble Stone | Sand and Gravel | EPS | Ceramic Tiles |
|---|---|---|---|---|---|---|---|---|---|---|
| Thickness (m) | 0.23 | 0.012 | 0.05 | 0.12 | 0.1 | 0.02 | 0.02 | 0.1 | 0.1 | 0.012 |
| Conductivity (W/m-K) | 0.84 | 0.16 | 0.12 | 2.5 | 1.13 | 0.88 | 2.77 | 2 | 0.035 | 1.3 |
| Density (kg/m$^3$) | 1700 | 600 | 510 | 2400 | 2000 | 2800 | 2600 | 1950 | 25 | 2300 |
| Specific Heat (J/kg-K) | 800 | 1000 | 1350 | 1000 | 1000 | 896 | 802 | 1045 | 1400 | 840 |

**Table 2: Building Material Properties**

| Roof | Floor | External Wall | Internal Wall | Door |
|---|---|---|---|---|
| Cement Plaster | Sand and Gravel | Cement Plaster | Cement Plaster | Plywood |
| RCC | Cast Concrete | Fired Clay Brick | Fired Clay Brick | |
| Cement Plaster | Mortar | Cement Plaster | Cement Plaster | |
| | Marble Stone | | | |

**Table 3: Layers from Outside to Inside for the base case** (Ramesh et al., 2012)

**Loads**

Typical Internal Loads data has been gathered for Lighting, ElectricEquipment, Occupancy and Gas usage. Recommended Infiltration Loads data has been gathered as well. The air conditioning is done with a Unitary AC which conditions the entire zone. The system has been sized using EnergyPlus. The cooling setpoint has been kept as 29°C based on the assumption that people from hotter climates can adapt to this temperature. For the base case, ISHRAE weather data for Ahmedabad has been used.Table 4 and 5 summarizes the load data.

| Load | AC | Electric Equipment | Electric Equipment | Electric Equipment | Electric Equipment | Electric Equipment | Lighting |
|---|---|---|---|---|---|---|---|
| **Type** | Unitary | Refrigerator | TV | Computer | Washing Machine | Electric Water Heater | Kitchen |
| **Time of Use** | 24 by 7 | 24 by 7 | 4 hours/ day | 12 hours/ day | 1 hour/ week | 1 hour/ day for 2 months | 0.5 hour/ day |
| **Wattage (W)** | | 65 | 100 | 20 | 780 | 4500 | 80 |

**Table 4: Loads Data**

| Load | Lighting | Occupancy | Occupancy | Occupancy | Cooking Gas | Infiltration | Infiltration |
|---|---|---|---|---|---|---|---|
| **Type** | Rest of the area | 2 Adults, 1 child | 2 Adults, 1 child | 1 Adult, 1 child | LPG | Kitchen and Bathroom ACH = 10 | Rest of the area ACH = 5 |
| **Time of Use** | 5.5 hour/ day | 24 hours for Weekends, 14 hours for Weekdays | 24 hours for Weekends, 14 hours for Weekdays | 10 hours for Weekdays | 2 hours/ day | 24 by 7 | 24 by 7 |
| **Wattage (W)** | 40 | | | | 1100 | | |

**Table 5: Loads Data**

## SIMULATION

EnergyPlus 7.1 has been used for building energy simulation. The steps are as follows:

1) The reference building data is collected for construction materials, internal gains, infiltration loads, etc.

2) The building floor plan is decided and the building is drawn in Google Sketchup. The thickness of the building material and the layers is found based on the structural safety.

3) EBE energy is calculated and EnergyPlus simulation is run for sizing the AC and getting the annual energy use.

4) OPE is calculated through the results of EnergyPlus simulation.

5) LCE is the sum of EBE and OPE.

The above process is repeated for analyzing scenarios like different climates, orientations, addition of building materials, etc.

## RESULTS

Firstly, the OPE is analyzed and the different components of energy consumption are looked at. The total OPE comes out to 74.5 GJ/ year or 521.3 kWh/m$^2$-year. It is to be noted that all the energy consumption is in thermal units. The electrical to thermal conversion ratio used is 0.3. Figure 4 shows that AC load is much higher than any other load. Focusing on reducing this load should be the first priority. Figure 5 shows that Refrigeration load is over half of the total electric equipment load. Since the AC load is the highest, so through Figure 6, the heat gain components for the building are found. The total initial EBE of building materials comes out to 106.1 GJ or 14.8 kWh/m$^2$-year assuming the life of the house as 50 years. In Table 6 and 7, results for LCE for different climates, orientation, overhangs and material are shown.

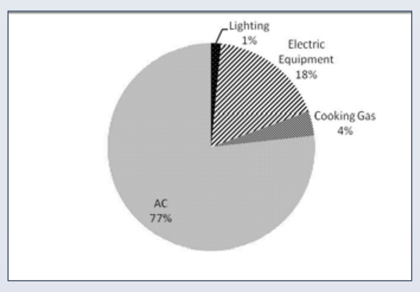


**Figure 3: Energy Consumption**

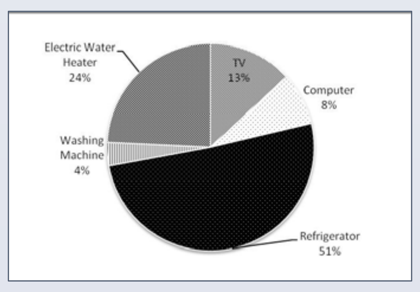


**Figure 4: Electricity Consumption**

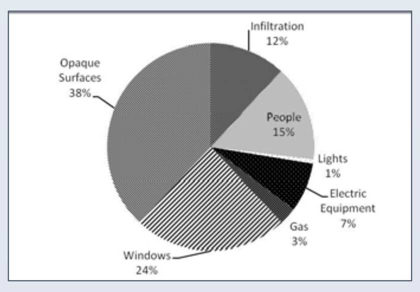


**Figure 5: Heat Gain Components**

| City | Climate | OPE (kWh/m$^2$-year) | LCE (kWh/m$^2$-year) |
|---|---|---|---|
| Ahmedabad | Hot and Dry | 521 | 536 |
| Jodhpur | Hot and Dry | 439 | 454 |
| Mumbai | Warm and Humid | 375 | 390 |
| Hyderabad | Composite | 400 | 415 |
| Bangalore | Moderate | 183 | 198 |

**Table 6: LCE for different Climates**

| Case | Orientation | OPE | LCE | % LCE Savings |
|---|---|---|---|---|
| Base | North | 521 | 536 | |
| Base | South | 542 | 557 | -4 |
| Base | East | 557 | 572 | -7 |
| Base | West | 577 | 591 | -10 |
| Insulation | North | 338 | 358 | 33 |
| Overhangs | North | 500 | 515 | 4 |

**Table 7: LCE for other parameters**

## CONCLUSIONS AND FUTURE WORK

A framework has been established to calculate the life cycle energy of any building. A reference building is chosen and a baseline for LCE use is found, which needs to be improved as we move towards low energy buildings.

AC load represents over 70% of the total LCE and so efforts should be put on reducing this load. Adaptive comfort range should be found out for different climates and the cooling setpoint should be made to vary all throughout the year as per adaptive comfort range to reduce the cooling load requirements. Also, natural ventilation should be modelled into EnergyPlus to see how it can be used with an AC.

Use of insulating building material like EPS and ceramic tiles reduce the LCE by 33%.

Use of overhangs reduces the overall LCE by 4%. Optimization of the size and location of overhangs should be looked into to reduce the heat gain through windows. Different types of smart windows should also be simulated along with a cost benefit analysis to assess their feasibility.

Change in orientation scenarios show that the LCE can vary up to 10%.

Along with LCE, lifecycle costs should also be calculated to check the feasibility of any energy reduction option.

The non-structure EBE should be estimated to have a better idea of the LCE components.

Calibration of simulation models needs to be perfomed for program's accuracy.

This analysis can also be extended to perform a macro analysis for the entire target group based on this reference building.

## NOMENCLATURE

| | |
|---|---|
| ACH | Air changes per hour |
| EBE | Embodied Energy |
| EWS | Economically Weaker Sections |
| LCE | Life Cycle Energy |
| LIG | Low Income Groups |
| OPE | Operational Energy |

## REFERENCES

References can be provided upon request.

## CONTACT


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