



The Energy and  
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# TECHNICAL BRIEF

## BUILDINGS & ENERGY EFFICIENCY



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*This technical brief is published by the Energy & Environment Partnership programme to provide technical background on the concept on energy efficiency in buildings. It provides and introduction to energy efficiency considerations, refers to standards for energy efficiency in buildings, to the different aspects of energy efficiency, as well as the benefits of energy efficient buildings.*

# 1. INTRODUCTION

*Improving energy efficiency in existing and new buildings is a major area of development in the EEP region, with Botswana, Namibia and South Africa having made substantial progress in this regard. According to the United Nations Environment Programme as well as the International Energy Agency, the building sector contributes up to 30% of global annual greenhouse gas emissions and consumes up to 40% of all energy.<sup>1,2</sup>*

*Major components of energy consumption in buildings are:*



*The human factor is intimately woven into the end-use of energy inside buildings, since a significant proportion of the total energy use in buildings is required to enhance the comfort of the building's occupants and for operation of associated appliances.*

<sup>1</sup> Page 7, Energy Efficiency Requirements In Building Codes, Energy Efficiency Policies For New Buildings; J Lausten, [https://www.iea.org/publications/freepublications/publication/Building\\_Codes.pdf](https://www.iea.org/publications/freepublications/publication/Building_Codes.pdf)

<sup>2</sup> United Nations Environment Programme (2009) 'Buildings and Climate Change Summary for Decision-Makers'. UNEP DTIE Sustainable Consumption & Production Branch, Paris, France

## 2. STANDARDS FOR EE

### 2.1. BUILDING CODE COMPLIANCY

Buildings account for a massive portion of global energy demand. The typical lifespan of buildings can easily exceed five decades and there may typically be one or two decades between refurbishments<sup>3,4</sup>. With steep rates of population growth recorded for sub-Saharan Africa since the 1950's<sup>5</sup> and the projected regional population increases (anticipated to be the greatest absolute population addition between 2013 and 2050<sup>6</sup>) there is continuous need for new buildings. The importance of energy standards for new buildings is paramount, given global population growth and concomitant construction tendencies.

In the mid 1900s, EE requirements for buildings were only established in some cold-climate first-world countries and were aimed at addressing poor thermal insulation and moisture- and air-infiltration that were associated with public health problems. During this time, Scandinavian countries were the first to introduce insulation requirements for thermal conductivity values (U- or R-values), prescription on insulation materials, and multi-glazing. It was only during the global oil crisis in the mid-seventies that some other national governments initiated more comprehensive EE standards.

Building codes have evolved over the last decade to be more prescriptive on energy efficiency requirements. The codes of individual countries aim to enable basic energy savings within their environmental contexts. Geographical climate variations within countries lead to further prescription through municipal by-laws, regulations

and acts which vary between regions and municipalities. Building codes typically address the minimum efficiency requirements of structures, but leave room for significant improvements in efficiency.

### 2.2 EMERGENT EE STANDARDS

There are several emergent green building energy standards that improve on the basic energy-saving requirements of building codes. These energy standards offer an aggressive baseline for measuring the energy consumption of buildings and set performance standards for energy efficiency. The design and engineering principles of these international EE standards are relevant within the sub-Saharan context, and the affordability of implementation is made possible by significant reductions in the operational expenditures of such EE buildings. For the purpose of the discussion in this technical brief, three major standards will be discussed:

#### 2.2.1. ENERGY STAR<sup>7</sup>

This voluntary standard was formulated in the early 1990's by the Environmental Protection Agency and Department of Energy in the USA. The standard was applied predominantly to energy efficient appliances (which saved 20-30% more energy than prescribed federal standards), but also had an impact on the built environment. Energy Star qualified homes are independently verified to be at least 30% more energy efficient than homes built to the 1993 national Model Energy Code or 15% more efficient than the rigorous Californian state energy code.

<sup>3</sup> <http://www.engineering.ucl.ac.uk/engineering-exchange/files/2014/10/Fact-Sheet-Lifespan-and-Decisions-Social-Housing.pdf>

<sup>4</sup> Building Maintenance Strategy: A Sustainable Refurbishment Perspective; E. Chan; Universal journal of management; Horizon Research Publishing; 2014

<sup>5</sup> Esteban Ortiz-Ospina and Max Roser (2016) 'World Population Growth'. Published online at OurWorldInData.org. Retrieved from: <https://ourworldindata.org/world-population-growth/> [2016/07/19]

<sup>6</sup> Population Reference Bureau (2013) '2013 World Population Data Sheet'. Washington, USA

<sup>7</sup> <https://www.energystar.gov/buildings/facility-owners-and-managers/existing-buildings/save-energy>

These savings are based on heating, cooling, and hot water energy use and are typically achieved through a combination of the following:

- building envelope upgrades,
- high performance windows,
- controlled air infiltration,
- upgraded heating & air conditioning systems,
- improved efficiency lighting, and
- upgraded water-heating equipment.

To earn the Energy Star seal, a building must submit a year's utility bills to a verifying agency to prove that it is energy efficient.

### 2.2.2. LEADERSHIP IN ENERGY AND ENVIRONMENTAL DESIGN (LEED) <sup>8</sup>

LEED building certification is a rating system for the construction, operation and maintenance of green buildings. The standard is not exclusively focused on energy efficiency and also includes positive scoring for renewable energy powering of green structures. Third-party energy analysis of LEED certified buildings show that these structures have efficiencies that are in the same range as those of Energy Star buildings.

Although LEED certification is increasingly internationally adopted, certified buildings historically have not been required to prove relative energy efficiency as in the case of Energy Star certified buildings. Although LEED has been popularized for its comprehensive rating system, it has come under scientific and engineering scrutiny due to inconsistencies that have surfaced between LEED certification and empirically-proven energy savings. The newest version of LEED certification (which came into effect in 2016) requires Energy Star-type standard EE validations to resolve this issue.

<sup>8</sup> <http://www.usgbc.org/education-at-usgbc>

<sup>9</sup> <http://passivehouse.com/>

<sup>10</sup> pg 2; Passivhaus Primer: Introduction; An aid to understanding the key principles of the Passivhaus Standard; [http://www.passivhaus.org.uk/filelibrary/Primers/KN4430\\_Passivhaus\\_Primer\\_WEB.pdf](http://www.passivhaus.org.uk/filelibrary/Primers/KN4430_Passivhaus_Primer_WEB.pdf)

### 2.2.3. PASSIVHAUS <sup>9</sup>

The German Passivhaus (or passive house) standard is an aggressive energy-saving standard for buildings. The standard integrates with architectural designs through stringent air-tightness and insulation measures. Due to these measures, the Passivhaus standard is most effectively implemented during construction of new buildings. The standard is especially focused on efficient space heating, with measured improvements of 90% in space heating energy use. The premise of the Passivhaus approach is that a structure should maintain a comfortable indoor temperature without active cooling or heating, on the hottest days of summer or the coldest days of winter. Figure 1 depicts the buildings functional aspects considered in the Passivhaus standard.

The Passivhaus standard includes the following requirements:

- High insulation: The building must be designed to have an annual heating and cooling demand of not more than 15 kWh/m<sup>2</sup> per year OR be designed with a peak heat load of 10 W/m<sup>2</sup>.
- Low consumption: Total primary energy consumption must not be more than 120 kWh/m<sup>2</sup> per year.
- Air-tightness: The building must not leak more air than 0.6 times the house volume per hour at 50Pa.

Passivhaus insulation standards allow building heating or cooling requirements to be sufficiently low to mitigate the need for standard energy-intensive temperature control systems <sup>10</sup>. This allows for the 'tunnelling through the cost barrier' phenomenon, whereby increased insulation costs are offset by the by the reduction of HVAC costs.

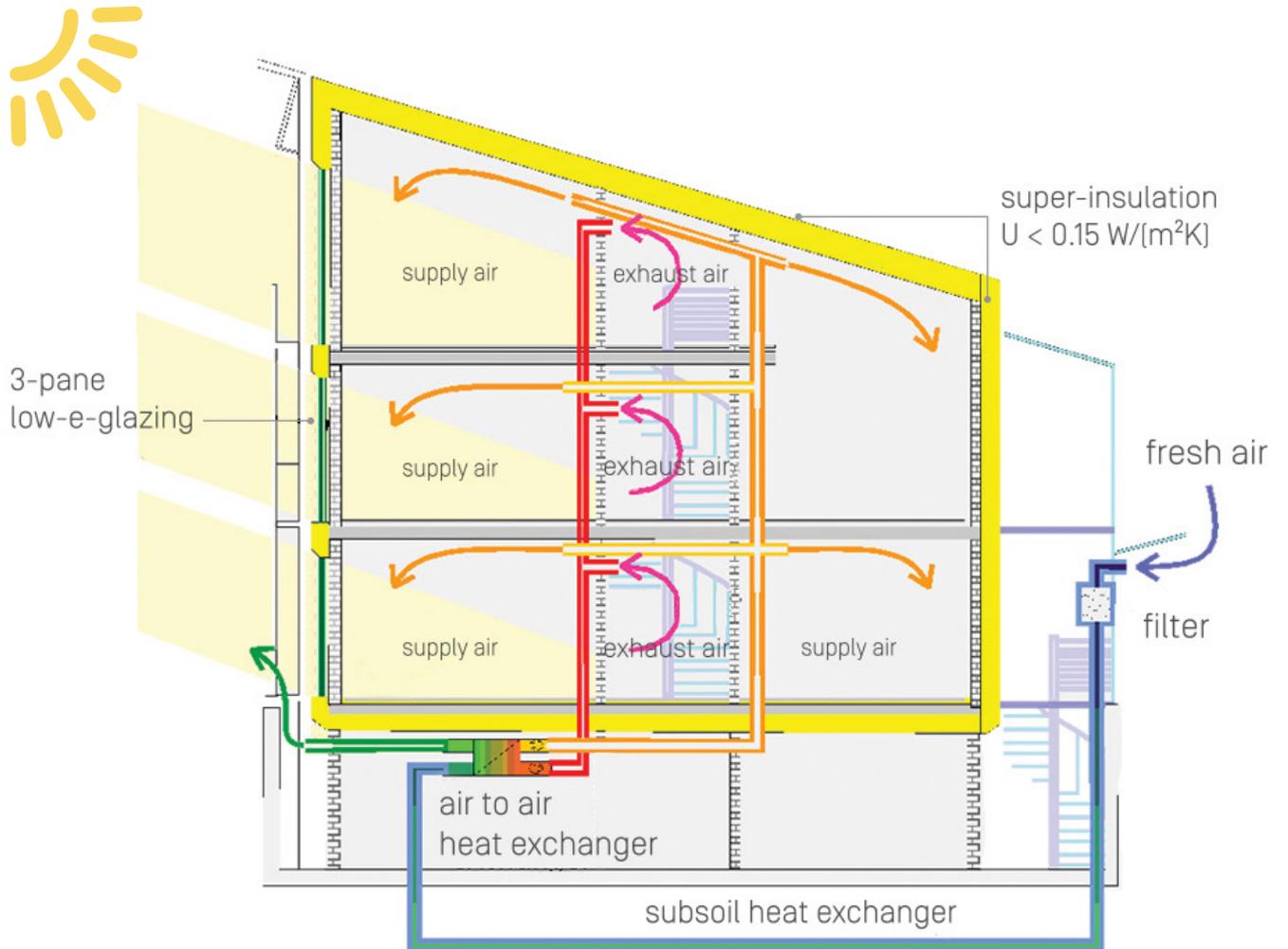


Figure 1: Cross section of a typical Passivhaus structure <sup>11</sup>

<sup>11</sup> [https://passiv.de/former\\_conferences/Kran/First\\_Passive\\_House\\_Kranichstein\\_en.html](https://passiv.de/former_conferences/Kran/First_Passive_House_Kranichstein_en.html)

## 3. EE APPROACHES IN BUILDINGS

### 3.1. TEMPERATURE CONTROL

Space heating results in significant energy consumption in cold climates. Energy losses (and resulting heating requirement) depend on:

1. the temperature gradient between indoor and outdoor air,
2. amount of air leakage between the building and the outside environment, and
3. the amount of heat that is lost through draining warm water out of the structure.

In hot climates, cooling is a major contributor to building energy consumption. Energy increases (and resulting cooling requirement) depend on:

1. the intensity and duration of sunlight that heats the surface of the structure,
2. the amount of solar radiation that penetrates through windows in the structure,
3. the temperature gradient between indoor and outdoor air,
4. the waste heat of appliances such as refrigerators, and heat losses from geysers that heat up the interior of the structure
5. the heat created by the bodies of occupants in the building.

The heat that is transferred through walls, ceilings, floors and windows is directly proportional to the difference in indoor and outdoor temperatures (the slope of the temperature gradient). Due to the fact that most structures in sub-Saharan Africa are not effectively insulated,

seasonal heat fluctuations demand energy consumption for indoor heating and cooling. Several factors that influence operational expenditures due to heating and cooling are discussed in more detail below.

#### 3.1.1 BUILDING ORIENTATION

In passive solar building design, building surfaces are designed to collect and store solar energy during the winter and discard or reject solar energy in the summer. Passive solar building techniques prescribe that principal windows should face the equator and be shielded with awnings, operated as follows:

- Solar blocking during summer: the early morning sun heats the interior of the structure, but mid-day sun does not penetrate the structure due to awning shielding.
- Solar gain during winter: the low winter sun penetrates the structure for longer periods of time and serves to increase the indoor temperature of the structure.<sup>12</sup>

There is an important distinction between passive solar design and the Passivhaus standard - due to the high thermal insulation of the Passivhouse standard, building orientation is less important<sup>13</sup>. However, orienting a roof towards the equator is still good practice in order to cater for maximized yield of solar panels in the event of their installation.

<sup>12</sup> Figure 1; NJ Green Building Manual; 2011; <http://greenmanual.rutgers.edu/newcommercial/strategies/buildingorientation.pdf>

<sup>13</sup> <http://elrondburrell.com/blog/passivhaus-solar-orientation/>

### 3.1.2. BUILDING SURFACE AREA TO VOLUME

The surface area to volume ratio should be kept as low as possible, to ensure minimal thermal transfer between the indoor and outdoor environment <sup>14</sup>. The complexity of a building's exterior significantly affects the surface area to volume ratio. By analogy of floor space to perimeter, Figure 2 illustrates this concept.

The structure on the left has a floor area to perimeter ratio of 4:10 whilst the structure on the right has an equivalent floor space but a floor area to perimeter ratio of 5:10. The structure with the greater ratio will allow more heat transfer between the indoor and outdoor environments. <sup>15</sup>

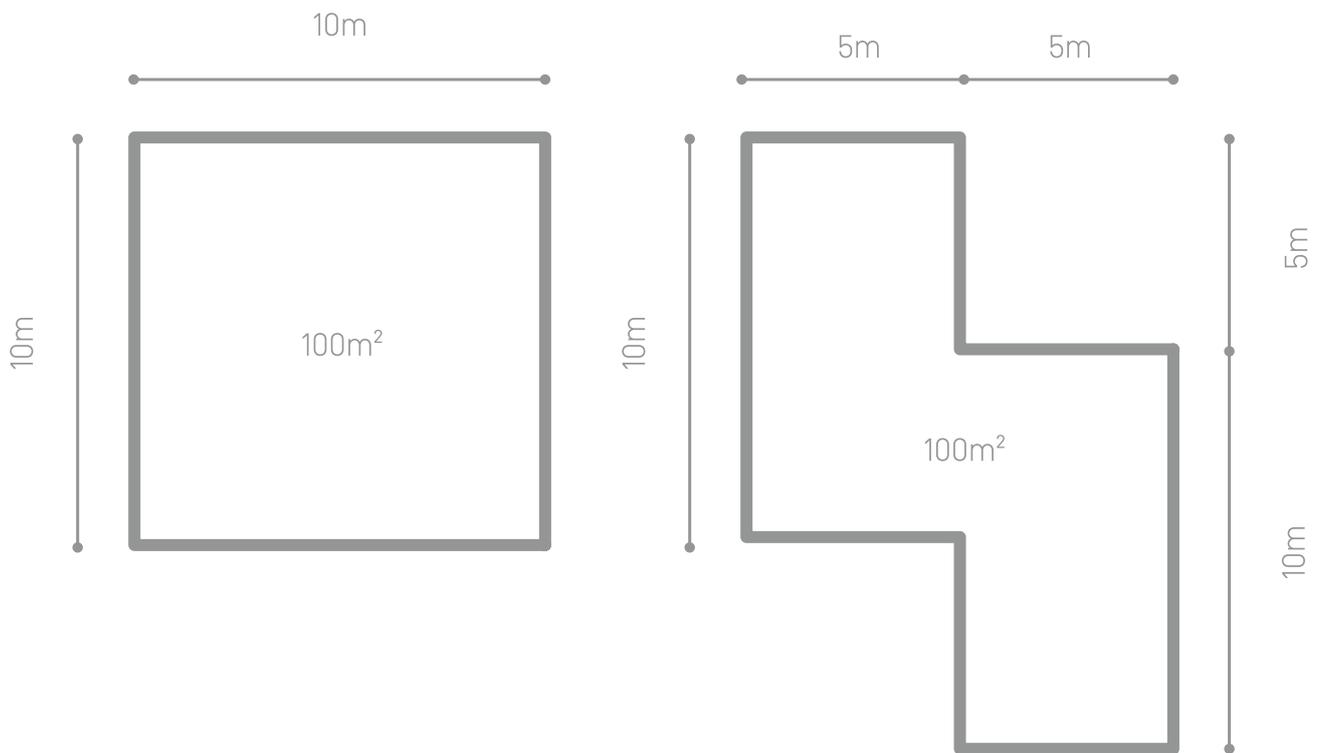


Figure 2: Structures with equivalent surface areas and different perimeters

<sup>14</sup> pg 127; Shape of buildings and energy consumption; V Geletka, A Sedláková; nstitute of Building and Environmental engineering, faculty of civil engineering, Technical university of Košice; [https://suw.biblos.pk.edu.pl/resources/i1/i4/i8/i8/r14488/GeletkaV\\_ShapeBuildings.pdf](https://suw.biblos.pk.edu.pl/resources/i1/i4/i8/i8/r14488/GeletkaV_ShapeBuildings.pdf)

<sup>15</sup> Figure 4; Passivhaus Primer: Introduction; An aid to understanding the key principles of the Passivhaus Standard; [http://www.passivhaus.org.uk/filelibrary/Primers/KN4430\\_Passivhaus\\_Primer\\_WEB.pdf](http://www.passivhaus.org.uk/filelibrary/Primers/KN4430_Passivhaus_Primer_WEB.pdf)

### 3.1.3. THERMAL INSULATION OF BUILDING SURFACES

#### *Insulation:*

Since the 1970's, air spaces and insulation layers between inner and outer walls, floors or roof spaces have been used to reduce thermal transfer<sup>16</sup> between the indoor and outdoor environments. With standards such as the Passivhaus, thick super-insulating materials with low R-values or low U-values are employed to mitigate thermal transfer. For example, Scandinavian countries require the insulation thickness to be approximately 335 mm in walls and 500 mm in roofs.

#### *Bridging:*

Thermal bridges occur in buildings as a result of: materials with significantly higher heat transfer capacities than the surrounding materials exposed to temperature differentials, locations of penetration through the thermal envelope of the building (air leakage) or through discontinuities in the thermal insulation of the building. Thermal bridging must be avoided to create a uniform thermal insulation<sup>17</sup>. Objects such as constructional steel or concrete that penetrate from the inside to the outside of buildings, act as thermal bridges to transfer heat between the indoor and outdoor environments.

#### *Insulated glazing:*

Double, triple and other multiple glazed windows use a gas layer and low emissivity surface coatings to provide thermal insulation in windows. Triple glazed windows offer higher thermal resistance than double glazed windows, since the inside and outside temperatures are separated by multiple gas layers which do not mix<sup>18</sup>.

#### *Thermal masses:*

Windows allow warming sunlight to penetrate into a structure. If a thermal mass such as a concrete slab is used to absorb and store direct winter sun during the day, it can radiate and distribute this thermal energy during the night.

#### *Air leakage:*

The Passivhaus standard specifies that a structure must be air-tight so that no indoor air is lost to the outside environment (specifying a maximum leakage rate)<sup>19</sup>. Fresh air into the structure is heated or cooled using heat exchangers and micro-heatpumps to transfer energy between the indoor and outdoor air<sup>19</sup>.

### 3.1.4. GROUND-COUPLED HEAT EXCHANGES

The ground temperature remains relatively constant throughout the year, regardless of ambient temperature. Ground-coupled heat exchangers capture heat from the ground in cold environments, or dissipate heat into the ground in hot environments. This technology most often requires active heat exchange devices which require power and complex control<sup>20</sup>.

### 3.1.5. SOLAR CHIMNEYS

Solar chimneys or thermal chimneys improve the ventilation of buildings by exploiting the natural convection of air that is heated by solar energy. Solar chimneys are a passive way of creating circulation over or through a structure<sup>21</sup>.

The operation is described as follows<sup>22</sup>:

1. The chimney is heated by sunlight, which drives convective heat flow and creates an updraft within the chimney.
2. The updraft in the chimney creates a pressure drop inside the space at the bottom of the chimney.
3. Colder air is 'sucked' into this space through the low pressure effect.
4. If an air intake is ducted through an underground pipe network, the ground-coupled heat exchange (describes above) will further cool the air which enters the ventilated space.

<sup>16</sup> [http://www.passivhaustagung.de/Passive\\_House\\_E/Passive\\_house\\_insulation.html](http://www.passivhaustagung.de/Passive_House_E/Passive_house_insulation.html)

<sup>17</sup> [http://www.passivhaustagung.de/Passive\\_House\\_E/passive\\_house\\_avoiding\\_thermal\\_bridges.html](http://www.passivhaustagung.de/Passive_House_E/passive_house_avoiding_thermal_bridges.html)

<sup>18</sup> pg 6; Passivhaus Primer: Introduction; An aid to understanding the key principles of the Passivhaus Standard; [http://www.passivhaus.org.uk/filelibrary/Primers/KN4430\\_Passivhaus\\_Primer\\_WEB.pdf](http://www.passivhaus.org.uk/filelibrary/Primers/KN4430_Passivhaus_Primer_WEB.pdf)

<sup>19</sup> <http://www.encraft.co.uk/wp-content/uploads/2015/03/Airtightness-testing-for-Passivhaus-projects.pdf>

<sup>20</sup> <http://energy.gov/energysaver/geothermal-heat-pumps>

<sup>21</sup> Ventilation impact of a solar chimney on indoor temperature fluctuation and air change in a school building; <http://www.wou.edu/~mcgladm/robotics%20energy%20transportation/Solar%2520Chimney.pdf>

<sup>22</sup> Chapter 1; Improvement Of Natural Ventilation In Building Using Multi Solar Chimneys At Different Directions; S. A. Hassanein, W.A. Abdel-Fadeel; Department of Mechanical Engineering, Aswan Faculty of Energy Engineering, South Valley University, Egypt; 2012

### 3.1.6. WASTE HEAT RECOVERY

There are several commercially available systems which extract the heat from warm water which is lost down the drains in a house. These systems are up to 60% efficient in regaining thermal energy. This waste heat recovery is especially useful to pre-heat incoming fresh air in cold environments.<sup>23</sup>

### 3.1.7. SHADING

Shading reduces the amount of sunlight that directly heats a structure. This can be achieved by installing a separate outer shell on a building. If solar PV appliances or solar geysers are not planned or installed on the structure, it is sensible to maintain deciduous trees on the equatorial side of the building in order to shield sunlight during the summer and permit sunlight to enter in winter.

### 3.2. EE DEVICES FOR HEATING

The efficiency of commercially available appliances that heat and cool indoor spaces, water and perishables has improved significantly in the past two decades. Beyond the EE improvements that have been introduced by Energy Star appliances since the 1990's, there are several attainable opportunities for improving the efficiency of heating and cooling devices discussed greater detail below.

### 3.2.1. HEAT PUMPS

Heat pumps use electrical energy to move heat from one location to another. Heat pumps can be used for the following applications:

- water heating (geysers),
- space heating and cooling (replacing air conditioners), and
- refrigeration (especially on industrial scale).

Heat pump efficiency depends on the temperature differences between the hot and cold sides in the energy transfer process. In the case of heating water, these devices are three to four times more efficient than electrical geysers. Heat pumps are one of the most important, relatively affordable, EE appliances with reasonable return on investment rates<sup>24</sup>.

Thermal insulation of water storage tanks and hot water pipes is an overlooked aspect which often compromises the efficiency of hot water generation and storage systems.

### 3.2.2. ENERGY SAVING SHOWERHEADS

Water heating consumes a large amount of energy in typical households. The end-use of the warm water in households is typically for hygiene. So-called 'energy saving showerheads' affect energy use reduction by significantly reducing the amount of water that is used for showers, which reduces the absolute amount of water that must be heated by geysers or heat pumps<sup>25</sup>.

### 3.3. EE IN LIGHTING

The human eye has limited light sensitivity, which means that minimum light intensity and contrast levels are required within the building for occupants to function effectively. In addition, different intensities of lighting are required for different activities; in general, more detailed activities (such as reading documents) require better lighting than less detailed tasks (such as walking down a corridor). Occupational lighting intensities have largely been codified in national standards.

<sup>23</sup> [http://www.passiv.de/downloads/03\\_certification\\_criteria\\_dwhr\\_en.pdf](http://www.passiv.de/downloads/03_certification_criteria_dwhr_en.pdf)

<sup>24</sup> Technology roadmap: Energy efficient buildings: Heating and cooling equipment; International Energy Agency; 2011; [https://www.iea.org/publications/freepublications/publication/buildings\\_roadmap.pdf](https://www.iea.org/publications/freepublications/publication/buildings_roadmap.pdf)

<sup>25</sup> Energy Efficient Showerhead and Faucet Aerator Metering Study multifamily Residences: A Measurement and Evaluation Report; 1994; <https://www.bpa.gov/ee/utility/research-archive/documents/energy-efficient-showerhead-faucet-aerator-metering-study-multifamily-residences.pdf>

Ergonomic illumination should be of such an intensity and quality to optimize human efficiency within respective spaces. Illumination quality can be assessed according to the following criteria <sup>26</sup> :

1. Intensity or brightness: The number of photons that illuminate a surface in order for specific tasks to be performed.
2. Contrast, glare and luminance ratios: The human eye constantly adjusts to block excessively bright light or to accommodate for low intensity light. In a room with large luminance ratios (brightly lit surfaces or point light sources together with dimly lit areas) the eye will restrict the amount of light in such a way that dimly lit parts of the room are obscured. Similarly, bright office down-lights cause the reflected rays from a typed page to be so bright that the reader's eyes restrict the light, so that veiling reflections obscure the typing on the page. Best practice is to illuminate surfaces in such a way that light is scattered and reflected throughout a room, which creates more ergonomic working conditions for the occupants.

### 3.3.1. PASSIVE LIGHTING

During daylight hours, an EE building should strive to use natural light instead of electrical light sources. The following considerations improve the efficiency of passive lighting:

1. Using sunlight effectively: skylights and large windows or transparent building materials allow sunlight into a building during daytime, without compromising the thermal comfort of the space.
2. Sunlight has to be scattered or reflected in such a way that it does not appear to originate from an intense point source. The effective use of blinds and louvers can aid in diffusing direct sunlight. <sup>27</sup>

### 3.3.2. ELECTRICAL LIGHTS <sup>28</sup>

Devices that create light have evolved significantly in the past three decades. During the late 1990's and early 2000's, compact fluorescent lights (CFL's) were recommended due to the technology's improved efficiency as compared to incandescent light bulbs. CFL technology boasted five to ten times the lifetime of incandescent lights, and used 25% of the energy of an incandescent light.

CFL technology is currently being replaced by light emitting diodes (LED's), which are significantly more efficient. LED lights have lifetimes which can be up to fifty times longer than typical incandescent lights, and use less than 10% of the energy of an incandescent light for the same brightness of light.

Whilst LED technology has been present for some time, high cost has limited demand for it. The proliferation of the technology and improvements in performance have resulted in a sharp reduction in bulb cost which is projected to continue. <sup>29</sup>

Even though LED lights are significantly more expensive than incandescent lights or CFLs at present, the operating costs of LED lights together with the reduced replacement frequency allow for rapid repayment on investment.

<sup>26</sup> pg 174; Task lighting solutions: Their economic and ergonomic benefits; K Tetlow; Provided by Humanscale; <http://www.humanscale.com/userfiles/file/tasklightingsolutions.pdf>

<sup>27</sup> pg52; [http://www.rmi.org/Content/Files/E07-02\\_Stanford\\_1Buildings.pdf](http://www.rmi.org/Content/Files/E07-02_Stanford_1Buildings.pdf)

<sup>28</sup> <http://www.designrecycleinc.com/led%20comp%20chart.html>

<sup>29</sup> U.S. Energy Information Administration [2014] 'LED bulb efficiency expected to continue improving as cost declines'. Retrieved from <http://www.eia.gov/todayinenergy/detail.cfm?id=15471> [2016/07/19]

### 3.4. BUILDING MANAGEMENT

It is important to realize that buildings don't need to breathe fresh air or stay warm. Issues such as indoor air quality, temperature control and quality lighting are design criteria which are followed for the safe and ergonomic occupancy of buildings. Given that human occupation is directly linked to energy use in a building and occupants largely control the energy use applications, it also means that human behaviour affects the energy consumption of a building.

Human occupation of buildings is largely associated with negligent or wasteful practices such as leaving lights on in unoccupied rooms, or keeping doors and windows open in heated spaces. Instead of solely relying on human operation to regulate energy consumption, several strategies have been developed to circumvent poor human operation.

#### 3.4.1. AUTOMATIC ON-OFF CONTROL

The most basic control approach for managing energy consumption is to manage the on-off status of energy-demanding systems, with setpoints or simple rules. Ubiquitously implemented examples are:

1. Motion sensors can be used to manage space lighting in underground parking areas where full-time lighting is not necessary. The lights will only be switched on in areas where movement is detected.<sup>30</sup>
2. Thermostats can be used to regulate a room's temperature around a desirable setpoint, which allows for optimum comfort without regular human intervention.
3. Motion sensors can be used to trigger automatic hand dryers in shopping complexes or office parks.

Although the amount of energy saved by these systems depends on the stochastic nature of their usage, the energy-saving potential is obvious due to the fact that they mitigate wasteful or unnecessary use of energy-demanding systems.

#### 3.4.2. MONITORING

By logging data on energy consumption, human operators can gain useful insights on consumption trends. Data analysis may help to identify energy waste and can lead to adjustments in behaviour and consumption trends.

#### 3.4.3. AUTOMATION

Building management systems (BMSs) or building automation systems (BASs) are complex control systems that monitor a building's temperature control, lighting, water heating and other energy systems. The system does not only collect data, but adjusts loads based on a set of rules. The EE impact of BMSs is attributed to the fact that wasteful consumption practices are mitigated through these consumption rules. Moreover, these systems can also be used to implement load balancing, whereby non-critical loads such as geysers and air conditioners are switched off during peak times. Load balancing ensures that a building's power consumption never exceeds a maximum current level, which results in reduced electricity tariffs and reduced demand on the energy grid.<sup>31,32</sup>

<sup>30</sup> <http://challengeforsustainability.org/toolkit/energy-efficiency/motion-sensors/>

<sup>31</sup> pg 15; Case Study 1; <http://www.industry.gov.au/Energy/EnergyEfficiency/Non-residentialBuildings/GovernmentBuildings/EnergyEfficiencyOperations/Documents/bms-guide.pdf>

<sup>32</sup> <http://www.environment.nsw.gov.au/resources/business/financing-case-study-9.pdf>

## 4. BENEFITS OF EE BUILDINGS

### 4.1. LOWER OPERATIONAL COSTS

By implementing the measures discussed above, electricity consumption and costs on EE buildings are significantly lower than that of their standard counterparts. Net-zero buildings (which have year-round zero energy consumption) often tunnel through the cost barrier<sup>33</sup> by eliminating investments required for expensive heating and cooling equipment, which means that EE buildings can be constructed and operated for prices that are similar to those of normal structures.

### 4.2. IMPROVED HEALTH

If clean air is channelled from floor level, convective updrafts will ensure that the warmer and “dirtier” air is moved towards the ceiling. The result is that the air that is breathed by the occupants in a room is relatively clean and contains safe levels of oxygen and carbon dioxide, whilst the thermal comfort of a room can be maintained. By evacuating dirty air from the ceiling of a room, the health of the occupants can be positively affected.<sup>34</sup>

### 4.3. INCREASE IN HUMAN EFFICIENCY

There is evidence to indicate that human productivity increases with the quality of lighting and ventilation in a building. Investments in good quality light and ventilation leads to lower absenteeism due to illness, and improved productivity of a workforce. The repayment of infrastructure investment is not only through lower operational costs, but also through improved human productivity.<sup>35</sup>

<sup>33</sup> pg 122; Chapter Six: Tunneling Through the Cost Barrier; Natural Capitalism; A Lovins; 1999; NC-99-06

<sup>34</sup> <http://www.cdc.gov/niosh/topics/indoorenv/buildingventilation.html>

<sup>35</sup> A Literature Review of the Effects of Natural Light on Building Occupants; L. Edwards; National Renewable Energy Laboratory; 2002

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