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IJDR

ISSN: 2230-9926

International Journal of Development Research
Vol. 08, Issue, 09, pp.22927-22933, September, 2018

ORIGINAL RESEARCH ARTICLE OPEN ACCESS

IMPROVING THE ENVIRONMENTAL DESIGN CRITERIA FOR LOW CARBON MEDICAL FACILITIES

***N.M. Sirag and W.M. Abdellah**

Egyptian Nuclear and Radiological Regulatory Authority, P.O. Box 7551, Cairo, Egypt

ARTICLE INFO

Article History:
Received 17th June, 2018
Received in revised form
26th July, 2018
Accepted 19th August, 2018
Published online 30th September, 2018

Key Words:
Environmental Design
Radiation Protection
Radiological Facilities.

ABSTRACT

Buildings account for significant carbon dioxide emissions, both in construction and operation. Governments around the world are setting targets and legislating to reduce the carbon emissions related to the built environment, which arises from the consistently high energy performance. This paper describes an innovative, contribution to improving environmental design of low-carbon medical facilities such as smart hospitals, this innovation is achieved through environmental design by observation, analysis for cases studies, add local conditions for design problems, and impact performance of labor practices on energy consumption and carbon emissions. We managed it to improve to suit local environmental conditions, finally reach the search goal of reducing energy use under special medical conditions and achieving comfort zone conservation and carbon reduction in the management of green hospitals. The paper presents, the way to reduce energy usage under the special circumstances of medical services in addition to effectively achieve energy conservation and carbon reduction of green hospital management through the low carbon consumption equipment of the new construction.

Citation: Sirag, N. M. and Abdellah, W.M. 2018. "Improving the environmental design criteria for low carbon medical facilities", *International Journal of Development Research*, 8, (09), 22927-22933.

INTRODUCTION

World leaders gathered in Kyoto, Japan, in December 1997 to consider a world treaty restricting emissions of ''greenhouse gases,'' chiefly carbon dioxide (CO_2), that are thought to cause ''global warming'' severe increases in Earth's atmospheric and surface temperatures, with disastrous environmental consequences (Arthur, 2006). The health of individuals near carbon transport and sequestration sites must be considered in site risk characterization. The lethal effects of high CO_2 concentrations are well known, but the literature also reveals cause for concern for both the survivors of high-level CO_2 exposure and individuals who experience prolonged low-level exposure (2). Green building is the building that in life cycle saving resources such as energy by its greatest degree protecting and reducing pollution, and providing a healthy, comfortable and efficient space by building up harmonious relationship. The focus of this research is to investigate how to achieve low energy - low carbon hospital design through an analysis of In-use.

Corresponding author: **Sirag, N. M**
Egyptian Nuclear and Radiological Regulatory Authority, P.O. Box 7551, Cairo, Egypt

This is a term used to describe the operational phase of a building usually after the construction. In the 21st Century buildings and their construction must evolve rapidly to meet emerging challenges. In addition, predicted changes in climate could result in increased demands for building systems such as air conditioning (Barbu, 2013). The need for sustainable buildings is more pressing than ever and this means making real advances in energy efficiency through the application of building engineering physics. That in relation to carbon emissions in the building has been centered on its obligations to the Climate Change (Egyptian Environmental Law, 1994). The requirement to reduce carbon emissions is need to reduce energy consumption, because it is the main reason for carbon emissions. The policy is achieved through regulation: The Energy Performance of Buildings Regulations 2007, on the Energy Performance of Buildings. Acute high-level CO_2 exposure in the presence of low-level O_2 can produce significant persistent adverse health effects including headaches, attacks of vertigo, poor memory and ability to concentrate, difficulty sleeping, tinnitus, double vision, photophobia, loss of eye movement, visual field defects, enlargement of blind spots, deficient dark adaptation, and personality changes (2).

Low Carbon Building Design

Providing a healthy comfortable building that meets the occupant's requirements whilst minimizing the impact on the wider environment through consuming the minimum resources possible in the building's construction and operation. We need a coherent design strategy to help us achieve this, the design of a low-carbon building requires many factors are considered requirements (function, cost) cost occupant characteristics and requirements (comfort, health) site and location energy and other utility supplies building regulations environmental impact and regulations. All of these factors will affect the design choices and performance (The Royal Academy of Engineering, 2010).

- Occupant density (ventilation requirements, cooling/heating requirements)
- Occupant activity (design temperatures, ventilation, cooling/heating levels)
- Occupant type (children, adults, old/sick)
- Occupation of the building (intermittent, 24 hour)

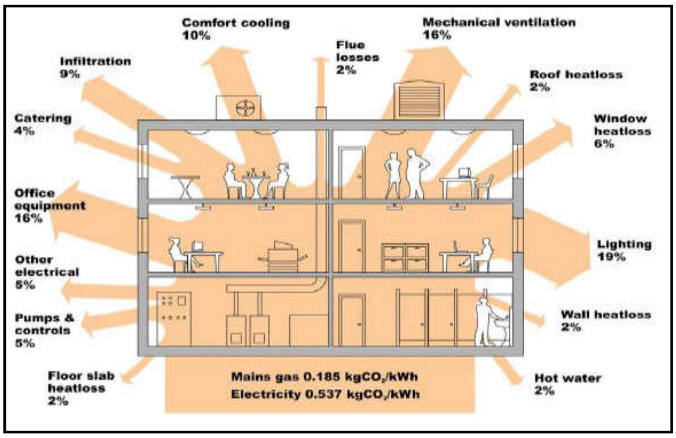

Fig. 1. Relation to Energy Consumption and Carbon Emissions in Buildings (With Emphasis on Smart Hospital Buildings)

Building Location

- Warm/Cool climate
- Available solar energy
- Wind speeds
- Rainfall
- Urban/Rural location (site constraints)
- Surroundings (shading, shelter from wind)

Building Regulations

- Building regulations:
- Insulation requirements
- Ventilation levels systems, etc.
- Location
- Local Regulations Energy Strategy
- Regulations Buildings Performance Directive

Building form

- Building orientation
- Building depth (shallow plant/deep plan)
- Glazing areas/Shading
- Structure (heavyweight, lightweight)
- Infiltration (surface area/volume)
- Space usage and layout - flexibility of use (changes of use in building lifetime)
- Amount and placement of glazing
- Insulation levels
- Response to heat input
- Heavy weight (materials exposed thermal mass)
- Lightweight
- Moisture transport
- Heating and/or Cooling
- Delivery mechanism (convective/radiant/mixed)
- Ventilation (mechanical, natural, contaminants)
- Lighting (daylighting, task lighting)
- Humidification/dehumidification and air conditioning

This information is provided to help the client identify opportunities in current and future Low Carbon Environmental Building Design (LCEBD).

Scope of the Present Work

In several studies, intoxication leading to unconsciousness was evident in ≤30 s in patients inhaling 30% CO2 in 70% O2. Some patients exhibited seizures that were characterized as decerebrate (no cerebral functioning) (6,7). At this concentration, 71% of patients in one study had ECG abnormalities of atrial or nodal activity, including premature atrial and nodal beats, and atrial tachycardia (8). Rhesus monkeys exposed to CO2 in 21% O2 exhibited arrhythmias atv~26% CO2 and died at >60% CO2 (9). At the time of death, the ECG showed systolic arrest, which is also reported to occur with a blood pH between 6.45 and 6.50 resulting from severe acidosis of origins other than that of inhaled CO2. As acute hospital energy consumption translates directly into carbon emissions (but not all emissions) it is necessary to consider how energy performance standards impact carbon emissions. It must consider the building chemical engineering that informs the engineering design as much as the working practices over which the science is applied. Low carbon developments should ideally be located within existing mixed-use conurbations. They should also avoid the risks associated with climate change and consider existing environmental conditions. Environmental models can be used to understand the effect of wind on structures, internal comfort and natural ventilation, sunlight on natural and artificial lighting systems, and weather data on internal comfort conditions and the need for artificial conditioning. Also, façades and ventilation systems will be affected by external noise levels and the need for pollution control. This analysis helps the client and design teams to develop effective building forms that support natural daylight and ventilation, provide suitable solar shading and achieve the most effective level.

Design: The energy demand of a building's operation can be reduced by the application of a multiple stage energy hierarchy, starting with a clear understanding of how user needs can best be supported, before moving on to the optimization of the building form, its environmental systems, the integration of low or zero carbon technologies. The length of stay in hospitals is shorter than in the UK. In France, hospitals are designed with single bedrooms for recovery and patients have less post- operative complications through good daylight, natural ventilation and access to gardens for recuperation (10).

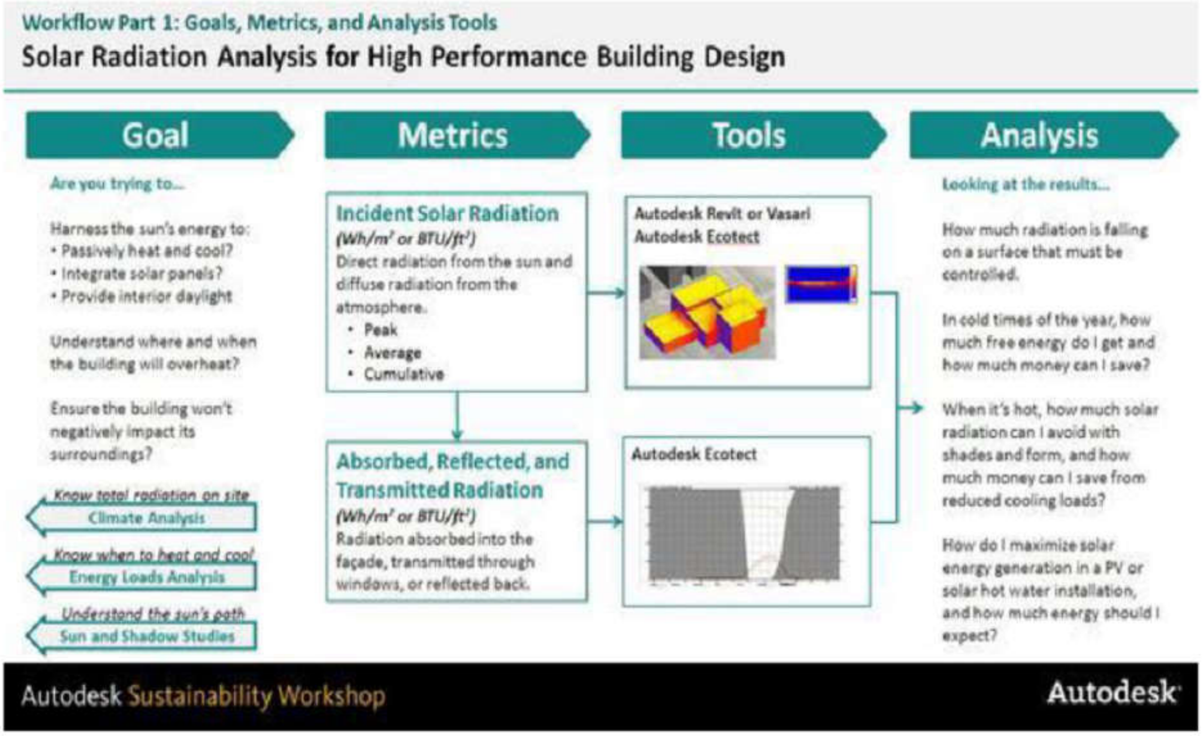

Fig. 2. Methodology Was Using A Liner Study Solar Radiation Analysis

Experimental and Methodology: A new smart hospital redevelopment, it provided an opportunity to study each of the three research objectives from three distinct perspectives.

- The analysis of occupancy presence and diversity.
- The energy and carbon impacts of occupancy.
- The data required for an effective engineering briefing process for low energy – low carbon performance in response the diversity of use.

From studying the work flow part 1, for the '*Internal environment*' it is impacted by a number of factors:

- The role of the occupant, which can be in terms of the number of occupants, the activity of the occupants and their physiological tolerance for example, to heat, humidity and pollutants in the air.
- This tolerance impacts their interaction with the 'Building structure such as the need for fresh air, through the opening of windows for example. This action will be influenced by the '*Outdoor environment*'.
- The 'Occupants' will react to the 'Internal environment' by placing demands on the systems that condition it, and in doing so they will interact with 'Controllers' that will send instructions to the engineering systems to modify the '*Internal environment*' to provide a level of comfort appropriate to their needs.

The practice of simulation to understand the impacts of occupancy on energy consumption is a common feature of research in this field. Simulation enables complex systems involving multi-dimensional/ disciplinary interrelationships to be understood. In the engineering design process simulation will often be used as a decision support tool as illustrated.

The literature review identifies the use of simulation in:

- Whole building simulation during the design phase.
- Whole building simulation during the In-use phase.
- Specific areas of a facility requiring detailed analysis.

The proposed Building Information Modeling, (BIM)(11) integrated Multiple Criteria Decision Making, (MCDM) system is demonstrated using data from a typical hospital building called project A. Project A is 48 m above ground level and included three towers. Its total floor area was 47340 m2. Some variables in this study were simplified for convenience without affecting the final simulation with eQUEST simulation engine, namely, the interior and exterior decorations and the thermal zones (12). Data collection and simulation process to generate the simulation model using eQUEST software, required variables related to building design and building services installation were derived from the original design and contract document as necessary. Additional data were mainly obtained through discussions with architects and from building energy codes (BECs). The weather data obtained from the eQUEST database represented the conditions. In addition, the total electricity consumption of a building indicated energy consumption in the present work. Considering the applicability of 9 Low Carbon Building (LCB) measures and the reality of project A together, some revises needed to be done for LCB measures. The information describing the geometry of buildings in the simulation by HVAC as a single-zone air-handling system based on the data. Thus, "Water-cooled HVAC system" does not improve design. LEDs are advantageous in terms of robustness and service life, but are mostly used as lighting for external decorations. As such, they were both excluded from the potential LCB measures. Finally, 7 LCB measures were tested in relation to the improvement of design measures for project A at the design stage.

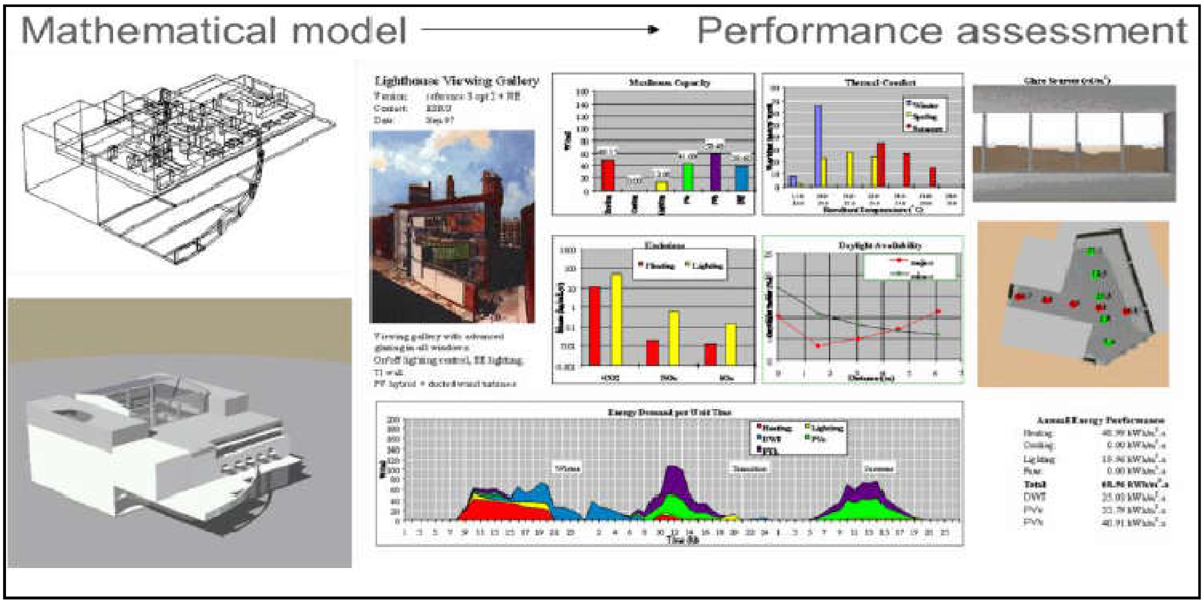

Fig. 3. Mathematic Model and Performance Assessment

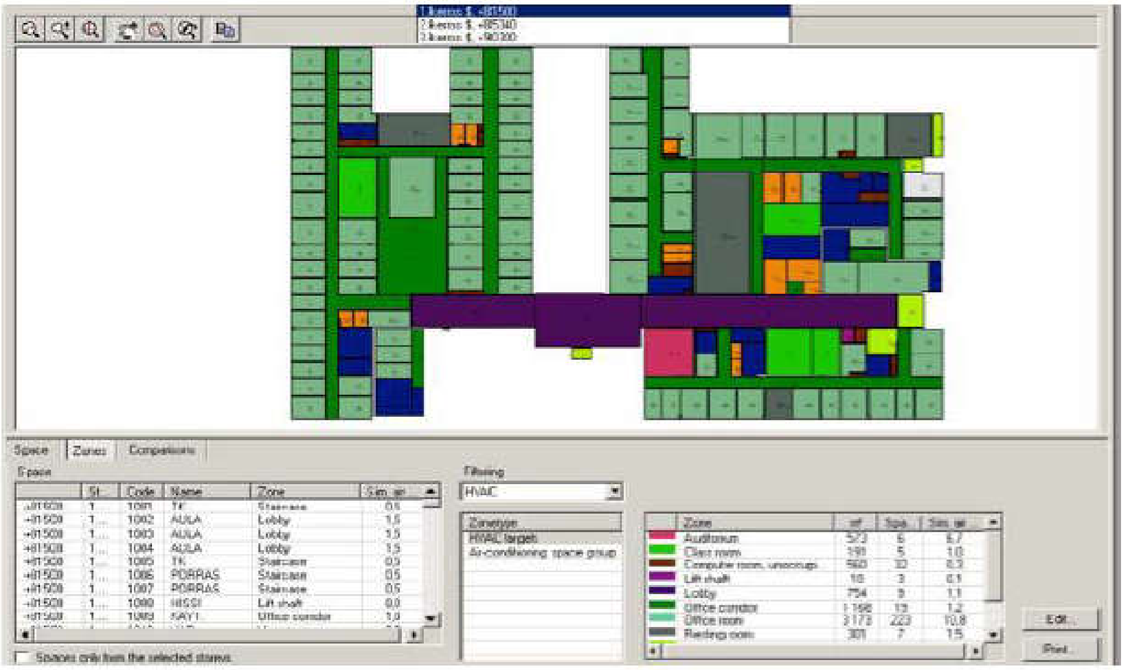

Fig. 4. Example of ROOMEX Space Grouping (Source: Granlund OY)

Energy Modeling

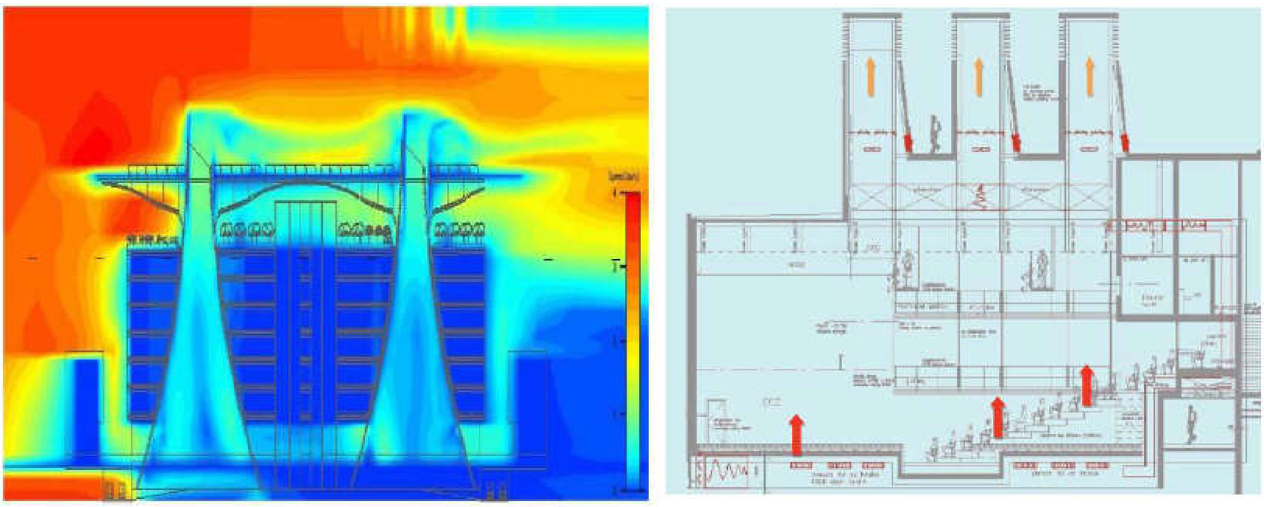

Fig. 5. The Building Information Model The energy analysis was carried out using eQuest

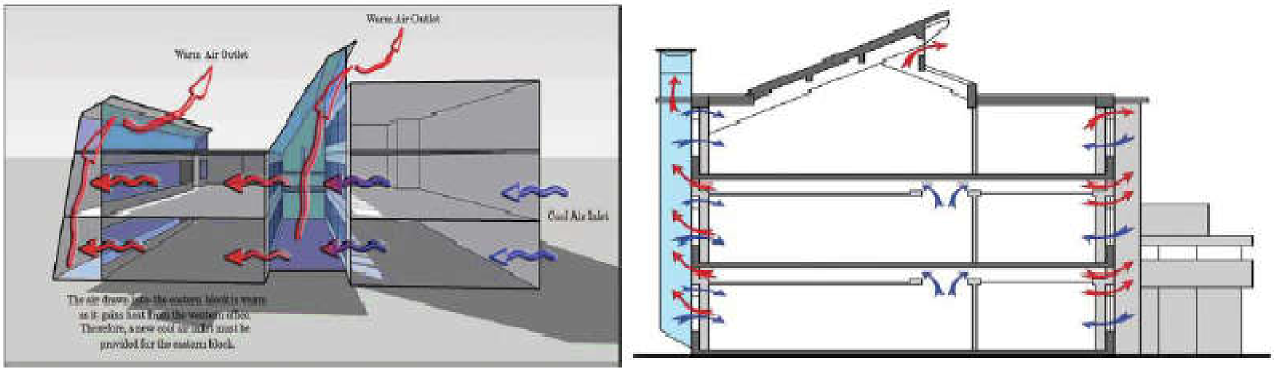

Fig. 6. Possible air flow paths with additional facade

A 'Session' is defined by the period in which an Outpatient clinic is scheduled. Typically, clinics operate two-session days, being a morning session and an afternoon session. For each session a clinician will have a 'List', this being the list of patients that are scheduled for each session. Consequently a 'Session' will comprise one or more 'Lists' depending on how many clinicians have been assigned to each Session. Built the model using OutCAD and eQuest. The latter enables a detailed parameter set to be established for each zone and sub-zone. A key parameter was the occupancy diversity for each zone and sub-zone. The data for each of these was that provided from the Occupancy Analytics study. It was through the use of ROOMEX the latent and sensible heat gains arising from occupancy presence and equipment loads, for example, could be assimilated into the models applied (13&14). The architecture and building fabric specifications were provided. On completion of the model, it was then validated with the engineering designer to ensure that building area, volume and geometry accorded with the architectural model as well as the engineering model that was derived from it. The conclusion of this exercise was that the BIM and the engineering designers BIM were sufficiently aligned to enable the energy analysis to be carried out (15). The energy analysis was carried out using eQuest. These tools are used and not others. The reason was because that these tools would enable us to achieve the objectives of this analysis.

RESULTS

- The results obtained from the Occupancy Analytics simulation including the following: An engineering review concluded that the engineers could never have assumed the extent of diversity of use that Occupancy Analytics provides.
- The diversity profiles for can then be modelled to understand the energy and carbon impacts where the engineering systems can be controlled to achieve those profiles.
- The Occupancy Analytics data enables the engineering design to be carried out from first principles for each functional entity in the hospital. This means that cooling and heating load profiles can be constructed 'bottom-up' rather than through 'top-down' estimates based on the over peak ventilation, cooling and heating load profiles for the whole facility.
- Control peak ventilation, cooling and heating loads between functional entities and so reduce the overall peak loads.
- The report does achieve a comparison between the engineer's design and the In-Use forecast Baseline. requirement was to understand the impact of variances in the range of probabilities of occupancy presence and diversity in each zone, aggregated for each into whole hospital energy model.

The data illustrated that to achieve much improved predictability of performance properly informed by In-use. Equally, this regard is to develop operational policies and working practices. that also seek to minimize energy consumption and the associated carbon emissions, whilst still optimizing health outcomes.

Proposal for alternative façade system: A proposal for the façade would be add to a secondary space, as demonstrated in the diagrams. This would capture heat from the early morning sun, which could be utilized to heat the space area. The original façade could be retained behind this additional space allowing occupants to open their own windows to control natural ventilation into the building (Amir Azad, 2016). Clear glazing allows for the greatest solar gains; however, this is likely lead to overheating in the new space, which in turn would lead to overheating in the spaces area. This could be mitigated by adding shades, as in the existing atrium, however, positioning these on the inside of the glass is inefficient since these do not prevent heat entering the space. It may, therefore, be more suitable to use coated or colored glass, which would reduce the solar gain, but would also reduce the likelihood of overheating, as seen in Jessop West, Sheffield. Defining it as an unoccupied space, with access only required for maintenance, would reduce the impact of any overheating and would, in effect, create a twin-skin façade, proven to be very effective in providing passive ventilation. If this new space was configured in a similar way to the existing atrium, with exhaust louvres above the height of the building, it is likely that this new space would increase the effectiveness of the stack ventilation. However, since this space would encase the eastern bloc, the air drawn into the eastern offices is likely to be air from the western block, which would not be as cool as desired. Therefore, there should also be provision for a cool air inlet to the eastern bloc which would be achieved by adding openable windows to the northern facade or by integrating inlet vents, at ground level, to the secondary façade.

Recommendations

- Government should commission and finance a follow up report to establish the numbers of new building engineering that will be required to will be necessary not only to design and deliver the low carbon buildings that will be required under the future revisions of the building regulations, but also to assess the compliance of such buildings for building control (5).

- Government should make education and research in building engineering chemistry and physics a priority in policy for climate change mitigation and energy security.
- Government should lead by example and immediately commission post occupancy evaluation (POE) of all new buildings in the Government estate constructed since the introduction of the 2006 revision of the Building Regulations, to compare with their target performance criteria. This will quickly establish a useful national database of design techniques and carbon performance.

Make buildings more efficient in use

- Reducing the amount of air leakage- Large uninterrupted areas of double skin sheeting or sandwich panel that are properly fixed and sealed, suffer very little air leakage. Eaves, corners, ridges and joints over masonry walls all have air gaps which need good detailing and good construction to minimize leakage. Windows, doors, vents, structural penetrations through the envelope all have joints that allow leakage. Keeping the number of these to a minimum and improving the detail and erection of these will help to minimize air leaks. Good fillers and seals can very much reduce air leakage. Generally, the joints of translucent sheets to metal sheets are harder to seal correctly.
- Doors can have rapid opening and closing to minimize the time they are open.
- Increasing the thermal insulation of the envelope- This can be done with thicker fiberglass or poly-isocyanate foam although if there is an increase in thickness there can be a diminishing return.
- Reducing thermal bridging- Again every door, window and vent will transfer heat through the envelope. In particular, structural steel which passes through the skin can transfer heat and needs a thermal break. The smaller the number of such thermal bridges, the better.
- White or light-colored sheeting reflects more heat on summer days and gives out less heat in winter or at night. For example, in sunny climates white sheeting may reach 50 degrees C and dark sheeting may go to 100 degrees. If inside is to be 25 degrees, you get 3 times less solar gain with the white sheet.
- Efficient lighting and internal equipment will reduce energy use.
- Hot air rises to the roof, and can be directed downwards using fans with socks or de-stratification nozzles.
- Various wall finishes on south facing walls can trap heat which can be used for space heating. 'Solar Wall' is an example. Pinholes in a dark outer sheet can let air enter the gap behind it, and then heat it in sunshine; this hot air can then be pumped to heat buildings.
- Buildings can be built with 'green roofs' with insulation and then a membrane, over which soil or other growing medium is placed. Then suitable plants are planted. This can absorb Carbon Dioxide (but here you need great care. Planting grass which is then mowed, and the mowing composted, changes CO_2 to vegetation and then to methane which is 25 times more damaging than Carbon Dioxide). 'Green Roofs' are expensive, and need maintenance; but they also reduce heat transmission through the roof so do have a value.

Recycle construction materials at the end of the building's life: In the perfect world, timber structures would be taken to bits and the wood would be re-used or burnt in a waste to power plant. Though the majority of it can be burnt in situ or sent to landfill. Landfill is extremely damaging as the wood can rot over the years and produce large quantities of methane, 25 times more damaging than carbon dioxide. Nothing much can be done with concrete except to break it up and use it for road-base and doing so takes up energy. Recovering the steel content can be difficult as concrete cannot be recycled to any advantage. A similar problem occurs with masonry walls as the product is of low value (down-cycling). Steel buildings can be almost entirely recyclable. The purlins, rails and frames can be melted to make new steel, and this takes 3 times less energy than making new steel. Steel cladding can also be recycled; although foam filled sandwich panels are difficult because of their chemical content, the floors made of composite style decking and concrete are difficult to recycle, and are usually distributed to landfill, though at least they are thinner than regular concrete floors. The salvage rate for steel buildings is around 94%.

Conclusion

The present paper provides a new understanding of occupation rather than reliance on traditional principles, the objective has been to establish a new benchmark in hospital energy and carbon performance. A major finding was that conventional design practice grossly over-estimates occupancy leading to the poor energy and carbon performance described.

There are three routes to reducing hydrocarbon fuel burn involved in buildings:

a. Reducing the amount of embodied carbon' materials used in the original building constructions.
b. Making buildings more efficient in use.
c. Recycling the materials at the end of a building's life.

Finally, we reached a details exemplary standards of low carbon building design, and sustainable development, comprehensive energy conservation management in medical services.

Many options available in a low-energy building design

- Well construction and insulated
- Passive solar technology,
- Day lighting, efficient lighting
- Well maintained, efficient distribution systems
- Natural ventilation
- Mechanical ventilation/heat recovery
- High efficiency heating and cooling devices

By reached to the addition of the results for the international cases studies, which have reached very good results, were studied obtained results and methods of study. Then we applied them in local case studies after adding our local conditions. Simulations and application of appropriate treatment and design methods for the local situations were carried out. And thus, we have added to the improvement in the international standards to suit the local circumstances. The research has discovered that the cases of poor in-use performance and poor predictability of performance in hospitals are directly linked. The central factor that leads to both is a poor understanding of clinical user practices and the impact of those practices on the design and chemical engineering of the hospital.

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