ABSTRACT

The role of the built environment and the construction industry in sustainable development gained global attention due to their significant share in global warming, GHG emissions, energy demand and depletion of non-renewable resources. Residential buildings carry the largest share amongst buildings and place heavy demands on natural resources for building materials, energy and water. The significant share of energy and natural resources involved in the production of building materials emphasizes the need for appropriate conservation strategies based on scientific study. This initiated efforts for comprehensive assessment of a building's energy consumption and environmental impacts over its life span, termed as life cycle. Life Cycle Energy (LCE) in buildings comprises two major components, Embodied Energy (EE) and Operational Energy (OE). EE comprises the net energy involved in production of building materials, its transportation to the construction site, and construction. OE in buildings comprises energy required for occupant comfort and productivity which includes energy for lighting, heating, cooling and ventilation, normally excluding energy used for appliances (plug loads). While OE reflects the direct energy consumption in buildings, EE primarily comprises inherent capital energy associated with materials and building construction. Conventional approaches to energy conservation focus on OE as it affords some degree of active measures to regulate energy consumption. However, in addition to the EE already expended, the climatic-response of the specific building design and material used can have a significant bearing on the OE. Assessing the life-cycle energy of a building is thus complex. Moreover, EE assessment to support low-energy building design currently lack consensus on the methodology to be adopted. This is further exasperated by the lack of data on the energy involved in manufacture of building materials. The current study attempts to address these challenges by proposing and adopting a practical framework for EE assessment and generating data for prominent building materials in India based on first-hand data collection. The study reveals that a range of EE value for a building material is more practical to define, as a unique value does not hold good. This is attributed to the fact that the parameters determining EE of a material differ widely depending on the type of industrial process employed, its energy efficiency, geographical location, raw materials adopted, etc.

Earlier studies on building energy conservation addressed only OE, as it generally carried a large share of the life cycle energy. But the fact that in some cases

EE can outweigh OE of the building over its life, is gradually receiving attention. With improvements in OE efficiency of buildings, EE can constitute a greater share of the net life cycle energy. Lower the OE, higher the share of EE in LCE. Assessing relative share of EE and OE in buildings becomes a significant input to identify the potential areas for energy conservation. With this objective, the present study assessed EE and OE for few traditional and conventional dwellings in different climate zones of India using field survey data on building materials, construction technologies and OE etc. This study provides and insight into the energy in buildings with particular reference to the climatic-response associated with the thermal performance of traditional and modern buildings in India. The study reveals a wide range of EE value of rural and urban dwellings studied. The analysis for both rural and urban dwellings results did not reveal any definite correlation between EE and OE, and EE and LCE. However, the relative significance of EE and OE in LCE varied for urban dwellings depending on the climate zone. The results reiterate the importance of EE assessment for LCE analysis in buildings.

Given available computational support, attempts are made to assess OE in buildings at the design stage itself adopting building simulation models. There has been extensive research since last few decades in developing various simulation tools for modeling building energy performance including that of air-conditioning, ventilation, lighting and other plug-loads. Building simulation studies facilitate OE analysis for various design alternatives keeping in mind low-energy performance. OE in buildings is greatly influenced by the local climate and the specific thermal characteristics of the building envelope. The thermal performance of the building envelope determines its ability to regulate indoor thermal comfort in response to external climatic conditions. To assess the thermal performance of building envelope, it is crucial to ascertain the thermal properties of constituent materials. Thermal conductivity, in addition to specific heat and density, is paramount to ascertain to understand thermal behavior, and also as crucial data to support OE building simulation studies. The present study includes experimental investigation on thermal properties of different envelope materials, to generate input data for building simulation studies.

An ideal building envelope would passively regulate indoor thermal comfort through the year, so as to place no demand on OE to maintain thermal comfort. Building simulation studies enable proper designs for suitable thermal performance of building envelope to achieve minimum OE. In this perspective, the present study includes building modeling and simulation study of traditional and conventional dwelling for their influence on OE. One of the objectives of this section of the study is to understand the intricacies involved in building modeling and simulation. The study examines OE in traditional and conventional dwellings for various wall materials in different climate zones. The results reveal variations in OE for various climatic conditions, but limited variation for different walling materials. In the traditional dwelling, natural ventilation was found to play a dominant role in regulating indoor thermal comfort while in the conventional dwelling thermal performance of the fenestration (glazing) strongly influenced indoor thermal comfort.

Thus, the present work links studies on energy in buildings and associated aspects of building materials in a systematic manner to present a comprehensive research study.