Chapter 9
Exploring Energy Efficient Procurement Options in Building Construction

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Abstract There has been a significant increase in interest and research activities in energy efficient building construction in recent years. In the construction phase of building's life cycle, contractors provide resources and select means and methods of construction. To make the construction phase less energy intensive, the contractor has to purchase the required resources from the jobsite proximity to minimize the transportation energy. Sometimes, it might not be possible to analyze and practice energy saving measures for the whole project because of time and budget constraints during this phase. Therefore, it will be helpful to a contractor if he can focus on the most energy consuming activities on the project. This is possible, if the contractor has access to energy data of the project to identify which activity's resources consume the most energy. The contractor may then explore less energy intensive alternatives, and procurement methods that are available for those resources. This research focuses on applying IT to tackle the issue by developing a spreadsheet-based tool to estimate energy consumption in material and equipment procurement for construction activities of a project. The proposed method uses the project's bill of quantity, and data related to materials transportation and equipment operation to estimate the probable energy consumption during construction. A case study was performed to demonstrate the application of the tool and discuss possible alternatives to save energy consumption. The proposed method allows contractors to identify energy intensive activities during construction and deploy energy efficient procurement to reduce energy consumption of a particular project.

Keywords Energy efficient construction • Energy information system • Construction contractors • Embodied energy

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9.1 Introduction

The building construction project imposes loads on the environment in various forms, namely depletion of resources, contamination of air, soil, and water. These loads are generated while various demands, such as materials and energy are met to construct the building. The construction industry uses more materials by weight, than any other industry in the United States [1]. Moreover, the environmental impacts of building construction, partly caused by large consumption of energy, are imposed during the whole life cycle of a building [2, 3]. Energy consumed during the life cycle of a building may be divided into operational energy, embodied energy, and decommissioning energy [4–6]. Operational energy is required for heating, cooling, ventilation, lighting, equipment and appliances. Embodied energy is non-renewable energy required to initially produce a building and maintain it during its useful life. It includes energy used to acquire, process, manufacture the building materials, including any transportation related to these activities (indirect energy); energy used to transport building products to the site and construct the building (direct energy); and energy consumed to maintain, repair, restore, refurbish or replace materials, components or systems during the life of the building (recurring energy). Embodied energy is measured as a quantity of non-renewable energy per unit of building material, component or system. The embodied energy makes about 15–20 % of the total energy consumption during building life cycle. However, the share of the embodied energy will become more significant when buildings become more energy efficient, as shown in Fig. 9.1 [5, 7].

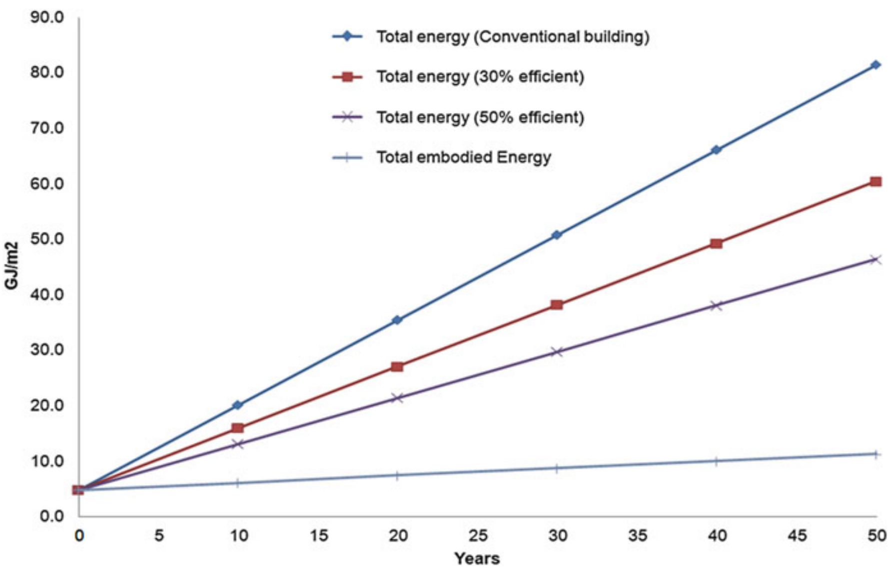

Fig. 9.1 Energy use in buildings: the changing relationship between embodied and operational energy (50 years life cycle)

Among various phases of embodied energy, energy consumption during construction phase is less explored [8]. In the construction phase, contractors provide resources and select the means & methods of construction. To make the construction phase less energy intensive, the contractor has to purchase the required resources from the jobsite proximity to minimize the transportation energy or to purchase more energy efficient resources. This is possible, if the contractor has access to energy-profile of the project to identify which material procurement and equipment transportation & operation consume maximum energy. The contractor may then seek less energy intensive alternatives that are available. This work focuses on developing a spreadsheet tool to estimate energy consumption in material procurement and equipment transportation & operation for construction activities of a project.

9.2 Energy Estimation Tool

The construction phase of a building life cycle involves numerous activities such as construction of temporary structures, transportation and installation of building materials and components, site work, etc. These activities consume energy and affect the environment. The aim of this research work was to develop an energy estimation tool for a contractor, hence only energy consumptions for transportation of materials from manufactures to a jobsite, and on-site equipment transportation and operation were taken under consideration.

When a building construction project is started, the general contractor prepares a detailed estimate for the materials, workers and equipment required. A bill of quantities (BOQ), which is not only a list of materials but also a list of tasks/items required for the execution of the project, is prepared. The framework for the proposed tool (Fig. 9.2) uses a project's bill of quantity, and data related to materials transportation, and equipment transportation and operation to estimate energy consumption during construction. Materials, transportation modes, their purchase distances; equipment, transporting distance, and per hour fuel consumption are assigned to each project activity.

An estimation of amount of energy consumed in transporting of a material is dependent on mode of transportation, energy consumption to transport 1 kg of material to 1 km distance, quantity of material required to finish the activity, and the distance of material manufacturing unit to the job site. In a construction process, an activity might include different materials transported from different distances using different transporting modes. The total sum of these energy requirements will be the total energy required to transport the materials for that activity. The system calculates total energy required and arranges the activities of BOQ in a descending order to identify energy intensive activities.

An estimation of amount of energy consumed in transporting a heavy equipment is dependent on transporting vehicle fuel consumption and transporting distance, while operating a piece of equipment is dependent on hourly energy consumption of

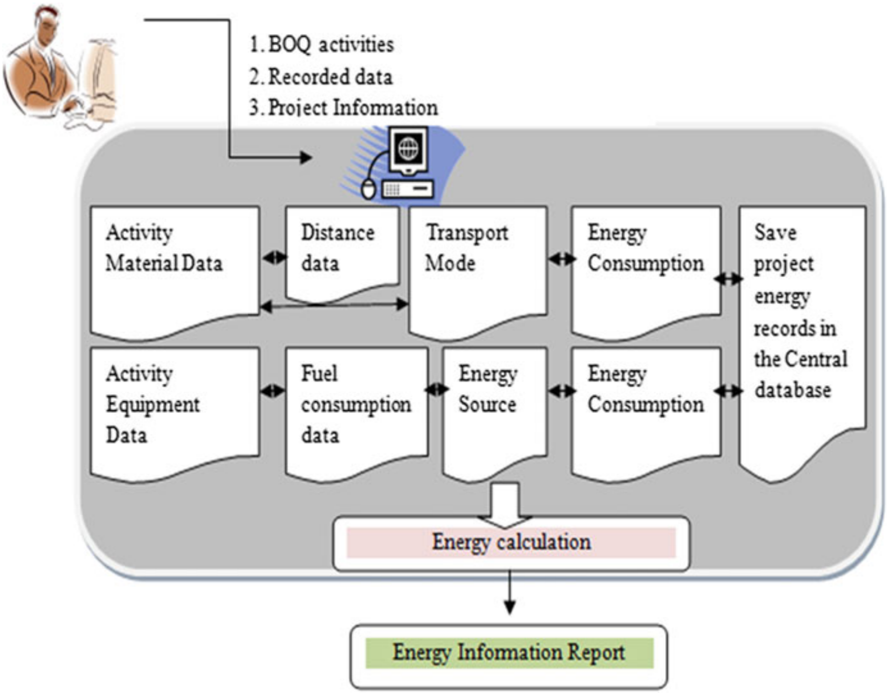

Fig. 9.2 The framework to estimate material transport energy and equipment energy consumption

a piece of equipment and number of operating hours to finish the activity to which it is assigned. In a construction process, an activity might include various pieces of equipment of different strengths and energy sources. Equipment were assumed to be transported within 80 km from the jobsite. The total sum of these energy requirements will be the total energy required to operate these equipment to finish the activity. The system calculates total energy required and arranges the activities of BOQ in a descending order to identify energy intensive activities.

At the end of the estimation process, a report containing information about energy consumption of each activity and high energy-demanding activity is generated. This report can be utilized by the contractor to consider alternative sources for energy intensive procurements for the project.

Many researchers have mentioned the lack of project related energy and environmental data to accurately assess energy consumption and environmental impacts [8, 9]. Currently, most of the work at this phase is performed by researchers using a case study and applying LCA application packages, which might use data on a national level average. These data might be good to get an overall picture, but could be less meaningful if a contractor wants to improve its supply chain at local level or for a project. In order to do so, he needs a system that can estimate and record the relevant data to improve energy estimation on future projects. The framework as shown in Fig. 9.2 can be extended to record the related data by adding one more sheet that saves data for various activities for various projects. Figure 9.3 shows the

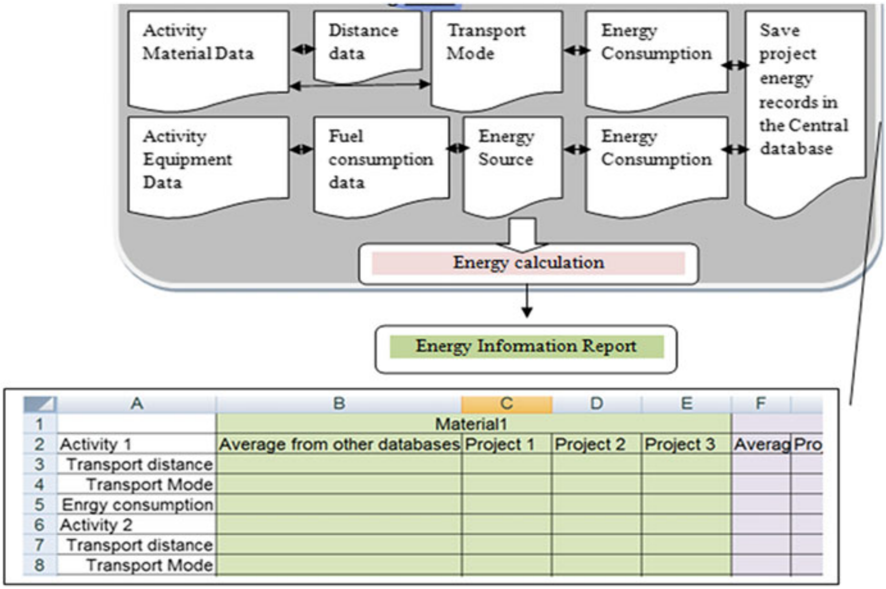

Fig. 9.3 The extended framework to estimate and record material transport energy

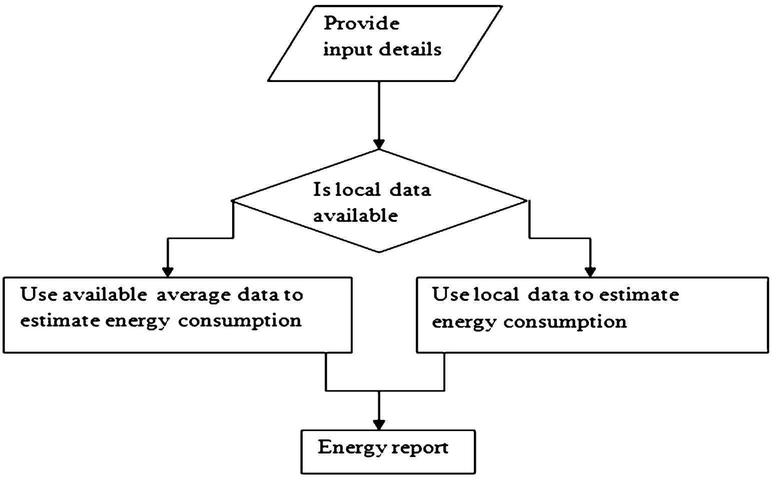

Fig. 9.4 The flowchart to implement the tool on a project

extended framework with a snippet of spreadsheet to record data for projects. It shows an attached spreadsheet for materials only, however the complete sheet contains the details for equipment, too.

Figure 9.4 shows the flow chart to implement the tool on a project. The tool can be used to estimate energy consumption using national average data collected from various databases and available literature, if more reliable and local data is not available for any activity. Once the required data is recorded for some projects the database is now rich with the data used for local construction practices and a company's procurement system. Therefore, the next estimation for a similar project could be done based on the recorded data.

9.3 Case Study

Based on the framework shown in Fig. 9.2, a simple spreadsheet based tool was developed. A repair garage case study is presented here to demonstrate the application of the tool. An example of a repair garage was taken from Means Scheduling Manual [10]. The garage was of 30 × 12 m size, with a reinforced concrete footing, concrete slab on grade, concrete block bearing walls, offices and restrooms, mezzanine over the offices, bar joist and steel deck, built-up roof, sky lights, mechanical and electrical systems, and doors and windows. Figure 9.5 shows a snapshot of the bill of quantities for construction of the garage. The Means Scheduling Manual could be referred for additional details of the repair garage.

Each activity was assigned materials and equipment required to finish one unit of the activity. Each of the materials was assigned distance to transport from the manufacturing units to the job site. At this stage, the distances were considered uniform for all the material. The calculations of energy consumptions were forwarded to the energy data report sheet, which presents the total energy consumed against each activities in the bill of quantities sheet, project related information (Fig. 9.4).

A	B	C	D
Bill of Quantities (BOQ)			
Ref . No.	Description	Quantity	Unit
311110100020	Clear and grub	4050	sq m
312316130060	Excavation footings/utilities	141	cu m
312323131400	Backfill mechanical	103	cu m
312323130015	Backfill manual	34	cu m
310516100100	Bank run gravel	57	cu m
312216101150	Hand Grade finish	372	sq m
312323130500	Air Tampering	34	cu m
31113450020	Footing Forms	56	sq m
32110600500	Reinforcement	4.55	Tonnes
33105701900	Conc 20 MPA	16	cu m
31113651000	Bulkhead Forms	24	L m
32205500100	WWF 6.6 10/10	420	sq m
33105704300	Concrete slab 25 MPA	40	cu m
33529300250	Finishing Concrete stl twl	400	sq m
34113500050	PreStresses slabs 150 mm	50	sq m
42210260350	300 mm foundation Block	75	sq m

AP	AQ	AR
Project Information and Material distance (Uniform)		
Project Information		
Building Footprint (L m x B m)	30	12
Site Dimension (L m x B m)	36	14
Building Stories	1	Storey
Project Duration (Calendar Days)	80	days
Project ID	GarageEx1	
Construction Manager	XYZ	
Project Description	Example	
Default values		
Workers transport	75	kms

Fig. 9.5 Input data used in the spreadsheet tool

9.4 Results and Discussions

Figure 9.6 shows the output of the energy estimation system for the construction of the repair garage.

The output demonstrates the energy consumption details of the top five material energy intensive activities and the top five equipment energy intensive activities, out of all the given activities in the BOQ. It is clear (Fig. 9.6a) that materials for bearing wall construction were consuming the maximum amount of energy. Therefore, a contractor can focus on this activity while purchasing materials to reduce the transportation distance or ask manufacturers to use energy saving mode of transport to reduce energy consumption and associated carbon emissions. The recommendation to search for a nearer purchasing location might not be satisfied, if the material recommended by the project architect is available only at that location. This limits the application of energy saving recommendations. However, the recommendation could be sent to the owner to discuss this issue with the architect. Another alternative with similar performance could then be selected.

It is also clear from Fig. 9.6b that the equipment used to clear and grub the site were consuming maximum energy. As presented in [11], a variation in equipment transporting distance does not have much impact on total energy consumption. Therefore, a contractor who is looking for reducing energy should focus on reducing transportation distances for materials, but can rent equipment from a more distant place if they are more energy efficient. If it is not possible to find an energy efficient model, a model with an alternative fuel type such as natural gas,

a

M	N	O	P
Bill of Quantities Energy Consumption (MJ)			
Sl	ID	Description	Material Transport Energy
1	42210344300	Bearing Wall 300 mm	11,199
2	33105704300	Concrete slab 25 MPA	6,864
3	33105701900	Conc 20 MPA	2,772
4	42210260350	300 mm foundation	1,975
5	75113200200	T&G roofing	1,610

b

Bill of Quantities Energy Consumption (MJ)			
Sl	ID	Description	Equipment energy
1	311110100020	Clear and grub	12731
2	52119100440	Open web joists	8090
3	310516100100	Bank run gravel	7612
4	312323131400	Backfill mechanical	6902
5	312316130060	Excavation footings/utilities	4099

Fig. 9.6 Energy estimation report: activities in descending order. (**a**) Material transport energy. (**b**) Equipment transport and operation energy

rather than diesel, could be recommended. This might not save energy, but would be helpful in minimizing environmental impact due to construction equipment. Although, the final decisions should be made based on a detailed analysis, but these information can help in focusing on energy intensive activities and hence promoting energy saving practices.

The potential for reducing energy consumption might not be high, however. Limitations may arise due to a specific material being available at certain locations only, which is not in the contractor's control. Generally, contractors buy the least expensive products (including transportation) and available local machinery to deliver the work that satisfies the contract specifications and schedule. The contractors might not want to break old and long-term relations for saving energy on a project. Moreover, the contractors may not be financially motivated to reduce energy consumption when purchasing materials and deploying energy efficient models. In these situations, the project owner may require a maximum distance for material purchase in the specification or provide some incentive for purchasing materials from local vendors and deploying energy efficient equipment. The U.S. Green Building Council LEED rating system already provides credit for materials that are purchased within an 800 km radius. However, a low cost might not be the only reason in the selection of resources at times. The availability of resources, the production rate of a manufacturing unit for materials, specialty in manufacturing a particular item, availability of machinery, and/or relations between parties may play a role in the selection process. In some of these cases, energy efficient construction may be given priority if contractually required. In cases where several providers with some variation in purchase cost are available, the selection could be based on optimization technique.

9.5 Summary

In summary, contractors can play a major role in development of energy efficient means and methods to reduce energy consumption, hence carbon footprint during construction phase of the building. The proposed framework allows contractors identify energy intensive activities during construction and deploy energy efficient procurement to reduce energy consumption of a particular project. In addition, collecting energy consumption data during construction and updating the database will increase the accuracy of estimating energy consumption for the future projects.

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