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About Embodied Energy, Operational Energy and Life Cycle Analysis of Housing
Discussion Paper

Defining the Concepts

Embodied energy refers to the quantity of energy required to manufacture and supply a home, including all the energy used in the production of raw and processed materials required in its construction.

Operational energy refers to all of the energy used in the operation of a finished home, over its useful lifespan, excluding embodied energy and energy required to demolish, disassemble and dispose of the home when its lifespan is over.

Life Cycle Analysis (LCA, also known as cradle-to-grave analysis) involves measurement of all environmental impacts related to the existence of a home (not just energy-related impacts), from the raw and finished materials required to build it, through its operational lifespan, and including the recycling or disposal of construction wastes when the home is demolished. Both embodied and operational energy use are included when conducting an LCA.

How Each Concept Works

Embodied Energy

Embodied energy refers to all the energy used to produce and transport the materials and products that go into constructing a home, plus the energy used in the on-site construction process itself. Such a calculation is based on analyzing how each material or product is produced and how it gets from its point of origin to the construction site. For manufactured products, such as heating equipment, this can be a very complex process, as it needs to account for each component used in the manufacturing process.

A simple illustration of embodied energy can be made in relation to wood products used during construction. For instance, the embodied energy of wood framing used in a home would be determined by measuring the amount of energy consumed in converting standing timber to delivered framing lumber at the building site, factored by the gross amount of wood used (including waste materials). This would involve measuring the energy use, per unit of wood, related to each step in the production process:

- Timber harvesting
- Transportation of the timber to the mill
- Sawmill operations to produce and dress the raw lumber
- Kiln-drying the lumber
- Packaging and shipment of the lumber to the wholesale distributor
- Trans-shipment of the lumber to the building site

The per-unit embodied energy value would then be applied to the total amount of wood used to determine this specific embodied energy input. Similar analysis would then be done for every other material used in

the building process. Finally, the energy used on-site during construction for lighting, heating and powering tools would be determined.

The total amount of energy required to produce all material and product inputs, plus that used during the construction process would represent the embodied energy of the home.

Operational Energy

Operational energy use includes all the energy used in the home during its entire lifespan, from the day the new homebuyer moves in, until the day, many decades later, when the home is demolished to make way for new development, or because it is no longer serviceable.

Operational energy use includes the energy used for heating, cooling and lighting, as well as energy used by occupants in their daily lives to operate appliances, computers and televisions, etc. In addition, the embodied energy in materials and products required to maintain the home between the time it is completed and demolished is also calculated into its operational energy requirements (i.e., repainting, re-shingling, etc).

In terms of the operating energy requirements of a home, there are some aspects that the home builder has influence over, and many others where this is not the case.

For instance, the builder initially determines the thermal performance of the building envelope and, while owners may choose to upgrade the home over time, this initial performance level will have a profound effect in the home's performance over its entire lifespan.

Similarly, the builder will decide what type and efficiency of heating equipment to install, and may select appliances for the home. These builder choices will have impacts during the lifespan of these specific products, but energy requirements may change when builder-supplied equipment wears out the homeowner replaces it.

There are many other areas of operational energy use where the builder has no influence. If homeowners buy a plasma television, decide to install a hot tub, prefer baths over showers, or turn down the furnace at night, these decisions can have a significant cumulative impact of the homes operational energy use. The builder has no influence over customer lifestyles, and cannot, therefore, affect owner-driven operational energy use.

Similarly, over the life of the home, owners may choose to add to the structure, remodel it, or change its function, for instance by operating a home-based business. The original builder obviously has no role in these decisions, all of which will alter the energy use characteristics of the home.

Life Cycle Analysis

Life cycle analysis attempts to calculate the total sum of environmental impacts that result from a home being built, lived in and ultimately, demolished. Such analysis is not limited to determining energy use, but attempts to tabulate all environmental impacts, including those related to water use, toxic releases, and both direct and indirect land impacts.

The concept that underlies life cycle analysis – that every aspect of building and operating a home results in discrete, measurable environmental impacts – is clear and undisputed. However, developing the capacity to reliably calculate these impacts for a given home, in a given location, built using a unique mix of materials and products, and occupied by individuals who will have their own unique lifestyle, is inordinately complex.

It is sufficient to note that life cycle analysis is an exceedingly complex process, the accuracy of which is full dependent on the reliability of the data used. Life cycle analysis is an evolving discipline, the usefulness of which remains a matter of some debate.

How Much Does Embodied Energy Matter?

The issue of embodied energy has become a debating point for some material producers who seek a market advantage based upon their product's typically lower embodied energy. For instance, the wood, steel and cement industries have debated this issue for a number of years, as each industry seeks to position itself as the preferred "green" option.

In terms of the overall environmental impacts from residential energy use, the central question is: how much does embodied energy really matter? Here, the evidence is quite clear. Some research suggests that the amount of embodied energy in a home is as much as 20 to 50 times less than the operational energy used by occupants during a homes lifespan. This puts the relative importance of embodied energy into perspective.

Embodied Energy – In Context

Much of the embodied energy information presented by material producers is selective. This can undermine the accuracy and meaningfulness of the data.

The most common "spin" applied in embodied energy analysis is to assume an unrealistically short lifespan for a home, thus increasing the apparent significance of its embodied energy in relation to operational energy use. One recent study assumed that a new home had a useful lifespan of only 30 years. Other studies have assumed life spans as short as 20 years. As embodied energy must be "amortized" over the lifespan of the home, in much the same way as capital costs, assigning an unrealistically short lifespan to a home makes its embodied energy component appear more significant than it is.

As well, in most cases, considering embodied energy will not provide a builder with actionable information. For instance, it is clear that, per unit of finished construction, the use of wood will involve far less embodied energy than the use of concrete. However, in most applications, wood and concrete are not fully interchangeable materials, which makes the comparison less than useful.

Should Builders Consider Embodied Energy When Making Building Decisions?

For builders constructing market housing, even homes that are highly energy efficient by current standards, embodied energy should not be a significant concern. Homes should be built to deliver a safe, healthy and comfortable living environment, to be energy efficient, and to be affordable for their intended market.

If builders or home buyers want to invest additional money to further reduce the environmental impact of a home, such additional investment could more effectively address operational impacts, primarily energy and water use. Addressing operational impacts will almost always yield the greatest environmental benefit for each dollar spent, much greater than equivalent investment in reducing embodied energy.