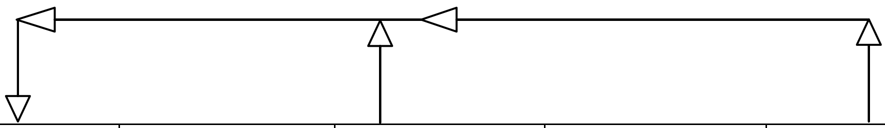
Material selection and embodied energy

1 Introduction

The building life cycle demands both operational and embodied energy (Figure 1). It has been estimated that in conventional buildings, operational energy represents approximately 80-90% of total life cycle energy, while embodied energy accounts for the remaining 10-20% (Kotaji, Schuurmans and Edwards, 2003: 5). The intent of energy efficient building design is to directly target the reduction of the dominant operational energy component. In the last two decades, the integration of both passive measures and active technologies into “green” building design has drastically reduced operational energy – in many instances, savings of 50% and more were achieved. In contrast to this, embodied energy reduction strategies are less prominent; and the popular material resource strategies, for instance, the use of recycled content materials, are also not assessed to confirm whether they are yielding the desired environmental benefits or not.

However, as the operational energy component is reduced, life cycle energy is also reduced; but the embodied energy component increases (Sartori and Hestnes, 2007: 256). For instance, in a comparative study, a significant reduction in life cycle energy, namely, 60% was achieved by an energy efficient home over an equivalent conventional home. Additionally, the embodied energy increased from 9% for the conventional home to 26% for the energy efficient home, while the operational energy decreased from 91% for the conventional home to 74% for the energy efficient home (Keoleian, Blanchard and Reppe, 2001: 153-154). More recently, this result was found valid in sixty case studies, despite climatic differences, and regardless of building type and other contextual factors (Sartori and Hestnes, 2007: 256). Achieving an energy optimised building therefore requires the ability to investigate both the operational and the embodied energy implications of alternative design options.

Recycling of materials / component



Embodied energy	-Material extraction and processing -Construction material fabrication	-Material transportation -Construction process	-Material extraction and processing -Construction material fabrication -Material installation	-Material extraction and processing -Construction material fabrication -Material installation	-Dismantling or demolition - Material transportation
Operational energy			Heating cooling Lighting Appliance use		
	Material production	**On-site construction**	**Use/ maintenance**	**Refurbishment**[1]	**Disposal**

Building life cycle

Figure 1: The make up of embodied and operational energy over an illustrative building life cycle. Adapted from Yohanis and Norton, 2002: 78

[1] Refurbishment is included for illustrative purposes only. Due to its highly uncertain nature, it is established practice to exclude it from actual embodied energy calculations

Predicting the embodied energy contribution of a single material is however not as easy as green building practices assume. As illustrated by the example in Box 1, the choice of a material implies the choice of integral constituents such as insulation, mortar or glue. In the example, it turns out that after installation, the embodied energy of the recycled material is higher than that of the virgin raw material. Comparisons should therefore be made in the context of building systems, rather than on a product-to-product basis (Trusty and Horst, 2006: 15). Thus the challenge for building designers is to understand the choices from a systems perspective; otherwise it will not be possible to design for optimal embodied energy, hence LCA.

Box 1: is it a material or a system?
Steel studs containing the maximum percentage of recycled steel that technology currently allows require substantially more energy to produce than do wood studs. The difference becomes even greater when expanded polystyrene is added to wall sections to make insulation properties in the steel framed wall equivalent to that of the wood frame construction (Bowyer, Howe, Fernholz and Lindburg, 2006)

The Life Cycle Assessment (LCA) concept is a science-based tool that is used to measure the environmental performance of a product over its entire life cycle. Where the extent of the inquiry ends with transportation of the product to the point of disposal, it is a cradle-to-grave analysis. If it includes the recycling potential, it is deemed a cradle-to-cradle analysis. Environmental performance is measured in terms of a wide range of potential impacts on human health, ecosystem health and natural resources.

Table 1: Embodied effects typically investigated in an LCA

Inputs (extractions from nature)	Outputs (releases to environment)
• Energy • Materials • Water • Land	• Acidification • Climate change • Eutrophication • Eco-toxicity • Human toxicity • Photo-chemical oxidant formation • Ozone depletion

In LCA, the potential environmental impacts associated with material production, use, maintenance, transportation and disposal are referred to as “embodied effects”, where the word *embodied* refers to attribution or allocation in an accounting sense as opposed to true physical embodiment. In the building community, the tendency is to refer only to “embodied energy” (Trusty and Horst, 2006: 15). However, as implied by the comprehensive list of effects typically investigated by LCA (Table 1), all the extractions from and releases to nature are embodied effects, and there are also embodied effects associated with the making and moving of energy itself (known as pre-combustion energy). The LCA is known as Life Cycle Energy Analysis (LCEA) where all aspects of life cycle energy use are assessed in a study. Alternatively, the study scope could be limited to either an embodied energy or operational energy analysis.

This chapter aims to raise the awareness of the green building community to the embodied energy implications of material choices; and to provide a practical road map which can inform decisions leading to the optimal life cycle energy performance of buildings. The published results of building-related LCEA and embodied energy analysis studies are used as illustrative examples. The preliminary results of a South African embodied energy case study are included and discussed.

2 Embodied energy defined

Descriptions of the life cycle energy of a building distinguish between three distinct categories of embodied energy, namely, Initial embodied energy; recurring embodied energy; and demolition energy. The initial embodied energy of a building is the sum of the energy embodied in all the material used in its construction. Initial embodied energy, which is accrued during the material production and on-site construction life cycle stages (Figure 1), is influenced by material production energy, material mass, transportation distance, construction methods and context of application. Recurring embodied energy is the sum of the energy embodied in the material used to maintain and replace worn out materials and components; and to rehabilitate a building over its service life. The major factors influencing the recurring embodied energy contribution of a material are its service life, replacement factor and nature and frequency of maintenance. Demolition energy is the energy required to demolish or dismantle a building and transport the remains to the point of disposal. As compared to total life cycle energy, demolition energy has been found negligible regardless of material choice.

3 Initial embodied energy

3.1 Material production and material mass

In the building sector, it is well known that material production accounts for the largest share of the initial embodied energy of a building (Cole, 1999). It is therefore common practice to select materials in consideration of only material production energy. However, the initial embodied energy contribution of a material rests on the synergy between production energy and material mass and not on production energy per se. For instance, a study compared the contribution of materials to the initial embodied energy of a three bedroom house and found that despite the relatively low production energies (Table 1) of concrete, timber and ceramic tiles, their use in large quantities in construction of the dwelling meant that these three materials accounted for about 90% of the initial embodied energy. Despite its relatively high production energy aluminium contributed negligibly to the initial embodied energy due to its very limited use in the house (Asif, Muneer and Kelly, 2007). The modern tendency to use aluminium doors and windows can however contribute significantly to the energy input into a building (Venkatarama and Jagadish, 2001). The results therefore vary widely for a single material and design decisions need to be made on a case by case basis.

A more generally applicable outcome of Asif et al's study, which is supported by the results of other building-related energy studies, is that the tendency to use concrete in large quantities in construction generally makes it responsible for a very large share of the initial embodied energy and associated environmental impacts of a building.

Table 2: Initial embodied energy contributions of materials used in constructing a home. (Adapted from Asif, Muneer and Kelly, 2007)

Material	Quantity (kg)	Production energy (MJ/kg)	Contribution to initial embodied energy (%)
Concrete	130 000	1	61
Timber	5725	8	14
Ceramic tile	4030	5.24	15
Glass	313.6	13	2
Aluminium	25.3	232	3

3.2 Transportation distance

Material transportation may play an important role in the make up of the initial embodied energy of a building. It is therefore almost always assessed in a study. In the studies where materials were obtained locally, that is, within an average travelling distance of 50 km, transportation energy was found to be negligible. (Junnila, Horvath and Guggemos, 2006; Keoleian et al, 2001). However, heavy reliance on imported building materials can make material transportation a significant contributor to initial embodied energy. In a study which compared two high rise residential buildings in Hong Kong, Chen, Burnett and Chau (2001) found that the embodied energy of imported steel and aluminium accounted for more than 75% of the total embodied energy of each building. They concluded that a switch in the source of the key building materials, in this case steel and aluminium, from virgin raw materials to the recycled versions could potentially save more than 50% on the total embodied energy of each building. This finding in respect of recycled materials contrasts sharply with the example from Box 1, thus highlighting once again the need to avoid a "one size fits all" approach when embodied energy is used as a criterion for material selection.

3.3 Construction method

According to figures first mooted in the 1980s, the construction process probably accounts for only 7-10% of the initial embodied energy of a building (Cole, 1999: 336). For this reason, it is generally omitted from building-related energy studies and data are rare. However, results from the limited number of published studies highlight an important relationship between materials, their construction methods and the contribution to initial embodied energy. For instance, in a comparative study, which investigated the on-site construction of wood, steel and concrete structural building assemblies, Cole (1999) found that for steel assemblies, the construction energy is a lower proportion of the initial embodied energy than typically assumed; and for wood and concrete assemblies it is higher (Table 3).

Table 3: Construction energy of alternative structural materials Adapted from Cole, 1999: 344

Material	Construction energy as a portion of initial embodied energy
Concrete	11-25%
Steel	2-5%
Wood	6-16%

The result in respect of concrete and steel is supported by a more recent study which found that as compared to steel, a concrete structural frame entails higher construction energy (Guggemos and Horvath, 2005). This is because concrete construction methods result in a greater use of temporary materials, longer use of equipment and larger transportation impacts. On the other hand, the painting, torching, cutting and welding of steel contributes substantially to emissions of Volatile Organic Compounds (VOCs) and heavy metals. Selecting steel in lieu of concrete would therefore result in an exchange of embodied toxicity for embodied energy. Some of the energy saving recommendations arising from the latter study in respect of concrete construction methods includes modular design and off-site fabrication.

3.4 Context of application

When examined in the context of building sub-systems, the distribution of the initial embodied energy follows a similar pattern, regardless of structural materials and building type. Cole and Kernan (1996) compared alternative wood, concrete and steel structural systems. They found that despite the difference in structural materials, the distribution of the initial embodied energy followed the same pattern in all three buildings, namely:

- Envelope materials represent the largest single component, that is, 26-30%.
- Structural materials represent 20-24%
- Services materials represent 20-25%
- Finishing materials contribute the least, that is, 12-15%.
- The building structure and envelope together represent about 50% of the initial embodied energy

The study by Keoleian et al (2001) which investigated the life cycle energy implications of a residential home, suggest that the latter finding is valid for dwellings.

4 Recurring embodied energy

4.1 Service life

Service life is the period of time after on-site construction or installation during which a building or its parts meet or exceed performance requirements (Kotaji et al, 2003: 78). The designed service life (DSL) of a building reflects the durability of the structural system and envelope materials. Building designers typically base the DSL on their experience of the actual service lives of similar local buildings. In general, the actual service life of a built facility may not be the same as the DSL. For this reason, a shorter DSL is frequently assumed for commercial buildings which are more prone to functional obsolescence. The potential service life of a material or component can be obtained from material manufacturers or may be derived from the experienced (economical) service.

Table 4: Building service life examples

Country	Building service life (years)	
	Residential	Non-residential
Finland	80	
Netherlands	75	20
Sweden	40-50	
United Kingdom	60	60
USA	60	60

4.2 Replacement factor

The replacement factor provides a means to compare the durability of finishing materials to that of the structural system and envelope materials. It is an indication of the number of times (including first installation) that resource input is needed for installation of the material or component within the DSL (Chau, Tik, Hui, Lui and Yu, 2006: 1843). Accordingly, the contribution of a material to the life cycle energy of a building will be its initial embodied energy scaled up by the replacement factor. The contribution of each material or component is determined by application of the following formula, namely:

Replacement factor = DSL/ service life of material

In estimating the recurrent embodied energy contribution of a material it is current practice to include only routine maintenance and replacements in a study, and to exclude all unplanned activities such as refurbishment because the latter are totally uncertain.

4.3 Nature and frequency of maintenance

Maintenance causes material use and also determines the service life of a material. An embodied energy analysis distinguishes between the embodied energy contribution of routine maintenance, which is included in the study, and purely aesthetic maintenance which is excluded because the later are totally uncertain. The frequency of maintenance (service life) is determined by product manufacturers and displayed on certificates or made available in product data sheets.

4.4 Implications of recurring embodied energy

Until now, the belief that recurring embodied energy is a minor contributor to building life cycle energy, and therefore not an important criterion for materials selection, is pervasive in the building community. The results of building-related energy studies however indicate the opposite to be true. In the comparative study of three office buildings, Cole and Kernan (1996: 311-312) found that despite the differences in structural materials, the recurring embodied energy followed the same pattern in all three buildings, namely:

- For a short DSL, say 25 years, the recurring embodied energy was always less than the initial embodied energy
- For a longer DSL, the recurring embodied energy exceeds the initial embodied energy by age 50 years.
- For a very long DSL, say 100years and more, the recurring embodied energy is 200-300% the initial embodied energy by age 100 years.
- Envelope and structural materials contribute the most to initial embodied energy, but the least to recurring embodied energy. In contrast, finishes contribute the least to the initial embodied energy, but are the key source of recurring embodied energy
- Over a 100 year period, the building components contributing the most to recurring embodied energy, ranked in order of importance are finishes, building services, envelope materials and structural materials.

The results of Cole and Kernan (1996) have been validated in a number of subsequent studies, namely:

- In the comparative study of a conventional home and an energy efficient home, Keoleian et al (2001) observed that a finishing material with high production energy, but a short service life, in this instance, carpet, contributes substantially to recurring embodied energy. They concluded that a switch to a floor finish which is initially more costly, and requires routine maintenance but no replacement during the DSL would substantially reduce its recurring embodied energy contribution and also result in life cycle cost savings.
- In a comparative study of two office buildings, one located in the United States and the other in Finland, Junnila et al (2006) found that frequent replacement of carpets and some ceilings; and periodic repainting contributed the most to the recurring embodied energy of both office buildings.

- Chen, Burnett and Chau (2001) found that the longer the lifespan of a building, the larger the recurring embodied energy, and the (relatively) smaller the initial embodied energy.

5 Demolition energy

Regardless of building type or constituent materials, demolition energy is found to be minor when compared to the rest of the life cycle energy of a building. Data are rare because most studies disregard demolition energy altogether; or it is mentioned in the study, but not reported in the results. One study found that demolition energy accounted for 1-3% of the life cycle energy of a three-storey office building.

However, when the fate of materials and their embodied energy is considered beyond the current scope of a building-related LCEA, it is clear that the end-of-life (EOL) management of buildings is at odds with the concept of Sustainable Construction. As much as 50% of all materials extracted from the Earth's crust are transformed into construction materials and products. It follows that when these same materials enter the waste stream, they account for some 50% of all waste generated prior to recovery (Koroneos and Dompros, 2007: 2114). Internationally, the rates of recovery of construction and demolition (C&D) waste is poorly documented, but is probably low – for instance, of the approximately 136 million tonnes of C&D waste generated annually in the USA, it is likely that less than 20% of the total mass are salvaged in some way (Kibert, Sendzimar and Guy, 2000: 910).

Taking into account the potentially negative environmental effects associated with the inordinate waste of materials and the loss of their embodied energy, there is a need for the green building community to engage with step changes which can drive the shift from a waste management mentality to one of recovery management. The key concepts and techniques advocated in support of a more sustainable EOL management for buildings are:

- A closed loop industrial system to facilitate the re-distribution of C&D waste and products degraded by age back into the industry for purposes of either recovery or waste management (Kibert et al, 2000: 908)
- A construction-specific LCEA model which goes beyond mere accounting for demolition energy to assess the potential for reducing the embodied energy requirements of future buildings through material recovery management practices (Sartori and Hestnes, 2007: 257)
- Classification of recovered materials for purposes of direct reuse, Product Recovery Management (PRM) or waste management; and the use of an LCA-based energy accounting model, namely, Energy Saving Value (ESV) to assess how much energy is saved when secondary materials are substituted for primary materials (Schultmann and Sunke, 2007).
- An Extended Producer Responsibility (EPR) policy requires producers to be responsible for their products after their useful life. The basic drivers of EPR are reduced pollution and resource use over a product's life cycle. For buildings, EPR provides an opportunity to divert recovered materials away from landfills and into direct reuse, PRM, and incineration with energy recovery.

However, closing the loop is contingent on a shift in design mentality which facilitates disassembly as opposed to demolition. The amount of potentially recoverable material is determined by building design but at present, the notion of design for disassembly is the exception rather than the rule in the green building community. South African case study

5.1 Background

The operational energy of the South African building stock accounts for about 31% of total electricity use (CIDB, 2008:17), making this sector an important role player when it comes to energy demand. A key environmental issue of concern for the nation is that the energy demand of the economy outstrips the electrical power supply. To reduce pressure on the electricity supply, government has set an overall policy target of energy efficiency improvement of 12% by 2015. The sector-specific target for the residential building sector, which is measured in relation to operational energy, is 10% by 2015 (DME, 2008: 17).

However, in the low-income residential sector, energy demand reduction requires a focus on embodied as opposed to operational energy. Government's intention to build about two million of its standard subsidy home (SSH), commonly known as the "RDP" house, by 2015 presents an ideal opportunity for the low-income housing sector to contribute to meeting the sector-specific target. The low-income sector currently represents 50% of households but contributes only about 10% of the electrical energy demand of the residential building sector.

Due to affordability issues, the electrical energy demand of the low-income housing sector is unlikely to increase substantially in the near future (CIDB, 2008: 18), despite the planned, mass roll-out of new homes. By contrast, the energy demand of materials manufacture is likely to increase because cement, which is energy intensive in its manufacture, is the key building material for SSH. Additionally, the risks to human health and safety could escalate due to the sector's dependence on cheap, but hazardous energy sources (Klunne, 2006).

5.2 Objectives of the case study

The mandate of the CSIR Built Environment (BE) is to provide research and development solutions aimed at improving the performance and competitiveness of the South African building and construction sector. The present LCA case study aims to augment industry energy efficiency initiatives by showcasing embodied energy reduction strategies for low-income housing. The study investigates whether the switch from conventional, material technologies as represented by SSH, to innovative, material technologies, as represented by the CSIR House (CH), can result in measurable performance improvement in respect of embodied energy use over the whole building life cycle.

5.3 Methodology

The study was conducted on the basis of two experimental houses located on the CSIR Pretoria campus. The SSH is a 40m2 four room dwelling, constructed according to the standard plan and approved specifications of the National Home Builders' Registration Council (NHBRC). To replicate normal space heating conditions in the SSH, no ceiling is included; and SSH was oriented on site without regard for thermal comfort. The conventional material technologies which characterise SSH are the following, namely:

- Substructure: Concrete strip foundation on hard core fill; solid concrete block foundation walls; and 75mm concrete floor slab on hardcore fill.
- Superstructure: Solid concrete blocks
- Finishes: 25mm thick floor screed; and StippleCrete to external walls

Table 5: Material groups defined and applied to model CH & SSH

Material group	CSIR House (CH)	Standard Subsidy House (SSH)
Concrete elements	Stabilised fill Reinforced concrete window frames CSIR 50mm thin concrete raft foundation Reinforced, site mix block core fill Non reinforced, site mix concrete apron	Non reinforced, ready mix concrete strip foundation Non reinforced, ready mix ground floor slab
Concrete block	Modular, hollow concrete block	Solid concrete block
Finishes	Floor screed Insulated ceiling panel Perlite plaster Paint (external wall) Polystyrene cornice	Floor screed Stipplecrete (external wall)
Mortar	Super-structure	Sub-structure Superstructure
Steel	193 mesh 75mm Brickforce Y10 rebar	75mm Brickforce

The CSIR House provides equivalent usable floor area, room function and volume when compared to SSH. Passive solar principles, that is, appropriate north-south orientation; north-facing windows, cavity walls, insulated ceiling and plastered external walls were incorporated into the design of CH to optimise its thermal performance. The innovative material technologies which distinguish CH from SSH are the following, namely:

- Substructure: CSIR 50mm thin concrete raft foundation on stabilised fill
- Superstructure: Modular, hollow concrete blocks; and precast concrete window frames (applied to four out of seven windows to minimise thermal bridging).
- Finishes: Insulated ceiling board; and thermal (perlite) plaster to external walls

The initial embodied energy and recurring embodied energy demand of the two dwellings was quantified at whole building level and compared over a DSL of 50 years. The materials included in the scope of the embodied energy analysis are listed in Table 5. Materials deemed equivalent were excluded from the scope of analysis, for instance, the entire roof structure, doors and windows were not analysed. Similarly, the demolition energy was excluded on equivalence basis. Material service life assumptions and replacement factors are indicated in Table 6.

Table 6: Service life and material replacement factors assumed for the South African case study

Description of material or assembly	Service life (Years)	Replacement factor
Bricks & blocks	50	1
Concrete	50	1
Paint	10	5
Plaster	20	2.5
Polystyrene	Indefinite	none
Rebar	50	1
Stipplecrete	8	6.25
Screed	20	2.5
Thermal insulation	50	1

5.4 Results and interpretation

The build up of recurring and initial embodied energy follow a similar pattern, namely, the super-structure and the substructure represent the largest components of the initial embodied energy, 45-48%; and 31-42% respectively, but do not contribute to recurring embodied energy. In contrast, the finishes contribute the least to the initial embodied energy, 10-24%, but are the main cause of recurring embodied energy.

When compared to SSH, the life cycle energy performance of CH is potentially better than that of SSH, namely:

- The initial embodied energy of CH (64 875MJ) is lower than that of SSH (66 569MJ). The savings of 1 694MJ is sufficient to supply free basic electricity at the rate of 50 kWh per month to about 10 low-income homes.
- The operational energy was not assessed. Thermal performance measurements however show that the interior of CH is cooler in summer and warmer in winter, thus when in use, the operational energy demand and by implication, the space heating requirements in winter of CH will be lower than that of SSH
- Over the whole life cycle, the combined embodied energy of the sub and super-structure of CH (49 443MJ) is substantially lower than that of the SSH (60 901MJ).

However, at the end of the DSL of 50 years, the position of the two dwellings is reversed, that is, the total embodied energy of CH (92 220MJ) is higher than that of SSH (82 635MJ). This is because of the sizeable difference between the initial embodied energy of CH finishes (15 415 MJ) as compared to that of SSH finishes (5 669 MJ), namely, 270%. As an experimental project, it is concluded that the embodied energy of CH were successfully optimised in the context of the sub and superstructure. The chosen finishes for CH however constitute a “hotspot” which can be addressed by switching to a more durable external wall finish.

Table 7: Contribution of sub-systems to embodied energy

Sub-system	Contribution to initial embodied energy				Contribution to total embodied energy			
	CH (MJ)	%	SSH (MJ)	%	CH (MJ)	%	SSH	%
Sub-structure	20 408	31	28 140	42	20 408	22	28 140	34
Super structure	29 035	44	32 770	48	29 035	32	32 770	40
Finishes	16 800	25	7 000	10	42 760	46	21 735	26
Totals	66 260	100	67 900	100	92 220	100	82 635	100

6 Lessons learnt

In the last two decades, efforts to align the life cycle energy performance of buildings with the requirements of sustainable construction have mainly focussed on reducing the dominant operational energy component. However, as the green building community moves towards the ultimate "zero energy building", embodied energy has emerged as the next frontier in building life cycle energy management. Analysis of the results of previous building-related energy studies; and the lessons learnt from the South African case study identify the following issues as the key shortcomings of the current material selection process, namely:

- Production energy, which is commonly referred to as "embodied energy" in the green building community, frequently serves as the only yardstick for choosing one material over another. However, it may not always be the most important factor determining the initial embodied energy contribution of a material.
- The "one size fits all" practice of specifying recycled materials in order to avoid the production energy of raw materials may be environmentally beneficial in one instance, but may prove to be environmentally unfavourable in another instance.
- The choice of a material has systems implications, that is, it entails the choice of constituent materials such as grout, glue, steel reinforcement or insulation. However, there is a tendency to compare materials on a simple product-to-product basis.
- Recurring embodied energy, which arises from routine maintenance, is viewed as a minor component of total life cycle energy. However, the results of embodied energy studies consistently show that due to the long DSL of buildings, recurring embodied energy is frequently larger than the initial embodied energy
- Service life (durability) may be the most important criterion when it comes to the selection of interior finishing materials such as paint or carpet. However, green practices do not place sufficient emphasis on the link between service life and contribution to recurring embodied energy.
- Green building designers give insufficient thought to the fate of materials and their embodied energy at the end of the building life cycle therefore building design which facilitates dismantling and re-use of materials is the exception rather than the rule.

Additionally, the South African case study demonstrates that:

- When building with cement-based materials, the initial embodied energy contribution of the sub-structure and the super structure could be substantially reduced by switching from conventional to innovative material technologies
- When comparing alternative materials, in particular, finishing products, a whole life cycle perspective which factors in the service life is the only way to ensure true equivalence of the alternatives.

7 Road map for the material selection process

Given the individualistic nature of buildings, case by case LCEAs, similar to the South African case study, would constitute the ideal framework for addressing embodied energy. While various software packages for conducting LCA are now commercially available in South Africa, data challenges, specialised skills, costs and time are typical constraints to credible results. In the absence of country-specific tools and data, the following strategies can serve as a basic framework for optimising the embodied energy of buildings, namely:

Overall strategy

Do not base your options on environmental attributes, for instance, recycled content. There are multiple factors which determine the initial embodied energy and recurring embodied energy contribution of a building material. These are transportation distance, production energy, material mass, construction method, context of application and service life. Obtain as much information as possible on these factors and use them as a check list when comparing alternative materials. Identify and act on environmental trade-offs, for instance, avoiding the toxic effects of an interior finishing product should be more important than avoiding embodied energy. Consult LCA-based product information sources to support your choices. Suitable information sources are Ecospecifier[2] (SA), GreenSeal[3] (USA) and GreenSpec[4] (UK)

[2] http://www.ecospecifier.co.za
[3] http://www.greenseal.org
[4] http://www.greenspec.co.uk

Design strategy

Design with facility maintenance and EOL in mind. Focus on durability and innovative detailing which facilitates dismantling rather than demolition

Specification strategy

Select envelope and structural materials in consideration of the chosen DSL. The materials should be able to go the distance with little or maintenance

Optimise initial embodied energy and avoid recurring embodied energy. For instance, face bricks do not entail recurring embodied energy. By contrast, the popular "Tuscan" style will require routine maintenance..

Consult product datasheets and speak to suppliers when selecting finishes. Long life finishes which require periodic maintenance are generally preferable to short lived finishes which require frequent replacement. In this regard, stretch carpets are best avoided, unless linked to a product take back scheme.

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