"PROJECT HOME BUILDERS, MAY BE A DRIVING FORCE FOR SUSTAINABLE HOUSING."

S .T. K. West,[1]

ABSTRACT
This paper discusses the results of a study on embodied energy in various wall panel systems and clearly demonstrates the need for thorough evaluation of materials. Energy content for the various material panel systems are analysed through Process Energy Requirements (PER) and lifecycle assessment. Gross Energy Requirement (GER) calculations are also structured for evaluation and discussion.

Discussion includes, the need to query perceptions against materials and the possibly incorrect validation for "green" favoured materials. It is shown by example that products should be analysed on full lifecycle studies and GER established where possible. Issues such as, buildability and on-going maintenance are addressed and urged that they must be built into the sustainability equation being part of the matrix of economic sustainability.

Cost and economic sustainability are shown to be critical components of sustainable building, especially for developing countries where sustainability is vital and capital to fund and maintain projects is in short supply.

From the case study the question of emission factors for power supply used in the manufacturing of products is mentioned with discussion on aluminium being processed using hydro electricity supply and its subsequent reduced green house gas emissions. The high cost of producing aluminium must be acknowledged but also the fact that it is durable and recyclable.

All the panel systems in the case study present unique features and at the present time their utilization ultimately depends on the buildings function, cost, availability, location, personal choice and aesthetics. It is the authors belief that by adding basic mandatory energy rating requirements this will allow market forces to meet these energy standards and at the same time do so by the most economical path which in turn, if guidelines are set for the use of renewable and recyclables this process will be largely self regulating.

Finally the paper concludes that government needs to foster rating schemes by financial incentives i.e. reduced council rates and fees for developments that comply to best energy design guidelines and this, when benefits are realised, will be taken up by the project home builders and the general public.

Keywords: embodied energy, sustainable development, economic sustainability, cost efficiency, energy rating.

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[1] Senior Lecturer, Project Management program, University of Technology, Sydney. PO Box 123 Broadway, NSW 2007 Australia.

INTRODUCTION

The Construction program at the University of Technology, Sydney (UTS) has developed an enviable record of sustainably designed and built community projects.

The experience of designing and building community projects has involved extensive evaluation of materials and designs such as; polystyrene cladding, insulated steel cladding and aerated concrete building systems. A function that has evolved with designing and specifying community buildings is the close attention to economic sustainability and the justification of materials used in projects, which requires a comprehensive evaluation of embodied energy and on-going consumption.[1]

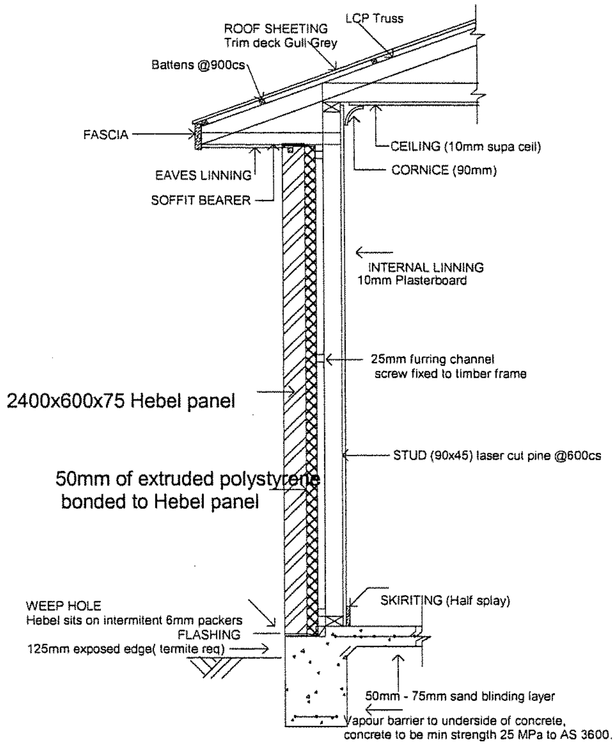
Arising from the close scrutiny of cost and materials assessed are some questions regarding "what are acceptable materials and methods?" This evaluation of materials and methods has brought about some points of conjecture, which challenge conventional wisdom relating to green building labelling.

One area of conjecture is thermal mass and insulation. These terms are sometimes confused and low embodied energy materials / high thermal mass materials such as insitu concrete, are often thought of as being good insulators. In reality, concrete because of its density exhibits high thermal conductance i.e. it is a poor insulator, and offers little benefit for walls and ceilings compared to lightweight high insulation systems.

In a temperate climate with reasonably stable soil temperatures a concrete slab on ground floor with carpet insulation will correspond to soil temperature range, which is acceptable in Sydney. However, in cooler climates insulation would be beneficial especially to exposed slab edges as concretes insulation value is very poor. While concrete provides high thermal mass, using carpets, which insulate the slab from absorbing incident radiation, diminish this advantage.

High density, high thermal mass is assumed to be beneficial for energy efficient house design but little consideration has been given to lightweight insulation designs. High thermal mass is often over rated as a means of providing sustainable qualities (as it contains large amounts of material/ energy and maybe a source also for heat conduction in summer time if not adequately shaded)

Under many conditions lightweight highly insulated structures may be considered more sustainable. The case study of wall panels includes materials of various densities and insulation all applied to the standard timber frame veneer as depicted in figure No1.below:



Detail AA

S West ©

Figure No1. Typical timber frame with external veneer

The materials assessed in the wall panel case study are listed below highlighting their density and corresponding insulation values.

Density of materials (external veneer)

Density of brickwork say 2000 kg/m^3
Density of concrete say 2400 kg/m^3
Density of aerated concrete say 600 kg/m^3
Density of extruded polystyrene 30 kg/m^3

Insulation of materials: R = m^{2}K/W [2]

Brickwork = 0.08
In-situ concrete panel = 0.06
Aerated concrete panel = 0.97
Polystyrene panel = 2

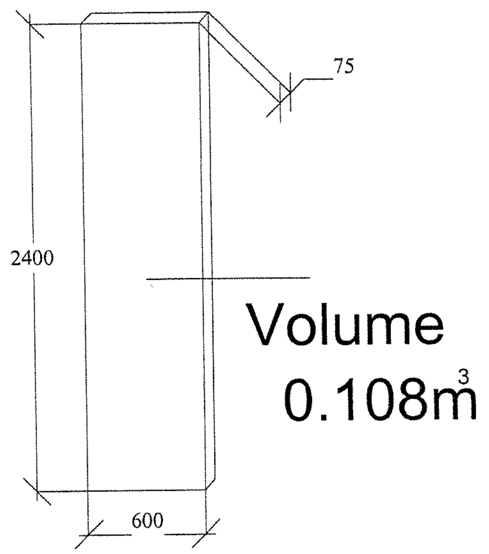
From the tables above it can be seen that as the density of these materials decreases the insulation value increases, due to entrained air in less dense materials providing increased thermal resistance.

Renewable / sustainable plantation pine timber has been used as the structural frame in our projects in Australia because of the outstanding features of this renewable resource, with its ability to lock in carbon and give off oxygen during its growth.

CLADDING SYSTEMS CASE STUDY

The external cladding system is the area that this research focus has been directed towards and several proposed systems have been evaluated.

External cladding panel systems were evaluated for their appropriate sustainability based on standard panel sizing as shown in figure 2 below: It should be noted that only Process Energy Requirements (PER) were initially evaluated -cost of transport and haulage (crane lift for in-situ concrete for example), time to erect, durability and maintenance are all factors to be considered in suitable panel selection, as well as basic PER.



panel comparison

Standard panel dimensions = 2400 x 600 x 75 = volume = 0.108m3

Figure No.2 Standard external wall panel.

An initial assessment from embodied energy tables (Lawson 1996) reveals the following embodied energy measured in MJ/kg [3]

1) Insitu concrete has 1.7 MJ/kg.,
2) Brickwork(clay) has 2.6MJ/kg
3) Aerated concrete(Hebel) has 3.6 MJ/kg
4) Polystyrene has 96 MJ/kg
5) Aluminium has 170MJ/kg

On the basis of the above it would appear that polystyrene and aluminium would be the last choice to ever use! However, with durability, insulation and buildability as considerations the panels require further analysis than perfunctory MJ/kg.

Comparing MJ/ m3

Density of concrete say 2400 kg/m3
Density of brickwork say 2000 kg/m3
Density of aerated concrete say 600 kg/m3
Density of extruded polystyrene 30 kg/m3
Density of aluminium 2700 kg/m3

So reworking the formula:

The embodied energy of the materials MJ/m^3 are:

Brick clay (2000kg/m3 x 2.6 MJ/kg) =**5200MJ/m3**
Insitu concrete (2400 kg/m3 x 1.7 MJ/kg)=**4080 MJ/m3**
Aerated concrete (600 kg/m3 x 3.6 MJ/kg) =**2160 MJ/m3**
Extruded polystyrene (30 kg/m3 x 96 MJ/kg) = **2880 MJ/m3**
Expanded polystyrene (16 kg/ m3 x 96 MJ/kg) = **1536MJ/ m3**
Aluminium sheet (2700kg/m3 x 170 MJ/kg) = **459,000 MJ/m3**
Paint acrylic (1050 kg/m3 x 61.5 MJ/kg) =**64,575 MJ/m3**

From the density of materials we can derive the mass of each panel cladding system fixed to a timber frame and the total embodied energy:

Mass of **brick panel** (110mm) **316kg = 821MJ** embodied energy / panel

Mass of **concrete panel 260 kg=** 442MJ + furring channel / panel 123MJ embodied total = **565MJ**

Mass of **aerated concrete 65 kg** = 230MJ embodied energy / panel+ furring channel / panel 123MJ embodied energy / panel = total of **353MJ**

Mass of **extruded polystyrene 3.2 kg** = 307MJ embodied energy / panel+ furring channel / panel 123MJ embodied energy / panel = total of **450MJ**

Mass of **aluminium sheet 3mm =11kg** = 1870MJ embodied energy / sheet panel +
Mass of **expanded polystyrene** 1.73 kg = 166MJ embodied energy / panel = Total system = **2036 MJ**

An allowance must be made for finish coatings to polystyrene and aerated concrete panels and a comparison can be made between these systems that require maintenance and an aluminium skinned expanded polystyrene system that is considered relatively maintenance free.

Mass of paint film 2mm = 3kg of paint/panel = 186 MJ embodied energy/panel
(Initial skim coat of 2mm may not be required; it could be 300 micron, depending on the paint system applied.) Recoating will also depend on the paint chosen's quality, but generally a reapplication or top coating will only be required say every 5 years = 0.45kg x 61.5 MJ/kg = 27.8 MJ)

Lifecycle assessment

A basic life cycle analysis using PER and maintenance, assuming all wall panels meet minimum R2 performance), with ***no allowance*** for ease of installation, cranage or safety issues, the following calculations of lifecycle energy per panel were calculated:

1) **Polystyrene with acrylic paint finish**:

The embodied energy for extruded polystyrene (450MJ) with an initial 2mm acrylic paint finish (186MJ) = 636MJ/ panel. With the addition of 10 repaints during a 50 year life cycle added an additional 278MJ the total energy per panel = **914MJ**

2) **Aerated concrete with acrylic paint finish**:
Aerated concrete (353MJ) + paint (186MJ) plus maintenance (278MJ) = **817MJ**

3) Expanded polystyrene (166MJ) with a 3mm exterior aluminium sheet(1870MJ) = **2036MJ - maintenance free**

From these figures presented it can be assessed that the aerated concrete and polystyrene panel systems, which have similar insulation value contain half the embodied energy of the aluminium skinned panel.

Based on the above calculations aluminium skinned panels would be hard to justify compared to other panel systems. However, decreeing a product as "green or not green" requires thorough evaluation as buildability, safety and emission factors need to be considered.

A materials Gross Energy Requirement (GER.) needs to be evaluated from the first input of energy. In the case of polystyrene this is from being a waste by-product of oil refining and in the case of aerated concrete the high energy aluminium content used as an additive needs to be evaluated upstream and downstream i.e. was the aluminium refined by hydro or coal fired power source? – These are complex assessments but need to be calculated to arrive at accurate figures.

Tracing the total energy cycle is the only true determinant to assess a materials (or built up components) embodied energy and energy consumed during its lifecycle and this involves assessing the source of power supply (emission factors) in manufacture, transport and on going insulation value and durability.

True assessment of base power supply is needed for accurate greenhouse emissions. By way of example Aluminium with a 170MJ/kg of embodied energy based on coal fired power stations PERis a heavy energy consumer and with coal fired power station this would correspond with high CO_2 output, unless as the case may be with Tasmanian hydro processing of aluminium with its subsequent low CO_2 emissions.

Aluminium produced by hydro may be deemed to be more environmentally beneficial as so far as CO_2 emissions are concerned, but its total lifecycle assessment even if produced by coal-fired source should still be open to market choice - considered by basic market forces on the pro's and con's of supply and demand v function i.e. Other material considerations such as aluminium skin being only a 3mm covering in a wall panel, but very durable and its easily recycled, need to be assessed in total before materials are declared unsatisfactory.

On going energy savings due to insulation and low maintenance are important parameters and significant research was conducted in this area by (Evans and Ross, 1998) This was highlighted in a report prepared for the NSW Department of Urban Affairs and Planning by Manidis Roberst Consultants(1996). The report looked at using insulation over a complete life cycle for the Sydney 2000 Olympic games village. The report concluded" *The reduction in energy consumption over the whole life cycle of a typical building through the use of insulating material was quite spectacular. The savings in energy for heating the building was around a hundred times the amount of energy used to manufacture the insulating material. This was reflected in similar reduction in the lifecycle emission of greenhouse gases*."[4]

BUILDING COSTS AND ENERGY EFFICIENCY- THE (CE) FACTOR

Total building costs are part of the sustainable equation often over looked by developed nations. (Sustainability on a world scale, needs to be for the masses, energy efficient designs in the West are sometimes confused with sustainable designs)

The "equation" for sustainable buildings needs to be more than MJ/m^2per anum and CO_2 related emissions, it requires some cost control factoring brought into the equation – **Cost Efficiency (CE) to produce ongoing economically viable sustainable building designs** i.e. *Initial construction cost $\$/m^2$ to build an energy efficient building needs to be monitored against occupancy $/m^2$ and ongoing energy consumption plus the social benefit(triple bottom line).*

Cost should be a consideration in sustainability equation and opulence acknowledged as economic extravagance i.e. - *cashed-* up large corporations are able to buy 5 Star energy efficiency which may not necessarily relate to sustainability and this has to be monitored, to compare outlay to benefit for occupancy numbers. It has been labelled "spend big to save a little" i.e.- "Hi tech" approach –the initial cost to produce an energy efficient building may not be able to be paid back over several lifetimes. (This is not economic sustainability and cannot apply to developing nations where sustainability in housing is a truth and not a by- word, as capital is just not available)

Cost efficient construction with low energy consumption standards should be the preferred sustainability profile rather than glittering high tech buildings. Builders and designers need to conform to ongoing energy savings in new designs, meeting mandatory MJ/m2 profiles- that refer to ongoing per annum consumption during occupancy with an appropriate *CE* factor applied.

If a building is designed to meet a minimum energy consumption standard, market forces will drive the design/ material components to meet the minimum consumption standards for the lowest cost for the consumer market which, inturn may represent the best sustainable option i.e. *lowest total energy used in construction to achieve an acceptable energy consumption standard.*

Energy is a constant in the material supply and demand chain! This is a hypothesis that needs greater evaluation and if proven could show that by meeting minimum MJ/m2 energy standards by applying cost efficiency (CE) the energy consumption would be self-limiting and there may be no great need for prescriptive monitoring.

Cost and consumer demand, for building materials are linked to energy i.e. to produce a commercially viable product the energy trail is self adjusting: it may be cheaper to produce, to build with or for example to have on going energy consumption savings due to improved insulation during the life of a building, these factors combined and when understood make it an appropriate choice then for the consumer.

Apart from a buildings design and on going consumption other considerations are:
1) Renewability/ recyclable content
2) O.H.S issues related to manufacture and use eg toxicity, ease of handling and safety ergonomics.

Energy in building materials is a component of the manufactured cost and the materials functional (insulation) on going consumption cost. Energy as a "constant" in the supply and demand chain will in the end affect the economics of manufacturing, transport and end site use and depending on the physical make up of the material its subsequent durability, insulation value and hence, on going energy consumption of the building during its lifecycle.

These complex variables in assessing a buildings impact on greenhouse gas emissions over its lifecycle maybe simplified by adopting an "Adam Smith" approach and letting market forces take their course with little prescriptive government input.

By way of example, if a mandatory system required walls to meet an R3 rating.
An aluminium clad polystyrene panel may be considered as a suitable system based on several operational factors – ease of assembly, durability etc however, the essential governmental requirement for this exercise would be meeting the R3 rating.

Based on meeting the high insulation value, a thin layer of aluminium external skin possesses benefits of low maintenance durability and provides a UV barrier for the high insulating UV sensitive polystyrene backing which provides the rigidity for the panel. It is a very fast simple panel system to erect, and this system may prove to be attractive if the material can be sourced at a reasonable price, which largely depends on energy efficiency in mining, production and distribution.

The supply and demand curve and transport will affect panel preferences. For example the cost of building with aluminium sandwich panel in Sydney may be acceptable where as transporting the panel to Townsville may be cost prohibitive. Therefore in Townsville another system may be considered based on economics of sourcing materials and distribution economics, which are themselves GER energy considerations. (This is in fact an example of how the Adam Smith approach operates.)

By way of explanation if a compulsory target is set that a building must be designed to use a minimum MJ/m2 or kwhr level and it can be shown that this building has used renewable/ recycled resources where possible then considering that a competitive environment will reduce cost to the consumer – it may well be that Project home builders will be the driving force for sustainable housing by having the cheapest construction – thus lowest energy to produce a building to meet stipulated government performance standards.

A rating system that is over regulated and needs to have accredited professionals to oversee the system will introduce another cost factor into the total building cost equation and this may not be beneficial compared to a simple self regulating approach that compares assembled products backed by manufacturers ***certified*** product performance (eg insulation) values for example.

To some degree the green building product labelling might not be required and we might be able to follow the "Adam Smith" approach- applying the invisible hand principle i.e.- If the product is cheaper to install and offers on going energy savings in operation and its overall lifecycle analysis is better then - that is all that is required to satisfactorily assess a materials or built up panels green potential.
(Allowing for renewable, recyclable content, toxicity and safety issues.)

That is; if a building is appropriately designed to meet a set MJ/m2 minimum performance rating and energy is considered as a ***constant*** in the cycle, then energy can be related to end product costing i.e. that PER process energy, transport, fixing in-place and on-going energy savings will then relate to lowest cost.

Lowest cost building design rated against minimum standard energy performance ratings may well produce the most sustainable buildings.
High tech infrared reflecting glass rather than simple shading means high cost and high cost buildings are not economically feasible for developing countries, where the real sustainable energy focus needs to be employed.

It is essential to economically scrutinise materials over their lifecycle to include recycling, consider the case of polystyrene.
Polystyrene is a fossil fuel derived product and therefore by association -**not sustainable** as it has a limited life! However, both bricks and concrete fall into the same category but are generally accepted as being more sustainable.

Even if polystyrene has a limited life (petroleum based), it can be recycled easily, provides excellent insulation and has many other benefits.

(It should be acknowledged that almost all building products apart from timber are non renewable!)

If styrene is a by-product of petroleum refining then it is making a useful product from a by-product of refining, which will continue, as transport is still fossil fuel dependent. CO_2 ratios of *all* products need to be assessed i.e. depending on emission type PowerStation's to supply energy to manufacture, petrol to mine and for end place transport distribution- all need to be fully evaluated the same as styrene.

Establishing that styrene is a product made from petrol, then its energy consumption/ insulation/ recyclability/ lifecycle compared to other products total energy consumption needs to be evaluated.

All products need to have their total energy component examined to compare appropriately to one another. Taking into account the energy to mine resources, fabricate and transport, out of steel, gyprock, glass, concrete, bricks and timber the only product that is renewable is timber.

Timber has the fantastic attributes of being renewable, giving off oxygen and locking in carbon, however in the US architects are winning awards for environmentally sustainable houses that try to reduce wood use as they feel it protects habitat, so even this is a point of conjecture in some quarters.

From Lawson, the embodied energy of clay bricks are 2.6 MJ/ kg. A panel of brickwork 2400 x 600x 110 (0.158m3) would weigh 316 Kg (allowing a density of 2000kg/m3), compared to 6 kg of acrylic paint/polystyrene panel – a weight factor of 52 times.

Brick veneer with an insulated timber frame has similar embodied energy figures to both the polystyrene system and aerated concrete panel system. So why would a house with a brick veneer be anymore sustainable to a polystyrene veneer panel house if they use the same timber frame? Polystyrene or aerated concrete would be cheaper, easier (weight) and faster to build and have better on going insulation energy savings.

CONCLUSION

All renewable resources such as plantation timbers should be given priority in assessment schemes. New products need to be encouraged, further researched and developed such as synthetic plastics from Soya bean, and old methods rekindled such as Linoleum from linseed and diesel from peanut oil.

A self-regulating energy rating scheme may prove to be more beneficial than an over regulated approach. A system applying simple checks and balances relating to minimum design requirements including a cost efficiency (CE)- building cost/m^2/ No of occupants with attached social bottom line would be more beneficial sustainably.

Evaluating and acknowledging good designs with bonuses and rewards through reduced government fees and bank lending rates would encourage designs that include renewable and recyclable content etc.

Adopting or specifying a favoured low embodied energy product may produce a captured market syndrome and result in lack of price competition and hence have an adverse affect on economic sustainability factors.

By adopting a self-regulating energy rating scheme rather than an unwieldy bureaucratic approach applied through consultants and auditors, it maybe in the future, that cost efficient project homebuilders will be the driving force behind sustainable housing.

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