ENERGY CONSUMPTION IN CCA TREATED WOOD PRESERVATION

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Summary

The energy streams needed in the manufacture of CCA-treated pine lumber were estimated, using utility and fuel invoices for a 'typical' treating site in midwest USA. Meter readings aided the allocation of diesel, natural gas and electric energy consumption to stages of the production process, other site activities, and delivery of the treated wood. It was found that the treating process itself was not very energy demanding, and adds only about 9 % to the energy used in all stages of producing the bright, untreated lumber.

Transport, using diesel fuel, absorbs about 67 % of all the energy needed in producing and delivering treated wood, from the forest to the retailer or end user. Other significant demands for energy were kiln drying after treatment (adds 42%), and force-fixation of CCA in the wood using various heating processes in use today (adds 5-8%).

Total production energy demand for CCA treated softwood lumber is low when compared to other building materials.

1. Introduction

The energy needed to produce building materials is a topic of great interest in North America. This is particularly so in Canada and Northwestern States of the USA, but is slowly coming to the attention of a wider group of people through the activity of consumer protection groups, and advocates of "green living".

When fossil fuel is consumed to produce heat, motive power or electricity, a non-renewable resource is consumed in the process, and the environment impacted in many ways. Activities such as coal mining, oil and natural gas drilling and extraction are themselves consumers of energy. They also impact the landscape, and cause geological changes through brine injections and subsidence. The burning of fossil fuels adds carbon dioxide to the atmosphere, as well as oxides of nitrogen and sulfur. Questions have been raised at the highest international scientific levels about man's exaggeration of the "greenhouse" effect, and acid rain is blamed for distruction of forests in eastern USA, and in Europe.

The extraction and burning of fossil fuels was long thought to cause negligibly small changes to almost infinitely large resources, i.e., the atmosphere, oceans and lithosphere. Some scientists see measurable worldwide effects and blame specific causes. Among these, increasing levels of fossil fuel oxidation are widely seen as detrimental to the planet Earth, and its living inhabitants.

Canada boasts a "green plan", and appears to be at the forefront of nations studying the energy used to produce building materials, with the goal of reducing the energy coming from fossil fuels. In a study sponsored by Natural Resources Canada, Forintek Canada Corp. is finalizing a computer model to advise building designers about the environmental impacts of their choice of components (Forintek and Trusty, W.B., August, 1994 and January 1995). What is the intrinsic, man-introduced energy content of a wall, roof or foundation when made from steel, concrete, wood, bricks or other materials? What waste has been generated in manufacturing the materials, or will result from its use? What total environmental impact can be blamed on a designer's choice of materials? This impact is not over when the components are made; it includes the consequences of future events too (Forintek and Trusty, W.B. June, 1994). For instance, when the building is eventually demolished, what can be done with the debris? Can it be recycled? If so, what will be the future environmental costs? In thinking about this, we need to bear in mind that landfilling of waste building materials may well be forbidden in a few years time.

The depth and detail of the NRC sponsored project is impressive, and it will undoubtedly be copied by other nations.

In the USA, we have seen exhaustive efforts by some utilities to <u>reduce</u> the sales of power to customers. For example, the Bonneville Power Authority in the Pacific Northwest has sponsored studies at wood fiber plants. They were looking for ways to reduce the energy used in the production of paper, fiberboard, plywood, lumber, etc. (URS/Transenergy Systems, 1985). The "Green Cross Code", a accreditation program of Scientific Certification Systems, demands data on energy input and on many other facets of environmental impact from producers who want their building-related products certified by the Code.

With these trends in mind, and as producers of treated wood, we thought it was time to look at the energy consumed in our industry's production processes. The results given in this paper are not intended to be precise, or widely useable at present. However, they do reflect real life events in Canada, USA and Northern Europe in the last two years. We believe that a better understanding of energy demanded to produce treated wood will help guide future business decisions.

1.1 Energy Cost

Intentionally, we do not attempt to translate energy used into financial costs. There are several reasons for this.

1. The cost per unit of energy varies widely from place to place.
2. The cost per unit of energy depends on the primary fuel used.
3. Energy conversion efficiencies of heaters, boilers, vehicles vary widely.

4. Costs can be calculated by interested readers for their own special circumstances, using our, or other peoples', energy use values.
5. In future investment decisions, the quantity of energy needed per unit of production may become more important than the cost of that energy.

1.2 Uses of Energy in Producing Treated Wood

A list can be made to highlight each time some form of energy is needed in any production process. An example for treated wood is shown in Figure 1. We start our list with a living tree, in a forest. Up to that moment, if we ignore seed germination, culture, planting out and forest management, the only energy absorbed by the tree has come from sunlight. But the moment the tree feller puts saw or puller to the tree, energy is consumed. The list in Figure 1 is not exhaustive, but shows some events and places where motive or thermal energy is needed. Fortunately for our study, we were able to turn to the report of the Committee on Renewable Resources for Industrial Materials (CORRIM), whose Panel II reported in 1976. (CORRIM II, 1976). In this landmark study, the panel summarized energy inputs needed to convert forest trees into products such as plywood, fiberboard, paper and, for our purposes today, softwood lumber. In this paper, we use their values of the total energy needed for forest extraction, manufacture and transport. Their data was based on 1970 energy requirements. Today, machines and mill processes may be somewhat more efficient, but having no way measure this we adhered to the 25 year old values in this project.

The CORRIM II Report effectively delivers wood products all the way to building sites. Lumber treating plants were not very common in the early 1970's, so CORRIM II did not allow for delivery to such places. We could think of no good way to calculate any energy saved by delivery to a treater. Instead, at the risk of exaggerating transport energy needed, we will add to the CORRIM II energy estimate, to allow for transport from treating plant to a building site, or to wholesale or retail lumber suppliers.

The unchanged CORRIM II "energy content" will be used for our chief raw material, i.e., kiln dried, untreated softwood lumber, delivered to the treating plant.

Figure 2 Shows the main stages of wood treatment where energy is needed; some stages are optional.

2. Energy Units

We felt the need of a single energy unit for expression of our conclusions; the CORRIM II Report chiefly used "million British thermal units" (Btu) (oil equivalent) per Oven Dry (OD) ton (of wood). We decided a more useful unit would be the Megajoule (MJ) per thousand board feet (mbf). The primary fossil sources of energy, fuel oil, diesel oil, coal and natural gas are usually rated in Btu per gallon (of oils), Btu per ton (of coal) or 100,000 Btu (Therms) per cubic foot (of natural gas). No use was made of propane, geothermal or solar energy in our studies.

Electricity is supplied in units of kilowatt-hours (kWh), from whatever primary fuel (coal, oil, gas, nuclear, hydro, etc.). We used the following energy conversion factors, each expressed to four significant figures;

One Megajoule (MJ)
= One Million Watt-Seconds
= 0.2778 kWh
= 947.8 BTU
= 2.390×10^5 calories
= 9.478×10^{-3} therms

The conversion from Oven Dry (OD) tons of wood to mbf was made in two stages: the first from the CORRIM II Report:

One cubic foot = 0.0137 OD tons (softwood)

plus the standard factor we adopted for a typical mix of treated softwood products:

1 mbf = 65 cubic feet

1 mbf = 0.89 OD tons (softwood).

This latter conversion, like the energy input numbers presented in this paper, are shown to only two significant figures, indicating the limited claims we make for the accuracy of our conclusions. For better narrative flow, actual energy calculations appear in the "Calculations" section at the end of the paper.

3. Inclusion or Exclusion of "Free" Energy from Wood Residue?

When trees are converted to lumber, there are a number of combustible by-products such as bark, branchwood, wood chips and sawdust. Commonly, sawmills burn this waste to supply thermal energy for kiln drying and to generate electric power to run mill machinery. Therefore, sawmills have a supply of "free" energy available, which reduces the "imported" energy needed by their operations. This is in clear contrast to other building materials such as cement, concrete, bricks, steel, glass and aluminum, all of which consume energy, but enjoy no offset in the form of energy releasing byproducts.

The result is that the energy needed to product lumber can be expressed to two ways:

Gross: Taking account of both "imported" and "free, by-products" energy used, or

Net: Taking account of only the "imported" energy.

The CORRIM II Report developed the following figures for Gross and Net energy input for making and delivering softwood lumber:

	Reported Value	Converted Value
Gross Energy:	7.76 Million Btu/OD ton	7,291 MJ/mbf
Net Energy:	2.91 Million Btu/OD ton	2,733 MJ/mbf

Both energy input figures, Gross and Net, are appropriate expressions of different ways of looking at the energy used. The choice of which to use mainly depends on non-energy aspects. For instance, if we want to know how much carbon dioxide is created in burning fuels to run a sawmill, the gross energy requirement is more relevant, as it takes account of both "imported" and "by-product" fuels, both of which release carbon dioxide to the atmosphere.

As this paper attempts to measure with fossil fuel consumed, we will choose the net energy value for softwood. This more appropriately reflects the use of these non-renewable fuels to produce the main raw material for our treating process.

4. Energy Content of CCA Preservative

The CCA Type C oxide we use, like wood, has consumed energy at each stage of its preparation. It starts with the extraction of chromite ore (almost exclusively in Southern Africa or Turkey), with the recovery of arsenic trioxide, a worldwide waste product of metal refining. The third metal component, copper, comes originally from ore extraction, but is now more commonly processed from refined scrap copper. Preparation of the three metallic oxide components of CCA involves many energy-absorbing (and some energy releasing) stages. The process concludes in reacting the three oxides to make the CCA concentrate shipped to treating plants, and CCA manufacturers know the energy needed for this mixing reaction stage. However, it is far from easy to calculate the total energy needed to produce one pound of CCA oxide, starting from the beginning, i.e., mining the metal-bearing ones. The task made even more difficult since two of the components (arsenic and copper) are recycled products from other industries, some of them thousands of miles away.

The North American producers of commercial CCA oxide are jointly sponsoring Green Cross Code certification by Scientific Certification Systems, which should be concluded in 1996. This will reveal a carefully calculated energy input per pound for the first time. Meanwhile to satisfy our need for a value to include in this paper, we estimated a value of 67 MJ/oxide lb. (See 'Calculations').

5. Energy Used in Treating Wood

Most of the energy values reported here come from a study of one of our company's treating plants in midwest USA. The plant was chosen because of factors such as:

1. At about 35 MMBF annual production of treated southern pine, ponderosa pine and red pine, lumber and plywood it falls in to the mid-size range of CCA plants in USA.
2. The treating equipment is similar in performance to most of our plants, in degree of automation, speed of treating, and horsepower, etc.
3. Being in a continental climate region, summers are hot and winters cold. The plant is fully enclosed. Treating and conditioning areas (drip pad) are in heated and insulated buildings. Heating is by fan-assisted, indirect fired natural gas units.
4. The plant is also fitted with our worktank heater system, a PLC controlled natural gas fired boiler/heat exchanger device. This is capable of warming CCA treating solution to 80 °F (27 °C) and enables the plant to treat efficiently in the coldest of weather. Solution temperatures are set higher, the colder the bright wood temperature, and the more snow or ice in the units to be treated. The aim is to produce treated wood at an average temperature of at least 60 °F (16 °C).
5. The plant also includes a dry kiln, fired by natural gas, capable of drying about 20 mbf of treated lumber at a time.
6. In addition to the above production units, energy is consumed by yard fork-lifts and one lift dedicated to the conditioning building, by a stacker, yard lighting and by the sales/management office which takes heat, light and power for office machines.
7. Most treated wood is stored outdoors in the 15 acre site (average dwell time 5-6 weeks).

In analyzing energy uses, our approach was to collect all fuel invoices for the site, then calculate the total site uses of energy over a 2 to 3 year period. Then, as far as individual fuel meter readings allowed, we broke the overall energy use into departments. As there were not enough meters to give a full analysis of fuel used by each unit, we then calculated the "most likely" share of fuels by each unit, using the known heater capacities motor horsepower and so on. If a 'primary' fuel was involved (diesel oil, natural gas) we stopped there. But, with electricity, we carried on to back-calculate the consumption of primary fuel energy used in generating the electric power. In this way, we attempted to trace all energy inputs to energy content of the primary fuel used. (See "Calculations".). Figure 3 shows the estimated energy consumption per department, averaged over the period.

Figure 3 shows that the vacuum pressure treating process itself consumes much less energy than the site offices, if we exclude the building and worktank heaters, which are used only in the cold weather. (Again, the values in Figure 3 are averaged over the entire year, so will obviously run at a much higher level in the depth of winter).

Movement of wood around the site by fork-lift consumes about eight times more energy than the pumps and controls of this treating plant. We should point out here that the plant studied uses a combination of vacuum and pneumatic pressure pumps. In our experience, a plant which uses dual-purpose compressors to product vacuum and pressure will consume about three times the energy shown in Figure 3 during the treating cycle.

6. Kiln Drying

Kiln drying after treatment (KDAT), has a high energy requirement, partly because of the high heat of evaporation of water. So, return of the moisture content of treated lumber to 19% or less after treatment takes over three times the energy input needed to produce wet, treated wood.

Of course, KDAT usually achieves another purpose: almost full fixation of the CCA component inside the wood. A number of groups have studied the effect of kiln drying temperature on the strength of treated wood , and several warned that a high kiln humidity is needed in the early part of the drying process to optimize fixation (e.g. Boone et al, 1995).

7. Accelerated or Forced Fixation

There is ample evidence that the process "fixation" - in which the main metal oxide components of CCA react in wood to form water in soluble complexes - is temperature dependent. Five years ago, Anderson (Anderson, 1990) reviewed the ways then available of using heat energy to speed the fixation reaction. More recently, a number of researchers have confirmed the time/temperature conditions that are needed to fix increasing percentages of each metal (e.g. Cooper et al 1995), and shown that this is species dependent (Wilson, 1971; Forsyth and Morrell, 1990).

It should be noted that 'fixation' proceeds naturally at all temperatures much above freezing, and nearly all the unleached CCA in wood will fix in commonly treated softwoods, given time. The need to accelerate or force this fixation to completion in a short time is not always apparent. Typically, much of the treating production will remain at the plant site long enough, and in a warm enough condition, for a high degree of fixation to result.

If a treater judges, or finds by testing his recently treated wood, that too much of the CCA could leach and threaten stormwater, fresh or salt water bodies, flora or fauna, he should not ship the wood. His choices of 'Best Management Practice' will include:

1. Hold the material for a longer time until the target non-leachability level is reached.
2. Somehow inject thermal energy into the product, to shorten the time needed to reach the same target. Anderson (1990) listed most of the energy donating processes available.

- Hot Air Process
- Pressurized Hot Water Process (MSU Process)
- Atmospheric Hot Water Process
- High or Low Pressure Steam Injection
- Hot Oil Process

To our knowledge, the MSU Process, Super Heated Steam Injection and the Hot Oil Process are not in current use, and we exclude them from future discussion here. One other process (Radio frequency heating) seems to have potential. It is currently being studied at the University of British Columbia.

We have estimated energy requirements for the following processes:

1. Hot Air Process: information, from Canadian sources, on energy demands of meeting the CSA standard of fixation for lumber. Stickening of each layer is needed.
2. Atmospheric Hot Water Process: information from suppliers of full scale units. The end point of fixation is chosen not to meet a fixation standard, but to reduce stormwater contamination levels in uncovered treated wood storage yards to "acceptable" levels.
3. Low Pressure Steam Injection: we visited a number of low pressure steam plants in Northern Europe, which were apparently able to satisfy exacting government stormwater limits for chromium, copper and arsenic, in uncovered treated storage yards. Stickening of every, or every second layer is needed.

8. Summary of Energy Demands

Our estimates of energy inputs associated with CCA treatment, bringing together all the main stages of production of treated wood, are shown in Figure 5. In Figure 6, we align our conclusions about treated wood (with and without different methods of accelerating fixation and kiln drying) with other common building products' energy demands, when each system is used to build a 100 square foot section of wall. (Based on CORRIM II).

9. Conclusions

- CCA treated wood is based on one renewable raw material (the lumber) and consumes two bioactive industrial by-products (arsenic and copper), which are otherwise not in great demand, and are difficult to dispose of safely.

- In this study, transport consumed 67% of all energy costs of converting trees into treated lumber, and delivering it.

- The treating process itself, even allowing for the energy content of CCA oxide, is not very energy demanding, and adds less that 9 % to the energy consumed in producing dry softwood lumber for treating.

- Forced fixation adds an additional 5 to 8% to the energy demand of the treated wood, and dry kilning an additional 42%.

- We point out that only energy inputs have been discussed. There are many other environmental impacts involved in the production of building materials, and in generating energy (for example, water consumption and water pollution, air pollution, landscape and geological changes).

- Untreated softwood lumber and plywood have a much lower energy demand than any other common lasting building material, when compared in the construction of a standard wall unit.

- CCA Treatment consumes very little more energy, and the long-lasting product remains lowest of all common building materials in energy demand.

10. Acknowledgments

The authors thank all correspondents, chemical suppliers and plant owners who contributed information for this paper. We take full responsibility for the assumptions made, and imprecise energy values quoted here, believing that they still allow meaningful energy input comparisons between methods of producing treated woods, and between competing building materials.

11. Calculations

1. Delivery of treated wood (by truck):

Average load on truck = 16 mbf
Average customer distance = 100 miles
Average round-trip distance = 200 miles
Average diesel consumption = 5.5 mpg
Energy content of diesel = 138,000 Btu/gal
1 MJ = 947.8 Btu

So, calculated energy used in an average delivery, per mbf

$$= \frac{200}{5.5} \times 138{,}000 \times \frac{1}{16} \text{ Btu/mbf}$$

= 313,636 Btu/mbf = 331 MJ/mbf

2. Conversion of electric energy to primary fuel equivalents.

The power company which supplies the midwest USA plant with electricity generates it from three primary energy sources:

Primary energy source	% of output in kWh	Conversion efficiency
Coal	80%	32%
Nuclear	15%	n/a
Hydro	5%	n/a

The conversion efficiency is clearly dominated by coal burning, so we felt comfortable using the 32% energy conversion efficiency from coal to electricity.

Therefore, after calculating the electrical energy used in any process stages, we multiplied that by:

$$\frac{100}{32} = 3.125$$

to give the equivalent coal energy that would have been consumed at the generating station to produce that quantity of electrical energy.

2. Energy input in manufacturing CCA-C oxide concentrate.

A. Arsenic acid manufacture and mixing of CCA concentrate.

Figures from manufactures indicated that two energy sources were used to make one pound of CCA-C (oxide):

		MJ/lb.
Natural gas:	0.137 MJ/lb.	= 0.137
Electricity	0.098 MJ/lb. x conversion factor 3.125	= 0.306
	Primary energy equivalent, SUB-TOTAL	= 0.443 (A)

B. Energy used in earlier extraction, refining, chromic acid manufacture and delivery to mix plant.

As described in the body of the paper, we were unable to trace these energy inputs, or to fairly allocate energy costs between, say, arsenic and lead in the smelting of lead ore (arsenic being a by-product), or between the energy used to smelt copper ore to the crude metal, its purification and drawing into new wire, and the reuse of that same wire (now scrap) for CCA production.

So, we chose an arbitrary factor (x4) for the CCA factory energy demand, to allow for all the fossil fuel energy that should be attributed to eventual CCA.

<u>Assumed extraction, transport energy, etc.</u>

$$\underline{\text{MJ/lb.}}$$
$$= 0.443 \times 4 = \underline{1.77} \text{ (B)}$$

C. <u>Delivery of CCA to treating plants</u>

We assumed the following:

Average delivery distance = 400 miles
Average round-trip journey = 800 miles
Load (lb CCA-C oxide) = 24,000 lb./truck
Average diesel consumption of truck = 5.5 mpg
Diesel energy content = 138,000 Btu/gallon
1 MJ = 947.8 Btu

So, calculated delivery energy per pound of CCA-C oxide

$$= \frac{800}{5.5} \times \frac{1}{24{,}000} \times \frac{138{,}000}{947.8} \text{ MJ/lb}$$

$$= \underline{0.882} \text{ MJ/lb (C)}$$

Adding (A) + (B) + (C), we get the total estimated energy input in 1 pound of CCA-C oxide:

$$(0.443 + 1.77 + 0.882)$$
$$= \underline{3.1} \text{ (rounded) MJ/lb CCA}$$

To convert this energy estimate to one for the 'CCA energy' content of treated wood, we assumed an average intake of 0.33 lb. CCA per cubic foot of wood, 65 cubic feet per thousand board feet.

So, 'CCA-energy' component of treated wood

$$= 3.1 \times 0.33 \times 65 \quad \text{MJ/mbf}$$

$$= \underline{67} \quad \text{MJ/mbf}$$

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Figure 1: Some of the energy-absorbing stages in producing dry softwood lumber from trees.

Diesel or Gasoline Fueled:

- Forest entry
- Felling
- Debranching
- Extraction
- Loading trucks
- Transport to mill
- Move to storage
- Move from storage
- Move to log mill
- Move to resaws
- Move to kilns
- Move to surfacing chain
- Move to grading chain
- Remove from grading bins
- Move to stacker
- Move to product storage, stack
- Move to truck/railcar loading area, load
- Deliver to treating yard

Electrically Powered:

- Debark logs
- Saw into cants
- Resaw into rough lumber
- Sticker
- Unsticker
- Surface to size
- Separate into bins by grade
- Restack, grade-stamp, band
- Wrap units (if necessary)

Natural Gas/or Oil, Electrically Powered:

- Kiln dry (whitewood)

Figure 2: Some of the energy-absorbing stages in CCA treated wood production.

Diesel or Propane Fueled:	
	Off-load trucks and railcars; carry to storage area and stack
	Unstack, carry to stacker (or plant)
	(Carry to plant from stacker)
	Load trams
	Unload trams & stack in conditioning building (Dedicated lift)
	Move to off-feed chain (Dedicated lift)
	Off-lift, transport to storage, stack
	Unstack, transport to trucks; load trucks
	Yard maintenance (snow clearing, etc.)
Electrically Powered:	
	Restack units
	Supply water (pumps)
	Winch in/out of cylinder
	Mixing
	Initial Vacuum, Flood
	Pressure (Transfer)
	Final Vacuum, Drain
	Sump pumping
	Off-feed chains
Thermal Energy:	
	Heat & light storage buildings
	Heat & light conditioning buildings
	Heat & light plant building
	Heat worktanks
	Kiln dry after treatment (KDAT)
	Force fixation

Figure 3: Approximate energy use over a 2-3 year period of individual departments/(activities) of a treating plant in midwest USA.

Department/activity	Energy source (1)	Energy consumed per unit of production (MJ/mbf).
Treating plant forklifts	Diesel	38
Stacker	Electricity	14
Treating plant (pumps, controls)	Electricity	14
Worktank heater	Natural gas	55
CCA energy	Various	67
Treating buildings - heat	Natural gas	31
Offices - light, equipment operation, yard lights.	Electricity	27
Offices - heating	Natural gas	11
Dry Kiln	Natural gas heaters, electric fans	1,400

Figure 4: Summary of energy input of accelerated (forced) CCA fixation methods.

Method	Location	Energy Input (MJ/MBF)	Objectives
Hot Air Process* (Modified kiln chamber)	Canada	240	Pass 'Chromotropic Acid' test.
Hot Water Process*	USA	170	Reduce Cr, Cu, As in yard stormwater to acceptable levels.
Low Pressure Steam Process*	Holland	190	Reduce leaching in rain simulation test, imposed by government.
Dry Kiln (for comparison)	In-company, USA	1,400	KD-19 moisture level.

* Energy for Moving, Stickering
* De-Stickering not Included

Figure 5: Total Energy Input: Forest to Customer for CCA treated wood (Midwest, USA)

Starting material, untreated softwood		MJ/mbf
Forest extraction through milling, kiln drying,		
Net (based on CORRIM Panel II):		2,733
Treating (averaged for year, without KDAT or Forced Fixation):	MJ/mbf	
Yard and dedicated forklifts	38	
Stacker	14	
Treating plant	14	
Worktank heater	55	
CCA energy	67	
Treating buildings, heat, etc.	31	
Offices, light, equipment, yard lights	27	
Offices - heating	11	
Treating total:	257	
Delivery to customer:	330	
Treating and delivery total:		587
Forest to customer total:		3,320

% Extra energy demanded in treating and delivery $= \frac{578}{2733} \times 100$

$= 21\%$

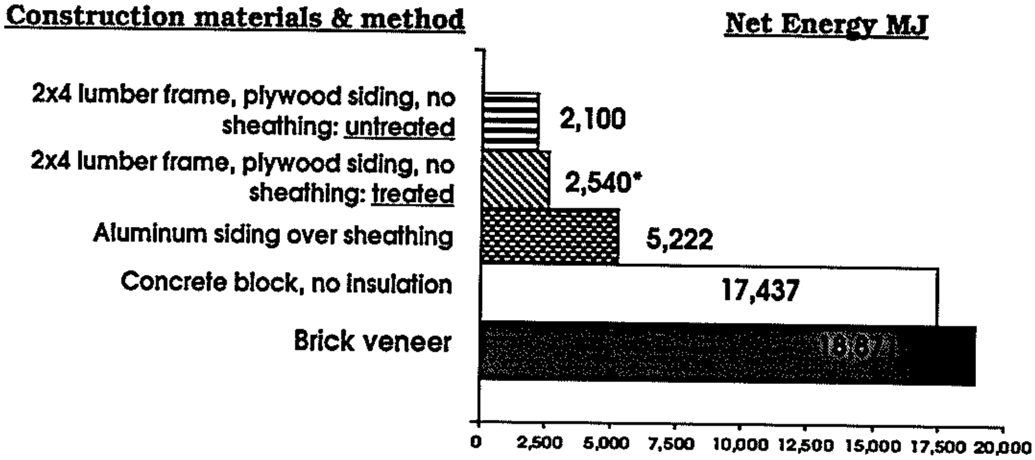
% Extra energy demanded in treating operations $= \frac{257}{2733} \times 100$

$= 9\%$

Energy Input of Various Building Materials and Treated Wood

(After CORRIM II Report)

Premise: a 100 square foot section of wall is built, and energy demands totalled for extraction, manufacture, delivery of the materials and erection.



***Applying same treating energy inputs (MJ/mbf) for plywood as lumber.**

<u>Figure 6</u>: shows the slight increase that CCA treatment causes in energy demand of softwood lumber and plywood. The treated product remains lower in total energy intake that all other common building products.