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MSc Architecture: Advanced Environmental and Energy Studies

Unit 6: Life Cycle Assessment

Essay Title: Can the green building assertion that polybutylene pipes are preferable to copper pipes for hot and cold plumbing supplies be refuted with an in-depth life cycle assessment of these two materials?

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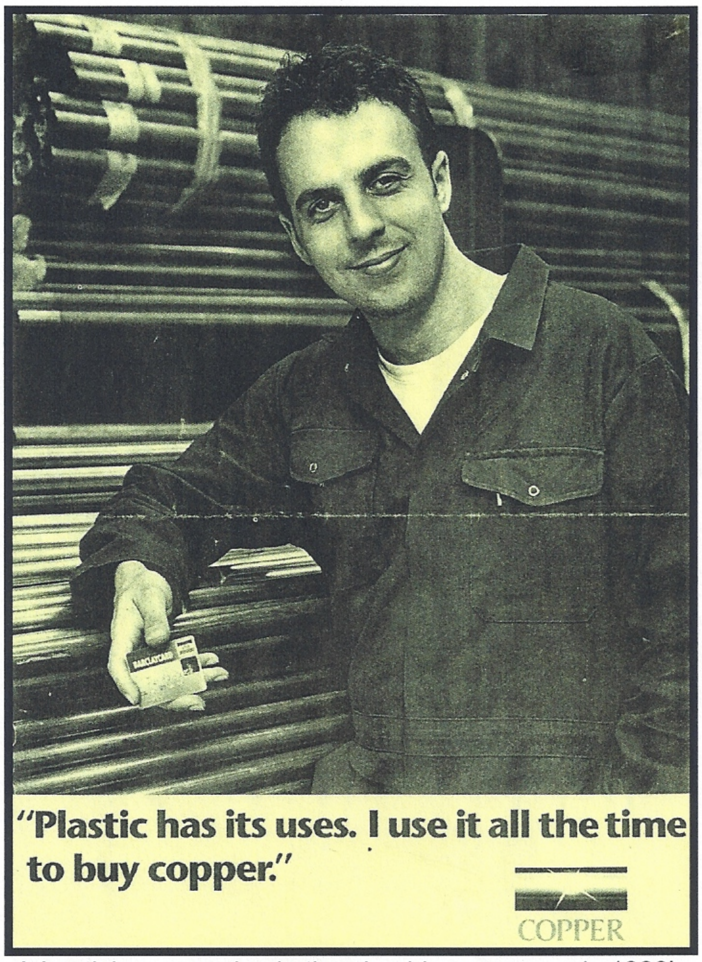

Advertising campaign in the plumbing press, early 1990's

Can the green building assertion that polybutylene pipes are preferable to copper pipes for hot and cold plumbing supplies be refuted with an in-depth life cycle analysis of these two materials?

- **Declaration of interest**

As a plumber of 20 years standing there were certain materials that I used on site in preference to other materials due to their quality, both in ease of working and longevity, compared to the alternative. They were lead sheet for roofing applications, uPVC for all soil and discharge pipes, and copper tube for hot and cold water supply, central heating and gas pipework. As I began to find out about the environmental impacts of these materials I had to make a decision as to whether to still use them. Lead and uPVC I could easily accept as being of extreme environmental concern and I do not work with these materials now.

But copper tube to be replaced with Hep_2O?? It was 1997 that I first heard this view expressed, at a Walter Seagull workshop. I challenged the workshop co-ordinator as to what facts he based this pronouncement on. He replied he could not say but was adamant that it was the case. As Hep_2O can be easily used by DIYers, and copper much less readily so, I argued you could recommend it for that reason, but certainly not from any environmental credentials. The mining of copper causes a lot of environmental damage that's clear but I was not convinced that environmentally a plastic (any plastic) could be better than copper, especially given the vibrant recycling scrap metal industry that we have in the UK.

By 1998 I was working in the field of sustainable construction. The Whole House Book was published in that year and it too recommended polybutylene pipe over copper for hot and cold plumbing supplies. The reasons it gave are as follows: "......does not corrode, can be recycled and is of less polluting manufacture than copper..." (In fact copper is based below stainless steel because it "corrodes fairly easily"). My initial response on reading this was threefold. Corrosion of copper pipes is only an issue in a very few areas of the UK and then usually only from private water supplies, where water percolating through peat leads to a low pH and the resulting acidic water is not treated before being pumped to the property. Public water supplies are treated to give a pH of between 5.5 and 8.5, a level of acidity, which will not damage the integrity of copper pipes.[footnote 1] Secondly, it may well be possible to recycle polybutylene but the reality is that it is virtually never recycled whereas copper tube virtually always is. And finally, can any plastic, coming as it does from the oil industry, really be less polluting?

This essay is my search for proof to substantiate my gut feeling of years ago that in fact copper is preferable to polybutylene on environmental grounds and that the advice to use Hep_2O is incorrect.

1. Corrosion **is** an issue for underground copper pipes (Table Y) due to the high range of aggressive soils sometimes encountered. Table Y copper tube, which originally replaced lead in underground mains pipework was thicker walled to prevent against this. The introduction of mdpe pipes for underground pipework has a range of advantages from a technical point of view and should continue to be specified. Corrosion is also an issue if burying in concrete screed. Copper pipe used in these situations therefore needs to be protected. This used to be by covering with a bitumen impregnated tape or similar. Now plastic coated copper pipe is available. From a technical and environmental viewpoint polybutylene pipe is preferable in this situation.

Can the green building assertion that polybutylene pipes are preferable to copper pipes for hot and cold plumbing supplies be refuted with an in-depth life cycle assessment of these two materials?

Life Cycle Assessment

Life cycle assessment is a way of addressing the environmental impact of a material. It looks at this impact across the whole life of the material, from raw material extraction and processing, to manufacture, transport and distribution, use of the material during the construction process, any maintenance that may be required, and finally whether it can be recovered or re-used after demolition of the building.

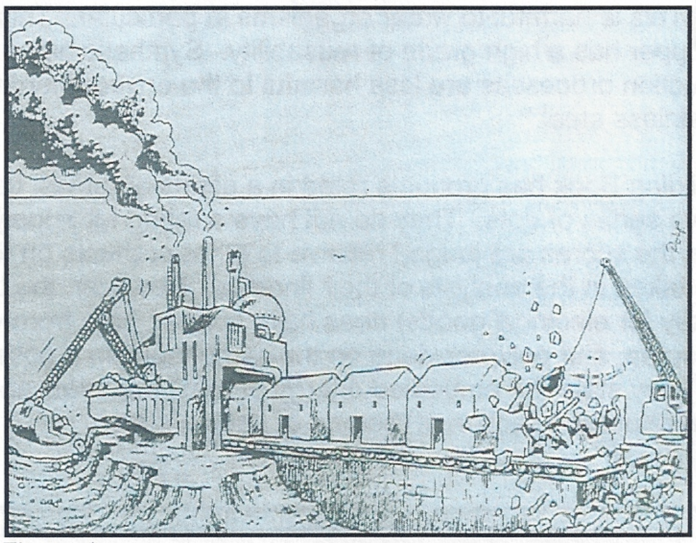

Figure 1

There are many different LCAs of different materials available now. However, many can only be accessed by the payment of a high yearly registration fee, such as BRE (UK), Athena (Canada) and LISA (Australia). Therefore this essay looks at three of the methods available in printed form whilst sourcing other relevant information from a variety of sources. Using varied sources helps to balance the degree of subjectivity that there is in every LCA that is undertaken. The three LCA methods consulted were: Hazardous Building Materials (2nd Edition), The Environmental Preference Method pioneered in the Netherlands and published in the Handbook of Sustainable Building, and the Green Building Handbook (Volumes 1 and 2).

Hazardous Building Materials addresses three aspects of the material under the headings technical, health and environmental. Technically the material is rated from 1 to 3 against the alternative materials available. Under health, the potential health hazard to occupants when the material is in position in the building and any potential health hazard to the occupant if the material was disturbed by maintenance, replacement or fire is addressed. There are 4 main categories under environmental hazards. These are the environmental impacts from the extraction and manufacturing process, the construction process, during the life of the building, and on demolition, whether as waste or in recycling. Both health hazards and environmental hazards are rated under a hazard scale of 0 - 3 identified as: 0 - none reasonably foreseen; 1 - slight/not yet qualified by research; 2 - moderate; 3 - unacceptable. There are no figures for embodied energy in the book.

Copper pipes are ranked 1 technically, 0/0 for health with a comment of No significant risk seen to occupants, 2/0/0/0 for environmental issues with a comment of "High embodied energy. Pollution from manufacturing. High recycled content.

Depletion of scarce resource." Polybutylene is also ranked as 1 technically, 0/0 under health hazards, and 1/0/0/1 for environmental issues with the comment: "Moderate embodied energy. Pollution from petrochemicals. Downstream score assumes some recycling."

The Environmental Preference Method breaks the LCA of a material down into several distinct phases. They are extraction, production, building process, building occupation and decomposition. Materials are rated as preference 1, preference 2, preference 3, and not recommended. There are notes on the selections made but no references and no figures. Polyethylene, polybutylene and polypropylene are preference 1 and copper is preference 3. It comments: " The main concern with using copper pipes is corrosion leading to contamination of the waste water with copper.[footnote 1] This is harmful to water organisms in particular. This is not offset by the fact that copper has a high grade of reusability. Synthetic pipes do not corrode and their production processes are less harmful to the environment than those for copper and stainless steel."

The Green Building Book has products rated in a series of tables, using a very visually effective series of dots. They do not have a rating for supply pipework in building and as the scores are judged relative to other products on the same table care has to be taken in the analysis of their findings. However, the table below (which is actually for electrical goods) does have copper, both from virgin ore and from recycled scrap, and polypropylene on the same table so a possible comparison can be made. They state the embodied energy of most materials and have a comprehensive reference section at the end of each chapter.

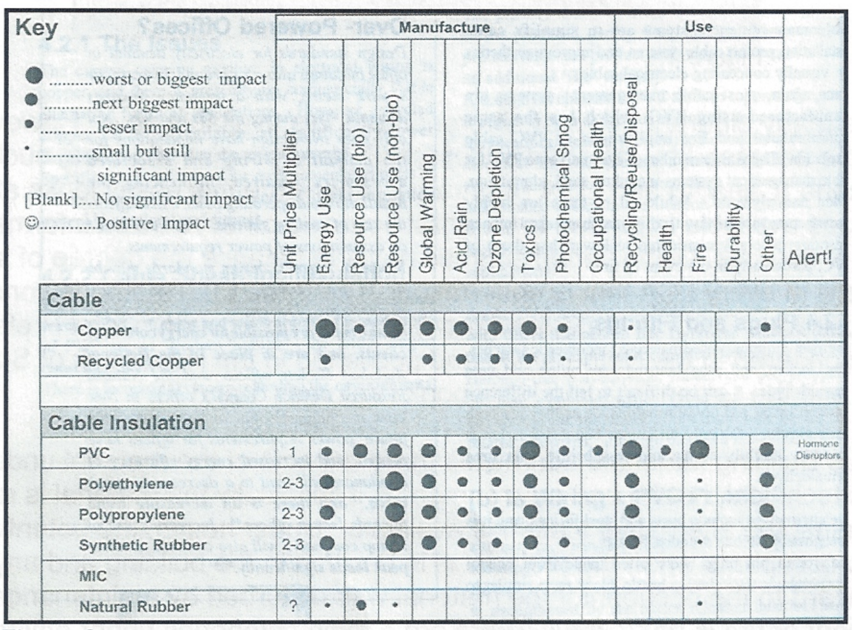

Figure 2

Footnote 1: Polyethylene (PE) and polypropylene (PP) are other members of this family and all portray similar qualities. In the light of difficulties finding embodied energy figures for polybutylene, figures for PE and PP have sometimes had to be used. If so this is highlighted in the text.

Copper
Copper is a non ferrous metal with a melting point of 1083°C. Copper tube was first used in public buildings as early as 1900, and it began to be widely used for cold and hot plumbing supplies in the UK in the 1930s. There are four grades of copper used in the construction industry today. Table X copper tube is the type used for virtually all above ground copper pipe work and is the tube this essay addresses. It is bendable and is for use above ground only. It has a wall thickness of 0.7 mm for 15 mm pipe and 0.9 mm for 22 mm pipe. Table X copper can be jointed by mechanical means or by soldering.

Polybutylene
Plastics have been introduced gradually into the plumbing industry since the 1970s but have been used in place of Table X copper tube only since the late 1980s. Polybutylene (PB) is a member of the polyolefin family of plastic. A number of compounds are added to provide colour, plasticity, stability, fire retardation, and resistance to degradation by UV radiation. [footnote 2] It has a melting temperature of 125 °C (high for plastics) and so can be used for hot water supply pipework as well as cold. It is thinner walled than polyethylene pipe and so can be made to the same external diameter as copper tube rather than the thicker walls of mdpe pipe. It is generally called by its trade name on site (eg Hep2O, Polyplumb). It can only be jointed by mechanical means.

Because pipes made of materials in the polyolefin family of plastics permit the permeation of oxygen though their walls they cannot be used for central heating pipework unless a barrier is added. Therefore polybutylene barrier pipe is available for these circumstances, produced with a protective layer of ethylene vinyl alcohol, which effectively prevents the ingress of gases.

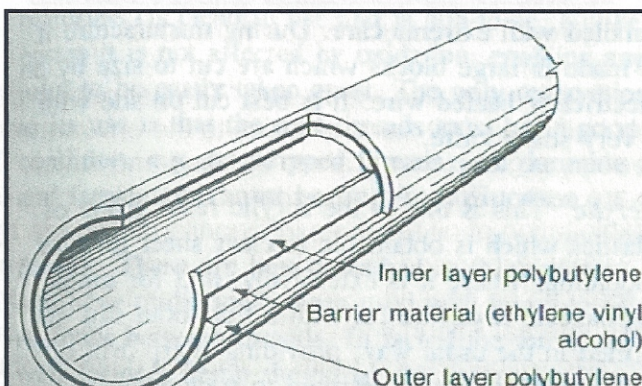

Figure 3

The environmental impacts of copper mining and oil exploration
Both mining for copper and drilling for oil cause huge amounts of environmental destruction. Additionally, the rights of indigenous people are usually ignored (despite what Shell's new adverting campaign would have you believe).

Footnote 2: This is an issue for rainwater pipes due to the acidity of rainwater but I contest it is not an issue for supply pipes within most buildings as explained in the footnote under the declaration of interest.

Modern copper mining generates many more tonnes of waste than useful product. The current deposits of copper ore being mined are generally only between 0.5 and 2.0 per cent copper by weight. Therefore for each kilogram of copper between 50 and 200 kilograms of waste are produced. This excludes any overburden that has to be moved to access the copper ore.[1] Heavy metals leach into watercourses from mine drainage and tailings with associated acidification of water. Once the process of acid generation has started it is extremely difficult to stop. The combination of acidity and dissolved contaminants kills most forms of aquatic life. Streams become sterile and unfit for human consumption.[2] Copper production also uses a staggering 15,900 litres of water for every kg of copper produced.[3] Mining often takes place in areas where water is scarce. In these regions the consumption of water for mineral processing can have a severe impact on aquifers levels leading to competition for water that can affect nearby village wells. This competition for water can impose critical developmental constraints.[4] Emissions to air include heavy metals, carbonyls, fluorides, alkali and acid fumes, dust and resin fume.

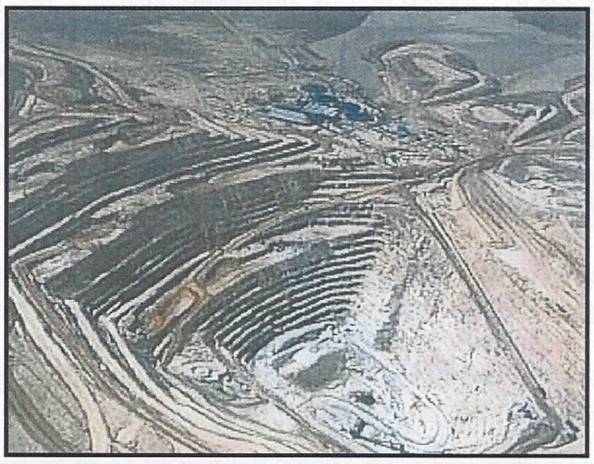

Figure 4. La Escondida copper mine, Chile

The impacts of oil extraction are also significant. “The petrochemicals industry is responsible for over half of all emissions of toxics to the environment releasing a cocktail of organic and inorganic chemicals to air, land and water. The most important of these are particulates, organic chemicals, heavy metals and scrubber effluents.” [5] The exploitation of oil reserves in Ogoniland, Nigeria by Shell is probably the most widely recognised example of the widespread environmental and social devastation that can be caused. Since 1993 over 1000 Ogonis have been killed by the Nigerian Internal Security forces[6], acting as a private army for Shell Inc. Transporting crude oil to refineries and refined oil to the country of use means day to day operational discharges of oil, (eg when cleaning out tankers), which pollute the marine environment; as do oil spills when they occur. There is also concern as evermore remote areas are now being earmarked for exploration (eg Alaska).

Depletion of a scarce resource

The Hazardous Building Book warns that using copper causes “depletion of a scarce resource” but does not issue the same warning for plastics, which are derived from oil, which is also a scarce resource. As the table below shows, copper and oil will not last long at present extraction rates. The Ecology of Building Materials states copper reserves as 36 years and oil 40 - 50 years. The figures may differ slightly but what is undeniable is that both are a vanishing resource and in terms of global sustainability the use of both should be reduced to a sustainable rate.

	Predicted level, 2040	Desired reduction (%)
Fossil fuels		
Oil	stock exhausted	85
Gas	stock exhausted	70
Coal	stock exhausted	20
Metals		
Aluminium	stock for more than 50 years	none
Copper	stock exhausted	80
Uranium	depends on use of nuclear energy	not quantifiable

Source: Weterings, RA and Opschoor, JB (1992) *The ecocapacity as a challenge to technological development* Rijswijk: Advisory Council for Research on Nature and Environment

Figure 5

Production process

Traditional copper smelting releases large quantities of SO_2. Modern plants resolve this problem by dissolving the ore in sulphuric acid and extracting the pure copper by electrolysis. This gives a very high grade of copper and now accounts for 13% of world copper production. Both are highly intensive procedures using vast amounts of energy and producing toxins into the air, land and watercourses.[7] Heavy exposure to copper fumes when smelting is a health hazard for plant workers.

Plastic polymers are produced using high energy processes with oil or gas as raw materials, which themselves have a high embodied energy. Petroleum refining and synthetic polymer manufacturer are major sources of NOx and CO_2, both major greenhouse gasses. They are also major sources of SO_2 and NOx, the gases responsible for acid rain. Plastic production also uses water in the production process although much less than for copper. It takes 3100 litres of water to produce 1 kg of polypropylene. Volatile organic compounds are further released during oil refining. Cancer and chemically induced nervous problems are more frequent amongst workers in the plastics industry than in the general population.[8] However, it is generally recognised that the production processes of polyethylene and polypropylene pollute the least of all plastics and it is likely the same is true for polybutylene manufacture.

Embodied energy

The amount of embodied energy within a particular material is the amount of fossil fuels used to produce that material. It is not only the energy used for the production of the material but also the energy used during extraction and production. The burning of fossil fuels causes emission of harmful substances, which contribute to the greenhouse effect (CO_2), acid rain (NOx and SO_2) and smog (NOx and hydrocarbons). In addition "energy use itself is a consumption of scarce raw materials"[9] unless renewable forms of energy are used.

The available figures for embodied energy are not consistent. There is also confusion about where they start and end. Complications also arise because of the different units used and the wide range of different plastics available all of which have a different embodied energy. To simplify a complicated situation I have used MJ/kg as the base unit and converted all figures to this (although still quoting in the original units).

In 1998 The Whole House Book rated the embodied energy in plastics as being 45,000 kWh per tonne (162 MJ/kg) and for copper 15,000 kWh/tonne (54 MJ/kg) i.e. copper was just 30% of the embodied energy of plastics. (See table below). In Tomorrow's World the figures are (in BTUs per pound) 25,900 for copper (60 MJ/kg) and 49,500 for plastics (115 MJ/kg). This is nearly twice as high an embodied energy content for plastics as for copper.

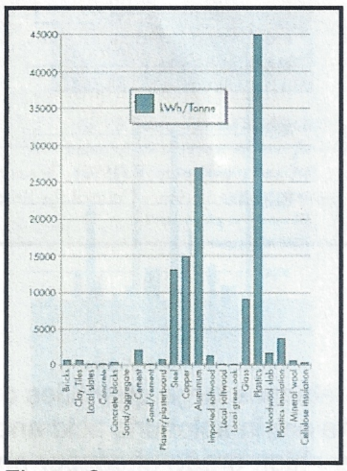

Figure 6

The Ecology of Building Materials shows the embodied energy in plastics ranging from 40 MJ/kg for UF (expanded urea-formaldehyde) to 110 MJ/kg for PUR (expanded Polyurethane). Giving an embodied energy figure for "plastic" is really not very useful; the actual plastic must be specified. This is shown very clearly in the Hazardous Building Book which rates polypropylene, polyethylene, ABS, PVC, high density polyethylene as all having moderate embodied energy and copper having high embodied energy without giving the actual MJ/kg figures. From various other sources it can be seen that PVC has one of the lowest embodied energies of plastic materials (68 MJ/kg) and that rates for the others range from 85 -120 MJ/kg. Copper is rated at around 70 MJ/kg.[footnote 3] Ranking all these different plastics under the same embodied energy comment of 'moderate' whilst ranking copper as 'high', clearly shows one of the difficulties in Life Cycle Assessment analysis if actual figures are not quoted.

So what is the embodied energy for polybutylene? Polyethylene (PE) and polypropylene (PP) are rated as 67 MJ/kg and 71 MJ/kg respectively in the Ecology of Building Materials. Unfortunately it does not have a figure for polybutylene. The British Plastics Federation advises that "the total figure for polybutylene would not be all that different to PE (high and low density) and PP."[10] The APME Eco profiles[11] give the average gross energy required to produce 1 kg of polypropylene in European plants as 80.03 MJ.

Therefore, following the advice from the BPF regarding embodied energy of polybutylene as being very close to that of polypropylene, a whole range of figures seem to show that kilogram for kilogram copper uses less embodied energy than polybutylene for production from virgin ores per kg, (70 MJ/kg for copper as against 80-85 MJ/kg for polybutylene.)

Footnote 3: The Ecology of Building Materials gives copper an embodied energy figure of 70 MJ/kg. In the Green Building Handbook the embodied energy of a kg of copper is estimated at 70 MJ, 9% of which is in transport to the UK.

- **Recycling**

Recycling addresses both resource depletion, the environmental impacts of mining and always results in a lower embodied energy figure than using virgin material. Between 88 and 95% of energy is saved if copper is recycled instead of being produced from virgin ore. The figure for plastic is even more impressive (97%) as shown below. The Green Building Book states that copper production from scrap uses between 10 and 60 MJ per kg depending on the purity of the scrap copper used. This is a saving of 86% if the purity of the scrap is high but only a 15% saving if it is low.

	Energy needed to process (BTU/pount)		*Amount of energy saved by recycling (per cent)*
Material	*Virgin ore*	*Recycled material*	
Steel	8300	7500 (40% scrap)	10
		4400 (100% scrap)	47
Aluminium	134,700	5000	96
Aluminium ingot	108,000	2200–3400	97
Copper	25,900	1400–2900	88–95
Glass containers	7800	7200	8
Plastics	49,500	1350	97
Newsprint	11,400	8800	23

Source: Hayes, D (1978) *Repairs, Reuse, Recycling – first steps toward a sustainable society* Worldwatch Paper 23. Washington, DC: Worldwatch Institute

Figure 7

At this stage it is important to look at the situation within the UK for both copper and plastic recycling. Hazardous Building Materials states, "some downstream recycling of plastics is assumed" in its rating score for polybutylene. How realistic is this statement in the UK? Plastic is virtually never recycled on building sites unless a comprehensive waste policy is in position (rare on even the biggest sites yet alone on the thousands of small sites up and down the country). Any plastic pipe ripped out is skipped.[12] Even if it was collected "the wide variety of plastics present in waste make separation and recycling of plastics an expensive and complex process. Currently, post consumer recycling of plastics is negligible."[13] Therefore, almost all polybutylene ends up in landfill. Although it is unlikely to cause any toxic effects it takes up space, which is, in itself, a problem given the lack of landfill sites available in the UK. Polybutylene can be recycled as long as it is "not contaminated". The definition of contamination is not clear. Almost all plastics are impure because of their additives and thus recycling is not straight forward. In addition, "if a polybutylene pipe had an EVA barrier/layer, it would make it more difficult to recycle. Unless you could separate the layers at source [footnote 4] the pipe waste would have to go in as a mixed polyolefins batch. This would mean that possible outputs for the recyclate are reduced in number and may decrease the opportunities for recycling the waste generally."[14] It can be incinerated without giving off dangerous fumes.

By contrast, every piece of copper tube ripped out or left over on virtually every building site in the UK is collected, stored and eventually taken to one of the many scrap merchant dealers who are part of the very large and well organised scrap metal industry in this country. The price paid for scrap copper at the merchants is rated on purity and goes up and down in line with the world markets for virgin copper.[15]

Footnote 4: It is not possible to separate the EVA layer from polybutylene barrier pipe at source as it is a totally integrated layer within the pipe and is less than 0.5 mm thick.

In 1997 37% of world copper consumption came from recycled copper.[16] This figure has been increasing slightly since the 1960's and if there was enough scrap copper this figure could be increased markedly as there is no difference between scrap copper or virgin copper once it is processed.

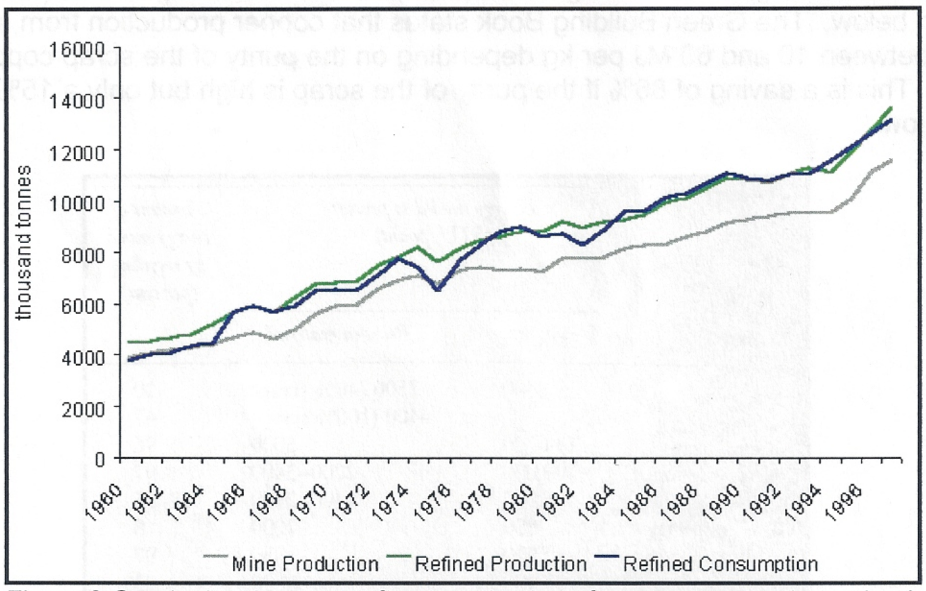

Figure 8 Graph showing total refined production of copper greater than mined production due to recycled copper use

IMI Refiners Ltd are a copper refiners very similar to most other UK refiners. They supply copper billets as the start stock for copper tube and use 1400 tonnes a week of copper of which 500 tonnes is recycled and the rest is virgin copper (mostly produced by electrolysis from South America and Russia). They get 250 tonnes of scrap a week from Yorkshire Copper Tube Ltd (i.e. scrap directly from the manufacturing process) and a further 250 tonnes from the scrap metal industry. 98% of the scrap is UK obtained. When world copper prices are low scrap merchants sit on their stocks to wait for the market to improve and the UK copper industry experiences a shortage of copper. They will sometimes buy from overseas if scrap is available elsewhere when the UK market is depressed like this. Refineries in the UK used to use low quality scrap but this has now been banned by the Environment Agency due to excessive pollution when it is burnt. They maximise the use of scrap copper because it's cheaper than virgin copper. As small bits of scrap tend to clog the furnace up, and as scrap copper takes longer to melt than cathode copper, the maximum scrap IMI Refiners will use is 40%. For every good quality tonne of copper going out of the refinery just 633 kWh of power has been used in its production. (2.3 MJ/kg)[17] Whilst this figure is obviously not the total embodied energy of the copper as it is energy use at the final stage of the production process only, it is an interesting figure nonetheless as it shows the huge embodied energy savings that can be made using recycled copper.

Health issues

Toxicity concerns once a materiel is in a building comes from three different routes of exposure. They are ingestion of the solid material, inhalation of a gas or vapour released by the material, and contact with the skin.[18] Neither copper nor polybutylene off gas or are a health hazard if touched.

Copper is an essential trace element and the human body regulates its level of copper by means of a homeostatic effect. Acute exposure to large doses of copper has known adverse health effects but long-term low level exposure is not believed to be associated with any ill effect. The WHO recommends a maximum permissible level of copper in drinking water of 1.5 parts per million due to taste and discolouration effects above this level. Therefore cupro-solvent water is a hazard to pipes but not to health. "Copper as a metal or alloyed in brass presents no health problems for occupants."[19]

It is the additives in polybutylene, as with all plastics, that could be toxic. If these were dissolved by standing water then a danger to health could occur. However, as polybutylene has been approved for use in water supplies by WRAS the danger to health of these additives is nil. There are no known inhalation hazards associated with polybutylene pipe in buildings.

The jointing method used for copper or polybutylene pipe may have a health effect. Polybutylene is joined using mechanical fittings and so there are no health implications on site. If copper is soldered then the flux used will have a minor negative effect on health.

Performance and durability

Within any life cycle assessment, performance of the material studied is very important, as is its durability. Polybutylene pipes cannot be used for gas and oil supply pipework as they eventually degrade due to the chemical reaction with these components. They also cannot be used for solar heating systems or primary or gravity circuits from solid fuel back boilers because of their low melting point. Nor can they be connected directly to boilers. In all these cases metal pipes (in reality copper) must be used.

Polybutylene pipe is also affected by chlorine, which causes it to fail and leak. This has caused major problems in the US, so much so that polybutylene pipe is now banned in some states for installations in domestic properties and over $950 million has been paid out in damages by the manufactures to householders.[20] However UK polybutylene suppliers state that in the UK "short term chlorination for disaffection of supply pipe work and normal levels of chlorine in UK domestic water supplies will not have an adverse effect. It is not suitable however for systems that carry a high concentration of chlorine, eg supplies to swimming pools."[21]

Copper and polybutylene pipe have very different characteristics. Hep$_2$O can be cabled which is a major factor in making installation on site faster and allowing work to continue on upstairs floors while cabling is done at high level below. Joists remain stronger than if they were notched. Hep$_2$O will not burst if the water inside it freezes but needs to be lagged to the same specification as copper pipe. It is a poor conductor of heat as are most plastics which have the advantage that heat loss is less rapid than thorough copper pipes but it will still occur and pipes should still be lagged to prevent this.[footnote 5] Condensation can be a problem on copper tube carrying cold water through rooms with high humidity. Replacing with polybutylene pipe prevents this occurring. Using Hep$_2$O above floor level though is less satisfactory. The pipe has to be clipped much more regularly than copper as it sags and cannot be bent within a small radius thus leading to a high number of fittings.

There is a general durability issue for most plastics used in a building. They should be able to last the life of the building and as the table below shows this is not guaranteed. In most situations polybutylene pipe will not be as durable as copper pipe.

Footnote 5: It could also be argued that this heat retaining capacity cannot have that much effect in practice given the preponderance of plastic pipes in underfloor and in wall heating systems where good heat transfer is needed

Table 9.11: The anticipated lifespan of certain plastics

Type of plastic	*Assumed lifespan (years)*
PMMA	Less than 40
PIB	11–less than 40
PVC	8–less than 30[1]
PE	2–15[1]
UP	5–less than 35
EPDM	Less than 30
PUR	7–10
CR	2–less than 40
IIR	2–less than 35
T	22–less than 50
Si	14–less than 50
ABS	15
MF	6–10
PF	16–18
NBR	10
EVA	3
PA	11–less than 30
PP	3–less than 10
SBR	8–10
PTFE	25–less than 50

Notes:
The evaluation includes both external and internal use and built-in situations. Positioning within water or earth is not included. The most protected locations achieve the best results.
(1) Does not apply to buried cold water pipes in thicker plastic, which lasts longer, especially PE.
(Sources: Grunau, 1980; Holmström, 1984)

Figure 9

Conclusion

Having stated the case for each of the materials what do I conclude? As regards the environmental impacts of mining and production both copper and polybutylene seem to be pretty well matched in the amount of environmental problems they cause (apart from the excessive water use involved with copper). They are also both a scarce resource. In terms of embodied energy copper from virgin ore uses approximately 85% of the embodied energy of polybutylene. Between 35 - 40 % of copper production in the UK is from scrap metal reducing the embodied energy figure even lower. There is no recycling of polybutylene pipe in the UK now and unlikely to be much in the future. Health wise, once installed in the building neither copper nor polybutylene has an adverse impact on the health of the occupants. Copper is more durable than polybutylene in many situations. From this it looks as though copper is in fact the preferred material.

However this is not the case because of the weight difference between the two. A 1m length of 15 mm copper tube weighs 260 grammes. A 1m length of 15 mm Hep$_2$O pipe weighs 60 grammes. This is a weight difference of 4.5 in favour of polybutylene. At 22 mm diameter the difference is even greater. With a 1m length of 22 mm copper tube weighing 500 grammes as opposed to the 100 grammes of the same length of Hep$_2$O the difference is a factor of 5. As most of the other impacts of copper v plastic are level it comes down to embodied energy. Kg for kg copper is slightly better but it would need to be 5 times better to make up for the excess weight. Given the fact that most copper tube is made from 40% recycled scrap this is unfortunately still not enough. It would need to be 80% a figure that is unlikely to be reached because there is just not enough scrap copper available. So does this mean polybutylene pipe should be used?

I would argue that the case for polybutylene pipe is not yet proved. The jointing method used will also have an impact on the LCA of the chosen material. Copper is usually jointed using soldered fittings. When using soldered fittings a flux is used to aid cleaning of the pipe and to help the solder run. Heat has to be applied to the fitting to melt the solder. This causes fumes and also CO_2 emissions. However, the fittings themselves are much smaller (weigh just 4 mm to 8mm as against 26 or 42 mm for a 15 mm coupling) and are much less highly engineered than grab ring fittings, which are the only method of jointing polybutylene pipe. In addition Hep$_2$O needs an aluminium insert to prevent it collapsing under the pressure of the fitting, a material with its own huge environmental impacts. It is obvious that these highly engineered joints have a far higher adverse environmental impact than do copper soldered joints **as long as lead free solder is used.**

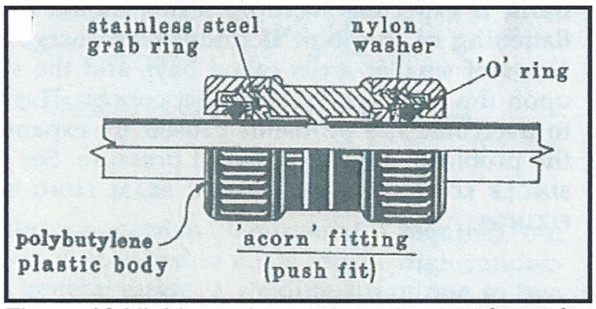

Figure 10 Highly engineered mechanical fitting for polybutylene pipe

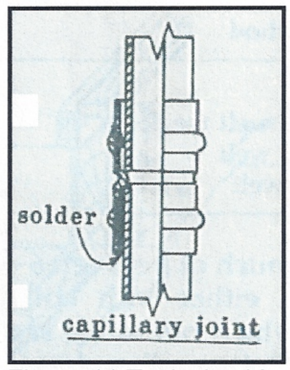

Figure 11 Typical soldered fitting for copper tube

More in depth work needs to be done on services in ecological building, especially as more and more composite pipes are coming onto the market [footnote 6]. The case for copper is not proven, but polybutylene is not the answer in all cases and is not the environmental panacea it seems to be portrayed as in some publications.

It seems that this time the plumbers out on site have made the right environmental choice purely from a pragmatic, what saves time on site angle. They use polybutylene pipe for cabling under floorboards, and use copper with soldered fittings for the final connections above floor level. This minimises the use of Hep$_2$O or Tectite fittings, which are so highly engineered, and yet maximises the positive attributes of polybutylene pipe. I would argue that from an environmental viewpoint this mixed use of copper and polybutylene should be followed.

Footnote 6: For example does the fact that polybutylene barrier pipe will not be able to be recycled mean that copper could possibly be preferable from an environmental angle for pipework below floorboards as well as above?

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