The ethics and evaluation of embodie

Jon Morris (F), Principal, OneEngineer looks at the reasoning behind the ethical basis for discounting carbon content of buildings

When deciding upon whether it is more environmentally friendly to construct a solid building, with lots of carbon spent, or a more lightweight but perhaps less durable building, how should the task be approached?

We know that future generations are likely to have less oil than us. We also know that we probably need to reduce carbon emissions now. However, the effect of these two considerations on the future is uncertain.

The engineering community can assess the lifespan and carbon content of buildings more easily than we can judge society's future. On the other hand, the UK Treasury has reviewed the impact of financial expenditure on society's future in great detail.

One possible way of assessing carbon impact would be to use societal discount rates recommended by the Treasury's green guide[1] and then to use a range of financial projections for oil to adjust the discount rate: This might provide an idea of the relative discount rate that should be applied when treating carbon fuels as a unit of measure.

In addition to falling straight into the 'too difficult' box, this idea does not fully account for the climatic risks of carbon emission nor does it address the specific considerations relevant to buildings infrastructure.

Instead, this article seeks to find a suitable working hypothesis based on the ethics of financial discounting and by applying those ideas to our usage of carbon fuels for the construction of infrastructure.

The term 'embodied carbon' reflects the amount of carbon dioxide required to make a product. Carbon could be treated as a measure of value to be shared between ourselves and future generations: with only limited resources available, how, when, and for whom should we be spending that carbon?

This article looks firstly at the ethical considerations of discounting and applies these to carbon using it as a unit of measure. In the second part it looks at various building examples analysed, using the first part's conclusions, for whole life carbon.

Embodied 'costs' are sometimes described in terms of energy rather than carbon. However, different delivery methods[2] produce varying CO_2 emissions: This makes some comparisons using 'energy' misleading.

Embodied carbon costs are not as significant as the costs of energy in use[3]: If the impact of a reduction in embodied carbon is to increase the energy spent on heating, lighting and so on, the overall carbon impact is very likely to be higher. Therefore any embodied calculation may be of marginal impact and should be viewed in the context of overall carbon emissions.

The ethics of discounting

Ignoring inflationary effects, financial discount rates[4] are used to reduce the value of future financial outcomes to allow comparison. This allows for future risks associated with a project.

When used for societal evaluations, the use of Social Time Preference (STP) discounting assumes that future generations will be better off: Part of the STP discount is applied to 'even up the score'. This component (known as μ.g) relates to consumption.

The Stern Review[5], a Treasury document, uses these techniques to evaluate the financial impact of doing something, or nothing, on future consumption. Stern notes that '*if consumption falls along a path then the discount rate can be negative. There is no presumption that it is constant over time.*'

Stern also notes that '*If the ethical judgement were that future generations count very little regardless of their consumption level then investments with mainly long-run payoffs would not be favoured. In other words, if you care little about future generations you will care little about climate change.*'

Future generations may not exist: This consideration 'points to the use of a positive, but small, rate of pure time preference' (L). The figure used by the Treasury[5] corresponds with a 90% probability of humanity surviving a 100-year period.

Another part of the STP discount, a further 'pure time preference', takes account of humanity's preference for having things now rather than waiting (∂).

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Fig 1. Discounting factor falls as comsumption increases over time / Fig 2. Consumption growth rate

ied carbon in buildings

On the other hand, Frank P. Ramsey, the great mathematician and philosopher-economist described pure time discounting as 'ethically indefensible and [arising] merely from the weakness of the imagination'[6].

This article is not intended to be a financial comparison but does use some similar concepts, particularly in the use of discounts and systemic risk[7].

Financial discounting

Fig 1 shows a simple example of a financial discounting factor falling as consumption increases over time. The dashed line represents the discount due to assumed increases in consumption by society:

To model the above growth, we used a simplified initial discount rate of 2%[1] and an annual decline in the discount of 0.58%. This positive discount, albeit declining, implies an increase in the consumption of goods by society along historical lines.

The reasons for using a declining rate are dealt with in great detail by Stern and are described in a more easily consumable form by Jiehan Guo[8].

Using the above discounting for financial evaluation (and ignoring market systemic risk factors for the asset type), an investment maturing in 50 years would have to return an inflation adjusted £400 for every £100 spent now. Consumption would have grown by 250% (Fig 2).

One argument[8] for positive discounting is Rawlsian[9] rule of intergeneration equity in which society should try to maximise the well-being of the poorest among all generations: a positive discounting argument assumes that future generations will be better off. Therefore, the argument goes that the poorest people today would be sacrificing their own good for better-off future generations if positive discounting were not introduced.

However, it is difficult to see how the type of growth seen in last century would be compatible with a sustainable model when using carbon as the unit of measure. The last century was one of massive change in consumption patterns, financial discounting assumes growth of consumption.

Carbon discounting and consumption

However, if we accept that consumption of carbon must fall as we approach Peak Oil[10], then the consumption of fossil based carbon fuels cannot physically continue to grow, although it might be replaced by other forms of energy.

The Climate Change Bill[11] suggests that we must reduce consumption to 40% of current levels by 2050 and cut levels by 26-32% over the next decade (note that these figures are described as *minima*).

Using the above figures we can interpolate a graph of projected carbon fuel consumption (Fig 3).

The discount rates used to produce the graph above are negative, larger than the comparison consumption components of the financial discounts shown above, and falling at a faster rate. These rates imply that the indexed value of carbon will increase as consumption is constrained (Fig 4).

Thus there are two competing arguments for a discount rate applied to carbon when the carbon itself is used as a measure of relative value:

A positive rate:

- Carbon spent now on infrastructure may produce diminishing systemic value due to increasing consumption.
- Future generations may not exist.
- Future generations may develop alternate sources of fuel at a lower cost.
- Society wants to consume now rather than later.

A negative rate:

- The actual reducing supply of carbon fuels right now and in the coming decades.
- The risk of further politically enforced reduction in supply due to climate change risks.
- Consumption of goods may have to decrease in the long term due to lack of fuel.

Another possibility is to combine sections of each argument and negatively discount for the known 'fast fall' in carbon consumption

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Fig 3. Graph of projected carbon fuel consumption / Fig 4. The indexed value of carbon increases as consumption is constrained

and to combine this with longer term pure time positive discounts for the 'we want it now' argument, the possibility that future generations may not exist and that future generations may develop alternative carbon fuel sources (Fig 5). This methodology may address some of the concerns of both arguments listed.

Effects of discounting applied to cyclical renewal

For whole life embodied carbon calculations, we are largely concerned with effect of discounting on the rate of renewal of buildings infrastructure. For instance, an alternative might exist between a low embodied content structure requiring renewal at a fast rate and a high embodied content structure requiring renewal at a lower rate.

Although rare in practice, the best solution is long lasting infrastructure with low embodied carbon contents.

When cyclical renewal is analysed with a positive (falling) discount the future is always of lower value than the present. In this instance, the lower initial carbon content would usually be desirable.

If we assume that there is no discount, the future is set at the same value as the present: In this situation, the lowest annual carbon spend is desirable.

Alternatively, if we assume negative falling discount with anything other than a miniscule rate of reduction in the discount, the discount rate will tend to zero at infinity. Therefore any evaluation of the rate of any repeating cycle using a falling discount will, more or less, be equivalent to a zero initial discount rate. In this situation, the lowest annual carbon spend is also desirable.

We also ran trials of a negative to positive falling discount described above. The impact on cyclical renewal (of infrastructure) for various renewal periods and discount values was found to approximately equate to zero discounting. In this situation, the lowest annual carbon spend is also desirable.

Summary of discounting

If discounted, the probable range for consideration is –3% to +3%. The argument for a negative initial rate was felt, based on the arguments above, to be the strongest for the evaluation of the country's building assets.

For cyclical renewals, the majority of scenarios tested (including negative rising to positive) equated to zero discounting. Hence the rest of this paper largely ignores discounting and sets the discount rate at 0%.

Discounting simplified

If carbon fuel is likely to be worth more to future generations than it is to us, the discounting rate should be low or zero. In other words, we are saying that we do not value our lifestyle more highly that that of future generations.

This implies that assets that might have high initial carbon emissions but low annualised emissions may be more valuable to future generations than low initial carbon emissions with higher annualised emissions.

At first this may seem counter-intuitive given the need to reduce emissions now. However, in the future, we may need, but may not be able to economically construct, some types of assets if carbon fuels are not available: A balance is needed between these opposing views.

Much, if not most, of our current carbon expenditure in the buildings sector is spent on the space heating of existing dwellings. This activity produces no assets for future generations. If we wished, carbon could be saved on a large scale by modifying existing homes.

The evaluation of carbon assets

If we set the discount rate at 0% for renewed infrastructures, the important consideration becomes the annualised expenditure of carbon rather than initial consumption due to construction. The remainder of this article largely considers annualised emission rather than initial 'carbon capital'.

Bath University [12], together with a number of other bodies, has undertaken significant work on the embodied energy of common construction materials. Table 1 lists examples of common materials together with the 'cradle to gate' carbon cost:

From these figures, it is possible to produce a materials profile for any given component of a building. Table 2 shows a simple example profile calculation:

For the sample buildings analysed later in

Table 1. Common materials with cradle to gate carbon cost

Fig 5. Addressing some of the concerns with negative and positive discounts

this article, the total embodied spend on the basic structure was found to lie between 350 and 650kg CO_2/m^2. However, this figure can be a lot higher[13] depending on the type of materials, structural layout and 'optional extras' such as appliances, fittings, carpets etc.

Asset lifespan

After adjustment for site carbon costs, future maintenance and demolition, each component was assigned a lifespan[14] modified as necessary for the particular use of the building. Table 3 shows some examples of generic lifespan assumptions.

To evaluate overall the carbon impact of a building, each component can then be summarised into a 'whole building' database to provide the building's total anticipated carbon use per annum.

Infrastructure lifespan

UK energy policy[15,16] suggests that many of our buildings will need to last much longer than would previously have been the norm. If this is correct, traditional survival rates for buildings will need to increase. Others[17] suggest that demolition rates should increase but that residential buildings in particular will need to survive long periods.

Some infrastructure building assets, particularly industrial and some types of commercial, have short lifespans. For many of these cases, it would be inappropriate to assume that the stock will be renewed.

Sample studies

The type of whole building annualised carbon calculation described above was carried out in a study for the Green Building Bible[18] into common alternative residential frame designs. These frame types varied from SIPs frames through timber, concrete, traditional and pre-cast. The frames were designed primarily on an economic basis with a secondary design criteria being low annualised carbon.

These evaluations were for residential buildings. The use of steel as a comparison material was, in these instances, inappropriate for the types of frame considered.

On analysis, the frame types had remarkably similar annualised carbon spends: Although not always true, the general rule for normal structural materials seems to be that the higher the durability, the higher the embodied carbon expenditure.

An example annualised carbon evaluation is shown in Fig 6. In the example, the type of brick chosen for the SIPs frame, from a carbon point of view, is incompatible with the anticipated life of the frame. Hence, the demolition cycle for this relatively high embodied brick skin is related to the lifespan of the SIPs panel. This led to a higher evaluation of annualised content.

Summary

Embodied carbon considerations may become more important in the future. However, minimisation of energy losses is likely to remain the more important consideration.

If we take the view that sustainable development should meet '*the needs of the present without compromising the ability of future generations to meet their own needs*'[19] then embodied carbon expenditure is probably best assessed using whole life costing techniques. Given the ethical discussions above, my opinion is that carbon expenditure should be discounted to zero until the impact of climate change and the financial effects of Peak Oil are better quantified.

For buildings, particularly residential, that are likely to have long term uses, there seems in most instances to be little difference between the choices typically available for structural form. Obviously, the designs must be undertaken with a view to saving carbon for this to be true.

Many of the considerations for individual components of buildings in this article are likely to be covered by the BRE *Green Guide* as specified by the *Technical Guidance to Code for Sustainable homes*[20]. However, the BRE *Methodology for Environmental Profiles of Construction Materials*[21], on which the Green Guide is likely to be based, uses 60-year evaluation periods and may not therefore be appropriate for the assessment of the structure of long life buildings.

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Table 2. A simple example profile calculation

Table 3. Some examples of generic lifespan assumptions

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Fig 6. An example annualised carbon evaluation

TECHNICALNOTE

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