Defining absolute environmental limits for the built environment.

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The question posed by the paper is whether it is possible to define working limits on environmental impacts from the built environment in terms of global carrying capacity. The main focus of the paper is on energy related impacts, since these are global and relatively well understood. Four possible approaches to defining limits are explored: static equilibrium, asymptotic, integral of excess and planned future. The conclusions that emerge from this exploration are that global environmental constraints are very tight, but also dynamic and strongly influenced by the trajectory of social and technological development over the coming century. Their use as the basis for practical, quantitative metrics of sustainability therefore involves a large measure of subjectivity. A fifth approach – the developmental approach - is identified, which instead of focusing on long term external constraints to human activity, focuses on the internal, short to medium term dynamics of the built environment itself. It appears likely that the developmental approach, guided by qualitative conclusions from analysis of global carrying capacity, is likely to be most fruitful.

Introduction

This paper presents a discussion of the nature, purpose, impact and limitations of environmental performance targets for buildings. The main reasons for engaging in this discussion, for revisiting questions that have been addressed on numerous previous occasions, is a pervasive concern that environmental performance targets in use at the beginning of the 21st Century are more arbitrary, more subjective, than we would like.

Efforts to construct environmental targets as part of the development of a range of environmental performance assessment tools began more than 15 years ago (BRE 1990, Cole 2004) and have continued with the development of the Environmental Preference Method (Aninck & Boonstra 1996), the Green Building Tool (Cole & Larsson 1999), LEED (USGBC 2003) and others. These broad environmental performance assessment tools established metrics in a range of environmental impact categories; the categories used by BREEAM 98 were:

- operational energy and CO_2
- transport
- pollution of air and water other than by CO_2
- materials
- water
- ecology and land use
- health and well-being

The Ecopoint scale that underpinned BREEAM 98 was established through a series of focus groups with industry representatives and academics in the UK that were undertaken in 1997 and 1998. The scale was set so that 100,000 ecopoints would be roughly the annual environmental impact of a UK citizen. The function of the focus groups was to establish a broad consensus on the weighting of different environmental impact categories (Howard 1998). The Ecopoint system is however, not normative, in the sense that no clear view is taken of what it is necessary to achieve in global terms, as opposed to what is currently typical. The establishment of these performance metrics therefore leaves open the question of whether it is possible to define absolute standards of performance.

The distinction between relative and absolute environmental standards is one that was explored by a number of authors during and following GBC98. Cooper (1999:323) observed that unless methods for assessing the built environment were capable of measuring performance against carrying capacity criteria, ‘their ability to contribute to the sustainability debate is likely to remain limited’. Kohler (1999:310) stated that environmental performance assessment methods based on relative performance hid ‘the real mass and energy flows which determine the effective environmental impact’ and obscured the ‘differences in impact between individuals and different countries’.

Cole (1999:231) wrote:

> “Broadly speaking, three distinct roles for building environmental assessment methods were evident during the development and testing of GBTool:
>
> - Providing a common and verifiable set of criteria and targets so that building owners striving for higher environmental standards will have a means of demonstrating that effort, i.e., a mechanism to influence market receptivity and demand for higher environmental performance standards.
> - Providing the basis for making informed design decisions, i.e., a design tool that can provide direction and guidance at all stages during the design development by highlighting priority issues and suggesting the possible trade-offs between options.
> - Providing an objective assessment of a building’s impact on the environment, i.e., a tool to evaluate energy and mass flows between built and natural systems and provide a common yardstick for measuring progress towards sustainability.”

He continued:

> “This requires making a distinction between the three roles identified above and making the distinction explicit in the structuring of the assessment method. The paper emphasizes this point by differentiating between what can be termed ‘green’ assessment methods that offer

> relative assessments and 'sustainable' assessments that offer absolute ones."

In an unpublished note written at GBC98 and referred to by Cole, I argued that:

> Physical indicators of sustainability can be normalised […] using the word "normalised" to mean:
>
> > divide one physical quantity by another with the same units so that when the resulting ratio is one, something significant is happening.
>
> Wherever possible, each physical indicator of sustainability should be normalised (in the above sense) by some measure of the total sustainable level of activity described by that indicator. The human principle of equity intrudes here, in that denominators should represent equitable shares of the total sustainable level.
>
> This will give rise to a series of **physically based, carrying capacity normalised indicators** that will be defined on the following scale:
>
> | | |
> |---|---|
> | 0 | no impact |
> | <1 | you have some headroom |
> | 1 | you are using your sustainable fair share |
> | >1 | you are using more than your sustainable fair share |
> | ≈10 | try harder... |
>
> There will be physical indicators where we find it difficult to define the equitable share of a sustainable level of activity. Furthermore sustainable levels are not necessarily constant. Uncertainty about normalisation does not make it pointless to try. Honesty, humility and transparency are the only sustainable attitudes in the face of uncertainty.
>
> I have elsewhere suggested using total sink capacity to normalise carbon emissions. Although we have not identified and quantified all carbon sinks, we can measure total sink capacity directly and quite accurately. We also know how many people there are in the world. It is therefore comparatively easy to construct a normalised indicator of carbon emissions.

The objective of this paper is to revisit this robust, but potentially simplistic position, to see whether it is indeed supportable. Is it possible to place environmental targets on an absolute, objective basis? Is it possible, to use Cole's terminology, to develop viable and uncontentious, absolute indices of sustainable building practice?

Possible approaches to defining absolute limits

In this core section of the paper, I discuss a series of possible theoretical approaches to defining absolute limits. Where numerical illustrations are needed these are framed in the context of global limits to land and sea areas, and energy and climate change related-limits. Some of these approaches are quite clearly simplistic, but their inclusion in this discussion throws useful light on important issues.

Static equilibrium approach

The static equilibrium approach to limits divides the current size of any given resource by the current human population of the earth. In the next few paragraphs, this will be illustrated by calculations of land area and CO_2 emissions. Of these, the simplest are the calculations of land area per person, which underpin Wackernagel's & Rees' work on ecological footprints (Wackernagel & Rees 1996):

fair earth share per person = surface area of earth / current population
$= 5\times10^{14}\ m^2 / 6.6 \times 10^9$
$\approx$ 8 ha per person

fair land share per person $\approx 5\times10^{14}\ m^2 / 6.6 \times 10^9 /4$
$\approx$ 2 ha per person

fair ecologically productive land share per person $\approx$ 2/3 fair land share
$\approx$ 1.3 ha per person

In presenting such calculations, the author is mindful of the criticisms that have been levelled at the ecological footprint approach as a policy tool (see for example, Pearce 2005). These criticisms are however not relevant to the purpose of this section of the paper. The approach to defining limits illustrated in the above calculations suffers from three obvious problems – neither the human population (see figure 1) nor, in many cases, the total size of the resource are constant, and while total areas of land and sea are easy to measure, definitions of ecologically productive areas are problematic, for several reasons. In the case of land:

- they require a judgement about how unproductive land must be before it can be excluded from the total
- they ignore the large variations in productivity of productive land, and the potential for dramatically increasing the productivity of unproductive land through technologies such as irrigation[1]
- they take no account of the possibility that direct and indirect impacts of human activities may significantly reduce productive land areas over the rest of this century; for example, it has been suggested that climate change could lead to die-back of tropical forests from the middle of the century (Cox et al. 2000, Cox et al. 2004).

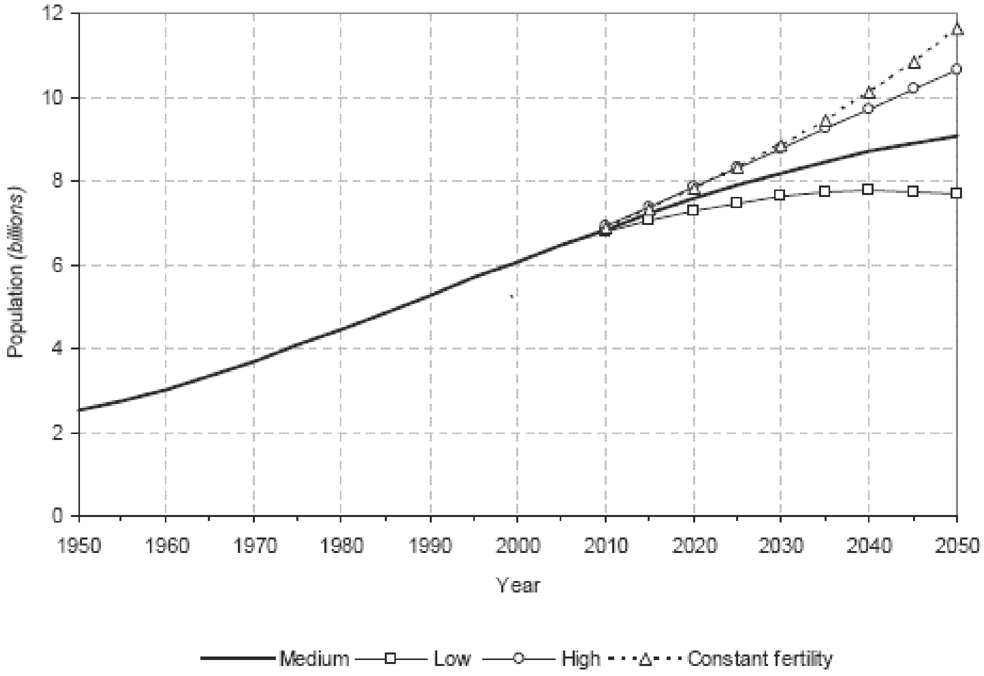

Figure 1. Projections of world population. Source: Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat, 2005.

The fundamental nature of the above problems mean that detailed calculations of land areas are complex and of limited value in the search for absolute targets for the built environment – it is this conclusion and the reasons for that will be carried forward in this paper. However, the author is unwilling to leave the subject of ecological footprinting without one further observation. The primary value of the Wackernagel's and Rees' work lies not in the detailed quantitative work that it supports, but in the qualitative insights that it provides. For example, the ecological footprint concept makes clear that under current conditions, land and sea are the ultimate determinants of wealth. This assertion would be deeply unsurprising to observers from before the industrial revolution, one of whose effects has been to obscure this connection for those of us who have come after. Yet it is clear that the primary function of modern technology is not to replace, but to extend, intensify and mediate the grip of wealthy societies on land and sea.

The discussion of global limits presented in this paper assumes that global resources are divided equally between different societies. It is worth acknowledging the utopian nature of the proposition implicit in this approach. If acted upon, it would mean the end of large-scale, systematic differences between rich and poor, the end of the distinction between North and South, the end of imperialism. It would represent an abrupt departure from the last 5000 years of human history. Whether or not it is accepted as a guide to action, or even as a useful analytical device, it is in this last respect at least, entirely in step with the likely outcome of the next half century.

For the second example of how difficult it can be to define the size of the resource, we can consider the problem of defining limits to CO_2 emissions. Starting from the Bruntland definition of sustainable development as development that satisfies the needs of today without harming the ability of future generations to satisfy their needs, we may argue that, at the very least, the current generation should not change the composition of the atmosphere[2]. To hold atmospheric concentration of carbon dioxide at its current level would require net emissions of CO_2 to be reduced to the level of the net global sink capacity for the gas. This is currently in the region of 3 Gt of carbon per year (Houghton et al 2001). The resulting per capita limit on CO_2 emissions would be approximately 0.46 t/a. For comparison, emissions per capita in the UK in 2005 are projected to have been 2.53 t/a, 5.5 times larger than the estimate based on the static equilibrium approach. Globally, anthropogenic emissions exceed sink capacity approximately 2.5-fold.

The main problem with using net sink capacity as the basis for setting limits to CO_2 emissions is that it is unlikely to remain constant. Two thirds of the global net sink capacity is accounted for by oceanic uptake. The ability of the sea to absorb CO_2 is subject, among others, to the following uncertainties:

- the fact that the solubility of gases in water falls as the temperature rises
- the possibility that both changes in the thermohaline circulation and increases in the temperature gradient in the surface layers of the ocean may change the rate of transport of CO_2 -rich surface water into the depths[3]
- the fact that reduced sea ice cover will increase the area of water in contact with the atmosphere

The first and second of the above mechanisms reduce the ability of warmer oceans to absorb CO_2, while the third may increase it.

The probability of policies that would curtail further growth of atmospheric CO_2 concentration being implemented in the near future is vanishingly small, but if such policies were implemented, and discounting the above effects, the flux of CO_2 into the oceans would fall as the concentration of the gas dissolved in the surface layers of the ocean moved into equilibrium with the atmosphere. Assuming that the capacity of land-based sinks did not vary significantly from the present value of 1 Gt/a, the flux into the oceanic sink would fall towards zero, roughly exponentially, with a time constant in the region of 80 years. Total sink strength would therefore fall by approximately half over the century following a decision to stabilise the atmosphere – figure 2.

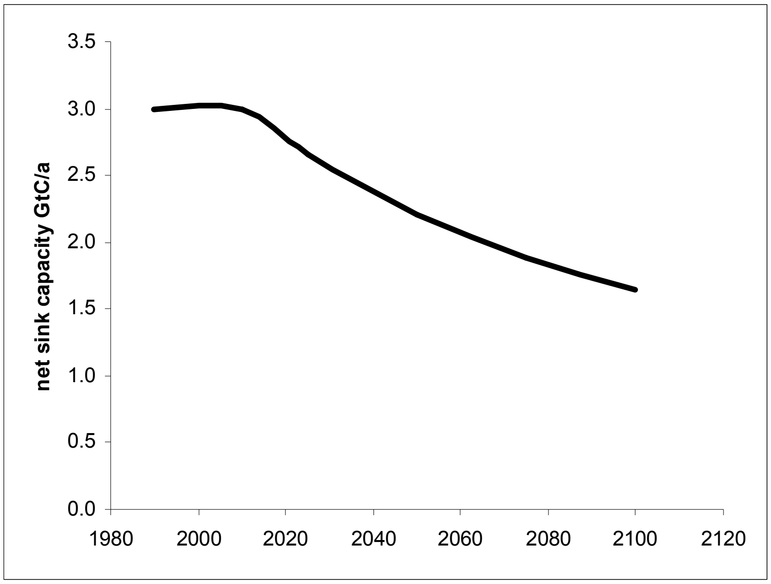

Figure 2. A possible trajectory for global net CO_2 sink capacity following a decision to stabilise the atmosphere in 2010. Assumes that land-based sinks are unaltered over the period shown and that changes to the strength of the oceanic sink arise solely from the stabilisation of the oceanic mixed layer, with a time constant of 80 years.

Asymptotic approach

The above leads naturally onto a discussion of asymptotic limits. The asymptotic approach to limits recognises that the world is currently far from a stable or sustainable state. It assumes, perhaps optimistically, that the human population will stabilise and that resource use will progressively and asymptotically approach sustainable levels. For any given resource, the asymptotic limit may then be defined as the asymptotic size of the resource divided by the asymptotic human population of the earth. In the case of land areas, taking the asymptotic population to be 10 billion:

asymptotic earth share per person = surface area of earth / population
$= 5 \times 10^{14}\ m^2 / 10^{10}$
$\approx$ 5 ha per person

asymptotic land share per person $\approx 5 \times 10^{14}\ m^2 / 10^{10} / 4$
$\approx$ 1.3 ha per person

As noted earlier, there is no reason to suppose that the proportion of ecologically productive land will remain constant and it is possible to conceive of a number of scenarios in which the proportion would fall. But on the assumption that the proportion retains the value currently ascribed to it by Wackernagel & Rees, the asymptotic ecologically productive land share per person would be in the region of 0.9 ha per person.

The asymptotic approach to limits is close to the philosophy of the contract-and-converge movement. The big advantage of limits based on the asymptotic approach is that they are not rendered out of date by predictable changes in the relationship between human society and its ecological niche. But in the case of CO_2 emissions the approach leads to a simple result. For several hundred thousand years before the advent of large-scale human activity, the concentration of CO_2 in the atmosphere remained in the range 180 – 300 ppm (Houghton et al. 2001, Barnola et al. 2003). This suggests that in the absence of more complex arguments, the long-run asymptotic sink magnitude should probably be taken as[4] zero.

It is unfortunately hard to avoid more complex arguments. It is unlikely that in the face both of the impending extent of human development over the course of this century and of climate change itself, that land-based sinks will remain constant or that absorption by the oceans will be unaffected. As noted earlier, there are grounds for expecting significant land-based sinks of CO_2 to reverse in the second half of the century and, in addition, for higher temperatures to trigger significant emissions of methane. It is clear that once the biosphere became a major net source of greenhouse gases, the importance of anthropogenic emissions of fossil carbon from energy conversion would diminish sharply, possibly to the point of irrelevance. Were such a point to be reached, the luxury of being able to consider measures to slow and/or halt climate change would have been foregone, and the most pressing problem would be how to adapt to the new conditions with the minimum loss of human life and culture (Lovelock 2006).

That such an outcome might be possible is indicated most persuasively by the fact that it appears to have happened once before, at the end of the Permian. There remains more uncertainty about the sequence of events that resulted in the largest mass extinction event of the last 600 million years than there is about the smaller and more recent extinction event of 65 million years ago. Furthermore, the nature of the planet at the end of the Permian was significantly different from today – not least in the disposition of the continents. Nevertheless, recent literature (Benton & Twitchett 2003, Kiehl & Shields 2005) establishes the plausibility of a model based on an initial release of CO_2 from large scale and prolonged volcanic eruptions in what is now Siberia, which caused an initial rise in global temperature, which in turn triggered a massive release of methane from methane hydrates on sea floors and tundra, which led, in the words of Benton & Twitchett (2003:358), "to an ever-worsening positive-feedback loop, the 'runaway greenhouse'."

It has proved difficult to discuss the possibility and policy implications of such a runaway greenhouse effect without appearing to undermine the case for prompt and vigorous action to reduce CO_2 emissions. The case for such action would indeed be weak if the scientific community were certain that such action could affect neither the extent nor the rate of warming, nor reduce the probability that initial anthropogenic warming would be large enough to trigger large scale biospheric releases of greenhouse gases. If on the contrary, there appeared to a significant probability that prompt action might achieve all of the above goals, then the case for such action would be strong. This statement can be framed economically: the amount that can rationally be spent to avoid a severely negative outcome depends on extent to which expenditure is expected to reduce the probability of that outcome, multiplied by the costs that would be ascribed to the severely negative outcome, should it come about. The non-zero probability that a runaway greenhouse effect may already be unavoidable is therefore balanced by the very high costs that would be likely to be ascribed to it [5].

The balance of opinion among climate scientists appears to be that several more tipping points almost certainly exist, but they are unlikely to be reached before the end of the 21st Century and are still, in principle, avoidable (Hansen 2005, Schellnhuber et al. 2006). The prevailing uncertainty about where, in terms of the magnitude of initial warming that would be needed to reach them, such tipping points may lie, strengthens rather than weakens the case for prompt and vigorous action to avoid reaching them.

The reason for this extended discussion is that it raises the interesting possibility that the range of possible future climates accessible as a result of human activity might in the long term be discontinuous. The accompanying uncertainties make it impossible to define asymptotic limits except in probabilistic terms, and, over a significant range of possible futures, likely that if they were so defined, they would be negative.

Integral of excess approach

With different degrees of sophistication, both the static equilibrium and the asymptotic approach focus on the requirements of sustainability. The integral of excess approach focuses instead on the magnitude and duration of departure from sustainability[6]. The argument, in the case of climate change, is that because of the pressing nature of the problem, what is important is not the asymptote, but how fast we can approach it and how much damage we do on the way. The approach is illustrated below (figure 3).

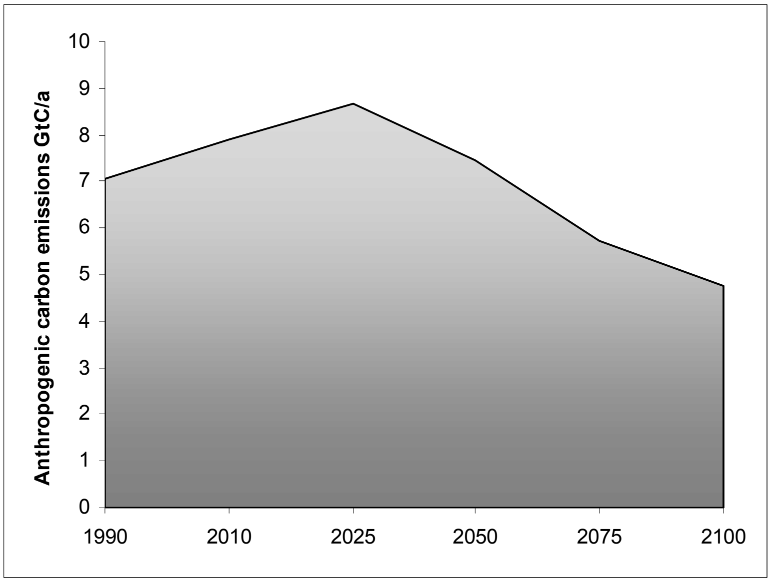

Figure 3. Anthropogenic carbon emissions under IPCC scenario IS92c (Nakicenovic & Swart 2000). The area under the curve, shaded in grey, represents the integral of the excess of actual emissions over the assumed long term sink capacity – in the case of this scenario, a total of some 770 Gt of carbon over the period from 1990 to 2100.

One of the earliest examples of the integral of excess approach was provided by the IPSEP project (Krause et al. 1989)[7]. Despite its age and the fact that is has since been overtaken by the work of the IPCC, this early study very clearly illustrates the principles, implications and limitations of the integral of excess of approach.

On the basis of a detailed review of the sensitivity of land-based eco-systems to climate change, the IPSEP team proposed an upper 400 ppm limit on atmospheric CO_2. Further work suggested that this would be equivalent to a global fossil carbon budget of 300 Gt. The next step was to propose a set of rules for partitioning this budget between industrialised and developing countries – in the end, the approach taken was to assume a half-and-half division. The resulting scenarios are shown below.

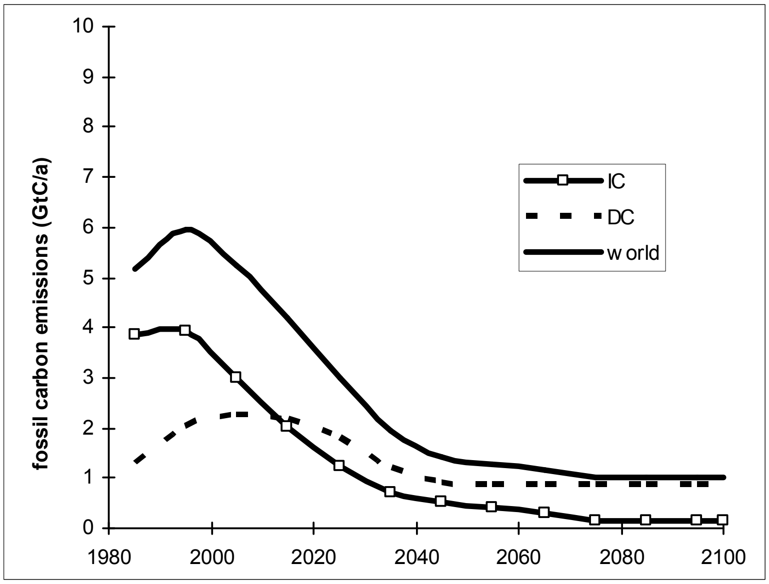

Figure 4. Carbon emission scenarios based on 300 Gt global fossil carbon budget, split equally between industrialised countries (IC) and developing countries (DC). After Krause et al. (1989).

It is worth noting that very similar arguments to those presented by Krause et al. were used as the basis for the German Parliamentary Enquete Kommission's recommendations (Bundestag 1991)[8]. This document and the analysis that it represented provided the strategic background for the highly influential Passivhaus standard[9] (Feist 1998).

As a basis for well-defined absolute limits to CO_2 emissions, the approach presents a number of problems. The least convincing part of the IPSEP study was the attempt to argue for 400 ppm as an upper limit to atmospheric CO_2 concentration, which was then used to define a global fossil carbon emission budget for the period from 1990 to 2100. This is not because such a limit is unsupportable, but because arguments in this area are unavoidably speculative, complex and dependent upon judgement.

Two further problems associated with this approach relate to limits to integration and the assumption that impacts on the environment are identical regardless of when, within these limits, emissions take place. The first problem is largely side-stepped by the IPSEP carbon emission scenarios, since under these, emission rates are close to zero by the end of the 21st century. But scenarios in which CO_2 emissions remain high at the end of the century beg the question of the significance of emissions in the 22nd Century. This second problem arises because the earlier a given quantity of CO_2 is emitted, the larger its impact on climate by any given subsequent date - because of time lags in climatic system, primarily associated with thermal capacity of ocean, emissions that take place over the next quarter century will have more impact on the climate of 2100 than emissions that take place in the last quarter of the century[10].

Problems of context

A problem common to all of the approaches considered above is how to convert global limits to human activity into constraints on the built environment. Related to this is the problem of accounting for the interactions between the built environment and of the wider technological context. To be a useful guide to action for the built environment community, it must be possible to translate whole system limits into limits on the built environment and ultimately into design targets for individual buildings and building sub-systems.

In the case of energy, the first of these two problems is commonly addressed by assuming that reductions in CO_2 emissions required at the level of the economy as a whole, apply also to the built environment. The case for this approach is based on the fact that, for most advanced economies, the built environment accounts for about 50% of total emissions. Rigorous global emissions limits become unachievable unless such limits are applied in full to the built environment.

The problem of wider technological context relates in the main to the energy conversion and distribution infrastructure that supports the built environment. The history of energy supply over the last century shows sustained and powerful downward trends in the CO_2 emissions associated with supply both of electricity and fuels for direct combustion to buildings. The trend for electricity is shown in figure 5. The point about this figure is that the trend can be extended for several more decades based on incremental improvements to existing technology. Crucially, the future paths indicated in figure 5 can be achieved by a range of different mixes of technology, all more or less credible. For example, zero carbon electricity can be delivered by renewables, nuclear and so-called clean coal using carbon sequestration in almost any proportions. Given the wide range of technological solutions available, coupled with recent political pronouncements on the importance of reducing CO_2 emissions, it appears likely that the long term trend will continue downward and that a factor of ten reduction over the period from 1950 to 2050 is possible.

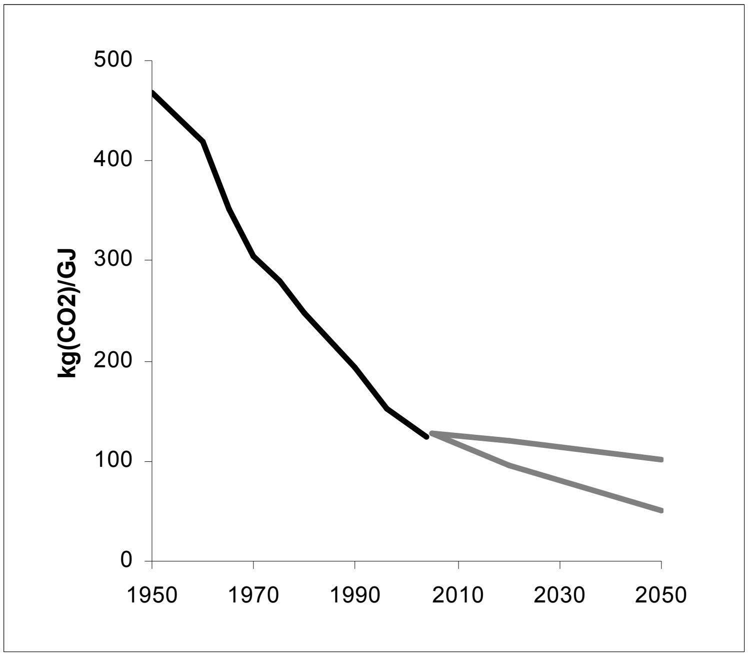

Figure 5. Carbon intensity of UK delivered electricity from 1950 to 2004, and possible future paths assuming electricity generated by combined cycle gas turbines (efficiency increasing from 47% in 2004 to 60% in 2050) plus a proportion of zero carbon electricity varying from zero to 50% in 2050. Based on data from Digest of UK Energy Statistics (DTI 2005).

At present, in most countries, the carbon intensity of delivered electricity is two or three times as high as the carbon intensity of natural gas. This means that electricity consumed in buildings accounts for around 50% of total CO_2 emissions from the built environment. Yet much of the research and most of the practical measures undertaken over the last quarter century to reduce the environmental impact of buildings have been directed at reducing emissions from space and water heating.

The potential impact of combining continued vigorous end-use measures in the housing sector with continued decarbonisation of the electricity supply system was explored in a recent PhD thesis by Johnston (Johnston 2003, Johnston et al. 2005). The result was to make a 60% reduction in sectoral CO_2 emissions by 2050 comparatively straightforward to achieve. Indeed the study found much larger reductions to be possible if low carbon electricity were combined with heating systems based on heat pumps. The point can be illustrated by reference to the Passivhaus standard. As noted earlier, this reduces emissions from space heating by 80-90%, but actually only halves emissions for all end uses under current conditions (Schnieders & Hermelink 2006). Remaining emissions from dwellings built to this standard are dominated by electricity used by lights and domestic appliances, which is unaffected by the thermal envelope measures that form the core of the standard. But a halving of the carbon intensity of delivered electricity in conjunction with the Passivhaus standard would achieve an overall reduction in direct emissions of the order of 75%[11].

The main conclusion from this brief discussion of the interactions between the built environment and electricity supply systems is that, in addition to other sources of uncertainty, technical performance goals for the built environment are powerfully dependent on parallel developments in other categories of infrastructure. Studies which assume a static electricity supply system are likely significantly to overestimate the difficulties inherent in reducing the CO_2 emissions from the built environment (see for example, Boardman et al. 2005).

Planned future approach

The importance of technology and policy context revealed in the foregoing brings us to the planned future approach to limits. The planned future approach deals head-on with context, by specifying the context in as much detail as is necessary to constrain all major sub-systems. Examples of such futures include the scenarios presented in the Energi 21 plan for the Danish economy (Danish Ministry of Energy and Environment 1997) and, going further back in time, the work of Leach et al. (1979) and Olivier et al. (1983). The recent work of Lovins et al. (2005) contains significant elements of a planned future.

Planned futures are most commonly generated either to support or to challenge national policy. In the former case, the overt goal of the work is to provide a detailed planning framework for decision making throughout the economy. It is however often possible to discern a secondary goal, of advocacy for the futures thus described. In the second case, that of studies aimed at challenging existing policies, the balance of these two goals is reversed and such studies are probably better thought of as alternative rather than planned futures. Despite the different goals of the two approaches, there do not appear to be systematic differences in the levels of detail present in each. Detail is required both to support strategic decision making and to challenge a prevailing climate of opinion.

From the perspective of attempts to define absolute indices of environmental performance planned futures overcome some of the formal problems identified for the static equilibrium, asymptotic and integral of excess approaches. But indices based on such futures are contingent on structures of analysis and assumptions that delineate but ultimately cannot banish the fundamental uncertainties associated with guessing the future – which is unknown because it has not happened yet. More practically, planned futures are rarely built with the objective of calculating absolute environmental limits to human activity and are rarely global in scope – not least because of the cost of constructing them. Finally, planned futures are often overtly partisan – constructed to build rather than to represent consensus[12]. They are therefore unlikely to be able to deliver uncontentious measures of environmental impact.

Developmental approach

One of the most important messages from the above is that it is effectively impossible to define precise absolute environmental targets for the built environment. The most that one can conclude is that in key categories, current environmental impacts exceed by many times what can be sustained. One can go further and note that it does not matter greatly whether targets are based on the assumption that a three-fold reduction in environmental impact is sufficient to achieve sustainability, or that nothing less than a factor of ten is enough. Either case renders most existing infrastructure environmentally obsolete, particularly if continued economic growth at anything approaching historical rates is assumed. Against this background, the absolute level at which targets are set is less important than the direction in which they point. The empirical measure of the effectiveness of such targets is their impact on innovation, not the degree to which they embody an absolute external measure of sustainability[13].

The author's own experience of the process of developing the energy performance requirements for the 2006 revision of Part L of the Building Regulations for England and Wales[14] suggests that key factors in success of developmental targets are likely to be:

- their relationship to regulation and other systems for incentivising the reduction of environmental impact – targets that form the basis for regulatory standards can be powerful agents for change
- their relationship to currently available technology – energy targets must challenge but not overwhelm the capacity of industry to deliver improved performance
- they must be pragmatic, reflecting current and emerging technological and market opportunities
- they must be dynamic, with clear programmes for revision – targets which are not regularly revised eventually act as a brake on rather than a spur to technological innovation
- the process for setting and revising targets must take account of the lead times of the systems and industries that they affect; the further ahead stakeholders can see, the more demanding the targets that can be set
- the importance of devising targets that segment rather than homogenise markets – targets are likely to have the largest impact on innovation if they increase rather than reduce the range and diversity of business opportunities within the sector
- the importance of framing regulation in a way that maximises tendency for integration throughout the industry, including the design process and the supply chain
- the importance of consultation as part of a process for building consensus, coupled with a clear recognition within the business environment of the importance and validity of corporate social responsibility
- the importance of an overarching long term environmental agenda established by government – in the case of the 2006 revision to Part L of the Building Regulations for England and Wales, this has been

provided by the 60% reduction commitment in the Energy White Paper (DTI 2003)[15].

Developmental targets need to be both backward and forward looking. Rather than being defined in terms of global limits to carrying capacity, they are probably best defined in terms of current performance. Thus the energy standards that underpin the 2006 revision to Part L of the Building Regulations for England and Wales, are based on the estimated performance of buildings built to the preceding 2002 standard, coupled with a consensual view of the rate of change that could be tolerated by the construction industry in this market. While the 60% reduction commitment contained in the 2003 Energy White Paper that preceded the review played a powerful role in shaping the climate of opinion within which it took place, the resulting standards are not directly or mechanically related to the 60% reduction commitment. Finally, there was a clear recognition in the consultation document that initiated the public review process (ODPM 2004), that a single review of energy performance standards would be insufficient to move the construction industry of a major industrial country to a sustainable state, and that this review would therefore be merely the first of a series. The function of this particular standard was not to move the industry across the chasm to a sustainable future but to define the next stepping stone and enable the industry to move to it.

The relationship between the above process of regulatory development and environmental performance assessment schemes in use in the UK is instructive. The unexpectedly rapid development of Part L since the publication of the Energy White Paper caused it to overtake environmental performance assessment schemes such as BREEAM, particularly in the housing sector (Rao et al. 2000, ODPM 2005). These in turn are now undergoing rapid development to ensure that they can continue to fulfil their most important original function – to provide guidance for and means of recognising developments that go beyond minimum regulatory requirements. This is a clear empirical demonstration of the developmental and pragmatic nature of these environmental performance schemes.

During the writing of this paper it became clear that the emphasis on pragmatic incrementalism in the description of developmental targets was potentially misleading. Such an approach does not automatically mean that problems such as climate change are not being taken seriously nor does it mean moving slowly. Moreover a developmental approach does not remove the need for a long term strategic vision nor preclude medium or long term strategic decision making. But it does depend on the view that not all factors can be dealt with by such decision making, that many decisions are best taken over shorter cycles and that the complexity of the factors and processes that determine energy use in the built environment renders it poorly suited to approaches to change that are unable to harness and promote learning within relatively short review cycles[16]. If such review cycles can be effectively implemented it is at least possible that a developmental approach may result in faster rates of change than other approaches.

Conclusions

The central purpose of this paper has been to examine the proposition that it is possible to define environmental performance standards for the built environment in terms of global carrying capacity.

The main focus of the paper has been on energy related impacts, reflecting the perception that this is the category of impact where such an approach is most likely to meet with success. Four possible approaches to defining limits are explored: static equilibrium, asymptotic, integral of excess and planned future. The central qualitative conclusion that emerges from this exploration is confirmation that current environmental impacts are unsustainable by large factors. But while analyses of global constraints provide essential qualitative insights into the problems of sustainability, the quantification of global constraints is unavoidably uncertain. Major sources of uncertainty include the potential impact of climate change on the behaviour of the main carbon sinks, with the possibility that land-based sinks will reverse during the second half of the 21st Century. Such changes are also likely to impact on timber production in the currently most productive tropical regions. A second area of current concern is the possibility that current models of ice sheet dynamics seriously underestimate the risk of ice sheet collapse within 1 to 3 centuries (Hansen 2005).

The process of translating global targets into specific targets for buildings and building systems introduces further uncertainties. Some of the most interesting surround possible developments in energy supply systems, most obviously in electricity generation. Significant reductions in the carbon intensity of electricity impact on overall CO_2 emissions both directly, by reducing emissions associated with current end-use systems, and indirectly by increasing the viability of new end-use technologies such as heat pumps. The potential for such interactions is considerable and increases the further into the future one looks. Global constraints cannot therefore provide a unique, objective and unambiguous metric for built environment performance standards.

The alternative to basing targets on long term external constraints to human activity is to base them on the internal, short to medium term dynamics of the built environment itself. This approach is referred to as the developmental approach. Such targets, set pragmatically, regularly revised, forming the basis for regulation and para-regulatory systems and promoting and sustaining innovation appear likely to be most fruitful. On this view, the future emerges from a series of short and medium term decisions and the importance of the long term global analysis is largely symbolic[17]. This is, however, to underestimate the importance of a clear qualitative view of long term environment constraints. Experience both from the UK and Germany suggests that such a view is essential to the establishment of an environment and climate of opinion that makes it possible to make and implement appropriate short to medium term decisions. Within this model of environmental targets and decision making, the analysis of possible long term goals for the built environment provides a qualitative framework within which to build the consensus needed to drive developmental goals and vigorous and concrete short-to-medium term action.

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Endnotes

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[1] The historical record of sustainability of irrigation systems is mixed, and many systems have failed completely. Failures include much of the "fertile crescent", reduced to desert since classical times and, more recently, the Aral Sea basin (IFAS 2000). Partial failures include the Murray-Darling basin in Australia (Natural Resource Management 2004).

[2] But note that holding the composition of the atmosphere constant does not prevent further climate change. For this and other reasons, there is no direct and simple argument from the Bruntland definition of sustainability to a prescription for reduced emissions of greenhouse gases.

[3] A complete collapse of thermohaline circulation as a result of warming of surface layers appears to have played a part in the end of Permian extinction event (Benton & Twitchett 2003, Kiehl & Shields 2005), though against a very different arrangement of land masses.

[4] Significant departures have probably taken place, for example during the Permian extinction event. Lovelock has suggested that there may be a long term tendency for atmospheric CO_2 concentration to fall, balancing the increased intensity of the sun (Lovelock 1989:125).

[5] The author is however unaware of any economic analyses of runaway climate change.

[6] The difference between these two approaches can be thought of in terms of the cry of St Augustine, "Oh Lord, make me virtuous, but not yet!" The asymptotic approach focuses on the nature of the future state of grace, while integral-of-excess approach focuses on the extent of the sin in the meantime.

[7] The author explored some of the implications of the IPSEP scenarios in a previous paper (Lowe 2000).

[8] Wilfrid Bach, a co-author of the final IPSEP report, also served on the Enquete Kommission.

[9] The Passivhaus standard is built around an absolute primary energy target of 120 kWh/m^{2}a and a target of 15 kWh/m^{2}a for space heating (Informationsgemeinschaft Passivhaus Deutschland, undated). These limits are intended to reduce energy demand for space and water heating by approximately 90% compared with the German housing stock and by approximately 80% compared with new housing, in line with the goals set out in the early 1990s in the report of the Enquete Kommission of the German Parliament (Bundestag 1991:156-192).

[10] One reviewer of the present paper questioned the emphasis given to the 18 year old study IPSEP study of climate mitigation compared to more recent work under the aegis of the IPCC. The main reason for this is that the IPCC scenarios are based heavily on the internal dynamics of the global socio-economic system. In contrast, the IPSEP study started from a clearly defined climate change goal (based on a conservative view of the maximum rate of temperature rise to which land-based vegetation could be safely exposed) and then constructed and analysed a carbon scenario that would achieve this goal. The IPSEP study therefore more clearly illustrates both the implications and limitations of attempting to calculate top-down environmentally based limits to human activity than do the IPCC scenarios. Hansen's recent 1 K, 475 ppm scenario (Hansen 2003) was based on an approach similar to that of the IPSEP study, but with a warming limit based on a conservative view of the stability of polar ice sheets rather than vegetation. Hansen notes that he faced criticism for publishing a paper that could be seen as independent and critical of the position taken by IPCC and states that it is important that IPCC conclusions not be considered as being close to gospel truth.

[11] At the same time, it would halve emissions associated with electricity used to build dwellings to this standard.

[12] A final point is that the implementation of planned futures, particularly where these represent a significant move away from business-as-usual, requires high and sustained levels of consensus – as illustrated by fate of the Danish Energy 21 plan following the change of government in Denmark in 2001.

[13] This is not to say that the outcome for climate would be the same regardless of whether in 2050 emissions had actually been reduced by a factor of three or a by factor of 10. The former would be consistent with a world in which global emissions were more or less at today's levels, and in which climate change continued unabated. The latter would be consistent with a sharp reduction in global emissions of CO_2 and the possibility that potentially dangerous climate change might be avoided. The point that is being maintained here is that

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in the short-to-medium term, any non-marginal reduction target is potentially revolutionary. The key to the ultimate outcome are the conceptual shifts and processes of innovation that are precipitated by the adoption of the long term target, not its precise magnitude.

[14] The Building Regulations of England & Wales are divided into 14 parts, running with some omissions, from A to P. All are available online (http://www.odpm.gov.uk/). Separate regulations are published for Northern Ireland and for Scotland.

[15] Note however that the relationship is not mechanistic – the Energy White Paper legitimises Part L but does not prescribe it.

[16] Effective learning does however require feedback. Lack of empirical knowledge about energy use both in new and existing buildings is a significant constraint on the development of policy and if left unaddressed will become even more problematic in the future.

[17] Some readers may find that this comes close to being a restatement of the view of history as “one damn thing after another”. What distinguishes it from ODTAA is the long term qualitative framework that underpins and guides it.