SUSTAINABLE BUILDING ISSUES FOR THE 21ST CENTURY

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This discussion paper provides an overview of the range of issues that may be faced over the next century by the construction industry in various regions. The scope of discussion includes climate change impacts and issues of fuel, water, and materials scarcity. It outlines the links between these impacts and the building sector and proposes a strategy to address them. Finally, likely developments in the building sector over the next decades are suggested.

1. INTRODUCTION

The issue of green and sustainable building has become a subject of intense interest in many countries during the last decade, extending to practitioners as well as policy analysts and researchers. In addition to government-funded research activity in new technologies, practical action is being taken at the level of manufacturers, developers and practitioners in the form of energy regulations and performance certification for equipment and buildings. The principal driver is climate change and its impacts on the built environment, but other issues such as cost escalation and shortages of fuels and materials will also affect the sector. However, coherent and integrated strategies are not evident, although the required ingredients are well known.

2. ISSUES FACING THE BUILDING SECTOR

2.1 Climate Change implications

A considerable number of papers produced by IPCC and others have outlined the science behind climate change predictions, possible impacts, mitigation measures and possible adaptation. In this short paper, we attempt only to identify some of the key links between climate change and the building sector.

The anthropogenic driver of climate change is the increasing concentration of greenhouse gases (GHG) in the atmosphere, chiefly CO_2. The World Resources Institute (WRI) estimates[1] that buildings are directly responsible for 15.3% of global GHG emissions. To this should be added a share of industrial emissions (for materials) and for road transport. A very conservative estimate of building-related GHG share would therefore be in the range of 20% to 25%, and this would be higher in developed countries. It is therefore clear that a strategy for the diminution of GHGs will have to include the building sector as a main target for GHG reductions.

One of the most sobering aspects of the work done by the IPCC is their exposition of the time scales involved[2]. IPCC demonstrates that CO_2 emissions today have a positive feedback on global mean temperature that lasts for over one hundred years, and the resulting sea level rise due to thermal expansion lasts well over a thousand years. Even if action to reduce greenhouse gases is immediate, the effects of current emissions are still to come. Action is therefore needed, but in addition to the difficulty of obtaining political action, the slow rate of change in the building sector creates a special problem.

The overall impacts are also clearly identified by IPCC, and the following excerpts from the 2007 IPCC report[3] identify some major climate trends for the 21st Century:

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[1] World Resources Institute website at www.wri.org
[2] See IPCC 2000 report
[3] *Working Group II Contribution to the Intergovernmental Panel on Climate Change, Fourth Assessment Report; Climate*

Figure 1: Excerpt from IPCC scenario

Warmer and fewer cold days and nights over most land areas	virtually certain
Warmer and more frequent hot days and nights over most land areas	virtually certain
Frequency of warm spells / heat waves increases over most land areas	very likely
Heavy precipitation events…	very likely
Area affected by droughts increases	likely
Intense tropical cyclone activity increases	likely
Increased incidence of extreme high sea level	likely

IPCC also predicts that temperature increases will be most pronounced towards the end of the century, with the Northern Hemisphere the most exposed. Another major impact will be changes in precipitation patterns, with mid-latitude regions, up to and including southern Europe suffering 10% to 20% reductions in annual precipitation. River flooding is likely to be a more immediate problem, as some rivers and surrounding terrain will be unable to cope with heavy rain events.

Sea level rise from the melting of ice fields and from the thermal expansion of warmer oceans is a certainty, but the extent and speed of this phenomenon appears to remain a matter of some debate. However, a recent paper[4] gives no room for complacency:

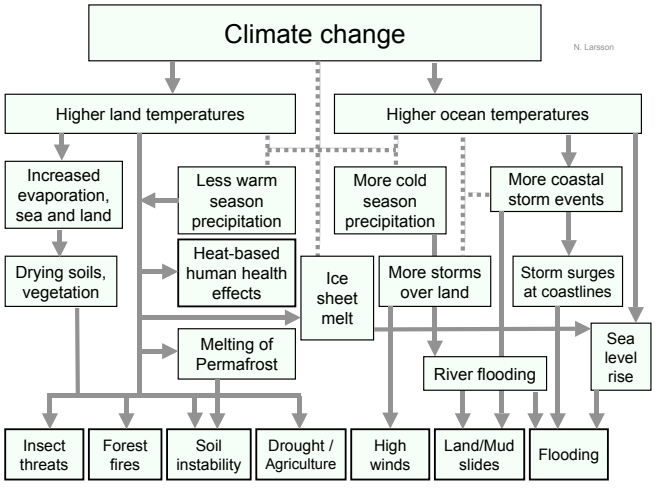
> *If equilibrium sea level rise is many meters, a response time of centuries provides little consolation to coastal dwellers. They would be faced with intermittent floods associated with storms and continually rebuilding above a transient sea level. Thus we suggest that sea level change may define a low level for global warming that constitutes dangerous change, due to the large concentration of people and infrastructure along global coastlines.*
> *Present understanding of ice sheet response to global warming does not allow sharp definition of a "dangerous" level, but BAU scenarios are surely well into the dangerous regime. Even global warming of 1 C conceivably could produce a long-term sea level rise of several meters (Otto-Bleisner et al., 2006; Overpeck et al., 2006). However, climate forcing on the ice sheets is far smaller with global warming <1 C than with global warming 2–3 C, and the resulting slower changes of the ice sheets would allow a better chance to develop climate mitigation strategies or adapt to sea level change.....*
>
> *Global warming in "business-as-usual" (BAU) climate forcing scenarios, for climate sensitivity consistent with paleoclimate data, is at least 2–3 C by 2100 (relative to 2000) and still increasing rapidly. Implications include an ice-free Arctic in the warm season, other regional climate changes outside the range of historical experience, and initiation of ice sheet changes that presage future sea level change out of humanity's control. The Earth, in a broad sense, would be a different planet than the one that existed for the past 10 millennia.*

In the Conclusions of the same paper, the authors state that:

> *Nevertheless, we can conclude that the world is already close to the dangerous level. The sharpest criterion is probably maintenance of long-term sea level close to the present level, as about one billion people live within 25m elevation of today's sea level. Uncertainty exists about the time for ice sheets to respond to climate change (IPCC, 2001; Hansen, 2005a), but analyses in this paper and comparison with atmospheric composition in prior warm periods (Hansen et al., 2007b) suggest that a CO2 level exceeding 450 ppm is almost surely dangerous, and the ceiling may be even lower.*

Figure 2 outlines a composite picture of the interaction between some of the major anticipated climate change impacts, while Figure 3 explores the links between some of the major anticipated climate change impacts with building sector concerns.

Figure 2: Overview of climate change effects that affect the built environment



Change 2007: Climate Change Impacts, Adaptation and Vulnerability; Summary for Policymakers, 6 April, 2007.

[4] *Dangerous human-made interference with climate: a GISS modelE study*; J. Hansen et al in Atmospheric Chemistry and Physics, Vol. 7, 2287-2312, 2007.

Figure 3 More detailed linkages between climate change effects and the built environment

Cause	Intermediate effects	End Result
Higher global temps	Summer temps. Melting permafrost Need more AC Insect population	Population health Methane, structural Operating cost More energy & GHG Repair / control
High winds	Wind damage	Repair / rebuild
Drought	Water supply Soil instability Forest fires	Ration or import Prohibit new construction Repair / relocate Rebuild / relocate
Rain & Flood	Flood damage	Repair / relocate
Sea level rise	Vulnerable areas	Relocate
Note that all end results also involve economic loss		

There will be multiple impacts on the building sector and complex interactions in some areas. The discomfort and health problems caused by higher summer temperatures will lead to more demand for air conditioning. Another factor increasing cooling demand is likely to be the increasing importance of the urban heat island effect. Both of these factors will increase power demand, which in turn generates more GHGs as well as smog. This vicious circle will be one of the most problematic of all climate change impacts on the building sector.

Higher temperatures will also allow damaging insects to migrate into new regions and, in Arctic regions, will promote permafrost melting which in turn creates serious structural problems and may lead to large releases of Methane, a powerful greenhouse gas. The combination of higher temperatures, higher evaporation rates and drought will increase the probability of forest fires.

An important impact of higher temperatures is the effect on human productivity and health. The heat wave in Europe of 2003 caused an estimated extra mortality of about 14,800 persons in France, and about 35,000 in Europe as a whole.[5] In this context, the urban heat island effect is of special concern, since it adds to temperature stresses. Aerial thermography carried out by B. Dousset[6] showed that the added temperature in central Paris was in the order of 4 deg.C to 5 deg.C during the time of the heat wave, and similar studies in Athens[7] have shown differentials of 12 deg.C between urban central areas and the periphery. This implies that, with future higher temperature conditions, the added stress of the urban heat island effect may be enough to cause many additional deaths in some cities. No estimates of losses in productivity during heat waves are available, but they are probably substantial.

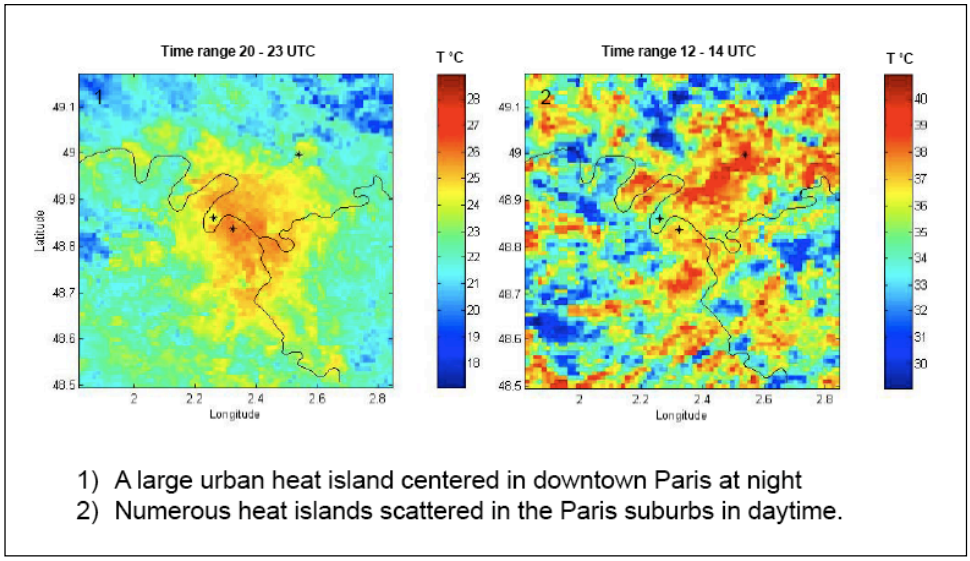


Figure 4: Urban Heat Islands, Paris, August 4-13, 2003, B. Dousset

It is already well known that buildings in regions exposed to hurricanes or cyclones are quite vulnerable to wind and storm surge damage, and this can force relocation and rebuilding as well as punishing increases in insurance costs. Unfortunately, coastal and riverside

[5] Lessons from the 2003 heat wave: a French perspective; Jean-Luc Salagnac in Building Research & Information, Vol. 35, No. 4, July-August, 2007

[6] Presentation by B. Dousste to ESA user consultation meeting, Athens, June, 2007

[7] The Mediterranean Built Environment of the Future, undated PPT presentation by M. Santamouris, University of Athens.

locations continue to be favoured for house construction by a significant number of individuals.

Changes in precipitation patterns predicted by IPCC[8] will cause more precipitation in some areas, and less in others. This will affect the location and design of buildings and, where large declines are forecast, will probably limit new development.

Figure 5 indicates that northern hemisphere regions will have increased rainfall, especially during the December to January period, while Southern Europe, Mexico, the Caribbean, North Africa, southern Africa, parts of South Asia and western Australia will have reduced precipitation during both seasons. As with most climate change impacts, these effects will be more visible during the last part of the Century.

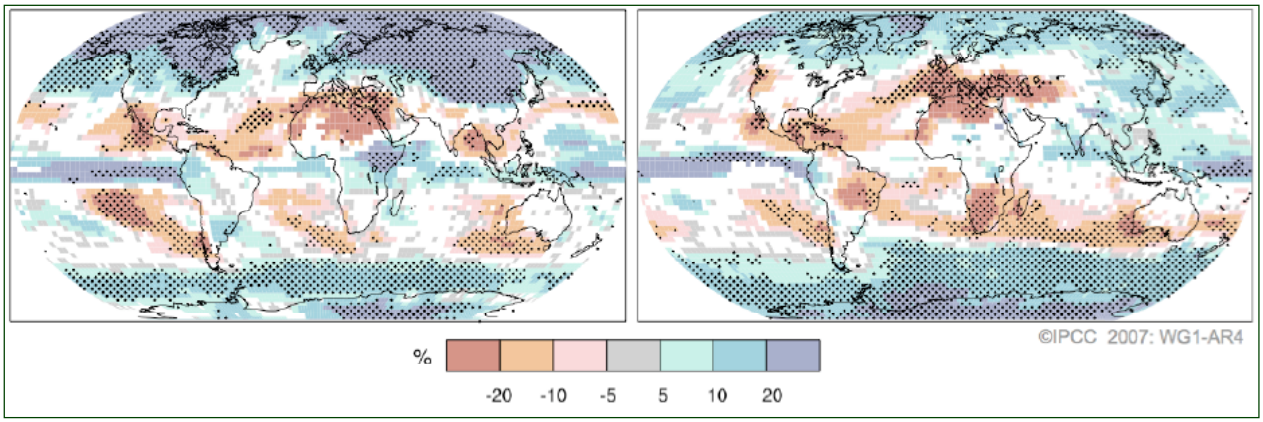
When these effects are combined with freshwater resources that are already limited (e.g. North Africa), or where aquifers are being rapidly depleted, (e.g. Shanghai and Sydney), then the future looks quite dry[9].

converge to make the life of developers, designers and builders especially difficult.

There is a great deal of uncertainty about when oil and natural gas will run out, but no doubt at all that these two fuels will become increasingly expensive and scarce during the 21st Century[10]. As these are the only fossil fuels that can be used at a significant scale to heat buildings, this means that buildings designed today will almost certainly have to be retrofitted for some other form of energy source during its lifetime. Hopefully, affordable renewable energy technologies will emerge in time, but given humanity's tendency to avoid unpalatable facts, it seems more likely that there will be mass conversions to electric power for heating as well as cooling, generated by coal or nuclear. This is not a very good or logical prospect.

Fuel costs and possible shortages will also create problems for automobile owners, especially for those large segments of North American society who have houses in outer suburbs and have one car per adult

Figure 5: Projected Patterns of Precipitation Changes 2090-2099 relative to 1980-1999:
left December to January; right June to August



2.2 Other issues for the building sector: demand, scarcity, supply problems

Climate change impacts are not the only challenges that will be faced by the building industry during the next century. Several of these factors will

occupant. There may be respites in cost hikes in the form of greatly increased fuel efficiencies or car sharing, but no general solution save that of increasing densities in such areas to a point where public transport becomes economical, something that would take decades.

[8] IPCC 2007, based on SRES A1B Scenario.

[9] A BBC radio broadcast on 16 September, 2007, gave the news that the Government of Australia is making water restriction measures permanent.

[10] See predictions made by ASPO, the *Association for the Study of Peak Oil & Gas*, at www.peakoil.net, and predictions of declining natural gas output made in *Canada's Energy Outlook: the Reference Case 2006, Natural Resources Canada*, at ww.nrcan.gc.ca

Another factor to be considered is the increasing prices for certain building materials, such as cement, steel, copper and nickel. Some of the increase is due to temporary shortages caused by the huge demand for cement to satisfy the extremely rapid growth of China and India, but there are also some longer-term difficulties in increasing the supply of certain materials because of increased difficulty in accessing the remaining resources. No doubt suitable alternatives will be developed, using a minimum of fossil fuels, but this will take time.

2.3 Synergistic effects

The problem for the building industry is that all of the climate change impacts and the other trends and effects described above will be playing out at the same time, although the relative importance of trends will vary according to location. For example, developers in SE Australia and southern Spain may be hard-pressed to obtain development permits in the future, as sources of potable water diminish still further, while designers in northern Europe and Eastern Canada may be finding ways of coping with excess precipitation. While policy makers in North America will be trying to reduce the demand for over-sized homes, authorities in London will be establishing policies to encourage the building of flats with more bedrooms, and the Mexican government will be trying to find ways of building housing for the 7 million who are without proper housing; and Latin American countries reportedly[11] have a collective housing deficit of some 17 million dwellings, and as late as 2000, water treatment and electricity services failed to reach between 25% to 50% of the region's population.

In all of these regions, industry leaders will have to deal with these region-specific issues while simultaneously coping with the more general effects of climate change that will slowly emerge, but will accelerate during the last half of this century.

We may retain a sense of optimism, by assuming that we will learn how to cope with climate change impacts and resource deficiencies and that building costs, after rising to deal with these problems, will again stabilize as new efficiencies bear fruit. Despite such optimism, it seems clear that the global building industry will pass through a period of difficult adjustments to changed circumstances.

3. Dealing with difficult circumstances

Having sketched out some of the challenges that will face the industry during the next decades, and perhaps the next century, it is clear that the problems are wide-ranging and will therefore have to be addressed on a broad front. These issues cannot be addressed only by governments or the private sector, but will require close cooperation between all major actors in the industry.

3.1 Establishing goals

We are currently in a transition period, with much of the industry showing an openness to adopt "green" or "sustainable" performance goals, but with much confusion still prevalent as to what these terms actually mean. Then there are some researchers who are working towards the goal of "regenerative" design. Figure 6 provides an overview of how these concepts may relate, along with the more easily understood terms "good practice" and "regulation". It should be noted that as one moves upward from regulation, the scope becomes increasingly oriented towards community design and operation, with the regenerative concept pertaining primarily to eco-regions.

Figure 6: Macro performance goals

	Community scale	Building scale
Regenerative Bring ecosystems back to full health	To be explored	
Sustainable No negative impact on ecosystems	Very little use of vehicles, pedestrian oriented, green space	Very high performance, feed electricity to grid
Green Substantial improvement in environmental performance	Emphasis on higher densities, mixed uses, control of car, provision of public transport	
Good Practice Performance levels achieved by top 25%	Community planning follows conventional suburban path.	Performance levels achieved by top 25%
Regulation Minimum performance according to regulation and/or industry practice	Transport, water, sewer etc. seen as quite separate	Some emphasis on energy performance, but not much else

[11] *Regionalize it! This and other lessons learned from SB04 Latin America;* regional report prepared for Tokyo SB05 conference by Vanessa gomes and Maristela Gomes da Silva; SB05 Tokyo Proceedings, October, 2005.

These are general goals, and must be supplemented with much more specific objectives at each level, but it is quite apparent that the circumstances will require that most new buildings reach a "sustainable" performance level and that retrofitted buildings (about 97-98% of the building stock) must reach "green" performance levels.

3.2 Establishing strategies

At the global level, Nicholas Stern has suggested the following three principles as forming an essential part of a global effort to reduce the momentum of climate change:

- Establishing a carbon price, through tax, trading or regulation, is an essential foundation for climate-change policy;
- Policies are required to support the development of a range of low-carbon and high-efficiency technologies on an urgent timescale;
- The removal of barriers to behavioural change is a third essential element, one that is particularly important in encouraging the take-up of opportunities for energy efficiency. Barriers include a lack of reliable information, transaction costs, and behavioural and organisational inertia.

It will be noted that Stern's prescriptions will require action on a broad front, and it is likely to be difficult to generate the political will needed.

Many policymakers and researchers in the climate change field rightly insist that energy efficiency lies at the core of any GHG reduction strategy. This is quite true, but improved efficiency is insufficient if high incomes and cultural preferences lead to over-sized buildings and housing.

In the field of public and commercial buildings excess is found in interior ski hills in hot climates, grandiose Olympic and Expo facilities or over-sized hotel and conference facilities.

In the housing sector, the average area of new houses in Canada increased 50% during the period 1990-2000[12]. In the USA, the *National Association of Homebuilders* (NAHB) reports[13] that the number of persons per household has shrunk slightly in the last decade, to about 2.6, while the average size of new houses grew by about 40 m^2 to about 240 m^2.

The energy efficiency of housing has improved during the same period, but the savings have been largely nullified by the increase in house sizes and in the proliferation of household appliances. For example, a report on residential appliance use in California[14] shows market saturation in excess of 60% for clothes washers, clothes dryers, refrigerators, dishwashers, ovens, and ranges. California is a mature market, and the energy implications for a country like China are sobering.

The increasing application of space cooling is one of the most worrying trends, since almost all cooling is achieved by use of electricity. Figure 7 shows that cooling has not penetrated greatly into the European building stock, but how long will this last, given higher ambient temperatures and service quality demands?

Figure 7: Cooling Penetration by Region[15]

	Tertiary	Residential
Europe*	<27%	<5%
USA	80%	85%
Japan	100%	65%

* Predominance in Southern Europe (74%)

Other data along the same lines in Figure 8[16] shows typical energy intensity values for space cooling in commercial buildings, in China, USA and selected European countries. The difference between China and other countries highlights differences in level of service for cooling and, again, we must worry if China aims for the same service level for cooling as in the USA.

Figure 8 Annual energy consumption, including cooling, ventilation, lighting and office appliances, according to Yi Jiang, Tsinghua University

Country	China, large floor plate	China, narrow floor plate	France	Norway	USA
Typical annual electric power consumption, kWh/m^2	100-150	20-60	165	226	356

[12] Unpublished data, Canadian Homebuilders Association

[13] *Trends in Sustainability*, undated PPT presentation, US EPA Region III.

[14] *California Statewide Residential Appliance Saturation Study, Final Report*; prepared for the California Energy Commission by Kema-Xenergy, Itron and Roper ASW, June 2004.

[15] *Climate Change: A Focus on Building Energy Use to 2050*, PPT presentation to IEA Future Buildings Forum by Eduardo de Oliviera Fernandes, data from Adnot, 1999, June 2004.

These observations lead us to conclude that efficiency is one part of a required strategy, but a reduction in construction volume and in the demand for level of service quality must be another. The reason is clear: energy consumption that is only 25% of conventional is excellent, but if the building is clearly superfluous, there is still a problem. And if a building is fully cooled when design measures or operating measures could minimize cooling while maintaining acceptable comfort levels, there is an excessively high level of service. Clearly, a carbon tax would provide a useful constraint, although measures would have to be implemented to exempt energy-related renovation activity from such a levy.

Successful strategies for this sector must be broad in extent, including regulations, incentives, technology development, education, training, demonstrations and information dissemination. Good strategies also require the establishment of an initial set of performance targets, and the provision of constant monitoring to ensure that adequate progress is being made. This implies easy access to full sets of performance data for buildings, which is currently difficult because the private sector prefers these to remain private for competitive reasons.

The appropriate macro steps in a policy framework, suitable for application at a local government or national level, can be summarized as follows:

1. Establish challenging performance goals, targets and regulatory requirements for urban areas and for existing and new buildings;
2. Increase the sustainability of urban areas, through an emphasis on high-density and mixed-use areas, serviced by district heating and cooling systems and efficient local public transport.
3. Greatly increase the environmental performance of existing and new buildings and related equipment through lean design, low carbon content and very high levels of energy efficiency;
4. Reduce the volume of production of new construction[17], through development restrictions, incentives for renovation and/or carbon taxes;
5. Monitor performance and revise targets accordingly.

There is much European and North American activity in the fields of standards and regulatory development and in improving the environmental performance of buildings and equipment (1 and 3), but less to date in areas (2) and (5). The most difficult area to address, however, will undoubtedly be the development of measures to reduce production and consumption (4), since this will involve fundamental changes in modern western lifestyles and new methods of measuring economic success.

3.3 Ensure that sufficient and appropriate resources, methods and tools are available

The first pre-requisite is that the human and organizational infrastructure must be capable of establishing the necessary measures. This means first of all that key decision makers in major sectors such as governments, professional associations, building owners and manufacturers must be aware of the major issues on the horizon and must be willing to deal with them. Second, financial institutions must become more familiar with performance issues and assign appropriate valuations to buildings that are certified. Third, technical and management skills within the industry must be at a level sufficient to deal with the complexities of local climate change predictions, development of new technologies suited to local conditions, assessment of performance and renovation needs of the existing building stock and development of strategies for improvement of new stock. The lack of skills for high-performance renovation is a major problem in the UK as stated by Lowe:

> *Recent work (Lowe et al, forthcoming) shows that the empirical heat loss from individual new UK dwellings may exceed predictions by as much as 50%….The problems as a whole stem from the combined effects of low levels of knowledge and skill, poor supervision, poor corporate management/ responsibility coupled with structural problems such as excessive use of sub-contracting and from the use of construction methods that have evolved piece-meal over the last thirty years…*[18]

Radical improvements in performance of the built environment means that inter-disciplinary work will be

[16] Adapted from *Living Style: the key factor for building energy efficiency*; Yi Jiang, Tsinghua University, June, 2007.

[17] One may hope for a diminution in the production of buildings that are either of dubious functional utility, or have excessive area or volume relative to functional needs, and the number and power output of related appliances and equipment,. But such changes require major changes in values and lifestyles, so they are not likely.

[18] Pg 348, special issue on Climate Change, in *Building Research & Information*, Volume 35, No. 4, July/August, 2007.

required, involving politicians, scientists, building designers, planners and transportation specialists. Some action will result from the implementation of effective regulations, but the cost savings resulting from energy efficiency is a powerful motivator, where building owners and operators are fully aware of the possible savings. Experience in Europe and North America also indicates that private sector firms can get more business if they develop special skills in environmental design and construction.

4. What's Likely To Happen

Given the complexity of the issues facing us, and the great variation in regional conditions and priorities, it is interesting to speculate on what the future may look like by mid-century. It should be noted that not all the trends discussed are desirable, and that some useful trends may need support to reach fruition.

4.1 Context

- *There will be very high fuel costs everywhere and a scarcity of fossil fuels in some regions.*

  Specialists in the area of energy cost predictions appear to agree that we have entered an era of oil costs staying at levels above $50 USD per barrel. With a few exceptions, this is a global market and the cost trend will ensure that energy savings translate into significant monetary savings, an important factor in gaining more support for energy efficiency. However, the new cost plateaus will cause affordability problems.

- *Low-income people will face severe housing affordability problems*

  In all regions with a winter heating need, the increasing cost of fossil fuel will create affordability problems for low-income people, The problem will be exacerbated where low-income people are living in rural or low-density areas, since the use of private vehicles will become very costly. It is likely that governments will have to provide some form of energy subsidy in such situations, but many will find this difficult to implement.

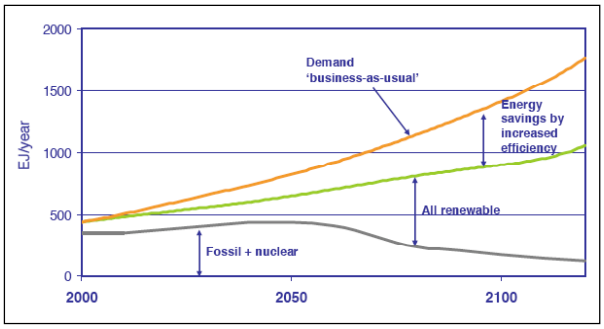
- *More nuclear power is inevitable*

  Although many nuclear power plants are now nearing the end of their service life, nuclear power appears to be destined for a comeback, not so much because the problems of high capital cost or nuclear waste disposal have been solved, but because of the pressing need to reduce reliance on fossil fuels, coupled with the relatively slow growth of renewable energy sources and the continuing high demand for power, especially under conditions of increasing temperatures.

- *Renewable energy technologies for local generation and for buildings will grow - but how fast?*

  Extensive subsidies in some countries, such as Germany, have resulted in extensive application of solar technologies, but it is not certain whether this rate of growth will continue once subsidies end. The premise is that wider application and new technologies will reduce costs, but it is not clear if some of these technologies, with the exception of solar hot water pre-heating and wind energy, will be competitive with conventional energy sources in the medium term, despite the optimism of the Future Buildings Forum, as shown in Figure 9. Carbon taxes would greatly alter the situation, and district-scale systems might also improve economies, although there is no clear consensus on this point[19].

Figure 9: Projections for Global primary energy demand by type, Future Buildings Forum[20].



- *Cross-disciplinary university SB curricula and working practices will grow*

  One of the barriers in implementing high-performance concepts is that success depends very much on the ability of designers, builders and

[19] See Yi Jiang, ibid.

[20] *Climate Change: A Focus on Building Energy Use to 2050*, PPT presentation to IEA Future Buildings Forum by Eduardo de Oliviera Fernandes, June 2004

operators to understand each others' needs and modes of operation. Part of this problem can be addressed by making strenuous efforts to implement cross-disciplinary forms of education at the post-graduate level, and to support the rapid implementation of the "integrated design process" (IDP) which has demonstrated significant performance benefits through system integration.

- *Performance certification and labeling programs will be widely implemented*

  It is demonstrably true that the rapid spread of performance certification systems, such as BREEAM have created a market transformation in the UK, while LEED has done the same in the USA and Canada. These rating systems are not necessarily sophisticated, but their apparent simplicity and effective marketing programs have made them very popular within the communities of designers, builders, manufacturers and clients alike. There are some concerns that the ratings do not necessarily reflect regional differences, or guarantee a high level of energy or GHG performance, but this is now emerging as a priority to be addressed by the groups operating these programs. Europe is taking a somewhat different approach, by starting from a base of energy performance requirements, and spreading out to cover water and material issues. These different trends will soon converge, and will form powerful weapons in the struggle for performance improvement. Interest in these systems is also rapidly developing in other continents, and Japan and Korea, for example, have successful operational systems.

- *Integrated simulation support tools will be widely available*

  There is great variation in the size of firms within the construction sector, and there are many small firms that find it difficult to support a wide range of specialized skills within the firm. Sustainable design requires new skills and sophisticated analysis, and the trend towards an integration of individual design and simulation tools will be very important in improving the quality of work of mainstream firms. Such integrated tools will include provision for embodied and operating energy simulation, costing and indoor environmental performance. Progress is rapid, and we may soon expect sophisticated design platforms that allow designers to test out design options during the process.

- *Data on performance of existing buildings will be widely available*

  There is a clear need for government officials who manage subsidy or regulatory programs to have access to good data on the actual operating performance of buildings. The data need extends to factors that help to interpret performance data, such as historical occupancy patterns, equipment densities etc. More and better performance data would also help clients to formulate their requirements more clearly. One roadblock is that such data are widely considered to be commercially confidential, but we may assume that pressures from governments will change this position.

4.2 Trends in urban management

- *Provision of rapid public transport to more small communities near urban centres*

  As cities grow, most of the expansion is in the form of low-density suburbs, and this has led to a rapid growth in the use of private automobiles for commuting, with attendant problems of emissions and excessive infrastructure requirements. Public transport has not been economically viable in the past in such situations because of the low density of new areas. In many cases, existing smaller population centres in the region that were once totally independent towns or villages, can become integrated into the greater urban region through the provision of high-speed public transport systems. In some cases, such as Shanghai, a series of new population nodes are being established outside the main urban area to accommodate increasing growth. The success of this strategy depends almost entirely on incentives to use public transport and disincentives to use cars.

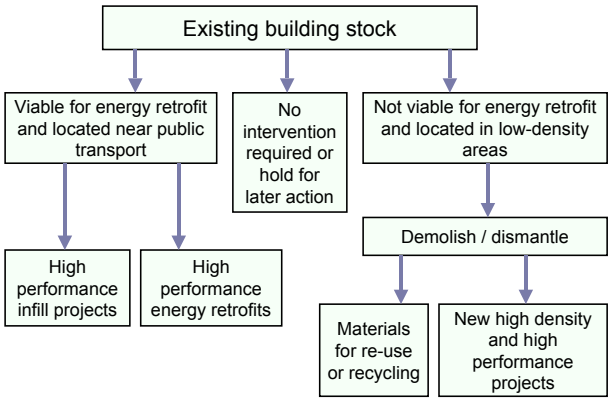
- *Increased infill and retrofit activity*

  Another urban phenomenon that will see rapid growth is removal of regulatory barriers and the provision of incentives to encourage infill developments on abandoned or under-utilized sites. Depending on the historical development

patterns, this can be an effective way of accommodating more growth in an efficient manner.

- *Triage of existing buildings for retrofit*
  The existing housing stock constitutes some 96% to 98% of the total stock, and any solution to climate change will obviously depend on aggressive programs to greatly improve its performance. This is not a simple task, since every existing building has a unique history. A starting point is to carry out triage of the existing building stock to determine priorities for energy-oriented renovation, maintenance or replacement by high-performance new construction. This approach is shown in Figure 10. Such programs will require subsidies, combined with the effective enforcement of energy and water regulations. This is probably the most important single measure that can be implemented.

Figure 10: Schematic of triage approach for existing building stock



4.3 Trends in building design and operation

The likely developments in the field of building design and operation over the next few decades are more difficult to identify, in view of the great variation of building types and regional conditions and policy differences. However, some general trends can be identified that will result from a combination of public policy and economic pressures:

- For reasons of space limitations and operating environmental efficiency, certain domestic activities, such as laundry and cooking, will move from homes to service establishments, at least in dwellings intended for small households.
- It will take heroic efforts and a long time to reduce the grossly inflated housing space standards that are currently prevalent in North America. However, the areas of dwellings in places such as London[21] and Taipei may increase.
- All services, such as electricity, water, heat and cooling, will be individually metered;
- There will be more mixed-use buildings, to maximize synergistic operating energy effects and to reduce commuting travel;
- Extremely high energy costs will lead to a general expectation of levels for energy performance that are is least 75% better than current norms in new buildings, and 50% better in existing buildings;
- Super-tall buildings (over 60 floors) are likely to emerge as a significant building form, especially in Asia, despite the poor energy efficiency and questionable social environment of such buildings.
- Larger buildings (say, over 10,000 m2) will become prevalent because of the greater energy and cost efficiencies possible and because of the advantages of professional management;
- Buildings will be designed to be more adaptable to change in building uses, such as office to retail or residential, which will require careful consideration of column bay sizes, floor-floor heights and floor bearing capacities;
- There will be greater interior flexibility for changes in systems such as lighting and mechanical, to increase overall operating efficiency;
- New construction materials with reduced carbon content will be developed, and will be used to replace all or part of high-mass materials, such as concrete and masonry;
- Buildings will be used more intensively, and 24-hour building use will be more widely applied;
- Time-sharing of second homes will be generally accepted.

[21] *Housing Space Standards*, A report by HATC Limited for the Greater London Authority

5 Conclusions

Broad policy recommendations and predictions of future trends are often shown to be incorrect in retrospect, but in this period of great change and stress, we need to identify the range of future trends that may place significant pressures on the industry. This short paper attempts to outline of a range of such future impacts and trends, some based on solid data, and others based on pure speculation based on experience.

Some of the most pressing specific issues within the next 50 years are likely to include a need to shift away from fossil fuels because of availability and price, a scarcity and high cost of some traditional construction materials, a rise in electrical consumption due to increased housing production in developing countries, and an increasing demand for air conditioning in all regions. Another major problem is likely to be the combined effect of increased summer temperatures and the urban heat island effect, leading to increased mortality in many urban areas.

At a general level, we may assume that pressure to greatly increase the energy and environmental performance of buildings will bear fruit, since there is a compelling economic logic to do so. The need to reduce production of new buildings and appliances, beyond the level of functional necessity, by changing lifestyles is likely to be a tougher nut to crack.

Technical and economic solutions for all these problems are available or imminent, but the underlying problems will remain.