BUILDING SECTOR STRATEGIES FOR THE 21st CENTURY

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Summary

A considerable number of papers produced by IPCC and others have outlined the science behind climate change predictions, probable impacts, mitigation measures and possible adaptation. In this paper, we identify some of the key links between climate change and the building sector and point out inadequacies of existing mitigation measures under conditions of increasing global consumption levels. It is argued that the current approach will lead to a series of weather-caused disasters, and that will lead to a call for quick action. The history of responses to major disasters is not a positive one, and a strategy of preparing contingency plans for use under emergency conditions is therefore suggested as a means of rapidly reducing greenhouse gases. Finally, a number of specific measures are proposed.

Keywords: Climate change, impacts, building sector, buildings, temperature, wind, precipitation, flooding, mitigation, adaptation, resource depletion, key construction materials, efficiency, consumption, weather disasters, rapid reduction, contingency measures

1 Greenhouse gases in climate change

The anthropogenic driver of climate change is the increasing concentration of greenhouse gases (GHG) in the atmosphere, chiefly CO_2, but also including Methane, Sox and Nox gases. The World Resources Institute (WRI) estimates that buildings are directly responsible for 15.3 percent 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 percent to 25 percent, 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 main target for GHG reductions.

1.1 Trends in emissions and global temperature increases

The International Energy Agency[1] has concluded that … although opinion is mixed on what might be considered a sustainable, long-term level of annual CO_2 emissions for the energy sector, a consensus on the need to limit the global temperature rise to 2 ºC is emerging. To limit to 50% the probability of a global temperature increase in excess of

[1] IEA World Energy Outlook 2009, Executive Summary, pg. 7

2 ºC, the concentration of greenhouse gases in the atmosphere would need to be stabilized to a level around 450 ppm CO_2-eq.

Is such a target likely to be achieved? Although the IEA is guardedly optimistic, trends in emissions seem to point in a different direction. In its *2008 Climate Science Issue Brief*[2], the World Resources Institute cites recent research in the field: *Raupach et al. note that the growth rate of carbon dioxide emissions from fossil fuel consumption and industrial processes has grown from 1.1% per year over the 1990s to more than 3% per year from 2000 to 2004 ... The authors find that declining trends in energy intensity of GDP and carbon intensity of energy are now being slowed and even reversed, and thus decarbonization trends are not as strong as previously.*

The WRI editors comment that… *Scenarios of future climate-related damages (such as those of the IPCC), which to date have been based on more optimistic assumptions, may prove to be conservative descriptions of possible future damages*

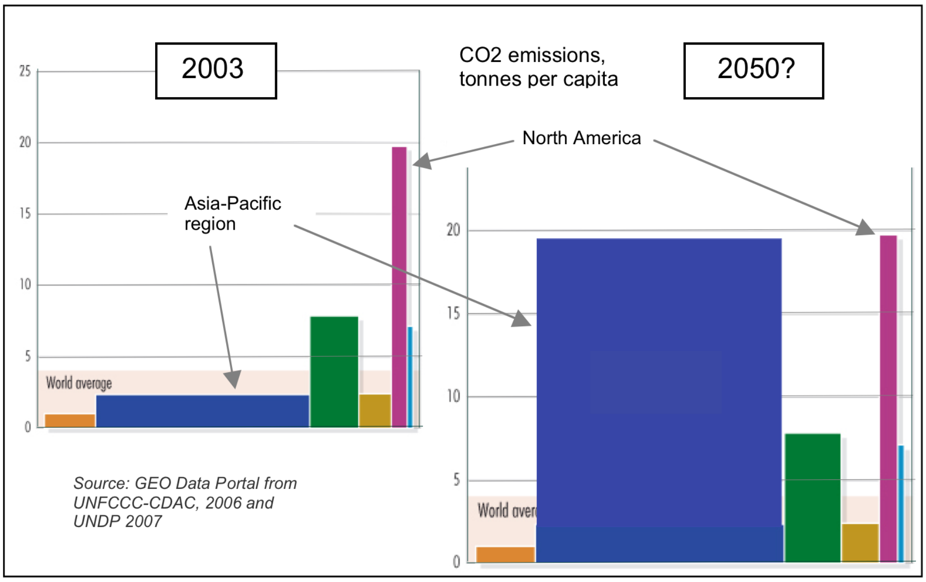

Fig. 1 Per capita CO_2 emissions by region; adapted from GEO Data Portal original at left, modified at right to show effect of emissions in 2006 in Asia and the Pacific rising by 2050 to the same per-capita levels as current North American levels. The width of the bars indicates relative population.

2 Global climate change impacts

One of the sobering aspects of the work done by the IPCC is their exposition of the time scales involved. IPCC demonstrates that CO_2 emissions today have a positive feedback on global mean temperature that lasts for over 100 years, and the resulting sea level rise due to thermal expansion lastswell over a 1,000 years. Even if action to reduce GHGs 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 impact is also clearly identified by IPCC, and the following excerpts from the 2007 IPCC Report identify some major climate trends for the 21st century: IPCC

[2] WRI Issue Brief, Climate Science 2007, World Resources Institute, September 2008

also predicts that temperature increases will be most pronounced towards the end of the century, with the northern hemisphere the most exposed.

From IPCC 2007			Personal and other sources	
Global effects	**Likelihood of future trends**	**Examples of major projected impacts**	**Possible direct effects on urban areas and buildings**	**Secondary effects**
Warmer and fewer cold days and nights over most land areas	Virtually certain (99% probability)	Reduced energy demand for heating; increased demand for cooling, declining air quality in cities	Growth of harmful insect populations, such as termites.	Repair of wooden structures.
			Melting permafrost in extreme North causes soil instability and release of Methane.	Repair, rebuilding, population relocation.
			Reduced space heating requirements.	Reduced energy consumption and emissions
Warmer and more frequent hot days and nights over most land areas	Virtually certain (99% probability)		Increased urban heat island effect leading to higher ambient temperatures	Increased peak power demand from fossil-based power generation plants, with high GHG emissions. This also leads to smog formation with negative health effects.
			Reduced feasibility of night cooling	
			Increased building space cooling requirements.	
Warm spells / heat wave frequency increases over most areas.	Very likely (90% probability)	Reduction in quality of life for those people in warm areas without appropriate housing; impacts on the elderly, very young and poor.	Reduced hydro or nuclear generation because of reduced flow rates and increased water temperatures.	Intermittent or reduced and more expensive power supply.
			Population mortality in housing and buildings with poor thermal performance and no space cooling, leads to greater demand for retrofit and space cooling.	Emergency building retrofits to improve hot weather performance.
				More space cooling installations leads to more pressure on power supply, greater GHG emissions and smog formation.
Area affected by droughts increases	Likely	Water shortages…reduced hydro generation, potential for population migration.	Water shortages because of reduced supplies and drought conditions.	Prohibition of new construction in areas with insufficient renewable water resources.
			Reduced hydro or nuclear generation because of reduced flow rates and increased water temperatures.	Intermittent or reduced and more expensive power supply.
Intense tropical cyclone activity increases	Likely	Disruption by flood and high winds, loss of insurance, population migration, loss of property.	Damage to infrastructure and buildings by storm events.	Temporary shelters Emergency repairs
				Higher requirements for construction quality and durability.
			Relocation of large populations after storm events	Prohibition of new construction in vulnerable areas, such as coastal areas.
Increased incidence of extreme high sea level (excludes tsunamis).	Likely (long term)	Costs of coastal protection v. relocation, loss of insurance, population migration, loss of property.	Relocation of large populations over the long term	Increased pressure on developable land; pressure also on land valuable for agricultural or ecological purposes.
			Temporary shelters Greenfield infrastructure, housing and other building construction	Very high capital expenditures, high GHG emissions from materials production and construction.

Fig. 2 Outline of probable climate change impacts, partly taken from IPPC 2007 AR-4 report[3].

2.1 Specific impacts of global temperature increases

One of the major impacts will be changes in precipitation patterns, with mid-latitude regions, up to and including southern Europe suffering 10 percent to 20 percent reduction in annual precipitation. River flooding is likely to be amore 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 thermal expansion of warmer oceans is a certainty, but the extent and speed of this phenomenon appears to remain a matter of debate.

[3] IPCC AR4 Working Group 1, Summary for Policymakers, 2007, p. 8. Note that *Virtually certain* are events with a 99% probability of occurrence while *Very likely* are events with 95% probability of occurrence.

Higher temperatures will also allow damaging insects to migrate into new regions. The combination of higher temperatures, higher evaporation rates and drought will increase the probability of forest fires.

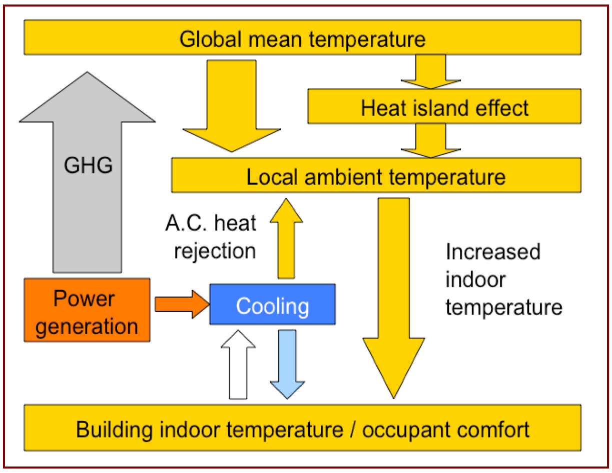

Fig. 3 Interaction between ambient and indoor temperature with cooling demand and power generation

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. This will increase power demand, which in turn generates more GHGs as well as smog. This vicious circle is one of the most problematic of all performance issues in the building sector.

The heat wave in Europe of 2003caused an estimated extra mortality of about14,800 persons in France, and about 35,000 in Europe as a whole. No estimates of losses in productivity during heat waves are available, but they are probably substantial.

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[4] showed that the added temperature in central Paris was in the order of four to five ºC during the time of the 2003 heat wave, and similar studies in Athens have shown differentials of12 ºC 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. It also suggests that a wise strategy for adaptation to climate change may be to first focus on reducing the heat island effect.

2.2 Precipitation

Changes in weather patterns predicted by IPCC 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. Northern hemisphere regions will have increased rainfall, especially during the December to January period, while parts of southern Europe and southern Asia will have reduced precipitation during both seasons.

[4] B. Dousset, ESA user consultation meeting, Athens, June 2007

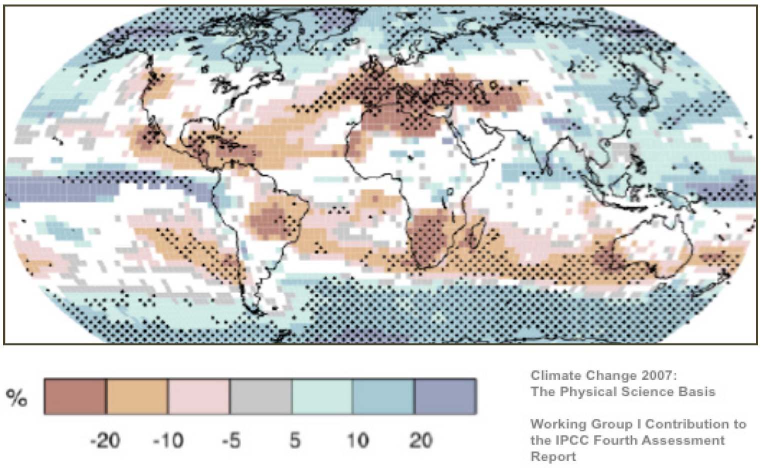

Fig. 4 Precipitation patterns projected by IPCC for the 2090 period.

As with most climate change impacts, these effects will be considerably more apparent during the last part of the century. When they are combined with freshwater resources that are already limited, or where aquifers are being rapidly depleted, then the future looks quite dry.

It is becoming increasingly apparent that, although overall changes will be gradual, specific weather events caused by climate change may be quite sudden and may result in considerable local wind and flooding damage. This may be an important factor in devising coping mechanisms.

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 locations continue to be the favorite locations of a significant number of individuals.

2.3 Mitigation and adaptation under climate change conditions

Two main approaches have been proposed to deal with climate change: mitigation and adaptation. In many cases, measures taken will address both issues; for example, improving hot weather performance of buildings will reduce health and productivity impacts on occupants, but will also reduce the need for additional cooling, leading to less need for increased power generation and GHG emissions.

3 Other issues: demand, scarcity and supply problems

Climate change is not the only challenge that will be faced by the building industry during the next century. Several of these factors will converge to make the life of developers, designers and builders especially difficult.

Fuel costs and possible shortages will create problems for automobile owners, especially for those who want to emulate the North American pattern of living in outer suburbs with one car per adult occupant. There may be respite 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 will take decades. The building sector also faces competition for fossil fuels with, for example, natural gas being used for power generation and space heating, as well as for the production of fertilizers.

4 The combined challenges of climate change and resource depletion

The climate and resource issues outlined above will result in major problems for investors, designers and operators of buildings in most regions. They will be complicated by the recession, which one hand makes it harder to find construction funding, while governments want to encourage construction employment on the other. Meanwhile, demographic changes will shift demand for types of dwelling units, which may alter the value of existing buildings to a considerable extent.

4.1 Efficiency

Great strides are being made in improving the ecological performance of materials and mechanical systems are rapidly increasing in energy efficiency. Progress is also evident in the environmental performance of some new large buildings through changes in design practice, such as the adoption of Integrated Design Process protocols.

However, performance improvements are mainly applicable to large and expensive new buildings, and more so in Europe than in North America or Asia. It should also be noted that new buildings in most regions represent only from 2% to 4% of the total building stock. Thus, high-performance exemplar projects represent only a very small portion of the total stock. Clearly, the stock of existing buildings should be the major focus of performance improvement efforts in the building sector.

In the sub-sector of single-family houses (the most energy inefficient form of building) there has been considerable improvement in energy performance in North America over the last 15 years.

4.2 Consumption

But we will not reduce overall greenhouse gas emissions nor depletion of key materials if the volume and rate of production of new buildings continues to grow. More specifically:

- The demand for new construction in developing countries such as China, India and Indonesia is high and will remain so for one or two decades, while the demand for higher standards of accommodation in developed countries continues.
- Those involved with the development of new museums, airports, Olympic or Expo events tend to be enthusiastic about their large new facilities. However, even if the projects earn gold labels because of good operating performance, the fact remains that considerable amounts of non-renewable fuels will be consumed far into the future. Besides, even if a “zero-energy” status is achieved, there are large amounts of embodied energy and emissions generated from the materials used in the construction process for the building and related infrastructure.

And then, there is the trend in developed countries to massively over-consume housing. During the period 1990 to 2008, there was an explosion of number and size of houses in the suburbs of North America. The data below is for the U.S.A., but Canada follows a very similar path[5].

- Between 1950 and 2004, the size of the average new house in the US expanded by 135%, from about 1000 square feet (93 m2) to 2349 square feet (218 m2);
- One in five new houses now comes in at more than 5000 square feet (465 m2). (The US National Association of Home Builders' 'showcase home' for 2005 was 5950 square feet (553 m2) or 15% bigger than the 2004 model.)
- Forty-three per cent of new construction features 9-foot ceilings compared with 15% in the 1980s.
- Meanwhile, between 1950 and 2003, average US household size fell from 3.7 to 2.6 people.
- **This means that floor space per capita increased by over 230% from 25 m^2 to 84 m^2.**

4.3 Conclusions re. consumption v. efficiency

The overall situation is that, although impressive efficiency gains are being made in building and equipment performance, excess consumption is wiping out these gains. More troubling is that consumption is culturally determined, and cultural changes usually require a decade or more of substantial information and incentives. Add to this the need for substantial amounts of new construction in developing countries, and it is unlikely that global reductions in greenhouse gas emissions will be sufficient to result in levels below 450 ppm of GHG, which in turn will bring into play some of the more dire predictions of IPCC.

5 The dilemma

IPCC has outlined possible climate change impacts and, despite the skepticism of some critics, it is very likely that we will have to cope with the kind of conditions that the IPCC has outlined in its less optimistic scenarios. Some regions and countries, especially in Europe, have responded in a positive way, but major private sector emitters are not likely to respond to a sufficient degree.

We therefore face a possibility of massive disruption of agriculture and industry and living and working conditions, possibly by mid-century and certainly by the end of the century. Although we all want to look for a happy ending, we are not likely to avoid this fate unless there is a major paradigm shift, and such shifts usually require major external events to be considered. The Depression, WW2 and 9/11 are historical examples of such conditions.

A major problem in motivating decision-makers to act is that the harbingers of climate change in North America and northern Europe have been, until now, relatively gradual and benign. This sequence may cause us to become numbed by a gradually escalating series of climate-related incidents and not act decisively until it is far too late. However, climate change may also be announced by a series of major and sudden natural disasters, an outcome that is certainly within the bounds of projections made by the IPCC. If such a series of sudden catastrophes were to have direct impacts on elites in developed

[5] From Rees, William E.(2009) *The ecological crisis and self-delusion: implications for the building sector*, in Building Research & Information, 37: 3, 300 — 311

countries, especially in the U.S.A. or Canada, there is likely to be a strong and immediate public demand for effective responses to mitigate the effects of the events, and this would provide a real opportunity to simultaneously deal with the greenhouse gas emissions that cause climate change. Sudden climate disasters are not a pleasant prospect, but it is one of the few scenarios that seems to offer the potential for resolute action.

We have a duty to explore the possibility of catastrophic climate-induced events and what the consequences might be.

6 A scenario for rapid GHG reduction

Imagine that emergency measures are declared in your highly developed country, after a series of massive climate-related events;

- Governments might be led to announce that, in addition to urgent re-building efforts, national emissions must be reduced by large amounts over a very short period (say 80% by 2025 instead of 2050), along with promises of massive fines if targets are not met;
- Reaching such performance requirements would be very difficult, because strategies for such a rapid and deep reductions would have to be invented on the fly;
- We can foresee that such actions might be achievable in, for example, in the automotive or the consumer goods sectors, but it will be much harder to do so in the building sector;
- The building industry is very large and complex, with a few large players and very many small ones on the production side, and with control even more dispersed on the demand side;
- And buildings are almost all unique, so global approaches need local modifications.
- Undoubtedly, there will be some immediate proposals for sweeping measures but all will be hastily prepared and some of them will have side effects of excess profits and social dislocation;
- But if they are the only plans on the table they will be accepted, because, in the panic, nobody will have the time or the will to develop well-considered plans;

What might be the reaction to such a situation?

6.1 Immediate reactions

Given the scenario outlined above, a government might well announce that emissions from the building sector must be reduced by 75% over a five-year period, along with promises of massive fines if targets are not met.

Reaching such performance requirements will be very difficult, because very few countries have central departments with direct responsibility for the building industry. Also, the industry is very large and complex, with a few large players and very many small ones on the production side, and with control even more dispersed on the demand side.

6.2 Results

- First, we would expect a surge in demand for man and materials to carry out urgent repair, re-building and re-location needs;

- This would, within weeks, deplete the supply of skilled and firms in the affected region;
- Manufacturers of building materials would be faced with urgent production requests, but would face greatly increased power costs, and might also have to cope with a disrupted labor force and plant conditions;
- Prices for materials and services of this type would therefore reach astronomical levels;
- Owners or managers of existing commercial buildings would have to reduce operating hours to meet GHG reduction targets;
- Residential tenants will face mandatory energy cuts;
- The value of buildings with poor energy efficiency will plummet;
- Suburban building land values will also face massive drops because of controls on new building and stringent limits on private vehicle emissions, which will bring new construction in outer suburbs to a halt.
- And, on the way, many standards for good design and operations, such as adequate lighting levels, indoor comfort conditions, and work to preserve heritage buildings will fall by the wayside, at least temporarily (say for 20 years);
- Social tensions will rise to very high levels when those who want to pursue their normal paths (commercial building development, building your dream home) are faced with permit refusals, while climate refugees and families suffering from energy poverty are given priority;
- And the need to deal with repair and remedial work will lead governments to say that they cannot afford more GHG mitigation measures;
- So climate change will continue unabated.

6.3 Possible contingency measures

Some of these consequences can be avoided if quick and decisive action takes place, but such responses are likely to be effective only if action plans have been developed *before* the emergency occurs, and are ready for immediate implementation. Such plans must support very rapid reductions in GHG emissions over a short time-frame – something like 75% over 5 years – but varying with the sector and specific cases. To be available when the time comes, such plans must be voluntarily developed *now* by a variety of public- and private-sector organisations, so they will be ready when needed. A large number of contingency plans will need to be prepared by individual governments and private-sector organizations, and that these cover most key sectors of the emission-producing economy;

Measures required for very rapid reductions might look something like this:

1. Immediately introduce carbon taxes, to reduce the carbon intensity of building-sector related goods and services; and simultaneously reduce existing income taxes;
2. Immediately ban the construction of new coal-fired generation power plants and the extension of existing plants, unless significant GHG sequestration is provided;
3. Rapidly reduce peak loads in electrical networks through the rate structure and through load ceilings;
4. Rapidly implement measures to facilitate feed-in tariff policies from decentralized renewable power sources;
5. Develop strategies for minimizing speculative price rises for construction materials;

6. Prepare risk assessment studies of existing urban areas and building stock with regard to possible climate change impact events, such as floods, wind storms, heat waves etc.[6]. Such work is a necessity for post-disaster recovery.
7. Develop alternatives for power outages and other service interruptions (water, food and other supplies, communications etc.);
8. Ensure that facilities of critical importance, such as hospitals, public transportation systems, water and sewage treatment and pumping systems, remain provided with electrical power, heat, water and other vital services;
9. Make realistic plans for rapid relocation of key facilities such as docks[7] and airports, and of large populations in areas vulnerable to flooding or fire[8];
10. Develop strategies to rapidly implement passive survivability including food security[9]; transitioning[10] large urban and suburban milieux to service frameworks to localized, small urban areas and communities that greater self-reliance;
11. Establish programs for the rapid conversion of surplus office buildings to residential uses;
12. In areas with housing shortages, rapidly identify empty non-primary dwellings, and develop measures to ensure that they are more fully utilized, while respecting property rights of owners;
13. Develop measures to prevent the proliferation of secure and gated communities as a disaster response, unless these are socially balanced;
14. Introduce an immediate triage program for urban areas, to determine zones that would be targeted for performance upgrades or, if the potential is limited, targeted for dismantling and replaced by high-performance re-development;

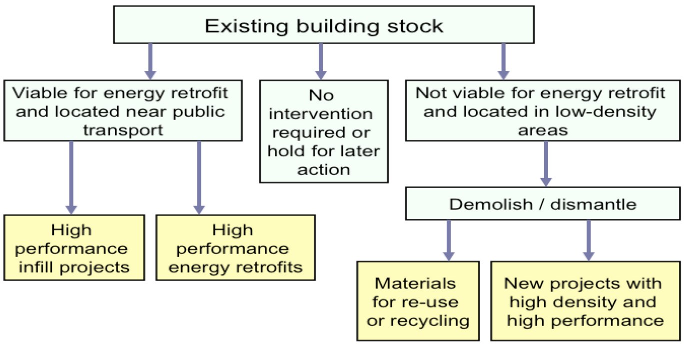

Fig. 5 Triage of urban neighbourhoods

[6] See for example *Methods for risk assessment and mapping in Germany*, preface to special issue of *Natural Hazards Earth System Science* 6, 721-733, 2006, and also *Winter storm risk of residential structures - model development and application to German state of Baden-Würtemberg*, P. Heneka, T. Hofherr, B, Ruck and C. Kottmeier, in *Natural Hazards Earth System Science* 6, 721-733, 2006.

[7] The U.S. military is well aware of the dangers that many of its coastal bases are facing; see *National Security and the Threat of Climate Change*, CNA Corporation, 2007.

[8] The dismal efforts at relocation and rebuilding in New Orleans are a reminder of how extensive and well coordinated the required efforts will have to be if they are to be successful;

[9] See http://www.buildinggreen.com/auth/article.cfm/ID/3206/ and http://www.igreenbuild.com/cd_2752.aspx

[10] Transition Town Totnes is the UK's first community in its Transition Initiative: http://totnes.transitionnetwork.org/

15. In areas designated for performance upgrading, establish immediate programs of urban infill to increase densities and renovation of existing buildings to greatly reduce GHG emissions (by at least 80%) and to improve water performance;
16. Impose a *freeze* on new construction in un-serviced or low-density areas or potential flood areas, and a zero operating GHG emissions requirement for new construction that is permitted;
17. Ensure a rapid reduction in operating emissions of public buildings, private office, hotel and multi-unit residential buildings, through implementation of "shovel-ready" retrofit plans and better operating practices, all while minimising disruption or reduction in service levels to occupants;
18. Operators of manufacturing plants and service-sector facilities should have plans ready to rapidly reduce peak loads and emissions in their facilities, by means of changes in industrial processes, operating hours or other relevant means;
19. Prohibit the sale of appliances and equipment that do not meet certain operating efficiency criteria (e.g. "A" label in Europe), and establish a program for rapid scaling up of efficiencies;
20. Establish a crash training programs for regulators, renovation contractors, simulation specialists and others needed to upgrade performance in new and existing buildings;
21. Rapidly implement public education programs to promote conservation by office tenants and residential owners or tenants in energy, water and materials;
22. And then deal with homeowners' existing housing, through a combination of intensive education, promotion of infill units on existing lots, and intensification of existing government performance renovation programs.

It is clear that the content of GHG rapid reduction plans proposed above would be a sensitive matter in some cases, where the leakage of information *under current conditions* might pose political difficulties because of limitations on personal freedom of action, or harm standings in a highly competitive market. It is therefore suggested that participating organizations would not be compelled to share their plans with any outside organization, but only to report that they have completed a plan that satisfies the content criteria established in the project. The main emphasis here is to ensure that workable and humane plans are available for *rapid* implementation when circumstances demand it.

There are certain characteristics that such plans would have to be based on if they are to be effective.

- Measures proposed will have to be able to be very quickly implemented; beginning within weeks rather than months;
- The scope of proposed action will have to be defined (e.g. all or part of a property portfolio, certain segments of a customer base etc.);
- Estimates of speed and amount of net reduction in GHGs emissions will have to be provided, projected on a year-by-year basis over a 5-year time frame;
- Plans will have to identify measures to minimize negative social disruption or other secondary impacts;
- Identify main obstacles or sources of likely opposition and suggest coping strategies;
- Complementary action required by governments, other regulatory authorities or financial institutions to facilitate implementation of the plan should be identified.

7 Conclusions

Some governments, especially in Europe, have launched ambitious plans to reduce GHGs, but it is not yet clear whether their voters will agree with the changes in lifestyle that will be necessary to meet these targets.

Excessive consumption will not easily be reduced, and is likely to lead us into global temperature increases that will be considerably greater than the desired target of 2 ºC;

It will probably require one or more climate-induced disasters of major proportions to shock governments and their populations into real action, especially in North America. When that happens, there will be an immediate demand for contingency plans to reduce GHGs in a very rapid way and to implement urgent measures for climate change adaptation.

In view of on-going government inaction, it is most logical for national and local governments, as well as private organizations to develop such plans and keep them ready. The alternative is to do nothing now, but to be forced to accept hastily developed and unsound plans when an emergency is declared.