Worldwide Hospitality and Tourism Themes

Climate change and tourism: the implications for the Caribbean

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Abstract

Purpose – The purpose of this paper is to explore the role of travel and tourism industry in climate change and to consider the implications of climate change for the travel and tourism industry.

Design/methodology/approach – The paper outlines why the Caribbean is currently the most tourism-dependent region in the world and profiles the reasons why the island economies of the Caribbean are so vulnerable to climate change.

Findings – The paper advocates action based on the available evidence and the fact that most of the essential infrastructure for tourism is located at or near the shoreline, in areas that will be vulnerable to sea-level rise and storm surge. This combination of dependency and vulnerability makes the Caribbean a particularly pertinent and poignant example of how countries can come to rely on an industry that might prove to contain the seed of not only its own destruction, but also that of some vulnerable host economies.

Originality/value – This paper provides a comprehensive summary of the key evidence relating to the growing threat of climate change to the Caribbean.

Keywords Tourism, Caribbean, Climatology, Energy management, Environmental management

Paper type General review

Introduction

There are three issues of critical importance to the future of the tourism industry in the Caribbean:

(1) The Caribbean is the most tourism-dependent region in the world, as the travel and tourism industry is the largest source of both foreign exchange and employment. Unfortunately, the travel and tourism industry is also a significant contributor to the carbon loading of the atmosphere and the associated climate change.

(2) The nations of the Caribbean are mostly small islands, and much of the key infrastructure – including the main urban areas, principal roads, airports and wharves, as well as many of the hotels and resorts – is at or near sea level, and is therefore directly threatened by climate change.

(3) The main driver of climate change is the demand for carbon-based fuels, such as coal, oil and gas. With one exception (Trinidad) the English-speaking Caribbean nations are dependent on imported oil. Per capita energy use is relatively high, but much of this is used for air conditioning, transport and so on rather than manufacturing, and most buildings, water pumping and transport systems in the region operate with relatively low standards of energy efficiency, which reduces the economic competitiveness of the Caribbean nations (Green, 2004). This means that they too make some contribution to the problems of climate change, although these contributions are still very small in global terms.

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The nations of the Caribbean are therefore facing a serious dilemma. For many of them, their hopes for development rest largely on tourism, especially as other sectors, such as traditional agriculture, continue to decline, and most of them are currently committed to expanding tourist volumes or margins or both. However, the increase in demand for travel and tourism is contributing directly to climate change, which will have serious consequences for the islands. The response of most regional governments to date has been to emphasize the responsibility of the major carbon emitters, but this claim is unlikely to result in commensurate compensation, and is also somewhat undermined by the fact that the islands also consume energy inefficiently, and most of this is derived from oil, which means that the islands have to take some responsibility for their own misfortune. In addition, this claim is usually directed at the countries that have been responsible for the majority of carbon emissions to date, who happen to be the major donors to Caribbean aid programmes, rather than at China, which is now the largest emitter of carbon. As this suggests, some Caribbean Governments appear to see climate change as an opportunity to extend existing aid programmes, rather than focusing on the actual threat.

The threat is perhaps not yet sufficiently apparent, because most countries in the Caribbean are still allowing new housing and hotel developments in some of the most vulnerable areas, thus increasing the eventual cost should these areas be lost to the sea. However, the nations of the Caribbean will eventually have to respond to these existential threats, and their ability to do so will largely determine their future as viable states. The fate of the Caribbean may also serve as a harbinger for the future of the travel and tourism industry, and determine whether it too can adjust to the profound challenge of climate change.

This paper has been organized into three sections. The first section examines the extent to which the Caribbean depends on tourism. The second section gives a simplified summary of the climate change and energy issues, and the implications for the Caribbean. The third section considers possible solutions.

Part 1: Caribbean tourism

Clayton and Karagiannis (2008) note that Caribbean tourism, which is largely based on climate, beaches and scenery, has been growing since the 1950s (WTO, 1998). In 1980, there were six million tourist arrivals in the region, by 1990 there were over ten million. By 2000, the region had over 20 million tourist arrivals, with more than 12 million cruise passenger arrivals Caribbean Tourism Organisation – CTO (2002).

The Caribbean has been increasing its share of world tourism since 1980; it was 2.11 per cent in 1980, reached 2.41 per cent in 1987, declined slightly to 2.34 per cent by 1990, and reached 3.2 per cent in the late 1990s (CTO, various issues).

The Caribbean has become the most tourism-dependent region of the world. Tourism earnings now account for approximately 25 per cent of the Caribbean's gross domestic product (GDP) and significantly more in some Caribbean islands. Five Caribbean nations are now in the global top 20 in terms of the percentage of total employment that is related directly or indirectly to the industry. Antigua is currently the most dependent nation in the world; some 95 per cent of all employment is related, directly or indirectly, to the travel and tourism industry. Jamaica is currently the fifth most dependent economy in the Caribbean. The World Travel and Tourism Council (WTTC) satellite accounts for 2004 indicate that the tourism industry in Jamaica will, directly and indirectly, contribute about 31.8 per cent of total employment and about 36.0 per cent of total GDP. By 2014, this is projected to rise to 38.1 per cent of all employment in Jamaica and 42.9 per cent of GDP. In the Bahamas, tourism and tourism-related industries (such as construction) account for over 70 per cent of national income, directly and indirectly and provides employment for around 60 per cent of the population.

CTO data shows that visitor expenditure in 2000 ranged from 3.59 per cent of GDP in Trinidad and Tobago (which has a large oil and gas industry) to 83.06 per cent of GDP in Anguilla (which has little other industry). Estimates of total visitor expenditure in the region for the same period were US$19.9 billion; about US$979 per tourist. Vaugeios (2003) notes that this represented 50-70 per cent of the region's hard currency earnings, and points out that this contribution has grown dramatically; tourism is the only sector of regional GDP that has consistently increased its share of total income during the past 25 years, reflecting both the success of the industry and the decline of other traditional economic activities.

This situation has arisen for positive as well as negative reasons. The sub-tropical climate, beaches, natural beauty and convenient geographical location has enabled the Caribbean nations to develop competitive tourism businesses. On the other hand, the decline of traditional export industries such as sugar and bananas left many countries without a viable economic alternative.

Tourism earnings are now a critically important source of hard currency, and vital for the region's balance of payments. Tourism receipts rose from just under 18 per cent of current account receipts in 1980 to around 37 per cent in the 1990s. Tourism is also a labour-intensive industry, and its role in generating direct and indirect employment in otherwise fragile economies is regarded as one of its most important immediate economic benefits, although there are wide variations throughout the Caribbean in the proportionate importance of tourism in employment (Poon, 1993, p. 266).

Tourism has therefore become an indispensable source of livelihoods, tax revenues and foreign exchange, and makes an equally indispensable contribution to the balance of payments. The industry has significant potential for further growth, as the demand for tourism services appears to be both indefinitely expandable (it is always possible to add new products) and elastic (as the price of airfares, for example, has declined, demand for air travel has increased even more rapidly).

According to Jayawardena (2002), this success cannot be attributed to any good strategic decisions or wise planning by Caribbean Governments. Tourism drifted into its current prominence as a result of steady growth over decades, and as economic sectors like agriculture and manufacturing shrank in the face of growing global competition. However, it is clear that tourism has become the Caribbean's most competitive industry (Boxill *et al.*, 2002), and has become the main economic engine in many of the Caribbean island states.

The WTTC estimates for 2002 indicated that the regional industry would generate US$34.3 billion in economic activity, contribute US$7 billion to GDP, produce 2.1 million jobs and account for US$7 billion in capital investment (WTTC, 2002, 2007). The WTTC also anticipated that this contribution would continue to grow. However, the terrorist attacks of 11 September 2001 in the USA had a serious impact on these projections. Although the worldwide decline in travel and tourism demand was 8.5 per cent, the loss in the Caribbean was 13.5 per cent, which translated into a temporary loss of some 365,000 jobs. The WTTC analysis found that the greatest job loss was in the Dominican Republic (192,800), followed by Cuba, Jamaica, Haiti and Puerto Rico, with The Bahamas placed sixth with 10,200 job losses. WTTC also found that the greatest revenue losses were sustained by the Dominican Republic (US$837.2 million) and Puerto Rico ($589 million), followed by Jamaica ($299 million), The Bahamas ($282.5 million), Cuba ($281 million), Barbados ($169 million), Aruba ($141 million), Bermuda ($133 million), Trinidad and Tobago ($116 million) and Curacao ($113 million).

These losses reflected the extent to which Caribbean islands rely on the US market. Many Americans were reluctant to fly after 9/11, whereas Europeans were relatively unaffected, so countries that relied more on European visitors did not suffer to the same extent. More fundamentally, however, the reaction to 9/11 illustrated the importance of the industry to the regional economies, and also that they are acutely vulnerable to any shock or recession in the sector.

The Caribbean illustrates a more general phenomenon; the way in which a number of developing countries have increasingly dependent on tourism, although not generally to the same extent as in the Caribbean. In some cases, this is because they have relatively few alternative options for economic development (Clayton, 2003, 2004). The advanced technology and capital investment now required to develop or maintain a competitive position in many secondary or tertiary economic activities present a very effective barrier to new entrants. Lack of capacity, in terms of both the administrative and technical skill base, is a serious problem in many developing nations, the lack of expanding economic opportunities means that the graduates from developing nations frequently have to move abroad to seek employment, and the consequent lack of a strong professional cadre and ethos is one of the factors that can foster corruption. It has been hard, therefore, for many developing nations to move beyond their traditional economic activity of exporting their natural resources. Many of these natural resources – minerals, for example – are non-renewable, others – such as timber or fish – are renewable but are in many cases being exploited to exhaustion without any allowance for the time needed for the stock to replenish. Thus, many developing nations will not be able to pursue these traditional economic activities indefinitely.

Tourism, however, especially tourism based on the attraction of particular natural or social features (such as sunshine, beaches, mountains, forests, or a colourful, interesting culture), offers a way to use these resources without necessarily degrading or depleting them. Countries that have been endowed by nature or history with a good range of such features therefore have a genuine comparative advantage, which means that the tourism and travel sector has become economically indispensible for these countries.

The travel and tourism industries also generate demand in many other sectors, ranging from construction and engineering to a wide range of services. The livelihood of many millions of people today, in all parts of the world, therefore depends – directly or indirectly – on the long-term future of the travel and tourism industries.

The economic benefits that flow from the development of tourism are well known; unfortunately, the associated environmental problems have also become well known, as mass tourism imposes various burdens on the environment and infrastructure (Pattullo, 1996). Many of these impacts can be mitigated or avoided, with good planning and management; but poor governance and powerful developers with a cavalier disregard for constraints can cause unnecessary damage. Dysfunctional planning processes can result in poorly managed over-development and cause unnecessary environmental damage, a combination that can eventually force the local industry into a down-market, low-margin niche. There are grounds for concern, therefore, that tourists might respond to environmental deterioration by taking their custom elsewhere.

The industry has started to respond to these challenges, and there are some leading practitioners of good environmental practice in the Caribbean. Some leading members of the industry appear to see climate change largely as an additional environmental problem, one that will therefore be amenable to a combination of industry initiatives and government programmes.

However, the problems associated with climate change are far more profound. It now appears likely that climate change and the frequency of severe weather conditions will have a major impact on social, economic and environmental systems during the course of this century. Some of these impacts are reviewed in the next section.

The travel and tourism industry does contribute to the problem, and is likely to be particularly vulnerable to the consequences. It is unlikely to be a major source of technological solutions, for reasons that will become clearer after the next section, but it could play a vital role in encouraging a transition to a low-carbon future.

Part 2: Energy and the environment

Our current way of life depends on reliable, low-cost energy, most of which is currently derived from hydrocarbons. Recently, we face a combination of pressing energy-related challenges, including:

- sharply rising demand for energy in countries such as China and India, increasing competition and potential conflict for resources;
- the risk of increasing energy dependency on potentially unstable regimes, and growing resource nationalism, with the potential for oil and gas supplies to be used for political leverage;
- highly volatile prices, with serious implications for foreign exchange outflows, inflationary pressures and reduced rates of economic growth;
- concerns about supply constraints, with regard to rigs, pipelines, refineries and technical skills, and concerns about the approach of peak oil, with the ensuing decline in global production; and
- concerns about carbon loading of the atmosphere and the associated risk of climate change.

Some of the problems are likely to self-correct, given time. High-oil prices, for example, encourage greater efficiency and the development of alternative energy sources. The oil price is then likely to fall again, at least temporarily, as investment capital will be redirected from oil investments to follow the most promising opportunities, although the strong growth in demand from countries such as China and India will prevent oil prices from falling back for long (Campbell and Laherrere, 1998).

However, the downstream problems associated with the current pattern of energy consumption, in particular climate change, are unlikely to abate. The rapid development and industrialization of nations such as China and India, while otherwise welcome, is significantly increasing the global consumption of fossilized hydrocarbons and the consequent emissions of carbon dioxide (CO_2) to the atmosphere.

Peak oil

The point at which world oil production will peak, and then decline, cannot be determined exactly because it depends on a number of interacting factors (Aleklett and Campbell, 2003). These include the extent of remaining conventional reserves, advances in seismic, drilling, extraction and recovery technology, the potential development of heavier crudes and unconventional reserves (such as tar sands), the development of other hydrocarbon sources such as, for example, coal liquefaction and natural gases, and changes in market prices which determine the boundary between economic and non-economic sources, which are in turn influenced by geopolitical factors such as resource nationalism and substitution effects from other energy sources. See, for example, IMF Research Department (2000), International Energy Agency (IEA) (1998, 2004, 2007b).

However, the majority of current estimates indicate that the point of peak oil could occur before 2030. As this point is approached, liquid fuel prices and price volatility will start to increase significantly, which will have serious economic and social implications. This could also result in increased international tension, with a growing possibility of conflict to control the remaining reserves.

For example, a recent UK Government (2007) review noted that by 2020, half of the world's oil production will occur in potentially unstable regions. The review also noted that just two countries – Russia and Iran – control some 40 per cent of world gas reserves. With regard to the latter; external estimates suggest that Russian defence spending rose by 22 per cent in 2005, then by 27 per cent in 2006 and 30 per cent in 2007, financed primarily by their exports of oil and gas (www.globalsecurity.org). Increased dependency may therefore have a high-political price.

There are viable mitigation options on both supply and demand sides, involving substitution and greater efficiency, but the dominant role of hydrocarbons in the world energy mix means that it would take some ten-20 years of accelerated effort before these could be developed to the point where they could ensure that the worst effects of peak oil would be averted. This indicates that key decisions will have to be made in the next ten years.

Volatile prices

Energy diversification and greater efficiency is also important in order to protect both importing and exporting countries from the damaging economic and social consequences of large, rapid changes in energy prices. Between 1999 and July 2008, the price of oil rose 15-fold, from less than $10/barrel to over $147/barrel. This was mainly due to two factors; rising demand (especially from China), and a lengthy period of underinvestment that led to a situation where demand exceeded the readily available supply. Then, as a result of falling demand, the price slumped; oil lost nearly 80 per cent of its value in just six months. It was trading at less than $34/barrel in December 2008. These dramatic shifts can be very destabilizing for both customers and producers. As world oil production starts to decline (after peak oil), consumers will increasingly depend on high-cost sources, which will cause even more dramatic swings in market price.

The most vulnerable group will be energy import-dependent relatively poor countries with narrow or fragile economies and high debt to GDP ratios, which is true of a number of Caribbean islands. A sustained rise in energy costs results in high-foreign exchange outflows, which increases debt and poverty, triggering an increase in emigration and a haemorrhage of skills and capital as legitimate development options erode. Restricted government spending weakens domestic security, so increased poverty will result in rising rates of crime, which deters investors, thus delaying recovery and precipitating a further downward spiral. Some countries will face a daunting combination of climate change-related impacts and environmental degradation, increasingly costly energy, a worsening balance of payments position, resulting in currency depreciation and the associated rise in the cost of imports, declining revenues and reduced government spending, which will result in a growing possibility of conflict and migration.

The repeated tragedy here is that investment in renewable energy sources (the way to reduce vulnerability to volatile oil prices) is largely driven by the price of oil. When the price of oil is high, people invest in renewable energy. When the price of oil is low, investment in renewable energy also slumps. This creates the conditions for the next crisis. The only way to escape, finally, from this cycle is for a government to follow a firm, long-term energy policy, such as the one outlined by President Obama, which is intended to eliminate US dependence on imported oil within ten years by accelerating the development and dissemination of renewable and low-carbon energy sources[1].

Growing demand

It is also true, however, that basic energy services are still unavailable to 30 per cent of the world's population, and that significantly more energy will be needed in future as world population is set to increase by almost 50 per cent. UN projections indicate that global population will rise from 6.75 billion to about nine billion by 2050, predominantly because of two factors; the continuing rise in world average life expectancy and the relatively high-fertility levels in developing countries (UNDESA, 2006). Almost all of the additional population will be in developing countries; the populations of the world's 48 least developed countries are expected to rise from a total of 658 million to 1.8 billion, while the population of the less developed regions is projected to rise from 4.9 billion to at least 8.2 billion.

The IEA (2007a) notes that the world's primary energy needs are projected to grow by 55 per cent between 2005 and 2030, and that developing countries will account for 74 per cent of this increase, with two countries, China and India, accounting for 45 per cent of the total increase in demand. In 2005, for example, China added as much electricity generating capacity as the UK's current capacity, in 2006, China added as much as France's total supply. As a result, China has now overtaken the US to become the world's largest carbon emitter. Similarly, electricity demand in India is projected to quintuple over the next 25 years.

In South America and the Caribbean, some 90 per cent of the population is connected to the grid, but this average conceals a large disparity. In the main urban areas almost everyone is connected, but in rural areas less than two-thirds of the population has access to electricity (IANAS, 2008). Most governments in the region are, at least in principle, committed to ensuring that everyone, including the poor, has access to modern energy services. These are strong drivers for increased energy consumption.

If there is no significant change in policy, fossil fuels will continue to dominate the fuel mix, accounting for 84 per cent of the overall increase in demand between 2005 and 2030. Oil demand will reach 116 million barrels per day (mb/d) in 2030, representing a 37 per cent (32 mb/d) increase from 2006, while coal demand will rise by 73 per cent, and electricity use will double.

This will result in significant growth in emissions of CO_2, accelerating the rate of climate change. The accelerated draw-down of remaining reserves is also likely to leave the consuming countries increasingly dependent on imports of oil and gas from some potentially unstable countries and regions.

Perhaps, the most fundamental concern at present, however, is that hydrocarbons, such as coal, oil and gas, are responsible for most of the additional carbon loading of the atmosphere, and the associated greenhouse effect. The proportion varies by country, but in the USA, for example, these fuels accounted for 82 per cent of national carbon emissions in 2006 (EIA, 2008).

The greenhouse effect

The Earth receives energy from the sun. Most of this arrives as visible light, which is not absorbed by the atmosphere (the atmosphere is transparent to visible light), and so reaches the surface of the planet and is absorbed as heat. This heat is then re-emitted at a lower frequency (because the Earth is much cooler than the sun), in the infrared range. This would be radiated back out into space, if it were not for the fact that the Earth has an atmosphere, made up of a mix of gases, which is not transparent to infrared radiation. Some of these gases, including water vapor, CO_2 and methane, absorb some of the infrared radiation, and so slow the rate of leakage back out into space. As the atmosphere gets warm, it also radiates thermal infrared in all directions, including back down to the Earth's surface. So the atmosphere keeps the planet warm. The Earth's average surface temperature is 14°C; if there were no heat-trapping effect, the average temperature would be about -18°C.

Human activities add various gases to the atmosphere. Burning carbon-based fuels, for example, such as coal, oil and gas, releases the carbon that they contain into the atmosphere (as CO_2). This increases the heat-trapping effect, and so the planet gradually becomes warmer.

In 2007, the CO_2 concentration in Earth's atmosphere was about 384 parts per million by volume (ppmv). In 1832, the level was 284 ppmv, so it has now risen by 100 ppmv, or 35 per cent (Etheridge *et al.*, 1998). These emissions of carbon and other greenhouse gases have raised the average global temperature by about 0.8°C (IPCC, 2007). Emissions of greenhouse gases are continuing to rise, and many of the gases remain in the atmosphere for lengthy periods, so it is very likely that the temperature will continue to rise; a rise of 2°C may now be inevitable because of the time lag in absorption of CO_2 into the atmosphere. Stern (2006) estimated that there was a 75 per cent chance that the average global temperature would rise by 2-3°C over the next 50 years, and a 50 per cent chance that the temperature would rise by 5°C. A number of studies have suggested that the long-time lags involved mean that we may now have as little as five to ten years to make the policy changes needed to avert these increases in temperature.

Impacts

The IPCC (2007) report notes that rising sea levels, hurricanes, storm surge and floods will affect many countries. This suggests that it may eventually be necessary to retreat from extensive areas of coastal land, and parts of some coastal cities and some low-lying island nations may eventually become uninhabitable.

The worst-case scenario developed in Stern (2006) suggested that the world could lose some 20 per cent of total economic output as a result of the potential loss of significant areas of land to rising seas, the loss of coastal settlements and infrastructure and a catastrophic collapse of agricultural and ecological systems in some regions. It is also possible that there will be significant changes in global patterns rainfall, which has serious implications for food security, water management and industrial production, with a projected 70 per cent increase by 2025 in the number of people without adequate safe water. This includes an estimated 600 million people in Africa, as a result of increased drought and desertification, and almost one billion people in Asia, especially in the areas affected by the loss of the Himalayan glaciers. Water supplies in south and east Australia could be severely limited by 2030, while nearly 80 million people are likely to face water shortages in Latin America and the Caribbean.

Recent forecasts (Cline, 2007) indicate that climate change could cause agricultural yields to fall by 10-25 per cent in tropical and developing countries by 2080, although these losses will be partly offset by gains in temperate countries. In the more extreme cases, India, which will become the world's most populous country, may suffer a drop of 30-40 per cent in agricultural productivity, Senegal a 52 per cent reduction, and the Sudan a decline of 56 per cent.

The IPCC and Stern reports also indicate that low-lying coastal areas in sub-tropical countries, such as Bangladesh, will be increasingly vulnerable to cyclones, flooding and storm surge. In Guyana, for example, part of the capital city and much of the best agricultural land lies at or below sea level, and could be lost to floods. In general, many of the world's poorest communities, living in marginal lands with few resources, are among the most at risk of storms, river and coastal flooding, water shortages, hunger and disease.

Even more extensive impacts may happen in future, as the surface temperature of the planet now appears set to rise for many decades to come. For example, it is possible that a sufficiently high rate of warming may trigger a non-linear and irreversible effect, such as the large-scale release of methane from clathrates in permafrost, causing more extensive and serious changes in global ecosystems. The IPCC report concludes that emissions of carbon must be stabilized by 2015 then reduced if we are to avert the most disastrous consequences.

Unfortunately, all attempts to reduce carbon emissions so far have failed. Carbon emissions are still rising at about 1 per cent per annum.

Sea level

Sea levels rise as the planet warms. The average rate of rise has been about 1.8 millimetres/year over the last century (Church and White, 2006), but there is some evidence that the rate has now risen to 3.1 millimetres/year (Bindoff *et al.*, 2007). Most of the rise so far has been because of thermal expansion of the water in the oceans, but there is likely to be an increasing contribution from melting ice in future. This does not include melting sea ice at the north pole, because this ice is floating in the sea and so already displacing the same volume of water, but it does include the ice in Greenland, Antarctica and so on because this ice is resting on rock.

The IPCC report predicts rises in sea level of 9-48 centimetres by 2080 in the "low emissions scenario", rising to 16-69 centimetres in the "high emissions scenario". These estimates included the rise caused by the expansion of sea water, but did not allow for the possibility that the Greenland and Antarctic ice sheets might start to flow more quickly as a result of increased melting at their base (the water underneath acts as a lubricant and allows the ice to flow more easily towards the sea), and thus increase the rate at which ice breaks off the sheets and melts into the sea (NASA, 2007). Once the potential additional contribution from melting ice is taken into account, sea levels could rise by 0.8-1.5 metres by 2100 (Brahic, 2008). Some scientists think it could be significantly more (Hansen *et al.*, 2000, Hansen, 2007a, b).

A rise of this magnitude would affect many cities, including New York, Miami, Buenos Aires, Vancouver, London, Sydney, Mumbai, Shanghai and Tokyo. In low-lying regions such as Florida, Louisiana, Guyana, The Netherlands, Bangladesh and elsewhere, large areas would be under water. In Bangladesh, about 10 per cent of the entire land area would be inundated by a 1 metre rise. Bangladesh has a population of 154 million, which is about half the population of the USA, living in an area slightly smaller than the state of Iowa, which is about 1.5 per cent of the land area of the USA, so the consequences of losing such a large portion of their territory would be disastrous. By 2100, however, the population of Bangladesh is projected to be almost 250 per cent bigger, so the consequences would be far worse.

Even the lower estimates of sea-level rise present a profound challenge for small island nations and countries with exposed coastal areas; it may become necessary to relocate vulnerable infrastructure and human settlements away from high-risk areas. However, Hansen has suggested that if the carbon level in the atmosphere reaches and remains at 450 ppmv, the warming would be sufficient to melt most of the remaining ice, which would eventually result in a total sea-level rise of 75 metres, which would result in the extinction of a number of nations and the loss of many of the world's great cities.

Predicting the weather

The world's weather systems are exceptionally complex and dynamic. There are both long cycles and rapid fluctuations, which means that a very long-term trend (such as global warming) can only be seen by looking at data recorded over many years; an unusually warm or cold season does nothing to "prove" or "disprove" climate change.

To take one relevant example, hurricane activity in the Caribbean shows a 20-30 year cycle of active and quiet seasons. This is because hurricanes can only form when a number of factors coincide, so most tropical storms cannot develop into hurricanes. One unusually active season does not "prove" climate change, just as one unusually quiet season does not "disprove" climate change.

Hurricanes present a particular threat to the Caribbean, so it is necessary to briefly explain the main factors involved. One particularly important factor in hurricane formation is an area of warm sea. This gives off some of its energy to the air above the surface of the water. This warmed air rises, which creates an area of low pressure. This draws in cooler air from outside the column of rising air. The air is drawn in with a slight spiral, because the Earth is spinning. This can then make the rising column of air start to spin slowly, counterclockwise in the northern hemisphere and clockwise in the southern hemisphere.

The rising air is saturated with the water that has evaporated from the sea. As the air rises, it cools, so the water then condenses and forms clouds. As the water condenses, it gives off some of the heat that it contains, and some of this released energy drives the winds faster. The increase in wind speed increases the rate of surface evaporation, which increases the transfer of energy from the sea. As the temperature in the centre of the storm rises, the air pressure at the surface of the sea continues to fall, which makes air flow even more rapidly into and around the storm. The whole system then becomes self-sustaining, as long as it is over warm water.

Another important factor in formation of hurricanes in the Atlantic is the easterly trade winds in the northern and southern hemisphere, which meet near the equator. The meeting of these strong winds generates powerful thunderstorms, some of which may then organize into larger, unified storm systems. However, if the winds are too strong, they can then shear these systems apart again. This is one reason why it is difficult to predict whether global warming will lead to more hurricanes in the Caribbean; warmer seas would tend to encourage the early stages of development, but it is also possible that there will be stronger winds that would disrupt systems before they could gather strength. It is possible that a number of such factors will change at the same time, so one plausible scenario is that there will be fewer but more powerful storms in the Caribbean.

The reason why hurricanes can do so much damage is their extraordinary power. The world's oceans cover most of the planet's surface, so they absorb most of the sun's energy; roughly equal to 37 trillion kilowatts annually. This is about 4,000 times the amount of electricity used by humanity. A typical square mile of ocean surface waters contains more thermal energy than 7,000 barrels of oil (DiChristina, 2009), and a hurricane can extend over many hundreds of square miles. So a tropical hurricane is, in effect, a giant heat pump, pumping heat from the ocean into the atmosphere at the rate of 50-200 exajoules per day. This is roughly equivalent to 200 times the output of every power station on the planet, or to the energy that would be released by exploding a 10-megaton nuclear bomb every 20 minutes.

This is why a powerful (Category 5) hurricane[2] can have sustained wind speeds over 156 miles per hour. Hurricane Wilma, in 2005, had top winds of 175 miles per hour. These winds spin around the eye of the storm, which can vary from 2 to 230 miles in diameter. So a community that suffers a direct hit from the eye of a hurricane might experience a slow build-up over many hours to 156 miles per hour winds from one side, then a brief lull while the area of calm in the eye itself passes over, then the extremely abrupt onset of equally ferocious winds from the opposite direction. Only the most robust buildings can withstand these extraordinary forces.

However, most of the fatalities caused by hurricanes involve drowning, rather than being hit by flying debris. This is for two reasons. First, hurricane winds push on the ocean's surface, which causes the water to pile up, so the hurricane drives a wall of water in its path. When the hurricane makes landfall, this storm surge can flood coastal areas far inland. For example, the eye of Hurricane Katrina made landfall in Louisiana at 6.10 a.m on 29 August 2005, with a storm surge of 9-10 metres (30-35 feet). The surge of water overwhelmed the levee system protecting New Orleans from Lake Ponchartrain and the Mississippi River, and several sections of the levees collapsed in less than four hours. The city, much of which lies below sea level, was then flooded.

Second, hurricanes lift vast volumes of water into the atmosphere; this then comes down again as torrential rain. In October 1998, Hurricane Mitch sat almost stationary for several days off the coast of Central America, raising water from the ocean and depositing it on land. Some areas received the equivalent of a year's rainfall in less than four days. Lakes and rivers overflowed, low-lying areas were submerged, and some 10-20,000 people drowned in raging rivers, floods and mudslides.

Countries then have to live with the aftermath. Hurricane Mitch left some 460,000 people homeless, while economic losses were estimated at US$6.0 billion, of which two-thirds was lost output from agriculture, forestry and fisheries. More recently, Cuba was hit by Hurricanes Gustav, Ike and Paloma during 2008, which caused damage and losses estimated at US$10 billion (over 20 per cent of Cuba's GDP).

As the oceans gradually warm as a result of climate change, hurricanes may get stronger. Emanuel (1987) suggests that wind speeds will increase by about 5 per cent for every 1°C rise in tropical ocean temperatures, although air resistance and other factors do impose a limit; the maximum potential for hurricane wind speeds is probably around 200 miles per hour.

It would appear sensible, therefore, to take steps to ensure the eventual stabilization of greenhouse gas concentrations in the atmosphere at a level that will not incur a serious risk of serious anthropogenic change in the Earth's climate and weather systems. However, actions must be accurately targeted, which requires analysis of the sources of emissions (Table I).

Road transport is responsible for 74 per cent of carbon emissions from all transport sources, while aviation contributes 12 per cent (IATA, 2009), so road transport contributes about seven times more than aviation (Berntsen and Fuglestvedt, 2008).

However, aviation, which is more directly implicated in the tourism industry, still contributes some 2 per cent of global carbon emissions, and about 3 per cent of all greenhouse gas emissions. This is less than the cement industry, which contributes over 5 per cent (Worrell *et al.*, 2001). Air travel has been a target for environmentalists, rather than the cement industry, probably because air travel is more likely to be seen as a non-essential luxury, whereas cement is seen as an essential commodity.

The paradox here is that the travel and tourism industry is far more important to developing countries than the cement industry, in terms of both revenues and employment.

Similarly, world shipping contributed about 3.5 per cent of total global carbon emissions in 2007, which too is more than air travel. Most of this was freight, rather than cruise shipping, but a cruise ship emits about 70 per cent more carbon per person per mile than an aircraft, so flying is actually a less damaging mode of travel.

Sector	Percentage of total
Electricity and heating	32
Agriculture, land-use change and forestry	24
Domestic and international transport	17
Manufacturing and construction	13
Other fuel combustion	10
Industrial processes	3
Fugitive emissions	1
Total	100

Source: World Resources Institute (2006)

Table I. Carbon emissions by sector (2000)

This is particularly problematic for the Caribbean, which now accounts for over half of world cruise ship tourism. Barberia (2003) notes that at least 40 per cent of the tourists entering nine of the region's leading destinations now arrive via cruise ship. Recent forecasts suggest that the growth rate of the industry will continue to outstrip that of the stopover business for the foreseeable future.

As these examples suggest, there has been a disproportionate focus on air travel to date, although the growth projections for air travel do give grounds for more serious concern. IATA's projections, for example, indicate that aviation will contribute some 5 per cent of all greenhouse gas emissions by 2050.

Implications for the travel and tourism industry

There are a number of ways in which the growing concern about climate change is likely to have an increasing effect on the travel and tourism industry over the next decade. For example:

- It may be necessary to introduce measures to get people to reduce their consumption of fossil fuel. One of the most obvious ways to do this would be to introduce carbon taxes, and the EU recently proposed to include airlines in national carbon emission totals and co-opt them into carbon trading schemes, which would have implications for airfares. Given that demand for transport is highly elastic, it would be necessary to have relatively high levels of tax on carbon-based fuels in order to achieve the desired rate of reduction in use. This would impact severely on the tourism industry, as tourism entails using a great deal of energy to move large numbers of people around the world for what are, after all, non-essential purposes. The impact on particular modes of transport would depend on the energy demand per passenger/kilometer, which means that ship fares would probably rise much more than the comparable air fares. It is possible, therefore, that the cruise ship share of the market might decline.
- Sea-level rise will affect coastal zones. Some beaches will disappear, others will be formed as currents and erosion patterns change. It is possible, therefore, that some existing coastal resorts will be left without their beaches.
- Any change in the frequency and severity of hurricanes would, obviously, be very serious for the Caribbean. Increased frequency could cause the tourist season to contract to relatively safe periods of the year. Two or three severe hurricanes in successive years, without time in between to restore damaged infrastructure, might destroy the industry completely.
- There is also the question of the impact on levels of disposable income around the world. It is very difficult to calculate the potential implications for the global economy of the cost of constructing sea defences for many of the major cities in the world simultaneously. High levels of public taxation and expenditure would cause levels of disposable income in many countries to decline, with obvious implications for non-essential expenditure on items such as holidays.
- While tourism in some countries (such as the UK) is expected to gain, the Mediterranean is projected to become increasingly arid while the Caribbean is likely to suffer from a higher intensity of hurricanes, flooding and storm surge. As noted earlier, Caribbean tourism is largely beach-based, so most of the hotels and resorts are at or near sea level, and therefore directly threatened by climate change.

Part 3: Finding solutions

We face, therefore, two deeply connected challenges; energy security and climate change. This combination represents a profound economic, social, environmental and governance challenge; there are few areas that have the same potential to impact on the viability of entire nations. Yet this situation also represents a remarkable opportunity. Human development and progress has largely depended, to date, on the consumption of natural resources. Recently, technological progress is opening up a new array of options and possible avenues of development. The current dilemmas with energy and the environment offer an opportunity to find a new basis for energy security and thereby create the conditions for long-term, sustained economic growth and social progress. This requires, however, a long-term commitment to increase energy efficiency and build new energy infrastructure, based primarily on renewable and low-carbon energy sources. There are a number of incentives for this course of action.

For example:

- increased economic efficiency means generating more economic output for less resource input, thereby increasing wealth while reducing pollution;
- increased energy security means reduced dependency on potentially unstable or manipulative regimes;
- greater energy efficiency and diversification means reduced dependence on a finite resource, such as oil; and
- greater efficiency and the development of low-carbon sources will help to reduce the rate of climate change, and will also mitigate a range of other environmental impacts.

Thus, progress in this regard is likely to generate multiple benefits.

There are many ways to reduce the carbon-intensity of economies. For example, it could involve promoting the more efficient use of conventional sources of energy, including hydrocarbons, encouraging the expansion of renewable sources, such as hydroelectricity, on and off-shore wind turbines, sub-sea turbines, photovoltaic cells and geothermal power, supporting the development of biofuels such as sugar and cellulosic ethanol and algal biodiesel, or accelerating the development of hydrogen fuel cells and pebble-bed reactors.

Clearly, the strategic priorities for action will vary between countries. For example, the oil importing nations are more likely to promote fuel efficiency, and invest in new renewable and low-carbon energy technologies, while the challenge for oil-exporting nations is to convert their revenues into new industries, technologies and skills (which could also be energy-related) that will provide a basis for their prosperity in a post-oil era. Similarly, the optimal technological solution will also vary between different locations and countries. For example, off-shore wind turbines would be suitable for a country with an extended coastline and favourable wind regime, hydropower schemes would be appropriate in a country with high mountains, non-porous rock and high-volume rivers, geothermal power could make a useful contribution where there are accessible hot rocks, while biofuel production would be suitable for a country with extensive areas of suitable agricultural terrain, adequate water supplies and biological feedstock, and a good solar regime. There would be particularly significant gains for developing countries; about two-thirds of economically feasible hydro-generating capacity and almost all wind energy remains untapped, and most of these resources are in low-income countries.

The world already has most of the skills, technologies and natural resources needed to develop and disseminate cleaner technologies, more energy-efficient solutions and low-carbon energy sources, but two additional measures are required. One is financing, but venture capital is already available, and mainstream lending will be forthcoming as new technologies are proven and become more established.

The remaining step is that new government policies are also needed in order to facilitate change, including funding for relevant research in energy technologies, support for the development of international carbon markets, and the liberalization of energy markets. One important way to increase the efficiency of biofuel production, for example, is simply to lower tariffs and remove barriers to trade, so that fuel crops can be grown where the environment is most suitable, and thereby produced at lowest cost, then the output can be shipped to the consumers. Similarly, many renewable sources are intermittent or only available in particular locations, so governments must allow companies to build cross-border energy distribution grids; these are needed to allow variable sources to be balanced against demand.

The optimal mix of policy measures required will also vary between countries. For example, the most cost-effective solution in one case might take the form of funding for research in, for example, zero-carbon homes, or building more efficient transport systems. In another country, it might take the form of subsidies or tax-allowances to encourage businesses to build new energy supply and distribution systems, or tax differentials to encourage consumers to switch to cleaner or low-carbon fuels.

One particularly important role for governments in regions such as the Caribbean is to ascertain which areas of human settlement and sections of essential industrial and transport infrastructure are located in areas likely to become increasingly vulnerable to sea-level rise, increased incidence of severe weather, flooding and storm surge in future, and to ensure that these vital assets are either protected or relocated in order to reduce the risk of future disaster. This will involve measures to enforce set-backs, to zone new developments out of such areas, and to amend building codes to ensure that any permanent new construction can withstand even hurricane conditions and flooding. It is also important to ensure that reefs, sea-grass and mangroves are protected, as these can all help to protect vulnerable coastline from storm surge.

This will not be a trivial exercise. For example, Jamaica is a small island nation with two international airports, both on the coast, and just above sea level. A significant part of the housing stock and economic and transport infrastructure is in areas that are likely to become increasingly vulnerable. Over time, zoning and planning can gradually move people and the infrastructure into safer areas, but this will take decades. It will also be necessary, therefore, to implement a number of short-term measures. Many of the necessary steps are known, as Jamaica has already suffered a number of serious natural disasters. Hurricane Gilbert struck the southern coast of Jamaica in 1988 and badly damaged the electricity infrastructure, the agricultural sector and a significant portion of the housing stock. Hurricane Ivan in 2004 did significant damage, especially on the south coast.

These events highlighted several key weaknesses. Relief efforts were seriously handicapped by the lack of electricity in the worst-affected areas and consequent inability to operate lighting, refrigeration (for, e.g. medicines), water pumps and communication networks and so on. Electricity is never normally available in the critical disaster and post-disaster periods when these facilities are most needed. These problems arise directly from the centralized generation of electricity and the network of distribution systems. These systems, especially the distribution poles and lines, are usually physically damaged during a hurricane or similar disaster, and it takes time to bridge the broken sections. Some individual sites have standby generators, but most communities do not. The development of decentralized sources of energy, such as photovoltaic cells, is therefore now a vital part of disaster preparedness. The treatment of waste is also of crucial importance. Hurricanes cause floods, which make sewers and septic tanks overflow. This, in conjunction with the bodies of drowned people and animals, can make the surrounding water a vector for virulent disease, especially in hot countries. One partial solution to both problems would therefore be to ensure that all new developments have secure solar-powered bio-digester tanks, partly in order to contain the sewage produced, but also to contribute to the energy supply. All such measures will have to be incorporated in building codes if they are to become the norm.

It is clear, therefore, that most of the technical innovation will be driven by the private sector and research institutes, but governments must take a leading role on the relevant policy issues.

Conclusion

In conclusion, the issues of energy security and climate change present a profound challenge, but also represent a remarkable opportunity, because technological progress has started opening up a new array of options. The accelerated development and rapid commercialization of new and cleaner energy technologies would allow the net global emissions of greenhouse gases to be first stabilized and then steadily reduced.

The question now is whether the travel and tourism industry can evolve from being part of the problem to being part of the solution. This cannot be addressed as if it were merely another environmental issue; a request to hotel guests to use their bath towels for a little longer will do little to solve climate change.

Real progress will depend on the extent to which the industry is prepared to take much bolder steps; moving hotels back from the sea, building in-house energy systems, demanding dramatic improvements in energy efficiency, encouraging a transition to renewable energy sources, using biofuels and so on. An even more important contribution, however, would be if the travel and tourism industry, which has significant political influence in many countries, were to encourage its host governments to implement some of the policy measures described above.

If the industry can make a positive contribution in this regard, it may help to ensure its own survival, as well as that of many nations.

Notes

1. The USA is the world's largest consumer of petroleum products; it requires nearly 21 million bbl oil/day, about half of which is used as gasoline. The US is also the world's third largest crude oil producer, producing some 8.7 million bbl oil/day, but consumes about three times more than it produces, so net petroleum imports (imports minus exports) accounted for 58 per cent of total US consumption in 2008, giving an import requirement of about 12 million bbl oil/day. President Obama is proposing to reduce this to zero via efficiency gains and substitution. The latter will include new electricity generating plant (to power electric vehicles), and a vast scaling-up of biofuels production.

2. The Saffir-Simpson hurricane scale is as follows: Category 1: winds 74-95 mph, no serious damage to buildings; Category 2: winds 96-110 mph, minor damage to, e.g. roofs and windows; Category 3: winds 111-130 miles per hour, minor structural damage to buildings, flooding at coast; Category 4: winds 131-155 miles per hour, serious structural damage to buildings, flooding far inland; Category 5: winds 156 miles per hour and over, catastrophic building failures, deep flooding far inland. There is no Category 6, because Category 5 can cause complete devastation, so it is not necessary to qualify the extent of the devastation beyond that point.

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