Can Cities Sustain Life in the Greenhouse?

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Data from the Global Environmental Monitoring System indicate that pollutants such as sulphur dioxide and total suspended particulate routinely appear in the lower atmosphere of major cities at concentrations well above health guidelines set by the World Health Organization. As well, cities are major contributors to the build-up of greenhouse gases which now threaten climate change. These findings underscore the detrimental relation that has evolved between urban industrial society and the atmosphere. If this peculiar civilization is to be changed, three principles—equity, sustainability and peaceful development—must guide the reevolution of urban life. The paradigm of commodification needs to be replaced with a model of a commons of life. The article provides a theoretical framework and strategy for reforming global climate policy and urban sustainability planning in a manner consistent with life in the commons.

Keywords: *cities; climate change; urban policy; solar cities; sustainable energy; social equity*

Environmental Conflicts of Modern Urbanism

For the past 200 years, urban industrial society has sought the promotion of wealth and economic opportunity based on rapid growth in the production and consumption of commodities. These aspirations have been realized through technological advance and often the colonial and environmental exploitation of other nations and cultures (Nelson, 2004; Esteva, 1992; Redclift, 1984; Noble, 1983). In the 20th century, complex energy systems based on the use of fossil fuels and nuclear power acquired an increasingly dominant role in supporting the expansion of this economic system while also contributing to its spread throughout the globe. Indeed, the fossil fuel and nuclear energy regimes have fostered a belief in an energy-civilization equation (Basalla, 1980) that associates progress with living beyond the carrying capacities of nature (Daly, 1990 and 1991; Martinez-Alier, 1990). In the embrace of this cornucopian ideal, modernity evolves as if the costs and benefits of ways of life can be tallied without regard to material constraints (Byrne, 1987; Gardiner, 2004). Advocates of this urban-industrial vision find proof of progress in the North's ascendancy to the apex of the global financial wealth pyramid (UN Population Fund, 2001).

Although some improvements in Northerners' health and economic security have accompanied adherence to this mode of development, a wider pattern of social and environmental problems has also become evident directly as a function of urban society's unique success. These include persistent pollution, environmentally unsustainable resource use and social inequality within and across nations. As troubling and harmful as such trends may be, they are precursors to yet another emerging trend: the transformation of earth's atmosphere and climate. Under this transformation, nature is no longer simply exploited for its particular attributes but is in fact redesigned to meet the needs and interests of technological civilization. The emergence of acid rain and holes in the upper ozone, the extinction of plant and animal species (and the engineering of new ones), the reduction of the planet's capacity to breathe (due to deforestation, among other things), the manufacture of highly toxic, long-lived radioactive poisons so dangerous that they require 1,000 year

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security zones and the stimulation of consumptive appetites that in the aggregate portend a change in global climate—all of these form an environmental legacy that only urban industrial societies, throughout all of human history, could have bestowed to the future. As Nicholas Shackleton (1990), a noted climatologist at Cambridge University, has suggested, "we are going outside what nature has experienced in the recent past 500,000 years" (Cited in Stevens, 1990: C1).

At the core of this legacy rests the commodification of social and ecological relations, by which human experience increasingly transpires within an urban reality driven by the production and consumption of an abstraction, namely wealth. Acting on the assumption that the urban artifice can provide heretofore unavailable economic prosperity, societies now regularly release a flood of pollution, threatening air, water and soil quality and the diversity of earth's plants and animals. The disregard for natural limits reflects the logic of technology and capital, which values growth over sustainability. In this scheme, nature represents little more than a stock of raw materials and a reservoir for the absorption of industrial wastes, as society bets its fate on the synchrony of growing energy use and expanding economic gain.

Urban Industrialization and Climate Change

Recent research allows us to understand ever more precisely how urban life is affecting the natural environment. For example, through the Global Environmental Monitoring System, a database built by international scientific cooperation, we have learned that urban industrial society is transforming the lower atmosphere's chemistry throughout much of the world. Pollutants such as sulphur dioxide (SO_2) and total suspended particulate routinely appear in the world's major cities at concentrations well above health guidelines set by the World Health Organization (Figures 1 and 2).

In the United States, the Environmental Protection Agency's ongoing studies of the lower atmosphere of the continental part of the country have revealed that only a tiny portion of its airshed can normally be regarded as free of industrial pollution. Protected by the Rocky Mountains, this area lies distant from metropolitan centers and claims as its principal residents the wild animals and plant life of four national parks (Figure 3). This example underscores the detrimental relation that has evolved between urban industrial society and the atmosphere.

Beyond pollution and environmental decay, urban life may now be contributing to a change in the global climate. Sponsored by two UN science agencies, the UN Environment Program and the World Meteorological Organization, the Intergovernmental Panel on Climate Change (IPCC) was formed in 1988 to investigate the possibility that anthropogenic (or human-caused) emissions of carbon dioxide (CO_2) and other heat-trapping gases might actually force a new, warmer climate in the 21st century. This phenomenon portends impacts on a scale beyond anything heretofore imagined, as until recently the pattern of pollution depicted in Figures 1 through 3 was considered limited in its spatial scope.

Early efforts by the IPCC to identify potential impacts of climate change revealed not only the immensity of this research task but also the lack of existing research and the uncertainties associated with climate impacts. Nevertheless, by the completion of the IPCC's 1996 report, few doubts remained about the scientific evidence of climate change and human involvement in the warming trend, a conviction that only mounted with the panel's Third Assessment Report in 2001. As suggested by these studies, increasing global average surface temperatures contribute to highly differentiated deviations from normal climate patterns, and anthropogenic emissions of greenhouse gases (GHG) comprise the leading cause.

The conclusions of the 1996 IPCC report played a key role in stimulating milestone efforts to address climate change. In December 1997, the Kyoto Protocol was adopted at the Third Conference of Parties (COP-3).[1] For the first time, binding targets for reductions in so-called GHG emissions[2] were established. North America, Europe (including Eastern Europe and the republics of the former Soviet Union), Japan, Australia and New Zealand (the so-called Annex I countries[3]) collectively agreed to lower their emissions at least 5.2% below their aggregate 1990 level within the commitment period of 2008 to 2012 (see Article 3 of the Kyoto Protocol, 1997).[4]

Although marking an historic step in seeking an international solution to the threat of climate change, the Kyoto Protocol calls for actions that achieve much less than what is actually required, according to the best available scientific estimate. More specifically, early IPCC estimates indicated that a 60% decrease, at least in GHG emissions, from 1990 levels would be needed for a return to climate stability (IPCC, 1996). The Second Assessment Report suggested that this reduction need to be achieved by 2050 to stabilize atmospheric concentrations of CO_2 and equivalent

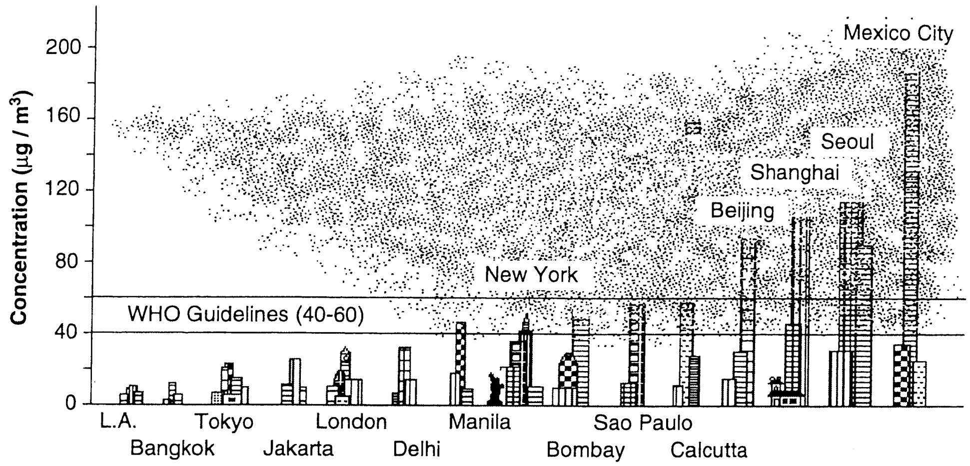

Figure 1. **SO_2 Pollution in 15 Megacities**

Source: World Health Organization and (United Nations Development Program) (1992).

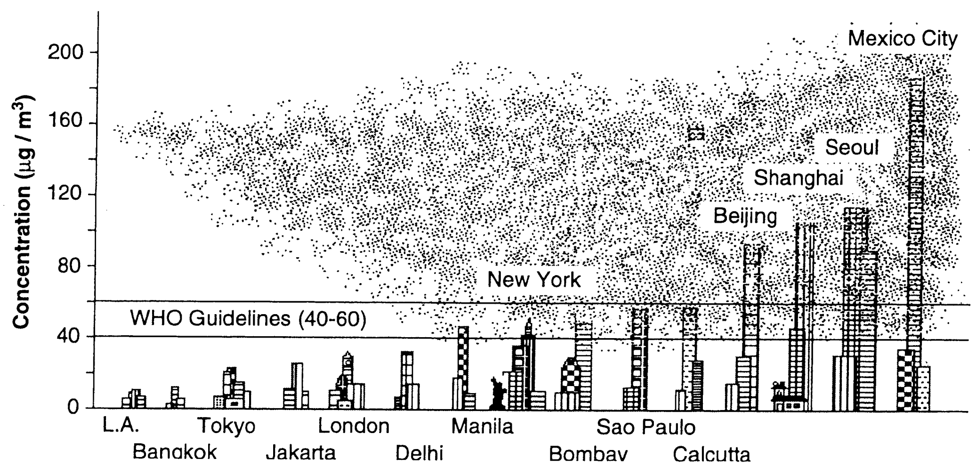

Figure 2. **Total Suspended Particulate Pollution in 15 Megacities**

Source: World Health Organization and UNDP (United Nations Development Program) (1992).

GHGs at 350ppm by 2100. However, more recent calculations, which account for the effects of climate change on the carbon cycle alongside increased emissions levels since 1990, indicate that cuts during a longer period would be required (and nevertheless may leave higher concentrations of GHGs in the atmosphere). The 2000 Special Report on Emissions Scenarios and the 2001 Third Assessment Report both call for emissions to drop 50% below 1990 levels by 2050 and to continue their decline to stabilize concentrations at a dangerously high 450ppm by 2100, further marginalizing Kyoto's aspirations for a 5.2% cut.

Meeting at The Hague in November 2000, negotiators at COP-6 settled on the means available to countries to reduce emissions, providing detailed definitions for the three policy tools created at Kyoto. These include emission trading (ET), joint implementation (JI) and a clean development mechanism (CDM). Nevertheless, in the effort to facilitate an economically efficient achievement of targets, these measures almost certainly ensure that any emissions reductions made under Kyoto will prove insignificant even in comparison to the modest objective of 5.2% for Annex B countries (see Byrne et al., 2004).

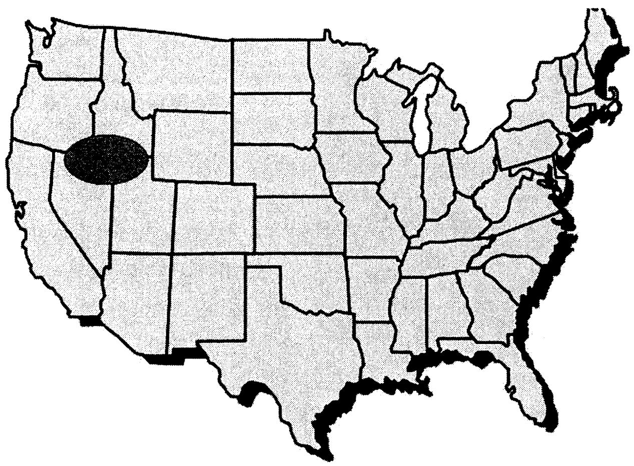

Figure 3. The Last Reservoir of Clean Air in the Continental United States

Source: U.S. National Park Services monitoring station data.

As this contrast between necessary and likely outcomes makes clear, international negotiations on climate change have failed thus far to embrace a new paradigm for understanding nature-society relations. Instead, economic issues and concerns—largely of the wealthy urban industrial countries—have dominated the debate. This circumstance has led to a growing suspicion that the climate change treaty represents less of an effort to develop effective environmental policy and more of an attempt to cultivate opportunities for new spheres of economic profitability (e.g., Byrne et al., 2004; Byrne & Glover, 2000). In this regard, the agendas of the UN-sponsored negotiations on climate change often seem better suited to Uruguay Round trade concerns than initiatives to protect the global environment.

Despite such flaws, the Kyoto Protocol was ratified by Russia in 2004. This event marked the necessary support of at least 55 parties, to include Annex I nations responsible as a group for at least 55% of total CO_2 emissions in 1990, for ratification as required by the UN Framework Convention on Climate Change. Accordingly, the Kyoto Treaty came into effect on February 16, 2005, even as the United States and Australia opposed ratification. The stances of these nations, moreover, could become increasingly problematic as the flexibility mechanisms under the Protocol commence in earnest, following the further development of rules and procedures at COP-11 and MOP-1. As participating countries gain greater experience with these mechanisms and as financial and business sectors make sizable investments in projects throughout the globe, it is likely that support for the Kyoto regime will only increase, even if the players pursue very different political and economic strategies along the way (Wittneben et al., 2006).

Nevertheless, if the currently destructive relationship between urban industrial society and the global environment is to be halted, the ethos of economic advantage as evidenced by Kyoto and global conventional energy regimes must give way to principles of equity, sustainability and peaceful development. More broadly, the paradigm of commodification that has guided nature-society relations in the urban industrial era needs to be replaced with one that restores the global environment to its rightful status as a commons. Using the international climate change negotiations as a case in point, we seek to demonstrate later why this basic paradigm shift is needed and how it can be accomplished.

An Equitable and Sustainable Approach to Avert Global Warming

To halt modernity's experiment with global climate change, principles of sustainability and equity must assume an essential role in the design of an international policy response. Sustainability may be operationalized as the adoption of the IPCC target for a 60% reduction in world CO_2 emissions. This clear benchmark for climate change negotiations[5] can guide the parties in setting near- and long-term reduction targets, so that sustainability can be reached by 2050. In addition, an international commitment to equity must include a principle recognizing that the biosphere belongs to all living things, so that no human being can claim entitlement in using its carrying capacity more intensively than another.

Based on these two principles, it is possible to define how much CO_2 and related gases can be emitted by each country without exceeding the absorptive capacity of the earth—a commons on which we all rely and benefit. The IPCC estimates that the biosphere is capable of absorbing between 14 and 17 billion tons of GHGs per year (based on molecular weight). Dividing this number by world population, about 5.2 billion in 1990, yields a sustainable GHG emission rate of approximately 3.3 tons of CO_2 equivalent (TCO_2-E) per person annually. Although this number currently represents an equitable distribution of access to the atmospheric commons, increases in population as projected by the UN point to an eventual decrease in the sustainable per capita rate, which should drop to 2.2 TCO_2-E by 2025.

Using this method of calculation, the United States is found to emit far more than its fair share of GHGs. Indeed, using CO_2 as a benchmark, Americans release approximately seven times the country's sink allotment (Figure 4). By contrast, China uses less than its fair share, despite heavy reliance on coal. Figure 5 shows per capita CO_2 emissions of various countries compared with the sustainable and equitable emission rate defined earlier. The width of each country's block corresponds to its proportion of world population. This graph dramatically demonstrates the overuse of the atmospheric commons by urban industrial countries in disposing of their excess CO_2 emissions. Indeed, all major industrial countries represent CO_2 debtors, whereas most developing countries count as creditors living within their budgets. The accrual of environmental debt can thus be seen as one principal way in which wealthy countries have attained economic success and power, treating the commons as a free good and not paying for its intensive use.

Adherence to the sustainability and equity principles described earlier means that the primary responsibility in reducing GHG emissions should fall to those countries that have triggered the current risks of warming. Specifically, Annex I countries in the Framework Convention on Climate Change must bear the immediate burden of change because they have served as the principal sources and beneficiaries in the release of emissions during the past 200 years.

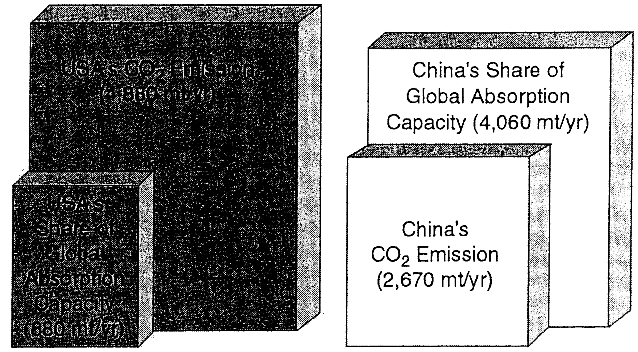

Figure 4. CO_2 Emissions vs. Democratic Share of Biospheric Absorption Capacity for the United States and China

Source: Byrne, Wang, Lee and Kim (1998).

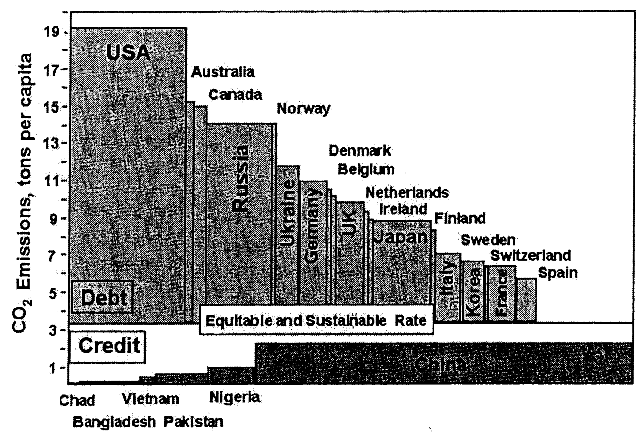

Figure 5. Selected National CO_2 Emissions Compared to the Sustainable and Equitable Rate

Sources: Byrne and Glover (2000); Byrne, Wang, Lee and Kim (1998).

Equity, Sustainability and the Kyoto Protocol

Relying on the equity and sustainability principles described earlier, it is possible to evaluate the implications of three key policies advanced by the Kyoto Protocol for their likely contributions to resolving the climate crisis. These include ET, JI and the CDM. As described later, these approaches stand to reinforce the existing paradigm for commodification of nature-society relations rather than restoring the atmosphere to commons status.

Emission Trading

The Kyoto Protocol allows ET only among Annex I countries, with many details finally worked out in Montreal during the 11th meeting of the Conference of the Parties to the Framework Convention (COP-11) and the first meeting of the Parties to the Kyoto Protocol (MOP-1) held November 28 to December 10, 2005. Under the Kyoto ET regime, Annex I countries can purchase emission permits from other Annex I countries that have lower cost CO_2 reduction options than those available to permit buyers. Both parties must meet their Kyoto emission rate caps for trades to be certified under the protocol. Advocates of ET argue that efficient levels of CO_2 reduction can be achieved from trading because societies have different marginal benefits and costs associated with mitigation, due to variations in income, economic growth rates, fossil-fuel endowments and energy systems. Thus, trading is promoted as a means to substantially reduce the overall global costs of CO_2 mitigation (Mortensen, 2004; Field, 1994).

However, serious flaws attend ET from an equity- and sustainability-based perspective (see Byrne et al., 2004; Byrne, Wang, Lee & Kim, 1998; Byrne, Wang, Hadjilambrinos & Wagle, 1994). For example, the emission caps set in Kyoto for Russia and the Ukraine call for CO_2 emissions in 2008 to 2012 that are equivalent to each country's 1990 level. This allowance may ultimately yield phantom emissions sales (so-called hot-air trades) because neither country is expected to realize 1990 emission levels by 2008 to 2012, even under generous business-as-usual scenarios. During its participation in Kyoto, the United States appeared to be counting on trades with former Soviet bloc countries to meet as much as 56% of its Kyoto commitments (Kopp & Anderson, 1998). By using such trading along with other flexibility measures, the United States could actually have been able to increase its carbon emissions by 12% to 16% above its national targets (Pearce, 1997).

The purchase of hot-air allowances, or allowances from nations that are not accompanied by meaningful long-term domestic carbon reduction measures, would significantly diminish the protocol's success in bringing about the deeper changes ultimately needed for sustainability. More specifically, relying heavily on purchased allowances may reduce the impetus for significant technological change in Annex I countries, leading to a continuation of unsustainable Northern development patterns. A trading regime also allows high-emission countries to postpone action, shifting that burden to future generations. This compounds intergenerational inequality, with its magnitude increasing in proportion to the number of trades taking place. Additionally, trading exacerbates present-tense inequities in environmental and social risks, as Southern countries are likely to experience higher near-term human and natural losses from an unstable climate system. Finally, by allowing CO_2 emissions growth for countries that can afford to pay for permits, the system is regressive, rewarding the wealthy with pollution rights and burdening the poor with a de facto obligation to clean up much of the mess.

Joint Implementation

The Kyoto Protocol authorizes JI projects among Annex I countries (Article 6), so that nations receive credits toward meeting their targets through project-based emission reductions or carbon sink expansions in other countries. With the private sector allowed to participate in these activities, JI permits high CO_2 emitters, for example, to pay for the development of tree plantations and use of more energy-efficient technologies in another Annex I country. Such action provides a means of offsetting CO_2 emissions in the paying country.

It remains unclear how JI, as defined in the Kyoto Protocol, can serve the goal of sustainability because the approach will only serve to counteract an Annex I country's increased emissions with another's reduced emissions (for example, Western Europe counts the sink value of a forest it plants in Eastern Europe as an offset to its own emissions growth—see Muhovic-Dorsner, 2005). With Annex I nations responsible for nearly two thirds of all CO_2 emissions since 1950 (Byrne et al., 1994), and with the need to reduce world CO_2 emissions to 60% of 1990 levels for achievement of climate stability, a program of emission offsets hardly seems responsive to the magnitude of the problem at hand. Current JI policy merely provides an option for continuing business as usual, relying on existing technologies linked to the original causes of the climate crisis instead of stimulating a shift to a low- and zero-emission technology path. Furthermore, by allowing Annex I countries to create offset programs and to retain the option of living beyond planet carrying capacity for CO_2, JI may result in long-term emission trends inconsistent with the goal of the UN Framework Convention on Climate Change for preventing "dangerous anthropogenic interference with the climate system" (cited in Agarwal & Narain, 1998).

JI likewise raises equity issues in addressing climate change because it transfers to other countries the responsibility to adopt measures that, in practice, would be needed in the paying country to lower its own emissions (Sachs et al., 2002; Metz, 2000). For example, JI may lead Russians and Ukrainians to adapt their economies and ecological systems for the prospect of climate change so that other Europeans can maintain high-consumption lifestyles (Muhovic-Dorsner, 2005). In this regard, JI postpones Annex I action for ending atmospheric overuse as a CO_2 sink, leading to present-tense and intergenerational inequalities comparable to those linked to emissions trading.

Nevertheless, some advocates propose extending the JI program to include transactions between Annex I and developing countries. However, such an extension can only exacerbate patterns of *environmental colonialism*, Agarwal and Narain's (1993) term for Northern exploitation of the South under the guise of climate change policy. Environmental assets in developing countries, such as forested areas, could fall under management of the North to prevent the latter's having to cease overexploitation of the atmospheric commons. Companies from developed nations could snatch up low-cost opportunities in the South to reduce emissions or expand sinks (the so-called low-lying fruit), requiring the developing world to undertake more costly conversions to high-efficiency technologies in future years to lower their own emissions to sustainable levels (Lynch, 1998; Nelson, 2004). In this respect, JI could undermine the self-determination that many Southern countries fought so hard to recently achieve. Finally, under an expanded JI scheme (the same would apply for ET in this case), developing countries would compete among each other for investments from developed countries, thereby frustrating South-South cooperation.

Clean Development Mechanism

The third major policy vehicle created by the Kyoto Protocol to meet emission caps set by UN-sponsored negotiations is the CDM. The CDM exists in the Kyoto Protocol as a mechanism for North-South cooperation and allows industrialized countries to earn credit for carbon reduction activities in developing countries. Under CDM, developed countries (or companies from developed countries) can choose to invest in projects or buy emission reductions in developing countries. With CDM, developed countries are able to use certified emission reductions from such project activities to meet their own national GHG reduction targets. The policy's rationale rests on the belief that developed countries will be able to reduce emissions at lower cost through projects in developing countries, whereas the latter will receive technologies supportive of their sustainable economic growth (see Article 12 of the protocol). Importantly, certified emission reductions under CDM commenced in the year 2000 and will count toward compliance with the first budget period of 2008 to 2012 (Fletcher, 2004; U.S. Department of Energy, 1998).

Because projects will occur in developing countries, which have no emissions limits, reliable procedures become critical in making sure that credited reductions are real (i.e., that they reflect genuine reductions below a realistic projection of future emissions; Kartha, 1998; Mortensen, 2004). Lack of adherence to detailed procedures for evaluating, monitoring, verifying and crediting projects can thus threaten sustainability in the same manner as hot-air trading under the ET mechanism of the Kyoto Protocol. In this respect, CDM, such as ET and JI, can allow a high-emission country to pursue a business as usual path with minimal disruption to its polluting behavior, yet the country may advertise its actions as proenvironment.

Moreover, CDM's effect may actually culminate in the reverse of sustainability, if developed countries bank CO_2 reductions in developing countries but the process leads over time to higher GHG emissions. For example, support of electrification projects in the South using high-efficiency plants from the North may reduce CO_2 emissions from what would otherwise occur via use of more conventional technology. But if such projects promote centralized electricity systems that spur rapid consumption growth to pay off capital costs, the net effect may be higher CO_2 emissions over time (Byrne et al., 2004).

An Alternative Policy Approach

In contrast to the Kyoto Protocol's trading strategy, Brazil argued for the creation of a penalty fund in which developed countries would be charged annually for surplus emissions above agreed-on targets until their achievement of a sustainable emission rate (Mumma, 2001; Bernow, 1998; Byrne et al., 1998). Under such an approach, the penalty fund could yield project activities resulting in certified emission reductions in southern countries while promoting development in those nations. This policy would encourage industrial countries to cut penalty payments by reducing their own emissions, whereas developing countries would receive capital investment in the economic, institutional and technological systems necessary for long-term sustainability.

A similar proposal by the Center for Energy and Environmental Policy (CEEP; see Byrne et al., 1998) calls for Annex I countries to make contributions (based on a graduated scale) into an international fund as a penalty for abusing the commons by emitting CO_2 above the equitable and sustainable rate. The monetary value of environmental debt payments into such a fund would be determined by an avoided cost method, whereby payments per ton of CO_2 emitted would be set at a value equal to the cost of avoiding a ton of emissions. Until environmental debtor countries reduced their CO_2 emissions to the sustainable rate, they would be obligated to contribute funds according to their level of emissions. Under CEEP's proposal, the calculation of environmental debt for each country rests on the cost of CO_2 avoidance multiplied by the excess CO_2 emissions of each country over the sustainable rate.[6] This fund could then underwrite CO_2 mitigation and sink expansion projects between debtors and creditors.

By advancing a sustainable emission rate as needed for climate stability, this alternative approach differs significantly from the current ET, JI and CDM measures promoted in Kyoto by Annex I countries. More specifically, wealthy countries would not be permitted to bargain with individual developing countries to reduce annual debt obligations. Instead, GHG debtors and GHG creditors would interact as blocs via the fund, thereby allowing creditor countries to set priorities for themselves and to withdraw funds according to these priorities.[7] This approach embodies a "historical polluter pays principle" and avoids the problems of environmental colonialism linked to other trading regimes, allowing the South to exercise its sovereign power and incorporating equity as a dynamic policy concern. The ultimate effect is to establish the mutual responsibility of all countries to protect the atmosphere as a global commons.

In conjunction with a CO_2 debt-financed fund as described here, CEEP also recommended a cap on ET among Annex I countries equal to a maximum of 25% of a country's target obligation—that is, each Annex I country would be expected to achieve at least 75% of its target through domestic measures; only 25% of a nation's obligation could be met by trading. Such a cap can ensure that Annex I countries vigorously pursue the technological, economic, social and policy changes needed to finally end unsustainable CO_2 emissions within their borders (see Byrne et al., 2004).

This alternative strategy would strongly encourage South-South and regional cooperation projects, removing the need for southern countries to pair with northern governments (CDM) or companies (JI) to pursue low-carbon development pathways. Although southern communities could still seek partnerships with northern investors and technology owners, such cooperations would be based on southern goals and needs. CO_2 mitigation and sink expansion projects resulting from South-South or South-North cooperation should be eligible for banking credits by the South, in the event that developing countries agree to voluntary emission targets after the 2008 to 2012 commitment period. In this manner, crediting South-South cooperation projects undertaken during the next 6 years provides recognition of the South's contribution to solving the climate change problem. This corrects the current policy orientation of ET, JI and CDM in the Kyoto Protocol, which appropriates projects in the South for the benefit of the North.

Peaceful Development

As argued in this article, equity and sustainability represent essential criteria for climate change policy. Nevertheless, a third criterion—peaceful development—also remains necessary, as discussions since Kyoto have revealed.

With worldwide political awareness increasing as regards the central role of fossil fuel consumption in creating the threat of global warming, nuclear energy advocates have sought to promote this dangerous technology as a useful means to alleviate the greenhouse effect. This maneuver contrasts with wider trends in the energy sector during the past two decades, whereby nuclear power has shifted from a much touted (and supported) conventional energy option to one beset with numerous problems and decreased importance in nearly all countries. Although the current U.S. administration includes nuclear energy among those sources it hopes to promote (White House, 2005), only Eastern Europe and Asia remain markets for new nuclear plants. Specifically, in the past decade, nuclear power plants have broadened their reach only into countries such as the Czech Republic, Japan, South Korea, India, Taiwan, China, Pakistan and Iran (World Energy Council, 2001). The nuclear industry is pressing hard for the continued expansion of such facilities in the developing world, arguing that nuclear power generation represents the least disruptive and most cost-effective climate-friendly option available to the world (World Nuclear Association, 2005).

Nevertheless, efforts to rehabilitate nuclear power in response to the threat of climate change remain deeply flawed. First, revitalizing nuclear power does not serve as a cost-effective response to global warming. Keepin and Kats (1988) and Hohmeyer (1992) long ago demonstrated—through comparative analyses of nuclear power, energy efficiency and renewables as GHG abatement strategies—that nuclear plants remain by far the economically inferior option. In fact, Keepin and Kats found that each dollar invested in efficiency in the U.S. electricity system displaced nearly seven times as much CO_2 as did a dollar invested in nuclear power. They concluded that even under the most optimistic assumptions about the future economics of nuclear power, efficiency would still displace between 2.5 and 10 times more CO_2 per unit of investment. In addition, Hohmeyer (1992) has shown that after a full accounting of the environmental and social impacts of energy production, nuclear power ranks far more costly than benign sources such as solar and wind energy. And, according to Germany's Oeko Institute, technologies capturing energy from wind, small hydro and solar sources emit less CO_2 when their entire fuel cycle is compared with both fossil energy and nuclear power sources (Hohmeyer 1992).

A second detriment of nuclear power involves its pervasive danger to society and nature, in the form of nuclear accidents no less fundamentally threatening than global warming. Just one month after *The Economist* (1986, p. 11), a British magazine, declared in its lead article "The Charm of Nuclear Energy" that the technology was "as safe as a chocolate factory," the lid blew off the No. 4 Reactor at Chernobyl. The explosion released the largest quantity of radioactive material ever from one technological accident, estimated at 200 times that of the Hiroshima and Nagasaki atomic bombs combined and causing widespread evacuations of almost 400,000 people (World Health Organization, 1995). In addition, the accident may have directly or indirectly endangered the health of at least 9 million people, including large populations in Belarus and Ukraine. Health impacts included an above-normal incidence of thyroid cancer (285 times the pre-Chernobyl level) and a 30% higher incidence of illnesses of all kinds than normal in contaminated areas (World Health Organization, 1995) .

A third failure of nuclear power lies in its production of extremely long-lived toxic waste, for which no means of safe disposal exists. After 30 years or so of electrical service, all nuclear plants become waste sites due to the accumulation of highly hazardous toxins threatening all forms of life for thousands of years (Byrne & Hoffman, 1988). One of these unavoidable wastes includes plutonium 239, among the most carcinogenic substances known to humankind. As 1994 noted nearly 30 years ago,

> It is so toxic that less than one-millionth of a gram (an invisible particle) is a carcinogenic dose. One pound, if uniformly distributed, could hypothetically induce lung cancer in every person on earth. . . . Each commercial nuclear reactor produces approximately 400 to 500 pounds of plutonium yearly.

And as Lenssen (1992) has noted, "the radioisotope plutonium 239 . . . is dangerous for a quarter of a million years, or 12,000 human generations" (p. 50).

Accordingly, even if nuclear power never caused a single accident in the history of its operation (already contradicted by fact), the regime nonetheless creates long-lived hazards on par with the threat of global warming as linked to the use of fossil fuels. Fundamentally, the nuclear and global warming threats differ only in the aspects of nature under direct assault: for global warming, it is the structure of the climate; for nuclear power, it is the molecular basis of life. Either scenario foretells eventual social and ecological disaster.

Fourth, nuclear power poses a direct threat of nuclear weapons proliferation. A nuclear bomb can be produced with only 12 to 24 pounds of plutonium (Nilsson & Abrahamson, 1991). With a typical light water reactor producing between 400 and 500 pounds of plutonium per year, nuclear power development represents an unavoidable threat to world peace. No monitoring or accounting system can remove this threat from the nuclear fuel cycle; it remains an institutional risk that accompanies the operation of any commercial-scale nuclear energy system. Furthermore, many speculate that both nuclear generating facilities and nuclear waste represent high-profile terrorist targets with the potential for catastrophic human suffering in the event of a successful attack (Bunn & Steinhausler, 2001). When combined, nuclear power's long-lived, toxic legacy and threat to peace oblige societies deploying it to build as nearly fail-safe guardian and security systems as humanly possible. In turn, these require technological and military elites to design and oversee them, lending to nuclear power the political character of an authoritarian regime (Byrne & Martinez, 1996; Byrne & Hoffman, 1988, 1996).

The inherently catastrophic nature of nuclear power provides ample reason to reject its use. In this context, it is especially irksome that current advocates of the technology not only ignore the politics of disaster and authoritarianism on which it is built but also ignore the fact that no empirical evidence exists of increased nuclear power use successfully reducing national CO_2 emissions. In fact, Takagi (1997) has powerfully shown that in Japan—one of the few remaining pro-nuclear power states—the 1965 to 1995 construction boom for nuclear power capacity coincided with rapid increases in national CO_2 emissions (Figure 6). This result may be attributed to the economics of nuclear power, the solvency of which depends on uninterrupted growth in electricity demand during the 30-year life of plants. Energy-intensive societies of the type consistent with nuclear power development will unavoidably increase fossil fuel use, so that nuclear energy–based systems will likely lead to higher CO_2 emissions and thus prevent, rather than foster, real solutions to the threat of climate change.

A final objection to the nuclear option centers on its likely exclusion of genuinely peaceful and ecologically benign options from the world's energy future. As Amory Lovins (1977) pointed out nearly thirty years ago, society cannot simultaneously choose so-called hard path technologies, such as nuclear power, and soft path options of energy conservation and renewable energy: They remain mutually exclusive

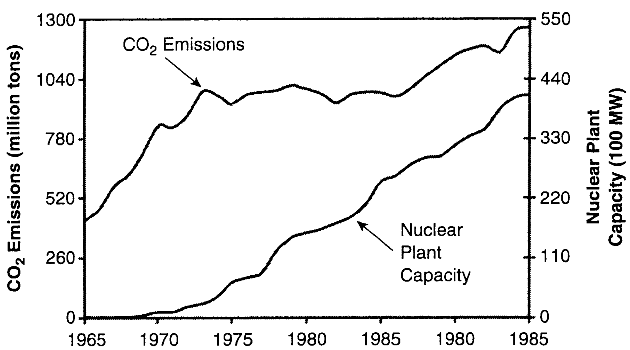

Figure 6. CO_2 Emissions and Nuclear Power: Japan's Experience

Source: Takagi (1997).

and contradictory. The politics, economics and technical logic of a large-scale, centralized energy system seeking ever-increasing consumption to remain solvent will clash with the values of a decentralized, moderate-scale energy system where less consumption is essential to success. For example, a $2 billion to $3 billion investment in nuclear power, the cost of a typical nuclear electricity facility, could be put at risk by vigorous efforts to save energy and to harness renewable sources such as wind, biomass, geothermal and solar energy. In this context, society would almost certainly be required to surrender soft path options to rationalize the use of nuclear energy.

Evaluated in these terms, the reduction in GHG emissions promised by nuclear power is hardly credible or attractive. Rather, the solution to global warming lies in peaceful energy strategies such as efficiency and conservation, renewable energy and materials recycling, reuse and reduction. More generally, a shift must occur from metropolitan overconsumption to an urban ethos and pattern of behavior that seeks to live with, rather than apart from, nature.

Reclaiming Our Atmospheric Commons

As the above analysis suggests, urban industrial life transpires not simply outside the constraints of nature, but relegates nature to commodity status, to be purchased and sold in the world political economy along with other products and services. In this regard, contemporary urban industrialism seeks sustainability as a facilitator of technological and economic advance. This presumption is manifested in discussions of trade-offs between environmental protection and material progress, but its deeper implication points to the demise of an idea of nature's inviolability. Nothing remains beyond the reach of technological manipulation according to advanced urban industrial logic: not the climate, not the atmosphere, and not species diversity (see, e.g., Byrne & Glover, 2005; Toly, 2005).

Ultimately, our best hope for an equitable, sustainable and peaceful future lies in an end to the commodification of nature and society as wrought by urban industrialism and a return to understanding the gifts of nature, including our atmosphere and climate, as elements of a commons of life (Byrne & Glover, 2002; Byrne, Glover & Martinez, 2002). We must also recognize that real sustainability depends on the societal exercise of normative constraints that enable all forms of life to prosper. Through efforts to shape the agenda of climate change to adhere to principles of equity, sustainability and peaceful development, we can take the critical first step in reclaiming our commons of life. Indeed, a genuine culture of cities, rather than the pseudomorphs that now occupy urban space (Mumford, 1938), may be reclaimed as and when we restore our global environment to its rightful commons status.

Notes

1. The Conference of Parties is comprised of the 161 signatories of the Framework Convention on Climate Change and is charged with negotiating treaty revisions and procedures for its implementation.

2. The principal GHGs include carbon dioxide (CO_2), methane (CH_4), ozone (CO_3), nitrous oxide (N2O), sulfur dioxide (SO_2) and chlorofluorocarbons (CFCs).

3. Annex I countries consist of 37 developed countries and economies in transition that originally agreed at the Earth Summit in 1992 to stabilize their CO_2 emissions at 1990 levels by the year 2000. These countries include Australia, Austria, Belarus,* Belgium, Bulgaria,* Canada, The Czech and Slovak Republic,* Denmark, the European Union, Estonia,* Finland, France, Germany, Greece, Hungary,* Iceland, Ireland, Italy, Japan, Latvia,* Lithuania,* Luxembourg, the Netherlands, New Zealand, Norway, Poland,* Portugal, Romania,* Russian Federation,* Spain, Sweden, Switzerland, Turkey, Ukraine,* United Kingdom of Great Britain and Northern Ireland and United States of America (*Indicates countries undergoing the process of transition to a market economy).

4. Adopting the principle of differentiated responsibilities, individual countries were assigned different targets. For example, Australia is permitted to increase its emissions by 8% over 1990 levels, whereas the United States is called on to reduce its emissions by 7% below 1990 levels.

5. Meeting the Kyoto Protocol requirement of an average 5.2% reduction in CO_2 below 1990 levels for all Annex I parties will not avert climate change. Indeed, it is estimated that the planet would experience a 4° F increase in temperature by 2100 (Masood, 1997) and a corresponding sea level rise of 14 to 20 inches (IPCC, 1997, p. 22). Given that nine of the hottest years on record have occurred

since 1987, with 1997 being the warmest (IPCC, 1997, p. 1), clearly much deeper CO_2 reductions than those specified in the Kyoto Protocol are needed to achieve climate stability.

6. Based on the above method, an estimate of the annual contributions to the CDM by environmental debtors to mitigate global GHG emissions can be made. For this purpose, the conservative, lower-end cost limit for avoiding CO_2 emissions of $5 per ton by 2025 was used in Byrne et al. (1998). Total contributions by Annex I countries begin at $7.4 billion in 1995, increase to $9.5 billion in 2015 and then gradually decline, reaching zero in 2050.

7. Of course, the fund would require monitoring, evaluation and enforcement mechanisms (that should include participants from the debtor and creditor countries as well as independent organizations).

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