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# Editorial

## Climate change, building energy use, and indoor environmental quality

A day of great change is dawning.

Since the advent of the industrial revolution, humankind has increasingly relied on fossil fuels to power its economies. Today, coal combustion generates more electricity than any other source and petroleum largely fuels the transport sector. Natural gas is increasingly being used as a fuel in buildings and to generate electricity. In extracting energy from these fuels, fossil carbon, long sequestered from the biosphere, is converted to carbon dioxide and released to the atmosphere. Largely as a result, the atmospheric abundance of $CO_2$ has risen from its pre-industrial level of 280 ppm to a level of 380 ppm today, and the $CO_2$ level continues to increase at a rate of a few ppm per year. The Intergovernmental Panel on Climate Change has predicted that 'business as usual' trajectories will be accompanied by a rise in atmospheric $CO_2$ to about 500–1000 ppm by 2100. These changes raise serious concerns that humans are fundamentally and substantially disturbing the Earth's climate system. In the absence of effective mitigation, one can anticipate substantially higher average temperatures globally, with greater increases occurring above continents, at high latitudes, at night and in winter. Among other changes, one also can anticipate altered patterns of precipitation and drought as well as rising sea levels from the melting of large continental ice masses. One should also expect surprises. WS Broecker (*Annual Review of Energy and Environment* **25**, 1, 2000) likened emitting greenhouse gases to poking an angry beast with a stick: we are not sure what the outcome will be, but chances are it won't be good!

Very likely, our collective response to the climate-change threat will include vigorous efforts to reduce the rate of fossil carbon release to the atmosphere. The scales are stunning. Today, 6 billion humans emit to the atmosphere roughly 6 billion tonnes of fossil carbon per year; the population average emission rate is thus 1 tonne of carbon per person per year or about 3 kgC per person per day. However, the rates vary markedly across populations. Per capita, US average emissions are among the highest at 15 kgC per person per day, 5 × the global average. Average emission rates by region, in units of kgC per person per day, are 12 for North America, seven for countries from the former Soviet Union, six for the Middle East, six for Europe, two for Asia and Oceania, two for Central and South America, and one for Africa (http://www.eia.doe.gov/environment.html).

To keep the atmospheric level of $CO_2$ from rising above 450 ppm, and to allow for global population growth to about 9 billion in the second half of the 21st century, the global average per-capita emission rate must be reduced to about 1 kgC per person per day by 2100. If this is to be done in an equitable manner, then it will be necessary to decarbonize most national economies to a substantial extent, including more than an order of magnitude reduction in per capita emissions in the USA. Although the US federal government has lagged behind international efforts to address climate-change concerns, the state of California has initiated aggressive action. In 2005, Governor Schwarzenegger signed Executive Order S-3-05, which established a statewide goal of reducing emissions in 2050 to 80% below the 1990 levels. Combined with the expected population growth from 30 million (1990) to 50–70 million (2050), California's policy is to reduce its fossil carbon emissions to about 1 kgC per person per day by 2050. Some countries have established comparably aggressive goals.

Large-scale reductions in fossil carbon emissions will require early, aggressive and sustained action across many fronts. All sectors that use substantial amounts of fossil energy will be affected. For countries that need to achieve reductions of an order-of-magnitude scale, one way to envision the required transformation is through a 'three-twos' approach. Approximately, an order of magnitude overall reduction can be achieved by implementing three independent, multiplicative factors, each a bit larger than two. For some sectors, we might consider these elements in a response portfolio: (i) reduce the carbon intensity of electricity generation; (ii) improve the energy efficiency of devices; and (iii) reduce the demand for energy-intensive goods and services. Consider, for example, indoor lighting. We can generate electricity from low carbon sources, such as substituting wind for coal or natural gas. We can improve the efficiency of lighting technologies, for example, by further developing compact fluorescent or light-emitting diode lamps. We can reduce overall demand for lighting through development and deployment of improved sensors and controls, through better use of daylight, and through expanded use of task lighting. A renewed conservation ethic and greater public practice of 'sufficiency' in developed countries could also play an important role in helping to meet climate-protection goals.

Buildings are natural targets for efforts to reduce carbon emissions. Energy use in buildings is high and relatively inefficient. Ürge-Vorsatz et al. estimated that 33% of the year 2002, global, energy-related greenhouse gas emissions occurred in buildings (*Building Research and Information* **35**, 379, 2007). Compared with business-as-usual, they estimate that ~30% reduction in emissions could be realized by 2020. In developed countries, measures with large potential include improved thermal performance of building envelopes (especially better insulation and better windows) and improved space-heating systems. In developing countries, important opportunities include cookstove improvements and more efficient air conditioning and refrigeration. Lighting improvements represent important opportunities everywhere. Many of the changes are classified as 'win–win' opportunities, in that money is saved at the same time that carbon emissions are reduced.

Overall, considerable progress toward reducing the climate impact of buildings can be achieved by doing more of what we already know how to do, and by doing this better. However, reducing emissions by the degree required is unlikely to be realized simply by making incremental improvements in current practice. Instead, on a time scale of decades, major changes are needed in the ways that buildings are powered and in how energy in buildings is used.

These challenges and opportunities should be of considerable concern to the readers of *Indoor Air*. It is noteworthy that studies of energy use in buildings and related climate impacts often fail to make evident the clear linkages of these issues with indoor environmental quality and health. If done poorly, large-scale changes in the built environment to improve energy performance pose risks of degrading indoor environmental quality. On the other hand, an integrated approach that considers indoor environmental quality as an essential component of good building design and operation holds the promise of another important class of 'win–win' outcomes that not only reduce fossil carbon emissions but also lead to more healthful indoor environments. Some of the transformations may even lead to 'triple wins', reducing carbon emissions, improving environmental quality, and saving money, too. The key point is this: buildings must satisfy the needs and interests of many constituencies, and especially those of their occupants. As we strive to reduce the climate impact of buildings, and to do so economically, we must take full measure of the important influences that the built environment has on human health and welfare.

Can we anticipate whether our collective societal response to climate-change imperatives will make indoor environmental quality better or worse? The great Danish physicist Niels Bohr said, 'Making predictions is difficult, especially about the future'. A related quote, of uncertain origin, is this: 'The best way to predict the future is to create it'. Let's get to work!

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