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Previsualizing a Post-Combustion World

“For when in all other places the *Aer* is most Serene and Pure, it is here Ecclipsed with such a Cloud of Sulphure, as the Sun it self, which gives day to all the World besides, is hardly able to penetrate and impart it here; and the weary *Traveller*, at many Miles distance, sooner smells, then sees the City to which he repairs.” — Evelyn (1661)

“Using the commons as a cesspool does not harm the general public under frontier conditions, because there is no public; the same behavior in a metropolis is unbearable. — Hardin (1968)

“There is nothing worse than a sharp image of a fuzzy concept.” — Ansel Adams

The taming of fire and its application for beneficial purposes is a great achievement of humankind. And yet, fire is not fully tamed. Carbon dioxide from the burning of fossil fuels is altering Earth’s climate. Emissions from power plants produce regional haze. Motor vehicle emissions foul urban air. Cooking with solid fuels pollutes the households of billions. Perhaps it is time for humankind to start planning to leave behind deliberate combustion.

Ansel Adams wrote about visualization, stressing the photographer’s need to imagine the captured and printed image before attempting an exposure. Minor White named a part of this process *previsualization*: imagining the outcome while studying the subject. For the purposes of this editorial, I use this term to acknowledge the difficulty to fully imagine a modern, future world that doesn’t rely upon combustion. Nevertheless, I believe that the effort to previsualize can inspire and guide efforts that promise beneficent outcomes.

Climate change concerns provide a strong impetus for divesting ourselves from our heavy dependence on combustion. Although lacking as yet is a sufficiently strong international agreement to effectively counteract anthropogenic climate change, some people and some governments are taking action. The case of California illustrates some important points.

In 2005, then Governor Arnold Schwarzenegger signed an executive order calling for strong future reduction in greenhouse gas emissions. The longer-term goal targets a reduction by 2050 to 80 percent below the state’s 1990 emission levels. A year 2015 executive order from current Governor Jerry Brown reaffirmed this goal. Allowing for expected population growth, the necessary per capita emissions reduction would be roughly 90 percent, to a level of about 1 kg of carbon equivalent per day per California resident. That per capita average greenhouse emission rate, if achieved worldwide during the second half of the 21st century, would help maintain the atmospheric CO₂ levels below an upper bound of ~ 450-550 ppm (based on predictions for the 21st century for ICPP scenarios RCP2.6 and RCP4.5). Those levels would not suffice to prevent some climate change, but these outcomes would be far better for the environment than unbridled continuation of business-as-usual, for which a year 2100 ambient CO₂ level is predicted to range from ~ 650 ppm to above 900 ppm (based on predictions for ICPP scenarios RCP6.0 and RCP8.5).

According to data from the US Energy Information Administration, the year 2012 global-average per-capita carbon dioxide emission rate from energy use corresponds to almost 3.5 kg of carbon

per day per person. The year 2012 average rate in California was 7 kg C per day per person and the US the average rate was 12.5 kg C per day per person. Deep cuts are needed to meet the 2050 goal that has now twice been articulated in California governors' executive orders. Williams et al. (2012) described the nature of the transformation in California's energy economy needed to meet the year 2050 greenhouse gas emissions target. Among their conclusions is that widespread distributed combustion of fossil fuels — in vehicles and in buildings — cannot continue. Instead, a strong transformation to more complete reliance on electricity is needed. Electricity generation could include natural gas combustion, but only if the carbon were effectively captured and sequestered (a relatively expensive proposition). Otherwise, it needs to be provided by a mix of low-carbon renewable technologies such as solar photovoltaic and wind power, and/or by means of nuclear power.

In a modern post-combustion world, we will no longer generate electricity by burning coal. Sulfur dioxide emissions will decline markedly, reducing both regional haze that is attributable to sulfate aerosols and ecological damage from acid deposition. Uncontrolled mercury releases to the environment will also decline. Regional air quality will improve.

In a modern post-combustion world, ground-based transportation may continue to rely heavily on the private car, but these will be powered by electric motors rather than by internal combustion engines. We can anticipate consequent improvements in urban ambient air quality including lower levels of outdoor ozone and other components of photochemical smog.

Today, in the United States, the fossil carbon emissions rate associated with energy use in buildings is nearly 5 kgC per person per day, evenly divided between the residential (53%) and commercial sectors (47%). Most of the emissions (73%) are associated with electricity use, and most of the remainder is attributable to the on-site burning of natural gas (and to a lesser extent petroleum) for space heating, water heating, and cooking. For California to meet its goals in year 2050, total emissions from the buildings sector must be trimmed to less than ~ 0.5 kgC per person per day, an order of magnitude improvement from current average US conditions. The distributed burning of fossil fuels in buildings must be discontinued, the efficiency for electricity use in buildings must improve, and carbon emissions associated with electricity production must decline, perhaps to as low as 20 gC per kWh.

The changes needed in California buildings for a post-combustion world will be challenging to realize, but they can be imagined. Water heating can be accomplished with solar thermal units, augmented by electricity. Cooking can be achieved using electricity. We can expect some reduced exposure to nitrogen dioxide that originates from inadequately vented natural gas combustion. Home heating for thermal comfort may be achieved through ground-sourced heat pumps, more capital intensive but also more energy efficient than direct resistance heating with electricity.

For developed economies, a primary impetus for the transition to a post-combustion world is to protect the climate. There are major challenges to face. Improved outdoor and indoor air quality can be anticipated as a major co-benefit of these efforts.

For developing countries (the low and lower-middle income countries), a primary impetus to strive for post-combustion conditions is the direct health benefits that would ensue. Major causes of ill health and environmental damage in especially the rural parts of developing countries result from the use of solid fuels for cooking and the use of kerosene for lighting. In the most recent global burden of disease study, household air pollution from solid fuels was rated as the third most important cause of ill health for the world's population (Lim et al., 2012). Many adverse consequences are associated with kerosene-based lighting (Mills, 2005).

It is well established that the use of solid fuels for cooking generates local exposures that are far above air quality limits suitable for protecting public health (Smith et al., 2013). Improvements can be realized through better stoves and improved venting. However, despite substantial effort over the past few decades, there is little evidence to suggest that the required scale of improvement can be achieved so as to eliminate cooking with solid fuels as a major risk factor for adverse health outcomes. Smith and Sagar (2014) suggest a need to rethink the strategy; rather than “making the available clean,” efforts should focus on “making the clean available.” Efficient and inexpensive induction cooktops could offer huge public health benefits if sufficient electricity, perhaps 1 kWh/d per person, could be provided to underserved populations.

For lighting the case for moving past combustion seems even more compelling. Burning kerosene is an expensive, hazardous and inefficient means of generating light. Electric lighting utilizing LED bulbs is a leapfrog technology that offers more lighting service of higher quality at lower overall cost. For example, a stand-alone photovoltaic panel of area 0.7 m² can generate about 0.5 kWh/d of electricity, enough to power approximately 50 3-W bulbs for 3 h/d each. The retail cost of a PV panel in the US is about \$200. The 3-W bulb might cost \$5, but could generate 260 lumens for 3 h/d throughout an expected lifetime of 20 y. The annual cost of using solar PV plus an LED lamp to provide a few hundred lumens for several h/d could be as low as about \$1 per year per person, an order of magnitude cheaper than the 30 lumens generated daily for 3 h from burning 100 mL/d of kerosene.

Humans are a remarkably adaptable species, but also have difficulty seeing clearly. I grew up in the suburbs east of Los Angeles at a time when the air pollution was much worse there than it is now. The standard weather report of denial at that time still resonates in my memory: “early morning fog giving way to an afternoon of scattered hazy sunshine.” Visibility impairment in the summertime was common so that one could not see the nearby mountains for months in succession. It was a pleasant and shocking surprise, upon moving as a young adult to the San Francisco Bay area, to learn that the sky could be blue on most days!

Air pollution was not invented in the 20th century. The opening quote from John Evelyn (1661) is from a lengthy treatise decrying the London's foul air in the 17th century. Brimblecombe (1987) documents an even deeper history of air pollution problems in that city, mostly a direct consequence of combustion. Claude Monet's paintings of London's Houses of Parliament from year 1900 depict vividly the nasty air pollution of those times.

Indoor environmental quality, human welfare, and energy use in the built environment are inextricably intertwined. Until now, most of the energy used in buildings has been provided through the direct or indirect combustion of fuels: wood, coal, and natural gas among others.

Over time, we have learned how to burn in ways that are less health harmful, through better combustion systems, use of cleaner fuels, and situating the combustion activity or the discharged effluents farther away from people. However, we have not succeeded in consistently applying that knowledge to good effect for all people. With 7 billion people on Earth, and with vigorous economies that depend on high levels of consumption for their effective functioning, it may be necessary to wean ourselves from combustion as our primary energy transforming process. Although it may not yet be possible to present a sharp image of the future, we can begin to work on the process of previsualization with some confidence that the post-combustion world is not a fuzzy concept.

William W Nazaroff
Editor-in-Chief

References

- Brimblecombe, P. (1987) *The Big Smoke: A History of Air Pollution in London Since Medieval Times*, London, Routledge & Kegan Paul.
- Evelyn, J. (1661) *Fumifugium: or The Inconveniencie of the Aer and Smoak of London Dissipated Together with some Remedies Humbly Proposed*, London, Godbid.
- Hardin, G. (1968) The tragedy of the commons, *Science* **162**, 1243-1248.
- Lim, S.S., Vos, T., Flaxman, A.D., Danaei, G., Shibuya, K., Adair-Rohani, H., et al. (2012) A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990-2010: a systematic analysis for the Global Burden of Disease Study 2010, *Lancet*, **380**, 2224-2260.
- Mills, E. (2005) The specter of fuel-based lighting, *Science*, **308**, 1263-1264.
- Smith, K.R., Frumkin, H., Balakrishnan, K., Butler, C.D., Chafe, Z.A., Fairlie, I., Kinney, P., Kjellstrom, T., Mauzerall, D.L., McKone, T.E., McMichael, A.J. and Schneider, M. (2013) Energy and human health, *Annual Review of Public Health*, **34**, 159-188.
- Smith, K.R. and Sagar, A. (2014) Making the clean available: Escaping India's Chulha Trap, *Energy Policy*, **75**, 410-414.
- Williams, J.H., DeBenedictis, A., Ghanadan, R. Mahone, A., Moore, J., Morrow III, W. R., Price, S. and Torn, M.S. (2012) The technology path to deep greenhouse gas emissions cuts by 2050: The pivotal role of electricity, *Science*, **335**, 53-59.