er.educause.edu

Climate Change and Higher Education

24-30 minutes

© 2009 Bill St. Arnaud, Larry Smarr, Jerry Sheehan, and Tom DeFanti. The text of this article is licensed under the Creative Commons Attribution-NonCommercial-NoDerivs 3.0 License (http://creativecommons.org/licenses/by-nc-nd/3.0/).

EDUCAUSE Review, vol. 44, no. 6 (November/December 2009)

Bill St. Arnaud (Bill.st.arnaud@gmail.com) is Chief Research Officer at CANARIE. Larry Smarr (lsmarr@ucsd.edu) is the Harry E. Gruber Professor in the UCSD Jacobs School's Department of Computer Science and Engineering and is the Founding Director of the California Institute for Telecommunications and Information Technology (Calit2), a University of California, San Diego, and University of California, Irvine, partnership. Jerry Sheehan (jerry@ucsd.edu) is the Chief of Staff at Calit2. Tom DeFanti (tdefanti@ucsd.edu) is a Senior Research Scientist at Calit2.

Comments on this article can be posted to the web via the link at the bottom of this page.

Climate change has taken center stage in global diplomacy.

As John Holdren, President Barack Obama's Director of the Office of Science and Technology Policy (OSTP) stated in 2008: "'Global warming' is a misnomer because it implies something that's gradual, that's uniform, that's mostly about temperature, and is quite possibly benign. What's happening is rapid, nonuniform, affecting everything about climate, and almost entirely harmful. A more accurate term is 'global climatic disruption.'"[1] Elected representatives in many countries, including the United States, Canada, and Australia, are thus hotly debating "cap-and-trade" systems. The hope of such legislation is that putting a market price on carbon will incentivize high-carbon emitters to decrease their emissions and will accelerate the rate at which innovative low- or zero-carbon energy is introduced into the economy.

Colleges and universities are being swept up in these developments, requiring strategic planning to be undertaken now. As an aid to those campuses starting such planning, we include here a brief review of the increasingly serious nature of climate change and the corresponding legislative and regulatory rules that are being put in place and that will affect higher education institutions. In the accompanying *EDUCAUSE Review* article "Campuses as Living Laboratories for the Greener Future," we indicate how achieving energy efficiency using campus cyberinfrastructure can help meet some of the current and future carbon constraints.[2]

The Science of Climate Change

We begin with a brief review of historical trends in the levels of greenhouse gases (GHGs) in the atmosphere. Approximately 50 percent of the radiative forcing that results in surface temperature rise is caused by carbon dioxide (CO_2),[3] with other major GHGs — such as methane, nitrous oxides, ozone, hydrocarbon and chlorofluorocarbons, plus black carbon — making up the rest. For simplicity, we will focus on CO_2 trends.

The now-famous "Keeling Curve" charts measurements, initiated by UCSD's Scripps Institution of Oceanography in 1958, to measure the CO_2 level in the atmosphere.[4] The resulting Mauna Loa Record graph shows that the CO_2 level has steadily increased during this period and has gone up 50ppm over the last 30 years, or ~1.67ppm per *year*. In comparison, in the 6000-year-long warming trend from the last ice age[5] to a climate in which agriculture and civilizations arose 10,000 years ago, the CO_2 level rose 80ppm, or ~1.33ppm per *century*. In other words, today's human-induced rate of increase of CO_2 is happening more than 100 times as fast!

As shown in V. Ramanathan and Y. Feng' s article "On Avoiding Dangerous Anthropogenic Interference with the Climate System," this increase to the current level (~385ppm) of atmospheric CO_2 will lead to a probable increase in global temperatures, over pre-industrial levels, of about 2.4oC.[6] Even though only about one-third of this temperature rise has occurred to date, current levels of GHGs are already having

major impacts on Earth's climate.

As an example, consider the rapid melting of the Arctic Sea ice. Recent research shows that although the Arctic region has been in a cooling trend for millennia, this trend was reversed during the twentieth century, with four of the five warmest decades occurring between 1950 and 2000. Indeed, the research suggests that the most recent ten-year interval (1999-2008) was the warmest of the past 200 decades![7] Augmenting the temperature records, recent satellite observations[8] have shown that the Arctic Ocean will be effectively ice-free in the summer sometime between 2020 and 2040, although it is possible it could happen as early as 2013, according to Walt Meier, research scientist at the National Snow and Ice Data Centre at the University of Colorado.[9] Ramanathan and Feng show that even more dramatic climate tipping points are being approached as we continue to add GHGs to the atmosphere.[10]

The problem seems to be that for a very long time, the Earth's system has been in a narrow stable state in which the CO_2 level has oscillated in a range between ~170ppm and ~400ppm. For example, recent data from deep Antarctic ice cores show that the atmospheric value of CO_2 during the last *eight* ice ages, going back 800,000 years, has oscillated between 170 and 300 ppm.[11] Extending this time period, a recent article in *Science* shows that a level of CO_2 as high as our current level (~385ppm) has not occurred on Earth for

over two million years.[12] Pushing this back even further, detailed deep-sea carbon and oxygen isotope records from ocean drilling reveal that Earth has been in a low (<~400ppm) CO_2 climate for over 20 million years.[13] With CO_2 levels now beginning to exceed this longtime upper level of ~400ppm, Earth is clearly entering a new climate regime on a very fast timescale compared with the natural variations, leading to the current climate being disrupted around the globe during this century.

If we could hold the line at <~400ppm, we could possibly adapt to the already committed changes. Unfortunately, countries continue to increase their emissions of not only CO_2 but also other GHGs, which will increase both the severity and rapidity of the global climatic disruption. A detailed global energy scenario projection through 2050,[14] with fairly drastic measures[15] put into place in the coming decades to move the world more rapidly to a low-carbon economy (Shell's Blueprint scenario), nevertheless concludes that by the time we stop adding CO_2 to the atmosphere, the long-term level could reach 550ppm — ~40 percent higher than today's value — a level that would create drastic climate change.

As an upper bound on the rise in atmospheric CO_2 concentrations, Report No. 169 of the MIT Joint Program on the Science and Policy of Global Change finds that if no restrictions are placed on emissions this century, global economic growth will lead to values of CO_2 of 900 ppm by

2100 — a tripling of pre-industrial levels![16]

Even more disconcerting is that — unlike many other environmental issues, such as acid rain, polluted waterways, and the Antarctic ozone hole, all of which repair themselves quickly once we stop adding pollutants — climate change induced by CO_2 is *effectively irreversible on a human timescale*. According to a recent analysis by Susan Solomon, a senior scientist at NOAA's Earth System Research Laboratory, and her colleagues, although a number of the GHGs are relatively short-lived in the atmosphere, the climate change due to increases in CO_2 concentration is very long lasting.[17] Note that the CO_2 levels in all their projections stay above the 300ppm ceiling of the last 800,000 years — for another thousand years! Thus, the longer we continue to add GHGs to the atmosphere, the more serious will be the climate disruption that we will have to live with for generations to come.

Regulation and the Potential Impact on Higher Education Institutions

What is clear from Solomon's computations is that to limit the extent of major climate disruption, we must act rapidly to slow the rate of increase of GHGs into the atmosphere and, indeed, must move as quickly as possible to reduce GHG emissions to near zero. Around the world, governments, from the local and the national levels, are now starting to understand the seriousness of climate change and are responding with a

variety of policies including carbon taxes, cap-and-trade systems, mandated carbon neutrality, and shadow carbon cost accounting. Already, the governments of Canada and the United Kingdom have announced moratoria on construction of new coal plants unless they support carbon capture and sequestration (CCS).[18] Many U.S. states — for example, California (SB 1368), Georgia, and Maine — have also enacted bills that effectively prohibit the construction of new conventional coal plants.[19]

In the United States, in March 2009, the Environmental Protection Agency (EPA) proposed the Mandatory Greenhouse Gas Reporting rule, which would require any U.S. entity emitting more than 25,000 metric tons of CO_2-equivalent ($mTCO_2e$) (thus becoming a "regulated entity") to report their emissions annually to a centralized federal registry.[20] This rule became law in September 2009 and will go into effect on January 1, 2010, with the first annual reports due to EPA in 2011.[21]

The U.S. Congress has also been increasingly active in the carbon regulation arena. The House passed the Waxman-Markey Bill (H.R. 2454: American Clean Energy and Security Act of 2009) in June 2009.[22] Members of the U.S. Senate are currently working on their version of the legislation, with the first hearings to be held on the Clean Energy Jobs and American Power Act from Senators John Kerry (D-MA) and Barbara Boxer (D-CA) in late October. Both of these legislative

efforts[23] are important because they mark the first proposed U.S. federal cap-and-trade system. Within the proposed frameworks, regulated entities are measured and then required to decrease their GHG emissions over time. If regulated entities do not meet targeted reductions, they are required to go into the marketplace and procure offsets equal to the amount by which they have exceeded their target.

It is important to note that the category of regulated entities will likely include colleges and universities, many of which are essentially small cities, especially those that have their own power plant to generate heat and/or electricity. Specifically, any higher education institution that generates over 25,000 $mTCO_2e$ will be subject to the EPA reporting and regulation requirements under the proposed Waxman-Markey cap-and-trade bill and may have to purchase emission permits.

Although a lot of attention is being paid to the proposed Waxman-Markey bill, many states and provincial governments have their own initiatives that have a more immediate and direct impact on colleges and universities. A prime example is the Canadian Province of British Columbia, which was the first jurisdiction in North America to introduce a carbon tax and to mandate carbon neutrality for *all* public-sector institutions. Much of the press and public furor has been focused on the carbon tax, yet what has attracted significant interest from state and provincial governments across North America is the mandated carbon neutrality for the public sector. According to the statutes, by March 2010 all public-sector institutions in

British Columbia must be carbon-neutral.[24] This includes all hospitals, colleges and universities, schools, museums, and municipal governments. If an institution fails to become carbon-neutral, it must purchase carbon offsets from the Pacific Carbon Trust (PCT) at the price of carbon, currently set at $25/tonne and regulated by the PCT. Under the current implementation, the University of British Columbia, a 50,332-student research university located between Vancouver and Okanagan, has made a preliminary estimate that it will be required to pay $2.8 million for carbon offsets and taxes in 2010, which is likely to rise to $3.4 million in 2012.[25]

Another international initiative attracting interest is the announcement by the United Kingdom that energy efficiency and emission reduction would be key priorities in a forthcoming government framework for higher education over the next ten to fifteen years. The government plans to link cutting emissions to funding agreements for higher education from 2011 onward. In his annual grant letter to the Higher Education Funding Council for England (HEFCE), John Denham, the government minister responsible for university funding and research, asked the council to set out a strategy for curbing emissions by 80 percent by 2050.[26]

The United Kingdom has been at the forefront in understanding the seriousness of climate change and in adopting policies that are often soon copied elsewhere in the world. It would not be surprising if U.S. funding agencies adopt similar strategies in the near future, given the strong

commitment to addressing climate change expressed by both John Holdren, director of the OSTP, and Steven Chu, U.S. Secretary of Energy.

Finally, in California, Assembly Bill 32 has now entered the implementation phase, requiring a reduction of GHG in the state to 1990 levels by 2020 and to 80 percent below that threshold by 2050.[27] The ten-campus University of California (UC) system has committed to an even more ambitious time frame with a goal to reduce the system's GHG emissions to 2000 levels by 2014, with a goal of becoming carbon neutral as soon as possible.[28] In 2008, for the first time, all ten campuses had their emissions measured, independently validated, and reported to the California Climate Action Registry (http://climateregistry.org/). In addition, individual campuses have developed their own climate action plans. For instance, in January 2008, UCSD became the first U.S. west coast university to join the Chicago Climate Exchange (CCX), the major North American voluntary, but legally binding, "cap-and-trade" emission trading system.[29] These efforts, along with earlier voluntary reporting, led UCSD to being the first California university recognized by the California Climate Action Registry as a "Climate Action Leader" for its measurement, independent certification, and reporting of emissions.

If some variant of the current Waxman-Markey bill becomes law, those campuses that have their own power plants will likely need to register with the EPA and could be required to

purchase carbon offsets. Those colleges and universities that purchase power from a utility could also see a big jump in their electrical costs. Although it is still early to make dollar-impact estimates, plausible costs for low-carbon and high-carbon campuses can be calculated. Of course, these numbers would actually be computed within the overall actions of a campus to balance its carbon portfolio, but we believe it is useful to provide a quantitative scenario.

To get a handle on the potential costs for a campus, let us look at the example of a 40 megawatt (MW) campus, such as UCSD. Given the mix of low-carbon (hydro, nuclear, solar, wind) and high-carbon (coal, oil, gas) sources of electricity in states and provinces of the United States and Canada, there is a wide range in the grams of CO_2 emitted per kWh of electricity produced.[30] Electrical utilities' calculations, by state, of CO_2 emissions range from a low of tens of grams (Vermont and Quebec) to a high of over 1,000 grams (Indiana and West Virginia). In California, electricity generation produces ~250 g/kWh, or 2,200 $mTCO_2e$ per MW-year. This is one of the lower carbon footprints in the United States, since gas or nuclear power plants generate the majority of power in California. In states where coal is the primary energy fuel, the equivalent footprint can reach over 8,700 $mTCO_2e$ per MW-year.

Therefore, if a campus has an average load of 40MW, the annual carbon footprint would be 88,000 $mTCO_2e$ in California and 348,000 $mTCO_2e$ on a campus that uses coal-generated

electricity. Assuming that carbon trades at $20 per metric ton (the price used in Congressional Budget Office estimates of the economic impact for Waxman-Markey emission permits), the cost to a California university will be an additional $1.8 million in the first year. For a university that uses coal-generated power, the increased energy cost will start off at around $7 million per year.

As awareness of climate change implications grows on campuses, especially with respect to the impending costs of cap-and-trade systems or carbon taxes, colleges and universities are undertaking assessments of their biggest contributors to GHG emissions. On many campuses, particularly research-intensive institutions, cyberinfrastructure — including data centers and local clusters — can be a dominant contributor of CO_2 emissions if the electricity is generated by coal-fired power stations.

Exact data is difficult to obtain, since most campuses do not track aggregate electrical consumption of cyberinfrastructure. However, we do know, from studies such as a recent Gartner report,[31] that more than 30 percent of an organization's energy consumption can be attributed simply to PCs and their peripherals. This baseline number excludes any additional energy consumption from clusters, high-performance computers, data storage, networking, and the like — all of which are growing as the campus research enterprise becomes more digital.

To date, campus IT operations, including those of faculty who

set up their own departmental clusters, have largely operated under the radar when it comes to measuring or paying for the utility costs associated with those operations. But as colleges and universities discover that cyberinfrastructure is significantly responsible for increased costs associated with electricity, cooling, and carbon offsets, they will be under the gun to produce a solution.

On the optimistic side, increased energy efficiency and virtualization can produce improvements in electrical consumption; but it is also likely, given the history of computing, that gains in efficiency will be quickly overwhelmed by the relentless demands for new applications and the increasing trend for larger and bigger datasets as more science becomes dependent on high-performance computing and networks. In "Campuses as Living Laboratories for the Greener Future," we discuss how colleges and universities must begin to reduce the carbon footprint of their campus cyberinfrastructure while they also use information technology and cyberinfrastructure in areas such as intelligent infrastructure and dematerialization to decrease emissions overall.[32]

Notes

1. John Holdren, "The Science and Physical Implications of Climate Change," presentation at the American Response to Climate Change Conference, The Wild Center, Tupper Lake, New York, June 25-26, 2008. See the slides and a video of his talk at *GreenMonk: the blog*, January 19, 2009,

<http://greenmonk.net/john-holdren-on-global-climatic-disruption>.

2. Bill St. Arnaud, Larry Smarr, Jerry Sheehan, and Tom DeFanti, "Campuses as Living Laboratories for the Greener Future," *EDUCAUSE Review*, vol. 44, no. 6 (November/December 2009), pp. 14-33, <https://er.educause.edu/articles/2009/10/campuses-as-living-laboratories-for-the-greener-future>.
3. See, for instance, Figure 2 in V. Ramanathan and Y. Feng, "On Avoiding Dangerous Anthropogenic Interference with the Climate System: Formidable Challenges Ahead," *PNAS*, vol. 105, no. 38 (September 23, 2008), pp. 14245-50, <http://www.pnas.org/content/105/38/14245.full.pdf+html>.
4. "Keeling Curve Lessons," Scripps CO_2 Program website, <http://scrippsco2.ucsd.edu/program_history/keeling_curve_lessons.html>.
5. See, for instance, Figure 1 in Eric Monnin, Andreas Indermühle, André Dällenbach, Jacqueline Flückiger, Bernhard Stauffer, Thomas F. Stocker, Dominique Raynaud, and Jean-Marc Barnola, "Atmospheric CO_2 Concentrations over the Last Glacial Termination," *Science*, vol. 291 (January 5, 2001), pp. 112-14.
6. Ramanathan and Feng, "On Avoiding Dangerous Anthropogenic Interference with the Climate System."
7. Darrell S. Kaufman, David P. Schneider, Nicholas P. McKay, Caspar M. Ammann, Raymond S. Bradley, Keith R. Briffa, Gifford H. Miller, Bette L. Otto-Bliesner, Jonathan T. Overpeck,

Bo M. Vinther, and Arctic Lakes 2k Project Members, "Recent Warming Reverses Long-Term Arctic Cooling," *Science*, vol. 325 (September 4, 2009), pp. 1236-1239.

8. Candace Lombardi, "NASA Images Show Thinning Arctic Sea Ice," *CNET News*, April 7, 2009, <http://news.cnet.com/8301-11128_3-10213891-54.html>.
9. Louise Gray, "Arctic Will Be Ice-Free within a Decade," *Telegraph.co.uk*, April 7, 2009, <http://www.telegraph.co.uk/earth/earthnews/5116352/Arctic-will-be-ice-free-within-a-decade.html>.
10. Ramanathan and Feng, "On Avoiding Dangerous Anthropogenic Interference with the Climate System."
11. Dieter Luthi, Martine Le Floch, Bernhard Bereiter, Thomas Blunier, Jean-Marc Barnola, Urs Siegenthaler, Dominique Raynaud, Jean Jouzel, Hubertus Fischer, Kenji Kawamura, and Thomas F. Stocker, "High-Resolution Carbon Dioxide Concentration Record 650,000-800,000 Years before Present," *Nature*, vol. 453, (May 15, 2008), pp. 379-82.
12. Bärbel Hönisch, N. Gary Hemming, David Archer, Mark Siddall, and Jerry F. McManus, "Atmospheric Carbon Dioxide Concentration across the Mid-Pleistocene Transition," *Science*, vol. 324 (June 19, 2009), pp. 1551-1554.
13. James Zachos, Mark Pagani, Lisa Sloan, Ellen Thomas, and Katharina Billups, "Trends, Rhythms, and Aberrations in Global Climate 65Ma to Present," *Science*, vol. 292 (April 27, 2001), pp. 686-93.

14. *Shell Energy Scenarios to 2050* (2008), <http://www-static.shell.com/static/public/downloads/brochures/corporate_pkg/scenarios/shell_energy_scenarios_2050.pdf>.

15. For instance, 90 percent of all OECD coal and gas power plants must use carbon capture and sequestration by 2050, even though a full-scale demonstration plant doesn't yet exist. In addition, an infrastructure more complex than the current global natural gas shipping and distribution system would have to be built to accomplish this goal.

16. A. P. Sokolov, P. H. Stone, C. E. Forest, R. G. Prinn, M. C. Sarofim, M. Webster, S. Paltsev, C. A. Schlosser, D. Kicklighter, S. Dutkiewicz, J. Reilly, C. Wang, B. Felzer, J. Melillo, and H. D. Jacoby, "Probabilistic Forecast for 21st Century Climate Based on Uncertainties in Emissions (without Policy) and Climate Parameters," January 2009, <http://globalchange.mit.edu/pubs/abstract.php?publication_id=99> and *Journal of Climate*, vol. 22, no. 19 (2009), pp. 5175-5204.

17. Susan Solomon, Gian-Kasper Plattner, Reto Knutti, and Pierre Friedlingstein, "Irreversible Climate Change Due to Carbon Dioxide Emissions," *PNAS*, vol. 106, no. 6 (February 10, 2009), pp. 1704-9, <http://www.pnas.org/content/106/6/1704.full>. See also a geological discussion in David Archer, *The Long Thaw: How Humans Are Changing the Next 100,000 Years of Earth's Climate* (Princeton, N.J.: Princeton University Press, 2009).

18. Jeremy Hance, "Canada and Britain Abandon Conventional

Coal," *mongabay.com*, April 29, 2009, <http://news.mongabay.com/2009/0429-hance_cleancoal.html>.

19. See "Coal Moratorium," SourceWatch website, <http://www.sourcewatch.org/index.php?title=Coal_moratorium>.
20. "Final Mandatory Reporting of Greenhouse Gases Rule," U.S. Environmental Protection Agency website, <http://www.epa.gov/climatechange/emissions/ghgrulemaking.html>.
21. "Final Mandatory Reporting of Greenhouse Gases Rule," U.S. Environmental Protection Agency (EPA) website, <http://www.epa.gov/climatechange/emissions/ghgrulemaking.html>
22. H.R. 2454: American Clean Energy and Security Act of 2009, <http://www.govtrack.us/congress/bill.xpd?bill=h111-2454>.
23. Although both Waxman-Markey and Kerry-Boxer propose cap-and-trade systems, the current bills differ in emission-reduction targets. Waxman-Markey requires a 17 percent reduction below 2005 levels by 2020, whereas Kerry-Boxer requires 20 percent. The difference between the two emission targets would be resolved during conference committee if Kerry-Boxer is passed by the U.S. Senate.
24. "B.C. Introduces Climate Action Legislation," Office of the Premier Ministry of Environment, news release, November 20, 2007, <http://www2.news.gov.bc.ca/news_releases_2005-2009/2007OTP0181-001489.htm>; "Bill

44 — 2007: Greenhouse Gas Reduction Targets Act," <http://www.leg.bc.ca/38th3rd/3rd_read/gov44-3.htm>.

25. Private correspondence between Jerry Sheehan (Chief of Staff, Calit2) and Charlene Easton (Director of Sustainability, University of British Columbia), July 31, 2009.
26. The letter can be found on the HEFCE website: <http://www.hefce.ac.uk/news/hefce/2009/grant/letter.htm>.
27. See California Environmental Protection Agency Air Resources Board, AB 32 Scoping Plan, <http://www.arb.ca.gov/cc/scopingplan/scopingplan.htm>.
28. See "Climate Action at UC," <http://www.universityofcalifornia.edu/sustainability/climate_action.html>.
29. Jim Gogek, "UC San Diego Begins Trading Greenhouse Gas Credits on Chicago Climate Exchange," UC San Diego news release, January 4, 2008, <http://ucsdnews.ucsd.edu/newsrel/science/01-08ChicagoClimateExchange.html>.
30. Doug Alder, RackForce, PowerPoint slides; Energy Information Administration, U.S. Department of Energy, "Updated State-Level Greenhouse Gas Emission Factors for Electricity Generation," March 2001, <http://tonto.eia.doe.gov/ftproot/environment/e-supdoc.pdf>; "Pounds of CO_2 per Kilowatt-Hour," BlueSkyModel.org website, <http://www.stewartmarion.com/carbon-footprint/html/carbon-footprint-kilowatt-hour.html>.
31. "Gartner Says More Than 30 Percent of ICT Energy Use Is

Generated by PCs and Associated Peripherals," Gartner news release, April 20, 2009, <http://www.gartner.com/it/page.jsp?id=941912>.

32. St. Arnaud, Smarr, Sheehan, and DeFanti, "Campuses as Living Laboratories for the Greener Future."