DOI:10.1145/3445037

Andrew A. Chien

Driving the Cloud to True Zero Carbon

THE RIGHT VISION is to operate the cloud with zero-carbon emission from power (scope 2). Not just offsetting through renewable energy purchases. Not just 24x7 matching. True zero carbon in electric power consumed, and with no increase as the cloud continues to grow. That's the right vision for our proud computing technology community to lead the fight against climate change, and to see increasing use of computing as a positive force to slow climate change.^{a,b}

Why must we act? The power grid is decarbonizing, but progress is slow. Aggressive states (for example, California and New York) have zero-carbon goals 20 or more years in the future, 2045 and 2040. Nationally, the U.S. produced 19% of its electric power from renewable resources (2020), and with "datacenter alley" reporting 12% renewables^c (Northern Virginia). This trails the world's 26% renewables today, and U.S. renewables are projected to double to 38% by 2050. At that rate, full decarbonization may be a century away!^d Substantial progress toward zero carbon in the next 10 years depends on aggressive action, cloud computing cannot just depend on power grid decarbonization.

In 2020, the cloud's power consumption exceeded 2% of total U.S. power, and hyperscale providers exceed 6% in regional power markets and grids.^e Add to that annual growth of 28% (2017–2019)^f as well as acceleration from COVID-spurred digitalization and machine learning, and it's clear that cloud power consumption

cannot be ignored in serious attempts to reduce anthropogenic carbon emissions.

Is it possible? Leading computing companies—notably Google, Facebook, and Apple have been carbon neutral for years. Amazon has committed to becoming carbon neutral by 2030. An avalanche of more aggressive commitments has been made in 2020.^g Why are these computing giants moving now?

Climate-change natural disasters have become common. The disruption of floods and wildfires has led hedge funds to shift climate-risk from a second to "first ledger" issue, and they have moved to assess climate-risk in business valuation.^h Climate change has come to the fore as a business concern, and this compels the business leaders of computing technology companies to make stronger, more ambitious carbon-reduction commitments, and to be on the side of progress toward true zero carbon.

In 2020, we have seen major national commitments to carbon-neutral economies by Japan (2050) and China (2060),ⁱ joining the European Union (2045). Government commitments produce growing pressure on all of the economy. And, with regulation of "big tech" on deck, that contribution to economic growth no longer confers a free pass.^j

So, yes, it's possible. The public, governments, and the hedge funds are all aligned. These commitments acknowledge responsibility and create a growing economic drive. There's little doubt we have the technological capability. The technical challenges are around how to

do it as cheaply as possible. Solving these challenges requires new research, technology, and large-scale investment.

What must we do? Here's a roadmap.

- Learn about renewables and the modern power grid: the key to carbon emissions is where and when power is consumed—not just power efficiency

- Create applications that can flex when and where they consume power, enabling time and space shifting

- Create carbon-aware applications that exploit flexibility and carbon-content information to reduce carbon emissions

- Design novel hardware architectures (and datacenter facilities) that provide inexpensive capacity to support such workload shifting

We must redesign cloud software and hardware to flexibly follow renewable energy. For cloud computing, the majority of carbon emissions arise from power consumed during operation (80% for typical four-year use). But embodied carbon for hardware and datacenter infrastructure (scope 3) cannot be ignored.^k One effective way to do this is to extend the lifetime of computing hardware, and creating a circular ecosystem.^l

Let's all drive cloud computing to true zero carbon!

^j A. Satariano. Big fines and strict rules unveiled against 'big tech' in Europe, *NYTimes* (Dec. 15, 2020).

^k B. Manne. Architecting a Sustainable Planet. Keynote at IEEE MICRO-53 Conf. Oct. 2020.

^l Extending the lifetime of scientific computing equipment; <http://bit.ly/3mBG0XG/>, and ITRenew: Expect more from your IT hardware; <https://www.itrenew.com/>

Andrew A. Chien, EDITOR-IN-CHIEF
COMMUNICATIONS OF THE ACM

Andrew A. Chien is the William Eckhardt Distinguished Service Professor in the Department of Computer Science at the University of Chicago, Director of the CERES Center for Unstoppable Computing, and a Senior Scientist at Argonne National Laboratory.

Copyright held by author/owner.

^a A.A. Chien. Owning computing's environmental impact. *Commun. ACM*, Mar. 2019.

^b A.A. Chien. What do DDT and computing have in common? *Commun. ACM*, June 2020.

^c Dominion Energy; <http://bit.ly/3h8OZd1>

^d Energy Information Agency. Annual Energy Outlook 2020, (Jan. 29, 2020); <https://www.eia.gov>.

^e Dominion Energy; <https://bit.ly/2Kw1X8L>

^f Google. Realizing a carbon-free future: Google's third decade of climate action, Sept. 2020.

^g S. Pichai (Google) 24x7 matching by 2030, J. Bezos (Amazon) Carbon Neutral by 2040, and S. Nadella (Microsoft) Lifetime offset by 2050.

^h M. Peregrine. Blackrock heats up climate change pressure on boards. *Forbes*, (July 19, 2020).

ⁱ China's next economic transformation: Going carbon neutral by 2060. *WSJ*, (Oct. 29, 2020). Japan promises to be carbon neutral by 2050. *Economist*, (Oct. 29, 2020).