☀ **NEWS FEATURE**

The quest for the sustainable city

Cities have become epicenters for confronting climate change, harnessing renewable energy, and mitigating pollution. The city plans striving for sustainability are many. Easy solutions are few.

M. Mitchell Waldrop, *Science Writer*

On April 17, Los Angeles (LA) Mayor Eric Garcetti used his annual State of the City address (1) to announce a major update of LA's four-year-old Sustainable City pLAn (2). Going forward, he said, LA would commit to recycling 100% of its wastewater by 2035; work toward 100% renewable electricity by 2045; mandate that every home, store, and office be carbon-emissions-free by 2050; and much more. At the same time, he pledged, the city would grow its economy; create 300,000 clean new jobs by 2035; and aggressively fight poverty, discrimination, pollution, and the other ills of society.

Garcetti described the updated plan, which was formally released on April 29, as "L.A.'s Green New Deal"—a not-so-veiled reference to the nationwide Green New Deal that had been introduced as a congressional resolution in February. That document laid out similar aspirations for the nation as a whole, albeit with far fewer specifics, and immediately stalled out, with various sides praising or vilifying it as visionary, naïve, essential for civilization's survival, ruinously expensive, or a nightmarish example of government overreach.

Los Angeles is among the many cities pursuing an aggressive sustainability plan–one that aims to, among other things, recycle more wastewater, use more renewable energy, and accelerate reductions in carbon emissions. Image credit: Shutterstock/IM_photo.

Cities striving for sustainability are struggling to incorporate multiple dimensions and values of sustainable development. Image credit: (c) European Union, 1995–2019.

But that impasse may well have been Garcetti's point: whatever nation-states do or don't do, the cities of the world aren't waiting around. Under the banner of "sustainability," they have been pursuing that same set of aspirational goals for a decade or more. And they've been doing so in a way that is strikingly concrete, pragmatic, collaborative, and nonpartisan.

New York, London, Copenhagen, and most of the other large cities in the developed world are now following sustainability plans, many of which are just as ambitious as LA's version. In fact, LA joins at least 19 other cities worldwide that have set a target of zero or near-zero net carbon emissions by 2050—a goal they hope to attain by promoting fully electric vehicles, renewable energy sources such as wind and solar, and buildings that meet stringent energy standards.

These big cities, along with several smaller ones, are acting because they have no choice, says Anu Ramaswami, an environmental engineer at the University of Minnesota in Minneapolis and head of a multiuniversity research consortium known as the Sustainable Healthy Cities Network. Every day, she says, local officials are forced to deal with the human costs of crumbling infrastructure, plant closures, poor health, racism, poverty, and pollution. And now cities are having to do it all in the context of climate change. When the floods come, she says, and the droughts, wildfires, rising seas, and all the rest, "the cities are going to be at the front lines, and they need to figure out how to respond."

The good news is that cities are embracing new technologies and new ideas—and are eagerly sharing what they've learned through a host of national and multinational organizations. Among the resources is a 2016 National Academies report titled, "Pathways to Urban Sustainability," (3) that offers a guide for sustainability efforts, from planning to implementation.

Cities certainly have their work cut out for them. Staying on the sustainability track that they have set for

themselves will require a healthy dose of money, innovation, political will, and resourcefulness, notes Luis Bettencourt, a physicist who directs the Mansueto Institute for Urban Innovation at the University of Chicago. But right now, he says, "if you ask, 'Who are the organizations with the agency to move this forward?' it's the cities."

Urban Arrival

There is a certain irony to this city-led activism, notes Karen Seto, a geographer who studies urbanization at Yale University in New Haven, CT. Speaking literally, she says, "there is no such thing as a city that's sustainable."

Partly that's because the concept of "sustainability" is ambiguous. It has always contained some notion of environmental stewardship: producing products and energy with minimal waste, pollution, or damage to the surrounding ecosystem. But now, policymakers tend to give economic prosperity and social justice equal weight to the environment, facets that are, as the 2016 Academies report emphasized, often overlooked. This "triple bottom line" approach makes it effectively impossible to measure a city's sustainability with a single number or even to agree on which metrics matter most. One proposed framework (4) calls for rating cities on 45 aspects of sustainability, from "public parkland" and "energy efficiency" to "quality jobs" and "good governance."

But mainly, says Seto, cities aren't sustainable by themselves because they aren't isolated from their surroundings. In many ways, they are more like organisms that ingest "food" from outside, in the form of electric power, fuel, water, or literal foodstuffs, and excrete "waste" to the outside, in the form of trash, wastewater, pollution, heat, and carbon dioxide. And just as with living things, the notion of sustainability makes sense only when you're talking about the ecosystem as a whole—in this case, planet Earth.

Still, says Seto, our global ecosystem would be a lot closer to sustainability if cities were less voracious in their consumption and profligate in their wastes. "Think about all the resources it takes to build and operate our cities," she says: "The energy, the food, the wood products, the impact on biodiversity. That footprint becomes huge." And it's only getting bigger. As more and more people flock to the cities in search of jobs, education, or even just clean water and electricity, the global fraction of urban dwellers has gone from roughly one-third in the 1970s to 50% in 2007 and is racing toward two-thirds by 2050. "We've turned into an urban planet," agrees Patricia Culligan, a civil engineer who studies urban issues at Columbia University in New York City.

That wasn't always so obvious. In the 1972 Stockholm Declaration (5), which was the United Nations' first formal recognition of people's right to a healthy environment, the text mentions "urbanization" only once in passing—and "city" not at all. But the accelerating pace of urbanization soon became impossible to ignore. In 1987, when the United Nations issued a follow-up report titled, "Our Common Future," (6) the study featured an entire chapter on "The Urban Problem."

Waldrop

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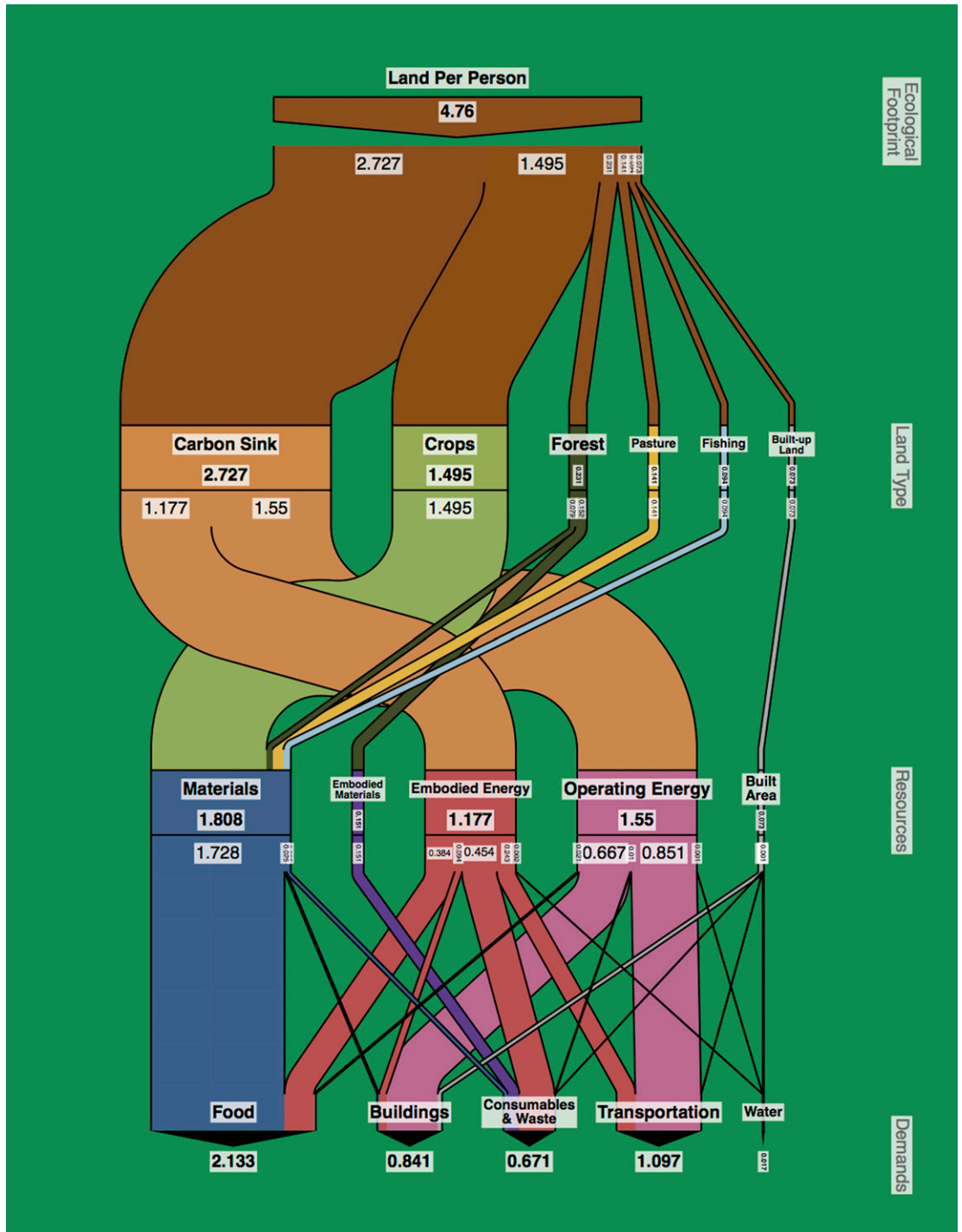
"Urban metabolism" or Sankey diagrams track a city's use of energy, land, water, and transportation. This one depicts the ecological footprint of Vancouver residents as it relates to land use. Image credit: Philip Mansfield (Yale University, New Haven, CT), generated using data from ref. 8.

In 1990, Toronto became perhaps the first city in the world to adopt a formal greenhouse-gas reduction plan. Others were close behind; by 1991, Toronto was coordinating its action plan with those of 13 other cities through a new organization known as the Urban CO_2 Reduction Project.

From today's perspective, those early plans were rather relaxed; they generally had modest carbon

reduction goals in the 15 to 20% range and allowed many years for meeting them. But the sense of urgency increased substantially in the 2000s as the evidence for climate change mounted and—especially in the United States—the likelihood of nationwide action receded.

In February 2005, on the day the United Nations' emissions-reducing Kyoto Protocol was set to go into effect—without US ratification—Seattle Mayor Greg

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Nickels launched the Mayor's Climate Protection Agreement: a pact asking US cities to make those reductions on their own. Hundreds of them signed on that year, and more than 1,000 would do so by decade's end. Then in October 2005, London Mayor Ken Livingstone asked 18 of the world's largest "megacities" to make a similar pledge. So many signed on that in 2006 the nascent international organization took the name C40, after its membership at the time; today, C40's membership stands at 94 cities.

Disaster Prone

After a drumbeat of disasters in the mid-2010s—from California's severe drought (2011–2017), to an endless series of wildfires throughout the American West, to chronic coastal flooding caused by rising sea levels and storms such as 2012's Superstorm Sandy—the concept of "sustainability" came to include more than just environment, economics, and equity. It also embraced notions of adaptation to irreversible climate change, as well as resilience: a community's ability to take a hit and bounce back.

Especially in the largest and wealthiest cities, the response has been to launch sustainability efforts that are correspondingly more ambitious. In 2018, for example, Vancouver became one of the first cities to mandate that all new construction be built to zero net carbon emissions standards. The techniques for doing this are well known, says Johanna Partin, director of the Carbon Neutral Cities Alliance, which represents Vancouver and 18 other cities that have pledged to slash or eliminate their emissions by 2050. Methods include the use of solar panels for power, advanced windows that minimize the flow of heat in or out, and ventilation designs that keep occupants comfortable through natural airflow instead of with conventional heating systems and air conditioners. When Vancouver did a feasibility study, funded by Partin's organization, it turned out that with careful design these low-carbon techniques would add only 1 to 2% to conventional construction costs.

That small increase is not irrelevant, however, says Partin. "The cost-effectiveness of housing is probably the biggest issue that many of our cities are facing these days," she says. "But it's not, like, five times as expensive." And once the building is occupied, she says, the additional up-front costs can quickly be offset by sharply lower utility bills.

Cities' ambitions also tend to be coupled with a strong sense of pragmatism, says Garrett Fitzgerald, a former sustainability director for the city of Oakland, CA. Certainly, that attitude was the impetus behind the Urban Sustainability Directors Network (USDN), a professional organization that was founded in 2009 to help sustainability officials in the United States and Canada share what does and doesn't work. USDN currently has about 1,000 members representing almost 200 cities, says Fitzgerald, who now serves as its head of strategic planning, and it has focus groups in climate preparedness, flood control, electric vehicle infrastructure, addressing equity, and a host of other areas. "One of our monthly phone calls might have representatives from 80 cities sharing stories about what they've done," says Fitzgerald, "Folks very liberally steal ideas from each other."

Recently, for example, USDN started working with a group of cities trying to make progress on the urban heat-island effect: the well-known tendency for built-up areas to be as much as 12 °C warmer than the surrounding countryside. This extra heat increases the risk of exhaustion, stroke, or even death, and boosts the demand for air conditioning. "So if you can reduce it," he says, "you can have pretty powerful greenhouse gas emission reductions, and can create some pretty powerful public health benefits."

But how? Everybody in this field knows the technical solutions, says Fitzgerald. Make roadways and roofs whiter and more reflective. Plant more trees for shade. And expand the city's green spaces, so that plants can cool their surroundings by evaporating water through their leaves. But what's become clear in the USDN-led conversations, he says, is that its members need help with implementation. What's the best reflective product to use if you're about to resurface a given stretch of roadway? How do you persuade your city's officials to mandate reflective (or green) roofs on all new commercial buildings? How can you quantify the impact of such measures, so that you can make a stronger case for why they're important?

So in addition to fostering discussions among the cities themselves, says Fitzgerald, USDN has begun to seek out and put its members in contact with outside consultants, nonprofits, and philanthropists who can provide tools, training, and data to answer such questions. "We're saying, 'Hey, there's this whole body of organizations who are trying to help you make progress,'" he says.

Teaming Up

That same search for practical answers has also led many cities into close collaboration with the research community, adds Fitzgerald: "Local governments are adept at the policy thinking—but there's very limited bandwidth in-house to do the analytical work."

In LA, for example, both the original sustainability plan from 2015 and its update this year were developed in close collaboration with researchers at University of California, Los Angeles' (UCLA) Sustainable LA initiative, which is led by environmental scientist Mark Gold. The initiative had its beginnings in 2012, says Gold, when UCLA Chancellor Gene Block asked the faculty to develop a Grand Challenge that could provide a focus for the university's environmental research. [Block also asked for a health-related challenge, which eventually became an effort to understand, prevent, and treat depression (2).] In response, says Gold, "we came up with the concept of 'Thriving in a Hotter Los Angeles'." They set three targets: 100% renewable energy, 100% local water, and enhanced ecosystem health.

The Grand Challenge lay in how to meet those targets—an urgent issue when it comes to Gold's own specialty, water. During the height of the drought, he notes, 90% of the city's water supply was coming from more than 200 miles away, mostly from Northern California and the Colorado River. Because both those

sources were suffering their own shortages, this was neither sustainable nor resilient. So he and his group did a three-year study (7) with the city of LA on how to get that fraction down to zero.

Again, the techniques for doing so are well known. One is to expand the city's green spaces, which can help absorb stormwater runoff before it swamps treatment plants and washes raw sewage into the ocean. Another is to upgrade the sewage plants so that they don't just treat the wastewater and release it but recycle it for reuse in washing, irrigation, and other non-potable applications. But green spaces can't absorb everything, says Gold, nor can they always filter out the toxins and heavy metals that rainwater picks up from the streets. And cleaning up all the smells and pathogens from wastewater requires membranes, filters, and other technologies that are neither cheap nor infallible. So what the study had to ask was whether it was technologically and financially feasible to get to 100% local water while also meeting quality standards set by the Clean Water Act.

The study's answers were encouraging enough that LA's new sustainability plan calls for getting the fraction of local water up to 70% by 2035, mainly by upgrading the city's four wastewater treatment plants to recycle every drop of wastewater. Because this current recycling figure is only 2%, says Gold, "this is a commitment to a complete transformation" and in only 16 years.

Livable Landscape

Such examples suggest cities can make big strides in sustainability without waiting for new technologies. More often, says Dan Guilbeault, who handles equity issues for the Urban Sustainability Administration in Washington, DC, it's a matter of marshaling the money, organization, and political will to implement the technologies that already exist—all while listening to community input.

When Washington, DC upgraded its sustainability plan this year, community gardens were a priority, along with better access to grocery stores. "We heard a lot from lower-income residents and residents of color that they really needed access to healthy food," says Guilbeault. Convenient transportation and navigable sidewalks were also high priorities, as well as access to green spaces, trees, and recycling and composting infrastructure.

Still, new technologies can be a big help. In New York, for example, Culligan and her colleagues are hoping to exploit a new generation of microminiaturized sensors that are wireless, low power, dropping fast in price, and exponentially growing in their ability to monitor the environment. One project, begun in 2018, is a two-year effort to develop networked sensors that can be plugged into the soil of green spaces all over the city to measure temperature, acidity, dissolved oxygen, and moisture content. Another project is to develop cheap sensors that could be strapped to bikeshare bikes to monitor carbon dioxide levels as people cycle around the city.

In a few years, says Culligan, "we'll be able to take all of this data and create maps of moisture, CO_2, temperature, and air quality in the city at a pretty granular level." That will allow officials to pinpoint exactly where particulates and other pollutants are coming from, target where they need to focus their cleanup efforts, and monitor how (or whether) those efforts are improving people's health and well-being.

Maribeth DeLorenzo, deputy director of DC's Urban Sustainability Administration, likes the idea of solar-integrated roofing material: photovoltaic panels designed to replace conventional shingles without greatly affecting the building's appearance (see News Feature: The solar cell of the future, https://doi.org/10.1073/pnas.1820406116). "That will be terrific for cities like DC that have really important historic properties," she says. Of course, technology quickly becomes obsolete, hence the relevant portions of sustainability plans need to be updated frequently.

And this year's updates will hardly be the last, adds DeLorenzo: "We're going to see huge changes in the physical structure of cities," thanks to technologies such as autonomous vehicles that promise to be massively disruptive in hard-to-predict ways. Will people give up owning their cars, for example, and instead rely on autonomous-vehicle ride-sharing? Will that increase traffic congestion or reduce it? Will parking garages disappear—or be completely given over to charging stations? Not even the most ambitious urban sustainability plans do much more than acknowledge the questions.

But that uncertainty is perhaps the best thing about sustainability planning, says DeLorenzo. Cities seem committed to making big changes—and the revolution is coming regardless. A focus on sustainability, she says, "helps put the right people in the room to think about how to optimize these changes."

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