Community Futures

Stantec

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Foreword

There are unprecedented challenges that cities and communities around the world are facing, ranging from growth and densification, aging infrastructure, climate issues and the impacts from severe storms, to social issues like affordable housing and income disparity. There are immense opportunities for positive change through new technologies, ecosystem regeneration and holistic, joined-up thinking by city and community leaders.

We recognize the need to continue to lead and innovate in this area. At Stantec, our promise is to Design with Community in Mind and we have been working with community leaders for over 65 years to improve the quality of life for citizens in communities around the globe. We need to continue to engage with the communities we serve to bring new and innovative solutions to the table: we should all *think globally, act locally.*

Gord Johnston
President and CEO
Stantec

Introduction

This book explores seven high-impact, high-uncertainty variables shaping the future of communities around the world. While discussed separately in each of the seven chapters, these variables are both interrelated and interdependent. Cities stand on the front line in the battle to mitigate environmental damage from climate change, regenerate the biosphere, and lay the foundation for sustainable and socially inclusive development. Ecosystem infrastructure—solutions that integrate across the natural and built environment—will be key to transforming community futures.

Infrastructure is at the center of things. Solutions that integrate across the natural and built environment—ecosystem infrastructure—will be key to transforming community futures. The overarching story is that while national and international cooperation and collective action are important, action at the local level on sustainability goals reaching out to 2050 and beyond is vital.

In many ways, the rate and scale of ecosystem-centered infrastructure redesign and renewal over the next few decades will shape the long-term future of communities, cities and the global environment.

Strategic long-term plans must be inclusive, address wider imbalances and engage the public in decisions. Expenditures may be required over the short term to deliver resilience over the long term. Over the last few decades, corporate, national and city leaders have tended to focus more on the short term, neglecting long-term resilience, community-building, social identity and cultural norms that characterized earlier eras of large-scale technological and industrial disruption.

Fragility of natural systems and infrastructure may produce social unrest for some communities. Urgent action may amplify deep-seated inequalities and division. In contrast, other communities—united by shared identity and narratives about the long-term future and cultural norms—can build on opportunities for renewal and regeneration.

This means that community leaders, in a context set by growing climate and biospheric crises, face the challenge of setting the long-term agenda and delivering vision-led innovation to create the context for radical action. The key is to anticipate the public's unarticulated future needs. In more extreme scenarios, there will be a premium on solutions that deliver quickly, using low-risk technologies and meet specific local concerns. Community-level action will prove crucial, though in some countries, states will dominate.

A fundamental uncertainty shadows this entire picture: Whether society can maintain social, economic and political stability in a transition to a sustainable future that takes place alongside both accelerating climate and biospheric change and potentially exponential innovation.

Critical Uncertainties: seven chapters on community futures

With a company purpose of "Creating Communities," at Stantec we always design with community in mind. We promote long-term thinking and innovation to address communities' needs in a rapidly changing and challenging world. >

In 2019, we commissioned Peter Kingsley, an independent expert in foresight and future thinking, to collaborate with Stantec experts in developing fresh thinking about the critical uncertainties and opportunities facing communities. This book, the result of that collaboration, contains a series of chapters exploring the high-impact, critical uncertainties that lie ahead.

The seven chapters that make up this book explore the long-term future: to 2050 and beyond. We can see them as intertwined narrative threads—not descriptions of linear trends, but rather components of a larger, dynamic and adaptive "system of systems."

In scenario terms, each narrative thread represents a "high-impact, high-uncertainty" variable. Each chapter tries to make sense of often conflicting evidence and signals. The chapters are intended to raise questions, to stress test strategies for national and city leaders in markedly differing circumstances around the world, and to set the scene for fresh, innovative strategic options.

The chapters begin by exploring the systemic risks to the world's climate and biosphere.

We then examine radical new technologies and how decentralized, distributed systems—from energy, water and agriculture to digital networks and urban transport—will shape the future and the strategic choices facing community leaders.

Infrastructure comprises both "hard" and "soft" varieties, and our next chapter examines the integration of natural and technology-based solutions as well as the development of "creative communities" that focus on socially inclusive well-being, on meeting human needs and on attracting talented, innovative people.

We conclude by exploring the critical role that governance and leadership will play in a volatile and highly uncertain world.

We show how these developments and technologies are gaining traction and how accelerating development cycles may change the landscape sooner than many anticipate. Scenarios embedded throughout the chapters raise two questions. First, "What might happen?" and second, critically, is about the strategic options that exist now, "What might we do?"

Cities stand on the front line in meeting the challenges of climate change, regenerating the biosphere and natural environment and creating sustainable, socially inclusive development. The idea that decentralization and local action will shape people's lives for generations to come echoes through each chapter. One size will not fit all. Never has *think global, act local* seemed more appropriate. ■

THE CHAPTERS

This compass icon indicates the related photo is a Stantec project.

David Smith

Senior Vice President

Corporate Strategy, Stantec

David is a leader in strategy for sustainable infrastructure. With more than 30 years of experience, David has led large-scale strategic consulting assignments and infrastructure delivery programs across the globe.

David holds a bachelor's degree in civil engineering and an MBA. He completed the Advanced Management Program at Harvard Business School and the Program for Sustainability Leadership at the University of Cambridge. He is a fellow of the Institution of Civil Engineers.

Nancy MacDonald

Vice President

Urban Places, Stantec

As our Urban Places director and Smart Cities lead, Nancy is heavily engaged in creating communities of the future. She is excited about future-proofing our communities, building infrastructure that will serve current needs and planning for the changing future. Nancy has led a wide range of both public and private sector planning projects, working with diverse groups of stakeholders as they solve complex urban challenges. She's currently co-leading Stantec's team working with Sidewalk Labs (an urban innovation developer) on smart, urban infrastructure design services for its proposed Quayside development in Toronto.

Peter Kingsley

Independent Foresight Expert

PJR

Peter is a globally recognized expert in foresight and future thinking. He recently co-founded The Oracle Partnership, which specializes in agenda-setting foresight, strategic risk and innovation.

He has delivered thought leadership and strategic advice to the boards of some of the world's leading investment banks, hedge funds, insurance underwriters and corporations. Earlier in his career, he held senior executive positions at Reuters and Dow Jones. He was also a partner at Stanford Research Institute's futures think tank.

Executive Summary

Abberton Reservoir
Colchester, United Kingdom

Ecosystem Infrastructure: shaping the long-term future

Communities face unprecedented change. There are major challenges to the long-term sustainability of communities brought on by increasing change in the climate, massive pollution of the biosphere and oceans, and loss in biodiversity. At the same time, there are immense opportunities for positive change through new technologies, ecosystem regeneration and holistic, joined-up thinking by city and community leaders.

Nº1

Chapter 1 focuses not just on the urgent need for systemic changes but also on the possibility that such changes might prove too little, too late. Warming that has already occurred may lock in extreme and irreversible harm to natural systems. However, shifts in human behavior and economic models could stabilize the environment and limit temperature rise. Dramatic innovation might also produce tools for slowing or even reversing carbon buildup.

The Intergovernmental Panel on Climate Change's (IPCC) focus on likeliest outcomes obscures the threat of plausible "wild card" events, but community-level planning will fail if it downplays or ignores worst-case scenarios. "Runaway" systems—for example, in the Arctic—may already be in motion. Sea-level rise poses one of the gravest risks to cities and is often compounded by subsidence, uncontrolled development, and groundwater extraction. Sea-level rise of up to 5.4 feet (164 centimeters [cm]) by 2150 would produce severe storm-driven flooding and saltwater contamination of drinking-water supplies. Traditional engineered solutions may fail in several ways, particularly by their inability to address unanticipated problems. The Dutch model of mixing engineering, natural systems and flexible thinking about how to live with water, developed over decades, looks like a more useful approach.

All told, the design and speed of implementation of sustainable infrastructure over the next 20 years will determine the long-term future of human civilization.

Nº2

Evidence suggests that human activity has begun reshaping Earth's natural systems, marking the start of the Anthropocene, a new geological era defined by human impacts. Chapter 2 suggests that accelerating biospheric damage—particularly to ocean and atmospheric systems—will transform political, community, investment and economic agendas and force more urgent responses.

These could play out in three ways. We could see a radical reconfiguration of human behavior that, nevertheless, fails to prevent fundamental and irreversible changes in the systems on which human life depends. Alternately, new technologies, leadership models and economic restructuring could turn the tide toward regeneration of the natural world and long-term security. A third scenario suggests that both of these could play out simultaneously. Shifting public attitudes, richer data, an evolving understanding of ecosystems, and growing political urgency all point in the right direction, yet it may take investor demands for transparency about climate risks to force the adoption of "sustainable development" thinking.

Nº3

Each of the systems in Chapter 3 outlines the fundamental issues that we face. A warming climate threatens water supplies globally. Power generation must cut carbon emissions to zero by 2050, even as demand rises. Food production consumes about 70% of global water and generates about 25% of global carbon emissions. Conventionally seen as operating independently, these systems actually overlap significantly. Water systems use energy, energy systems use water and food production uses both—meaning that a focus on synergies could transform all three and slash their environmental impacts. Adopting ecosystem thinking to reorganize all three as local networks, mixing innovative technology and natural systems, would deliver economic efficiency, environmental gains, community empowerment and better quality of life. At its most robust, this approach could regenerate both communities and the natural world. But the absence of local vision, a narrow focus on stranded assets, and a shortage of transitional funding could leave many communities stuck with conventional infrastructure, slowing the transition to sustainable systems.

Nº4

Chapter 4 examines the role that exponential technological innovation might play in shaping future communities. Delivering results quickly and accelerating innovative, digital infrastructure could jump-start biospheric regeneration. Systems that combine sensors, drones, data analysis, artificial intelligence and predictive algorithms will shape digital cities, even as they raise policy questions about limiting and controlling their intrusiveness. 5G technology will make full interconnection ("the Internet of Things") possible, transforming buildings, infrastructure, water, energy, agriculture and transport. It will create a new layer of infrastructure—digital networks that use deep, real-time intelligence to predict failures and guide responses that bolster resilience. Aerial drones will serve as part of this digital infrastructure, but policy will need to balance their benefits (low costs, dramatically better performance reporting) against risks of surveillance and terrorism.

Nº5

Chapter 5 describes the inflection point at which transport finds itself. Collectively, evolving forms of mobility will transform the built environment and cut pollution, carbon and travel times. An increasingly diverse mix of modes could unlock valuable urban real estate, now dedicated to parking, for sustainable new development and a richer public realm. A change already under way, shifting the goal of transport policy from moving cars to moving people, will give new priority to a range of modes, from e-scooters to ride-hailing to bus rapid transit. As power sources become fully renewable, electrification will lower operating costs and environmental impacts of all modes. Shared autonomous vehicles and aerial drones will both benefit from and spur development of sensor-driven, connected traffic systems that radically improve safety, reduce congestion and slash environmental impacts.

Full build-out of these systems will rely on the resolution of such thorny issues as data privacy, data ownership, data security and network stability; beyond those issues, unintended consequences, such as increased energy consumption, could slow their widespread adoption. As the global competition for talent grows more intense, cities will increasingly rely on a clear vision for transport that supports sustainable well-being, jobs and lifestyles.

Nº6

Chapter 6 looks at the role creative communities will play in responding to dramatic change. Cities will increasingly treat soft infrastructure—cultural resources, sustainability measures, natural and green spaces, and social inclusion—as an essential complement to traditional hard infrastructure in managing climate threats. Decarbonization will require an end to consumption-based, resource-intensive economic development; instead, it will favor a model organized around the knowledge economy. Soft features will attract the educated knowledge workers who'll fuel growth and help generate new revenues to pay for new responsibilities: decarbonization; the re-engineering of energy, water, waste, and agricultural systems; healthcare for an aging population; and integration of climate migrants.

To defend against climate impacts and adopt the opportunities of digital and radical transport, cities will face the imaginative challenge of exploring extreme scenarios and building locally tailored, long-term strategies for security and sustainability. They'll mix familiar structural solutions, like seawalls, with measures built around natural processes, like artificial wetlands that protect against flooding while boosting long-term environmental health. The most successful approaches will treat these networks not just as defenses against threats but also as opportunities to improve quality of life and build a sense of place and community.

Nº7

Chapter 7 explains why the slogan "think globally, act locally" represents the future for cities responding to these high-impact, high-uncertainty variables. With national governments slow to act on the decarbonization pledges made in the Paris Agreement, city and regional governments have taken the lead. Realistically, they have little choice because two-thirds of humanity will live in cities by 2050. The nuts and bolts of building and executing policy will happen here, where rising sea levels, flooding and extreme heat will hit first. Some cities have embraced resilience and support for green industries as a way of drawing knowledge workers and the investment that follows them. Technology has also helped; the plummeting costs of renewable energy, microgrids, and battery storage will make decentralized systems increasingly practical. Water and agriculture networks will follow a similar route, and digital systems will become pervasive. Together, they promise local independence, security and long-term resilience. Institutional investors and financial regulators will also play a role; worried about the safety of their investments, they'll push cities to act on these issues sooner and more aggressively.

In the end, local action represents the best near- and long-term hope for addressing the causes and threats of climate change and biospheric failure and successfully embracing the opportunities afforded by radical new technology.

Climate Change: the scale of the challenge

Nº1

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Extreme Scenarios Emerge

Global Climate Change Alliance+ Seychelles Climate Change Project
Seychelles,

Over the next two decades we may see a volatile, unstable climate; radical, integrated, systemic innovation; and political, economic, financial and social upheaval.

The background is well-known. Heatwaves. Drought. Flood. Wildfires. Accelerating loss of Arctic sea ice. Thawing permafrost and the large-scale release of methane. Fears of failing Greenland ice shelves and the collapse of the Western Antarctica. Rising sea levels. Storm surges. Extreme rainfall. Collapse in biodiversity. Ocean acidification and declining fisheries. Crop failures, soil degradation and dwindling habitats. →

The language describing the risks directly related to rising global temperatures and sea-level rise tell the story. Words like *mass loss, unprecedented, catastrophic*, *hottest*, *driest* and *extreme* pervade the Intergovernmental Panel on Climate Change (IPCC) reports of 2018, 2019 and the associated research papers.[1]

If we see natural ecosystems as the structural foundation on which civilization depends, then the language describing the next level—the human systems vulnerable to dangerous changes in natural systems—is similarly alarming. In the extreme, we could see existential risks. Political instability and failed states. The prospect of mass migration, with millions displaced, even in the most advanced regions, as some cities are forced to higher ground. Uninhabitable coastal regions. Starvation. Water wars. Financial market meltdowns. In the extreme, a credible threat to human existence.

Against this backdrop, there is evidence of increasingly urgent, system-wide and radical action as governments, cities, communities and companies around the world attempt to stabilize the climate and limit damage to the biosphere. In some countries, strong national leadership is driving sustainable development. Regardless of high-level international political action, community action and grassroots activism may yet shape investment in re-engineering communities and cities around the world.

Yet there remains fundamental uncertainty. One underlying concern is whether there will be widespread cultural shifts in values and attitudes, or at the other extreme, social outrage at political inaction. Because the frequency and severity of climate events directly affects more people's lives and larger numbers of communities, cultural change is possible, but far from certain. To illustrate, extreme events, such as flooding caused by hurricanes Florence and Michael, may already be playing a role in shifting both public and political opinion in Florida and North and South Carolina. Language like *resilience* and *just transition* are entering the lexicon.

In the extreme, if existential risks to civilization, national security and economic interests crystallize in the public imagination and amongst political leaders, there may be a revolutionary change in pace and scale of transformation along the lines called for by the IPCC. Changing public values, attitudes and sentiment will remain some of the critical underlying uncertainties. Sudden shifts are possible—at least in some parts of the world—as illustrated by the recent turnaround in attitudes toward plastic pollution and oceans. These early signs may gain momentum.

The second fundamental uncertainty is the impact even the most radical and urgent transformation in political and public action will have on the natural world, the global climate and sea levels.

Unstable weather, high-frequency storms and devastation may only get worse, regardless of human action, leaving some communities uninhabitable. It is possible that the natural world has passed the point of no return and that regardless of human intervention, at the extreme a "hothouse" world emerges and little can be done. It may turn out to be hubris that even radical innovation can influence the outcomes at scale and with sufficient speed.

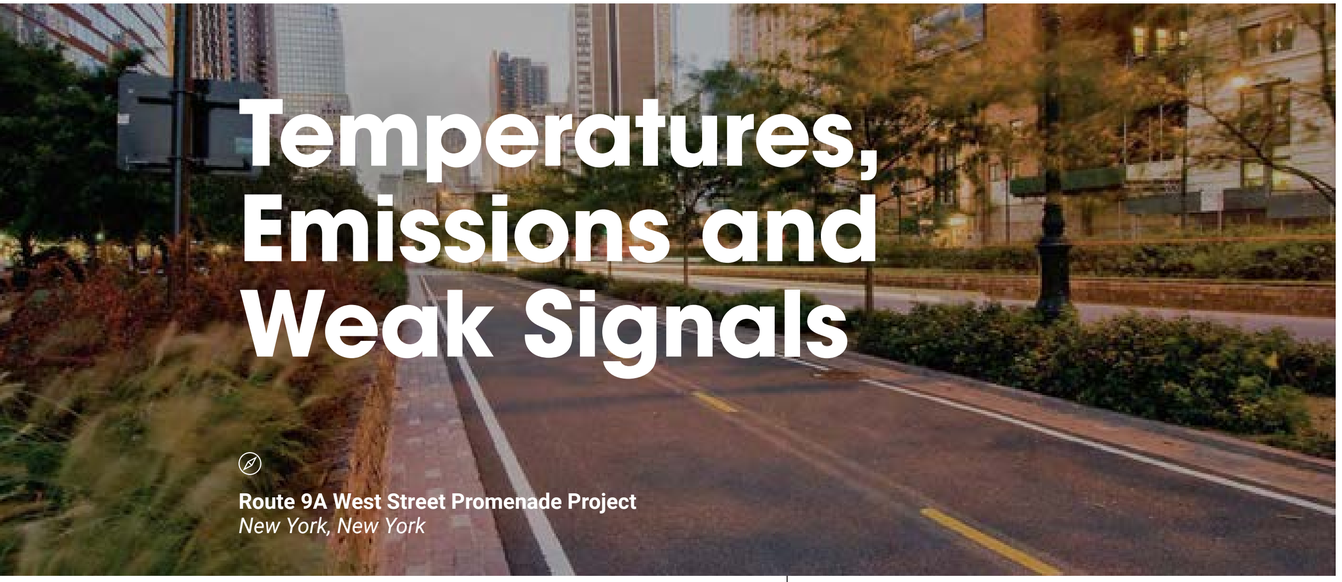
To put this in context, recent scientific reports not only point to the scale and urgency of systemic change needed, but to the possibility that even those may prove "too little, too late." In other words, warming that has already taken place may have locked in extreme climate change. The term "irreversible" now appears commonly, not as a forecast, but as an articulation of emerging worst fears.

On the other hand, it is also possible that a combination of natural climatic variation and changes in human behavior and economic models will help stabilize the environment, limiting the biospheric damage largely to the most vulnerable regions. What some call "exponential innovation" may slow and even reverse some of the impacts of the industrial economy on natural systems.

The IPCC's 2018 report puts this in context, consigning the original two-degree target set in the 2015 Paris Climate Agreement to history. The new target is 1.5°C (2.7°F) above pre-industrial levels. The planet has reached 1°C (1.8°F) already, so every fraction matters. The report says that global emissions must drop 45% by 2030 and reach net zero by 2050. A statistic in the report illustrates by keeping climate change to 1.5°C (2.7°F), compared to 2°C (3.6°F) 50% fewer people globally would be "exposed to a climate change-induced increase in water stress."

Leaving aside projections, emissions have continued to climb. Some critics now argue that even 1.5°C (2.7°F) represents a pipe dream and may be breached within a few years. ■

[1] Global Warming of 1.5°C, IPCC, Oct 2018, https://www.ipcc.ch/sr15/ & Ocean and Cryosphere in a Changing Climate, IPCC, Sept 2019, https://www.ipcc.ch/srocc/home/



Temperatures, Emissions and Weak Signals

Route 9A West Street Promenade Project
New York, New York

The research that contributed to the recent IPCC report tends to focus on "evidence," levels of "confidence" and "agreement." Although there is a high degree of consensus, the reports disguise potential extremes. It places little emphasis on “wild card’ events that might emerge at any time, nor on ambiguous “weak signals,” faint narratives, or competing ideas, where evidence appears contradictory.

Yet to community and city leaders investing in long-term infrastructure and public security, potential extremes are vitally important. Investors in infrastructure, unlike scientists, take a broader and deeper view of risk and will include nonscientific criteria in their assessments. As an example, Moody’s have signaled that they will downgrade credit ratings for communities if project designs do not take account of future climate change and related threats.[2]

To illustrate, just a decade ago, rising sea levels barely registered in the public mind; today, those people living in low-lying cities around the world are realizing that they could be displaced. Wildfires, until recently, were considered rare natural events. "Runaway" systems received little mainstream media coverage yet may already be in motion. The Arctic is warming faster than anywhere else. Some parts recorded temperatures 25°C (45°F) higher than normal and the region is at its warmest level in at least 40,000 years. This warming triggers a self-reinforcing sequence: warmer temperatures increase the melting of sea ice; reduced ice area reflects less solar radiation; more sunlight reaches water, warming it further and leading to even more melting.

To put all this in context, as George Church,[3] a Harvard University professor, notes that the Arctic tundra contains more trapped carbon than the entire atmosphere and rain forests put together. Thawing permafrost will release this carbon as well as methane. This destabilizes the ground, including in areas that host critical infrastructure. In Alaska, for example, infrastructure damage is estimated at US $5.5 billion between 2015 and 2019 under the IPCC’s "business as usual scenario." To some scientists, a permafrost meltdown is just a question of time. Others see no way of calculating the odds. A known with unknown possibilities, permafrost thawing has already begun. The uncertainty lies in its scale and speed.

Long-term, potential impacts are already the focus of resilience planning, particularly in the Arctic. There are lessons to be learned about systemic disruption around the world. A National Academy of Sciences report points to the possibility of a "climate cascade”—global disruption of multiple systems on which human society depends for survival.[4] In a matter of decades we might cross a threshold that leads to “Hothouse Earth,” in which self-reinforcing feedback loops “could prevent stabilization at intermediate temperature rises,” regardless of attempts to reduce emissions. The paper argues that even with uncertainty about timing, urgent, system-wide action is vital:

> *The Stabilized Earth trajectory requires deliberate management of humanity’s relationship with the rest of the Earth System if the world is to avoid crossing a planetary threshold. We suggest that a deep transformation based on a fundamental reorientation of human values, equity, behavior, institutions, economies, and technologies is required.*

In other words, a warming Earth may cross “thresholds" beyond which there is no turning back. At between 1°C (1.8°F) and 2.9°C (5.22°F), the melting of ice in the Arctic, Antarctic and Greenland amplifies warming. Between 3°C (5.4°F) and 4.9°C (8.82°F), the weakening Atlantic Meridional Overturning Circulation (the system that drives the Gulf Stream and keeps northern Europe temperate) and South Asian monsoons may accelerate warming still further. Other reports have used similarly extreme language: as Laurent Fabius, the former French prime minister, puts it, “The red alert is on. It’s a race against time".[5] ■

[2] Moody's Warns Cities to Address Climate Risks or Face Downgrades, Bloomberg, Nov 2017, https://www.bloomberg.com/news/articles/2017-11-29/moody-s-warns-cities-to-address-climate-risks-or-face-downgrades
[3] A Conversation With George Church, Edge, Feb 2018, https://www.edge.org/conversation/george_church-church-speaks
[4] Trajectories of the Earth System in the Anthropocene, Proceedings of the National Academy of Sciences, Aug 2018, https://www.pnas.org/content/115/33/8252
[5] Address by Laurent Fabius, International Conference 'Climate Change in the Middle East: Challenges and Solutions', May 2018, http://www.unsdsn.gr/getfile.php?fid=1360&ftype=4&file=455

Sea Levels

While academic research focuses on the extreme “Hothouse Earth” scenario, mainstream risk assessment doesn’t. That may prove a mistake, as crossing these thresholds would create dire threats from sea-level rise for cities around the world. →

So far in this century, the global average sea level has risen 2.4 inches (6.1 cm). Projections reflecting recent emissions growth rates suggest that levels could rise between 1.4 and 2.8 feet (43-85 cm) by 2100 and up to 5.4 feet (164 cm) by 2150. The risks are obvious: roughly ten percent of the world's population lives in areas less than 33 feet (1,006 cm) above sea level. In the US, about 16% of GDP is generated within coastal counties, many of which are growing in population and urban density.

To illustrate, 47% of the US population is expected to live in shoreline counties by 2020, with population densities six times higher than inland regions. Melting polar ice and extreme rainfall contribute to coastal impacts like flooding, saltwater contamination of freshwater supplies, coastal erosion and higher storm surges. Wetland and coastal erosion have already displaced rural communities in Louisiana. Drinking water contamination by saltwater has already hit Monterrey, Ventura and Los Angeles counties in California.

In California more broadly, sea cliff erosion is impacting infrastructure. Miami and many other areas along the Gulf Coast and Eastern Seaboard are experiencing regular flooding, particularly during "king tides."

Increasingly common flooding disguises the fact that sea levels—and their rise—vary around the world. Some land masses are rising, reducing potential impacts, while others fall. In some cases, natural and development-related subsidence and coastal erosion, often due to mismanagement of beaches and over-development, amplify risk.

In the United Kingdom, the Environment Agency, responsible for developing a long-term strategy to deal with flooding and coastal change, is preparing for a potential 4°C (7.2°F) rise in global temperatures. The plan aims to make all infrastructure resilient by 2050. With climate change and population growth projected to double the number of properties built on flood plains over the next 50 years, the UK will need £1 billion per year to build traditional flood and coastal defenses.[6] Entire communities may be moved away from coasts and rivers.

Tidal flooding is the most significant sign of sea-level rise, transforming landscapes and threatening lifestyles, communities and infrastructures. The East and Gulf coasts of the United States have been subjected to some of the highest sea-level rises. As the flattest US state, Florida is a clear example of how the future may play out. Key West has seen a threefold increase in coast flooding since 1990 and St. Petersburg has seen a 40% increase. Estimates can be made in other ways. For example, 2,120 square miles (5,490 square kilometers [sq. km]) of land in Florida lies less than three feet (91 cm) above sea level. This includes 300,000 homes, 35 public schools, 2,555 miles (4,111 kilometers [km]) of road, 978 Environment Protection Agency-listed hazardous waste dumps and sewage plants, and several power installations.

One study suggests that in the intermediate and highest scenarios described in the *US Third National Climate Assessment*, released in 2014, between 489 and 668 communities would be inundated and therefore uninhabitable by 2100. In the lowest scenario, 199 communities would be affected.[7]

In their September 2019 report, the IPCC note "sea-level rise is projected to continue beyond 2100 in all RCP (low/high greenhouse gas emissions) scenarios." Extreme sea-level events that historically occurred once per century are projected to occur "at least annually at most locations by 2100 under all RCP scenarios." Many low-lying mega-cities and small islands are projected to experience once in one hundred year events at least annually by 2050 under the majority of scenarios.[8]

The IPCC continues to demand action as it relates to the climate crisis. However, they also point to emerging solutions. In October 2018, they suggested the lower rate of sea-level rise at 1.5°C (2.7°C) provides "greater opportunities for adaptation including managing and restoring coastal ecosystems and infrastructure reinforcement."[9] Likewise, in September 2019 the IPCC remarked "intensifying cooperation and coordination among governing authorities across scales, jurisdictions, sectors, policy domains and planning horizons can enable effective responses to changes in the ocean, cryosphere and to sea-level rise."[10]

In the United States, 47% of the population is expected to live in shoreline counties by 2020. Population density will be six times higher than in inland regions.

The IPCC and other studies offer two broad lessons. First, in planning for infrastructure, long-term resilience and sustainability assessments must account for projected global sea-level rises, local geography and urban infrastructure conditions. Second, given the wide range of uncertainty about long-term impacts, local planning will fail if it downplays or ignores worst-case scenarios. Not only for community security but to convince investors, insurers and sources of public funds that ecosystem designs are sustainable. Long-term, in the volatile context of climate politics, means beyond 2050 and as far ahead as 2100. ■

[6] Environment Agency Chair calls for new approach to flood and coastal resilience, Environment Agency, May 2019, https://www.gov.uk/government/news/environment-agency-chair-calls-for-new-approach-to-flood-and-coastal-resilience
[7] Effective inundation of continental United States communities with 21st century sea level rise, Elem Sci Anth, 2017, http://doi.org/10.1525/elementa.234
[8] Ocean and Cryosphere in a Changing Climate, IPCC, Sept 2019, https://www.ipcc.ch/srocc/home/
[9] Global Warming of 1.5oC, IPCC, Oct 2018, https://www.ipcc.ch/sr15/
[10] Ocean and Cryosphere in a Changing Climate, IPCC, Sept 2019, https://www.ipcc.ch/srocc/home/

Sea Defenses

Katiki Beach Coastal Repair
Dunedin, New Zealand

The conventional assumption that sea defenses will solve the problem of sea-level rise may turn out to be a myth for some of the world's major cities. Whether communities can withstand and adapt to disruptive change—whatever climate and sea-level reality emerges—remains the ultimate challenge. →

A more dangerous myth holds that sea defenses and flood-resistant architecture represent the best technological, design, engineering and financial response to the challenge of long-term resilience.

This may prove overly optimistic. To illustrate, one popular view holds that sea-level rise represents the primary risk for the world's major cities. In reality, many of these cities are vulnerable to a combination of risks that only start with sea-level rise. Others include extreme rainfall; storm surges specific to local geography; river and surface-water risks; natural subsidence; and structural weakness created by decades of poorly planned development and groundwater extraction. Few cities have taken into account the potential of long-term systemic failure.

Some cities are sinking because of geological processes; some because rapid development has left them with weakened underpinnings; and some have built against, rather than with, natural forces. Many also face vulnerability to flash floods, both from the coasts and from upstream watersheds that will flood more frequently as the atmosphere warms, as happened in Houston during the 2017 floods. More cities need to adopt multi-stakeholder, watershed-based approaches, where networks of government, business and community partners reach across the connected areas of community, ecosystems and infrastructure to drive resilience.

The symptoms of this technocentric approach can

Engineering Services for Coastal Protection and Restoration Projects
Baton Rouge, Louisiana

be seen around the world. In the United States, Houston planners ignored clear warnings. In Florida, some markets show early signs of real estate prices under pressure, as the public recognizes the long-term threat. Yet ill-designed building continues.

In Jakarta, where population growth and rapid development have caused the ground to sink, construction not only drives subsidence but also cuts groundwater supplies. The risk has been known for some time, but only now is it being considered. Critics argue that projects promoted as "climate adaptation" are often anything but. Subsidence also plagues Manilla, at a rate of 2 inches (5 cm) a year, increasing its vulnerability to storm surges and flooding from typhoons. In Bangkok, built on a flood plain, the government has continued to invest in short-term "hard" infrastructure and fortification—making the situation worse—rather than adaptive planning for the long-term.

Dutch engineering firms have recognized for some time the limitations of artificial controls over river deltas. Recent initiatives, including the introduction of "Room for the River" and "water squares" that retain water, acknowledge that migration is a part of long-term solutions for some cities.

If we define *resilience* and *sustainability* as security for the world's communities; security as strategic options that will work in even the most extreme scenarios; and long-term as the next 100 years, then current thinking falls well short. ■

Hedging Strategies

High Sheldon Wind Farm
Sheldon, New York

The science undergirding IPCC reporting, and reinforced by other research, suggests that decarbonization and adaptation will present profound challenges. The IPCC calls for nothing less than full-scale re-invention of economic and urban systems, all in a highly compressed period. The Global Climate Action Summit[11] adopts a more optimistic outlook, however, arguing that required exponential changes have already begun, not least in the form of collaborative associations that unite cities, corporate leaders and investment groups.

To illustrate, growth in wind and solar energy could cut global emissions from electricity generation in half by 2030. Steel, aluminum, cement and plastics production could make similar cuts, using existing technologies. The transportation sector could match these results through a large-scale switch to electric vehicles and redesign of mass transit systems, shipping and aviation. Reforestation—a natural, low-cost and efficient form of geo-engineering—also has a major role to play. Precision agriculture could reduce water consumption, energy costs and emissions.

The emission reduction solutions taking shape have the potential to transform the landscape, if adopted urgently. Their key elements include:

- Energy efficiency, by far the simplest, most direct route to reduced carbon emissions
- Mass-scale reforestation and afforestation
- Carbon capture and storage
- Solar radiation management
- Solar and wind energy
- Electric vehicles and urban traffic networks

Above all, an effective response to the climate crisis will depend on the integration of systems and the speed of a transition. Delivering resilience and sustainability depends on action at all levels of urban infrastructure. This means everything from designing all buildings to protect people from extended hot weather, to building out connected greenspace networks to reduce the “heat island” effect, to re-designing drainage and road networks to handle increasing volumes of stormwater. More succinctly, it means a kind of “ecosystem design and re-engineering,” that looks beyond passive resilience to active regeneration.

The design and rapid implementation of sustainable infrastructure over the next 20 years will determine the long-term future of the planet and civilization. The resulting systems will have many complex interacting parts. Ultimately, the answers lie in taking a holistic, “systems of systems" perspective to urban regeneration, integrating previously separate systems for water, energy, agriculture, transport and construction.

Many of these solutions will require the active involvement of community and city leaders. Some will depend on developers, infrastructure designers, engineering firms and operators. Some regions and countries may require strong national intervention to create the necessary political framework for getting the work done. Acting now will reduce the overall long-term costs that would result if nothing was done. In all cases, there remains uncertainty about the economic and financial capacity to underwrite major long-term investment. Above all, that will depend on whether the public takes action and places confidence and trust in government in the face of tough changes.

We cannot afford to wait. Solving climate and sea-level problems will require visionary leadership; fundamental changes in worldviews and ways of thinking about systems; and new economic models that focus less on short-term consumerism and more on long-term sustainability. In practical terms, the solutions will involve integration of multiple technologies and design approaches within a new analytical framework that sees cities, above all, as complex interconnected systems that must adapt to the likelihood of extreme long-term change.

The future of communities is inextricably linked to climate and sea-level change, as well as to how quickly we can adopt innovative solutions and holistic, integrated design that crosses traditional boundaries.

Climate change and sea levels, however, represent only part of the picture. We now move on to explore the prospects for the biosphere, natural environments, and habitats, and for the possibility of regeneration of the natural world. ■

[11] Climate Action Summit, United Nations, Sept 2019, https://www.un.org/en/climatechange/assets/pdf/CAS_closing_release.pdf

Biosphere: from pollution to regeneration

Nº2

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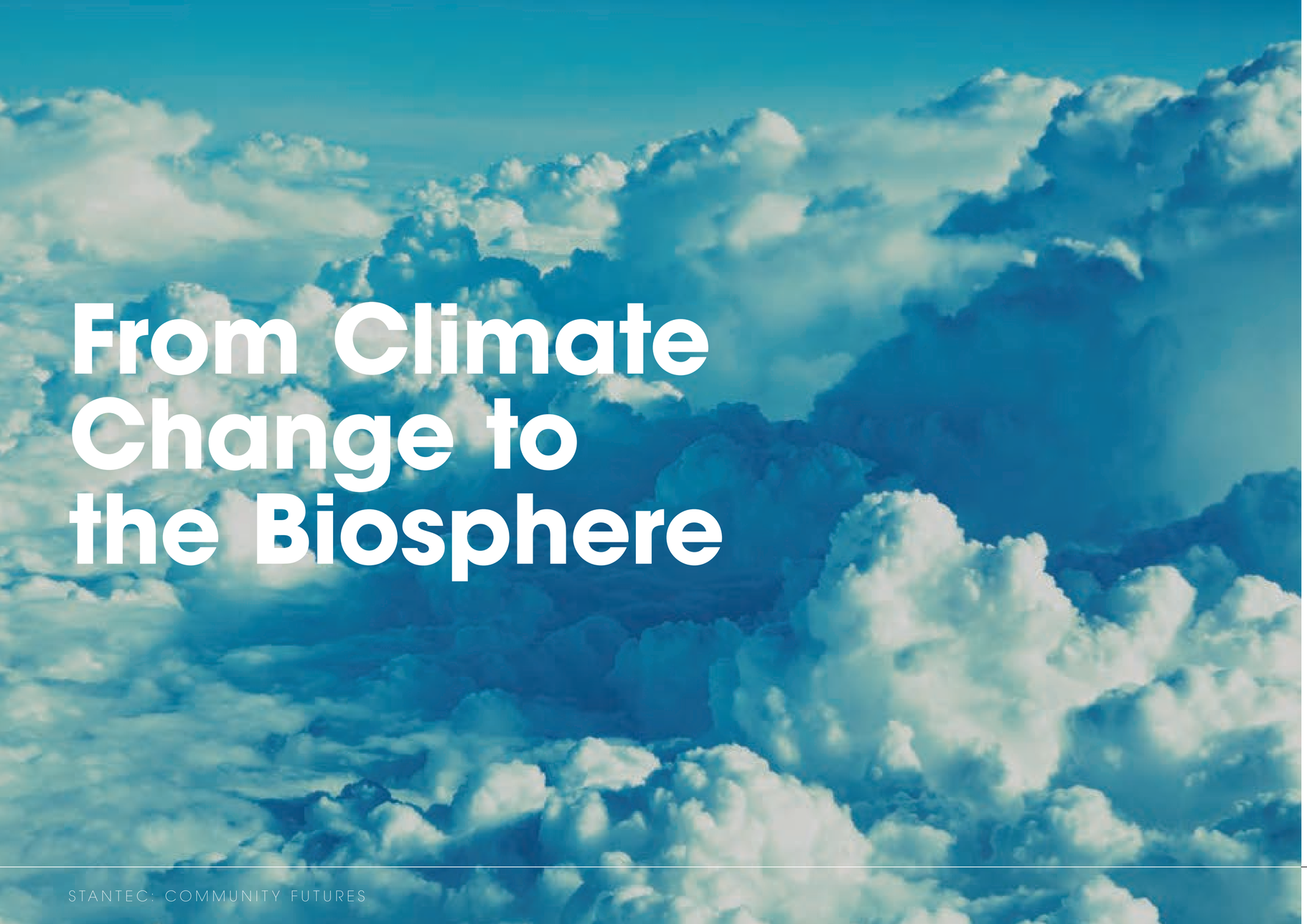


From Climate Change to the Biosphere

Climate change and carbon emissions have dominated headlines for more than a decade. As understanding of potential impacts posed has deepened, attention has broadened to focus on rising sea-levels, storm surges, flooding, wildfires, droughts, erratic weather patterns and habitat risk. →

The outcry about air pollution and plastics contamination has brought the global scale of damage to the natural environment into focus. Concerns about the health of oceans, river systems and the atmosphere are crystalizing in the public imagination. The accelerating rate of biospheric devastation has begun to drive urgent, and in some cases radical action, transforming political, community, investor and economic agendas.

Ecosystems, complex and adaptive, change continuously, sometimes abruptly, before they reach a new state of stability. The pervasive damage to the biosphere caused by urbanization, industrial production, agriculture, resource extraction and lifestyles, influences everything from habitat quality and loss of biodiversity to food supplies and human health.

The future of infrastructure will have direct bearing on the future of the planet in terms of carbon emissions and their effects on climate, sea levels and wider disruption. It will determine the future of the biosphere and natural systems—sometimes called "the infrastructure of life." Many inventive solutions rest at the local level, for both geographic and political reasons. Whereas climate and sea levels are long-term global challenges, transformation of community environments can produce social, environmental and health benefits quickly. Community leaders are on the front line.

Three emerging narratives reflect deep uncertainty about the future. A first points to fundamental, large-scale changes in natural systems and the biosphere, despite potentially radical changes in a consumption-focused global economy. A second suggests the potential for regeneration of the natural world and long-term security. A third sees the first two playing out in parallel, with both biospheric crises *and* radical re-invention through new technologies, leadership models and economic systems. ■

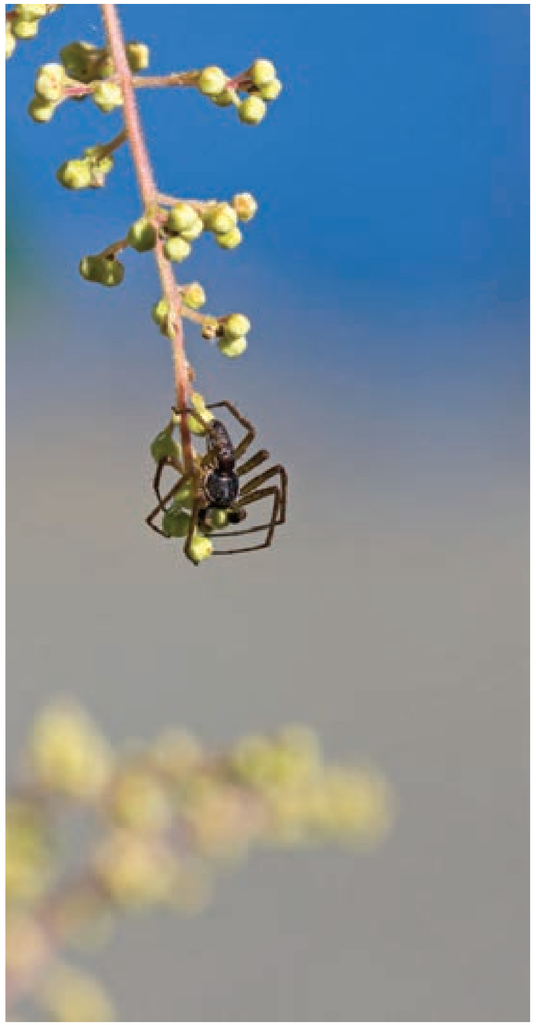
Biosphere: past to present

There is history here. In 2004 Will Steffen, a leading environmental scientist, led publication of *The Great Acceleration*,[1] a set of measurements describing the state of the biosphere and the impact of human activity on the natural environment.

The measurements encompassed both socio-economic and "earth system" trends. In an update, published in 2015, human activity—measured by everything from population to urbanization, fertilizer use, water consumption and transport—grew rapidly from 1950.[2] Over the same period, levels of carbon dioxide, nitrous oxide, methane, surface temperatures, ocean acidification, aquaculture, coastal habitat loss, exploitation of natural resources, tropical forest loss and "terrestrial biosphere degradation" all increased.

The findings of recent research from many sources carry similar stark messages. Take two examples: the United Nations Convention on Biodiversity and the World Wildlife Fund say the world has little time to change direction and halt large-scale extinction. Using similar language, both convey one message: only "urgent" action will prevent "collapse" of insect, bird, plant and mammal populations. We have entered a new human-influenced geologic time period, the Anthropocene, with overwhelming global evidence that human activity has begun altering atmospheric, geologic, hydrologic, biospheric and other earth-system processes.

Everything is interconnected. Biosphere-related risks, such as forest fires, droughts, floods, habitat and biodiversity loss and the spread of invasive species are intricately linked to climate change. The October 2018 IPCC report projects (with "medium confidence") that an increase of 2°C (3.6°F) in global atmospheric temperature would lead 18% of insects, 16% of plants and 8% of vertebrates to lose “over half of their climatically determined geographic range.”[3] The World Wildlife Fund *Living Planet Report* for 2018 showed that 60% of vertebrate populations



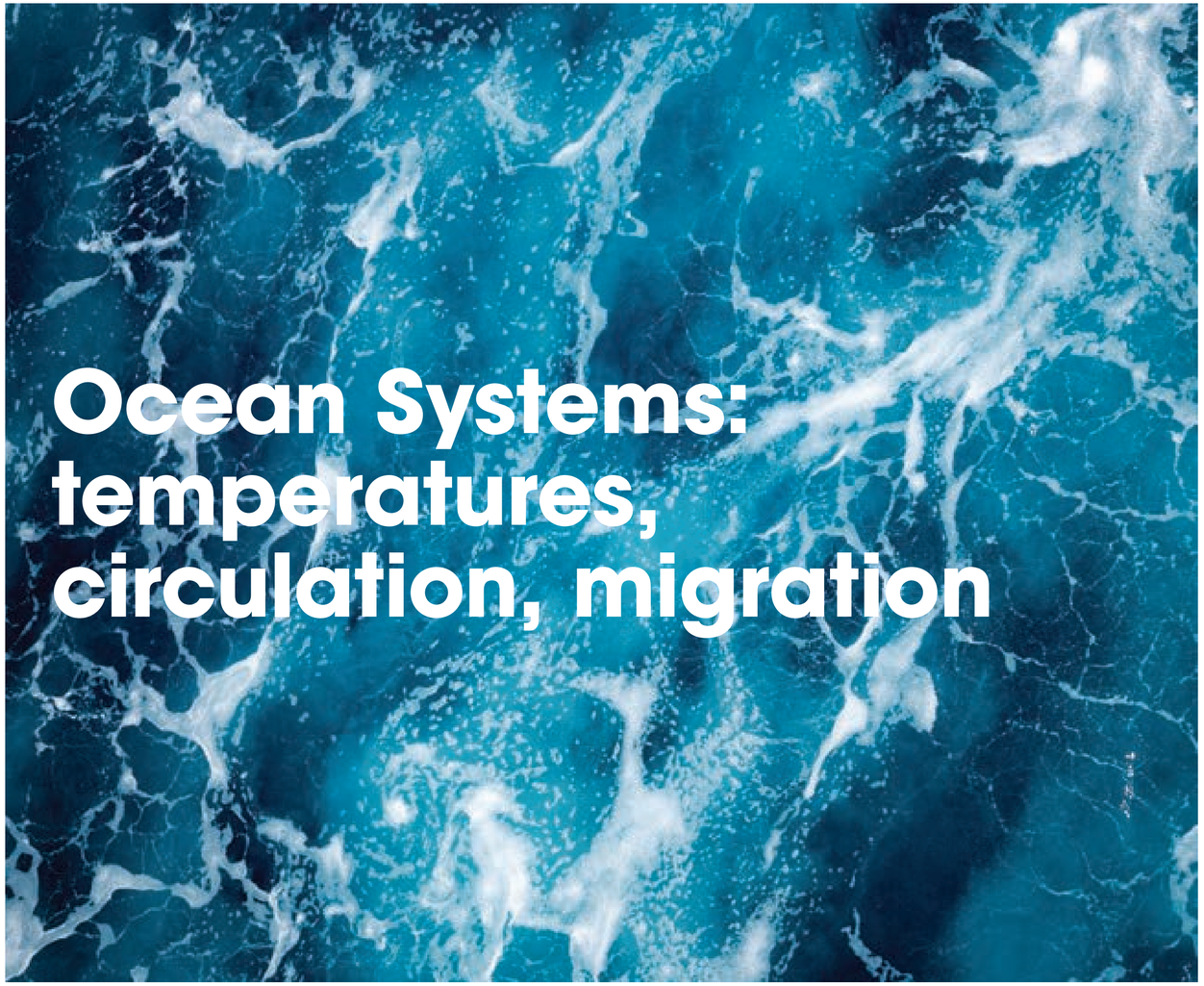
were lost between 1970 and 2014.[4] A "Loss of insect diversity and abundance," said the Institute for Water and Wetland Research, "is expected to provoke cascading effects on food webs and to jeopardize ecosystem services."[5]

The UN Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), published its Global Assessment Report in May.[6] The “most comprehensive assessment of its kind,” estimated that one million species are threatened with extinction. The chair of the IPBES, Sir Robert Watson, pointed to an “ominous picture” that, “The health of ecosystems on which we and all other species depend is deteriorating more rapidly than ever. We are eroding the very foundations of our economies, livelihoods, food security, health and quality of life worldwide.”

The "systems-of-systems" relationships to social, political and economic systems extend further. As UN Secretary General Antonio Guterres put it in 2018, "Protecting and restoring ecosystems and ensuring access to ecosystem services are necessary for the eradication of extreme poverty and hunger.”[7] Food and agriculture, water, forestry systems and carbon sinks depend on natural ecosystems.

The health of the biosphere, of infrastructure and human health are inextricably linked. According to the World Health Organization, “Health must be the number one priority for urban planners.”[8] ■

[1] Global Change and the Earth System: A Planet Under Pressure, Steffen et al, 2004, http://www.igbp.net/globalchange/greatacceleration.4.1b8ae20512db692f2a680001630.html
[2] The trajectory of the Anthropocene: The Great Acceleration, Steffen et al, Jan 2015, https://journals.sagepub.com/doi/10.1177/2053019614564785
[3] Global Warming of 1.5oC, IPCC, Oct 2018, https://www.ipcc.ch/sr15/
[4] The Living Planet Report, World Wildlife Fund, Oct 2018, https://www.wwf.org.uk/sites/default/files/2018-10/wwfintl_livingplanet_full.pdf
[5] More than 75 percent decline over 27 years in total flying insect biomass in protected areas, Institute for Water and Wetland Research, Oct 2018, https://www.ncbi.nlm.nih.gov/pubmed/29045418#
[6] Global Assessment Report on Biodiversity and Ecosystem Services, IPBES, May 2019, https://www.ipbes.net/global-assessment-report-biodiversity-ecosystem-services
[7] Secretary-General’s message on the International Day for Biological Diversity, United Nations, May 2018, https://www.un.org/sg/en/content/sg/statement/2018-05-22/secretary-generals-message-international-day-biological-diversity
[8] Health must be the number one priority for urban planners, World Health Organization, Mar 2018, https://www.who.int/mediacentre/commentaries/2018/health-urban-planning/en/



Ocean Systems: temperatures, circulation, migration

People around the world experience pollution and rising air temperatures directly. Wildfires devastate lives and communities. Water shortages undermine regional security, creating crop failures and driving mass migration. Degraded air quality harms the health of millions.

In contrast, the less-direct impacts of rising ocean temperatures may prove more important for the long-term resilience of the world's communities. The ocean absorbs more than 93% of the additional warmth resulting from human carbon dioxide emissions. Through a series of direct and indirect relationships, this produces dramatic changes in the atmosphere, in global sea levels, in the frequency and intensity of hurricanes and storm surges, in ocean habitats, and in ocean circulation.

Surface-level ocean temperatures have risen rapidly since 1980. In 2013, the IPCC estimated that mean ocean temperatures would rise between 1°C (1.8°F) and 4°C (7.2°F) by 2100. Although seemingly minimal, these increases represent the main driver behind sea-level rise (through thermal expansion of the ocean) and changes in polar conditions, which in turn affect atmospheric and ocean circulation.

In the northern hemisphere, Arctic amplification is causing a rapid decline in sea ice, decreasing the temperature difference between higher and lower latitudes. This weakens the jet stream and allows warm southern air to intrude into polar regions, increasing the loss of permafrost. It also pulls cold weather south, creating -60°C (-76°F) wintertime temperatures in the North American plains and Eurasia in February 2019.

The weakening of the "Atlantic Conveyor"—more formally, the Atlantic Meridional Overturning Circulation (AMOC)—also looms on the horizon, though the system is far from fully understood. The AMOC carries warm water from the Caribbean northeastward, giving Europe a much milder climate than it would otherwise have. In one extreme but possible scenario, AMOC shuts down under the volume of cold water streaming off the melting Greenland ice sheet as global air and ocean temperatures rise. ■

Transforming Knowledge

While biospheric damage may be partially invisible to the public eye, that may change dramatically with detailed intelligence from increasingly widespread drones and sensor networks. While specialists have understood the fundamental systems, the next two decades could transform knowledge of the mysteries of two-thirds of the planet. A network of sensors—the "ocean of things"—will monitor environmental, commercial and military activity both at the surface and on the ocean floor. →

The changes in the oceans have global environmental, social and economic repercussions. Yet it is the direct impact on coastal communities that may trigger changes in public attitudes. 40% of global population lives within 50 miles (80 km) of the coast, including two-thirds of the world's largest cities. In the US, the population density of coastal counties is more than six times that of corresponding inland counties.

Aside from sea level rise and increased intensity and frequency of hurricanes felt by coastal communities, increases in ocean temperatures are changing the distribution of important commercial and subsistence species. These distribution changes, some of which bring marine species towards the poles, some deeper, some further offshore, are transforming lives. Coastal communities that rely on the sea for food and economic survival are already seeing devastating changes. Fishing is a US $140-billion-a-year industry that, in some parts of the world, provides half of local food supplies.

Long-term mitigation and adaptation at local levels depends on scenarios for regional ocean temperature and changes in currents. This applies above all to fishing communities and the production of seafood and substitute sources of nutrition. This may include urban, vertical farming, regeneration of coastal ecosystems and new forms of aquaculture.

Amid dwindling supplies and growing competition, aquaculture is one of the world's fast-growing sectors that aims to meet global protein demands. As the global population rises, ocean farming is emerging at scale, with the first viable "ranch" to operate in US federal waters now working off the California coast. Aquaculture is a major part of peoples' lives in China, Japan, India, Norway, Vietnam and Chile. Production is aimed at not only producing fish for human consumption but harvesting fish to produce nutrients in the form of fishmeal. This in turn is depriving local communities of their staple diets, creating havoc on coastal and marine ecosystems and indirectly impacting sources of wild fish.

Away from the coasts, flooding and extreme rainfall have increased by more than 50% in a decade.[9] Many of these impacts tie directly to changes in oceans and sea-level rise. The impact on communities, infrastructures and economies is well-known. Less clear is the impact of toxic pollution. In Florida, for example, about 2,120 square miles (5,490 sq. km) of land lie less than three feet (91 cm) above the high tide line, including 300,000 homes, 35 public schools, 2,555 miles (4,111 km) of road, and 978 Environmental Protection Agency listed hazardous waste dumps or sewage plants, and several power plants. Current urban systems are not designed to be resilient against the release of industrial chemicals in major floods. ■

[9] New data confirm increased frequency of extreme weather events, European Academies Science Advisory Council, Mar 2018, https://easac.eu/press-releases/details/new-data-confirm-increased-frequency-of-extreme-weather-events-european-national-science-academies/

Bad Atmosphere

Reducing pollution is about sustainable living and system-wide action, reducing emissions and cutting industrial production of chemicals and agricultural fertilizers. Curbing air pollution requires an interconnected suite of sustainable-living measures, system-wide actions, cuts in emissions and reductions in industrial production of chemicals and agricultural fertilizers.

Until recently, the dominant narrative held that only countries like India, China, Iran and Pakistan suffered from poor air quality as a result of urbanization and industrial production. These countries face daunting obstacles, of course. Extreme temperatures and air pollution in Delhi have already damaged the health and livelihoods of millions.[10] Levels of particulate matter smaller than 2.5 microns across, a standard measure of air quality, have exceeded the highest classification for "hazardous."[11]

Yet no location on the planet escapes air pollution. More than 90% of the world's 1.8 billion children under 15 breathe toxic air every day. About 600,000 died from respiratory infections in 2016. High pollution levels carry a legacy of cardiovascular and cognitive disease in later life. San Francisco, shrouded in smoke from wildfires, earned the title "most polluted city in the world" in November 2018.[12] The city government shut schools and urged residents to stay indoors.

A recent report from the World Health Organization (WHO) called air pollution a "global public health emergency."[13] More than 90% of the world's population live in communities with air pollution that exceed WHO guidelines. According to *The Lancet,* pollution is the "largest environmental cause of disease and death in the world today, responsible for an estimated 9 million premature deaths." The full extent of chemical and pesticide pollution has grown increasingly clear, as sensors and statistical techniques improve.[14] The World Bank estimates global "welfare losses"–a measure of economic and productivity inefficiency–at US $5.11 trillion a year, or about 6.2% of global economic output.[15]

Another *Lancet* report, focused on health among children in central London, showed the direct relationship between air pollution, much of it associated with vehicles and both short and long-term outcomes.[16] Growing evidence suggests that while specialist reports like these are important, public values, attitudes, fears and action are vital to creating change. Stories with real world central characters that capture visceral human experience are more important than abstract science.

Wildfires illustrate the fragility of urban environments and ultimately may render some parts of the world both uninsurable and uninhabitable. Household pollution from heating fuel and cooking is also a primary health factor, particularly in low- and middle-income countries.

In short, air pollution arises from wider environmental factors, everything from energy generation and urban transport to domestic power and the use of solvents in packaging. Just as important are the functions of urbanized areas. Recognizing this connection, the WHO has begun developing policy recommendations that accelerate "the switch to clean cooking and heating fuels and technologies, promoting the use of cleaner transport, energy-efficient housing and urban planning. We are preparing the ground for low emission power generation, cleaner, safer industrial technologies and better municipal waste management."[17] Cities again find themselves center-stage, in October 2019 pledging to deliver clean air for the more than 140 million people that live in their cities by signing the C40 Clean Air Cities Declaration.[18] ■

[10] In India, Summer Heat May Soon Be Literally Unbearable, New York Times, Jul 2018, https://www.nytimes.com/2018/07/17/climate/india-heat-wave-summer.html
[11] Raising Kids in Delhi's Worsening Air, The New Yorker, Jan 2018, https://www.newyorker.com/culture/personal-history/raising-kids-in-delhis-worsening-air
[12] San Francisco: schools and cable cars to close over smoke from Camp fire, The Guardian, Nov 2018, https://www.theguardian.com/world/2018/nov/15/san-francisco-schools-close-air-quality-camp-fire-smoke
[13] Air pollution: everything you should know about a public health emergency, The Guardian, Nov 2018, https://www.theguardian.com/environment/2018/nov/05/air-pollution-everything-you-should-know-about-a-public-health-emergency

[14] The Lancet Commission on pollution and health, The Lancet, Oct 2017, https://www.thelancet.com/commissions/pollution-and-health
[15] The Cost of Air Pollution - Strengthening the Economic Case for Action, World Bank, 2016, http://documents.worldbank.org/curated/en/781521473177013155/pdf/108141-REVISED-Cost-of-PollutionWebCORRECTEDfile.pdf
[16] Impact of London's low emission zone on air quality and children's respiratory health: a sequential annual cross-sectional study, The Lancet, Nov 2018, https://www.thelancet.com/journals/lanpub/article/PIIS2468-2667(18)30202-0/fulltext
[17] More than 90% of the world's children breathe toxic air every day, World Health Organization, Oct 2018, https://www.who.int/news-room/detail/29-10-2018-more-than-90-of-the-world%E2%80%99s-children-breathe-toxic-air-every-day
[18] 35 Cities Unite To Clean The Air Their Citizens Breathe, C40 Cities, Oct 2019, https://www.c40.org/press_releases/35-cities-unite-to-clean-the-air-their-citizens-breathe-protecting-the-health-of-millions

The Great Regeneration: toward an end game

If short-term prospects for the biosphere appear bleak, long-term prospects look more encouraging. Viewed through the lens of invention and innovation, the concept of policy-driven regeneration has begun taking shape and is increasingly influencing coordinated policy, business, investment, innovation, public and private and consumer behavior. It will play a critical role in large-scale, system-wide change where multiple stakeholders take action toward common goals and purposes.

Public attitudes, pervasive biosphere sensors, in-depth ecosystem knowledge and a sense of political urgency all point in the right direction. It may take decades for the idea of sustainable development, environmental protection and the "great clean up" to dominate global thinking.

The rate of real-world implementation represents a fundamental uncertainty. Yet innovation hotspots and investment flows, together with policy changes by cities, major asset managers, pension funds and insurers, reinforce the narrative. To illustrate, AXA's CEO recently announced that the group will no longer underwrite the construction of coal plants, coal mines, oils sands or Arctic drilling.[19] This will cut insurance premium income, according to the company, by more than 100 million euros. They will also withdraw 660 million euros in equity investment. The insurance industry may act as the trigger for disruptive changes in public attitudes if, for example, the so-called "protection gap" between private insurance and public cover widens further.

Governmental policies and high-profile public awareness campaigns add to the evidence. Germany, for example, has announced that it will shut down all coal-fired power plants by 2038. Surveys have found that the Millennial generation ranks health care and the environment at the top of its political agenda. Political leaders will begin to take notice if public support for radical changes grows.

Major corporations, pressured by active investors, are diverting funding and developing hedging strategies aligned to the idea of regeneration. As the strategic and commercial arguments are more widely accepted, confidence and ambition will create positive feedback loops. Investors and financial regulators are demanding more transparency about climate risks and sustainable development. Some cities are adopting an "ecosystem" worldview and have begun looking for opportunities to integrate services for reasons of both efficiency and sustainability.

Meanwhile, natural solutions focus on revolutionizing land use by regenerating forests, wetlands, and grasslands, and by implementing integrated land, water and agricultural use policies.

Mirroring this, land values have continued to rise, driven by population growth, limited availability and rising food demand. Even so, only 36 of the countries that have signed the Paris climate agreement include land use as part of their strategies. The regeneration narrative is not yet working at all levels.

Deforestation is a natural target for government action. So too is reforestation—natural geo-engineering or natural carbon capture and storage—which could remove three gigatons of CO2 globally each year, equivalent to roughly 600 million cars. The "plant trees, reduce CO2 emissions" strand of the narrative is illustrated by China's long-term "Grain for Green" program that began in 1999. About 22% of the country is now forested, up from 19% in 2000, driven by US $100 billion in spending. India has adopted similarly ambitious targets.

From another perspective, there has been a surge in land and marine conservation. UN targets aspire to protecting 7% of the earth's oceans and 15% of the land area by 2020.[20] The Protected Planet Report echoes the main narratives about the race to create a sustainable world. As the authors put it ". . . the ecosystem services of the world's protected areas underpin global needs to address climate change; protect water sources and food production systems; alleviate disaster risk; and maintain health, well-being and the livelihoods of millions of people."[21]

Even in the face of widespread devastation of the natural environment—or perhaps because of it—the scale and ambition of local and international action to improve the quality of the biosphere and people's lives feel promising. ■

[19] The new division AXA XL adopts AXA Group's sustainability and climate strategy, AXA, Nov 2018, https://www.axa.com/en/newsroom/news/axa-xl-adopts-axa-group-s-sustainability-and-climate-strategy
[20] World on track to meet conservation targets, United Nations Environment Programme, Nov 2018, https://www.unenvironment.org/news-and-stories/press-release/15-terrestrial-and-7-marine-areas-now-protected-world-track-meet
[21] Protected Planet Report 2018, United Nations et al, 2018, https://livereport.protectedplanet.net/pdf/Protected_Planet_Report_2018.pdf

Critical Uncertainties

For all the activity, the evidence that human intervention can reverse declining biospheric health and introduce a "systems of systems" or "ecosystem" perspective remains fragmentary. It may be that action on some fronts arrives too late and we face systemic failure, at some scales, with profound implications for stability and security.

Public and political will remain the critical uncertainties, driving all others and revolving, above all, around global carbon emissions. Higher emissions warm the atmosphere and oceans, leading to rising sea levels and cascading impacts on biosphere stability.

Rising ocean temperatures may lead to runaway conditions, with extreme and potentially abrupt changes in currents that, in turn, could create food crises. Recurring flooding and river pollution from agricultural fertilizers may make some communities unsustainable. At the other extreme, action taken today could slow warming starting about two decades from now. Expansion of conservation areas may slow the loss of biodiversity. Targeted local action may create resilience, irrespective of regional and global disruption.

The same applies to atmospheric pollution: much depends on the rate at which the revolution in clean transport and energy generation takes place. The signs are positive: the cost of producing electricity from onshore wind fell by 25% between 2010 and 2017. In the same period, large-scale solar costs dropped 73%.[22] More than 4 million electric cars now travel the world's roads. Yet, during roughly the same period, emissions from buildings grew, driven by urban development.

Uncertainty remains, but regenerative initiatives will gather pace over time, new technology will become more integrated and investment returns will follow.

There is a possible virtuous circle on the horizon. For communities and investors alike, the regeneration model could prove a one-way bet. New technology and system innovation hold the promise of accelerating long-term returns. More specifically, fresh ideas—like the "blue economy," which focuses on sustainable use of ocean and coastal resources to create growth, improve livelihoods and jobs and maintain ecosystem health—are gaining traction. This wide-ranging concept captures inter-system relationships among fisheries, tourism, maritime transport, offshore renewable energy, aquaculture, seabed extraction and waste disposal.

This suggests how ecosystem design, re-engineering and "system of system" thinking holds the key to long-term sustainable development. The world's oceans and river systems have long been neglected: despite the fact that 71% of our "blue planet" is ocean, less than 1% is protected. Yet coastal populations continue to grow, and oceans face new pressures, like deep-sea mining.

Looking at infrastructure through this new lens would lead us to judge investment against regeneration benchmarks and criteria. Some infrastructure might not get built. Regeneration will increasingly shape the future, not development for development's sake.

Socio-cultural outcomes remain in doubt. Poorer communities are hardest hit by climate change, biospheric instability and extreme events, all of which amplify social inequalities. The *US Fourth National Climate Assessment*, published late in 2018,[23] illustrated that while the impacts of climate and biosphere conditions vary widely, vulnerable people are hit hardest. The common theme around the world is that low-income communities, children and older people are more exposed to extreme events and health risks.

Yet, despite a bleak picture and general uncertainty, there are signs that "green activism," "rewilding," and community-oriented thinking may coalesce as pressures on the environment and for sustainability grow. This remains the crucial question. Can public values and attitudes, particularly at the local level, create enough political pressure for radical transformation of policy?

Changes in the ocean and biospheric measures associated with *The Great Acceleration,* together with national and international action, new thinking about the natural environment and the emergence of holistic models, will shape the future of communities.

We now move on to explore the future of water, energy and agriculture and opportunities for transformation. ■

[22] Renewable Power Generation Costs, International Renewable Energy Association, 2018, https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2018/Jan/IRENA_2017_Power_Costs_2018.pdf
[23] Fourth National Climate Assessment, US Global Change Research Centre, 2018, https://nca2018.globalchange.gov/

Water, Energy and Agriculture: opportunity through transformation

Nº3

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Regeneration and Integration

For decades, the world's water, energy and agricultural systems rested on stable natural foundations. Yet a diverse, adaptive and resilient natural world is not, as everyone now knows, a given. Climate change and risks to the biosphere demand urgent action, at both global and local levels if runaway, potentially catastrophic disruption is to be avoided. →

As we move deeper into the Anthropocene era, layer upon layer of these deeply interlinked and overstressed systems and networks are at risk of collapse. In many parts of the world, infrastructure governance, investment and development remain fragmented. The conventional thinking holds that water, energy and agricultural systems operate largely independently.

Yet looking at infrastructure from a community-centered perspective reveals a different picture: these systems are closely linked. Water systems consume energy and vice versa. Food production is a major consumer of water and power and is a major source of carbon emissions.

An emerging alternative to the conventional narrative suggests that synergies among these core systems could transform everything from emissions to atmospheric and water pollution.

This alternative narrative envisions local solutions that combine state-of-the-art, inventive technologies and natural ecosystems thinking. This is a vision of radical, exponential invention. At a time when public and policymakers alike struggle to identify a path toward decarbonization and a sense of hope, this vision may gain momentum. It offers economic efficiency, environmental benefits and something more: the promise of community-level political empowerment and improved quality of life. This idea doesn't simply hold out hope of resilience under even the most extreme long-term scenarios. It promises something more radical: regeneration of both the natural world and local communities.

In practical terms, this narrative aligns with multiple developments in economic development. For example, the water industry widely practices catchment-area thinking; the power industry views distributed energy systems, combining renewables and battery storage, as comparable to conventional grid networks; and "vertical" farming or urban agriculture has become an investment hotspot.

Over the next few pages, we explore variations on this narrative and how they may evolve in different parts of the world. They may contribute to vision-led, ecosystem innovation that brings together new ideas of "soft infrastructure" that focus on well-being, natural solutions, technology, and community-centered policymaking and investment. At the other extreme, inertia may combine with policy complacency, a shortage of long-term funding and a lack of public support to slow the creation of solutions that deliver adaptation, diverse solutions and long-term stability. ■

Isabella Stewart Gardner Museum Expansion
Boston, Massachusetts

Transformation: at speed

Time is short. Radical ecosystem design and regeneration are no longer options, but imperatives.

The challenge to adopting this approach lies in a resistance to collaboration across established boundaries in the interest of the common good. Overcoming this resistance will require strong leadership at the community level and, above all, public support for investment in long-term solutions that may not fully pay off before the next century.

Against a backdrop of aging populations, increasing demand, pollution and potentially runaway climate instability, regeneration, strategic resilience and efficiency look even more critical.

Take water first. Rising temperatures increase stress on already vulnerable systems. The Mediterranean is one of 25 regions globally already facing major challenges, with 180 million people suffering water poverty.[1] Water supplies in industrial regions with growing populations face major challenges, even if warming is held to less than 2°C (3.6°F) above pre-industrial levels. The World Resources Institute projects that Mexico, Chile, Spain, Italy, the Middle East, South Africa, India, Australia and much of Indonesia will suffer from high or extremely high water stress by 2030.[2]

Energy systems face the challenge of cutting carbon emissions while meeting fast-rising demand. The 2018 report from the Intergovernmental Panel on Climate Change (IPCC) and the UN's 2018 Climate Change Conference set a simple global target: net zero emissions by 2050. Reaching this goal will require transforming primary energy production, the fossil fuel industry, transport and the built environment (which, between construction and operations, accounts for 40% of total emissions).

Agriculture, food production and land use consume about 70% of global water supplies and generate about 25% of global carbon emissions. Waste in food systems means wasted water, land, energy and labor. Growing populations will increase demand for food and water. A combination of water shortages, rising energy costs, potential crop failures and extreme temperatures may make some communities uninhabitable.

If ecosystem thinking, focused on the intersection of water, energy and food production, represents the starting point, then integration is the overarching design principle. Technology has a vital role to play. Pervasive sensors, mass data, simulations and predictive analysis will transform both community design and real-time operations. Live maps, once abstract ideas, will become the interface through which the real world operates.

Yet technologically driven efficiency alone won't be enough, or even the right solution for every problem. Ecosystem designs that harness natural systems—working with nature—will prove equally important. Efficiency in existing systems and in the relationships among them promises low-risk, low-technology and low-cost solutions. Efficiency means less waste.

The rate of infrastructure replacement over the next two decades will shape the future of communities. It will call for radical innovation in thinking in terms of natural systems, as well as in design, technology, finance and governance. There are clear signs that systemic innovation has momentum, particularly at the community and city level.

Multiple new approaches hold great promise, but how they ultimately play out—widespread acceptance and adoption or utter failure to launch—will shape the future to 2050 and beyond. These possibly transformative solutions range from implementing decentralized, distributed power grids; to localized agriculture; to sensor-driven adaptive design; to energy-efficient integration of solar power, battery storage and water desalination; to zero emissions and zero pollution and beyond; to precision management and security systems.

At another level, fundamental uncertainties surround how institutional investors will provide long-term capital to fund cities and major infrastructure design; how insurers will underwrite risk; and how city and national governments will reconcile short-term political pressures with the need to redesign and rebuild infrastructure systems for the 22nd century.

An overarching question hovers over all these uncertainties. Will public values and attitudes about everything from the health risks of pollution to primary security translate into support for, or opposition to large-scale, urgent and potentially expensive action? ■

[1] Water, Environment and Blue Economy, Union for the Mediterranean, 2018, https://ufmsecretariat.org/what-we-do/water-environment/
[2] Aqueduct Projected Water Stress Country Rankings, World Resources Institute, 2019, https://www.wri.org/applications/aqueduct/country-rankings/

Water, Nanofiltration, Reuse and Desalination

Water shortages threaten global security, as shown by instability in the Middle East over the last decade. By 2050, water crises may trigger mass migration in wide parts of the Americas, Africa, South Asia and the Middle East. A 2019 UN report concluded that shortages could threaten up to five billion people.[3] At the extreme, water shortages may provoke mass starvation, health crises, social unrest and regional wars. →

Chino Basin Desalination Project
Santa Ana, California

[3] World Water Development Report 2019, United Nations, Mar 2019, https://www.unwater.org/publications/world-water-development-report-2019/

Industry and agriculture together account for 90% of water consumption. The challenge is to reduce demand and manage scarce resources, all in the context of growing populations and climate change. Even in areas where rainfall is normal, groundwater is often not replenished. Rivers, lakes and aquifers are drying up, or polluted.

The complex relationships among pollution, wellbeing and health are primary fault lines that may have a more direct impact on public attitudes than the challenges of climate change. For example, in New Zealand, water pollution is the public's greatest concern. 82% of respondents to a recent survey wanted stronger protection for beaches, rivers and lakes, ranking the natural environment above housing shortages, living costs and child poverty.[4]

The overarching, emerging narrative is that "purity" and "regeneration of the natural world" in water, energy and food production will guide solutions. Whether the public and investors will underwrite the costs involved remains uncertain, given competing worldviews, one that looks to technology and one that focuses on natural solutions. Among an array of possible technological solutions, the Internet of Things (IoT), real-time sensor networks and nanoscale filtration stand out. Proponents of solutions based on natural systems highlight organic farming and "agro-ecology." Not mutually exclusive, these two approaches nevertheless introduce a political dimension that clouds the picture. ■

Nanofiltration

Similar schools of thought dominate thinking about pollution. Technology-forward solutions focus on after-the-fact detection, alert systems and remedies based on filtration. Natural-systems solutions look to root causes and attempt to address the sources of pollution and contamination for both water and air.

There is evidence of exponential growth in innovative filtration systems, many based on nanofiltration. Graphene promises both to improve water purity and reduce purification's energy demands. Another new methodology relies on "nanocagulent materials"[5] to remove water contaminants. ■

Reuse and Desalination

The same technologies apply to both reuse and desalination. About 300 million people globally depend on desalination for freshwater. Israel operates four major plants that supply about 40% of its water demand. Australia, Singapore and the wider Middle East also rely to varying degrees on desalination systems.

Until recently, conventional systems used reverse osmosis, an energy-intensive process that tied desalination at all scales to solar, nuclear and sometimes wave power. That connection suggests the potential for integrating water, energy and agriculture. Innovation has driven down costs, but the goal remains low-energy, small-scale solutions. Desalination remains a potential game-changer—an innovation hotspot that could produce a new water-supply model over the next two decades. As rising seas affect more regions, saline pollution of freshwater supplies will increase pressure to introduce unconventional and even high-cost systems, making the case for desalination stronger still.

Similarly, reuse is a huge opportunity; technology-enabled recovery and recycling of used water, at scale, will also be a game-changer in overcoming water scarcity. ■

Local Solutions, Natural Systems

Technological solutions have a surface appeal, despite the fact that widespread adoption may lie decades away. Yet history suggests that technology by itself rarely provides a silver bullet, and designing systems based on natural processes typically reduces energy requirements and operational costs. This explains UNESCO's emphasis on nature-based solutions. According to the agency's recent report, small scale-water harvesting, reuse, recycling, improved soil and vegetation management, catchment conservation and the rehabilitation of natural ecosystems all should play a role in securing water supplies.[6] Reforestation, reconnecting rivers to flood plains, restoring wetlands and introducing permeable pavements to mitigate extreme rainfall all form part of the solution.

More radical alternatives are gathering pace. Small-scale solar-purification systems include a growing number of "water from air" technologies. Estimates suggest that 13 trillion liters of water, about 10% of all the earth's lakes and rivers, float in the atmosphere.[7] ■

[4] 'Their birthright is being lost': New Zealanders fret over polluted rivers, The Guardian, Mar 2019, https://www.theguardian.com/environment/2019/mar/04/their-birthright-is-being-lost-new-zealanders-fret-over-polluted-rivers
[5] Actinia-like multifunctional nanocoagulant for single-step removal of water contaminants, Nature, Nov 2018, https://www.nature.com/articles/s41565-018-0307-8
[6] World Water Development Report 2019, United Nations, Mar 2019, https://www.unwater.org/publications/world-water-development-report-2019/
[7] This new solar-powered device can pull water straight from the desert air, Science Magazine, Apr 2017, https://www.sciencemag.org/news/2017/04/new-solar-powered-device-can-pull-water-straight-desert-air

Rising Energy Demand vs. Sustainability

Climate change, population growth, rising demand, zero-emissions targets and sustainability frame the energy agenda for this century. To use the language of the UN's Sustainable Development Goals, the world will need to make a transition to "affordable clean energy" by 2050. →

The widely accepted understanding of this goal has two components. First, as we discuss in Chapter 2, catastrophic climate and biosphere change can be avoided by limiting global temperature rise to between 1.5°C (2.7°F) and 2°C (3.6°F) above pre-industrial levels. Second, power generation will contribute to the effort by reducing carbon emissions and investing in radical technological innovation and conservation.

Both may turn out to be overly optimistic. All IPCC Assessment Reports have understated the rate of change and so in turn the scale of the so-called "transition" challenge. In any case, the outcomes will remain uncertain for decades even as emissions and temperatures rise.

The scale and urgency of the challenge is widely recognized. Responses range from energy efficiency—the simplest and most effective, particularly in the short-term—to more extreme "emergency" measures, such as geoengineering. The built environment accounts for about 40% of global emissions and a primary target for efficiency measures. Concrete manufacturing in particular remains a key sector in need of overhaul.

Reforestation, and transitions to renewable energy and electric vehicles will play a part. There is no single solution, given that the promise of fusion power is a distant prospect in the face of the need to achieve zero emissions by 2050. Other radical solutions, including mass-scale, next generation nuclear, have some supporters.

Relying on unproven technologies looks even less necessary in light of reports by academics led by Mark Jacobson at Stanford University, who argue that more than 90% of technical solutions already exist.[8] That would put global targets within reach by 2050 using a combination of solar, wind, hydroelectric, geothermal, tidal and wave energy. Electrification of everything from households and businesses, to boats, trains, aircraft and heavy vehicles, is feasible. In these scenarios, sharing power across distributed networks solves the problem of intermittent renewables. Each country and community would mix energy sources to meet specific needs. Cost represents a bigger challenge than technology. Some estimates suggest a full shift of energy sources would cost US $124.7 trillion over the next few decades.

A recent McKinsey report projects that by 2035 half of global power will come from renewables, whose cost will drop below that of coal and gas by 2030 (as the cost of wind energy has already). Electric vehicles and demand for oil and gas will plateau, despite rising economic activity and growing populations.[9] Similar estimates appear in a report by BP, which, like the other major fossil fuel producers, faces increasing pressure from shareholders to present details of how it will make the transition to a radically different industrial landscape.[10]

There are other signs of momentum and fundamental structural change. In 2019, Shell acquired Sonnen, which delivers residential solar and battery systems. In other words, some major fossil fuel firms have begun entering retail energy markets in anticipation of growing demand for decentralized power and falling prices for fossil fuels.

In Vietnam, government incentives and feed-in tariffs to grid networks have been so successful, attracting investors by long-term contracts, that existing grid infrastructure has fallen behind. Solar power can be delivered quickly, in contrast to grid redesign.

Conventional projections, however thorough, typically do not take account of the secret world of invention. Forecasts tend to emerge from economic models that shape their assumptions on current technologies, which likely understate rates of technological change. More extreme, radical breakthroughs may emerge. High-level international patent filings point to a surge in activity that has not yet trickled down to commercial applications. Green energy technologies accounted for about 18,000 patent applications in 2014, up from about 9,000 in 2005,[11] before falling slightly to 16,000 in 2017. The patents ranged across diverse fields: energy conservation, solar, biofuels, green transport, fuel cells, waste recycling, wind, nuclear and myriad novel approaches.

Waves of system-scale redesign and innovation already have the potential to deliver transformative results. To illustrate, new technologies, such as perovskite solar cells, developed over a relatively short period, convert more than 22% of the light they receive into electricity. That matches or exceeds the conversion rates of silicon photovoltaics, and a far-simpler fabrication process means perovskite cells could transform efficiency prospects.

At city scale, large-scale solar heliostats, combined with molten salt storage, have already begun operating at scale, as at the Crescent Dunes Solar Energy project in Nevada. This design first appeared in patent literature more than a decade ago.[12]

As in other fields discussed, the challenge lies in design and technological integration—and uncertainties remain. The system condition that underpins the transition is not simply technology, important as it is, but the evolution of localized solutions and distributed networks. ■

[8] 100% Clean and Renewable Wind, Water, and Sunlight All-Sector Energy Roadmaps for 139 Countries of the World, Jacobson et al, Sept 2017, https://web.stanford.edu/group/efmh/jacobson/Articles/I/CountriesWWS.pdf
[9] Global Energy Perspective 2019, McKinsey, Jan 2019, https://www.mckinsey.com/~/media/McKinsey/Industries/Oil%20and%20Gas/Our%20Insights/Global%20Energy%20Perspective%202019/McKinsey-Energy-Insights-Global-Energy-Perspective-2019_Reference-Case-Summary.ashx
[10] BP Energy Outlook 2019, BP, Feb 2019, https://www.bp.com/en/global/corporate/energy-economics/energy-outlook.html
[11] Global Innovation Index 2018, World Intellectual Property Organization, 2018, https://www.wipo.int/publications/en/details.jsp?id=4330
[12] Crescent Dunes, SolarReserve, 2019, https://www.solarreserve.com/en/global-projects/csp/crescent-dunes/

Agricultural Production, Distribution and Urban Farming

World population may grow to ten billion by 2050. Food production demand continues to rise. The race is on to find local and large-scale solutions to tough problems. Climate- and biosphere-related risks add to the pressure.

The scale of agriculture's impacts on local and global ecosystems—and particularly its contribution to carbon emissions—is significant. According to the UN Food and Agriculture Organization, food and agricultural production account for 25% of global carbon emissions. Two-thirds of that comes from livestock.[13]

The world's agriculture systems are failing, in both social and environmental terms. The two competing strategies for repairing them fall along a now-familiar divide. The New Vision for Agriculture initiative promoted by the World Economic Forum, with its technological focus, represents the first model. In this view, technology, innovation ecosystems, biotech, precision agriculture and synthetic food all operate within a digital infrastructure of sensors and robots.[14]

Precision agriculture and urban or "vertical" farming start-ups have begun attracting significant investment. Early-stage urban farm companies focus on producing fresh fruit and vegetables. They promise low water consumption, independence from questions of quality land, lower transport costs and high-quality products. High capital costs for construction and energy raise questions about their long-term viability, and smaller-scale specialists may come to dominate the field.

The second model focuses on "agro-ecology," organizing farming around principles of ecology, natural cycles and biodiversity. An emphasis on local scale and the circular economy leads this approach to integrate food, water, energy and waste management. The approach consciously seeks to wean itself from dependence on global agribusinesses that may act together as an oligopoly in everything from seed production to food distribution.

These approaches are not mutually exclusive. More important, they depend not on global, regional or national cultures and ideologies, but on local design and implementation, designed to meet local conditions. Both share certain thematic similarities: ecosystem thinking, localization and distributed-network design principles with the potential to transform agricultural production and distribution.

Among the many innovations, aquaculture is expanding rapidly, already delivering 50% of global fish production. Again, local implementation is key. China, India, Japan have fish- and seafood-farming traditions going back centuries. Norway, Vietnam and Scotland have recognized potential financial, environmental and social returns, despite concerns about the discharge of "dirty water."

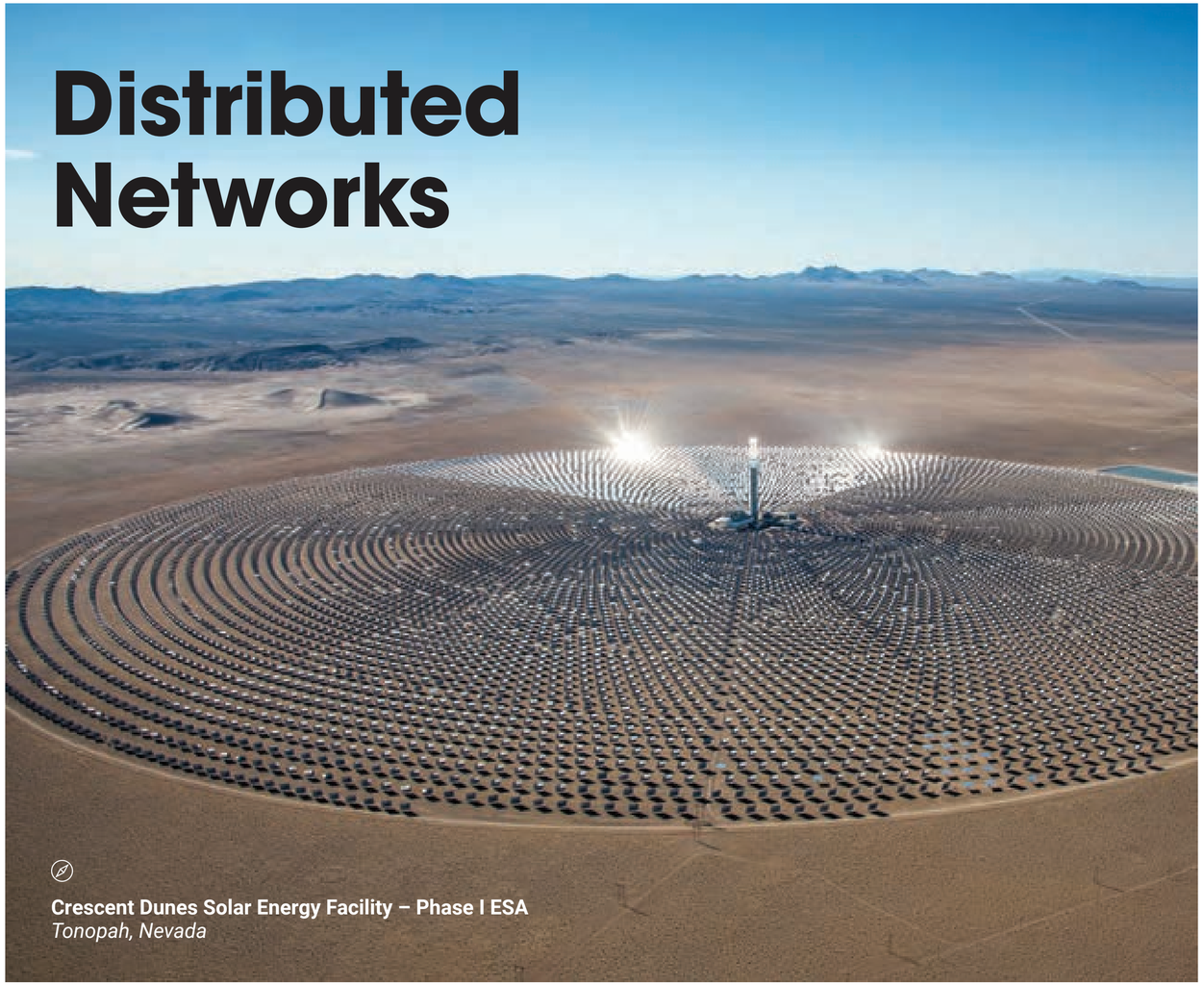
As livestock account for the bulk of agricultural emissions, meat substitutes are an invention hotspot. Investor activism in favor of sustainable farming is growing. According to the Farm Animal Investment Risk and Return investor network, 70% of the largest listed meat, dairy and aquaculture producers fail to manage climate risk.[15] Without concerted action, researchers at the Oxford Martin School estimate that population growth and dietary changes could increase environmental costs by 50% to 90% by 2050. On the other hand, halving food losses around the world alone would reduce environmental impacts by 16%.[16]

A large-scale switch from meat to cereal production may turn out to be more significant. Boosting crop growth through more efficient photosynthesis has recently been hailed as a breakthrough, as illustrated in publicity surrounding "fixing" photosynthetic inefficiencies.[17]

Amid the uncertainties and growing evidence of "systems of systems" innovation, two themes stand out: the development of localized and distributed networks and both investor and public activism, which we move on to now. ■

[13] The State of Food and Agriculture, Food and Agriculture Organization of the United Nations, 2016, http://www.fao.org/3/a-i6030e.pdf
[14] New Vision for Agriculture: Transformation Leaders Network, World Economic Forum, 2018, https://www.weforum.org/projects/new-vision-for-agriculture-transformation-leaders-network
[15] Coller FAIRR Protein Producer Index, FAIRR, Sept 2019, https://www.fairr.org/index/
[16] Our food system is at risk of crossing 'environmental limits', Oxford Martin School, Oct 2018, https://www.oxfordmartin.ox.ac.uk/blog/our-food-system-is-at-risk-of-crossing-environmental-limits-heres-how-to-ease-the-pressure/
[17] Synthetic glycolate metabolism pathways stimulate crop growth and productivity in the field, Science, January 2019, https://science.sciencemag.org/content/363/6422/eaat9077

Distributed Networks



Crescent Dunes Solar Energy Facility – Phase I ESA
Tonopah, Nevada

Water, energy and agriculture systems are heading in the direction of localized, community-centric networks—shorthanded as *distributed networks*.

Distributed networks offer a range of benefits across water, energy, and agriculture. Water capture and recycling reduces pressure to expand water-delivery networks. Integrated water management is framed at river basin or catchment scale. Solar panels provide self-sufficiency to millions of homes and sell spare capacity to re-engineered grid systems that helps smooth out issues of intermittency of renewable sources. New battery storage technology will play a vital role across the energy cycle, from generation, to distribution and local systems. Low-tech but proven pumped storage may expand its role. City-scale power, some based on solar concentrators with molten-salt storage, cuts dependence on national networks. Locally-grown food, brought into the mainstream by the "farm to table" movement, reduces resources used for cultivation and shipping.

Economics don't provide the only rationale for change. The vision of independent systems pays benefits in the form of stronger community identity and security as well as cultural values. The small Indian state of Sikkim has been 100% organic since 2016,[18] illustrating that sustainable policy and practice can achieve local success around the world, independent of national policies.

These three interconnected systems, however, don't operate entirely independently. Water footprints, linked to housing, industry and agricultural production, are inherently local. Broader definitions of the water cycle, which take account of the water content of trade in agricultural and other products, show that water consumption remains inseparable from large-scale food-distribution networks.

From another perspective, water-distribution utilities suffer from heavy leakage. Some regions of the UK and Ireland lose about 25% of total supplies.[19] Introducing new technologies, particularly sensors to alert operators and nanoscale sealing techniques, have the potential to cut waste and radically improve efficiency.

Similar principles apply to water pollution. Controlling use of agricultural fertilizer at its source offers a localized and effective way to protect water supplies. Even so, contamination has found its way to the world's oceans on a massive scale, and cleaning it up will require a shared global effort. Similarly, microscopic plastic particles, or micro-plastics, appear in most water supplies, food, and the atmosphere.

Synthetic fibers in clothes contaminate water systems, as do dust from paint and microbes from cosmetics. Synthetic pollutants cross boundaries of geography and even time. Despite having been >

[18] Indian state wins prize for showing 100% organic 'no longer a pipe dream', Thomson Reuters Foundation, Oct 2018, http://news.trust.org/item/20181012070040-jayoo/
[19] Reality Check: Have water companies cut leaks by a third?, BBC News, Aug 2018, https://www.bbc.com/news/business-45033486

banned for decades, polychlorinated biphenyls (PCBs) have lingered in the environment as "legacy contaminants." Humans can absorb these long-lasting toxins through food and other sources; they can alter DNA and impair fertility, cognition and immune systems. Other toxins, like perfluorooctane sulfonate will also remain in the environment indefinitely. They are transmitted between species and pervade food and water supplies. Pollution leaves a long legacy.

Localized systems can deliver major benefits, but the boundaries between them remain porous. Everything is connected. Purification and regeneration of the natural environment can come down to local action—although set in a global perspective. As we explore in Chapter Seven, the phrase *think global, act local* has become more relevant than ever. We will need to strike the same balance as geoengineering systems emerge: what risks might local weather management (already the focus of large-scale experimentation) or dispersion of reflective particles designed to cool the atmosphere pose for global systems?

Highly distributed networks, down to individual homes, have already begun transforming the structure of primary energy generation and distribution. Given rapid advances in technology and falling costs, the timing and scale of this change remain uncertain.

SMUD East Campus-Operations Center (EC-OC) Design Build Project
Sacramento, California

Localized energy, purification, catchment and "ecosystem" thinking may lead to rapid decentralization and network redesigns to improve resilience and security while reducing costs.
On the other hand, a lack of local vision, concerns about stranded assets and transitional funding may leave conventional systems in place in many parts of the world, raising maintenance costs and slowing the development of sustainable environmental systems.

The political environment does appear to be shifting, however, as illustrated by the rise in public activism such as the emergence of the politically potent idea of a "Green New Deal" in the US, which focuses on infrastructure renewal.

This is not simply a question of leadership; ultimately, public engagement will determine the outcomes.
There are signs of shifting attitudes; mass-scale action has begun to crystallize with the Extinction Rebellion protests and school strikes around the world. Imposition of "green taxes" and proposals for investing in long-term outcomes may prompt opposition based on public anger over near-term costs, austerity and inequality, as seen in the Gilets Jaunes movement in France.

This brings us to the future of digital technology, which will pervade the design, integration and operation of water, energy and agricultural systems and provide investors and public officials with the knowledge and vital intelligence to make long-term sustainability a reality. ■

The Rise of Digital Cities: pervasive systems and automation

Nº4

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Digital Infrastructure: all-pervasive

Growing evidence suggests that the world's natural systems may have passed the point of no return. At the same time, national and city leaders, communities, businesses and asset managers are investing in sustainable development. We may face both rapid environmental change and exponential technological and policy innovation.

In the race to cut carbon emissions, stabilize the climate and regenerate the biosphere, the rate of infrastructure invention and renewal will shape the future. Speed is critical to mitigating, adapting to and slowing what may become runaway conditions, and digital infrastructure will play a pivotal role. It has the potential to deliver relatively quick results, accelerate innovation and help regenerate the biosphere. Ecosystem design will shape digital cities, operating through sensors, drones, mass data, artificial intelligence and networks of predictive algorithms. ■

Unlimited Mobile Bandwidth, Pervasive Sensors

We can see digital networks as layers of adaptive infrastructure. They range from communication, internet protocols and standards, to sensors, media services, artificial intelligence and on to simulation and prediction.

Applications produced by these decentralized, distributed and non-linear networks will transform ecosystem design. Deep, real-time intelligence about the real world will anticipate failures and deliver operational resilience. Put more simply, cities of the future will be highly automated. Technology, socio-cultural norms, governance and politics will all influence the form automation takes.

Ultimately, this is a question of design and community choice. Digital systems will transform buildings, urban infrastructure, water, energy, agriculture and transport, blurring the boundaries among all of them.

Some of these technologies—like 5G, the next generation of mobile technology and the underpinning of the IoT—have already gone live in parts of Asia and North America. Infrastructure connected with 5G's virtually unlimited mobile bandwidth holds the promise of real-time, 3D visual and multi-sensory communications, providing instant access to everything from live video and virtual games to remote augmented-reality security services.

IoT will run off sensors embedded in buildings, security systems, vehicles and water, energy and transport infrastructure. Sensors will become pervasive, attached to things, places and people and delivering everything from live monitoring of atmospheric pollution to early warnings of medical emergencies. Sensors will read chemical changes, identify individuals by facial recognition, pick up heart rates, help manage noise levels and optimize traffic flow. They will transform the accuracy of both private monitoring and public surveillance.

Sensors and machines have begun to deliver insight into our most private, unconscious emotions and moods, raising fundamental questions about privacy and security. To illustrate, Affectiva, which emerged from the Massachusetts Institute of Technology, detects emotion in real time using facial recognition.[1]

Sensors will generate unparalleled granularity in many dimensions. Here, "dimensions" refers to real-time data ranging from emotional states of people in public places to machine security, to chemical conditions in streets and water systems, to energy production and other industrial processes. These radically new levels of data will transform the way we see the natural, constructed and human worlds. They will also create a critical basis for accurate simulations, design and operational resilience.

Data represents the lifeblood of artificial intelligence (AI), which drives predictive analysis. Yet, even the most advanced AI system will require human talent and expertise for effective operation. Taken together, these applications will create new forms of transparency and situational awareness. Design and operations will revolve around the principle of having city infrastructure predict and adapt to changes in real time. Holistic ecosystem design and operations will co-evolve, rather than develop separately. ■

[1] Emotion AI Overview. What is it and how does it work?, Affectiva, 2019, https://www.affectiva.com/emotion-ai-overview/

Getting Airborne: new points of view

Traditional ways of viewing cities and buildings from ground level will change as aerial drones create new ways of monitoring both interior and exterior spaces. Some argue that drones may be as disruptive as the internet—indeed, architecture has already felt their revolutionary impact. Norman Foster has observed that drones "heighten" our senses by delivering high-definition images of the "fifth elevation."

Sensors will take to the air in autonomous drones. Over time, they and the systems they support will evolve from routine live monitoring—for example, of irrigation systems and food production, already common—to environmental mapping and all aspects of urban infrastructure and cultural life.

Drones operate in situations that might prove risky for humans. Already, drones deliver medical supplies to remote regions in Africa. Possible wider applications include urban delivery, transport, surveillance, air pollution monitoring and weather forecasting. Insurance companies have patented a system that allows them to assess applications and evaluate claims remotely, directing video and sensor-equipped drones to accidents and fires.

This is not new. The military has also found multiple applications for drones, although some observers warn about the possibility of swarms of autonomous, miniaturized armed devices, much like insects.

In civilian applications, these concerns will lead to regulation and control, but on balance, the benefits may outweigh the risks. Drones can search for survivors after disasters, survey infrastructure for early signs of failure and improve building security. They can save lives in search and rescue situations, accelerate clean-up of oil spills and both monitor and fight forest fires.

Combined with video, embedded sensors, big data computing and artificial intelligence, drones can oversee water systems, pick up or predict potential chemical pollution incidents and disease outbreaks on large farms. They are a key component of preventive risk management and precision agriculture.

These benefits are not limited to low-level, miniaturized drones. Systems of new, geostationary high-altitude balloons, for example, will provide increasingly accurate live data to track hurricanes and extreme rainfall.

There are competing narratives about both privacy and aerial safety, particularly in urban areas. Police forces already use drones to track and monitor criminal activity. How surveillance is handled will depend in large part on national and local cultural norms.

The management of airspace may be more straightforward, except for the regulations needed to control misuse. Virtual barriers will protect sensitive installations. The risk is that tiny armed drones will become the weapon of choice for terrorist groups. As AI, robotics and autonomous weapons spread, society will face the challenge of preventing an arms race in lethal, large-scale systems capable of overwhelming cities and regions.

Cybersecurity will remain critical, but will also pose challenges for major cities, designers, and operators of critical systems. The outcome may accelerate the development of networked infrastructure that offers better guarantees of resilience, particularly in water and energy, or at the other extreme, constrain development. ■

Little Harbor
Tampa, Florida

Toward Ecosystem Design

Pervasive, sensor-based systems already operate in Chinese cities, where they create a mixture of awe and fear of "total" surveillance. Western observers see these cities as real-world experiments, and these early operational systems hold lessons for the future of community-level, ecosystem design.

The accelerating integration of pervasive data, machine learning and AI-driven systems of all kinds has already begun influencing community life. AI, primarily through simulation and predictive systems, has the potential to transform community development, from urban design to strategies for transport, real-time security and infrastructure. It will shape architecture and the built environment, as well as infrastructure, from water, energy and agriculture to transport. It will also play a vital role in promoting wellbeing and health, encouraging social interaction and creating a sense of shared space and community. In other words, AI will have a transformative role in shaping lifestyles.

Algorithm platforms that combine diverse sources of data will produce, over time, full, multi-dimensional maps of the real world. They will deliver important benefits in design and the architecture. Drones in particular will likely gain a new status as real-time, dynamic infrastructure. Free of the limitations of rail and road networks, they open up the idea that infrastructure is not linear and fixed, but flexible and adaptive.

The distinction between design and operations will blur, as adaptive, decentralized and distributed networks anticipate failures and manage flows of people, vehicles, water and energy. Community-wide networks will enable a revolution in transport: they'll optimize traffic based on dynamic, real-time recommendations generated by predictive algorithms. ■

Cyberwar, Security, Stability

Sensor networks and data manipulation will transform urban planning and design, yet uncertainties about security, expertise and privacy may hold back deployment and undercut investment.

Public concerns about surveillance may determine the shape of the autonomous city on the horizon. Cyberwar and network security and stability represent real dangers—and the IoT may make the dangers more acute. In a hostile, volatile and fragmented global political environment, security concerns about hybrid cyberwar and offensive cyber weapons—entirely reasonable—will slow progress.

Police and public security networks already use surveillance technologies foreshadowed in the film *Minority Report*.[2] Predictive systems already integrate geospatial information and behavioral research. New systems will have the potential to track everyone in public space. Facial recognition and lie-detection systems will become increasingly accurate, raising ethical challenges about personal freedom and security. In the US, these systems require opting in. In China, which offers no opt-out, 170 million cameras, equipped with facial recognition and AI, track 1.4 billion citizens. Similarly connected systems will offer nowhere to hide, forcing communities to face hard social and cultural choices.

Because they operate on collaboration and trust based on open security standards, public communication and data will be especially vulnerable. The Stuxnet virus attack on Iranian nuclear installations and the Zeus initiative, designed (but never used) to bring down electricity and urban support systems, illustrate the risks. Concerns over Huawei's role in the rollout of 5G networks echo the same theme. In the short-term, attacks on infrastructure will remain a fact of life.

[2] Minority Report [Film], Steven Spielberg, 2002, https://www.imdb.com/title/tt0181689/

Jalonnement dynamique Montréal 2018/ Parking guidance système Montreal 2018
Montréal, Québec

The backlash against Facebook, Google and Twitter illustrate both social and political vulnerability. The threats to democracy and security posed by intervention in elections may take decades to resolve. Boundaries separating technologies, corporate interests and political stability will become increasingly important.

So-called "hybrid wars" that combine propaganda, cyber-attacks and espionage have extended the scale, impact and speed of disruption of voting and public discourse in open democracies. Machine-driven, personalized voter targeting remains difficult to identify and control, even by experts and state-of-the-art AI.

In the absence of regulation, social media will rely on modifying behavior and manipulation, building on a deepening understanding and detection of emotion. The next wave of technology will focus on "emotion AI"—that is, bridging the gap between human emotion and machines. We can expect mass automation and mass personalization, as machine-created content intended as propaganda becomes pervasive, yet indistinguishable from human output, in the media. ■

Competing Narratives

The scale of the surveillance threat and public opposition to failure to guarantee privacy are leading to radical re-thinking of core web infrastructure. Tim Berners-Lee's Inrupt initiative is designed to "re-decentralize" the web to give everyone control over their own data and applications.[3] This has the potential to restore trust but may also undermine commercial social media and advertising models that have dominated web use for more than a decade. This and similar efforts may lead to the emergence of a "web of trust" on which digital infrastructure is public infrastructure and private data is secure.

Personal data ownership is only part of the picture. The deeper challenge, critical to a world of sensors, drones and artificial intelligence, is governance and ownership of public data. Derivatives of blockchain technology may play a vital role.

Some initiatives revolve around ownership of core networks and information. Take a simple example: the tensions between private and publicly owned data platforms. The Open Data Initiative advances the idea of making all information and data produced by publicly funded institutions freely available—in machine-readable, standard formats—for anyone to use in commercial or public-interest applications. This would make data and its supporting infrastructure freely available as public goods.

A competing idea is that development of core infrastructure is best funded by major technology firms, for private profit. The outcomes are as much about political philosophy as technology. In the US, private companies fund and control infrastructure, content, applications and services. Europe encourages innovation and private companies but treats public data as a public good, subjecting its commercial exploitation to public-interest regulation and control. In China, the government operates and controls infrastructure and content. Surveillance technologies are explicitly designed to maintain security in the interests of social cohesion.

There are, in other words, what Wendy Hall calls "Four Internets"—a fragmented digital realm with multiple walled gardens.[4] As she puts it, "The internet is not a monolithic architecture whose existence and form are guaranteed in perpetuity, but a fragile and contingent construction of hardware, software, standards and database, governed by a wide range of private and public actors whose behavior is constrained by voluntary protocols. It is therefore subject to evolution and political pressure."

More than national and international governance will determine how these competing models play out over time.

Even in the most liberal societies, the political trade-offs between public security and individual privacy are far from resolved. Weak governments, beset by increasing terror risks, lack authority to impose fair and sustainable policies. Authoritarian states have few reservations about imposing rules. Meanwhile, technological ingenuity accelerates the rate of change and, with it, the challenges of governance.

With the emergence, at scale, of sensors, drones and the IoT, a fifth internet may emerge: highly localized, community-designed and -owned, ring-fenced and secure against the outside world. This model may become the primary means by which critical services can be made resilient, in an age when digital infrastructure and real-world infrastructure become inseparable.

A key driver of shifts in the governance landscape will be the development of a shared agenda by city and community leaders and insurers, with their critical role in funding and developing credit ratings. Communities will demand security and stability. Insurers will demand sensor networks, early-warning systems and real-time scenario testing as part of risk assessment and pricing.

New localized business models may assemble novel combinations of public, private and individual funding. Some communities may decide to fund digital infrastructures, controlling access to public data, preserving privacy and ensuring stability. Quantum computing and cryptography will play a role, as will blockchain. If AI makes simulation and prediction possible, blockchain will open the door to secure transactions.

Integration of local interests and emerging technologies may hold the key. Long-term, locally developed visions of the world people want will determine the outcome. In this sense, digital technologies, themselves inherently distributed, will contribute to more decentralized, networked and personalized futures in everything from water and energy distribution to food production to sea defenses and pollution management.

Above all, digital technologies will play a vital role in the transport revolution, in everything from traffic management for a variety of new forms of mobility to autonomous vehicles and services, to which we now turn. ■

[3] One small step for the Web, Inrupt, Oct 2018, https://inrupt.com/blog/one-small-step-for-the-web
[4] Four Internets: The Geopolitics of Digital Governance, Hall et al [CIGI], Dec 2018, https://www.cigionline.org/sites/default/files/documents/Paper%20no.206web.pdf

Transport: radical innovation ahead

Nº5

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Past and Future: transport in context

Autonomous, electric vehicles. Robotic drones. Battery-powered aircraft. High-speed trains. Fleets of e-scooters and e-bikes. Descriptions of the future of transport conjure up images that might be taken from science fiction, yet some of the underlying technologies and urban worlds they will create are soon to become reality. Some of them are in operation. Others may be pervasive within a decade. Entire urban systems may be transformed by 2035. →

ACTIVE-AURORA Connected Vehicle Test Bed Network
Edmonton, Alberta

The story of transport is a story of convergence. There are growing public pressures to reduce carbon emissions and urban pollution. Major cities have begun imposing strict controls on fossil-fuel vehicles. At the same time, waves of technologies, from sensors to increasingly efficient batteries, promise not only sustainability and low-carbon cities, but convenience, choice and low cost.

Looking beyond the evolution of personal, electric-powered transport and "on-demand" services, fully automated control systems may emerge. The uncertainty is how the potential for low-cost, near pollution-free transport networks are realized in individual cities and communities and over what time-scale. There is a growing sense of urgency. Transport, particularly in urban areas, is a major source of rising emissions. Pollution is seen by the World Health Organization as the biggest threat to health around the world.[1] Public, investor and political support for radical action has grown. Asset managers and major investment managers have begun reducing support for fossil fuel industries and vehicles

At a global level, the challenge is well known. Urban transport, according to G20 Insight reports, contributes 40% of global direct emissions, mostly in higher-income countries, “yet 90% of the growth is from lower-income countries.”[2] According to an OECD report from 2017, the share of urban trips by private vehicles will increase in all developing regions by 2050. The conclusion: "It is important to integrate urban transport planning with urban land-use planning for successful sustainable development by focusing on mobility promotion instead of infrastructure development."

Lewisham Gateway
London, UK

The report called for "Development of a new ecologically-based urban model: compact in its morphology, complex in its organization, metabolically efficient and socially cohesive." A key component of this will be to rethink urban space, by encouraging walking, cycling and new generations of e-bikes and e-scooters.

A rapid transition to electric cars alone will make a substantial difference, even if realizing the emerging vision of autonomous systems may take decades. At the 2019 Geneva Motor Show, Audi showed only electric vehicles. Volkswagen has set a goal of launching 70 fully electronic models by 2028.

Realizing the full potential of technology will hinge on visionary leadership and the progressive integration of waves of new vehicles within sensor-driven and machine-controlled urban networks. In other words, while individual cars make headlines, the most important innovation will come from new generations of traffic management systems, shared vehicles and "transport as a service" models. Widespread adoption of ride-sharing, e-scooters and e-bikes will cut dependence on cars for short journeys.

More radically, transport may take to the air. Drones already deliver small packages in remote areas. Autonomous or piloted drones, some carrying passengers, are on the horizon. Short-haul electric aircraft have sparked intense competition and innovation. To put this in context, passenger and freight aviation has more than doubled since 2000 and represents 2% of the world’s emissions and 12% of the transport total.[3]

Collectively, these new forms of transport will transform the built environment and hold the potential to cut emissions, traffic volumes, density, noise, overcrowding and travel times. These changes could unlock valuable urban land, now used for parking, for sustainable, green development and for a substantially richer public realm built along narrower streets.

Transport is at a watershed moment. The underlying uncertainty is social behavior. In some cultural contexts, public acceptance and investor backing can change quickly. ■

[1] Air pollution: everything you should know about a public health emergency, The Guardian, Nov 2018, https://www.theguardian.com/environment/2018/nov/05/air-pollution-everything-you-should-know-about-a-public-health-emergency
[2] The New Urban Paradigm, Herrero et al [G20 Insights], Sept 2018, https://www.g20-insights.org/policy_briefs/the-new-urban-paradigm/
[3] Annual Analyses of the EU Air Transport Market 2016, European Commission, Mar 2017, https://ec.europa.eu/transport/sites/transport/files/2016_eu_air_transport_industry_analyses_report.pdf

Emerging Landscape

Bus Rapid Transit Corridor, MAX Purple
Calgary, Alberta

Before exploring broader strategic implications, we'll take a brief tour of the emerging landscape, and more important, the potential impacts it may have on the urban environment.

We can begin at human scale, with the resurgence of walking and biking. In many cities, safe walking routes have become a key urban design principle. Cycling has seen a resurgence. Instead of moving cars, policy makers are turning transport systems upside down, giving priority to pedestrians and cyclists first, then public transit, then freight and finally, individual cars.

This means that long before the vision of integrated autonomous systems and mass-scale automation, sales of e-bikes and e-scooters have surged. Cities like Amsterdam and Copenhagen have built extensive cycling networks. Bikes are used in more than 40% of commuting journeys in Copenhagen, traveling on 220 miles (354 km) of protected lanes.[4] Electric-powered "micro mobility" services bring immediate benefits, cutting demand for cars and reducing pollution. Investment follows: to illustrate, Ford X,[5] the motor manufacturer's mobility incubator, purchased Spin[6] among total micro-mobility sector investments of US $1 billion in 2018.

Subways, trams and light rail have also seen a resurgence. In North America, Portland's new light rail system has inspired smaller cities to take a fresh look at the format. More important, bus rapid transport (BRT) has gained momentum. Low capital costs and high capacity have led growth across Latin America, from Bogotá to Quito to Mexico City, and elsewhere, including in Istanbul, Lagos, Johannesburg and Tehran. In other words, relatively low technology approaches to established modes of transport have a long-term future.

Helsinki aims to eliminate all private car ownership within the city by 2025, taking advantage of technology-driven trends that will create new choices for urban communities. These include ride-hailing services operated by Uber, Lyft, Didi Chuxing and some major car manufacturers that offer travelers cheap short-haul options. These services, which bring passengers and drivers together via mobile apps, are popular around the world, but their impact is uncertain. These services[7] may reduce demand for transit networks and slow the growing interest in cycling and walking.[8] The ride-hailing companies themselves are in transition, piloting autonomous vehicle (AV) technology with the goal of making their fleets autonomous as the technology matures.

Small electric shuttle buses, with capacity for 10-15 passengers, are designed to operate at low speed over fixed routes, with no human drivers. More than 80 communities have launched pilot programs, including Rotterdam, the Netherlands; Columbus, Ohio, in the US; and Seongnam, South Korea. ■

[4] C40 Good Practice Guides: Copenhagen - City of Cyclists, C40 Cities, Feb 2016, https://www.c40.org/case_studies/c40-good-practice-guides-copenhagen-city-of-cyclists

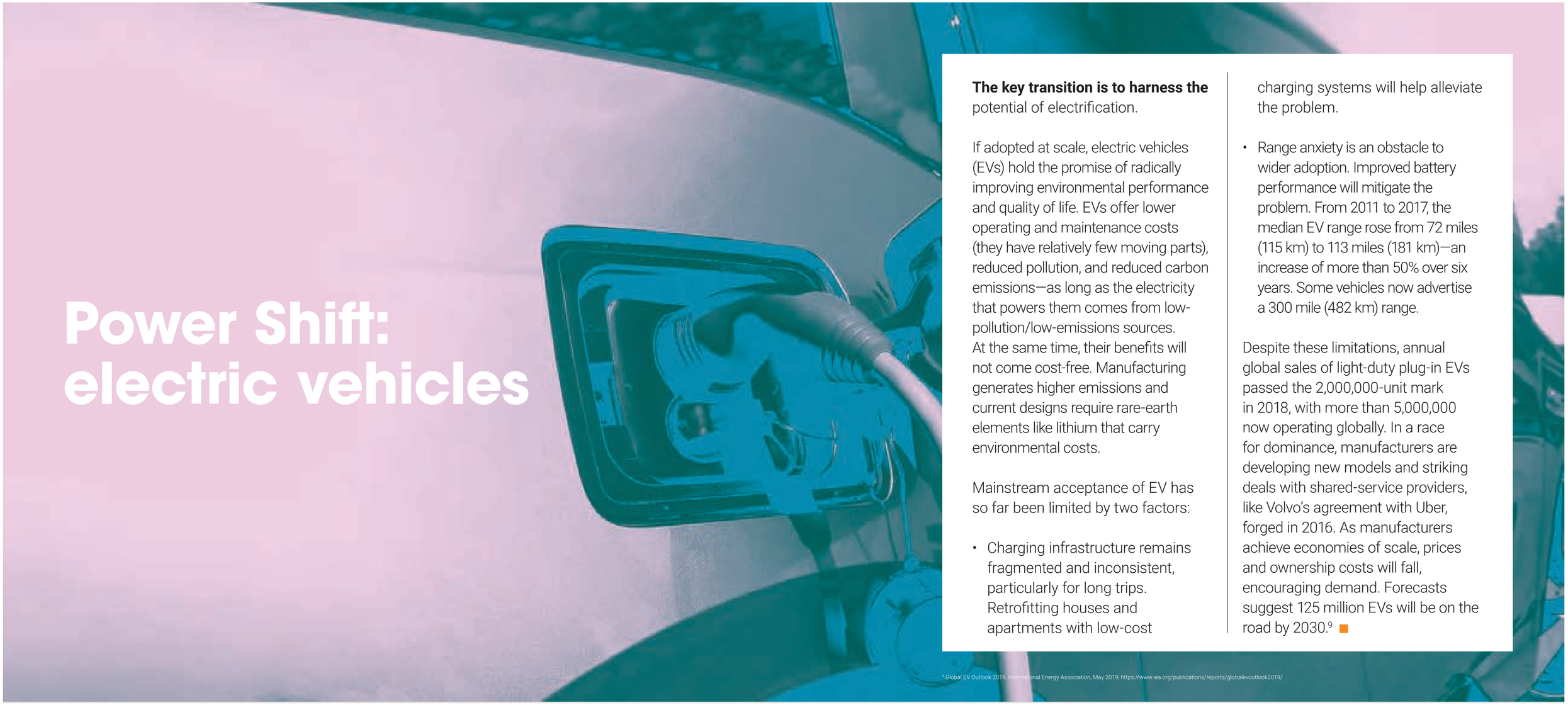
[5] Ford X [Ford Mobility's venture incubator], Ford, 2019, https://www.fordx.com/index.html

[6] Ford buys e-scooter company Spin for $100 million, The Verge, Nov 2018, https://www.theverge.com/transportation/2018/11/7/18073046/ford-electric-scooter-spin-acquisition

[7] Sometimes referred to as Mobile Service Providers (MSPs) or Transport Network Companies (TNCs)

[8] Disruptive Transportation: The Adoption, Utilization, and Impacts of Ride-Hailing in the United States, UC Davis Institute of Transportation Studies, Oct 2017, https://itspubs.ucdavis.edu/wp-content/themes/ucdavis/pubs/download_pdf.php?id=2752

Power Shift: electric vehicles



The key transition is to harness the potential of electrification.

If adopted at scale, electric vehicles (EVs) hold the promise of radically improving environmental performance and quality of life. EVs offer lower operating and maintenance costs (they have relatively few moving parts), reduced pollution, and reduced carbon emissions—as long as the electricity that powers them comes from low-pollution/low-emissions sources. At the same time, their benefits will not come cost-free. Manufacturing generates higher emissions and current designs require rare-earth elements like lithium that carry environmental costs.

Mainstream acceptance of EV has so far been limited by two factors:

- Charging infrastructure remains fragmented and inconsistent, particularly for long trips. Retrofitting houses and apartments with low-cost charging systems will help alleviate the problem.
- Range anxiety is an obstacle to wider adoption. Improved battery performance will mitigate the problem. From 2011 to 2017, the median EV range rose from 72 miles (115 km) to 113 miles (181 km)—an increase of more than 50% over six years. Some vehicles now advertise a 300 mile (482 km) range.

Despite these limitations, annual global sales of light-duty plug-in EVs passed the 2,000,000-unit mark in 2018, with more than 5,000,000 now operating globally. In a race for dominance, manufacturers are developing new models and striking deals with shared-service providers, like Volvo's agreement with Uber, forged in 2016. As manufacturers achieve economies of scale, prices and ownership costs will fall, encouraging demand. Forecasts suggest 125 million EVs will be on the road by 2030.[9] ■

[9] Global EV Outlook 2019, International Energy Association, May 2019, https://www.iea.org/publications/reports/globalevoutlook2019/

Automated Vehicles: toward autonomy

Vehicle manufacturers are scaling up production of electric vehicles, but the widely shared longer-term vision focuses on autonomous vehicles, from passenger cars to long-distance trucks. In the short-term, manufacturers have introduced a range of driver aids designed to deliver everything from navigation alerts and steering assistance to automatic braking and reduced collision risk.

Industry standard classification begins with Level 0, no automation. Level 1 delivers driver assistance. Level 2 brings partial automation and Level 3 offers an automated driving "system" that monitors the environment. Each of these levels are in operation. So-called "high automation," Level 4, puts the system in control.

Designed to operate without drivers, Level 5 vehicles have full autonomy. Critics argue that they are several decades away, yet at the other extreme Elon Musk has claimed that Tesla will have one million "robotaxis" in operation by 2020. The technology is advancing rapidly, ahead of regulatory and network operation thinking.

Level 4 and 5 vehicles are in advanced development and testing. Level 5 machines are already in use on private land and in the mining industry. The uncertainty about timing at scale revolves around technology (including the ability to operate in adverse weather conditions), liability responsibility and cybersecurity.

The primary claim of AV technology is the potential to improve safety dramatically. Combined with Artificial Intelligence (AI), advanced sensors, and connected vehicle (CV) technology, AVs might outperform humans in avoiding collisions.

However, Level 5 AVs might also have other impacts. They could increase traffic volume and density, as widespread, low-cost access may attract many more passengers. Further uncertainties include how passengers might choose among multiple alternatives. At the other extreme, machine control will allow vehicles to travel much closer together, potentially reducing pollution and freeing large areas from parking congestion.

The development of individual, self-managing autonomous vehicles cannot be separated from the idea that the vehicles themselves and the urban traffic-systems infrastructure that ultimately may operate them will increasingly form part of distributed, real-time networks. CV technology allows vehicles to communicate with other vehicles or with the infrastructure, such as traffic lights, to improve safety. Examples of early CV technology include transit toll collection, with cooperative adaptive cruise control on the horizon.

Many electric and automation technologies are already finding application in trams, buses and light rail systems.

This brings us to city-scale advanced traffic management and the promise of fully automated systems. Decades ago, traffic signal systems operated on fixed-time sequences, according to time of day. Current technology gathers data on traffic flow, congestion, incidents and driver destinations. Adaptive traffic and response systems already improve the efficiency of road networks, aided by vehicle detection, centralized management and predictive, AI-based modeling. The relationships between sensor data about vehicles, passengers, locations, weather, collisions and traffic flow are moving toward integration. On the horizon: a vision of automated systems that control both individual vehicles and the entire transport network.

Yet fundamental uncertainties remain. Some are related to privacy concerns and trust in network providers. Others concern ownership of personal data. Others, to cybersecurity, vulnerability and stability. ■

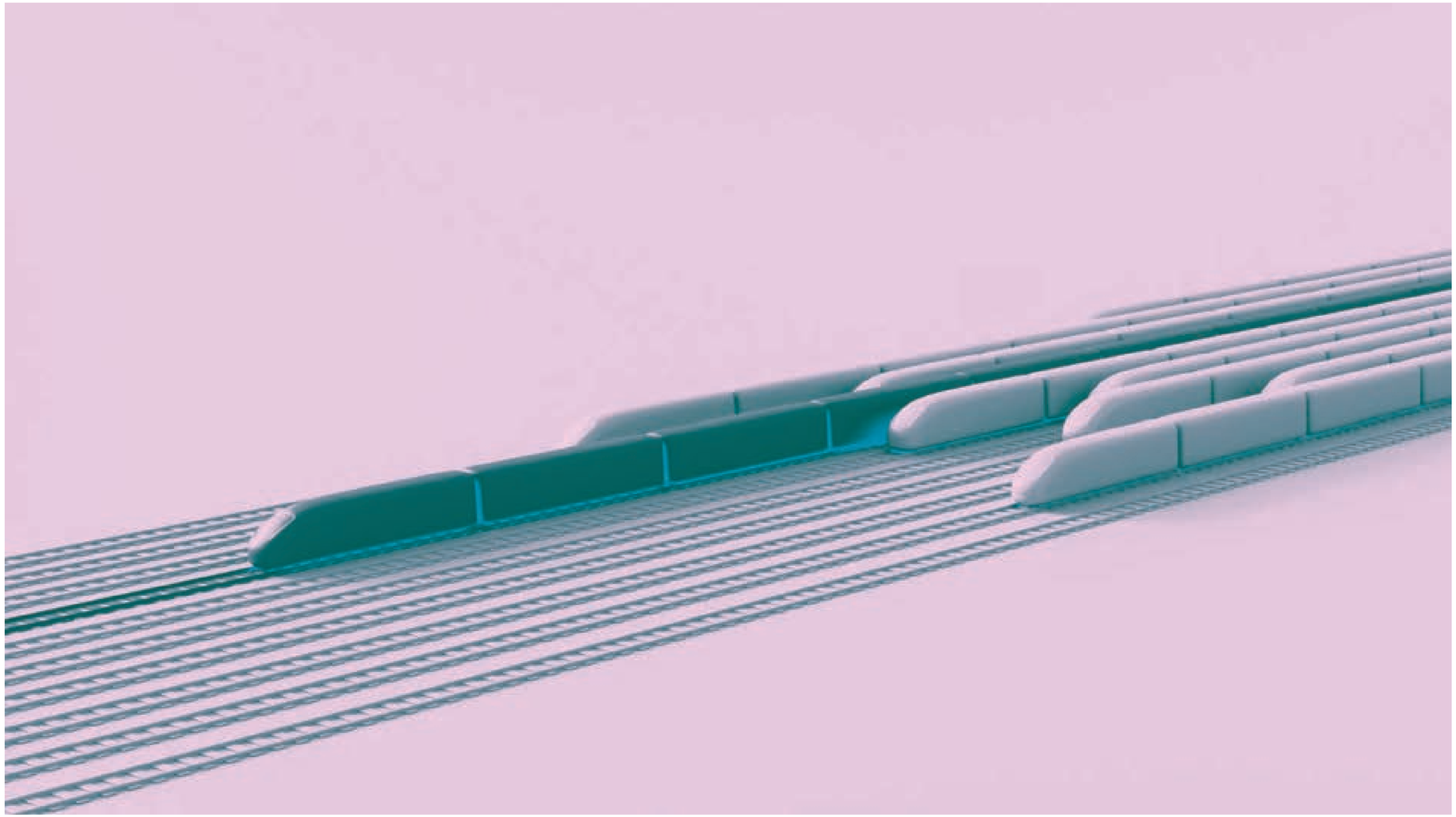
Resurgent Rail

Many of the sensor network and AI predictive systems designed for road transport have parallels in rail networks. Some focus on improved safety, others on increasing the capacity of existing tracks by reducing the gaps between trains.

Yet intercity travel is the primary focus of innovation. Amid changing attitudes to air transport and tourism, high speed rail services are attracting more passengers. Unless the aviation industry can deliver cleaner, more efficient and convenient services, particularly on short-haul routes, rail may continue to grow.

High-speed trains are well-proven, both technically and commercially. They are commonplace for some international routes, such as between London, Paris and Brussels, and intercity routes in China, Japan, France and Spain. Trans-continental routes form part of China's Belt and Road initiative.

Long-term, we may see more radical train technology in the search for higher speed, city-center to city-center convenience and reduced emissions and pollution. ■



Taking to the Air

Preparing cities for autonomous (self-driving) transportation research project
Chicago, Illinois

Just as electric cars will dominate the first wave of the next transport revolution, electric aerial vehicles could emerge more rapidly than autonomous systems. By shifting to sustainable power sources, Norway intends all short-haul flights to go electric by 2040.[10] Airbus hopes to have an electric plane capable of carrying 100 passengers 700 miles (1,126 km) by 2030.[11]

For all the innovative potential of terrestrial vehicles and networks, the deployment of self-managing aerial vehicles and drones may prove the most revolutionary innovation of all.

Robotic delivery already uses automated machines to deliver goods directly to customers, typically over short distances. In military operations, drones have become commonplace. In commercial, peaceful applications, one major obstacle to drone adoption is the need for a legal framework. Wing, the drone package delivery service from Alphabet, received permission in 2019 to begin operations in Virginia by the US Federal Aviation Administration, which is investigating the implications of widespread drone use on airspace safety.

Aerial drones already deliver medical supplies to remote areas in Africa and in disaster zones. Robot delivery has been in operation in hospitals and high-hazard industrial zones for some time. With the growing popularity of e-commerce and food delivery services, some companies have begun adapting these machines for last-mile delivery to homes and businesses.

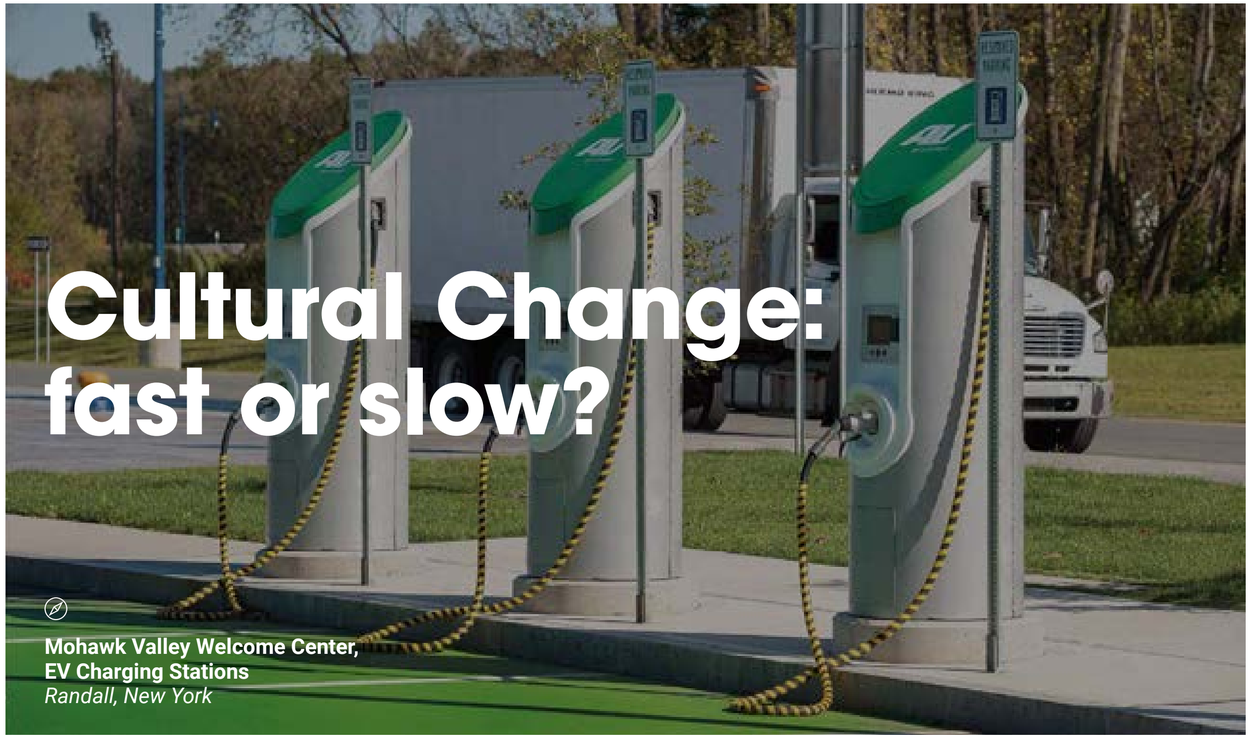
Robots could decrease the use of traditional courier and food delivery services, decreasing network congestion on the ground and alleviating pressure on short-term parking. Delivery robots deployed in various cities by companies such as FedEx, Starship Technologies, Dispatch and Marble have used machine learning to adapt to operation on sidewalks.

Many drone applications focus on data gathering. Insurance companies have patented the use of drones to assess damage. In agriculture and water infrastructure, drones oversee and monitor for signs of crop damage and chemical pollution. Above all, in the transport context, drones form part of growing networks of airborne systems that combine high resolution, real-time video, sensors and AI to deliver intelligence about traffic volumes, accidents and road conditions.

On the longer-term horizon, Boeing, Bell Helicopters, Uber and others have invested in development of passenger drones. Without the need for ground-level infrastructure, they could transform transport, should they prove feasible. There is potential to transform point-to-point transport. Airspace management is a primary focus of investment and innovation. ■

[10] Norway aims for all short-haul flights to be 100% electric by 2040, The Guardian, Jan 2018, https://www.theguardian.com/world/2018/jan/18/norway-aims-for-all-short-haul-flights-to-be-100-electric-by-2040
[11] Bringing zero-emission technology to aviation, Airbus, 2019, https://www.airbus.com/innovation/future-technology/electric-flight.html

Cultural Change: fast or slow?



Mohawk Valley Welcome Center, EV Charging Stations
Randall, New York

A new transport revolution is underway. Over time, the distinction between public and private transport will likely disappear. Transport networks will become radically more efficient, reducing overcrowding, lowering both emissions and pollution, and cutting costs. Citywide networks will play a more important role than autonomous vehicles in realizing the most ambitious visions of full automation.

We can expect growing competition among different modes of transport, from short journeys of about 1 mile (1.6 km) that typify e-scooters in urban areas, to long journeys and the competition between high-speed trains and aircraft. In some countries, design thinking will focus on integrated networks, with the aim of simplifying choices and avoiding wasteful overlaps between systems. In others, fragmented systems will vie for passengers and freight.

The timing of these changes will depend on how quickly communities can redesign, fund, and rebuild infrastructure to realize the potential benefits. Such sweeping changes will depend on committed, visionary community leadership. The outcome may be "green cities," with vast amounts of space freed up by reduced demand for parking zones, roads and retail space. On the other hand, progress may be piecemeal and fragmented, evolving by trial and error rather than by strategic ecosystem design.

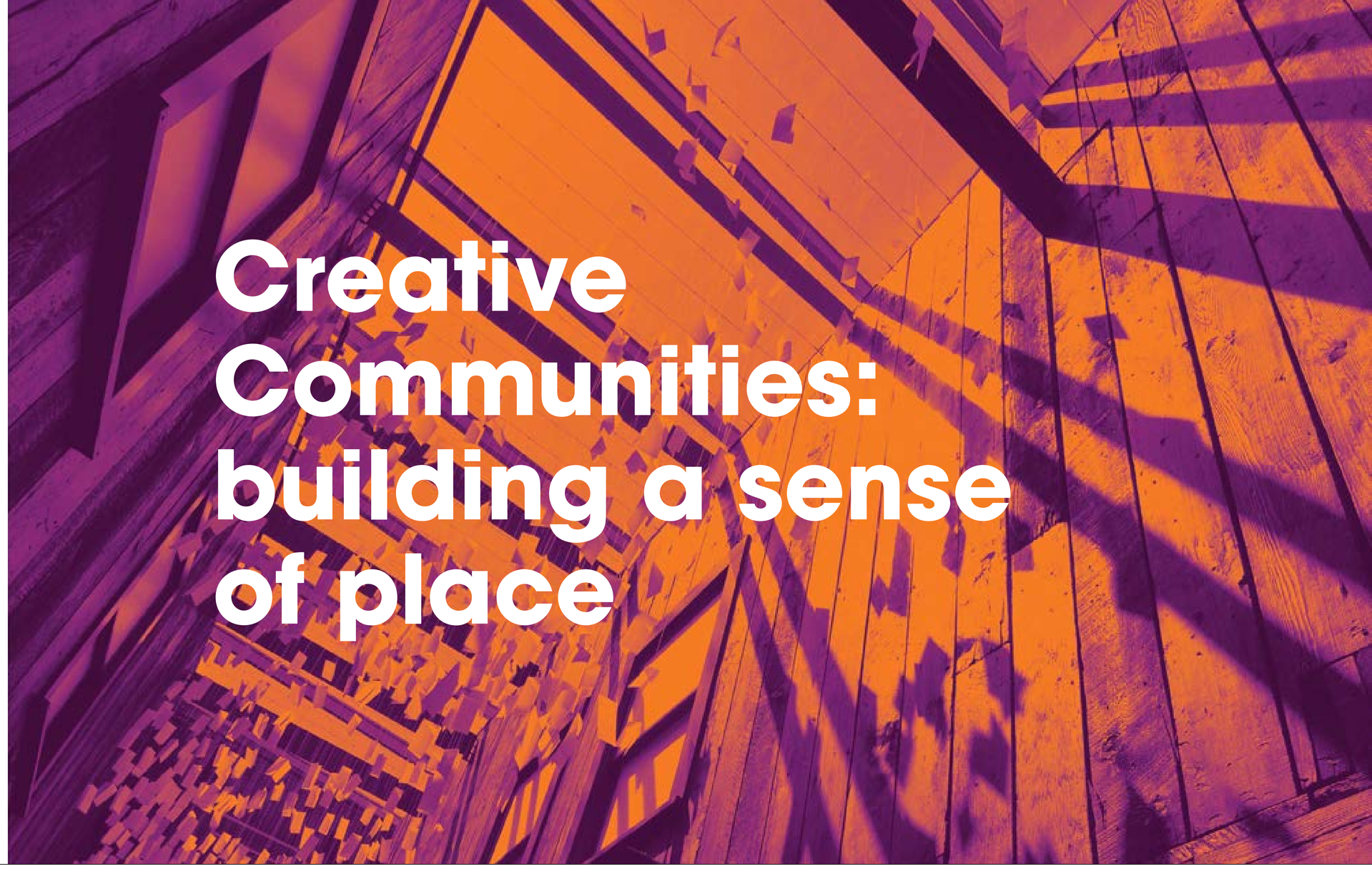
Given the scale of investment and commitment by city leaders, manufacturers and governments alike, the transition to electric vehicles themselves—as distinct from urban transport, monitoring and control networks—will represent a question not of "if," but "when." London's Ultra-Low Emission Zone, introduced in early 2019, imposes charges on all fossil fuel vehicles. Many cities intend to ban conventional fossil fuel vehicles from central areas. Shenzhen has electrified its entire 16,000-vehicle fleet of buses. These milestones signal the potential scale of disruption that may lie ahead. Policy and regulatory action may deliver short-term shocks as the technological revolution gathers pace.

Privacy, security, cyberwar and mistrust in AI could slow progress. Complexity risk and the challenges of navigating the range of technological, social, political and financial constraints loom large.

The underlying uncertainty is cultural, not technological. The question is whether public values and attitudes may act as a barrier to widespread acceptance and radical change—or an accelerator.

Climate and biosphere risks represent the primary sources of volatility and have created the sense of urgency that may make radical change possible. As increasingly fierce global competition for talent rests on demonstrating a clear vision for resilient, sustainable wellbeing, jobs and lifestyles, transport infrastructure will become pivotal to success.

With this in mind, we explore the importance of "soft" infrastructure, creative and cultural industries and their role in sustainable development and growth. ■



Creative Communities: building a sense of place

Nº6

DAVID DIXON, STANTEC
PETER KINGSLEY, PJR

Herald and Greeley Squares
New York, New York

Communities around the world face significant disruption from climate change, overstressed ecosystems and waves of technological innovation. The solutions to these problems will demand major investment and increase pressure to find new, more sustainable long-term paths to security, wellbeing and economic growth.

How will the world fund the transformation? The costs of deploying decarbonization technology, cutting pollution, and re-engineering energy, water, waste and agricultural systems are substantial and urgent.

Meeting the needs of mass waves of climate migrants and providing healthcare to an aging population will create increasing demands to maximize economic growth, rethink the nature of work and develop more inclusive societies.

To put these costs into context, the global costs of decarbonization alone may exceed US $90 trillion by 2050,[1] equaling roughly 90% of *global* GDP in 2019. At the same time, aging populations in the developed world are absorbing rising shares of economic resources. In the US alone, as the number of people older than 65 triples by 2050, health care costs, in some scenarios, could consume all the discretionary federal budget.[2]

Yet traditional approaches to expanding economic growth are unsustainable. In Asia and other fast-growing regions, economic growth cannot be based on the conventional, consumer-centric, resource-intensive system of development followed by the West.[3] One answer is strong state leadership. In the West, sustainable development will come in part from a burgeoning knowledge economy, increasingly driven by creative industries. This sector, which depends on "obtaining, managing and using knowledge" already generates the majority of higher-paying jobs. To illustrate, since 2000 roughly 90% of net new jobs in the US have required a college education.

The shift from resource to knowledge-driven development requires fundamental shifts in planning and public investment. Since the advent of the industrial revolution, "hard infrastructure" has dominated public policy. Capital-intensive transport, energy, water and agricultural systems, typically involving substantial amounts of steel, concrete and increasingly scarce natural resources, have underpinned development. These investments will not disappear, but cities will increasingly combine them with engineered ecosystems—in essence, working *with* natural processes rather than fighting to control them.

As knowledge replaces resources as the key to economic development, the most important economic resource becomes talent—an educated, creative workforce. Hard infrastructure will increasingly share the stage with "soft infrastructure." This means a growing emphasis on place-based cultural resources, creative industries, sustainability, natural and green space, human-scale development and social inclusion. Each of these play a central role in attracting and retaining talent.

The growing value of soft infrastructure is challenging traditional practices across every layer of government and across the private and institutional sectors. While national governments pursue policies to make their nations more competitive in the global competition for talent, local governments have launched initiatives that combine hard and soft infrastructure to promote development by strengthening quality of life and celebrating diversity.

Led by creative talent, knowledge development and trading in ideas, corporations have begun shifting from short-term profit as the key to building long-term value to focusing on cultural value, diversity, livability and sustainability goals to attract and keep talent. Universities and hospitals are increasingly active in initiatives to enhance wellbeing, cultural amenities and social inclusion for their host communities. ■

[1] The cost of climate change, Axios, Oct 2018, https://www.axios.com/climate-change-costs-wealth-carbon-tax-303d7cff-3085-49d9-accb-ec77689b9911.html
[2] The 2019 Long-Term Budget Outlook, Congress of the United States Congressional Budget Office, June 2019, https://www.cbo.gov/system/files/2019-06/55331-LTBO-2.pdf
[3] The Sustainable State: The Future of Government, Economy, and Society, Nair, Oct 2018, http://www.global-inst.com/the-sustainable-state/

Post-Industrial Development

Tufts University, Collaborative Learning and Innovation Complex
Medford, Massachusetts

Creative industries, characterized by invention, ideas and intellectual property will play an increasing role in development, even as the impact of robotics and mass automation poses growing concerns about long-term employment. The creative economy—spanning sectors such as electronic games, sports, media and publishing, theatre, music, arts and humanities, and software development is growing rapidly. Museums, libraries, public heritage, restaurants and an array of experiential retail spaces are central to prospects for major cities, particularly in the developed world. In an era of growing diversity, these industries also play a central role in creating a sense of community and in defining identity.

To illustrate the scale of cultural and creative industries, the UN Conference on Trade and Development reports the value of creative goods and services trade more than doubled between 2002 and 2015 and continues to grow. A UNESCO report points out that "creative industries" generate more than 3% of world GDP, "substantially more than global telecommunications…and greater than the GDP of India, Russia, or Canada."[4] Other studies suggest that in an age of growing automation, more than 20% of jobs in the US and the UK will soon qualify as creative.[5]

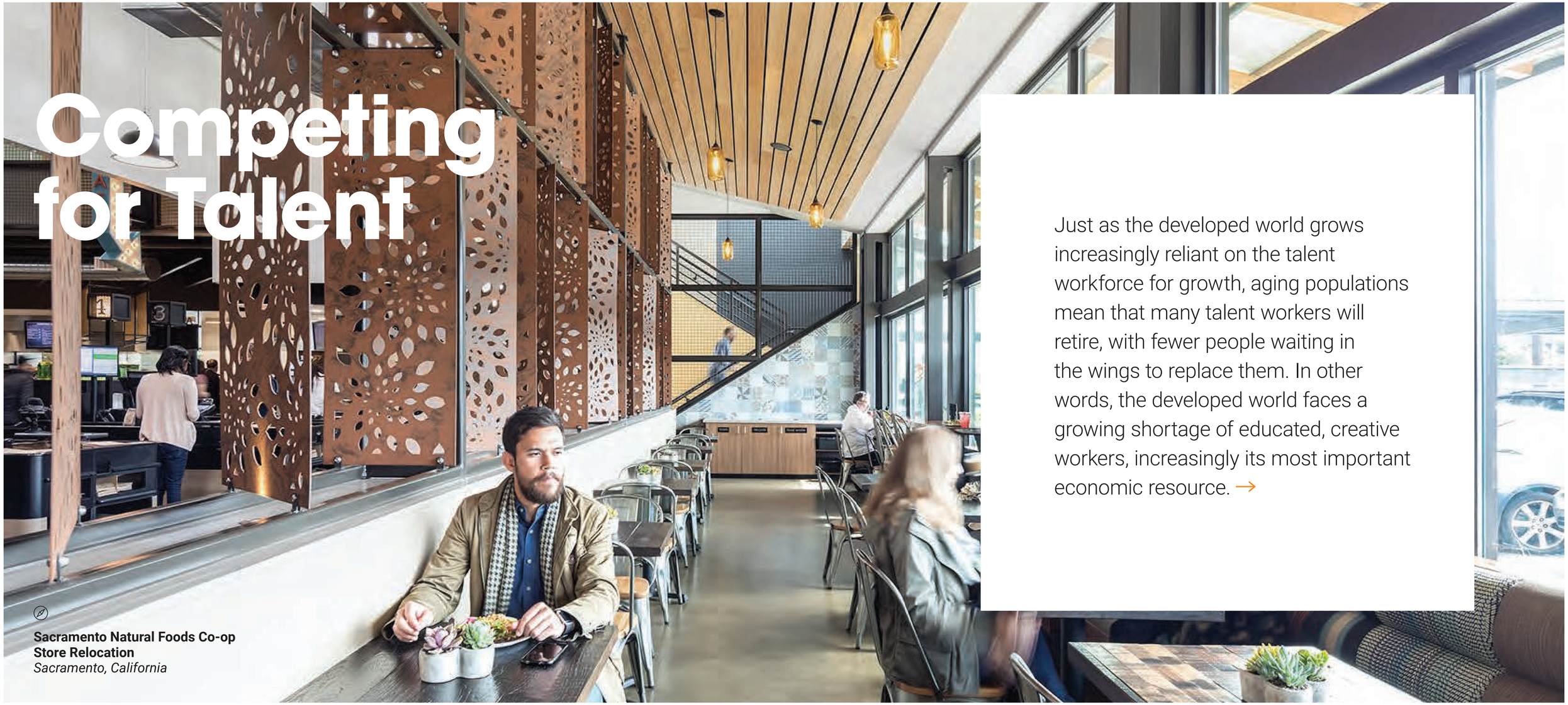
These developments are global. China, recognizing the importance of creativity and intellectual property, has made the transition from "made in China" to "designed in China" a central theme of its long-range economic planning In the US, one half of all retail leases in 2018 were for businesses serving food and alcohol, with creative chefs and entrepreneurs representing a growing share. Augmented, virtual and mixed reality will grow in importance within the creative industries.

When Charles Landry initiated the "Creative Cities" movement two decades ago,[6] he made the argument that this new economy begins and ends with human talent. The intangibles-dominated knowledge and creative industries are "employers," but this is not "work" in the conventional sense, since new definitions of "work" and "industry" are emerging.

While the knowledge economy benefits from many forms of capital-intensive hard infrastructure—particularly for moving people and information—development and growth hinge on soft infrastructure: community-rich, diverse urban communities that attract the educated, creative and talented people. ■

[4] The Global Creative Economy Is Big Business, CityLab, Dec 2015, https://www.citylab.com/life/2015/12/the-global-creative-economy-is-big-business/422013/
[5] Creativity and the Future Workforce, NESTA, Mar 2018, https://media.nesta.org.uk/documents/creativity_and_the_future_of_work_1.1.pdf
[6] Charles Landry and Franco Bianchini: Creative Cities. 1995. Demos in Association with Comedia.

Competing for Talent



Sacramento Natural Foods Co-op Store Relocation
Sacramento, California

Just as the developed world grows increasingly reliant on the talent workforce for growth, aging populations mean that many talent workers will retire, with fewer people waiting in the wings to replace them. In other words, the developed world faces a growing shortage of educated, creative workers, increasingly its most important economic resource. →

Given current immigration patterns, the US workforce will not match its 2010 growth in terms of total number of net new workers until after 2040. The outlook for most of the developed world—including countries like Australia, Canada and New Zealand that actively recruit immigrants—suggests even slower workforce growth.[7]

A study by global workforce consultants Korn Ferry projects that in 2020 a growing talent shortage will cost the 20 largest national economies more than US $1 trillion in lost annual output. This means lost production because businesses do not have enough of the right employees to run at maximum capacity. Within a decade, the study projects lost global output will top US $8.5 trillion.[8] This threat to economic growth has driven cities and regions across the developed world to compete more aggressively for the same pool of talent workers.

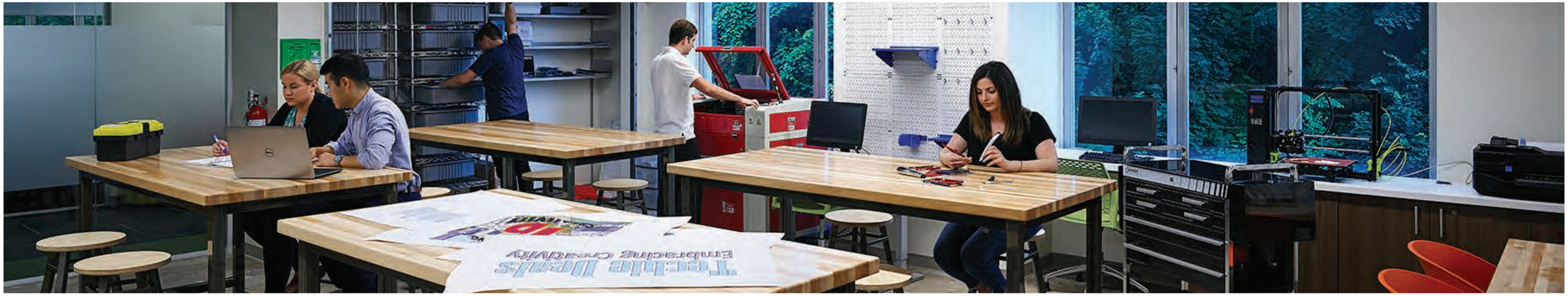
The Young and Restless in a Knowledge Economy, a landmark 2005 report released by CEOs for Cities,[9] concluded that to attract talent workers and the jobs and investment that follow would require cities to invest far more aggressively in soft infrastructure. This means safe walkable streets, vital arts scenes, parks and public spaces that promote a sense of community, distinctive locally owned stores and restaurants, and legal protections for human rights—rather than focusing narrowly on the hard infrastructure that moves goods.

Urban economist Richard Florida has made a similar case, using data to demonstrate that quality of place and culture play a decisive role in attracting and retaining talent workers. "Quality-of-place amenities were once thought of as an afterthought or something that happens after places get rich," he argues. "Now we know that amenities—not just restaurants and bars but the whole package of great museums and libraries—play a key role in drawing the highly-skilled knowledge economy workers back to the city, bringing economic growth with them."[10]

Elsewhere, Florida documents the effectiveness of performing arts organizations in attracting "knowledge class" jobs to cities. Over the ten years studied, "the 118 metros with at least one performing arts organization generated a whopping US $60 billion in annual income and more than half a million additional knowledge-class jobs."[11] Jed Kolko, chief economist at Indeed.com, examined US Census data and found that while the number of millennials in cities and suburbs has held relatively constant, their education level has shifted. Since 2000 the number of millennials with four-year college degrees has grown in cities and shrunk in suburbs.[12] ■

[7] The Talent Shortage: Someone Else's Problem, Korn Ferry Institute, Oct 2018, https://www.kornferry.com/institute/talent-shortage-future-of-work
[8] Ibid
[9] The Young & Restless in a Knowledge Economy, Forward Cities, Dec 2005, https://www.forwardcities.org/wp-content/uploads/2018/04/Young-and-Restless-in-a-Knowledge-Economy.pdf

[10] Why Quality of Place Matters, CityLab, Dec 2018, https://www.citylab.com/design/2016/12/why-quality-of-place-matters/509876/
[11] How the Arts Add to Urban Economies, CityLab, Dec 2015, https://www.citylab.com/life/2015/12/how-the-arts-add-to-city-economies/421191/
[12] Urban Revival? Not for Most Americans, Terner Center for Housing Innovation, Mar 2016, https://ternercenter.berkeley.edu/blog/urban-revival-not-for-most-americans



US Industrial Heartland: a case study

Duquesne University - Rockwell Hall Learning Commons Environment Renovations
Pittsburgh, Pennsylvania

Two initiatives underway in America's industrial and agricultural heartland illustrate how cities and regions can change course to respond to a new focus on culture and community. In 2017, the Mid-Ohio Regional Planning Council (MORPC)—a regional partnership responsible for allocating state funds to promote economic growth—released *INSIGHT 2050*.[13] They announced a shift in public investment focus from highways to lively, pedestrian-centered urban places in recognition that the region's economic future lies in an emerging innovation and knowledge cluster growing up around The Ohio State University and other Columbus research and educational centers.

Before MORPC had even begun its study, then-Columbus Mayor Michael B. Coleman launched a revitalization initiative to transform a depressed former industrial district, East Franklinton, into a creative community for artists, makers, and creative entrepreneurs—young talent workers the mayor saw as key to the region's economic future. Home to more college-age students than any US city outside of New York and Boston, Columbus had for years watched its graduates head to urban centers like Chicago, Atlanta and Boston to settle and find jobs.

In part, Coleman banked on these young adults' creative spirit to build businesses that would yield jobs and investment, but he also recognized that the creative lifestyles they fostered would persuade other talent workers to stay (or relocate) and put down roots in Columbus. The City committed funds to subsidize affordable housing for artists; encouraged conversion of a vacant warehouse into funky new headquarters for the city's marquee co-working and maker space; supported conversion of other industrial buildings into artists' studios; sponsored public art; and created new access to a system of riverfront parks and bikeways. The mayor's plan won the 2014 American Planning Association award for Innovative Economic Development. Five years later these investments in "soft" amenities have attracted more knowledge industry investment to the district than to any other part of the region. Developers have followed, proposing hundreds of millions of dollars in mixed-use projects. ■

[13] Insight2050, Mid-Ohio Regional Planning Council, 2017, https://getinsight2050.org/about/

The Conundrum: adding equity to the mix

The case for the value of soft infrastructure strategies is compelling. Yet the knowledge economy has exacerbated income inequality across the developed world. While many structural factors have contributed to a larger wealth gap—including economic development policy, less-progressive taxes and changes in corporate governance—the growth of knowledge economy sectors has aggravated the problem.

With their emphasis on advanced education, knowledge industries have steered the lion's share of the income growth they have produced to higher-income workers. The Korn Ferry study referenced earlier projects that by 2030 companies will have to spend an additional US $2.5 trillion to attract talent.[14] This trend first appeared in the US in the 1980s. While increased productivity flowed fairly evenly to all workers in the three decades following World War II, from 1980 the benefits of greater economic productivity flowed increasingly to the top one-fifth of US earners.[15]

The Great Recession and subsequent recovery focused global attention on this issue. The Organization for Economic Cooperation and Development (OECD) reports that post-recession income growth for most workers in developed countries has remained essentially flat, even as income gains for educated, higher-income workers have accelerated.[16] Compared to pre-recession levels, OECD reports, "income among the top one per cent of earners grew about four times as fast as the median income," following what the group calls a "long-standing trend."

MIT labor economist Michael Piore points out that this is not inevitable. He argues that a combination of more progressive tax policies; expanded collective bargaining for workers; increased public and private investment in skills-training and workforce-readiness programs; and a redefinition of job skills paired with growing AI and other technology could yield substantial income equity dividends.[17] He also points to the political risks of not investing in greater equity, noting that even though the State of New York would have underwritten most of the incentives used to attract Amazon's HQ2 to New York City in 2018, the company scuttled its plans in the face of vocal protests by residents convinced that the company's promised jobs would benefit few city residents yet add to strains on transportation and housing infrastructure.

Successful communities will need to tap into the wealth that the knowledge economy has created to fund affordable housing, education and skills training, and other key components of a robust equity agenda. Ironically, the same soft infrastructure of culture, creativity and inclusion that draws knowledge-sector businesses and can generate inequality also addresses a wider desire for a sense of community in a time of economic and social fragmentation. The challenges posed by differences of race, age, background and increasing income as well as the increased fraying of social bonds that social media has encouraged, are well documented. ■

[14] The Talent Shortage: Someone Else's Problem, Korn Ferry Institute, Oct 2018, https://www.kornferry.com/institute/talent-shortage-future-of-work
[15] The Productivity–Pay Gap, Economic Policy Institute, Jul 2019, https://www.epi.org/productivity-pay-gap/
[16] OECD Report Warns Of 'Unprecedented Wage Stagnation' In Developed Countries, Huffington Post, Jul 2018, https://www.huffingtonpost.ca/2018/07/09/oecd-report-unprecedented-wage-stagnation-canada-jobs-developed-countries_a_23477970/
[17] Conversation with Author, Mar 2019, https://economics.mit.edu/faculty/mpiore/brief

Forward-Looking Cities: creating a sense of place

Many cities have turned to creative, community-rich spaces that promote social bonds and interaction to strengthen civic cohesion in the face of formidable city-building challenges posed by growing economic and social inequality and climate change.

Marina Barrage in Singapore illustrates an ambitious marriage of hard and soft infrastructure to meet goals for climate adaptation, water security and quality of life. The creation of an enormous freshwater reservoir has strengthened management of rain-driven flooding and expanded Singapore's water supply. The reservoir supports recreation, such as kayaking and boating. A wide promenade atop the dam draws visitors to dramatic views of the skyline. The pump house roof spirals up from a ground-level children's play area to a wide, grassy lawn that has become popular for picnicking, kite-flying and wedding photos.

Birmingham, Alabama, located Railroad Park where its downtown, university campus and racially diverse neighborhoods meet in a conscious effort to invite people of every race, income, and background to come together on new common ground. Attractions include a reflecting pool and stream, multi-use trails, a playground and seasonal ice rink and concerts. Neighborhood groups from across the region now come to the park for potluck dinners in the heart of downtown. The park acts as a living symbol of Birmingham's efforts to make racial and economic diversity work in a city with a troubled past.

In Seoul, replacing a 1970s-era expressway with a 3.6 mile (5.8 km) linear park has helped spark a downtown revival. The daylighted Cheongyeocheon Stream, once buried beneath the elevated expressway, defines the park and acts as a draw for tourists and residents. The park has delivered a broad set of environmental benefits. These include protection against 200-year floods; sharp reductions in air pollution and urban heat island temperatures; a rise in biodiversity; an increase in transit use; and a drop in automobile use. It has also reversed downtown's image as a dying neighborhood. In the five years following the park's opening, the private sector sank nearly US $2 billion in new investment into the area.

Opened in 2018, Toronto's Bentway introduces resilience features beneath approximately 1 mile (1.75 km) of the city's contentious elevated Gardiner Expressway. Displacing outmoded industrial uses, the linear park has 55 outdoor "rooms," defined by the expressway's piers (known as "bents"), that can be programmed in groups or individually. A wide-ranging program—public art, performances, picnic areas, light shows, a winter skating track, and food markets—underscores the aim of serving nearly 80,000 people who have moved into nearby development in the past 15 years. The park provides storm water retention and filtration, but its key resilience benefit lies in its ability to connect communities and make dense urban living more appealing.

Copenhagen's Superkilen Park celebrates the city's diversity with art and programming that consciously evokes the mosaic of stories, traditions and countries of origin in the surrounding Norreboro neighborhood. The 355,000 square foot area (33,000 square meters) combines a zone for active play, a plaza that hosts a weekly produce market and a grassy area designed for picnics and quiet conversation. Careful design of a cross-park bike path minimizes conflicts between cyclists and park users. The park design incorporates objects from more than 60 countries, representing the points of origin of Norreboro residents. A plaque explains the source of each shape or object in Danish and the language used in the country of origin to symbolize and celebrate the neighborhood's diversity, "rather than," as one commentator put it, "perpetuating a petrified image of homogeneous Denmark."[17]

[17] "Superkilen," ArchDaily, 25 October 2012. https://www.archdaily.com/286223/superkilen-topotek-1-big-architects-superflex.

Soft Approaches to Managing Strategic, Long-Term Change

Radio Tower Creek Wetland Restoration and Enhancement Monitoring Program
Calgary, Alberta

To survive in the 21st century, cities face the challenge and uncertainties of developing soft infrastructure to help manage the impacts of large-scale climate change, sea-level rise and the threats to the biosphere. This means bringing together the creative industries, the knowledge economy and emerging green solutions to address increasingly serious risks to natural system.

In some cases, protecting communities against the impacts of a warming climate will often make more sense than moving them. Yet every city and region is unique. There is no one-size-fits-all, and each will face the imaginative challenge of exploring extreme scenarios and building long-term strategies for security and sustainability.

Creative approaches to this challenge might, for example, turn levies into waterfront parks and draw inspiration from Hamburg's HafenCity and Rotterdam's Waterplein, both designed to flood without damaging their function as active centers of community life. Creative communities will need to adapt this approach to harness the introduction of self-sufficient water, energy and food systems to help build a sense of place.

As we enter a world reshaped by technology—from artificial intelligence and genetically-targeted healthcare to virtual reality and autonomous mobility—we will need to learn from the past. Laissez-faire management of the physical, social, and environmental impacts of universal auto ownership in many parts of the world underscores the necessity of drawing on culture, creativity and inclusion to tame and leverage the best of transformative technologies. The underlying challenge is to channel their impacts toward creation of more humane, more sustainable, more livable communities.

Against this background, we now move on to explore the vital role of leadership and governance in what may turn out to be an era of radical change that focuses on transforming both hard and soft infrastructures to deliver a sustainable future. As we will see, local leaders are center stage in meeting the challenges of climate change and social stability. ■

Cities, Communities and Governance: think globally, act locally

Nº7

DAVID DIXON, STANTEC
PETER KINGSLEY, PJR

Alamosa CPV Solar Generating Project
Alamosa, Colorado

In the 1960s, *think globally, act locally* became the rallying cry for a grassroots environmental movement in the US and around the world. Fifty years later the reality of climate change, sea-level rise and the long-term challenges to the world's cities has given the phrase more importance than ever. Catastrophic storms, desertification, wildfires, and record heat and drought have brought home the costs of failing to mobilize an urgent, large-scale response to climate change and threats to biospheric security.

The international community has made minimal progress towards meeting the goals of the 2015 Paris Climate Agreement and the UN's Sustainable Development Goals. Some governments have acted as barriers to action. Some poorer countries demand financial support, or the right to burn carbon-rich fuels that will let them catch up to their wealthy neighbors. Fearing job loss and weak economic growth, some wealthier countries have balked at pursuing aggressive decarbonization. Countries rich and poor fear that taking the lead puts them at an economic disadvantage.

City and community leaders face challenges, from adapting to climate change and regenerating the natural environment, to re-inventing core water, energy and agricultural systems, to leveraging digital technologies, transforming transport systems and to creating—or restoring—a sense of place. Whether they meet these challenges is deeply uncertain and the outcomes will have a decisive impact on the lives of millions. ■

Act Locally: cities take the lead

If there are bright spots to be found in government's leadership response to the challenge of sustainability, they are primarily to be found in cities. While climate change and biospheric failures may appear as abstract threats at a national scale, they represent a clear and present danger to many cities and regions. →

The risks explored throughout these chapters explain why cities and regions have emerged as leaders on sustainable development, moving more quickly and more decisively than national governments. They collaborate and share best practices across boundaries, using platforms like the C40 Cities[1] and 100 Resilient Cities groups.[2] This is particularly significant because two-thirds of humanity will live in cities by 2050. Many cities have embraced response to sustainable principles as a boon to economic performance. They have recognized that long-term resilience planning and support for emerging green industries attracts knowledge workers and the jobs and investment that follow them.

Technology has also bolstered the case for local action. Decentralized and distributed solar, wind, microgrids and increasingly affordable battery-storage systems, for example, are now competitive with large-scale, centralized energy networks. Water and agriculture networks are following a similar route. Digital systems are becoming pervasive. Together, they hold the promise of local independence, security and long-term resilience.

In short, local action represents the best near- and long-term hope for addressing the causes and threats of climate change and biospheric failure, and successfully embracing the opportunities afforded through radical new technology. ■

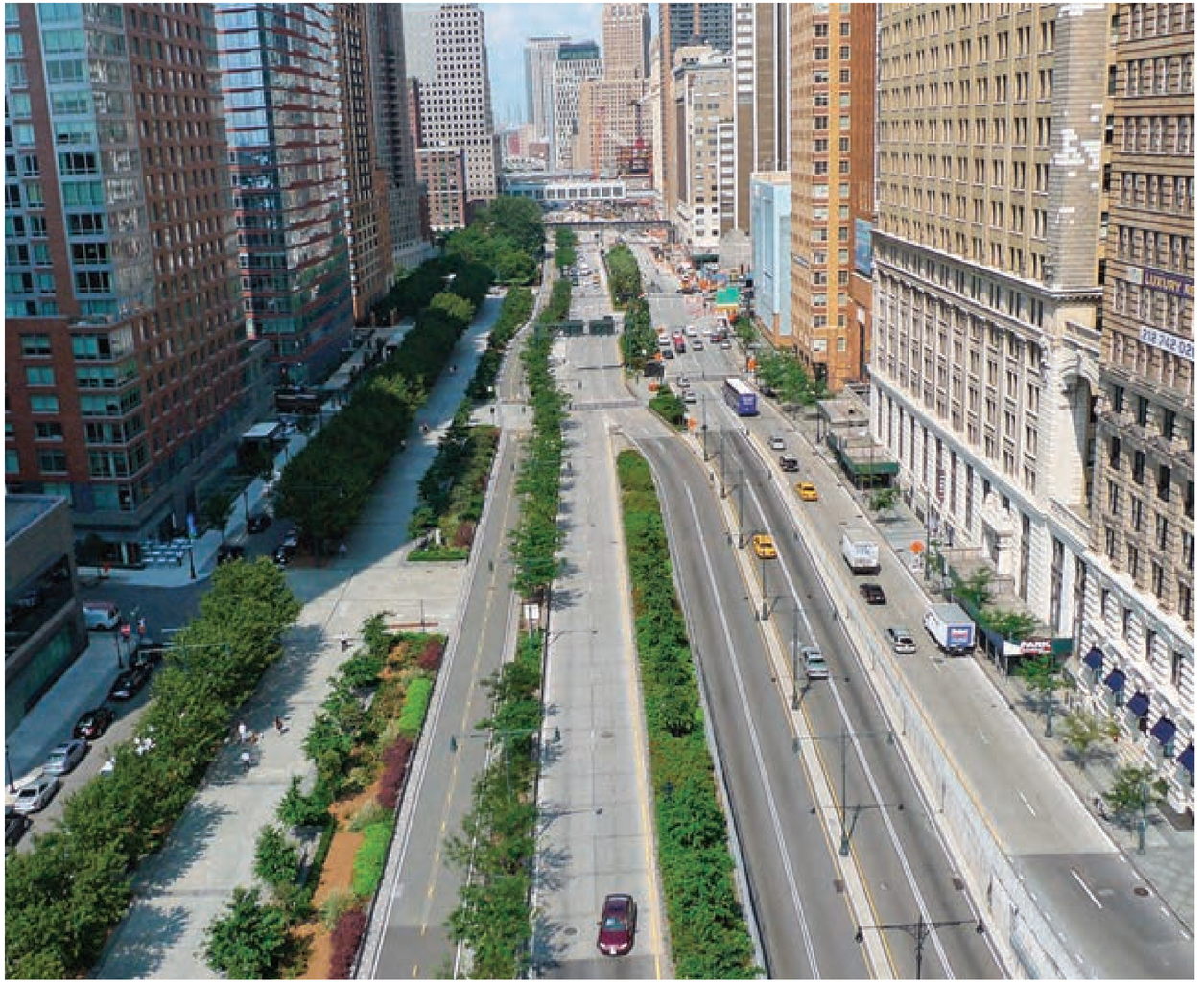
Project Management for ENMAX District Energy System Plant
Calgary, Alberta

[1] C40 cities are taking bold climate action, C40 Cities, 2019, https://www.c40.org/
[2] Helping cities become more resilient to the physical, social and economic challenges, 100 Resilient Cities, 2019, https://www.100resilientcities.org/about-us/

Acting Costs: inaction will cost more

As our introduction notes, public policies and "the design and rapid implementation of sustainable infrastructure over the next twenty years will largely determine the long-term future of the planet." The key uncertainty: can social, economic, and political stability survive a period of sweeping transformation in both the natural world and urban, technological infrastructures?

Timescale and cost will prove critical. The Intergovernmental Panel on Climate Change (IPCC) makes one thing repeatedly clear: human society has little time left to stop releasing carbon into the atmosphere. Business as usual will impose enormous financial and political costs. ■



Human society has little time left to stop releasing carbon into the atmosphere.

Route 9A West Street Promenade Project
Manhattan, New York

A Perfect Storm: competing problems

One reason national governments appear unable to devote sufficient attention and resources to decarbonization and adaptation is the welter of other challenges—some urgent—that threaten major social and economic change in coming decades. Beyond decarbonization, these include:

- **Aging populations.** The UN expects the number of people 60 and older will increase 50% between 2030 and 2050, reaching 2.1 billion and topping the number of children for the first time in history.[3] This older population will grow faster than the working-age population, increasing political stress as governments try to adjust funding formulas for healthcare and social insurance.
- **Economic disparities.** In wealthy countries, globalization, tax policies and job losses (some due to automation) have coincided with reduced social and economic mobility. Real household income in the US has not changed since the 1970s. Increases in wealth have concentrated largely in the top 5% of households. These trends threaten political stability. While artificial intelligence (AI) and green technologies may create a wave of better-paying jobs, governments will need to invest heavily in initiatives to promote greater economic equity and broader access to the benefits of rapidly evolving knowledge economies.
- **Radical technologies.** New winners and losers will emerge over the next two decades. The developed world will rebuild transportation infrastructure to integrate new forms of mobility, including autonomous vehicles. Smart city technology will introduce webs of sensors to monitor and manage traffic, energy, water, wastewater and other systems. AI will transform both industrial production and service industries. How these changes play out remains uncertain. They may bring unprecedented economic and environmental benefits but will likely also threaten the jobs of millions of people across the globe and require massive new investment in infrastructure.
- **Retrofitting existing infrastructure.** The developed world faces the challenge of re-engineering or replacing existing infrastructure. In the US, the cost of this may reach US $2 trillion, or roughly 10% of the US economy, by the late 2020s.[4] The European Investment Bank suggests that Europe needs to spend US $750 billion annually to keep pace with its infrastructure needs.[5]

These challenges of politics and governance will increase pressure on community cohesion and stability. Climate change may lure governments into the "priority trap"—focusing on one problem at the expense of others. To avoid the trap, governments at all levels will need to retrain themselves to take a more holistic, ecosystems approach to problem solving. There are reasons for optimism. City and regional governments have proven nimble at responding to multiple priorities. ■

[3] World Population Ageing, United Nations, 2017, https://www.un.org/en/development/desa/population/publications/pdf/ageing/WPA2017_Highlights.pdf
[4] Infrastructure Report Card, American Society of Civil Engineers, 2017, https://www.infrastructurereportcard.org/wp-content/uploads/2017/04/2017-IRC-Executive-Summary-FINAL-FINAL.pdf
[5] Investment in infrastructure in the EU - Gaps, challenges, and opportunities, European Parliament, 2018, http://www.iberglobal.com/files/2018-2/infrastructure_eu.pdf

Act Locally: guiding principles

High Water Protection Program
The Hague, Netherlands

In the face of all these challenges, *think globally, act locally* is taking on new meaning. Broad changes in policy, funding and regulatory regimes are needed at all levels of government. The urgent task of adapting to climate change, regenerating the natural environment, transforming water, energy, agriculture and transport systems will largely fall to local government.

In 2005, the flooding of New Orleans during Hurricane Katrina focused attention on the truths of global climate change and systemic risk.[4] Lessons from that preventable disaster suggest four principles for policy and action:

- **Identify threats and act now to address them.** The threats associated with climate change are in plain view. Hurricane Katrina's devastation was a surprise because local leaders chose for decades to ignore well-understood hazards of crumbling levees and unprotected channels to the open sea. Every city and region understands the collective dangers of not pursuing aggressive decarbonization.

- **Focus on community, equity, and inclusion.** While very different crises had forced US cities like Atlanta (fear of economic decline), Birmingham (civil rights), and Boston (school desegregation) to fashion new social compacts that transcended deeply rooted divisions and unlocked the ability to address threats and move forward, longstanding racial divisions blocked New Orleans's efforts to make the critical decisions and investments essential to protect the community from a disaster that many had predicted for decades. Hurricane Katrina triggered New Orleans's moment of truth. In the wake of Katrina, New Orleans acted locally. From across the racial spectrum, leaders in government, the private sector and institutions came together to forge a new social compact. Moral arguments for inclusion carried less weight than the urgency of making tough decisions about protecting the city. A culture of inclusive engagement began to displace racially defined political competition. Historic differences gave way to a realization that New Orleans would have to come together and build a shared political will to make decisions about rebuilding, fight for essential resources and adapt to rising sea levels.

- **Build "multitasking infrastructure."** When Dutch architects, planners, and engineers helped launch the "Dutch Dialogs" in post-Katrina New Orleans, they shared their experience with adaptation to natural threats. In the wake of the Second World War, the Netherlands had faced a critical decision: build defensive infrastructure to protect against North Sea storms, like the one that killed 2,000 people in 1953, or rebuild infrastructure for livability—housing, schools, parks, transportation, ports. The Netherlands >

[4] Full disclosure: this author led development of the citywide post-Katrina master plan for New Orleans.

could not pay for both, yet it could not afford not to *have* both.

The Dutch adopted a mantra: *a guilder spent on protection must be a guilder spent on quality of life*. This demonstrates that cities are best placed to deliver long-term, holistic solutions. Rather than pouring funds into storm gates and sea walls, the Dutch chose to invest in "multitasking infrastructure." Waterfront parks were designed to hold back seas. Artificial barrier islands protect against flooding and serve as seaside resorts. New port facilities unlock economic growth but also function as appealing waterfront urban districts. Fifty years later, Hamburg, Germany, adopted a similar approach, protecting the city against increasingly violent storms while preserving its historic core, boosting its economy and creating an amenity-filled waterfront. HafenCity has risen on land reclaimed from the River Elbe and showcases exceptional contemporary urban planning and design. Designed to accommodate storm-driven flooding, the district combines amenities that bring people to the water the rest of the year.

Under Mayor Michael Bloomberg, New York City proposed building "Seaport City,"[6] a new urban district designed to protect the city's densely packed southern tip and create new business and amenity resources. We can expect to see more cities around the world adopting this multitasking approach.

- **Prioritize protecting and rebuilding, relocate if** necessary. Some of the most poignant stories of New Orleans after Katrina concern attempts by federal officials and outside consultants to bar residents of two long-established African-American neighborhoods—the Lower Ninth Ward and New Orleans East—from rebuilding their devastated neighborhoods. Early declarations that relocation should take precedence over efforts to re-establish these communities aggravated longstanding social divisions. That led to deep suspicion of federal motives and significantly slowed recovery.

Ultimately residents were proved right. The multiple challenges and extraordinary costs of relocation—building tens of thousands of new housing units; reproducing an extensive informal social safety net in which neighbors helped neighbors; creating new access to jobs for many who lacked cars; preserving a rich community culture; and, of course, the difficulty of finding acceptable relocation sites—proved overwhelming. "Democracies are not empowered to uproot and relocate something so complex as a living community," noted Marshall Truehill, former chair of the New Orleans Planning Commission and a widely-respected leader of recovery efforts following Hurricane Katrina, adding "it would be less complicated—and potentially less expensive—to lower the Gulf of Mexico than to find right new homes for 50,000 New Orleanians."[7]

NGOs and national governments often focus on grand plans to move millions of people out of harm's way, but recovery efforts in New Orleans; Kobe, Japan; Christchurch, New Zealand; and parts of Somalia ravaged by famine and war all tell us that top-down relocation plans will likely spark widespread opposition. Often, but not always, they prove more expensive. As New Orleans demonstrated, finding relocation sites is complex. Policymakers may understand the logic of "strategic retreat," but people being told to move often view the decision as a failure to respect their cultural, social and economic ties to place and to help them remain. This disconnect reinforces the importance of acting locally. Officials closest to implementation typically have a richer understanding of the costs of relocating and potential to protect people in place, which they can balance against future risks.

However, as the Brookings Institution notes, the world experiences roughly 400 natural disasters, affecting 200 million people, annually. While a large majority choose to return home,[8] Brookings points out that relocation sometimes represents the only option. Once again, there is no one-size-fits-all.

More important, history may not be a guide. Potentially extreme sea-level rise and rainfall over the next few decades will change the calculations and definitions of long-term resilience. City leaders have a responsibility to explore even the most extreme scenarios and develop long-term strategies that work, whatever may emerge. Engagement with communities facing threats that may materialize decades in the future presents new leadership challenges when short-term economic, cultural and psychological costs may weigh heavily against long-term security.

Relocation is possible. The East Baltimore Development Initiative (EBDI),[9] launched to give the city access to biotech investment, represents one of the most successful efforts in the US to relocate a neighborhood. The community, largely African-American and low-income, took a central role in every aspect of planning and implementation. Residents owned the plan. EBDI took a case-management approach to the full spectrum of neighborhood issues. They found housing that worked for each household. They addressed health, social and economic concerns that complicated relocation and helped local business that had depended on neighborhood patronage to find new opportunities. ■

[6] Bloomberg taps Dutch firm for Seaport City study, The Real Deal, Oct 2013, https://therealdeal.com/2013/10/03/bloomberg-taps-dutch-firm-for-seaport-city-study/
[7] Conversation with New Orleans Planning Commission staff reviewing options for rebuilding the New Orleans East neighborhood, Truehill [comment by] et al, Nov 2008
[8] Natural Disasters, Conflict, and Human Rights: Tracing the Connections, Brookings Institution, Mar 2010, https://www.brookings.edu/on-the-record/natural-disasters-conflict-and-human-rights-tracing-the-connections/
[9] East Baltimore Development Initiative, EBDI, 2019, http://www.ebdi.org/about

Investor Activism, Politics and Public Attitudes

City leaders are not alone in driving regeneration and renewal. Institutional investors and financial regulators, concerned about the slow pace of government action, have shown increasing signs of taking active, interventionist positions. The shift in momentum may be decisive.

Corporate leaders, dependent on long-term finance, face pressure from regulators and investors to develop rigorous scenarios and explain their strategies to deal with climate change, threats to the biosphere and converging waves of change. The same principles apply to city, community and utility leaders. The regulators' goal is transparency for ordinary investors. Corporations, recognizing the risks to their license to operate, are investing heavily, making commitments to cut emissions and reduce pollution.

To illustrate, Larry Fink, the CEO of Blackrock, with US $1.7 trillion under management and one of the world's largest asset managers, has raised the stakes. *Long-term* has dominated the language of his annual letter to CEOs for the last two years,[10] as have discussions of social goals and stewardship. He warns that without rigorously defined long-term strategies, corporations will lose his support.

How this will carry through in practice remains uncertain, but an acknowledgment at this level is significant. Estimates suggest the aggregate costs of funding core infrastructure to 2035 could reach close to US $90 trillion[11]—an unprecedented level, over a short time scale. It means that investors have begun playing closer attention; long-term returns matter, but increasingly, so will environmental, social and governance factors.

In parallel, cities continue to take a lead, collaborating across regional and national boundaries, irrespective of national policies. The C40 Cities alliance requires its 96 member cities to deliver detailed plans, by 2020, for achieving carbon budgets consistent with the IPCC's 1.5°C (2.7°F)-of-warming target. They have mapped the cities at risk[12] from heat extremes, water shortages, food security and energy disruption by 2050, and in October 2019 went further, putting inclusive climate action at the center of all urban decision-making in a "Global Green New Deal …recognizing a global climate emergency. The call to action is clear.[13] ■

[10] Chairman's Letter, Larry Fink [BlackRock], 2018, https://www.blackrock.com/corporate/investor-relations/larry-fink-chairmans-letter
[11] $90 Trillion Infrastructure Transformation Imperative for Sustainable and Climate Safe Growth, United Nations Climate Change, Oct 2016, https://unfccc.int/news/90-trillion-infrastructure-transformation-imperative-for-sustainable-and-climate-safe-growth
[12] The Future We Don't Want, C40 Cities, 2018, https://www.c40.org/other/the-future-we-don-t-want-homepage
[13] Mayors Announce Support For Global Green New Deal, Recognize Global Climate Emergency, C40 Cities, Oct 2019, https://www.c40.org/press_releases/global-gnd

Cities and Leaders

Blue and Green Corridors
New Orleans, Louisiana

We have known about the threat of a changing climate for decades, but increasingly powerful computer models and a growing pool of climate data have helped bring the risks into sharper focus. The lived experience of the 21st century has also played a role in broadening public awareness, from ice loss in the Arctic to more droughts and wildfires to record heat. Seven of the planet's ten hottest years on record have occurred in the last decade, and all ten have occurred in the last two decades.[14]

We know, in short, that we must act now. We also know that initial attempts at action have produced only limited results. At the international level, few mechanisms exist to enforce pledges for reducing greenhouse gases made in the Paris Climate Agreement. At the national level, government leaders often favor policies with short-term payoffs over those that address long-term needs.

Instead, city and regional governments have emerged as the lead actors in reducing the impacts that have driven planetary warming and climate instability. They may operate within frameworks established at the international level. They may work to meet targets set at the national or provincial levels. But the nuts-and-bolts work of applying policies is happening where the crisis—from rising oceans to superstorms to extreme heat—will make itself felt first.

Think globally, act locally has never mattered more. ■

[14] https://www.climatecentral.org/gallery/graphics/the-10-hottest-global-years-on-record

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