Policy Responses to Emerging Topics in Urban Sustainability: Distributed and Localized Infrastructure in Cities

Science-Policy Dialogue Report No. 1

ICLEI
Local Governments for Sustainability

Sustainable Healthy Cities

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ABOUT US

The Sustainable Healthy Cities (SHC) Network is a U.S. National Science Foundation supported sustainability research network focused on the scientific advancement of integrated urban infrastructure solutions for environmentally sustainable, healthy, and livable cities. We are a network of scientists, local government representatives, industry leaders, and policy partners committed to building better cities through innovations in infrastructure design, technology and policy. Our network connects across nine research universities, major metropolitan cities in the U.S. and India, as well as infrastructure firms and policy groups to bridge research and education with concrete action in cities.

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FOREWORD SCIENCE PERSPECTIVE

The Sustainable Healthy Cities (SHC) Network is a U.S. National Science Foundation-supported network of scientists, local governments, industry leaders, and policy partners committed to building better cities through innovations in key urban infrastructure and food provisioning systems. Our work is unique in that we are addressing multiple sectors—energy, water, buildings, transportation-communication, wastewater and waste management, food supply, and public space/green space—and their interactions, as they shape multiple sustainability outcomes in cities. Through conversations with our city and policy-partners, our network is focused on diverse sustainability outcomes, including wellbeing, health, economy, environment, equity and livability.

Core areas of work for the SHC network include advancing the science of tracking infrastructure-related sustainability outcomes, and applying those learnings to questions of localized and distributed infrastructure. Are our cities more sustainable when we invest in more localized and distributed infrastructure and food supply systems? What are the trade offs and co-benefits, and their distribution across society? These are our overarching research questions, relevant to many cities that are setting goals for local solar energy generation, urban agriculture, and food waste-to-energy projects, while also grappling with the advent of electric vehicles, smart meters and autonomous transport.

Our research network is keenly aware that urban infrastructure transformations from spatial design and technology perspectives must go hand in hand with practice and policy considerations. So, at our network's annual meeting in August 2017, we intentionally designed the agenda to enable conversations that would allow us to capture policy and practice responses to the research findings and questions being raised at the frontier of localized and distributed infrastructure research, as represented by the lines of research being pursued by SHC network researchers.

This document presents a synthesis of those conversations. Indeed, documenting such science-policy dialogue is a core function of our research network. Put simply, how city staff and policy makers react to emerging lines of research about new infrastructure configurations—the questions they have, the concerns that are raised by them, the topics they are most excited by—are important data points for understanding the real-world political economy in which new science findings around localized and distributed infrastructure will be internalized and deployed.

If you are a city practitioner or an urban policy-maker, we hope this document provides greater understanding of the science questions, advances and the knowledge gaps in the localized and distributed infrastructure research space, and their policy and practice implications, as articulated by your peers. For researchers, we hope this document paints a more complete picture of the policy and practice landscapes in cities where new science about local and distributed infrastructure systems is being processed and deployed.

This science-policy dialogue report is designed to be the first in a series of reports that the SHC network will be developing over the next few years on the topic of sustainable urban infrastructure. The knowledge co-production captured in this report would not be possible without the ongoing and active engagement of our government and policy partners with network researchers.

We thank our partners for their insight, excitement and commitment in working with the research community to build better cities. We very much look forward to continuing the dialogue and journeying together to advance an actionable science of sustainable urban infrastructure systems.

Sincerely,

Dr. Anu Ramaswami

Director, Sustainable Healthy Cities Network

Professor, Public Affairs and Engineering, University of Minnesota

Sustainable Healthy Cities
A National Science Foundation-supported Sustainability Research Network (SRN)

FOREWORD- PRACTICE PERSPECTIVE

Successful collaborations that cross the academic-practitioner “divide” to produce knowledge that is usable by practitioners, especially those in government, have always been a challenge to achieve. The area of sustainability research is a multi-disciplinary area where it is important to achieve this type of success on a regular basis, as one of the goals of this type of research is to provide actors in the public sphere with research results to enable them to make necessary changes in practice and policy that are both efficient and effective.

There are structural and institutional reasons that make successful collaborations difficult. It is because of these challenges that the Sustainable Healthy Cities (SHC) Network has made the successful bridging of the academic-practitioner divide around sustainability science and decision-making one of its key objectives. This translation document and the others to follow over the life of the Sustainable Healthy Cities Network provide evidence of this objective.

Town+Gown is a university-community collaboration program, utilizing several models of university-community collaboration, which is situated on the practitioner side of the divide and within a governmental unit—the City of New York. A named collaborator on the Sustainable Healthy Cities Network’s proposal to the National Science Foundation, Town+Gown has participated in the development of post-convening materials aimed at local government practitioners, including those working in the “test bed” cities for this network, such as New York City.

Town+Gown’s experience in facilitating work across the academic-practitioner divide involves negotiating differing expectations, motivations, understanding and language to produce work of benefit to both sides. Academic institutions need to publish and advance novel research, while government practitioners, despite the open data movement, still have confidentiality concerns and, to some extent, discomfort in revealing to the public what they do not know. Government practitioners also need research to reflect their operational, jurisdictional and political constraints, all of which are not always readily evident to researchers not directly involved in the day-to-day details of urban management, local and regional governance, and the public policy decision-making process.

The discussions captured in this document not only seek to cross the academic-practitioner divide, but they also present peer-to-peer interactions across practitioners that are rare in practice, such as interactions among the nine test bed and partner cities of SHC.

This translation document is the first of many that will follow during the life of SHC and, with other planned translation documents, contributes to a model for successful collaborations to produce knowledge that practitioners in the public sphere can make actionable—either by changes in practice and policy or by leveraging future research based on continued interactions between practitioners and academic researchers.

Sincerely,

Terri Matthews

Director, Town + Gown

New York City Department of Design and Construction

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Executive Summary: Policy Responses to Distributed and Localized Infrastructure in Cities

The Sustainable Healthy Cities Network represents an interdisciplinary group of researchers—working alongside city, industry, and policy partners—committed to advancing the science of distributed and localized infrastructure in cities. In August 2017, the network hosted a dialogue to consider the science, policy, and practice of distributed and localized infrastructure in cities. Over the course of two days, the dialogue explored emerging science findings and key policy and practice responses to those findings. This document highlights those policy and practice discussions.

WHY DISTRIBUTED AND LOCALIZED INFRASTRUCTURE?

Localization and decentralization of key infrastructure systems has emerged as a potential strategy for helping cities achieve multiple sustainability outcomes spanning environment, economy, health, wellbeing, and equity. Examples of this movement include cities declaring their intention to increase local renewable energy generation, decrease reliance on imported water, or increase local food production. Distributed infrastructure systems can include rooftop solar panels, bike and car sharing options, autonomous vehicle fleets, urban farms, rain gardens, and on-site wastewater treatment, just to name a few.

SCIENCE-POLICY DIALOGUE: A HIGH-LEVEL VIEW

Cross-cutting discussions from an opening plenary session helped frame high-level reactions to the following key questions: 1) What does the action-focused view from cities look like regarding distributed and localized infrastructure as a tool for advancing sustainability goals? 2) How do trends around localization and distributed infrastructure interact with larger trends in urban sustainability policy and action? 3) What would a future with more distributed and localized infrastructure mean for city data collection and benchmarking efforts? Below are key takeaways:

Supplementing, Not Replacing: It is important to frame conversations about distributed and localized infrastructure as supplementing rather than replacing traditional centralized or existing infrastructure systems.

Tangible, Locally Felt Co-benefits: Many cities want to depoliticize sustainability actions. One strategy is to keep the topic of conversation on tangible, locally-felt co-benefits. Community choice, resource efficiency, and local resilience are all important frames.

Citizen Science for City Data: Increased direct interaction with community members on data collection efforts could improve the quality and legitimacy of fine scale data collection within city boundaries.

Working toward a Dashboard: Developing a citywide dashboard that represents data from the full suite of desired outcomes across sectors and operational areas within a city can help build understanding of how decisions in one sector or operational area affect another.

Cross-sector and trans-boundary considerations of trade offs and synergies are an important part of any city effort to develop a comprehensive view of sustainability action. There is a need for more robust data, science, and research to inform, at fine scales, the processes of evaluating anticipated benefits and trade offs from specific infrastructure actions that cities might take.

SCIENCE-POLICY DIALOGUE: A SECTORAL VIEW

Over the two-day workshop, network researchers presented high-level research findings. City representatives shared perspectives on the implications of the research findings, and the group as a whole discussed challenges in translating science into actionable policy. The highlights below share select research takeaways and science-policy discussion topics that emerged from the dialogue.

Energy

Select research takeaways: 1) Fine-scale data can reveal trends in actual energy use to inform broader system planning under new urban form and technology scenarios. 2) Consumers vary widely in how they respond to both billing and program-related messaging.

Select science-policy discussion points: 1) Enlisting customers in real-time load-balancing is a currently large and untapped opportunity. 2) Transitions from gas to electric heating will play out differently in different cities. 3) Expecting a rapid transition to electric vehicles, cities are keenly interested in how this transition will play our spatially.

Green Infrastructure (GI) & Food Systems

Select research takeaways: 1) Not all GI (trees, greenery and urban farms etc.) provide the same benefits, and not all areas of a city need or will benefit from all GI types in the same way. 2) There are not sufficient fine scale data or models to quantify benefits from small-scale GI, such as heat and flood mitigation. 3) Among urban food actions, diet change and food waste management can provide more environmental benefits compared to urban agriculture.

Select science-policy discussion points: 1) Understanding how GI interacts with more traditional grey infrastructure is critical. 2) There are potential urban sprawl trade offs when considering how best to use land in an urban area for green cover or urban agriculture. 3) Urban food action plans may benefit from clarifying the benefits of urban agriculture beyond food self-sufficiency.

Transportation

Select research takeaways: 1) Americans currently are relatively unfamiliar with autonomous vehicle (AV) futures, and their opinions may evolve rapidly as the transition moves forward. 2) Early thinking suggests that fleet-operated AV service models may enhance equitable access to mobility services. 3) Land use and travel modes can affect subjective wellbeing, spanning concepts like in-the-moment happiness or longer-term assessments of life satisfaction.

Select science-policy discussion points: 1) There are trade offs in the ways that AVs and electric vehicles (EVs) will impact future vehicle miles traveled. 2) The widespread use of AV will have implications for urban development patterns and urban lifestyle preferences. 3) Under certain policy scenarios, AV futures may unlock road space currently dedicated to parking, creating opportunity for repurposing.

Water and Wastewater

Select research takeaways: 1) Lab-scale research is incubating new technology for waste-to-value recovery from difficult-to-treat urban organic wastes, such as food waste. 2) Value added products from waste include energy that can be used within circular economies in cities, as well as platform chemicals used in common cosmetic products.

Select science-policy discussion points: 1) Food waste integration with wastewater treatment should be explored further as a possible greenhouse gas mitigation lever in cities. 2) Waste-to-value conversion viability is affected by public perception concerns. 3) Competing department/agency regulations and goals can limit cross-sector waste reuse, especially around wastewater.

LOOKING AHEAD

Answering the questions raised by this dialogue will require new modes of collaboration within and across research, practice, and policy communities. The Sustainable Healthy Cities Network is committed to advancing the science of knowledge co-production and science-policy communication on the topic of sustainable urban infrastructure. The ongoing work of the network and its partners intends to build on this foundation of joint science-policy dialogue on emerging distributed and localized infrastructure in cities.


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An Introduction to the Science, Policy and Practice of Distributed Infrastructure in Cities

INTRODUCTION

The Sustainable Healthy Cities (SHC) Network represents an interdisciplinary group of university researchers—working alongside city, industry, and policy partners—committed to advancing the science of distributed and localized infrastructure systems in cities for multiple sustainability outcomes.

The goal of the network is to better understand the ways in which distributed and localized infrastructure interventions are—or are not—well positioned to deliver diverse sustainability gains relating to the economy, environment, equity, health, and wellbeing. SHC considers these diverse outcomes across key urban infrastructure sectors and their interactions, including: energy, green infrastructure and urban food systems, transportation, and water/wastewater.

Why Distributed and Localized Infrastructure in Cities?

The localization and decentralization of key urban infrastructure systems has emerged as a potential strategy for helping cities maximize sustainability outcomes. Examples include cities that have declared their intention to increase local renewable energy production within their boundaries, decrease their reliance on imported water supplies, or increase their ability to produce food locally. Distributed infrastructure systems can include rooftop solar panels, bike and car sharing options, autonomous vehicle fleets, urban farms, rain gardens, micro-parks, and on-site wastewater treatment facilities, just to name a few, all of which are also often linked to larger systems.

While transitions to localized and distributed infrastructure systems have recently gained momentum, scientific understanding about how the scale and spatial configuration of key infrastructure systems affects their ability to deliver multiple sustainability outcomes in cities is limited (Ramaswami et al., 2016). Advancing such science in partnership with cities and practitioners is a key goal of the network.

Purpose of this Report

In August 2017, the network convened more than 100 participants—including faculty researchers, graduate students, city and regional government representatives, policy partners, and industry representatives—to consider the implications of distributed and localized infrastructure systems for sustainability futures in cities.

Over the course of two days, network-affiliated researchers presented high-level research findings from recently or soon to be published work. External experts, city representatives and practitioners shared reactions to the research findings, and the group as a whole discussed challenges in translating emerging science into actionable policy and implementable programs at the city level.

This document represents a synthesis of the policy and practitioner reactions to emerging research on distributed and localized infrastructure, as represented by SHC re-

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searchers in 2017. The report can be read as a "state of" report regarding science-policy interactions on topics of localized and distributed infrastructure systems.

Three Key Starting Points

Three key starting points undergirded the larger workshop conversation.

First, urban sustainability concerns regularly cross jurisdiction boundaries and span multiple scales in terms of governance, implementation, and impact considerations. Put simply, considerations of sustainable urban infrastructure extend well beyond the boundaries of a city proper. Urban sustainability is complex, in part, because of these multi-jurisdictional, multi-scalar dynamics (Ramaswami et al., 2016).

Second, to address this complexity, urban sustainability science and policy will benefit from a systems thinking perspective. Understanding systems interactions—e.g. between natural, engineered, institutional, and social systems—as they impact diverse sustainability outcomes can better inform urban sustainability practice and policy-making (Ramaswami et al., 2012). Dialogue that links systems science with values judgments embedded in policy-making can benefit both science and policy.

The third key premise undergirding the workshop is a recognition that future-oriented conversations around distributed infrastructure are about distributed and localized infrastructures interacting with and complementing centralized infrastructure systems, not necessarily replacing them. From a practical perspective, all cities will be subject to "infrastructure lock-ins" whereby they have already committed to or are already reliant on centralized systems that have a useful life span expected to last decades. These lock-ins, however, do not mean that distributed infrastructure solutions cannot be strategically coupled with existing centralized systems to maximize sustainability outcomes and avoid new lock-ins.

Structure of the Report

This document presents key policy and practitioner responses to emerging research on distributed and localized infrastructure systems, as represented by the work of SHC researchers in 2017. It does so across the major sectors in which the network is conducting research:

energy | green infrastructure and urban food systems | transportation | water and wastewater

To facilitate a discussion about policy and practitioner responses across these sectors, network researchers first presented key areas of emerging research related to each sector. A panel discussion and open forum conversation followed each set of research presentations. For each sector discussion, this document presents:

1) A brief synopsis of the emerging research topics presented by SHC researchers

2) Science-policy dialogue that emerged in reaction to emerging research topics

3) Key policy & practitioner considerations looking to the future

The report ends with a cross-cutting discussion about charting the path forward on managing transitions toward emerging localized and distributed infrastructure in cities. Discussion topics that arose from the workshop include a focus on the urban management and implementation considerations of localized and distributed infrastructure, perspectives from multi-city organizations, factors influencing the success of science-policy communication in the urban sustainability space, and an explicit view towards the future regarding research and practitioner engagement efforts needed to answer key questions around distributed and localized infrastructure in cities.

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Topics in Distributed and Localized Energy Infrastructure

EMERGING SCIENCE FINDINGS

Sustainable Healthy Cities Network researchers are working to understand how distributed and renewable power generation in cities will interact with the larger electricity grid, incorporating new technologies, energy transitions, and consumer interfaces. The panel session began with research presentations featuring emerging or recently published work. External researchers and city government discussants then reacted to the slate of research presentations.

Modeling Fine-Grain Energy Distribution in Cities: Understanding a city's electrical distribution system—how electricity gets from generator to customer—is an important part of understanding how distributed energy systems could be practically implemented. Electrical models being developed by SHC researchers include real world information on both electrical topology (wires and transformers) and premise-level meter data, collected at 15-minute intervals for all meters in the system and at faster intervals for a subset of buildings in Fort Collins, CO and Tallahassee, FL. All data is geospatially indexed, allowing the electrical system to be overlaid with property records and demographic data. Using these data, it is possible to better understand detailed patterns of electricity usage across a city, and how distributed energy resources, such as rooftop and community photovoltaic generation, can best be integrated into the city's energy system – all of which are nherently cross-disciplinary questions combining the social, physical and political sciences. (Zimmerle, 2017).

City Energy Planning under Different Technology and Urban Form Scenarios: Understanding how today's electricity usage patterns connect to equity and environmental outcomes requires understanding the spatial distribution of energy use at the census block-level or finer. It also requires an understanding of how the "larger grid" operates both temporally and spatially, as new technologies are introduced within cities such as electric heating, electric vehicles and district energy. Both fine-grain and grid-level understanding is needed to accurately assess patterns of GHG emissions, air pollution, cost, and resilience. This type of data can also inform future energy planning in cities under different technology scenarios, including waste-to-energy conversion and local renewable energy generation. Collecting data on the spatial distribution of energy use in particular allows for an understanding of how these future technologies could affect energy demand under different scenarios of urban form—compactness or sprawl (Modi et al., 2017).

KEY RESEARCH TAKEAWAY 1: Understanding electricity use data at finer temporal and spatial scales allows researchers to better understand actual patterns of use. More detailed understanding of energy use and demand can help inform efficiency and conservation efforts as well as future electricity planning in cities taking into account different technology and future growth scenarios.

Energy Consumer Behavioral Data: A two-city study of Tallahassee, FL and Fort Collins, CO reveals trends in energy consumer behavioral data with respect to electronic billing and voluntary compliance programs. Electronic billing appears to be associated with decreased energy consumption. Electronic billing was more frequently adopted in smaller, older homes. Consumers who have opted for electronic billing tend to live in areas with a higher percentage of minority residents and in areas where residents are less likely to have achieved high levels of education. A consumer's level of energy use does not appear to influence the decision to receive electronic billing statements. With respect to voluntary participation (efficiency, conservation, etc.), low-compliance programs are more likely to be participated in by people with homes of lower market value, by people with larger homes, and by people living in census blocks with a higher percentage of minority residents. Those participating in high compliance programs are more likely to live in homes of higher market value, to live in smaller homes, and to live in census blocks with a lower percentage of minority residents (Curley, 2017).

Seasonality in Behavioral Nudging: Behavioral nudges can increase the effectiveness of policy program messaging. SHC researchers find that the extent to which the content of messaging influences electricity utility customer behavior – both consumption and participation in policy programs (i.e. energy conservation program, solar farm subscription) - is seasonal and sensitive to weather events. Moreover, all things being equal, the social media discussion about utility programs increases in summer months. This likely reflects an attempt to focus on tips and programs that have the largest impact on summer's peak demand. (Curley and Feiock, 2017).

KEY RESEARCH TAKEAWAY 2: Energy consumers exhibit varied behavior when it comes to opting for electronic billing and participating in voluntary compliance programs for efficiency or conservation. Detailed understanding of current consumer behavior can help inform efforts to increase participation in electronic billing and voluntary compliance programs. Understanding patterns in messaging can help inform decisions about how to maximize positive reception of messaging and potentially trigger sustainable behavior change.

KEY SCIENCE-POLICY DISCUSSION POINTS

Are baseline expectations of 100 per cent reliability and industrial quality power supply (i.e. no load shedding or voltage fluctuations) necessary for all consumers? Would people or facilities with flexible power needs accept a rate cut in exchange for slightly reduced total reliability or power quality? From a utility and regulator perspective, total reliability is still a key concern when it comes to integrating renewable supply to the grid.

There is an opportunity to integrate real-time usage data with social media analysis trends and impacts in energy usage. In this type of effort, social media becomes a contextual factor for understanding how people and events interact with energy usage behavior.

Opt-in programs for real time monitoring and feedback still require consumers to buy new hardware to install alongside their meters. The role of maintaining new hardware has proven labor intensive for utilities. Cost considerations and overall level of effort both seem to affect consumer interest in opt-in programs.

Benchmarking presents uncertainties with respect to consumer behavior. For those consuming electricity below the area average, it is an open question whether their usage levels will trend towards the average after being made aware of their relatively low consumption habits.

Utilities are anticipating a rapid transition to electric vehicles. They are expecting the transition will take place quickly once a widespread shift begins, but they are not yet sure when and where the transition will start, which makes current planning difficult.

Strong and appropriately calibrated data-sharing agreements are important for meeting the fine-scale data needs of researchers and the privacy and legal constraints of utilities who are responsible for protecting consumer data.

Often, public utility commissions—not utilities—are the entities responsible for putting in place regulations that unnecessarily restrict data sharing. Utilities find themselves in a position where they would be willing to share data, but are trying to avoid violating current regulations.

FUTURE POLICY AND PRACTICE CONSIDERATIONS

Cities are interested in understanding how a transition to electric vehicles will play out spatially. This includes understanding how best to arrange charging infrastructure and how such transitions will be served by renewable energy.

Cities are still grappling with the equity and land use implications of community and rooftop solar installation. Typologically, cities do not yet have a clear understanding of what makes a desirable distribution structure for rooftop

and community solar from either a technical or equity perspective. Furthermore, it is still unclear whether and how land use regulations will accommodate the physical footprint needs of distributed energy generation infrastructure.

Cities are interested in research about the best information and messaging strategies that influence consumer behavior. There is a particularly acute need for understanding what affects consumer behavior vis-a-vis conservation efforts as well as general usage trends.

A new frontier of utility consumer interaction is to offer real time messaging on usage data. Can a text message asking people to temporarily reduce usage in exchange for a rate benefit serve as a load balancing tool? Many major utilities have launched smartphone apps focused on general information and billing, but less experimentation has happened around real-time demand updates.

There are options for structuring data sharing agreements such that university researchers are neutral brokers. This often involves considering researchers as contractors who, as a function of their contractor agreements, assume responsibility for protecting the data.

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Topics in Distributed and Localized Transportation Infrastructure

EMERGING SCIENCE FINDINGS

Sustainable Healthy Cities Network researchers are working to understand how travel behavior, new technologies and land use configurations interact to determine urban mobility futures. The panel session began with research presentations featuring emerging or recently published work. External researchers and city government discussants then reacted to the slate of research presentations.

American Preferences for Autonomous Vehicles: Roughly a third of adult Americans would choose an autonomous vehicle (AV) for their next vehicle purchase, assuming cost-competitiveness with human driven vehicles (HVs). For a vehicle that has dual autonomous and human driving modes, Americans estimate they will drive their vehicle in manual mode (as in HV) 64 percent of the time. Less than 20 percent of Americans choose shared AVs as their primary mode of travel under different per-mile cost scenarios. Respondents indicated, however, that shared AVs are particularly attractive for traveling to destinations where parking is a challenge. The average American thinks that AVs should be allowed to travel empty up to 20 percent of the time, whereas 25 percent of Americans think that all empty travel (a vehicle without passengers) should be banned. American public opinion on AV use, regulation, and willingness to pay could change rapidly as the technology becomes more ubiquitous (Quarles & Kockelman, 2018a; 2018b).

Equity Implications of Autonomous Vehicle Adoption: The Federal American with Disabilities Act requires public transit services be made available to persons with disabilities. A court case referred to as the Olmstead Decision sets standards for transit service provision for persons with disabilities. Services cannot be different from those without disabilities. States develop and implement "Olmstead Plans" to comply with federal standards. The fleet model for AV operation—in contrast to privately owned AVs—is relatively unfamiliar to many Americans accustomed to private vehicle ownership but is premised on flexibility and could complement existing transit services by enhancing first and last mile access. It is unclear whether the fleet model for AV operation can be made to effectively serve people with disabilities. There are open questions as to whether AV adoption will enhance the ability of seniors to age in place, as well as questions of who exactly among seniors will be best positioned to benefit from widespread AV adoption (Douma, 2017).

KEY RESEARCH TAKEAWAY 1: Americans currently are relatively unfamiliar with what AV futures could look like, and their opinions may evolve rapidly, as was the case with other widespread technology shifts, including smartphone adoption. Implications of AV technologies, both individually owned or fleet operated, for the elderly and people with disabilities are unclear. Early thinking suggests that fleet-operated AV service models could enhance equitable access to mobility services.

Distribution of, and Investment in, Bike Share Stations: The Minneapolis/St. Paul Nice Ride bike-sharing program, in 2015, had a system of 190 stations, with 30 percent of the cities' population and 71 percent of the cities' jobs located within a quarter-mile service area surrounding the stations. The study assessed station accessibility (by income , race, and gender) between 2010 and 2015 as the system expanded. Station-location strategies implemented in 2012 that focused on densifying station accessibility in job-rich areas contributed to inequities in station distribution across the broader service area (Wang & Lindsey, 2017). Station accessibility is positively correlated with frequency-of-use by bike share members. These effects (i.e., increased frequency of use) are larger in the areas with more bike infrastructure, higher population density, and a higher percentage of recreational, retail, or industrial land use (Wang and Lindsey 2018a). After controlling for station accessibility, bike infrastructure, and other correlates of bike demand, bike share members living in disadvantaged neighborhoods tend to have higher frequency-of-use, take longer trips, and use more stations to satisfy their daily needs. The results demonstrate the importance of bike share programs in satisfying the travel needs of members living in disadvantaged neighborhoods (Wang & Lindsey 2018b).

KEY RESEARCH TAKEAWAY 2: Investment decisions focused on increasing ridership overall can sometimes be at odds with investments focused on meeting the mobility needs of disadvantaged populations. Both goals must be considered and balanced in designing a sustainable *and* equitable bike share system.

Travel Mode and Subjective Wellbeing: With the use of a smartphone-based survey called Daynamica, SHC researchers have been able to collect wellbeing predictors (e.g. happiness, meaningfulness, exhaustion, stress, sadness, and pain) and correlate them to daily activities and travel behavior. This tool has led to a deeper understanding of how transportation and daily activities affect wellbeing. For example, with Daynamica, SHC researchers were able to identify biking and walking as the "happiest" modes of transportation and taking the bus as the least happy mode of transportation (Fan, 2017).

Neighborhood Design and Life Satisfaction: Urban and suburban neighborhoods vary across design and built environment factors. An outstanding question is how land use and transit, two components of neighborhood design, affect life satisfaction and considerations of subjective wellbeing. Population density, land use mix, the density of cul-de-sacs, and the presence of open space are all neighborhood design variables that can impact residential satisfaction and life satisfaction through individual perceptions (Cao, 2016).

KEY RESEARCH TAKEAWAY 3: The subjective wellbeing (SWB) of residents--which spans diverse concepts like happiness, cognitive wellbeing and life satisfaction--is one of many sustainability outcomes that transportation and land use policymakers can take into account. SWB is affected by multiple infrastructure-related factors and at multiple time scales, both "in the moment" and over longer periods of time. The science of measuring infrastructure-SWB relationships is still evolving.

KEY SCIENCE-POLICY DISCUSSION POINTS

There are critical trade offs in the ways that AVs and electric vehicles (EVs) will impact sustainability considerations. AVs may increase mobility as well as total vehicle-miles traveled, even if those added miles are ultimately more efficient and safer, on a per-mile basis. There are 10 percent efficiencies to be gained just by smoothing the load on engines that AVs can deliver relative to human drivers. EV technologies can promise reduced tailpipe emissions—a critical factor affecting air pollution in cities—but, unless the underlying electricity gird is supplied with renewable energy, carbon emissions will be displaced (to the point of power generation) without necessarily being reduced. The full life-cycle environmental impacts of electric vehicle battery production and disposal are also a concern.

The impact of AV technology on livelihoods will vary as onboard tasks evolve. For example, truck driving as an occupation is not going away, even in a future autonomous trucks. Commercial trucks are large and expensive pieces of equipment, often carrying valuable cargo, and will still require physical accompaniment by attendants. However, onboard tasks for a "driver" could evolve with employees serving as vehicle attendants doing other work en route.

The widespread deployment of shared AV technology has implications for how we understand public and mass transit systems. Publicly provided mobility solutions may look significantly different from the various typologies of rail and bus lines that characterize transit today.

The legal implications of a shift to AV technology are relatively straightforward. Litigation of automobile crashes will transition from a personal liability framework to a product liability framework under both private AV ownership conditions and fleet ownership conditions.

Credit: Wikimedia Commons, Grendelkhan

Fleet owners are the actors best positioned to generate economic returns through a shared AV business models. Current AV technology is still prohibitively expensive for most individuals. Management at the fleet level is where sufficient efficiencies can be generated to return economic profits early on.

Vehicle type and style for general-purpose travel will likely converge and become increasingly homogeneous in a shared AV future. At the same time, there will be increased specialization of vehicle types for populations with special needs or unique mobility situations.

Fragmented jurisdictions pose a challenge for greater investment in sustainable transit and mobility options. There is a challenge in getting city political leaders, especially at the council or district level, to consider what is best for the city overall, not simply what is best for a given neighborhood or jurisdiction that they happen to represent.

The physical separation of bike lanes from motorized vehicle traffic is critical for convincing hesitant riders to make the shift to biking as primary mode of transport. Physical separation can be facilitated most readily by the installation of a curb. Separated lane markings, street trees and other non-permanent boundaries represent a less robust form of protection for cyclists.

FUTURE POLICY AND PRACTICE CONSIDERATIONS

Expanding AV and EV technology will have revenue implications for state and local governments. AV technology can be programmed so that vehicles do not speed or commit traffic infractions, resulting in lost ticketing revenue for local governments. Gas taxes are a key financing mechanism for transportation infrastructures. Gas tax revenues will decrease as EV technology displaces fuel combustion engines. Shifts to a road-use tax or increased tolling are relevant alternative revenue streams in a future with widespread AV and EV use.

AV futures can unlock road space currently dedicated to parking. Under a fleet operated shared AV scenario, AV futures will likely mean less need for parking because AVs will be in regular motion during an approximately eight hour shift, on to pick up the next rider, needing roughly only one shared vehicle to do the job of eight private vehicles. Policy makers should consider what they will do with extra road space previously dedicated to parking (e.g. repurposing for bike or shared AV lane, extended sidewalks, etc.).

The widespread use of AV will have implications for urbanization patterns and urban lifestyle preferences. AV technologies could encourage more sprawl as commuting long distances becomes easier due to decreased driver responsibility. AV technologies could also promote densification as parking and the challenges of owning a personal vehicle in a dense urban context would be less of a consideration for why someone might choose not to live in the city. Urban land use planning and travel policies are therefore critical to sustainable AV deployment, however we do not yet know what form such planning and policies should take.

The role that social cohesion plays in the successful outcome of bike and car sharing programs is unclear. For example, installation of bike share stations and bike lanes is in some cases seen as a trigger for fears of impending gentrification in a given area of a city.

AV technology presents an opportunity for reshaping the way para-transit mobility options are made available to seniors and other vulnerable populations. There are experiments and pilots underway considering the role that drivers retrained as para-transit caregiving attendants can play in a future AV landscape.

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Topics in Distributed and Localized Green Infrastructure and Urban Food Systems

EMERGING SCIENCE FINDINGS

Sustainable Healthy Cities Network researchers are working to understand how green infrastructure (including trees, greenery, urban farms etc.) and urban food systems affect local, as well as regional, sustainability outcomes. The panel session began with research presentations featuring emerging or recently published work. External researchers and city government discussants then reacted to the slate of research presentations.

Green Infrastructure (GI) and Ecosystem Service Typologies: An ecosystem service framework is one way of representing diverse benefits of urban GI including food production, heat mitigation, stormwater management, recreation or cultural amenities etc. Fine scale data and models are not widely available yet to inform the local benefits of small and large scale GI interventions. A study in New York City found that experts perceive different GI types to return different benefits. Large vegetated land (parks, wetlands, community gardens) are perceived to provide the most services. Non-vegetated stormwater green infrastructure and vacant land are perceived to provide the fewest services (Culligan et al., 2017).

Strategic Siting for Green Infrastructure: Spatial analysis can identify hot spots where GI is needed most to advance policy or outcome priorities (i.e. stormwater abatement, reduced air pollution, increased access to parks etc.). There are opportunities to identify sites based on synergies where a GI site is well located to advance multiple outcome priorities at once. Trade offs can also occur where a specific site is well positioned to advance one outcome priority but not another. In Detroit, synergies emerged around managing storm water, reducing urban heat island effect, and improving air quality, meaning siting to advance one of these priorities often advanced all of them. There were trade offs when prioritizing to maximize green space connectivity. Current siting of GI in Detroit does not necessarily align with where GI siting would advance the outcomes expert stakeholders said were the most important to them (Meerow & Newell, 2017).

Understanding Street-level Flood Risk: Accurate prediction and mapping of flood inundation extent at the street level is possible with integrated modeling tools that also use earth observations. Modeling is premised on a pre-defined stream network, weather input data, SWAT and ICPR hydrologic models for the stream network, model calibration, and geospatial data inputs, which together result in a flood inundation map, showing where a city will experience flooding, to what degree, and under what circumstances. It is an open question whether street-level flood prediction mapping across a city is sufficient for understanding, managing and communicating flood risk to specific at-risk areas as well as to the city at large (Merwade et al., 2017).

KEY RESEARCH TAKEAWAY 1: Not all GI (trees, greenery urban farms etc.) provide the same benefits, and not all areas of a city need or will benefit from all GI types in the same way. There are not yet sufficient fine scale data or models to quantify benefits from small-scale GI interventions. Strategic consideration of which GI type will provide the services most needed in specific parts of a city is needed to fully leverage GI as a strategy to return sustainability and resilience benefits.

Diverse Food System Actions Impacting Environment, Health and Equity: Systems based methods have been developed to assess multiple environmental impacts on water, land, energy, and greenhouse gas emissions, within city boundaries and overall, arising from a portfolio of urban food system actions being considered in many US and global cities. These actions include conventional urban agriculture, new vertical farming technologies, diet shifts, food waste management and food equity plans that provide basic nutrition to underserved populations. The methods are being applied to diverse cities including New York City, Minneapolis-St. Paul, and Delhi, India. Study results found that city-level food actions can provide environmental benefits of the same magnitude as actions taken in conventional farming/distribution sectors, quantifying the important role that cities have in shaping global food system outcomes. Among urban food actions, diet change and food waste management provided substantially more system-wide environmental benefits compared to urban agriculture. In cities like Delhi, conventional urban agriculture can further stress an already water-stressed environment and vertical farming technologies showed little impact because, at present, they only apply to fruits and vegetables, while major system impacts are generated by grain cultivation (Boyer & Ramaswami, 2017).

Exploring Inequalities and Motivations for Alternative Local Food Provisioning: Preliminary results from a study in Minneapolis-St. Paul indicate that the spatial frequency of backyard vegetable gardens and community gardens is correlated with neighborhood income, density and the percent of renters. These data were used to estimate the total contribution of in-boundary backyard and community gardening relative to a city's overall food demand. The contribution of backyard and community gardening to local food self-sufficiency is found to be relatively small, raising the question of what benefits are achievable through increasing urban agriculture and for whom (Ambrose, Boyer, Kosse, & Nixon, 2017). SHC researchers are surveying broad motivations for attending farmers markets, participating in community supported agriculture (CSA) programs, and engaging in backyard and community gardening. Understanding these motivations will help identify incentives and levers for various food action (Ambrose & Ramaswami, 2017).

KEY RESEARCH TAKEAWAY 2: Among urban food actions, diet change and food waste management can provide more system-wide environmental benefits compared to urban agriculture. The local spatial distribution of benefits from urban agriculture should be clarified to better inform the goals of food action planning. Understanding motivations of why individuals engage in alternative food production and consumption practices will help inform the implementation of food action plans.

KEY SCIENCE-POLICY DISCUSSION POINTS

Among green infrastructure interventions there is a distinction between ecologically designed systems (natural and self-organized) and imposed or engineered green infrastructure solutions. Preservation or restoration of a particular natural asset that provides ecosystem services (e.g. preserved wetlands, restored waterways) is separate and distinct from green infrastructure interventions that are actively constructed and deployed as engineered infrastructure interventions (e.g. bioswales, green roofs).

It is possible to frame conversations about "green infrastructure" and "urban agriculture" with residents and the general public in non-technical terms. For example, it is possible to talk about green infrastructure interventions and outcomes emphasizing language about parks and common points of reference that will be familiar to neighborhood residents, even if that same framing emphasizes less obvious outcomes and benefits beyond simple recreation. Similarly, it is possible to reach larger audiences on the topics they care about by talking simply about "food" without relying on terms like "urban agriculture."

Maintenance and stewardship strategies for green infrastructure in cities may give rise to equity concerns. Cities might decide to install green infrastructure in places where there are existing social entities—for instance a business improvement district—to help ensure stewardship. Cities are piloting projects to understand the level of resources required of the city to directly maintain green infrastructure installations without relying on community-social infrastructure. This has implications for how to best channel new green infrastructure facilities to areas without existing community-social infrastructure to provide maintenance for those installations.

Accurately understanding the public perception of green infrastructure co-benefits is important. People are motivated to care about a variety of issues, which may not overlap with what experts understand as critical sustainability inflection points. Researchers and policy-makers should be prepared to make connections between green infrastructure policy and what the general public cares about, which can vary widely.

It is difficult to encourage thinking of green infrastructure as an interconnected system in the way that energy and transportation are thought of as inter-related. The current tendency is to consider green infrastructure facilities in isolation. There are opportunities for synergies across domains of urban management to share indicators that might inform the siting of green infrastructure. For instance, public health indicators could be more directly integrated into green infrastructure siting.

Creating a sustainable food system will require reconsidering and accommodating multiple understandings of "local." There are rural communities well beyond a city's boundary that may not be captured by traditional understandings of "local" but which nonetheless can be powerful partners in helping cities meet their food needs sustainably and with reduced supply chain risk exposure even if they may fall outside of a certain distance threshold of what otherwise might be considered local.

As a sustainability policy-prescription, it is potentially unrealistic to communicate that everyone should "eat locally." It is often not a realistic possibility for many residents within cities. Transformation of food systems will need to emphasize interventions and actions at multiple levels, particularly at the systems level, and not simply at the level of individual choice.

It is important to think about where, and from whom, data on green infrastructure and food systems are being gathered. There are pockets of population that are more educated, more knowledgeable, or just care more about a particular topic and thus are overrepresented in


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current outreach and research efforts. Alternatively, there is a concern about certain segments of the population that are fatigued from "being data-mined."

Full self-sufficiency of local food systems may not be an advisable goal for cities. Instead, the better option may be to adopt a value proposition about achieving a certain level of self-sufficiency. This requires evaluating what level of self-sufficiency a city considers desirable as a sustainability policy goal and then considering how to reach that goal.

Urban food systems interventions could be thought of as infrastructure that can be actively built into neighborhoods. It is currently not always the case, but urban foods systems planning could be understood as a core function of cities in the same way that a parks department is understood as a core function.

FUTURE POLICY AND PRACTICE CONSIDERATIONS

Understanding how green infrastructure interacts with more traditional grey infrastructure is critical in urban environments. This interaction framing is in contrast to considering green infrastructure performance as disconnected from its impacts on, or interactions with, grey infrastructure. A key concern for cities is that their existing grey infrastructure systems may become overwhelmed or fail under periods of high stress. It is helpful to think about how green infrastructure can help mitigate the threat of system failure by diverting or reducing stress on grey infrastructure systems.

There are trade offs to account for when considering how best to utilize land in an urban core for pervious cover protection or urban agriculture. Dense urban development patterns that reduce pervious land cover in their immediate zones of development can return sustainability benefits in other ways, potentially by mitigating outward sprawl and encouraging transit friendly communities. Restrictions on high density development to protect pervious land cover or promote urban food production may encourage increased sprawl.

Some assumed benefits of green infrastructure are supported by quantifiable models, others are not. Bridging the gap to be able to quantify the impact of a wider swathe of green infrastructure interventions and the benfits they provide will help decision makers more comprehensively evaluate trade offs.

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Topics in Distributed and Localized Water and Wastewater Infrastructure

EMERGING SCIENCE FINDINGS

Sustainable Healthy Cities Network researchers are working to understand the potential role of new technologies in facilitating onsite wastewater treatment processes. The panel session began with research presentations featuring emerging or recently published work. External researchers and city government discussants then reacted to the slate of research presentations.

Versatile Reactor Based on Cow Stomach for Transforming Urban Organic Wastes into Platform Chemicals: As a waste treatment technology, anaerobic digestion (AD) is an ideal option to locally convert urban organics wastes into bio-power or chemical products. However, overall organic waste streams contain different fractions of difficult-to-treat materials like fruits, vegetables, yard and paper waste all of which contain a high concentration of lignocellulosic materials, which degrade slowly under anaerobic conditions. However, the microbial community present in the stomach of cows (rumen) efficiently degrades grass, a lignocellulosic substrate, under anaerobic conditions. SHC researchers are testing a new anaerobic membrane bioreactor that mimics the rumen, because of its ability to degrade lignocellulosic materials, to enhance hydrolysis and produce high concentration of valuable platform chemicals from difficult-to-treat urban organic waste (Shrestha et al., 2017).

Sourcing Ethanol for Production of Platform Chemicals from Brewery Waste: Ethanol and other organics present in organic waste can be converted to medium chain carboxylic acids which can further be transformed into the chemical base for useful (and commercially valuable) products like antimicrobials, lubricants, biofuels and fragrances. SHC researchers are studying the use of sustainable sources of ethanol, like brewery waste, as one source material for producing these types of platform chemicals. If successful, the solution would represent a form of cross-sector waste and material exchange to increase resource efficiency (Shrestha et al., 2017).

KEY RESEARCH TAKEAWAY 1: Lab-scale research is incubating new technology for waste-to-value recovery from difficult-to-treat urban organic wastes, such as food waste. 2) Value added products from waste include energy that can be used in circular economies within cities, as well as platform chemicals used in common products, such as lubricants.

Cross Sector Distributed infrastructure for Waste and Wastewater Infrastructure in Cities: Developing world cities deal with multiple infrastructure deficits including open wastewater drainage, pollution from using dirty cooking fuels, and burning garbage, including food waste. New community scale technologies for combined food waste and wastewater treatment can provide clean cooking fuels in underserved communities, solving three major infrastructure problems: wastewater treatment, solid waste treatment and indoor air pollution due to dirty fuel use (Ramaswami et al., 2017). Similar energy recovery from wastewater also has potential uses in developed world cities--including the Minneapolis-St. Paul region--where these strategies are being considered in next generation district energy systems that use heat from industry waste and sewage.

KEY RESEARCH TAKEAWAY 2: Cross-sector distributed infrastructures at the intersection of food waste, wastewater, and energy systems has great potential to provide multiple sustainability benefits. Technology development at this nexus can be applied beneficially in different ways in both developing and developed world cities.

KEY SCIENCE-POLICY DISCUSSION POINTS

Onsite waste treatment has not been perfected yet. Onsite municipal wastewater and sewage treatment facilities can require substantial upkeep and maintenance in order to avoid pathogen contamination concerns. This raises infrastructure stewardship and maintenance questions. What sort of maintenance requirements and standards is it necessary to have in place?

Waste-to-value conversion viability is affected by public perception concerns. The public may be hesitant to use a product that is a result of waste reuse. Branding and monetization are critical components of getting any waste-to-value conversion model right.

Dynamics of concentration and product separation are highly determinant variables of profitability when it comes to extracting waste from waste streams for conversion to a valuable product.

Competing department regulations and goals can limit cross-sector waste reuse. There are departmental and operational barriers that limit the degree to which wastewater can be leveraged in cross-sector resource exchanges. For example, city public health departments may have a different perspective on the acceptable uses of untreated grey wastewater than do city departments responsible for green infrastructure management.

FUTURE POLICY AND PRACTICE CONSIDERATIONS

Historically, onsite waste treatment has not been considered for dense neighborhoods but may be an economically and resource efficient option, especially in developing country contexts. Planning tools for such contexts are needed that calculate and compare the cost, resource requirements and burden on the environment of onsite treatment facilities taking into account neighborhood design, density, material requirements, waste transportation needs, and byproduct reuse.

Spatial scenario planning models for distributed waste systems and waste exchanges are needed. Given competing priorities for land use in high density situations, scenario planning models that help consider the most effective use of land for GHG and energy reductions are valuable tools for cities.

Financing wastewater reuse is complicated and a potential area for additional research. Mechanisms for financing waste recovery interventions in the waste stream are different from energy financing mechanisms or other infrastructure sector financing. It is necessary to better understand the available business models for localized waste treatment, considering when it makes sense for households to finance localized waste treatment efforts.

Food waste integration with wastewater treatment should be explored further. Food waste is a large source of GHG emissions for cities due to the embodied energy in the food supply. Food waste prevention and recovery can serve as one of the most impactful leverage points for a city trying to reduce its greenhouse emissions (see Boyer and Ramaswami, 2017 on page 19).

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Charting the Path Forward: Managing Transitions to Distributed and Localized Infrastructure in Cities

This final section presents overarching considerations and policy implications for managing transitions to distributed and localized infrastructure systems in cities. The cross-cutting discussions that emerged from the workshop focused on three aspects of managing such transitions: 1) key considerations for local government operations, drawing on the perspective of individual cities, 2) key considerations from the perspective of multi-city organizations informing the development of indicators, capacity building, and knowledge platforms, and 3) effective ways for urban sustainability researchers to engage with practice and policy audiences at multiple levels.

URBAN MANAGEMENT AND IMPLEMENTATION CONSIDERATIONS

As infrastructure services are localized (brought physically into the boundary of the city) and/or decentralized (increasingly spatially dispersed throughout a city) there are urban management implications for city administrations. The following discussion provides a high-level survey of some of the urban management and implementation concerns that were highlighted by workshop participants.

Changing Service Domains

A transition toward localization can imply that a city is assuming new responsibility for overseeing, managing, financing, or regulating an infrastructure service that was previously the responsibility of another entity, inside or outside the city. For example, a city that assumes new responsibility for food policy planning and urban agricultural production will be entering a new service domain if this was not previously an area of policy making and operations for them. This has practical organizational and resource allocation implications for a city administration. For example, it may require recruiting additional staff in order to acquire new in-house technical expertise. It may similarly require altering the landscape of mandates and responsibilities across a city's current departmental make up.

Whether a particular service domain has been a long-standing part of a given city's management portfolio will of course be context dependent. Cities that operate municipal power utilities are no stranger to energy as a municipal service domain. Other cities that are just beginning to engage with policies pertaining to direct renewable generation within city boundaries, behavior change campaigns, and district energy systems, just to name a few, may be operating in less familiar territory.

Operational Impact

The decentralization of infrastructure facilities under the purview of an existing city service domain may have practical implications for how a city manages operations within that service domain. Reorienting from a centralized system to a decentralized system can change how a system is operated, as it can involve a transition to more, but smaller sites. For example, distributed wastewater treatment facilities that provide on-site treatment for an individual building or cluster of buildings will operate differently than a centralized wastewater treatment facility for a city as a whole. The implications of system failure for a small system are different from those of a large system. The viable or applicable uses of treated waste and wastewater from a small system may be different from those of a centralized system. The degree of property owner involvement and engagement in the monitoring and maintenance of a smaller system will be different from that of a centralized system.

Stewardship and Community Engagement

The increased stewardship and community engagement needs of decentralized infrastructures (more but smaller sites) are particularly important for cities. The prospect of having many more publicly owned sites to manage, whether they are green infrastructure sites or facilities relevant to another sector, means that the workforce needs of a city department could increase as they need more workers to manage more sites, or alternatively, the skills needed by that labor force could change as the activities they are expected to carry out change. An city-wide infrastructure strategy that relies on many small sites may involve increased direct participation and collaboration with private property owners who may directly host and manage such sites (e.g. green infrastructure installations on private development). There are opportunities to consider the viability of community or citizen-led stewardship efforts as a strategy for reducing the direct maintenance and stewardship responsibilities of city staff.

Citizen-led stewardship efforts raise practical questions. For instance, what sort of burden would be placed on communities or individual stewards, and what responsibilities would still remain with the city? Will communities and/or individual residents be receptive to calls that they actively support the maintenance and stewardship of certain infrastructure sites? Will diverse communities across a city respond to that call in the same way? Which types of facilities and sites are appropriate for community stewardship and which require more specialized or professional oversight? What sort of training and coordination support would citizen stewards need in order to properly maintain a given site or facility? Who is responsible in the event of a failure to maintain a given site or facility?

Increased need for community engagement can also arise as a result of decentralized infrastructures given that facilities and sites may simply be closer and more present in the lives of residents, even if those residents are not directly responsible for stewardship or maintenance. Rather than a centralized facility affecting only the residents of the area of the city in which that facility is located, a decentralized system might rely on many more sites that would in turn affect many areas of the city. Given the common prevalence of not-in-my-back-yard (NIMBY) sentiments in neighborhood change and development processes in cities and communities of all types, city administrations could potentially face at least initial resistance to any expanded infrastructure footprint in a neighborhood or area that is not accustomed to the presence of such infrastructures.

Equity Implications

The notion of spatially reconfiguring key infrastructures has potential equity implications. As facilities decentralize, there is a potential opportunity to lessen the concentrated burden of infrastructure sites in a particular community. Infrastructure "burdens" in effect could potentially be diluted and spread more evenly across the city as a whole rather than being concentrated in one area of the city.

For infrastructure sites in which community or citizen stewardship may be a viable option, there are equity implications to consider when thinking about neighborhood capacity for stewardship as a prerequisite for infrastructure installation. Some cities have found success in asking business improvement districts to care for and steward new green infrastructure installations. However, if the presence of an active business improvement district is seen as a prerequisite for a particular area of a city to receive green infrastructure investments, this type of dynamic could compound disinvestment in areas of the city without a business improvement district.

Decentralized infrastructure also has the potential to raise equity concerns when considering the idea of neighborhood-based services. If infrastructure provisioning in a given sector moves away from a centralized system, in which all residents are served by the same system, does this give rise to concerns of disinvestment and poor service performance in marginalized or impoverished areas of a city? Neighborhood disparities already exist in many cities when it comes to place-based infrastructures like schools, roads, food access, green space etc. It is an open question whether the decentralization of currently highly centralized infrastructure systems like electricity and water supply would lead to similar spatial disparities.

MULTI-CITY ORGANIZATION VIEWPOINT

To gain a more aggregated local government and practitioner view on topics of distributed and localized infrastructure, the workshop began with a plenary conversation among representatives from ICLEI USA, the International City/County Management Association, and Star Communities. The conversation highlighted infrastructure trends and policy constraints, offering a high-level view informed by their collective work with hundreds of local governments across the US. The panel was anchored in the following key discussion questions:

1) What does the view from cites look like regarding distributed infrastructure as a tool for advancing sustainability goals?

2) How does the trend of more distributed infrastructure interact with larger trends in urban sustainability action and policy?

3) What would a future with more distributed infrastructure mean for city data collection and bench marking efforts?

The discussion generated by these questions centered around messaging, data and indicators. High-level takeaways from the plenary discussion are represented below:

Supplementing, Not Replacing

The role of distributed infrastructure depends on the objective of each city deploying distributed infrastructure. In most cases, it is often important to frame conversations about distributed infrastructure as supplementing rather than replacing traditional centralized or existing infrastructure systems.

Credit: Wikimedia Commons

Tangible, Locally Felt Co-benefits

There is concern about looking for ways to keep topics related to distributed and localized infrastructure from being politicized. One strategy is to keep the topic of conversation on tangible, locally-felt co-benefits. Community choice, resource efficiency, and local resilience are all important frames for considering and building support for sustainability action including distributed infrastructure. In particular, health implications of distributed infrastructure can represent a more tangible point of connection for local leaders than considerations of global climate change. Program recommendations could emphasize co-benefits that are tangible and local (health vs. climate change) and that resonate with broad audiences.

Data Driven Decision Making

Cities are overwhelmed by the task of looking at finer scale data. There is often a tension between collecting frequent or fine scale data such that only one or the other is collected. Cities are confronting challenges in accessing and analyzing data which can be used to make more informed decisions. Using data for distributed infrastructure decision making requires linking city staff to direct research products and subsequently translating those products into policy relevant action. This process of linking and translating can help narrow any gap that might exist between practitioner and the researcher perception.

Citizen Science for Urban Data

Citizen science efforts, which involve residents in the direct collection of data via crowd-sourcing platforms and other tools, have not played a significant role in city data collection efforts to date. Increased direct interaction with community members on data collection efforts could improve the descriptive quality and legitimacy of the data collected. While such methods show promise, they also raise questions about population representativeness.

Working Toward a City Dashboard

Developing a citywide dashboard that represents data from the full suite of desired outcomes across sectors and operational areas within a city can help build understanding of how decisions in one sector or operational area affect another. Cross-sector considerations of trade offs and synergies is an important part of helping a city develop a comprehensive view of sustainability action, including those actions related to localized and distributed infrastructure.

These discussion takeaways highlight the need for more robust data, science, and research to inform, at fine scales, the processes of evaluating anticipated benefits and trade offs from specific localized and distributed infrastructure actions that cities might take.

SCIENCE-TO-POLICY COMMUNICATION NEEDS

Connecting scientific research on urban infrastructure and service provision to actionable information for practitioners and policy-makers is and will continue to be critical for achieving urban sustainability outcomes. Science-to-practitioner and science-to-policy communication requires active translation on the part of research communities.

Speaking to Different Practitioner Roles

A key reality that researchers should have in mind when undertaking science-to-practitioner translation is that there are a wide variety of practitioner constituencies within individual city administrations. The “practitioner” view is not a uniform one and will look quite different depending on where one sits within a city administration.

Various parts of a city administration are going to have different urban management responsibilities. City staff that are responsible for economic development may have a different perspective from staff responsible for technical system management and operation, which may have a different perspective from staff responsible for neighborhood and community engagement, etc.

When communicating the relevance of scientific findings to practitioners, it is important to try to speak to as many of these practitioner views and perspectives as possible, however, not necessarily at once. Diluting a research message so that it is as broadly applicable as possible will likely be less effective than taking the time to distill and target the relevant findings of a report for multiple specific subsets of the policy and practitioner audience. Notably, this second approach of distilling and targeting research communication for multiple audiences is more time intensive than


Credit: Sustainable Healthy Cities Network

the generalization approach. At the very least, researchers should be clear about the practitioner roles and perspectives that specific research communication efforts are taking into account, which includes being clear about which roles and perspectives are not being taken into account.

Sustainability Office Capacity and Structure

Just as there are differences within the various roles of a city administration, science-to-practitioner communication efforts also need to account for differences across city administrations, specifically considering staff capacity and resources for sustainability functions. Many large cities may have in-house specialist expertise on a wide variety of sustainability topics. However, smaller cities may have only a single, or small team of, staff generalists responsible for overseeing a wide range of sustainability services and programming. This difference in the size and specific expertise that makes up a city's in-house sustainability practice will inform the level and degree to which they are likely to engage with specialized findings from the latest academic research.

Regardless of city size, cities may also differ in how sustainability functions are incorporated into their operations and administrative structures. Some cities have chief sustainability or resilience officer roles that sit within a mayor's cabinet. Others house sustainability functions within an environmental protection division, or expect all city departments to individually incorporate relevant sustainability functions within their work.

This diversity in both sustainability office capacity and configuration presents both a challenge and opportunity for science-to-practitioner communications. On the one hand, it means that researchers will need to spend time appropriately targeting and calibrating their research translation efforts. On the other, it means that there may be multiple potential points of entry within a single administration. For example, the path to a chief sustainability officer is likely different from the path to a director of public works or any other departmental head. However, each will offer their own advantages and disadvantages from the perspective of trying to have a practical impact on city sustainability policy or operations.

Balancing Generalizable and Custom Findings

Infrastructure and sustainability researchers engaged in science-to-practitioner communications efforts should be cognizant of both knowledge generalizability and customization. Generalized knowledge that can drive a discussion of best practices in a field or sector as a whole is valuable for cities, but so too are findings that can be readily adapted and customized for local context.

City practitioners are often looking for "off the shelf" knowledge products that can be used to inform policy decision making. Generalized knowledge about shifting understandings of best practice in a field can be a powerful tool, but explicit guidance from researchers on how to downscale, or make locally relevant the concrete impacts of general knowledge to a particular city or community is also a powerful tool. Researchers should be thinking about ways to develop science-to-practitioner communications products that can support both types of strategies at both the general (field as a whole) and downscaled (community specific) levels.

Local Co-benefits and Meeting People Where They Are

Researchers seeking to translate scientific findings for practitioner and policy application should take into account the larger political environments in which they are communicating those findings.

In particular, city administrations are often looking for ways to de-politicize sustainability decision making. One key strategy for this is to reframe sustainability decision making around tangible local co-benefits. Scientific findings that help practitioners and policy makers make the case for sustainability and infrastructure decision-making that connect to a range of local benefits, not exclusively to global carbon emissions benefits, can be particularly powerful.

This approach is not meant to discount the importance of impacts on global carbon emissions. Rather, it stems from a pragmatic recognition on behalf of urban management practitioners and policy-makers of the need to "meet people where they are" which often means connecting sustainability decision-making to tangible local benefits that people see in their daily lives. This is particularly true when working with local government officials and policy makers, which have an explicit mandate to worry about concerns within their local jurisdiction. If science-to-policy communication is going to be relevant for local practitioners, it increasingly needs to do the work of "meeting people where they are." This includes taking into account locally relevant political constraints.

A VIEW TOWARD FUTURE RESEARCH AND SCIENCE-POLICY ENGAGEMENT

The following key research questions remain ripe for additional scientific inquiry and science-policy engagement. They speak to both questions of advancing science and strategies for connecting that science to arenas of sustainable infrastructure practice and policy-making.

•How to quantify trade offs among sustainability outcomes for practitioner decision support?

•How to quantify local co-benefits as a strategy for "meeting people where they are?"

•How to model interactions between and among infrastructure and sustainability outcomes to identify the "best" mix of infrastructure scale and localization?

•How to design messaging that encourages people to change behavior?

•What are the equity implications of different local and distributed infrastructure configurations?

•What business models exist for supporting localized and distributed infrastructure transition?

•What governance and finance arrangements across jurisdictions and scale most effectively support sustainable infrastructure transitions?

Answering the questions raised by this dialogue will require new modes of collaboration within and across research, practice, and policy communities. The Sustainable Healthy Cities Network is committed to advancing the science of knowledge co-production and science-policy communication on the topic of sustainable urban infrastructure. The ongoing work of the network and its partners intends to build on this foundation of joint science-policy dialogue on emerging distributed and localized infrastructure in cities.

Sustainable Healthy Cities

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ICMA INTERNATIONAL CITY/COUNTY MANAGEMENT ASSOCIATION

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