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Review of climate action plans in 29 major U.S. cities: Comparing current policies to research recommendations

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ABSTRACT

This study reviews the research literature's recommendations on which policies a city can pursue to reduce its greenhouse gas emissions. Using these recommendations, we develop a multi-parameter, analytic scoring rubric for quantifying the comprehensiveness of a city's climate action policy plans. The scoring rubric is used to assess the plans of 29 major U.S. cities revealing trends about urban climate policy in the United States. Most of these plans strongly pursue policies aimed at building quality, mass transit, non-motorized transport, and independence from automobiles. However, the general absence of dense development and parking restriction policies from U.S. cities' climate action plans impedes their ability to leverage those strengths to achieve broad strategies that reduce building energy consumption and shift transportation modes. Moreover, low-density, high-population, high-emitting cities in energy-intensive climates – places that need greenhouse gas reductions the most – are more likely to have deficient climate action plans. These results suggest that many U.S. cities' climate action plans lack the cohesiveness to make them fully successful. Consequently, unless they reevaluate their climate action plans, many U.S. cities might struggle to achieve the broader greenhouse gas reduction strategies needed to significantly contribute to global climate change mitigation.

1. Introduction

Global climate change mitigation requires many different sectors to develop long-term strategic policy plans. While national-scale supply-side sectors, such as the electric power industry, have been implementing greenhouse gas (GHG) mitigation plans for some time, there is a growing focus on reducing the GHG emissions from our largest centers of consumption – cities. Urban areas currently account for 70% of both global energy use (Grubler et al., 2012) and greenhouse gas (GHG) emissions (Cities, 2017). Continued urbanization (Buhaug & Urdal, 2013) threatens to intensify these impacts unless cities can develop and implement successful, urban-scale climate action plans.

Research supports the value of climate change mitigation policy at the urban level (Biello, 2014; Rees & Wackernagel, 1996), suggesting that the shortcomings of international, global-scale, climate-focused treaties can be balanced by self-organized, cooperative agreements between cities (Ostrom, 2010). Urban areas also provide the infrastructure, access to capital, connectivity, and services that facilitate the innovation needed to implement GHG reduction strategies (Glaeser, 2011). Cities mirror this optimism, and U.S. cities have been particularly vocal about their dedication to climate change mitigation in light of U.S. President Trump's intentions to withdraw the United States from the Paris climate agreement (Madhani, 2017). Yet, other writing points out the numerous challenges that cities face – their focus is too local (Hughes, Colijn, & Serpell, 2017), their resources are too limited (Hughes et al., 2017; The Editorial Board, 2018), they report too little data for measuring their progress (Barrett & DeWit, 2017), and they have a poor track record of achieving GHG reduction goals with most of their gains coming from national or state level policies beyond their influence (Brooks, 2017).

Overcoming these challenges requires that cities pursue effective GHG reduction strategies driven by well-developed climate action plans. Researchers have studied a variety of strategies for reducing urban GHG emissions, but few studies have attempted to synthesize them into a holistic definition of what a comprehensive urban climate action plan actually looks like. As a result, we cannot confidently say whether our cities' climate action plans contain the necessary components to make them successful.

This study answers that question by developing a climate action plan scoring rubric. It begins by reviewing the scholarly literature on

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urban GHG reduction policies. We translate that review into a multi-parameter, analytic scoring rubric, which we use to evaluate the climate action plans of 29 cities in major urban areas across the United States. The results provide a broad look at the strengths and shortcomings of U.S. cities' climate action plans and illustrate a new tool for assessing urban climate change mitigation policy.

2. Background

This study reviews the research on urban climate change mitigation policy to develop a scoring rubric that we use to evaluate the climate action plans of 29 major U.S. cities. One other project attempts a similar scope (Heidrich, Dawson, Reckien, & Walsh, 2013; Reckien et al., 2014). This previous project uses published frameworks and processes to develop a scoring rubric for assessing the climate change preparedness of cities in the United Kingdom (Heidrich et al., 2013) and Europe (Reckien et al., 2014). They rank cities' climate change adaptation and mitigation activities by scoring each city's assessment, planning, action, and monitoring. Our study differs from their work in three main ways. First, we develop our scoring rubric from a detailed literature review. Second, our analysis attempts a much broader scope. We divide urban climate mitigation planning into 22 separate policy types. We score each of these policy types individually and also analyze their interrelationships. Third, our case study applies the scoring rubric to cities in the United States.

In the United States, urban areas account for over 70% of greenhouse gas emissions, especially via the power, transportation, industrial, and building energy sectors (Marcotullio, Sarzynski, Albrecht, Schulz, & Garcia, 2013), as shown in Fig. 1. Emissions intensity, however, varies greatly between cities. San Diego, California for example, emits half as much CO_2 per capita as Memphis, Tennessee, and suburban developments tend to emit much more than city centers (Glaeser & Kahn, 2010). Many insights can be drawn from exploring why some cities emit fewer GHGs than others.

Much of the disparity between cities' GHG emissions can be explained by examining their energy use. Urban GHGs originate mainly from energy consumption – either directly (e.g. transportation fuel) or indirectly (e.g. power sector emissions via electricity consumption) (Grubler et al., 2012). A city's per capita energy use is influenced primarily by climate, global economy, consumption patterns, building quality, urban form, and transportation (Grubler et al., 2012). Similarly, the most important factors influencing urban greenhouse gas emissions are economic activity, population density, gasoline prices (Creutzig, Baiocchi, Bierkandt, Pichler, & Seto, 2015), climate, and power sector fuel mix (Glaeser & Kahn, 2010).

Cities might reasonably expect to impact GHG emissions by influencing these underlying causes, yet only some of these factors can be effectively addressed by urban policy mechanisms. Urban policy tends to have limited influence on the most significant causes of emissions,

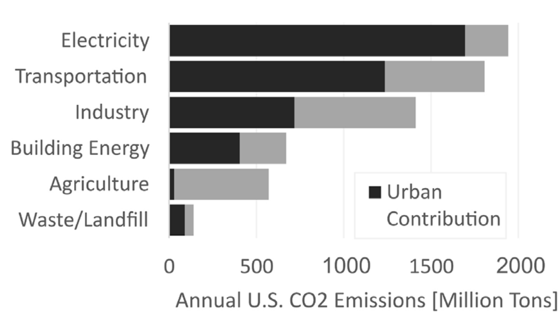

Fig. 1. Based on data from Marcotullio et al. (2013) and U.S. Environmental Protection Agency. (2018), urban areas account for 70% of U.S. greenhouse gas emissions. Note that the "electricity" category includes energy consumed by buildings and the "building energy" category focuses mainly on point-source emissions from fuel combustion for heating, cooking, and water heating.

such as climate, trade, industry, and income. Alternatively, cities have significant influence over the factors that influence GHG emissions the least, such as fuel substitution, district energy systems, distributed renewable generation, and urban afforestation (Seto et al., 2014). However, a few strategies, such as building energy efficiency, technology adoption, infrastructure, and urban form are both amenable to urban policy and influential on urban emissions (Seto et al., 2014).

While infrastructure policy is most significant in rapidly growing cities undergoing regular construction projects, urban form policy is important for influencing transport and energy use patterns in mature cities where infrastructure construction is already locked in Seto et al. (2016), Unruh (2002), as in the United States. Urban form – the configuration of roads, buildings, public structures, green spaces, the distribution and mix of land uses, and the relative location of activities and places of origin and destination – falls well within the influence of urban policy (Seto et al., 2014) and indirectly impacts emissions via its influence on the transportation and building sectors (Creutzig et al., 2016; Silva, Oliveira, & Leal, 2017). Smaller spatial separation between daily destinations, especially home and work, decreases average travel distances leading to lower energy consumption and emissions in the transportation sector and to reduced infrastructure construction requirements (Vojnovic, 2014). Increased urban density also leads to smaller housing units, more shared walls, and other architectural form features that reduce building energy consumption (Madlener & Sunak, 2011).

The synergies between urban form and other strategies illustrate a major theme – urban climate action policies influence each other in complex ways, so effective climate action plans cannot rely on piecemeal solutions (Lohrey & Creutzig, 2016; Vojnovic, 2014). For example, policies that support mass transit, disincentive private vehicles, develop pedestrian infrastructure, encourage mixed-use development, and promote higher density will support each other's effectiveness (Gately, Hutyra, & Wing, 2015; Newman & Kenworthy, 2013). Beyond synergies, policies also exhibit trade-offs and dependencies. Trade-offs exist between disincentivizing automobile use and encouraging vehicle electrification, for example, and successful district energy systems depend strongly on high urban density (Grubler et al., 2012).

Density deserves more discussion because it is uniquely impactful and U.S. cities struggle to achieve it. Population density in the U.S. tends to be lower than European and Asian cities (Steemers, 2003). One explanation for this low density is that the federally-funded highway system runs through the centers of most major cities providing massive urban road construction subsidies that have incentivized driving over other transportation modes. Consequently, U.S. urban planning is extremely automobile-friendly (Troy, 2012). This development pattern exhibits a path dependence on private vehicles (Arthur, Ermoliev, & Kaniovski, 1987) as well as infrastructure lock-in (Seto et al., 2016) with effects that may last for centuries. Other work suggests that urban sprawl and low density might indicate a society that prefers greater energy consumption and rural power sector emissions over automobile congestion and urban air pollution (Lohrey & Creutzig, 2016) – a reasonable hypothesis given the energy and land wealth of the United States.

This last observation about the interrelationship between sprawl, rural emissions, congestion, and urban air pollution illustrates a final important point about this study – climate action policies, while focused on reducing GHG emissions, can also impact economics, health, recreation and other components of urban residents' quality of life (Grubler et al., 2012). These interactions manifest as both trade-offs and co-benefits. Very high density leads to smaller, lower-utility living spaces (Lohrey & Creutzig, 2016), for example, while vehicle electrification can reduce urban noise and air pollution (Grubler et al., 2012). While these interactions are not unimportant, this study focuses on climate change mitigation only discussing quality of life impacts to add context. As a result, this study might under-value broadly beneficial strategies, such as increased green space, due to their limited influence on GHG emissions.

3. Urban strategies for climate change mitigation

Cities can pursue 22 different types of climate action policy that contribute to 5 broad climate change mitigation strategies. The strategy of “shifting transportation modes” uses a suite of policies aimed at urban form, private vehicle disincentives, and mass transit support to exchange automobile use for public transit. “Reducing building energy consumption” combines urban form, building construction, and energy efficiency policies to reduce the amount of energy being consumed in the built environment. “Reducing power sector emissions” uses smart grid management, low-emissions supply, and flexible electricity demand policies to support a clean energy transition in the electricity sector. “Improving public utilities and green spaces” incorporates green spaces into climate action planning and reduces water and waste emissions. “Addressing regional impacts” expands the climate action plan beyond the city's local context.

Each strategy provides a useful framework for discussing individual policies, but it also indicates overarching goals for reducing urban GHG emissions. The individual policies that make up each strategy cannot be pursued piecemeal but must be implemented simultaneously if the broad strategies are to be effective. Fig. 2 introduces the policy types with their strategic synergies, trade-offs, dependencies, and prioritization, which we synthesize in the following literature review.

3.1. Shifting transportation modes

Reducing GHG emissions from urban transportation generally requires a modal shift from private vehicles (e.g. cars, trucks, and motorcycles) towards public transit (“PT”, e.g. buses and trains) and non-motorized transport (“NMT”, e.g. cycling and walking) (Madlener & Sunak, 2011). Private vehicles consume much more energy per person than rail or urban bus routes (Federal Transit Administration, 2015; O.R.N. Laboratory, U. S. D. of Energy, Office of Vehicle E. Research, & U. S. D. of Energy, 2017), as illustrated in Fig. 3. That higher energy consumption translates into greater GHG emissions. And in the United States, where travel accounts for 14% of total energy consumption and private vehicles account for 98% of vehicle passenger-miles (O.R.N. Laboratory et al., 2017), fuel combustion in automobiles contributes significantly to GHG emissions (Marcotullio et al., 2013). To successfully achieve this modal shift, cities must simultaneously discourage automobile use and provide attractive transportation alternatives.

Cities can deter private vehicles by correctly pricing services that enable automobile ownership and internalizing their negative economic externalities. Private vehicle use benefits from numerous subsidized infrastructures (e.g. free parking) and unaccounted externalities (e.g. congestion) that artificially lower the cost of urban driving. Congestion charges, dynamically priced road tolls, higher parking prices (Creutzig et al., 2016), and fuel tax (Sterner, 2007) policies can reduce automobile ownership and transport distances. These deterrents achieve climate mitigation goals by directly reducing fossil fuel consumption while also indirectly creating demand for alternate transportation modes and encouraging the higher population densities needed to help those modes succeed (Creutzig, 2014).

Disincentivized automobile owners need transportation alternatives such as rail, bus, cycling, and walking, but making these modes attractive requires strong civic support. Economic policies like subsidizing transit fares or investing in dedicated PT + NMT infrastructure can initiate those transportation alternatives (Creutzig et al., 2016), but their long-term success relies on successful urban planning practices (Grubler et al., 2012). Urban form and PT + NMT exhibit strong synergies – successful PT + NMT infrastructure supports dense populations, which in turn generate PT + NMT demand and reduce travel distances, particularly when coupled with mixed-used development and small block layouts (Seto et al., 2014). For example, retrofitting existing roads to incorporate smaller blocks, wider sidewalks, medians, bike lanes, reduced traffic speeds, improved traffic signals, and bike parking (Seto et al., 2014) supports PT + NMT by improving urban connectivity (Lohrey & Creutzig, 2016). Transit-oriented development, where transit points act as hubs for important civic areas for the local community; transit-oriented corridors, where urban development along transit infrastructure is oriented towards walking, cycling, and transit; pedestrian zones, where car-restrictions, speed humps, necked-down intersections, tree-planted medians, and other strategies make walking safer and driving more tedious (Seto et al., 2014); and mixed-use planning, where new developments include places for living, working, dining, leisure, and shopping reducing a resident's need to travel beyond their neighborhood are all examples of long-term urban planning and land use policies that make PT + NMT attractive (Creutzig et al., 2016). These synergies suggest that urban form and PT + NMT infrastructure evolve simultaneously, so cities must balance more easily implemented solutions with more radical ones. For example, cities can easily create dedicated bus lanes while they wait for the density and capital needed to replace those lanes with light rail infrastructure (Grubler et al., 2012).

Considering this information, it is natural to wonder how much density and transit a city needs to achieve its GHG reduction goals. Data indicate that mass transit must serve at least 15% of the urban population until its environmental benefits become clear (Gately et al., 2015), though PT + NMT shares of 50–65% are ideal (Lohrey & Creutzig, 2016). Similarly, research suggests a 5000 persons/km^2 population density as a critical threshold for increasing PT + NMT shares (Frank & Pivo, 1994; Grubler et al., 2012; Lohrey & Creutzig, 2016) with a population of at least one million required for supporting subway systems, one of the most efficient transportation modes (Grubler et al., 2012). Densities above 15,000 persons/km^2, however, do not display strong emissions benefits (Grubler et al., 2012) and begin to exhibit levels of traffic congestion, air pollution, and smaller housing spaces that negatively impact quality of life (Lohrey & Creutzig, 2016).

While downtown portions of some U.S. cities might meet these density thresholds, the majority of the U.S. urban landscape does not (United States Census Bureau, 2010b), but cities can use a number of land use policies to encouraging a more sustainable urban form. They can promote “urban containment” by enforcing urban growth boundaries, which forces urban development upward instead of outward (Seto et al., 2014). Cities can promote better regional balances between jobs and housing (reducing vehicle travel) by mixing residential, commercial, and office zones more closely together and by incorporating affordable housing policies. Cities might also specify minimum permissible building densities in terms of floor area, building height, or number of residential units and can tax properties based on land value rather than building value, thus rewarding developers for pursuing denser building projects (Seto et al., 2014).

Even at ideal density and PT + NMT ridership, private vehicles will still contribute to transportation as evidenced by ultra-dense Asian cities having automobile shares of 20–40%, thus fully addressing transportation emissions requires policies for reducing private vehicle GHGs. Car sharing boosts private vehicle energy efficiency by increasing the number of passengers per vehicle, reduces the need for parking, and encourages PT + NMT demand (Chen & Kockelman, 2016) and can be supported through education and dedicated traffic lanes (Lohrey & Creutzig, 2016). Most long-term strategies, however, rely on supporting vehicle electrification by providing rebates (Madlener & Sunak, 2011), vehicle charging infrastructure incentives, waivers for congestion charges and parking fees, and preferred street access (Madlener & Sunak, 2011; Wiederer & Philip, 2010). The environmental benefits of electric vehicles (EVs) depend heavily on the cleanliness of the power sector, and, when considering life-cycle emissions, EVs currently emit more CO_2 than hybrid vehicles for many U.S. regions (Tamayao, Michalek, Hendrickson, & Azevedo, 2015). Until the power sector has become ubiquitously cleaner, vehicle electrification remains a lower

Fig. 2. City climate action plans can cover 22 different policy types with numerous interactions between them. These policies have been grouped into 3 different weights (Essential, Priority, and Additional). Broad strategy synergies are shown on the right. Trade-offs and dependencies are shown on the left.

priority goal (Brozynski & Leibowicz, 2018; Williams et al., 2012).

Paved, off-street surfaces devoted to free car parking, an extremely common design feature of U.S. cities, deserve special attention because they oppose the transportation modal shift in a variety of ways. For one, off-street parking encourages private vehicle use (Shoup, 1997) to the detriment of other transportation modes (Arnott & Inci, 2006; Manville & Shoup, 2005; Weinberger, Seaman, & Johnson, 2009). Off-street parking requirements also discourage density by pushing new development to areas where land is less expensive, usually in less dense areas (Fulton, 2001; Manville & Shoup, 2005), and by paving land that could be used for indoor or green spaces reducing urban density and urban containment opportunities. Cities can promote appropriate parking infrastructure by eliminating minimum off-street parking requirements (Manville & Shoup, 2005) and pricing on-street parking high enough to discourage congestion caused by parking seekers but low enough to keep parking spots relatively full (Arnott & Inci, 2006).

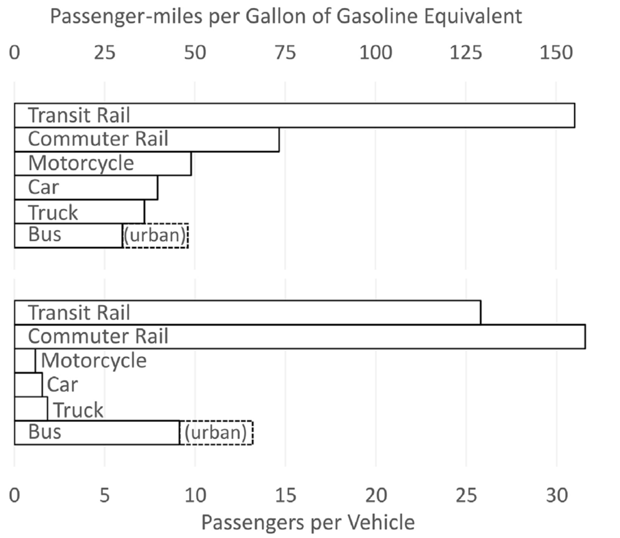

Fig. 3. Average passengers and energy consumption for different transportation modes in the U.S. in 2017 (O.R.N. Laboratory et al., 2017). Even with average ridership below their capacity, transit and commuter rail operate at much higher energy efficiencies than other transportation modes. U.S. buses tend to suffer from low ridership, on average, which reduces their per-person energy efficiency. Recalculating this efficiency based on higher ridership in urban areas (Federal Transit Administration, 2015) shows that urban buses can exceed the passenger-mile fuel efficiency of cars, particularly for well designed routes.

3.2. Reducing building energy consumption

To reduce emissions in the urban building stock, cities must limit the energy, emissions, and materials used for building construction and the energy used for space heating, cooling, lighting, and other services. In fact, building operations account for 41% of primary energy consumption, 72% of electricity consumption, and 38% of carbon dioxide emissions in the United States. Additionally, 15–21% of a building's lifetime energy consumption and 18–26% of its lifetime CO_2 emissions are embodied in the materials and activities needed for its construction (Frey et al., 2012). Reducing building emissions requires increasing operational energy efficiency, reusing existing buildings, and improving consumer habits.

Energy-efficient technologies such as lighting, weatherization, heating, and cooling all reduce operational energy consumption, and cities have many options for promoting them. An essential policy strategy involves enforcing stricter building codes with minimum standards for building characteristics such as insulation ratings and window quality as well as for cooling and heating equipment, water heaters, and other appliances that use energy or produce emissions (Creutzig et al., 2016; Seto et al., 2014). These building codes influence both new construction and retrofits of existing buildings (Madlener & Sunak, 2011). Cities might also provide rebates for owners to invest in building or appliance retrofits that would reduce their energy consumption and emissions (Arimura, Li, Newell, & Palmer, 2011) and educate consumers about these incentives using effective marketing (Stern et al., 1986).

Encouraging more energy-efficient architectural forms that incorporate features like daylighting and increased building depth, height, and compactness (Steemers, 2003) can also reduce operational energy consumption (Madlener & Sunak, 2011). Cities can encourage architectural forms with lower surface-to-volume ratios, lower per capita floor area, and increased shading, which can all reduce building energy demand (Creutzig et al., 2016; Madlener & Sunak, 2011) through code requirements or by supporting energy efficiency education for the architectural community (Mara, 2006; Thomas, 2015). Some lower-energy architectural forms will develop naturally by pursuing higher density (Gately et al., 2015). For example, housing type and size, which correlate strongly with energy consumption are significantly influenced by urban form and density (Ewing & Rong, 2008). Research suggests 5000 persons/km^2 as an ideal density target for reducing residential emissions (Baiocchi, Creutzig, Minx, & Pichler, 2015), which coincidentally matches the critical threshold for supporting shifts in transportation mode.

Finally, operational energy can also be reduced by encouraging proper energy consumption habits. Improving poor habits such as excessive thermostat settings and unnecessary lighting use can significantly reduce building energy consumption (Creutzig et al., 2016). Consumers can also stymie the benefits of improved building and appliance efficiency through the "rebound effect" whereby more efficient, less expensive building operations result in greater consumption (Azevedo, 2014). Research shows that CO_2 emissions decrease with education and with a positive posture towards climate policy (Baiocchi, Minx, & Hubacek, 2010). Educational marketing activities can help improve these consumer habits as well as encourage a conservation mindset in consumers that increases interest in energy efficiency rebate programs and environmentally sustainable policies (Reiss & White, 2008).

The embodied energy, emissions, and materials required for building construction can be reduced most effectively by retrofitting old buildings instead of constructing new ones. It can take over 40 years for the increased energy efficiency of a new building to overcome its initial embodied construction energy costs when compared to an equivalent retrofit project that reuses an existing building (Frey et al., 2012). An overall posture towards "Urban Regeneration", the repurposing of old industrial buildings for mixed-use development with residential and commercial spaces, prioritizes reuse rather than demolition and new construction, which can greatly reduce the embodied energy and emissions in development projects (Seto et al., 2014). Encouraging urban areas towards higher density also results in less land development and has been shown to reduce material and energy use in both the building and maintenance of cities when compared to the sprawling urban settlement patterns typically seen in the United States (Vojnovic, 2014).

Beyond construction, operation, and consumption aimed policies, cities can reduce building energy use through district utility systems where a centralized plant produces heating, cooling, and electricity for multiple buildings (Madlener & Sunak, 2011; Wu & Wang, 2006). The large-scale integrated equipment in district utility plants can achieve higher energy efficiencies than small-scale, individual building equipment leading to reduced energy consumption and emissions (Olsson, Wetterlund, & Söderström, 2015). These systems can only be economically built and operated in higher-density areas (Creutzig et al., 2016; Grubler et al., 2012). So, in terms of sequence, it is better to first pursue policies emphasizing denser development before developing district utility systems. Assuming appropriate density, cities can support district utilities by working with local electric utilities and regulators to identify possible project locations, facilitate infrastructure planning and development, and clarify the responsibilities and liabilities of the entity that will oversee ownership and operation of the district system. Cities might also be helpful in securing financing for district energy projects (Hawkey, Webb, & Winskel, 2013).

3.3. Reducing power sector emissions

Reducing emissions in the power sector by shifting supply away from high-emissions technologies, like coal power plants, towards low- or zero-emissions technologies, like wind and solar photovoltaic (PV) (Davis & Goldemberg, 2012), generally falls beyond the scope of urban policy. Cities might more effectively reduce power sector emissions by adjusting their own consumption patterns (Grubler et al., 2012), though they are able to impact the power sector supply transition in small ways. For example, cities can influence local electric utilities or large

Table 1
A rubric for scoring a city's climate action policy plans.

Policy type	Points awarded
Essential policies	
Building quality	3 – communicates intentions to improve building quality, but mentions no specific policies or building code updates
	6 – plans to update building codes to promote higher efficiency new construction and retrofits
	9 – promotes urban regeneration, net zero energy, and/or embodied energy accounting for construction and demolition materials
Parking restrictions	3 – includes one of restructured zoning requirements (e.g. revised parking minimums/ratios), improved pricing (e.g. increased off-street parking rates and unbundled parking), or high-efficiency incentives (e.g. preferential parking for EVs or carpools)
	6 – contains two of restructured zoning requirements, improved pricing, or high-efficiency incentives
	9 – contains all three of restructured zoning requirements, improved pricing, and high-efficiency incentives
Dense development	3 – mentions goals to increase density without specific policies
	6 – develops specific policies for one of density bonuses, repurposing existing buildings, minimum floor area ratios or building heights, or urban growth boundaries
	9 – develops multiple urban containment and density promoting policies
Priority policies	
Mass transit	2 – mentions goals to expand transit network without specific policies or development plans
	4 – includes specific plans for transit-oriented development, increased bus lines, expansion of transit network, etc.
	6 – outlines a complete overhaul of the current transit system and/or expands the transit network to include rail
Automobile independence	2 – mentions need for congestion management and includes one specific policy including ride-sharing/carpool support, fuel taxes, higher parking prices, congestion charges, optimized traffic light timing, etc.
	4 – includes two specific policies
	6 – includes more than two policies and/or goals to reduce vehicle travel by substantial amounts
Non-motorized transport	2 – mentions need to increase non-motorized transport without specific plans
	4 – includes specific plans for pedestrian paths, bike lanes, and/or complete streets
	6 – develops ambitious program for expanding bike/sidewalk infrastructure, traffic free zones, adding bike racks to buses, etc.
Mixed land use zoning	2 – mentions mixed-use planning without specific policies, or implements small-scope plans
	4 – develops city-wide plans for mixed-use and affordable development, financial incentives, and specific targets for proximity
	6 – includes land use survey for entire city to guide policy
Regional planning	2 – mentions regional transportation planning without specific policies
	4 – includes policies for transit between surrounding towns/suburbs, and/or mentions airport GHG emissions
	6 – includes policies for transit between other metro areas or states
Strategic growth	2 – plans mention "smart growth" or other verbiage allowing for future population growth
	4 – includes either policies focused on affordable housing (e.g. inclusionary zoning) or streamlined development (e.g. redesigned processes for approving permitting and zoning changes)
	6 – includes both affordable housing and streamlined development policies
Transparent assessment	2 – regularly updates climate action plan but city-level emissions data are not available on the city website
	4 – provides city emissions data on a scheduled basis
	6 – verifies city emissions data via an independent, third-party
Consumption-based analysis	2 – emissions accounting incorporates one consumption-based metric such as air travel emissions, construction emissions, life-cycle analysis, fuel processing, food packaging, waste disposal, etc.
	4 – emissions accounting incorporates two consumption-based metrics
	6 – emissions accounting incorporates multiple consumption-based metrics including life-cycle analysis
Consumer habits	2 – online resources, pamphlets, and suggestions in the climate action plan for consumers
	4 – workshops available for consumers, such as retrofit and appliance efficiency education – training for city employees
	6 – advertising and outreach to connect design professionals and commercial sector with educational tools – quantifiable outreach goals for engaging the public with educational tools
Appliance efficiency	2 – focuses on low-impact, city owned assets, such as street lighting or government buildings
	4 – also includes larger scope policies such as rebate programs and efficiency mandates
	6 – also includes aggressive strategies, such as Energy Star building leadership or plans for retrofitting majority of city's homes
Smart-grid management	2 – includes basic grid infrastructure updates, installing AMI infrastructure without describing future policies for its use, or energy management plans only include city government buildings
	4 – encourages one of smart grid technology, real time pricing, demand response, energy storage, or microgrids
	6 – includes more than one policy implemented at the city-wide level
Additional policies	
Green spaces	1 – mentions green space development with no specific policies
	2 – develops specific policies for increasing green space in the city
	3 – develops aggressive goals relative to other plans (e.g. everyone within a 5-minute walk to a park or 1 million trees planted)
Architectural form	1 – mentions only one policy, or promotes efficient architectural form without specific policies mentioned
	2 – mentions multiple policies and attempts to engage the design community through education and outreach
	3 – also actively promotes education and involvement of the design community through professional workshops and organizations
District energy systems	1 – promotes district energy integration with no specific plans or policies
	2 – identifies district energy or combined-heat-and-power projects, develops district energy financing plans
	3 – city already utilizes district energy systems
Vehicle electrification	1 – plans to transition city vehicle fleet towards hybrid vehicles
	2 – plans for EV charging infrastructure, EV incentives, electrification of transit, fuel taxes, etc.
	3 – plans for aggressive vehicle electrification with four or more policies mentioned
Clean power sector	1 – supports renewable energy, lobbies utilities for more renewables without specific policies in mind, or has low renewable goals
	2 – pursues coal divestment, renewable PPAs, RECs, and/or working with utility to develop new, utility-scale renewable projects
	3 – includes future goals for 100% renewables
Local renewables	1 – incorporates renewable energy technology in government buildings
	2 – includes policies that incentivize or remove barriers for one type of local renewable energy technology
	3 – promotes selling back to grid, maps out ideal locations, mentions incentives for multiple types of renewable energy technology
Water infrastructure	1 – limits policies to city government buildings, or plans to use renewable energy sources for powering the water system

(*continued on next page*)

Table 1 (*continued*)

Policy type	Points awarded
	2 – plans for water infrastructure improvements, water audits, leak detection, storm water capture, etc.
	3 – plans for city-wide real-time monitoring of water system (SCADA), thermal hydrolysis for wastewater treatment, decentralized water treatment
Solid waste emissions	1 – mentions waste reduction without specific policies, or only includes recycling policies
	2 – includes multiple policies covering composting, improved recycling, pay-as-you-throw, and/or consumer education
	3 – includes zero waste goals, waste-to-energy plants, landfill gas recapture

Table 2
This study examines the climate action plans of the 29 cities listed below.
Data from (BizEE Software Limited, 2017; Markolf et al., 2017; United States Census Bureau, 2010a, 2010b).

City analyzed	MSA Pop. Rank	Urban area Pop. (persons)	Urba n area density (pers./km^2)	City Pop. (persons)	City density (pers./km^2)	Degree days (CDD + HDD) (5-yr avg)	CO_2 emissions per capita (metr. tons/pers.)
New York City	1	18,351,295	2054	8,175,000	10,429	5900	8.3
Los Angeles	2	12,150,996	2702	3,792,000	3124	2700	7.5
Chicago	3	8,608,208	1361	2,696,000	4572	7300	16.0
Dallas	4	5,121,892	1112	1,198,000	1358	5400	9.7
Houston	5	4,944,332	1150	2,099,000	1352	4600	25.6
Washington D.C.	6	4,586,770	1340	602,000	3805	5700	9.4
Philadelphia	7	5,441,567	1060	1,526,000	4394	6000	10.7
Miami	8	5,502,379	1715	399,000	4299	4800	8.3
Atlanta	9	4,515,419	659	420,000	1217	4900	12.9
Boston	10	4,181,019	862	618,000	4938	6500	8.9
San Francisco	11	3,281,212	2419	805,000	6633	3000	9.8
Phoenix	12	3,629,114	1222	1,446,000	1142	6200	6.1
Riverside	13	1,932,666	1369	304,000	1446	4600	8.8
Detroit	14	3,734,090	1078	714,000	1986	7200	15.7
Seattle	15	3,059,393	1169	609,000	2800	5000	5.9
Minneapolis	16	2,650,890	1002	383,000	2737	8400	15.5
San Diego	17	2,956,746	1559	1,307,000	1552	2200	6.7
Tampa	18	2,441,770	985	336,000	1143	4300	12.7
Denver	19	2,374,203	1372	600,000	1868	7200	14.1
St. Louis	20	2,150,706	899	319,000	1991	6400	22.8
Charlotte	22	1,249,442	651	731,000	949	5000	9.3
San Antonio	24	1,758,210	1137	1,327,000	1112	4900	18.3
Portland	25	1,849,898	1362	584,000	1689	5000	6.2
Pittsburgh	26	1,733,853	740	306,000	2132	6500	25.8
Las Vegas	29	1,886,011	1747	584,000	1794	5800	11.4
Kansas City	30	1,519,417	865	460,000	564	6400	24.0
Austin	31	1,362,416	1006	790,000	1024	5000	9.4
Nashville	36	969,587	664	627,000	480	5500	11.8
Milwaukee	39	1,376,476	974	595,000	2392	7600	15.8

electricity consumers (including a city government's own buildings) to develop wind and solar PV assets, divest from higher-polluting assets, secure power purchase agreements (PPAs) with wind and solar developers, or trade renewable energy credits (RECs) in carbon markets (Abdmouleh, Alammari, & Gastli, 2015). Cities can also encourage local renewable generation investment, particularly solar power and heating, by providing subsidies, removing permitting barriers, and helping define the structures that allow renewables to sell power back to the grid (Abdmouleh et al., 2015).

While these policies might encourage some renewable development, their emissions impacts might be limited. PPAs and RECs can be subject to confusing emissions accounting games that can, for example, ignore the benefits of reducing energy demand in a building powered by "100% renewables". It's also unclear if these mechanisms encourage new wind and solar development or simply let consumers apply the electricity generation of distant renewable power plants towards their own emissions goals (Brooks, 2017). Locally, renewable energy generation within the city will help reduce urban emissions, but the dense cities needed to achieve transportation and building energy strategies will have limited rooftop space available for these technologies. Such cities might only be able to generate a few percent of their annual energy needs with local solar PV (Grubler et al., 2012) making rooftop solar a lower priority policy for deep urban decarbonization (Williams et al., 2012).

Cities might more effectively reduce power sector emissions by focusing on improving the flexibility of their electricity consumption. In contrast to being centers of passive demand (Keirstead, Jennings, & Sivakumar, 2012), cities with flexible electricity demand can balance the intermittent output of renewable generators (Deetjen, Rhodes, & Webber, 2017), shift energy use to times of the day when power sector emissions are lower, and defer new power plant construction by reducing peak electricity demand (Gelazanskas & Gamage, 2014). Cities can subsidize the installation of flexible grid technologies such as "smart" appliances that can interact with electricity markets and the development of demand-side management strategies, like time-of-use electricity rates that reward customers for adjusting their energy consumption timing to benefit the larger electric grid system (Creutzig et al., 2016). EVs, in particular, will contribute significantly to flexible electric demand in future electric grids (Sioshansi & Denholm, 2009; Tuttle & Baldick, 2012) and district utility systems with energy storage and electricity generation technologies may also play an important role (Deetjen, Vitter, Reimers, & Webber, 2018).

3.4. Improving public utilities and green spaces

Cities oversee public spaces and utilities that influence GHG emissions, and they can achieve some environmental goals by managing them more purposefully. Water and waste utilities, for example, generate greenhouse gases both indirectly by consuming energy to process, transport, and heat water (Sanders & Webber, 2012) and directly

Table 3
Each city's climate action plans (see the last column of Table 2) are measured against the scoring rubric in Table 1 to produce the following scores. The "% of Possible" numbers show the total scores in each row and column normalized to 100%.

	New York	Los Angeles	Chicago	Dallas	Houston	Washington D.C.	Philadelphia	Miami	Atlanta	Boston	San Francisco	Phoenix	Riverside	Detroit	Seattle
Essential policies															
Building quality	9	9	9	6	6	9	6	6	6	6	9	9	6	9	6
Parking restrictions	0	6	3	3	3	3	6	9	9	9	9	0	6	0	3
Dense development	3	9	0	0	6	3	6	6	0	3	0	0	3	0	9
Priority policies															
Mass transit	6	4	6	2	4	4	6	4	4	4	4	6	4	4	4
Automobile independence	6	6	4	4	4	4	2	4	4	4	6	2	4	4	6
Non-motorized transport	6	4	6	4	4	4	4	4	4	4	6	4	6	4	4
Mixed land use zoning	4	4	0	6	4	4	6	4	4	4	4	4	4	4	4
Regional planning	4	6	4	6	6	4	6	6	2	4	4	2	6	0	6
Strategic growth	4	4	0	2	2	4	4	6	4	4	2	0	2	2	2
Transparent assessment	4	4	4	4	2	4	4	4	4	4	6	4	4	4	4
Consumption-based analysis	0	0	0	0	0	0	0	0	0	0	2	2	0	2	2
Consumer habits	4	4	0	2	0	4	4	6	0	6	6	0	6	6	0
Appliance efficiency	4	6	2	4	4	4	4	2	4	4	4	4	4	4	4
Smart grid management	6	6	2	4	4	4	2	2	2	4	4	0	6	2	6
Additional policies															
Green spaces	3	3	3	2	2	3	2	2	2	3	3	3	3	2	2
Architectural form	2	2	2	2	1	3	1	3	1	2	1	2	2	3	1
District energy systems	1	0	0	0	0	3	0	2	0	0	3	3	2	0	2
Vehicle electrification	1	3	2	1	1	2	2	2	2	2	2	2	3	1	2
Clean power sector	2	2	2	2	2	2	1	1	1	2	3	2	2	1	3
Local renewables	3	3	2	2	2	2	2	2	2	3	3	1	3	1	3
Water infrastructure	3	2	3	2	1	3	1	1	2	1	1	0	3	1	0
Solid waste emissions	3	3	3	3	1	3	3	2	2	3	3	3	2	3	3
% of Possible	67	77	49	52	50	65	62	67	50	65	73	45	69	49	65

	Minneapolis	San Diego	Tampa	Denver	St. Louis	Charlotte	San Antonio	Portland	Pittsburgh	Las Vegas	Kansas City	Austin	Nashville	Milwaukee	% of Possible
Essential policies															
Building quality	6	6	6	6	9	6	6	9	9	3	6	6	6	9	78
Parking restrictions	6	6	3	6	6	0	3	6	6	3	3	9	3	0	49

(continued on next page)

Table 3 (*continued*)

	Minneapolis	San Diego	Tampa	Denver	St. Louis	Charlotte	San Antonio	Portland	Pittsburgh	Las Vegas	Kansas City	Austin	Nashville	Milwaukee	% of Possible
Dense development	6	6	0	0	9	0	3	6	6	3	6	9	6	3	43
Priority policies															
Mass transit	4	4	4	6	6	4	4	4	4	4	4	4	4	4	72
Automobile independence	6	4	4	6	6	4	2	6	4	4	6	4	4	4	74
Non-motorized transport	4	6	4	6	6	2	6	6	4	4	4	4	4	6	77
Mixed land use zoning	4	4	2	4	4	2	4	6	4	4	2	4	4	2	63
Regional planning	2	0	4	4	0	4	4	4	2	4	2	6	4	6	64
Strategic growth	4	4	4	0	0	0	6	4	2	2	6	6	2	2	48
Transparent assessment	4	6	4	4	4	2	4	4	4	4	4	4	4	2	66
Consumption-based analysis	2	0	0	4	2	2	2	6	0	0	2	2	0	0	17
Consumer habits	2	4	4	6	4	4	6	6	6	6	6	6	4	6	68
Appliance efficiency	6	4	4	4	6	2	2	4	4	2	4	6	2	4	64
Smart grid management	4	4	2	6	4	0	4	2	4	0	0	6	0	2	53
Additional policies															
Green spaces	2	2	2	2	2	2	2	2	2	2	2	2	2	2	76
Architectural form	0	1	1	1	2	2	3	2	3	1	2	1	2	3	60
District energy systems	3	0	0	1	2	0	0	3	2	0	0	2	0	1	34
Vehicle electrification	2	3	2	2	3	1	3	3	3	2	1	2	1	1	66
Clean power sector	2	3	2	3	2	2	2	2	2	3	1	2	2	2	67
Local renewables	2	3	2	2	2	2	3	3	3	3	2	2	2	3	78
Water infrastructure	1	3	2	2	3	1	1	2	3	1	0	1	1	2	54
Solid waste emissions	3	3	3	2	2	3	3	3	3	2	2	3	3	2	89
% of Possible	64	65	50	66	72	38	62	79	68	49	56	78	51	56	

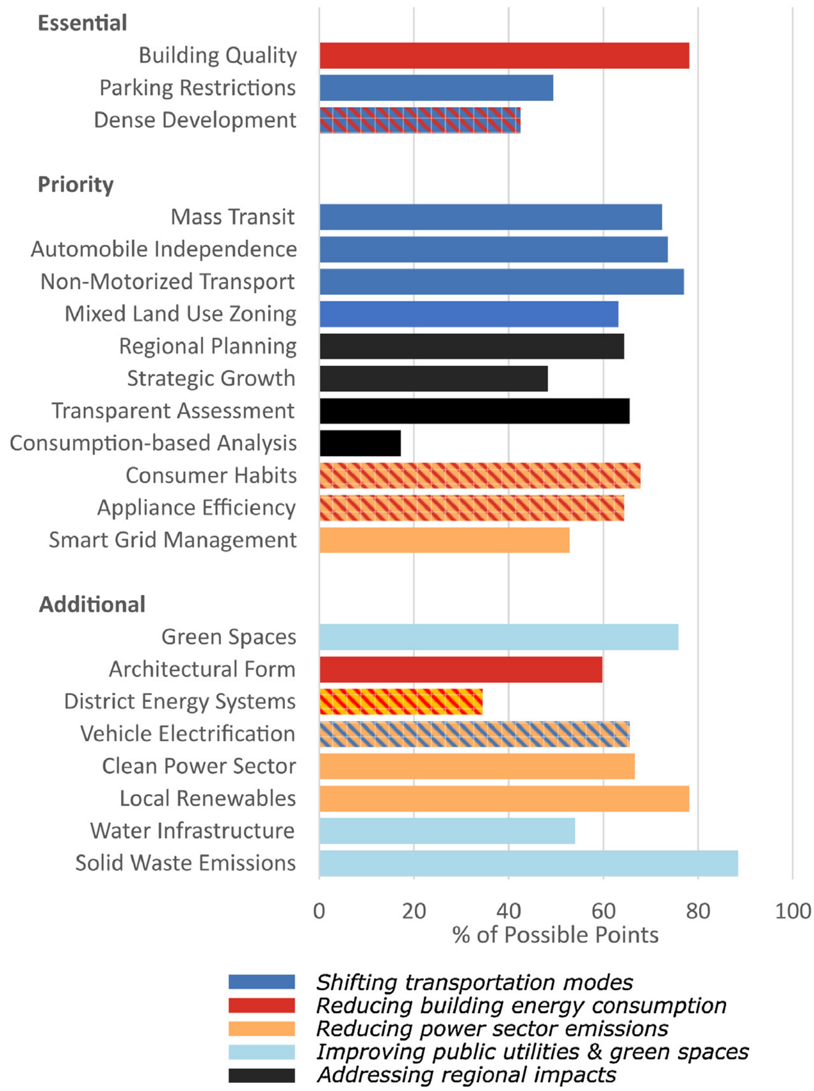

Fig. 4. Each policy type's score averaged across the 29 cities, grouped by weight, and colored by broad strategy relevance.

through emissions from the biological processes that occur during wastewater treatment and municipal solid waste landfilling (Edenhofer, 2014). While their overall emissions contribution might be relatively small, cities should not overlook the benefits of improving these utilities.

The water system's energy efficiency can be improved by reducing potable water demand and by limiting leaks in the water infrastructure. Water demand can be reduced by using water efficient fixtures, such as low-flow faucets or dual-flush toilets, and by substituting lower quality water for applications where potable water is not necessary (Grant et al., 2012). A city can pursue these methods by enforcing higher efficiency plumbing fixtures in their building codes (Inman & Jeffrey, 2006) and by updating their system for stormwater capture and reuse (Fletcher, Mitchell, Deletic, Ladson, & Seven, 2007). Between 10% and 50% of potable water is lost due to leaky water infrastructure (Grant et al., 2012). Many methods can help cities locate leaky infrastructure that needs to be repaired, including water audits, leak detection, or even high-tech, real-time monitoring systems (Mutchek & Williams, 2014). Water infrastructure planning might also incorporate decentralized water systems (where stormwater harvesting and wastewater processing occur at a community-level), which can provide operational benefits that reduce water loss and increase efficiency (Daigger, 2009; Vitter, Berhanu, Deetjen, Leibowicz, & Webber, 2018).

Wastewater emissions might be reduced by using less energy-intensive processing technologies, such as thermal hydrolysis, or by capturing the methane produced in the waste treatment process and mixing it into the natural gas infrastructure, a method that can also be used to collect methane emissions from municipal solid waste landfill (Shen, Linville, Urgun-Demirtas, Mintz, & Snyder, 2015). Reducing the amount of municipal solid waste that makes it to the landfill, especially organic portions, can also help reduce emissions in the waste sector. Cities can discourage excess trash generation by using volumetric payment structures (e.g. "pay-as-you-throw") and promoting recycling and composting by developing those services and educating residents about their benefits (Hoornweg & Bhada-Tata, 2012). Cities might also reduce emissions by investing in waste-to-energy technology that diverts methane (a more potent GHG than CO_2) from municipal solid waste to fuel urban electricity generation and heating systems (Holmgren, 2006; Moya, Aldás, López, & Kaparaju, 2017).

In addition to public utilities, cities oversee green spaces that influence urban emissions in complex ways. Green spaces also act as local carbon sinks for reducing emissions directly on a small scale (Strohbach, Arnold, & Haase, 2012). Regarding building energy consumption, green spaces provide local cooling effects that reduce the urban heat island (UHI) effect (whereby solar absorption from built up areas noticeably raises the ambient temperature in cities) (Silva et al., 2017; Solecki et al., 2005). In most of the U.S., where heating energy outweighs cooling energy, UHIs actually reduce energy consumption

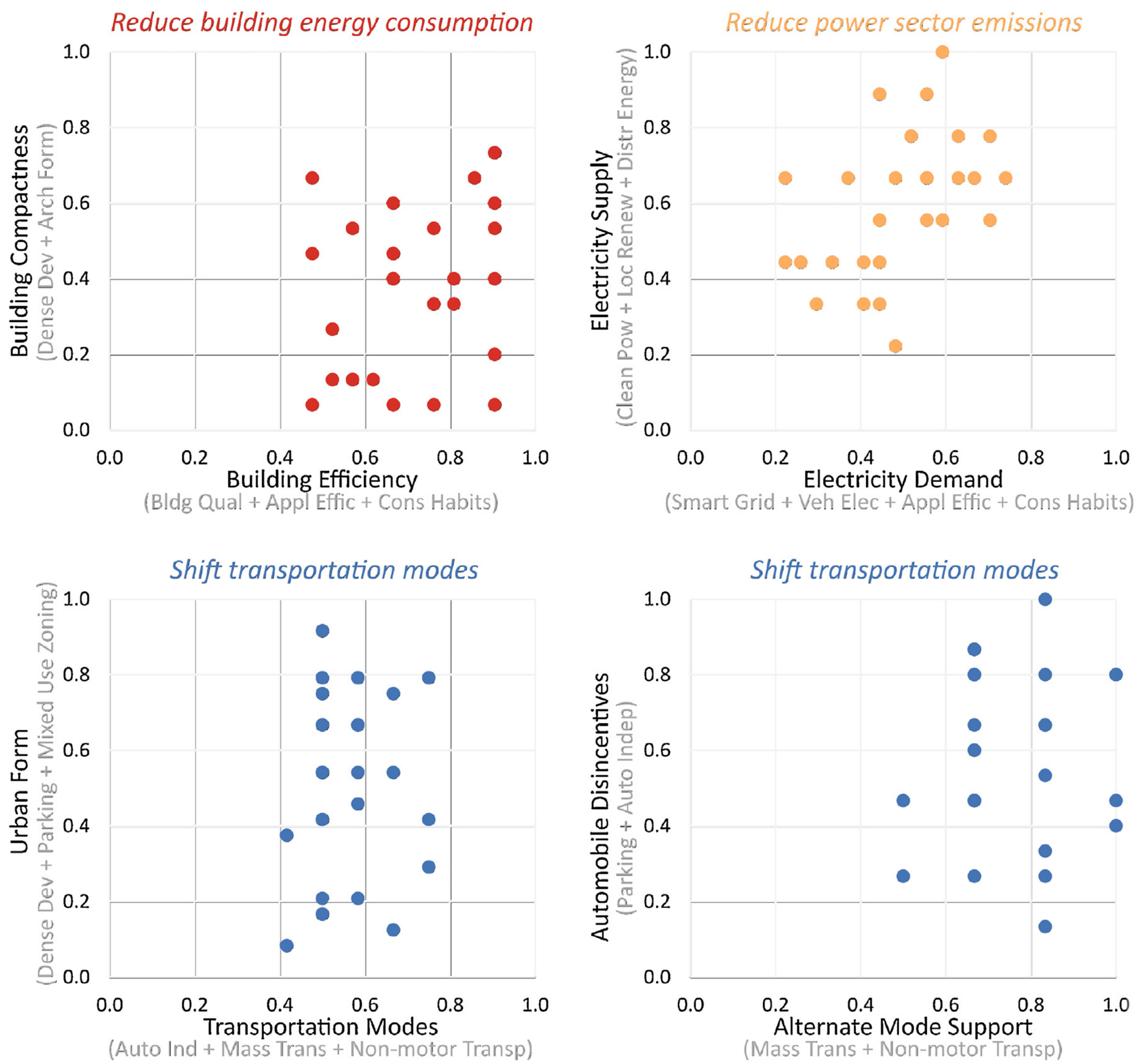

Fig. 5. Each scatter point represents a unique city's score, showing how balanced it is between the *x*- and *y*-axis policies. Scatter points in a chart's top right quadrant represent well-balanced, ambitious planning. Scatter points in the top left or bottom right quadrants indicate policy imbalances that will impede broad strategy implementation. Scatter points in the bottom left quadrant represent inadequate planning.

and green space cooling inhibits that beneficial effect (Ewing & Rong, 2008). Though, deciduous trees can provide building shading and cooling effects in the summer while allowing solar gains and more intense UHIs in the winter (Silva et al., 2017). Regarding transportation, trees on streets or small parks encourage NMT by providing pleasant urban environments and a sense of enclosure. Large green areas, however, may imply longer distances between origins and destinations, which increases travel distance by reducing connectivity (Silva et al., 2017). From a climate change mitigation standpoint, the benefits of density greatly outweigh the benefits of green spaces, and a general policy recommendation might be to focus on smaller green spaces in urban areas, limit large green spaces to areas outside of urban containment boundaries (Seto et al., 2014), and prioritize climate-appropriate tree species.

3.5. Addressing regional impacts

Thus far, strategies have focused on the local implications of climate mitigation policy, but ignoring how these policies impact urban areas beyond a city's jurisdiction through "spillover" effects can greatly inhibit the strategies' effectiveness. In one scenario, myopic transportation and urban planning creates a desirable but expensive urban core surrounded by low-density urban sprawl outside of the city's jurisdictional boundary. This sprawl prompts large, energy-intensive houses (Ewing & Rong, 2008), regional commuting via private vehicles (Jun, 2004), and unregulated development along unincorporated transportation corridors (Seto et al., 2014) that can each cause a net increase in regional GHG emissions. Similarly, cities with restrictive development regulations may become expensive enough to encourage residents to move away from the region altogether to a less expensive, development-friendly city with higher per capita emissions (Leibowicz, 2017).

Regional planning organizations provide an opportunity for cities to lessen these external impacts. Cities must work across geopolitical boundaries to coordinate growth, plan infrastructure, and address spillover (Betsill & Bulkeley, 2006; Seto et al., 2014). This cooperation is especially important in the transportation sector where managing corridor growth and transit development benefits from a regional planning scope (Rodier, 2009; Seto et al., 2014). Cities have access to numerous regional planning frameworks (Varga & Kuehr, 2007) and global organizations (Betsill & Bulkeley, 2006; Carbon Neutral Cities Alliance., 2017; Cities, 2017) that can provide guidance for successfully planning at the regional level.

Spillover effects at the national level might be more difficult for cities to address. Local climate is one of the most influential

Table 4
Top: total score statistics. Bottom: Pearson correlations between climate action plan scores and city characteristics from Table 2.

Total score statistics	
Minimum	38
Median	64
Mean	61
Maximum	79
Pearson correlations of score vs.	
Urban area population [excl. NYC and LA]	0.13 [−0.20]
Principal city population [excl. NYC and LA]	0.09 [−0.32]
Urban area population density	0.43
Principal city population density	0.31
Degree Days	−0.26
CO_2 Emissions per capita	−0.16

characteristics on urban GHG emissions (Glaeser & Kahn, 2010). Unfortunately, U.S. cities in mild climates tend to restrict development leading to higher housing prices that drive migration to U.S. cities in energy-intensive climates with pro-development policies that make them more affordable (Glaeser & Kahn, 2010; Leibowicz, 2017). Ironically, this scenario means that restrictive development policies aimed at climate change mitigation might trigger long-range migrations that increase GHG emissions overall (Glaeser & Kahn, 2010). Barring a national carbon market mechanism, cities must attempt to place their environmental goals within the context of their local climates. Cities in temperate climates might encourage development and population growth by eliminating density discouraging policies like maximum building heights while cities in energy-intensive climates might prioritize building energy efficiency and limit sprawl through urban growth boundaries and transit (Glaeser & Kahn, 2010).

Beyond strategic planning, cities can also address regional impacts by monitoring their environmental achievements with transparent, consumption-based accounting methods. A well-rounded climate mitigation plan will include a strategy for quantifying emissions (Fong et al., 2014) and energy consumption (A Better City, 2012), validating their calculations via a third-party assessor (Fong et al., 2014), and reporting the city's progress to its residents and regional stakeholders. This regular reporting provides accountability and feedback that helps cities achieve their climate change mitigation goals (Creutzig et al., 2015). Accounting methods can be further improved by acknowledging the large supply chains whose energy and environmental impacts, though directly tied to urban consumption, might be located outside of the urban geographic boundary (Ramaswami & Chavez, 2013). Consumption-based methods such as life-cycle analysis (Seto et al., 2014) and cross-boundary impact studies (Hillman & Ramaswami, 2010) can increase a city's emissions accounting by nearly 50% and can stimulate regional climate change mitigation strategies by internalizing the impacts of raw material sourcing, commuter travel, airlines, electricity generation, product manufacturing, and water delivery (Hillman & Ramaswami, 2010).

4. Climate action plan scoring rubric

Cities can pursue numerous policies to reduce their GHG emissions, which they often compile into a cohesive climate action plan. Rather than analyzing cities' change in GHG emissions over time to judge their previous climate change mitigation progress (Markolf, Matthews, Azevedo, & Hendrickson, 2017), this study evaluates their climate action plans to assess the comprehensiveness of their long-term GHG reduction strategies. We accomplish this evaluation by comparing the climate action plans of 29 major U.S. cities against the policy recommendations outlined in Section 3 by developing a multi-parameter, analytic scoring rubric.

The scoring rubric consists of 22 different policy types divided into Essential, Priority, and Additional policies worth a maximum of 9, 6, or 3 points, respectively. Priority policies, the default scoring weight, represent important policies whose exclusion would limit a climate action plan's effectiveness. A policy may be given more weight if it interacts with numerous other policies and is readily implemented through urban policy mechanisms. These characteristics are especially evident in the three Essential policies – Building Quality, Parking Restrictions, and Dense Development – whose exclusion would seriously undermine a climate action plan's success. We exclude some highly interactive policies from this Essential scoring weight – Mass Transit due to its dependence on Dense Development, Smart Grid Management due to its interconnection with primarily low-weighted policies, and Automobile Independence because its strong synergy with Mass Transit and Non-motorized Transport suggest that those three policies should be weighted equally.

Additional policies, the lowest scoring policy types, contribute to climate change mitigation but could be omitted from a climate action plan without significantly impacting broad GHG reduction strategies. Green Spaces has trade-offs with Essential and Priority policies and has limited impact on reducing GHG emissions. Architectural Form may be achieved via Dense Development without requiring specific low-energy architectural design policies. District Energy Systems depends heavily on Dense Development. Vehicle Electrification has trade-offs with private vehicle disincentives and can increase GHG emissions in a high-emitting electric grid. Clean Power Sector cannot be substantially influenced by urban policy. Local Renewables has few policy interactions and a trade-off with the Essential policy, Dense Development. Water Infrastructure and Solid Waste Emissions are relatively isolated from other policy types.

Table 1 provides greater detail on how these policy types are scored. In general, a city's climate action plan will receive minor points for acknowledging a policy type without mentioning specifics and will receive major points for implementing multiple specific policies aligned with that policy type. By comparing each city's climate action plans against Table 1 scoring rubric, each city receives a score for each policy type and an overall score for their whole climate action plan as shown in Section 5. Note that the rubric scores each city based on its climate action plan, not on its existing status, meaning that some cities might score low in policy areas that they have historically had success in. New York City's Dense Development policy plans, for example, score relatively poorly even though its current population density is the highest in the United States.

This study examines 29 major urban areas within the United States. This selection includes all of the top 20 most populous metro areas, and a subset of 20th–40th most populous metro areas selected to diversify

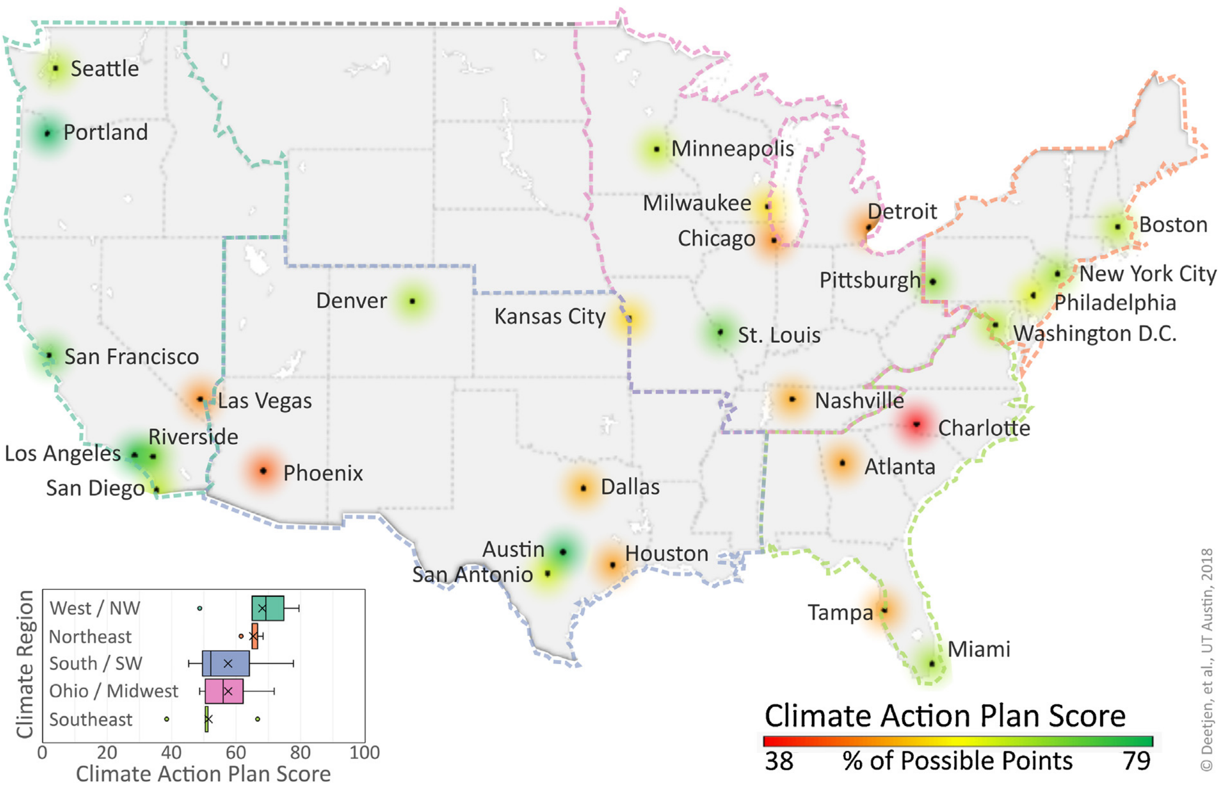

Fig. 6. The scores for each city's climate action plan are shown with their geographic location. The box and whisker plot uses NOAA climate regions (Karl & Koss, 1895–1983) to aggregate scores regionally.

the geographic coverage of the set. The total population of these 29 metro areas covers 37.3% of the U.S. population.

Each of these urbanized areas contains multiple cities, but this study only analyzes the climate action plans of each area's principal city. Since principal cities tend to have better developed climate action plans than their surrounding towns (Reckien et al., 2014), we assume that focusing on the principal cities will provide the most ambitious picture of urban climate action in the United States. Table 2 lists each of the studied cities including their municipal statistical area (MSA) population rank (United States Census Bureau, 2010a), urban area population (United States Census Bureau, 2010a), urban area population density (United States Census Bureau, 2010a), principal city population (United States Census Bureau, 2010a), principal city population density (United States Census Bureau, 2010b), degree days (BizEE Software Limited, 2017) (5-year average cooling degree days (CDD) plus 5-year average heating degree days (HDD); more degree days suggest that more energy will be needed to maintain building comfort (Weather Underground, 2017)), and per capita emissions (Markolf et al., 2017). Note that MSA boundaries often include rural areas, so population and density are based on urban area boundaries, which exclude undeveloped rural land. The last column of the table contains the citations that describe each city's climate action plans.

5. Climate action plan scores for U.S. cities

Applying Table 1 scoring rubric to the climate action plans of Table 2 cities yields Table 3 scores below. Though we score each city, we avoid analyzing individual cities to focus on broader trends for U.S. cities as a whole. Overall, the climate action plans score an average of 56.7, 60.5, and 65.5% of the possible points for the Essential, Priority, and Additional policy categories indicating reversed policy prioritization between U.S. cities and the scoring rubric. As illustrated in Fig. 4, U.S. urban climate action plans score well on Building Quality and transportation (Mass Transit, Automobile Independence, and Non-motorized Transport) policies but score poorly on Strategic Growth and urban form (Dense Development, Parking Restrictions, Mixed Land Use Zoning) policies. Since urban form influences building energy consumption and transportation, these policy imbalances will impede many cities' implementation of broader strategies to reduce building energy consumption and shift transportation modes.

Fig. 5 illustrates these policy imbalances. Plans to reduce building energy consumption neglect the synergy of achieving building compactness through Dense Development and Architectural Form, for example, and plans to reduce power sector emissions emphasize electricity supply over policies aimed at efficient, flexible electricity demand. For shifting transportation modes, U.S. urban climate action plans downplay the urban form and automobile disincentive policies needed to support Mass Transit and Non-motorized Transport.

Cities' overall scores range from 38 to 79% of the total available points and they correlate with city characteristics (Table 2) and regional location. The Pearson product moment correlation coefficients in Table 4 indicate how well the cities' scores correlate with the data from Table 2, where 1.0 is a perfect correlation, 0.5 is a moderate correlation, and 0.0 is no correlation. In general, we see a slight negative correlation between emissions per capita and total score, a small negative correlation for both climate (degree days) and population (if we exclude New York City and Los Angeles as outliers based on their large populations), and a positive correlation for population density. These results indicate that the highest scoring plans belong to lower emitting, smaller population, higher density cities in milder climates – the opposite of what is needed.

Like in Europe (Reckien et al., 2014), U.S. urban climate action plan scores tend to cluster regionally. Fig. 6 illustrates the variation in scores by NOAA climate regions (Karl & Koss, 1895–1983). The Northeast and West/Northwest regions hold ten of the fourteen cities scoring 65 or more points. The box and whisker plot in Fig. 6 shows higher scores in these regions and lower scores in the Southeast. The South/Southwest and Ohio River Valley/Upper Midwest regions tend to score somewhere in the middle with some low-scoring and high-scoring outliers.

This regional clustering could mean that cities in similar climatic and cultural areas are learning from each other and basing their climate action expectations on what is common among nearby cities. Research suggests that, while each city has unique environmental planning needs, learning from nearby cities is vital to achieving GHG reduction goals (Creutzig et al., 2015). This peer-to-peer learning also happens on an international scale through organizations such as the C40 Cities climate leadership group (Cities, 2017) and the Carbon Neutral Cities Alliance (Carbon Neutral Cities Alliance., 2017). Notably, of the fourteen cities scoring 65 points or more, nine (New York City, Los Angeles, Washington D.C., Philadelphia, Boston, San Francisco, Seattle, Portland, and Austin) belong to either of these international organizations, while only three of the fifteen cities scoring below 65 points belong to these organizations.

6. Conclusion

This study reviewed the academic literature's recommendations for reducing cities' GHG emissions via urban climate action policy. Those recommendations were used to develop a multi-parameter, analytic scoring rubric for assessing city climate action plans. We applied that rubric to 29 major U.S. cities to explore how well city climate action plans in the U.S. incorporate research-based policy recommendations.

The academic literature describes numerous policies for reducing urban GHG emissions. These policies form complex synergies, trade-offs, and dependencies for achieving broader GHG reduction strategies. Consequently, some policies merit higher priority than others. We identify Building Quality, Parking Restrictions, and Dense Development as being particularly essential. Building Quality impacts buildings' life-cycle embodied emissions and operational energy use and complements numerous other policies. Parking Restrictions supports population density and disincentivizes private vehicles to bolster numerous transportation policies. Dense Development influences building energy use via its impact on Architectural Form and supports a modal shift from private vehicles to public transit. Urban climate action plans must pursue a comprehensive set of these and other policies to reach their climate change mitigation goals.

Many U.S. cities' climate action plans, however, lack this comprehensiveness leading to policy imbalances that undermine their broad GHG reduction strategies. While U.S. cities tend to score well in Building Quality and transportation focused policies, many neglect the building compactness, urban form, and automobile disincentives needed to support them. This imbalance impedes broader strategies for reducing building energy consumption and shifting transportation modes.

Dense Development and Parking Restriction policies are noticeably underrepresented in U.S. cities' climate action plans. These two policy types are essential for achieving the higher densities needed to support mass transit, architectural form, district energy systems, walkable urban form and other GHG reduction policies. Yet, few U.S. cities meet the 5000 persons/km^2 threshold encouraged by scholarly research, and those that do may have highly dense urban cores that elevate average density concealing lower density areas. Even New York City, the United States' densest city, has many census tracts with densities below 5000 persons/km^2 (Population Division, 2010). Meeting these population density thresholds does not require cities to evolve into ultra-dense areas with high-rise buildings. These densities can be achieved by compact building designs and structures, such as town homes and apartments, with plenty of space for parks, courtyards, and other green spaces (Baiocchi et al., 2015; Grubler et al., 2012).

Higher population density along with lower population, milder climate, and fewer per capita CO_2 emissions also correlates with higher climate action plan scores. These correlations indicate that low-density, high-population, high-emitting cities in energy-intensive climates – places that need GHG reductions the most – are more likely to have deficient climate action plans. Low-scoring and high-scoring climate action plans also tend to cluster regionally, suggesting that low-scoring cities might benefit from extra-regional or international input for achieving their GHG reduction goals.

In closing, scholarly research supports numerous interconnected policies for reducing urban GHG emissions. We synthesize those policies into a scoring rubric that we apply to the climate action plans of 29 U.S. cities. Though Building Quality, Mass Transit, Automobile Independence, and Non-motorized Transport policies are well represented, the general absence of Dense Development and Parking Restrictions policies impedes cities' ability to leverage those strengths for achieving broad strategies that reduce building energy consumption and shift transportation modes. Moreover, low density, high population, high emitting cities in energy-intensive climates are more likely to have deficient climate action plans, and low-scoring cities are likely to have low-scoring neighbors that suppress regional climate action planning norms. These results suggest that many U.S. cities' climate action plans lack the cohesiveness to make them fully successful and may lack the peer support to improve them. As a result, unless they reevaluate their climate action plans, many U.S. cities might struggle to achieve the broader GHG reduction strategies needed to significantly contribute to global climate change mitigation.

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