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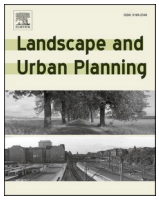

Research Paper

The role of urban agriculture in food-energy-water nexus policies: Insights from Europe and the U.S

Runrid Fox-Kämper [a,*], Caitlin K. Kirby [b], Kathrin Specht [a], Nevin Cohen [c], Rositsa Ilieva [c], Silvio Caputo [d], Victoria Schoen [e], Jason K. Hawes [f], Lidia Ponizy [g], Béatrice Béchet [h]

[a] ILS – Research Institute for Regional and Urban Development, Brüderweg 22-24, 44135 Dortmund, Germany
[b] College of Natural Science, Michigan State University, 288 Farm Ln, East Lansing, MI 48824, USA
[c] City University of New York Graduate School of Public Health and Health Policy, CUNY Urban Food Policy Institute, 55 West 125th Street, New York, NY 10027, USA
[d] Kent School of Architecture and Planning, University of Kent, Canterbury, Kent CT2 7NR, UK
[e] Centre for Agroecology, Water and Resilience, Coventry University, Ryton Organic Gardens, Coventry CV8 3LG, UK
[f] University of Michigan, School for Environment and Sustainability, Ann Arbor, MI, USA
[g] Department of Integrated Geography, Adam Mickiewicz University, Poznan, Poland
[h] University Gustave Eiffel-IRSTV, GERS, Water and Environment Laboratory, CS 5004, 44344 Bouguenais, France

HIGHLIGHTS

- Food-energy-water nexus policies that directly include UA are limited.
- Regulatory policies were ranked as most effective at promoting resource-efficient UA.
- Regulation-based policies dominate in case studies of Dortmund, Gorzów and Nantes.
- Among the five case study cities, the most distinctive UA policies are in New York City.
- Alignment between FEW nexus policies and UA indicates potential for future integration.

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ABSTRACT

The growth of urban agriculture (UA) has raised the awareness of city officials and civil society organizations of its potential effects on food systems. This has led to various policies to regulate and support UA. This research characterizes existing food, energy and water (FEW nexus) policies based on policy data from five case study cities in Europe and the U.S. (Dortmund, Gorzów Wielkopolski, London, Nantes, and New York City) to analyze their relationships to UA, and to identify policy types that support resource-efficient UA. The paper presents the results of an analysis of 78 policy documents related to UA and the FEW nexus, and the results of a Q-sort ranking by UA policy experts on the effectiveness of 16 generalized UA policies in promoting resource-efficient UA.

The number, type, and degree of support for nexus policies vary among the five case studies. The results show that the majority of policies (36) are implemented at the local scale, that few policies (19) incorporate all elements of the nexus, yet many nexus policies include UA indirectly. Regulations are more prevalent and are considered more effective at ensuring resource-efficient UA than incentives or awareness-raising policies. The study offers guidance to policy makers who want to improve resource use in future UA pointing at the increasing importance of local food policies.

1. Introduction

In this modern era of rapid social and biophysical change, cities face numerous challenges, such as shifting growth dynamics and climate change, that highlight perennial questions of balancing ecological, economic, and social concerns in urban planning. Although cities have

* Corresponding author.
E-mail addresses: Runrid.fox-kaemper@ils-forschung.de (R. Fox-Kämper), kirbycai@msu.edu (C.K. Kirby), Kathrin.specht@ils-forschung.de (K. Specht), nevin.cohen@sph.cuny.edu (N. Cohen), Rositsa.Ilieva@sph.cuny.edu (R. Ilieva), s.caputo@kent.ac.uk (S. Caputo), Victoria.schoen@talk21.com (V. Schoen), jkhawes@umich.edu (J.K. Hawes), lidia.ponizy@amu.edu.pl (L. Ponizy), beatrice.bechet@univ-eiffel.fr (B. Béchet).

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become increasingly disconnected from their food sources since industrialization and globalization reshaped the food system (Doernberg et al., 2019), urban food policy, planning and research are increasingly important for sustainable urban development. For decades, urban food production and supply have played a subordinate role in urban planning. Consensus held that the food system was largely a rural issue and therefore outside the scope of urban planning (Pothukuchi & Kaufman, 1999; Stierand, 2012). After prompting from scholars (Pothukuchi & Kaufman, 1999), the American Planning Association recognized this gap in 2007, noting that "among the basic essentials for life - air, water, shelter, and food - only food has been absent over the years as a focus of serious professional planning interest." (American Planning Association, 2007, p. 1). In other countries, urban food planning has gradually been incorporated in regional and supranational strategies with urban agriculture (UA) now gaining significant attention (Doernberg et al., 2019; Stierand, 2012).

Cities have turned from treating UA (i.e. the practice of growing food in and around cities that interacts with urban areas through the exchange of materials, people, and values (Mougeot, 2000; Smit et al., 1996)) as an anachronism to acknowledging its prevalence, to using UA as a strategic tool for sustainable development and resilience for stormwater management, flood protection, urban heat island mitigation, and organic residuals management (Cohen & Wijsman, 2014; Doernberg et al., 2019; Halvey et al., 2020). Global initiatives like the Milan Urban Food Policy Pact and growing interest in UA have led to increasingly supportive local policies (MUFPP, 2015; Halvey et al., 2020). Acknowledging the evidence that UA can generate considerable benefits, some municipalities have embedded UA in their policies to a greater extent than others, such as New York City's creation of an Office for Urban Agriculture (https://www1.nyc.gov/site/agriculture/index.page), and Montpellier and Lisbon's ongoing programs promoting UA (Scheromm and Mousselin, 2017). The role of the urban farmer is also receiving institutional recognition (e.g., the creation of AFAUP, Association Française d'Agriculture Urbaine Professionnelle https://www.afaup.org).

Despite UA's intersection with other urban issues, such as public health, social justice, energy, water, land use, transportation, and economic development, policy and governance research have largely focused on the land use impacts of UA, such as policies to identify and regulate plots or rooftops suitable for UA (Ackerman et al., 2014). Scholars have connected UA policies to societal goals, such as those to improve the knowledge base for locally produced food and raise awareness of nutrition and health, yet policies connecting these domains remain limited (Campbell, 2016). Minimal attention has been paid to the effects of UA policies on shifting patterns of resource use and availability. This was acknowledged in a 2018 call launched by Urban Europe and Belmont Forum, promoting research to 'find solutions to the Food-Water-Energy nexus for a sustainable urbanization' (https://jpi-urbaneurope.eu/calls/sugi/). Work examining the systematic integration of UA into urban food strategies and sustainability plans has demonstrated the important effects of UA across sectors such as food, water and energy (Cohen, 2012; Goldstein et al., 2016), yet resource use and Food-Energy-Water nexus links are rarely featured in UA policy research.

This study is based on research developed within the FEW-meter research project, funded under the Urban Europe/Belmont Forum nexus call (https://www.fewmeter.org). The project posits that against a backdrop of growth of the UA sector (Palmer, 2018) and increasing resource scarcity, it is important to question how resources in UA are used and regulated even though food produced in cities is still a small share compared to industrial agriculture outputs. The FEW (Food-Energy-Water) meter ascertained current UA resource use and food production levels through case study analysis of in-soil UA projects, hence generating insights on the opportunities and obstacles to a Food-Energy-Water nexus approach that can inform UA practice as well as the need for policies that can promote rational resource use (e.g. irrigation and rainwater harvesting, food waste generating compost, etc.). Although this project measured resource use only, other UA FEW nexus studies quantify UA impacts (e.g., Haitsma Mulier et al., 2022) and propose approaches that reduce resource consumption to attain a resource-efficient UA design (e.g., Yan & Roggema, 2019). However, studies that link the FEW nexus to policymaking are lacking (Zhang et al., 2019). Research examining how policies enable or stifle UA (Schmidt, 2012) point to the lack of clarity of relevant regulations impacting UA practices (Castillo et al., 2013), the unequal distribution of resources from funding programs (Cohen & Reynolds, 2015) and issues of access to land (de Oliveira et al., 2021). A limited number of studies compare the effects of policy and planning frameworks on UA across countries (e.g., Prové et al., 2016), among different cities in the same country (e.g., Huang and Drescher, 2015), or between supralocal regulatory frameworks, such as the Common Agriculture Policy (CAP) in the European Union, and UA land uses and practices at the local level (Curry et al., 2015). Some of the most detailed and comprehensive global policy-centered assessments of UA are of countries and cities in the Global South (e.g., (Mougeot, 2000; Quon, 1999). However, research on how UA is incorporated into broader policies that focus on the FEW nexus (i.e., regulating resource use to enable resource-efficiency) is still very limited. To our knowledge, this is the first paper examining how UA and the FEW nexus are incorporated at different levels of government in five different cities.

Moreover, the methods of most existing studies are limited. Many reviews of public policy use a case study research design for a specific city or region (e.g., Doernberg et al., 2019). While authors agree about the importance of stakeholders in UA governance, policy analyses and stakeholder input are often separated, with stakeholders interviewed about key attributes of agricultural policies without reference to actual policies (e.g. (Piso et al., 2019; Van Calker et al., 2005). This paper fills these gaps through a ranking exercise with key policy stakeholders in each of the five countries to explore which policies are perceived as promoting UA across multiple contexts. The paper focuses on a policy analysis of the FEW nexus in the context of UA, specifically in-soil UA, analyzing cities' food, energy and water policies. We also consider policies with indirect or second-order relationships to UA, such as green infrastructure and climate change resilience policies that affect UA or include UA as a policy component.

The aims of this paper are: (1) to analyze the actual and potential role of UA within existing FEW nexus related policies and (2) to identify policy "best-practices" to support resource-efficient UA. Our goal is to answer the following questions:

(1) How do existing food, energy and water policies directly or indirectly relate to UA and how can these policies be characterized? and
(2) Which types of policies are perceived by experts as most effective in promoting resource efficient UA?

2. Theoretical background on the FEW nexus and urban planning policies

This section briefly reviews supranational and national policies on the management of resources for food production as well as national and local policies focusing on UA to identify the focus of policy making in these sectors.

2.1. The food-energy-water nexus of UA policy

Consumption of resources such as water, energy and food is embodied in diverse goods and processes, with the complex connections among different resources adding challenges to identifying effective approaches to reduce resource use (Caputo et al 2021). Resource security is a political issue that becomes increasingly critical as resources become scarcer. The FEW nexus, the complex relationship among flows

of food, energy and water, has been debated globally for more than a decade (Albrecht et al., 2018). Food, energy, and water are key to three of the UN Sustainable Development Goals (2, 6 and 7 respectively) and are widely recognized as human rights. Yet, despite extensive scientific evidence on the FEW nexus, and the availability of tools for measurement and implementation, policy to address the FEW nexus has lagged (van Gevelt, 2020).

A major obstacle in the development of effective FEW nexus policies is siloed decision-making bodies that lead to compartmentalized policies that fail to address food, energy, and water simultaneously (Lawford et al., 2020; Weitz et al., 2017). For example, EU policies regulate food, energy, and water production through the Common Agricultural Policy, the Energy Efficiency Directive, and the European Water Framework Directive, respectively, with only cursory linkages among the three. A study reviewing 50 EU policies found that only one, in support of rural development, explicitly mentioned the FEW nexus (Venghaus & Hake, 2018).

In addition to compartmentalization, the complexity of identifying the linkages among food, water and energy use, and the lack of cross-sectoral expertise (Bazilian et al., 2011), which is necessary to identify feedback among systems, inhibits FEW nexus policymaking. Many studies provide tools to identify such linkages, but most are based on quantitative assessments (Arthur et al., 2019), with only a few translating these analyses to policy and governance pathways that enable the effective implementation of FEW nexus policies (Dai et al., 2018).

Even though cities comprise a significant share of global environmental footprint (Edenhofer et al., 2014) and metropolitan governments play an ever-expanding role in global environmental governance (C40, 2019), most FEW nexus-related studies and policies focus on the macro scale, regulating resource availability regionally or nationally (Biggs et al., 2015; Caputo et al., 2021; Zhang et al., 2019). Such studies investigate the broader food production and supply chain rather than urban food production specifically. However, cities influence resource use and depend on resource availability, which is in turn determined by the functioning of urban infrastructure and stakeholder practices (Artioli et al., 2017).

A few studies shift the spatial focus to cities as major nodes of resource use (Shah et al., 2021; Yan & Roggema, 2019). Some examine the nexus between other aspects of resource efficiency (not only energy and water), for example between UA and the transportation of food produced in the city (Elkamel et al., 2023), or the roles of technology and governance to optimize the FEW nexus (Schwindenhammer and Gonglach, 2021). A limited number of studies concentrating on the production of food in cities are based on primary data such as Dorr et al. (2023) that analyzes 72 UA sites' resource use across six cities and five countries, Miller-Robbie et al. (2017) analyzing the FEW and health nexus on a small, cultivated plot in Hyderabad, and Haitsma Mulier et al. (2022) quantifying the water, energy, nutrient, and food nexus in three urban farms across multiple cities. Mohareb et al. (2017) attempt to scale up primary data to analyze the impact of UA on the FEW nexus at a national level in the United States, suggesting that further studies based on primary data are needed to inform evidence-based policy making in this area.

2.2. UA in European planning policies

Historically, farming and gardening in and around cities in Europe have been shaped by local government regimes and rules (Steel, 2013). By the industrial revolution, urban farming began to be purposefully included in urban planning to achieve healthier urban environments and increase the overall well-being of urban dwellers, not just to increase food security. Sir Ebenezer Howard's well-documented 1898 Garden City model and the Plan of Seville from 1890 included horticultural fields providing vegetables for the city (Lohrberg et al., 2016). Crises and poverty have also been major drivers for UA, such as allotment gardens in the 18th century and victory gardens during the two World Wars (Bellows, 2004; Keshavarz et al., 2016).

In the post-war era, urbanization and the scaling of conventional agriculture caused cities to view urban farms and gardens as anachronisms. Although in many European countries, allotment gardens represent a significant share of land-use in cities and are acknowledged in zoning regulations and other laws, food production still "…is rarely considered as an urban issue, and as a result UA tends to receive little attention in local council legislation and city planning." (Gulyas & Edmondson, 2021, p. 9).

This is beginning to change. In recent decades, as UA grew in popularity, cities have begun to re-integrate farms into urban plans and policies. For example, spatial planners in Southern Europe have advanced policies (e.g., the Agricultural Park of South Milan - *Parco Agricolo Sud Milano* - created in 1990 and the Agricultural Park - *Baix Llobregat* - south of Barcelona) to protect urban agricultural land to meet growing demand for local food and preservation of region-specific crop varieties (Paül & McKenzie, 2013; Zazo-Moratalla et al., 2020). The 2008 financial crisis led to new community gardens in countries all around the Mediterranean Sea such as Portugal (Delgado, 2017), Spain (Espinosa Seguí et al., 2017) and Greece (Partalidou & Anthopoulou, 2017).

More recently, local governments in Western Europe have included UA goals in city plans and planning frameworks and incorporated UA projects in new urban developments (Ilieva, 2016; Roggema, 2016). For instance, the London Plan of 2008, the long-term strategic planning framework for the city, includes policies that explicitly acknowledge the role of food-producing UA as green infrastructure and health infrastructure and encourages planners to support it by preserving existing sites and creating new food producing land in Greater London. The newest version of the London Plan (Mayor of London, 2021) encourages incorporation of food growing spaces in childcare facility design and emphasizes UA as a means to create healthy food environments. Other examples of policies or pilot plans guiding new urban development through the lens of UA include the Brighton & Hove Planning Advisory Note (Brighton and Hove, 2020), the Ghent UA 2050 vision from 2014 (Prové et al., 2016); and the Almere Oosterwold plan (Jansma & Wertheim-Heck, 2021; Jansma & Visser, 2011).

2.3. UA in United States (US) planning policies

The US also has a long history of providing vacant land in cities for individuals, families, and organizations to garden for food, recreation, education, and profit, including school garden programs in the 1930s and victory gardens during World War I and II. In the 1970s, UA policies legitimized and supported grassroots efforts to combat urban financial crises, disinvestment, and property abandonment by encouraging residents to voluntarily turn vacant lots into community gardens (Horst et al., 2017; Lawson, 2004; Reynolds & Cohen, 2016). The gardens created in this period became valued for their contributions to neighborhood vibrancy and have been defended by community members when their land tenure came under threat, with varying degrees of success (Drake & Lawson, 2015; Reynolds & Cohen, 2016). By the 1990s and 2000s, growing sustainability movements and interest in food culture increased demands for localized food systems with reduced "food miles," including urban-grown food.

Despite support for UA, between 2007 and 2012 an estimated 1,615 of 8,550 gardens in the US and Canada were lost to development (Drake & Lawson, 2015). This led some North American cities to adopt policies providing long-term or permanent tenure for gardens and farms, revising restrictive or unclear UA zoning that made farms and gardens incompatible land uses, and allocating city-owned property for agriculture (Siegner et al., 2018). Some cities permitted UA in residential and commercial zones, while others created designated UA land uses, and a few created UA districts that allowed intensive farming (Meenar et al., 2017). Cities have also enacted policies to permit selling urban-grown produce on or near urban farms (Siegner et al., 2018) or

created community land trusts, non-profit organizations that hold the deed to land in perpetuity, to buy and maintain new UA parcels or to protect existing farms (Horst et al., 2017).

Cities have changed building codes to permit food production on or in buildings. For example, to encourage rooftop agriculture, New York City changed its zoning in 2012 to exempt greenhouses from counting towards a building's bulk and height limits (Pawlowski, 2017). Some cities have also adopted incentive programs to encourage property owners to grow food on their land, taxing cultivated urban parcels at a lower agricultural rate or providing tax rebates (Havens & Roman-Alcalá, 2016; Horst et al., 2017). Others have supported community gardens and non-profit urban farms with in-kind and financial support (Cohen & Reynolds, 2015; Diaz et al., 2018), as well as technical assistance to ensure safe food production in urban soils (Toronto Public Health, 2013). Urban planners have adopted policies to enable UA to better provide ecosystem services like stormwater retention (Clarke et al., 2018). Policies have supported urban farms as emergency food distribution spaces to support disaster recovery (Hara et al., 2018).

Our literature review reveals that the FEW nexus is important in the context of city resource use and UA, although the nexus has been examined mainly at macro scales. There is a deficit in translating this knowledge into governance pathways and effective policies that consider the FEW nexus. It also demonstrates that urban policies and research on UA policy primarily focus on land use and land availability as well as ecosystems services, but not on the use of energy and water resources from a FEW nexus perspective. As research about policies promoting FEW nexus thinking into UA is missing this research will contribute to filling this gap.

3. Material and methods

3.1. Analytical framework

We analyze the role of UA in FEW nexus policies through a policy inventory across five case study cities. For each policy we examine the FEW nexus relation, the degree of influence on UA, its scale, and policy type (Figure 1).

Policies are defined as the techniques used by the government to wield power to affect society (Mickwitz, 2003). As policies address issues in different ways, on different levels, and for different purposes, particularly with respect to the FEW nexus, we analyzed them according to the following characteristics:

3.1.1. FEW nexus relation

The FEW nexus relation is based on a definition by the Food and Agriculture Organization of the United Nations (FAO) of the FEW nexus as a concept to "describe and address the complex and interrelated nature of our global resource systems" that balances resource users' goals and interests "while maintaining the integrity of ecosystems" (Endo et al., 2017, p. 22). Our analysis considers the number of FEW nexus relations within one policy as an indicator of the integration of the FEW nexus concept in the policy, recognizing that the quantity of different FEW nexus elements is only one possible measurement method.

3.1.2. Degree of influence on UA

We considered how each policy directly or indirectly affects UA. According to Halliday (2019), who examined urban food policies, not every food-related policy affects UA, is marked as such and can include other goals such as urban regeneration, economic development, environmental protection, or public health (Halliday, 2019, p. 55).

3.1.3. Intervention scale

We considered the level at which the policy was initiated, from the supra-national to the national, regional, and local scale. Supra-national policies may include binding EU policies that require adoption by national law. National policies are initiated at the level of a country, while regional policies are adopted by a state or regional administration. Local policies are those of a municipality or a city district.

3.1.4. Policy type

Policy type describes the "degree of authoritative force involved" (Mickwitz, 2003, p. 419) and includes three main policy instruments: laws and regulations (referred to as "regulations"), economic incentives/disincentives ("funding or incentive-based"), and information ("awareness-increasing") (Bemelmans-Videc et al., 2017). Because the policy types are not mutually exclusive, we categorized policies by the primary impact on UA: changing rules or procedures; affecting costs; or informing the public.

3.2. Case study sites

Our study uses a multiple case study research design that allows for cross-case analysis. According to Ridder (2017), a systematic comparison in cross-case analysis can help to reveal similarities and differences and how they affect findings. Our case studies were selected with the intention of theoretical replication. The diverse status of UA implementation, different planning systems and the different histories and traditions of UA are among the reasons to expect contrasting results in the five cities. This allows us to compare the mechanisms identified among cases and advance the theoretical understanding of the policy integration of UA, as suggested by Yin (2014). Our analysis (for workflow, see Figure 2), draws from policy data collected for five case study

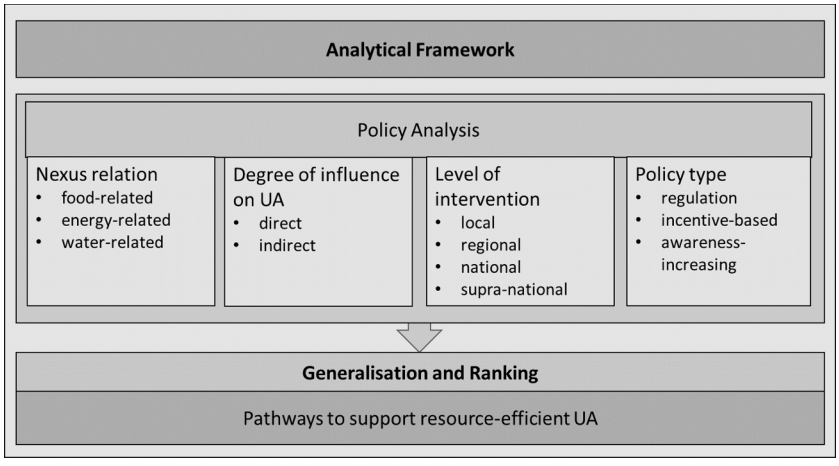

Fig. 1. Analytical framework.

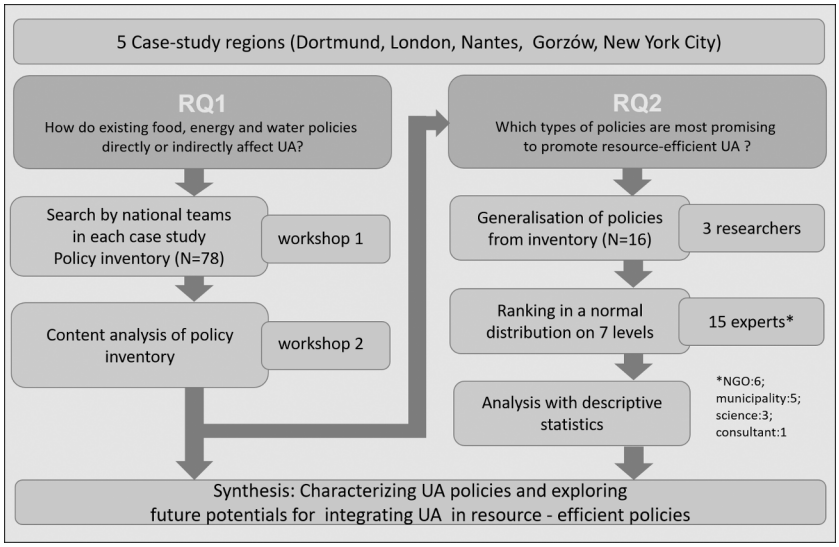

Fig. 2. Workflow of research.

metropolitan cities: Dortmund (Germany), Gorzów Wielkopolski (Poland), London (UK), Nantes (France), and New York City (US). The five cities were included because they were part of a larger study of food, energy, water, and social impacts of urban agriculture called the FEW-meter project (https://www.fewmeter.org).

The case-study regions were selected for inclusion in that project for their diverse nature of urban agriculture, involving different types and modes of organization. In Dortmund and Gorzów, allotment gardening has developed alongside traditional forms of commercial agriculture. Dortmund has 167 allotment gardens covering 423 ha and Gorzów has 36 allotment garden complexes covering 340 ha. The Nantes metropolis has a strong tradition of market gardening, which historically formed a ring around the dense center but largely disappeared in the 1970s. Some market gardening areas are now part of the 35 community garden sites of Nantes city. London also has a long tradition of UA. Today it is a leader in UA within the UK with many community growing and farming spaces across the city, including 197 members of Social Farms & Gardens, an urban agriculture organization, and over 2,000 cultivated spaces. In New York, there are approximately 550 registered community gardens and more than 800 public schools with garden projects (City of New York Mayor's Office of Food Policy, 2020). In addition, dozens of urban farms are operated by nonprofit organizations and private businesses throughout the city.

Despite these long histories of UA, food-growing is not a substantial user of land in any of the cities we studied. Correspondingly, the energy and water resources consumed by UA are minor relative to the overall footprint of the cities. However, this may begin to shift in coming years, as several programs like the London UA Strategy (Fleming, 2021) and the New York Mayor's Office of UA (Office of the Mayor, 2022) aim to expand the footprint of food-growing in the case study cities. Selected cities also differ in terms of size, demographic features, and socioeconomic status (Table 1). This diversity of form and emphasis on reinvigorated UA make these cities an ideal set of cases to answer our research questions.

3.3. Policy inventory

Between July and December 2019, we collected and analyzed policy documents in the five case study cities to identify food, energy, or water policies directly related to UA. This initial review identified 32 policies that addressed elements of the FEW nexus and directly related to UA We then enlarged our search to include policies indirectly linked to UA but that affect food, energy and water resource use. Research teams with deep knowledge of the policies of each case study conducted a second scan that identified 78 policies across all cases.

These policies were organized into categories as explained in the analytical framework (see section 3.1). We counted each policy as a single item and did not organize them according to impact, scale or scope. For example, a strategy valid for the whole city may have a bigger impact than a single regulation on water-use in allotment gardens, but

Table 1
Main characteristics of the case study cities.

	Dortmund	Gorzów	London	Nantes Metropole	New York City
Country	DE	PL	UK	FR	US
No of inhabitants	588,250[1]	123,610[1]	8,825,000[2]	684,371[3]	8,804,000[4]
Population. density (inhabitants/km^2)	2,091	1,442	5,596	1,281	11,314
Median income per capita USD (2017, UK 2018)	$20,106[5]	$12,499[6]	$31,024[7]	$21,861[3]	$31,177[8]
City area (km^2)	2,807[1]	85.71[1]	1,572.03[9]	523[3]	778.16[4]
Share of agricultural land in the city area (%)	39	52	NN[10]	30	NN[10]
Main types of UA in this study*	Commercial agriculture, horticultural farms, allotment gardens	Commercial agriculture, allotment gardens	Community farms and gardens	Horticultural farms, community gardens	Community farms and gardens

Data source: [1]Eurostat (2020), [2]Office for National Statistics (2021), [3]Banatic (2023), [4]United States Census Bureau (2020), [5]Statista (2023), [6]Statistical Office in Zielona Góra (2017), [7]Office for National Statistics (2020), [8]United States Census Bureau (2017), [9]Office for National Statistics (2023), [10]not known.
* Authors' own research as part of the FEW-meter project (2018–2022).

Table 2
Generalized policies used to rank effectiveness of UA policies. Each policy is shown with its related component(s) of the FEW nexus.

Type	Policy	FEW Nexus
Regulations	A law that requires city planners to provide community/allotment garden space for all interested residents.	F
	A law that designates money for UA projects and establishes a national UA support office.	F
	City zoning that allows agriculture in all residential and manufacturing areas.	F
	Laws that prohibit the conversion of a garden space into something else.	F
	A law that requires new or reconstructed roofs to have green roof covering.	E, W
	A law that requires cities to develop UA websites that inform residents about currently available and potentially available UA sites.	F
Funding or incentive-based	A local government-run organization that supports community gardens with garden sites and technical and infrastructure assistance.	F
	A local government program that funds, trains, and assists in school garden programs.	F
	Government funding for infrastructure that reduces stormwater run-off.	W
	Tax reductions per square unit of green roofs.	E, W
	A city program that supports community composting, accepts compostable scraps, and gives free compost to city residences.	Indirectly related
Awareness- increasing	A city strategy document that promotes UA as a way to provide access to healthy, affordable, and sustainable food for all.	F
	A city strategy to promote urban green spaces and green infrastructure in public areas.	Indirectly related
	A city program that encourages use of available recycling and compost opportunities.	Indirectly related
	An informational publication about water-saving behaviors in urban areas.	W
	A local fact sheet about renewable energy use in community gardens/urban farm sites.	F, E

each was counted once. The policies in the table were reviewed initially by one or two researchers from each country to identify the characteristics of each policy in comparison to others. The initial categorization was reviewed in a second workshop with one or two researchers per country with a focus on the relationships of the policies to the FEW nexus elements and their direct or indirect impact on UA. Policy characterization was assessed via descriptive statistics. The final policies table is available as supplementary material (Annex A).

3.4. Policy ranking

We engaged UA policy experts (n=15) who ranked the policies in our inventory based on their perceived effectiveness in promoting UA. Three to four policy experts were identified in each city by the national research teams to gain a set of UA experts with different perspectives. As a result, six representatives of NGOs, five of municipalities, three scientists and one consultant (n=15) completed the ranking exercise between April 2020 and October 2020.

To maintain consistency across respondents from different locations and enable us to observe common trends across different case study cities we developed a list of sixteen generalized UA policies derived from the 78 policies identified in the five cases. The process involved three steps. First, we removed the names of specific programs and institutions that would indicate the place or government agency involved. For example, “The New York Compost Project” became “A city program that encourages use of available recycling and compost opportunities”. Second, we sorted policies along three main policy types (regulation, funding or incentive-based, awareness-increasing) and the nexus relations of the policies and generalized similar policies to reduce the total number. Third, three authors iteratively selected preferred policies from the list according to our criteria of: 1) equal numbers of policies from the three policy types, 2) covering a range of topics across the FEW nexus, and 3) deriving policy content from various scales from local to supra-national (see Table 2 for the resulting list of generalized policies). The generalized policies may be indirectly related to the FEW nexus because they are based on actual policies; most policies are related to only one component of the FEW nexus.

After a 1 to 1.5-hour interview in which experts were asked questions about their knowledge of resource-efficiency in UA and the FEW nexus, policy experts received a link to an online survey using the software Qualtrics. The experts were asked to rank the effectiveness of the policies in promoting UA, like a Q-sort (Van Exel & De Graaf, 2005) or a diamond ranking (Niemi et al., 2018), with the following instructions: “Please sort the following policies based on your opinion about how effective they are in promoting resource-efficient urban agriculture. Please consider their effectiveness in promoting efficient water use, energy use, and food production”. For full methods see supplementary material (Annex B). Respondents accessed the generalized policy list in a random order and were asked to sort the policies into seven different levels of effectiveness. To achieve a normal distribution, respondents were instructed to select one policy as the most effective, one policy as the least effective, and to assign the rest of the policies to categories in-between. Similar normal distribution rankings have been used to examine farmers’ views of sustainability practices (Walder & Kantelhardt, 2018), the effectiveness of environmental policies (Frantzi et al., 2009), and multiple stakeholders’ preferred governance styles in UA (Piso et al., 2019). Policy rankings were analyzed using descriptive statistics. We used a Kruskal-Wallis test to measure the significance of observed differences in rankings across policy types.

4. Results

4.1. Characteristics of the policies

We collected 78 policies with FEW nexus elements that related directly or indirectly to UA over all five case studies. The number of policies differs significantly among the cases, with New York City (NYC) having the most (n=28), and Dortmund (n=13) and Gorzów (n=14) the fewest (Table 3). The six supra-national EU-policies were added to each of three case study cities affected by them (Dortmund, Gorzów and Nantes) so that the total number of policies increases to 90 when considered on a case-by-case basis.

4.1.1. Level of policy intervention

Most policies were local (a total of 36), while regional (13), national (23) and supra-national policies (6) were less common. Among cases, there were substantial differences (Table 3). While the policies affecting UA in NYC were mostly local, London had the same number of national and local policies, while Nantes had only a few local regulations with most at the regional level.

4.1.2. Types of policies

The categorization of the FEW nexus policies into the three main types revealed that most policies were regulatory (40), followed by

Table 3
Number of FEW nexus related policies directly or indirectly addressing UA in the five case study cities, at different levels of intervention, along three main types of UA policies and number of policies considering one to three FEW nexus elements (six EU policies added to the case studies Dortmund, Gorzów Wielkopolski and Nantes Metropole).

		Dort-mund	Gorzów	London	Nantes	New York City
No. of policies	Total	13	14	14	21	28
	National	7	8	14	15	28
	EU	6*	6*	–	6*	–
Level of intervention	Local	2	4	7	2	21
	Regional	1	0	1	7	4
	National	4	4	6	6	3
	Supra-national	6*	6*	–	6*	–
Policy type	Regulation	11	11	5	12	11
	Funding or incentive-based	1	1	1	4	16
	Awareness-increasing	1	2	8	5	1
No. of FEW-nexus elements	1	8	8	5	9	12
	2	4	4	6	7	8
	3	1	2	3	5	8

*including 6 identical EU policies.

funding or incentive-based (20) and awareness-increasing ones (18).

All case-study locations had multiple **regulation-based policies**, and regulations were by far the dominant type in Dortmund, Gorzów and Nantes (Table 3). Regulations include building codes and planning laws, rules for specific UA types such as allotment gardens (e.g., Family Allotment Garden Regulations, Gorzów, No. 70, Annex A) or for the processing of food (German National Food- and Fodder law, No. 3, Annex A), or regulations to curb resource use to protect the environment (Regulation (EU) 2020/741 of the European Parliament on minimum requirement for water reuse, No. 78, Annex A).

Funding or incentive-based measures were much more common in NYC, where they exceed all other FEW nexus policies. The New York City-run UA program "Green Thumb" (No 19, Annex A) supports community gardens on NYC property by providing sites, technical assistance, compost from parks, sanitation services, water cisterns, and administrative oversight. Other programs such as "Vital Brooklyn" (No. 33), "Gardens Rising" (No. 30), "PUREsoil NYC" (No. 21), the "NYC Compost Project" (No. 20), and "GrowToLearn" (No. 19) provide funding for open space projects, equipment, free compost or soil for community gardens or material and financial support for school garden programs (for details of all mentioned policies, see Annex A). Among the other cases, only Nantes had more than one funding or incentive-based policy; one of these is the project Nourishing Landscapes (Paysages nourriciers, No. 43, Annex A), which was developed during the COVID-19 crisis to promote vegetable cultivation in urban areas to provide free food for 2,500 low-income households in 2020.

Policies characterized as **awareness-increasing** were most often identified in London, the most prominent being the "London Food Strategy" (No. 58, Annex A), which aims to ensure all Londoners have access to healthy, affordable, and sustainable food in part by promoting the multiple benefits of food growing for individuals and communities. Nantes region also has several awareness-related policies, such as the Territorial Food Strategy for Nantes Metropole (Projet Alimentaire Territorial (PAT) Nantes Métropole; No. 44, Annex A) with similar aims as the London Food Strategy. The number of these types of policies in Dortmund, Gorzów and NYC was limited by comparison.

4.1.3. Direct or indirect relation of FEW nexus policies to UA

About a third of the policies (26) directly impacted UA, while nearly two thirds (46) addressed UA indirectly. Six policies had direct and indirect effects, among them three policies related to NYC. For example, the US Agriculture Improvement Act of 2018 (commonly known as "the Farm Bill", No. 35, Annex A) addresses the entire American food and agriculture system and thus has a significant indirect effect on UA, e.g., by affecting the costs of conventional agriculture. The 2018 Farm Bill also includes regulations that apply to UA directly, such as the creation of an Office of UA and Innovative Production at the US Department for Agriculture, grants to support research and cooperative extension services that enhance urban and innovative agricultural production techniques or support for new and beginning farmers and ranchers. The other two NYC policies and one policy from Nantes have compost or soil programs as a primary goal, and UA initiatives are affected directly as farms and gardens can receive compost or soil for free. Other policies are town and spatial planning policies from Nantes and Gorzów. For example, the Metropolitan Local Urban Plan (PLUm) (No. 47, Annex A) regulates land-use in Nantes and thus indirectly regulates options for UA, but also encourages UA strongly.

We selected FEW nexus policies indirectly or directly related to UA, so it is not surprising that policies with a primary goal related to the food sector or to promote or regulate UA dominate (Figure 3). Water-related policies also occur comparably often, while the third FEW nexus element, energy, was addressed as the primary goal in only one policy, a fact sheet about renewable energy in community gardens that was distributed by the UK Farms and Gardens association (No 62, Annex A).

4.1.4. The FEW nexus relation of the policies

Most policies dealt with only one dimension of the FEW nexus (Table 3). We looked at individual policies to determine if they relate directly or indirectly to only one element of the FEW nexus, such as food or water, or if they apply a more encompassing approach by addressing more than one FEW nexus component. Overall, 34 policies considered only one element of the FEW nexus, while 25 included two, and 19 included all three elements of the FEW nexus. None of the six EU policies considers all three FEW nexus elements.

At a case-study level, NYC has the highest number of policies dealing with multiple FEW nexus elements (8), followed by Nantes (5) and London (3), while in Gorzów (2) and Dortmund (1) policies dealing with more than one element of the FEW nexus are scarce. In NYC, four policies that consider the FEW nexus are funding or incentive-based with the other four regulatory. For example, NYC requires any roofs on new buildings or those undergoing major renovation to be covered by either solar panels or a green roof system (No. 9, Annex A). This regulation simultaneously addresses stormwater management, energy conservation, and opportunities for rooftop food production where suitable. In 2018, Nantes Metropole's green transition roadmap also aimed to transform most rooftops in the city to solar energy production or green roofs (Nantes Métropole Climate Plan, No. 46, Annex A).

In London and Dortmund, policies that take into account food, energy, and water have been characterized as awareness-increasing. Each two FEW nexus policies in Gorzów and in Nantes were characterized as regulatory, while Nantes had three additional awareness-increasing policies.

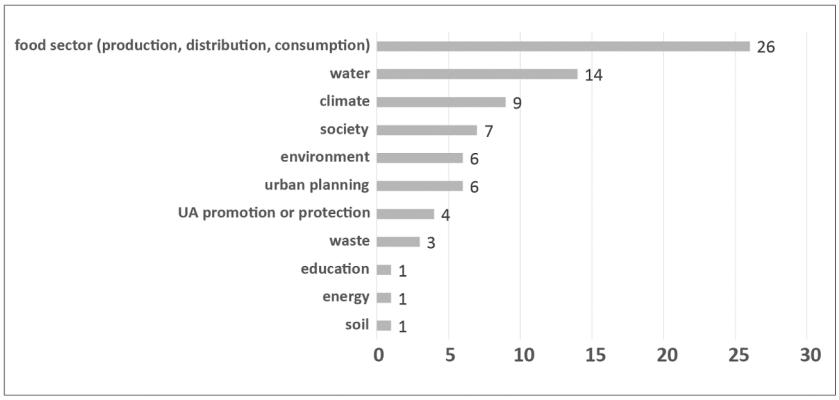

Fig. 3. Primary goal of policies, N=78.

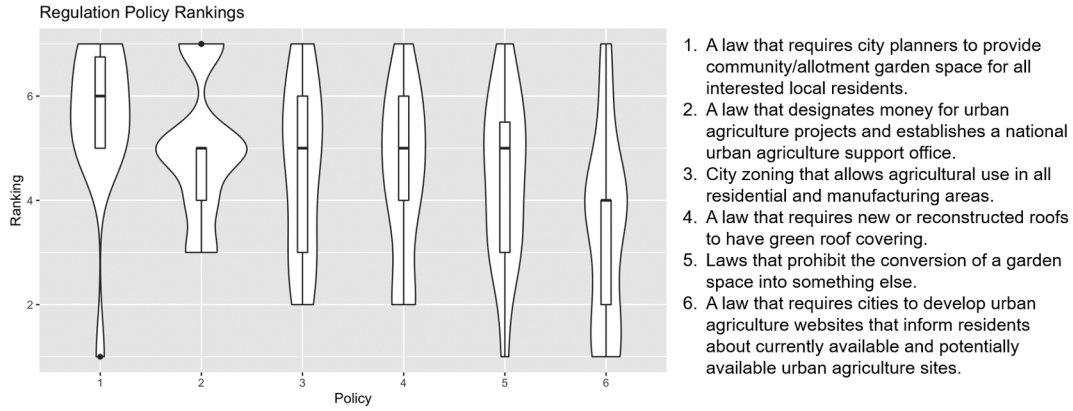

Fig. 4. Violin plots showing the range of responses (n=15) for each regulation policy. Median and interquartile ranges are shown with box plots within each violin plot.

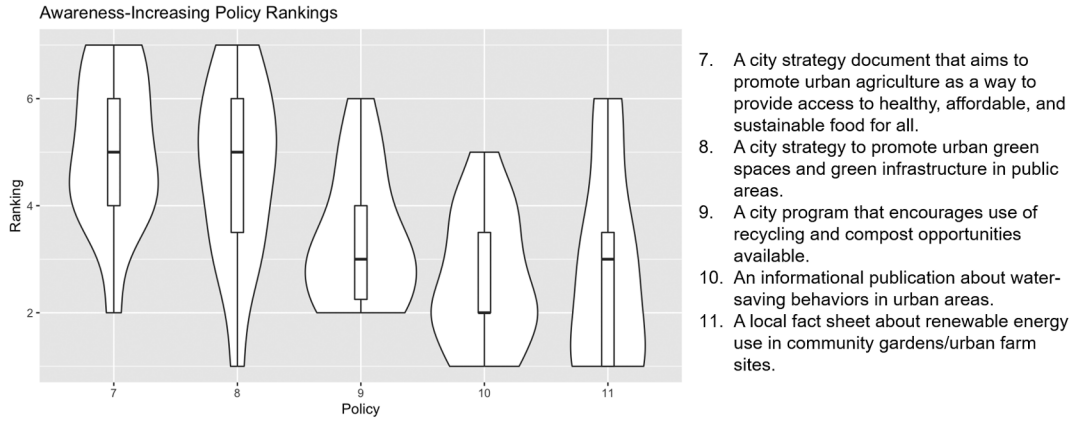

Fig. 5. Violin plots showing the range of responses (n=15) for each awareness-increasing policy. Median and interquartile ranges are shown with box plots within each violin plot.

4.2. Policy ranking

Fifteen policy experts across the five case-study cities ranked the relative effectiveness of each policy type in promoting UA. We present descriptive statistics of means and interquartile ranges for these rankings, across policy types and FEW nexus categories. Differences across policy scale were not evaluated since the entity enacting the policy was not specified in most of the policies we considered.

In general, policies categorized as regulatory were rated as most effective (Figure 4), with an overall mean of 4.6 ± 1.7. This difference was significant according to a Kruskal-Wallis test; follow-up pairwise Wilcoxon rank sum tests showed that regulations were ranked significantly higher than both awareness-increasing (mean = 3.7 ± 1.8; $p<0.01$) and incentive-based (mean = 3.9 ± 1.4; $p<0.05$) policies. There was no significant difference found between rankings of awareness-increasing and funding or incentive-based policies (Figures 5 and 6). A Kruskal-Wallis test with follow-up pairwise Wilcoxon rank sum test also showed that food-related policies (mean = 4.4 ± 1.7) were ranked significantly higher than policies related to other FEW nexus components (mean = 3.6 ± 1.6, $p<0.01$) and that were indirectly

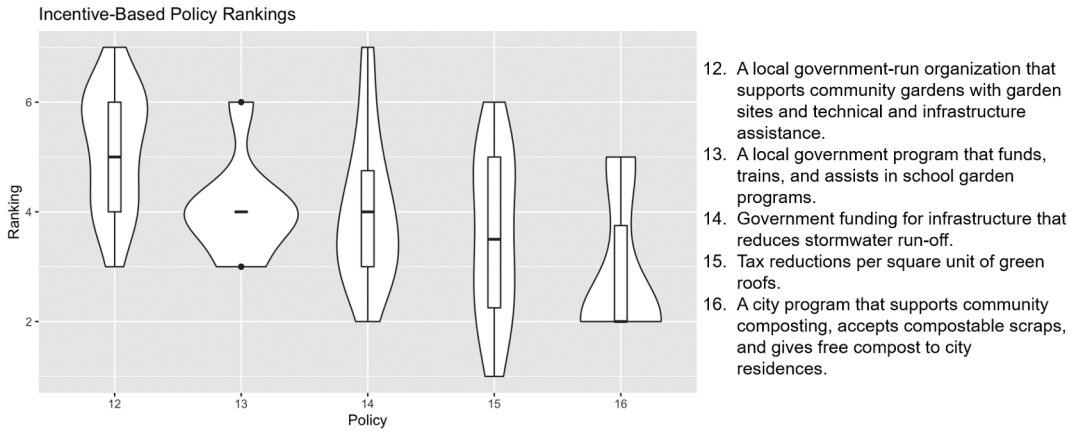

Fig. 6. Violin plots showing the range of responses (n=15) for each incentive-based policy. Median and interquartile ranges are shown with box plots within each violin plot.

related to the FEW nexus (mean = 3.7 ± 1.6, $p<0.01$) (see Table 2 for policy categorization). Additional Kruskal-Wallis tests of differences in rankings across interviewee nationality showed no significant differences.

The policy ranked most effective (5.6) was a law directly related to UA, and therefore the "food" component of the FEW nexus, requiring city planners to provide community/allotment garden space to all residents. The top ranked awareness-increasing policy ("A city strategy document that aims to promote UA…") and incentive-based policy ("A local government-run organization that supports community gardens…") had the same mean rankings of 5.1 and were also directly related to food. The policy ranked as least effective on average (2.6) was an awareness-increasing policy related to water: "An informational publication about water-saving behaviors in urban areas."

5. Discussion

5.1. Characterizing FEW nexus policies linked to UA from five case-study cities

The policy inventory reveals several important features and potential gaps in our case study cities' policies to increase the FEW nexus connections of UA, ultimately improving resource efficiency. While we did not measure the impact of policies, our study indicates that the number of FEW policies that consider UA differs among the five case studies.

The scale of FEW nexus policymaking differs by jurisdiction. Although UA is a local practice that is directly affected by local policies, the question of resource efficiency is relevant to all scales of government. Supra-national regulations at the EU level are of major importance, especially in Dortmund and in Gorzów, where regulations at lower levels of government are rare. In Nantes, a comparably strong regional authority, the Nantes Métropole, has a considerable influence on local policies dealing with sustainability, including those addressing the FEW nexus of UA. In the UK, apart from Greater London Authority, regional authorities were eliminated by national act, and while regional authorities exist in the other case study cities, they apparently do not act in this area of policy.

Considering all five case study cities, the most prevalent type of policy in our study is regulatory (laws, rules, and regulations) which our experts ranked as most effective at promoting UA. Of this policy type, the regulations vary significantly across our case study cities. Moreover, policy type does not indicate the effectiveness of a policy and the number of policies does not indicate how influential or effective these policies are. For example, most of NYC's local policies were funding or incentive-based, a strategy that the policy-makers we interviewed often rated less efficient than regulations.

The prevalence of incentive-based UA measures in NYC in our inventory of policies may be, on the one hand, a consequence of the existing zoning permitting UA across all neighborhoods and therefore not requiring further regulations. On the other hand, it may be a result of new federal and national regulations aiming at avoiding environmental impacts. For example, providing free water cisterns (see Rain Barrel Giveaway Program, No. 24, Annex A) is a way for NYC to comply with federal clean water regulations that require reductions of rainwater discharges to the sewage system. Capturing rainwater is less expensive than expanding sewage infrastructure capacity, so the city justifies paying for the cisterns and also benefits from the good publicity for the city.

The inventory for London characterized most policies as awareness-increasing, a type ranked as least-effective by our experts. The preference for this type might be related to the planning system in the UK which has a neo-liberal tradition with individual negotiations on the use of space instead of top-down regulations. According to Berisha et al. (2021), the UK planning system can be characterized as taking land use decisions "on a case-by-case basis against the background of non-binding plans" (Berisha et al., 2021, p. 10) while in France and Germany neo-liberal trends have been "cushioned by national spatial policies" (Waterhout et al., 2013, p. 151). Nadin and Stead (2008) identify the UK planning system as liberal at its roots as opposed to other European planning systems based on social democracy e.g., in Scandinavian countries, or conservative ideology, e.g., in Germany (Nadin & Stead, 2008).

Most policies in the inventory from Nantes, Dortmund and Gorzów case-studies are regulations, influenced by the six supra-national EU policies. Five of them are regulations and add to the regulatory local policies. Notably, besides the EU Common Agricultural Policy (CAP; No. 74, Table A), funding or incentive-based policies were identified neither in Gorzów nor in Dortmund.

Considering the variability among the five case studies, our findings support the theoretical notion that fundamental social change and large-scale transformations do not occur abruptly, but usually extend over several decades (Klerkx & Rose 2020). Using the differences in the history and spatial contexts of our case studies as a possible explanation for the differences in their status of policy implementation further highlights that transformations of the system do not occur in a linear fashion but are emergent. One possible reason why we found a greater number of FEW nexus policies and regulations with UA impacts in the US case study than in the European ones are the different histories and social, political, and land-use contexts in which UA projects and initiatives developed. Farming inside cities is a centuries-long tradition in many urban regions in Europe and has evolved more slowly and organically alongside established infrastructure and support systems for community

gardens in place, thus reducing the urgency for many new and additional policies to be introduced. Additionally, the extreme economic crisis, deterioration of public space, and the proliferation of vacant lots that New York City experienced in the 1970s made it a unique setting for its urban gardening movement to expand and for government officials to support it. In fact, some of these early grassroot efforts became quickly institutionalized through government programs such as GreenThumb which has helped create more than 1,000 gardens in the city since its establishment in 1978 (e.g., see The Trust for Public Land, 2001).

Currently, in New York City, there are more than 500 food producing gardens on city property and more than 700 school gardens (e.g., see Cohen et al., 2012) and, as of 2022, there is a stand-alone Mayor's Office for Urban Agriculture. Further, the city's vibrant food justice and community gardening movement (e.g., see Reynolds and Cohen, 2016; Ilieva, 2016) have created a history of activism and community engagement which has helped raise awareness and build support for UA among city residents and government officials and legislators. Finally, the different historical roots of UA in Europe and the US contribute to a different policy landscape at the national or international level. At present, there tend to be more policies focusing on UA developed by the U.S. Department of Agriculture (USDA) and the US Farm Bill (e.g., see USDA's Office of Urban Agriculture and Innovative Production, https://www.usda.gov/topics/urban) and USDA's Urban Agriculture Programs Fact Sheet) than by the European Union, which nevertheless has initiated important programs such as URBACT (https://urbact.eu/) and the European Forum on Urban Agriculture (EFUA, https://www.efua.eu/) Horizon 2020 project in support for food production in cities and greener cities more broadly.

5.2. Future potential for integrating UA in FEW nexus policies

The policy ranked highest across all categories was "A law that requires city planners to provide community/allotment garden space for all interested local residents". This confirms that, as stated in the introduction, policies on UA mainly focus on land issues. The high ranking of the policy creating a local UA support organization is in line with studies showing that community non-profit organizations are key in the resilience of local food systems (Kirby et al., 2020; Schmit et al., 2021). Policies that were ranked highly by our participants often explicitly addressed UA, and thus impact the food component of the FEW nexus.

Policies that addressed energy and water, or had indirect FEW nexus relations such as organic waste composting and green infrastructure policies, were generally ranked as less effective. Most of the energy, water, and indirect policies were funding- or incentive-based and awareness-increasing, which may contribute to these policy types receiving lower rankings than regulations. However, when these policies incorporated multiple components of the FEW nexus they were also most strongly related to resource efficiency. For example, the awareness-increasing policies on water-saving behaviors and renewable energy use received low rankings.

Two potential conclusions can be drawn from our ranking exercise, which may both have an influence on our results. First, policy experts who work in the UA sector may not consider the FEW nexus or resource efficiency when they consider UA policies. Instead, they prioritize the policy mechanism (with a preference for regulations in our sample), even when asked explicitly in our ranking to consider resource efficiency. When evaluating future FEW nexus policies aimed at integrating UA, the policy mechanism is therefore a key component. In one project across three developing cities, Lehmann (2018) reported success in integrating nexus components into urban planning through local, stakeholder-engaged processes. The framework for integrating the nexus into policies involves consideration of technological innovations, developing measurable objectives, capacity building for policymakers in understanding the nexus, and integration of governance systems from the local through the global (Lehmann 2018). Second, given that our policy ranking was based on actual policies, there is a lack of integration of the FEW nexus and UA in current policies. However, the share of policies indirectly targeting UA shows the potential for integrating UA in the future. There are several policies that regulate, inform or fund measures related to climate change in the city or promote green infrastructure, but none of these policies explicitly refer to UA. For example, Policies No. 54 and No. 55 of the London Plan 2016 (Annex A), without explicitly mentioning UA, focus on urban greening and green rooftops to support new planting in the public realm (including streets, squares, and plazas) and multifunctional green infrastructure, to contribute to the adaptation to and reduction of the effects of climate change. Another policy, the Water Efficiency Strategy for the UK (No. 64, Annex A), includes a chapter on water wise cities, but does not mention UA, despite UA's considerable water demands. In the Decision of the Council of the City of Dortmund of 2017 on green roofs (No. 2, Annex A) according to which flat roofs (a roof pitch of up to 15 degrees) must be greened at least extensively and kept professionally maintained, UA does not play a role. On the one hand, policies that refer to UA only indirectly do not explicitly exclude UA; on the other hand, the role of UA for climate change protection could be increased if UA was mentioned. As demonstrated by our experts' policy rankings, if the relation of a policy to the 'food' component of the FEW nexus is unclear, it will not be perceived as effective in promoting resource-efficient UA. Integrating more policies across the FEW nexus may improve the ability of policies to reach their goals.

5.3. Policy recommendations for FEW nexus considerations of UA

From our findings, we see three potential starting points to include UA in FEW nexus policies and improve resource efficiency.

First, one potential may be derived from shifting power to local authorities. This is an established trend and cities are increasingly enacting food policies, often including local food production considering land use which typically is regulated at local level (Ilieva, 2016). With more legislative power transferred to cities, we hypothesize that UA has the potential to expand food systems beyond *peri*-urban and rural farms to create a more integrated, comprehensive local food system with the potential to better manage resources and waste streams (Goldstein et al., 2016).

A second pathway for greater resource integration would be to provide financial incentives through more effective taxation policies. As elaborated by Fox-Kämper et al. (2022), increasing taxes for harmful technologies (i.e., polluting or inefficient) along with incentivizing eco–efficient technologies, can provide financial support to UA projects that apply resource-efficient practices.

Third, in theory, UA has a very high potential to function as a circular system, but certain regulations or the lack of regulations prevent further development in this direction (Wissmann et al., 2022). The increase of affordable green technologies in combination with the necessary policy revisions can enable a better reuse of "waste," including wastewater and food waste, which can theoretically be reused in urban food growing, but green technologies are currently restricted by disadvantageous policy frameworks.

5.4. Outlook for future research

From a FEW nexus perspective, the governance of inputs such as water and energy for UA is an issue that needs further research. Food, energy, and water systems are often subject to policies at both the national and local levels, although UA is regulated mainly at a local level. Our findings are consistent with the literature in showing that policies addressed more food- and water-related issues and much less the third element, energy. An in-depth analysis of the quality and impact of the FEW nexus in the policies in our inventory, which is beyond the scope of this paper, could identify future pathways for improving resource efficiency through inclusion of UA in FEW nexus policies. In four of the five

case studies, the UA FEW nexus was dealt with behaviorally, with programs or policies to encourage using less water or investing in solar panels, but not systemically through regulation. This opens opportunities for further research that could focus on studies of FEW nexus policies in other municipal domains like transportation or waste management or on methods to break down silos. Studies that develop indicators to measure the impact of policies also can help to identify efficient policies in the context of the FEW nexus in UA. We also identified some policies that discouraged resource efficiency in UA. Exploring the impact of such detrimental regulations and options to reverse these is another important research topic.

5.5. Limitations

This study examined the policy environment of five case-study cities. Thus, our analysis only reflects those sites, not the larger population of municipalities in each country. For example, the types of FEW policies pursued in cities with relatively abundant rainfall like London and NYC will differ substantially from drier, warmer cities like Phoenix and Madrid. Another limitation results from the sampling method that relied on policy selection by up to three persons per case study, a small sample that may have identified policies based on their subjective foci. The five cases represent a variety of communities with different UA systems, governance structures and policy environments, with different cultures of intervention. The data from our case studies illustrate the nature of FEW nexus UA policies in each location, but we cannot compare each city to the others. Another limitation may result from generalizing the policies to enable ranking by policy experts and from policy experts considering the general effectiveness in promoting UA more than promoting resource efficiency in UA. Generalizing policies may have reduced nuances in exploring local contexts but allowed us to observe whether there are common trends for policies with potential to promote resource efficiency in urban agriculture.

6. Conclusion

Our results reveal that FEW nexus policies that directly include UA are still quite limited. The most prevalent type of policy in our study is regulatory, also ranked by our experts as most effective at promoting resource efficient UA. But the context of each individual city matters as there are major differences in policy support among the five compared cities. It can be assumed that FEW nexus considerations will gain importance in the food system due to climate change mitigation and adaptation and concerns about food security and malnourishment. The share of FEW nexus-related policies indirectly targeting UA implies the potential for better integrating UA in the future. On the other hand, the growth of UA will create opportunities for changes to the larger food production and distribution system, but it will also strain existing infrastructure. Thus, there is a need to integrate UA as a critical component of local food systems and supply chains. Local *peri*-urban and rural farms are typically seen as the main actors of such systems but there is the need to expand the spatial and functional scope of food systems to include urban food production. This may be a future role for international organizations like the Milan Urban Food Policy Pact to promote FEW nexus-efficient UA within an integrated, comprehensive local food system (rural, *peri*-urban and urban) that helps better manage resources and waste streams.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The data collected was attached as Annex A

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Appendix A. Supplementary data

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