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Policy mixes for mainstreaming urban nature-based solutions: An analysis of six European countries and the European Union

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ABSTRACT

Nature-based solutions (NBS) are multifunctional and cost-effective innovations delivering urban sustainability, but they are not yet mainstream in urban development. This can be explained by persistent structural conditions in the urban infrastructure regime, resulting in barriers such as lack of collaborative governance, inadequate knowledge and limited funding availability. In this paper we argue that (supra)national governments could play an important role in breaking down these barriers by employing policy instruments and strategically combining these into policy mixes targeting multiple regime structures. By means of an empirical analysis across six European countries and the European Union (EU), we provide an overview of regulatory, financial and soft (supra) national policy instruments supporting urban NBS mainstreaming and how these are combined in policy mixes across cases. In addition, we investigate policy mix comprehensiveness by mapping the extent to which these target each of the relevant urban infrastructure regime structures underpinning barriers to urban NBS mainstreaming. We demonstrate that, with the exception of the EU, none of the studied cases employs a fully comprehensive policy mix. We conclude that by strategically adopting policy instruments with the aim of crafting a comprehensive policy mix, obstacles in pathways to urban NBS mainstreaming could be overcome.

1. Introduction

Urban nature-based solutions (NBS) represent multifunctional sustainability innovations addressing a range of societal challenges, varying from climate change and biodiversity loss to circular economy and healthy urbanization (Nesshöver et al., 2017; van der Jagt et al., 2017). The European Commission and IUCN are prominent proponents of NBS (IUCN, 2020; Wild et al., 2020). The NBS concept gained traction in the scientific literature very quickly, through clear synergies with existing concepts such as green infrastructure and ecosystem services, and the development of a research agenda on NBS providing substantial funding (Escobedo et al., 2019). Given its focus on ‘solutionism’ and developing a common language for a broad range of actors (Dorst et al., 2019), urban NBS have entered into academic debates on sustainability transitions. NBS are often studied in relation to cities (Frantzeskaki et al., 2019; Kabisch et al., 2017; van der Jagt et al., 2017), which represent key nodes in socio-technical systems responsible for a large share of environmental problems, while also acting as spring boards for

innovative solutions to help overcome these (Seto et al., 2017). Examples of urban NBS include green roofs, sustainable urban drainage systems, urban forests and communal gardens.

Despite their promise, the *mainstreaming* of NBS as an urban infrastructure is not yet successful (Davies and Laforzezza, 2019; Dorst et al., 2021; Frantzeskaki et al., 2019; Wamsler et al., 2020). Some might disagree, pointing to examples such as the widely adopted green roofs in the cities of Basel and Stuttgart (Mees, Driessen et al., 2014), the metropolitan urban forest in Melbourne (Gulrsrud et al., 2018), and the extensive green infrastructure networks for water management in Singapore and Berlin (Liu and Jensen, 2018). These success stories, however, are usually specific to a particular NBS type or city district and overall appear to be the exception rather than the rule (Davies and Laforzezza, 2017; van der Jagt, Toxopeus et al., 2020). Recently, a study of six European countries and the EU identified seven key barriers to the mainstreaming of urban NBS, including limited policy development, lack of knowledge and financial resources, competition over land use and challenges around private sector engagement, citizen engagement

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and collaborative governance (Dorst et al., 2022). Overcoming barriers to urban NBS mainstreaming requires identifying and addressing their root causes (e.g., cultural values, economic mechanisms, technologies and infrastructures), which have been referred to as structures underpinning the dominant approach to urban development (i.e. the urban infrastructure regime) (Dorst et al., 2021; Monstadt, 2009). This paper builds on this work by exploring the role of (supra)national governments in breaking down barriers to urban NBS mainstreaming through strategically employing policy mixes targeting the various regime structures underpinning them.

Research in policy and planning has focused on analysing the role of municipal governments in creating opportunities and breaking down barriers for urban NBS (e.g., Bush and Hes, 2018; Davies and Laforteza, 2017; Droste et al., 2017; Wamsler et al., 2020). Surprisingly little attention, however, has been given to the study of policy instruments employed by governments and public institutions operating beyond the urban and regional scales, with exception of the EU in Europe (Kirsop-Taylor et al., 2021). In this paper – and in response to this research gap – we postulate that European national governments and the European Union (EU) play an important role in the mainstreaming of urban NBS by their ability to influence multiple urban infrastructure regime structures simultaneously, which could build momentum for change.

The first objective of this study is therefore to provide an overview of relevant (supra)national scale policy instruments aimed at mainstreaming urban NBS employed across six different European countries and at the EU level. The second objective is to predict policy mix effectiveness for urban NBS mainstreaming, by exploring if different types of policy instruments are combined across the seven cases and by analyzing the comprehensiveness of policy mixes in addressing regime structures.

2. Theoretical framework

2.1. Mainstreaming urban NBS requires regime change

Regimes such as the urban infrastructure system represent configurations of social and technical (i.e. material), components guiding sectoral activities or urban processes (Geels, 2004; Hughes, 1987; Rip and Kemp, 1998). The urban infrastructure regime has been defined as: “stable urban configurations of institutions, techniques, and artifacts which determine “normal” socio-technical developments in a city and thus shape general urban processes and the urban metabolism” (Monstadt, 2009, p.1937). Although the urban infrastructure regime may give the outward impression of being stable, it is subject to the influence of various co-existing sub-regimes corresponding to different socio-material assemblages or sectors, each subject to different pressures (Bulkeley et al., 2015; Dorst et al., 2022).

We distinguish three broad, co-existing and interconnected urban infrastructure sub-regimes relevant to urban NBS mainstreaming: the regulatory domain, the urban development domain and the finance domain (Dorst et al., 2022). Each domain is characterized by different configurations of institutions, logics and practices shaping urban development in more or less direct ways. The *regulatory domain* is engaged with the development of legislation, regulation and policies. Relevant actors include different levels of government, government agencies, politicians, lobby groups and policy advisory organizations. The *urban development* domain comprises the actors associated with the urban development industry, such as construction companies, utilities, (landscape) architects, designers and housing corporations. The *finance* domain is responsible for financial services and includes e.g. banks, insurance companies and institutional investors.

The strong internal alignment of socio-technical systems gives regimes the appearance of being obdurate and difficult to shift towards a more sustainable trajectory (Bulkeley et al., 2015; Fuenfschilling and Truffer, 2016; Geels, 2005). According to the multi-level perspective, however, regime transitions could be expected if sustainability

innovations, emerging and developing in niches (i.e. spaces shielding emerging innovations from market selection processes), can be upscaled to the regime level under the right socio-technical landscape conditions (Geels, 2002, 2004; Smith et al., 2010; Smith and Raven, 2012). However, we question the relevance of the multi-level perspective for understanding pathways to urban NBS mainstreaming. NBS do not represent a particular technology (e.g. wind energy) or a cluster of technologies (e.g. energy efficiency measures) that can be standardized, optimized and copied from place to place without careful redesign, e.g. adapting selected plant species to geographical and meteorological conditions or recreational amenities to different user groups and place-specific environmental preferences (Buijs et al., 2016; Dorst et al., 2019, 2021; van der Jagt, Raven et al., 2020).

An alternative perspective on transitions in political geography more suited to urban NBS mainstreaming claims that the configurations making up the (urban infrastructure) regime are continually unfolding and that transitions require intervening in these configurations that are always ‘in the making’, rather than proceeding along a linear trajectory from small to large scope (Bouzarovski and Haarstad, 2019; Patterson et al., 2021; Stripple and Bulkeley, 2019; West et al., 2020). Urban NBS mainstreaming, then, means intervening in these configurations to reinforce pathways that support urban NBS and to avoid others that unravel urban NBS mainstreaming. This implies that change in dominant regime practices towards improved urban NBS mainstreaming could come from multiple, potentially synergistic, sources developing relatively independently from each other at different geographical locations and scales (Tozer et al., 2022). Consequently, the impact of, for example, a new technological innovation supporting urban NBS mainstreaming is potentially higher if coinciding with processes such as interdisciplinary partnerships experimenting with NBS, increased support for grassroots community initiatives, green investment instruments unlocking finance for sustainable investment, and regulations supporting biodiversity and climate action (Xie et al., 2020).

Recently, Dorst et al. (2021) developed a framework that ‘unpacks’ the urban infrastructure regime into eight structural dimensions, i.e. structures, which can be used to analyze the root causes of obduracy within the regulatory, urban development and finance domains. They discern the following regime structures: 1) *Policy and regulation*; 2) *Knowledge and expertise*; 3) *Funding structures*; 4) *Economic mechanisms and user practices*; 5) *Physical geographies*; 6) *Physical infrastructures and technologies*; 7) *Industry structure, actor networks, and organizational forms*; and 8) *Cultural values and guiding principles* (see Table S1 for descriptions and examples). In line with a relational ontology, Dorst et al. (2022) show how urban infrastructure regime structures tie together in a web underpinning well-known barriers to urban NBS mainstreaming, such as limited collaborative governance or low private sector engagement. Collectively, these co-aligned structures make up the urban infrastructure regime maintaining the urban development status quo. We therefore contend that a *comprehensive* approach to breaking down barriers to urban NBS mainstreaming is needed, which targets multiple of these interconnected and mutually reinforcing regime structures simultaneously.

2.2. Policy mixes to support urban NBS mainstreaming

Policy and regulation are fundamental for guiding the direction and velocity of sustainability transitions. They have the potential to do so by addressing lock-ins, i.e. obduracy or persistence of configurations in entrenched socio-technical systems (Ashford and Hall, 2011; Edmondson et al., 2019; Kivimaa and Kern, 2016). For example, government-supported experiments in living labs are an increasingly popular policy intervention to circumvent dominant regime logics (Bulkeley et al., 2016; Evans et al., 2016; Karvonen and van Heur, 2013). Policy instruments represent the techniques by which policy makers achieve their policy ambitions (Mickwitz, 2003; Wurzel et al., 2013), and it would therefore be relevant to study their role in urban NBS

mainstreaming. Particularly when doing so for higher levels of government because (supra)national regime-level structures (e.g. sectoral goals or dominant technologies) have a powerful influence over routinized practices at lower levels (Fuenfschilling and Binz, 2018). This is the predominant reason why regimes are often conceptualized and analyzed at the national or global level (Raven et al., 2012; Späth and Rohrer, 2012).

Policy instrument typologies have been developed, e.g. to compare different countries or sectors with each other (Wurzel et al., 2013). These typically distinguish three types: regulatory, financial (or economic) and soft (or supportive) instruments (Borrás and Edquist, 2013; Mees, Dijk et al., 2014; Wurzel et al., 2013), also referred to as sticks, carrots and sermons, respectively (Bemelmans-Vidéc et al., 2011). Regulatory instruments provide authoritative rule sets and can vary from ‘command-and-control’ regulation to agreements negotiated with a broad range of societal stakeholders (Weber et al., 2014; Wurzel et al., 2013). Financial instruments provide particular financial incentives or disincentives (Borrás and Edquist, 2013; Weber et al., 2014). Soft instruments are informational as well as organizational instruments aimed at voluntarily (re)organizing processes (Lee et al., 2019). Examples include information dissemination, voluntary agreements by industry or non-hierarchical network opportunities with government (Borrás and Edquist, 2013; Wurzel et al., 2013).

Over the last few decades, government, market and society have become increasingly interwoven – resulting in the delegation of some steering powers to non-governmental actors and a higher prevalence of interactive modes of governance (Arts et al., 2006; Driessen et al., 2012; Jordan et al., 2003). For example, urban sustainability is increasingly governed through ‘the politics of experimentation’ (Bulkeley et al., 2016). This development is paired with a move by governments from relying largely on command-and-control regulation to using *policy mixes*, characterized by combinations of traditional and new types of policy instruments, such as voluntary agreements and financial instruments (Jordan et al., 2005). Policy mixes have drawn the interest of transition scholars because complex multi-scalar socio-technical systems, such as energy systems, usually cannot be transformed on the basis of a single intervention, but require a long-term, multi-actor and multi-instrumental approach (Edmondson et al., 2019; Filippini et al., 2014; Kern et al., 2017; Scordato et al., 2018). We infer from this that governing through policy mixes is key to the mainstreaming of urban NBS.

2.3. Policy mix comprehensiveness as a predictor of effectiveness

The analysis of whether different instruments have been combined and how this influences policy effectiveness or efficiency represents the most basic approach to studying a policy mix (Rogge and Reichardt, 2013). An important consideration in predicting policy mix effectiveness is the diversity of their constituent instruments – engaging not only different scales of government, but also enticing financial and civil society actors to set more ambitious norms and go beyond the minimum of what is legally required of them. This ‘smart regulation’ increases the likelihood of social norms and cognitive routines changing from the inside-out within particular sectors and industries (Gunningham and Sinclair, 2017). Lee et al. (2019) similarly concluded, based on a literature review, that reinforcing mixes of policy instruments have higher effectiveness than individual instruments. Some mixes of individual instruments are more complementary than others but, in general, combinations of regulatory, financial and soft instruments are particularly effective for environmental innovation (Jänicke and Lindemann, 2010).

Another important policy mix criterion, along with aspects of stability, consistency with policy goals and credibility, is the *comprehensiveness* of the policy mix (Rogge and Reichardt, 2013; Scordato et al., 2018). This denotes “how extensive and exhaustive the policy mix elements are” (Reichardt and Rogge, 2016, p.65). Comprehensiveness is

often linked to effectiveness as policy interventions tend to be more effective if targeting a higher proportion of root causes underpinning societal problems, e.g. using a ‘mixing and matching’ approach (Weber et al., 2014). Empirical research operationalized comprehensiveness as the combination of demand-pull, technology-push and broader systemic interventions (Reichardt and Rogge, 2016; Rogge and Reichardt, 2013), which has demonstrated effects on eco-innovation (Costantini et al., 2017). Broader conceptualizations also include the extent to which policy targets multiple sectors and stimulates solutions varying in technical complexity, i.e. not only the low hanging fruit (Rosenow et al., 2017).

Based on a relational account of sustainability transitions (see Section 2.1), we adopt a different and more complex working definition of policy mix comprehensiveness as the number of urban infrastructure regime structures that are successfully targeted (Fig. 1). This provides a more granular analysis of policy mix comprehensiveness, tailored to urban NBS mainstreaming, compared to alternative approaches. Another advantage of this approach is that it allows for extending the analysis beyond policies explicitly aimed at improving urban NBS mainstreaming to also include instruments such as sustainable finance disclosure regulation with the potential of indirectly influencing urban NBS mainstreaming potential. Casting one’s net wide enough to include multiple policy domains is important because a relational ontology of transitions as continually unfolding asserts that there are multiple decision-making loci shaping the mainstreaming pathways of sustainability innovations such as NBS (Patterson et al., 2021; Tozer et al., 2022). Indeed, urban NBS mainstreaming is strongly influenced by the extent to which multiple policy domains (e.g. environment, planning, public health, mobility) engage in joint efforts to support this (Bush and Hes, 2018; Wamsler et al., 2020). Therefore, we complement the more traditional analysis of the types of policy instrument types used with one of policy mix comprehensiveness.

3. Method

3.1. Research strategy

This research draws on a comparative case study design with seven (trans)national cases: the EU, Germany, Hungary, The Netherlands, Spain, Sweden, and the United Kingdom (UK). In each of the cases, we studied the regulatory domain, the urban development domain and the finance domain of the urban infrastructure regime. For this particular study, the regulatory domain provided the most relevant data on policy instruments. Complementary information on policy instruments influencing urban NBS mainstreaming was obtained from the reports prepared for the other two domains. The units of observation were further broken down into the seven urban infrastructure regime structures outlined in Fig. 1.

3.2. Data collection

A mixed-methods approach to data collection was employed, including 243 semi-structured interviews (EU: $N = 35$; Germany: $N = 36$; Hungary: $N = 38$; The Netherlands: $N = 40$; Spain: $N = 35$; Sweden: $N = 33$; UK: $N = 26$), document analysis and 12 observational placements (a form of participant-observation) of typically 3–5 days at relevant organizations, networks or events with ≥ 1 placement for each case. A placement reporting form was used to record basic background information and observations on whether and how regime structures were influencing day-to-day decision-making. More detail on each of these methods is provided in the overview report of this study (van der Jagt, Toxopeus et al., 2020). For pragmatic reasons, the UK case study of the regulatory domain mainly focused on the UK government, not on the governments of the devolved nations. Interviewees were predominantly held with regime actors operating at (supra)national scale, such as governments, government agencies, NGOs, knowledge institutions,

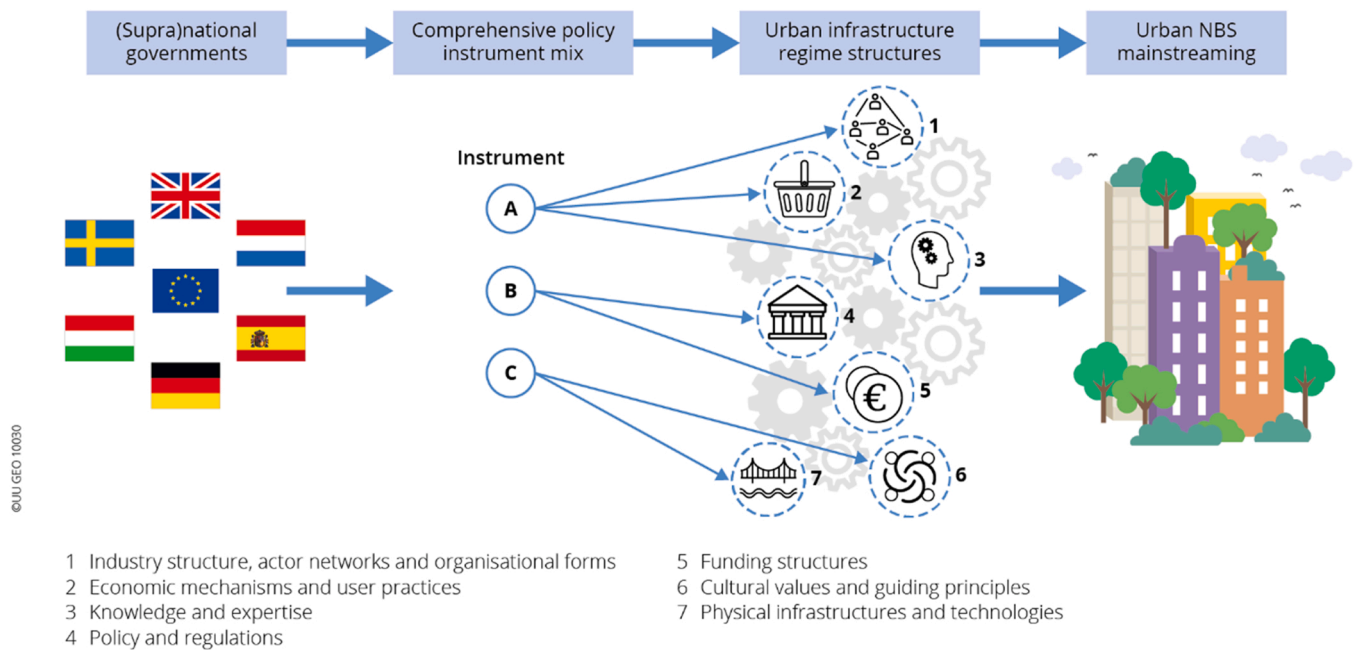


Fig. 1. Analytical framework. The eighth regime structure ‘physical geographies’, part of the urban infrastructure regime structure framework by Dorst et al. (2021), was excluded from our analysis because it refers to landscape factors such as meteorological factors and soil type, which cannot be directly influenced by any particular policy instrument.

utilities, urban development companies, banks and institutional investors. The questions focused on perceived conditions, barriers and opportunities related to each of the regime structures with respect to a particular case. Interviews were audio-recorded, transcribed and translated to English if necessary for data analysis. Interviewees provided informed consent to participate in the research and were briefed about the purpose of the study. The interview length was approximately 60–90 min. The data collection across the different cases was done by different researchers, depending on (language) capacity. A template was developed to report on the placements, including key observations (with relevance to the regime structures) and perceived impact. A jointly prepared research protocol served to ensure that all researchers adopted a similar approach to data collection and reporting. Data collection took place between June 2018 and November 2019.

3.3. Data analysis

Selected documents, interview transcripts and placement records were entered into NVivo or a similar tool for thematic analysis (Bryman, 2016) using the urban infrastructure regime structures. A total of 21 working papers were prepared to report findings (seven cases split by three domains each), which described conditions, barriers and opportunities for each of the regime structures. These working papers have been used as the basis for the analysis presented in this article.

We scrutinized the contents of these papers for references to regulatory, financial and soft instruments employed by different levels of government. These instruments did not have to be explicitly aimed at urban NBS mainstreaming, provided that interviewed experts acknowledged a connection. Identified policy instruments were transferred into a spreadsheet along with the following information: *case source*, *name of instrument*, *lead institution*, *description of instrument*, *instrument type*, *instrument subtype*, *year of introduction* and *targeted regime structure(s)* (van der Jagt, 2021). We only included those instruments that: 1) had already been implemented or were in a very advanced state of development in one or more of the cases, not those mentioned as interesting opportunities to explore in the future; 2) had been implemented by national government, a national public body or EU institutions and bodies, not those only implemented at regional or local

scales; 3) were perceived as significant drivers of *multifunctional* urban NBS mainstreaming (e.g. a green belt policy does *not* necessarily contribute to more multifunctional greenspaces); and 4) did *not* represent the national-level implementation of an EU policy instrument (e.g. a national grant programme exclusively drawing on EU funds).

For the coding of *instrument subtype*, we developed a new typology by combining components from existing policy instrument frameworks for environmental sustainability (see Table 1 for adopted subtypes and academic sources). Observed policy instruments were allocated to multiple (sub)types simultaneously if these represented policy programmes comprised of multiple policy instruments (e.g. a fund as well as a technical guide introduced as part of the same policy).

For the analysis of *targeted regime structure(s)*, we first developed a coding protocol (Table S1). A single instrument could be scored as targeting one or more regime structures. An important selection criterion was that an instrument had to be *unambiguously* aimed at addressing the dynamics within the selected regime structure(s). For example, a public-private partnership might be aimed at the co-development of technical knowledge, whilst new policy development is a potential, yet uncertain, outcome. In this instance, the policy instrument would be coded as targeting the ‘knowledge and expertise’ regime structure, but *not* the ‘policy and regulation’ structure.

4. Results

This section is structured based on the core aims of the study. The first part provides an overview of (supra)national scale policy instruments for urban NBS mainstreaming adopted in the studied cases. The second part shows the extent to which adopted policy mixes comprise a mixture of different instrument types. The third part provides an analysis of policy mix comprehensiveness for each of the cases by the studying the number of urban infrastructure regime structures targeted by policy instruments.

4.1. Policy instruments supportive of urban NBS mainstreaming

The research unveiled a range of regulatory, financial and soft instruments used across the studied countries and the EU to support urban

Table 1

Overview of instrument subtypes, including academic sources for each subtype, a description and a selected policy instrument example.

Instrument type	Instrument subtype	Academic source	Description	Selected policy instrument example
Regulatory	Environmental and spatial planning regulations	(Mees, Dijk et al., 2014; Wurzel et al., 2013)	Master plans, building codes and other forms of authoritative documents specifying rules or targets, often with a specific time frame	Biodiversity Net Gain policy (UK)
	Environmental certification or product declarations	(Gilbert et al., 2011; Nedopil et al., 2021; Stelling, 2014)	Environmental criteria, either mandatory or voluntary, that adopters of a standard should adhere to	The EU Taxonomy (EU)
	Technical requirements	(Mees, Dijk et al., 2014)	A prescriptive technology or practice	Mandatory flood risk stress tests (Netherlands)
Financial	Physical infrastructure, human capital and R&D funding	(Ferrara et al., 2010)	Different financial instruments, such as subsidies and grants, to fund environmental infrastructure, human capital through knowledge sharing or research and development of innovations	The Swedish Strategic Innovation Programme (Sweden)
	Reduced-interest loans	(Borrás and Edquist, 2013)	Soft loans used to support innovation and sustainable entrepreneurship	The Natural Capital Financing Facility (EU)
	Tradable permits	(Jordan et al., 2005)	Rights to use resources, which are capped by government, can be traded between different market actors	Tradable Development Rights (Germany)
	Public procurement	(Borrás and Edquist, 2013; Scordato et al., 2018)	Instrument to support demand by public bodies for particular (sustainable) products or services from third parties	Spanish Procurement Law (Law 9/2017) (Spain)
Soft	Inter-municipal exchange platforms	(Droste et al., 2017)	Platforms facilitating horizontal and vertical knowledge exchange for municipalities in order to align policies and learn about best practices	The Network of Local Governments + Biodiversity (Spain)
	Competition for awards/prizes	(Beers and Geerling-Eiff, 2014)	A competition opened by government to reward state-of-the-art practice by cities or non-governmental organizations	European Green Capital Award; European Green Leaf Award; European Green Week (EU)
	Information and education	(Rogge and Reichardt, 2013)	The sharing of data or expert knowledge relevant to sustainable development, or the introduction of tools (e.g. for ecosystem services assessment) that can be used for generating data or knowledge by industry and other actors	White Paper “Green Spaces in the City” (Germany)
	Innovation platforms	(Scordato et al., 2018)	Platforms such as living labs that build new coalitions between different types of stakeholders and which are engaging in knowledge co-development, knowledge dissemination and/or urban experimentation	City Deals (Netherlands)

NBS mainstreaming by influencing the actions of urban infrastructure regime actors. While space does not permit for a detailed overview of individual instruments (see van der Jagt et al., 2022 for the dataset, including instrument descriptions), the identified instrument (sub)types can be found in Table 1. We illustrate each of these subtypes with an example of an instrument identified in our data collection below.

Within the category of **regulatory** instruments, we identified three subtypes of instruments. An example of *environmental and spatial planning regulations* is the Biodiversity Net Gain regulation in England (UK). The National Policy Planning Framework encourages planning authorities to pursue a 10% biodiversity net gain through spatial policy, which means that urban development contributes to biodiversity through on- or off-site nature-based measures. At the time of data collection, the Department for Environment, Food and Rural Affairs (Defra) was consulting on the option of making this a mandatory measure under the Environment Bill. The EU Taxonomy, introduced in 2020, was the only example of *environmental certification or product declarations* encountered emerging from the analysis. It was developed in response to a recommendation in the European Commission’s Action Plan ‘Financing Sustainable Growth’ – prepared based on an advice by the High-Level Expert Group (HLEG) on Sustainable Finance. The EU Taxonomy acts as a certification system for sustainable investment activities, providing a common understanding for financial institutions to identify what counts as a ‘green’ investment, thus lowering transaction costs for sustainable economic exchange in Europe (Nedopil et al., 2021). It is perceived as an important step towards developing an EU green bond market, with the expectation that it will also unlock investment for large-scale NBS by institutional investors such as pension funds. We identified one case of a *technical requirement*, which is the mandatory stress test on flood risk for municipalities introduced by the Dutch government as part of the Delta Programme Spatial Adaptation. The stress test increases understanding of flood risk in urban areas, which is believed to benefit (urban) NBS mainstreaming as mitigatory measures.

Across the cases, we found four types of **financial** policy instruments. The first type is a cluster of financial instruments providing cash grants or subsidies, which we term *physical infrastructure, human capital and R&D funding*. For instance, the Swedish Strategic Innovation Programme (SIP) – coordinated by the Swedish innovation agency Vinnova, the Swedish Energy Agency (Energimyndigheten) and the Swedish Research Council for Sustainable Development – provides funding for cross-sectoral projects on strategically important topics, involving industry, the public sector and academia. In the past, there have been a number of themed calls relevant to urban NBS such as the 2019 call on ‘Green material development in the infrastructure area’. Examples of funded projects under this are ‘C/O Cities’ supporting smaller cities with knowledge tools to help integrate ecosystem services into town planning and ‘BiodiverCity’ on experimenting with multi-functional urban NBS in densely developed parts of Malmö. Of the other three types of financial instruments, we encountered one of each type. The Natural Capital Financing Facility (NCFF), is a *reduced-interest loan*, run by the European Investment Bank (EIB) as part of the EU LIFE Programme since 2014. It offers loans of > €5 million to fund large-scale NBS for climate action. The city of Athens (Greece) was one of the first to successfully apply to this fund, which it will use to roll-out green-blue infrastructure measures across 400 sites within its city boundaries.

The Tradable Development Rights in Germany represent an innovative type of *tradable permit*, which contributes to the protection of urban NBS. It limits the area of greenspace that can be used for urban development to 30 ha per day, divided across Germany’s municipalities. Certificates for urban development can be traded between municipalities, akin to the carbon emission trading system. The scheme is rewarding cities for urban densification efforts and protects high-quality greenspaces in the urban periphery. The Spanish Procurement Law (Law 9/2017) is one example of *public procurement* explicitly linked with support for urban NBS. The law serves to provide more transparency in public procurement and achieve better value for money through the

requirement to demonstrate environmental, social and innovation (i.e. multifunctional) value in the proposed projects, which incentivizes the inclusion of NBS in proposals. The law also increased the permitted duration of contracts between public and private entities, benefiting nature-based innovation with relative long-term return on investment.

We discern a total of four different **soft** policy instruments. An example of the first – *inter-municipal exchange platforms* – is The Network of Local Governments + Biodiversity in Spain. This represents a federation operating under the auspices of The Spanish Federation of Municipalities and Provinces (FEMP), with the aim to co-develop knowledge and influence policy relevant to biodiversity and related topics such as NBS in (peri-)urban areas. It has a membership of around 300 municipalities. One of their recent achievements is the development of the Guide of the Municipal Green Infrastructure, a handbook prepared together with a number of professional associations. They were also a key contributor to the development of the National Strategy for Green Infrastructure, Connectivity and Ecological Restoration. The EU uses several instruments enabling *competition for awards/prizes*, including the European Green Capital Award, the European Green Leaf Award and the European Green Week. These represent prestigious annual events and award schemes relevant to green and sustainable cities and towns, which help put best-practice examples of urban NBS into the spotlight for an international mixed audience of policy makers and practitioners.

A large number of instruments fell into the category of *information and education*. Perhaps the most complete example of such an instrument is the German White Paper ‘Green Spaces in the City’, published by The Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety in 2018. This is a guide designed by a broad group of experts to advise municipalities and other relevant actors on available delivery mechanisms for improved mainstreaming of urban nature,

along with a government commitment to support these via new funding programmes, policy concepts, portals for knowledge sharing, toolboxes and available practitioner guidance through to urban green space competitions, green building certification tools and vocational training opportunities. The guide is expected to lead to more integrated planning and multifunctional urban green spaces, supporting civic engagement, environmental justice, the urban climate and biodiversity.

The final category of *innovation platforms* is made up of a number of policy instruments of which the Dutch City Deals instrument, introduced in 2015, is an interesting example. City Deals are an instrument that is part of the Urban Agenda to support the development of new coalitions between government, cities, knowledge institutions and relevant private and third sector organizations around particular urban challenges. For example, the City Deal ‘The Values of Green and Blue in the City’ served to develop a TEEB (The Economics of Ecosystems & Biodiversity) City tool, and a spin-off spatial planning decision-making tool called the Green-Benefits Planner, enabling the monetization of urban ecosystem services. At the EU level, the Horizon 2020 Research and Innovation programme on NBS is another example of a large-scale knowledge building instrument.

4.2. The distribution of policy instrument types across the cases

The analysis of policy instrument (sub)type distribution by case, shown in Fig. 2, indicates that a mix of regulatory, financial and soft policy instruments was employed in six out of seven cases. The UK was the only case in this study for which no financial instruments were documented. However, the UK case employed a relatively high level of regulatory instruments in the form of environmental and spatial planning regulations. Germany and The Netherlands stand out as cases with

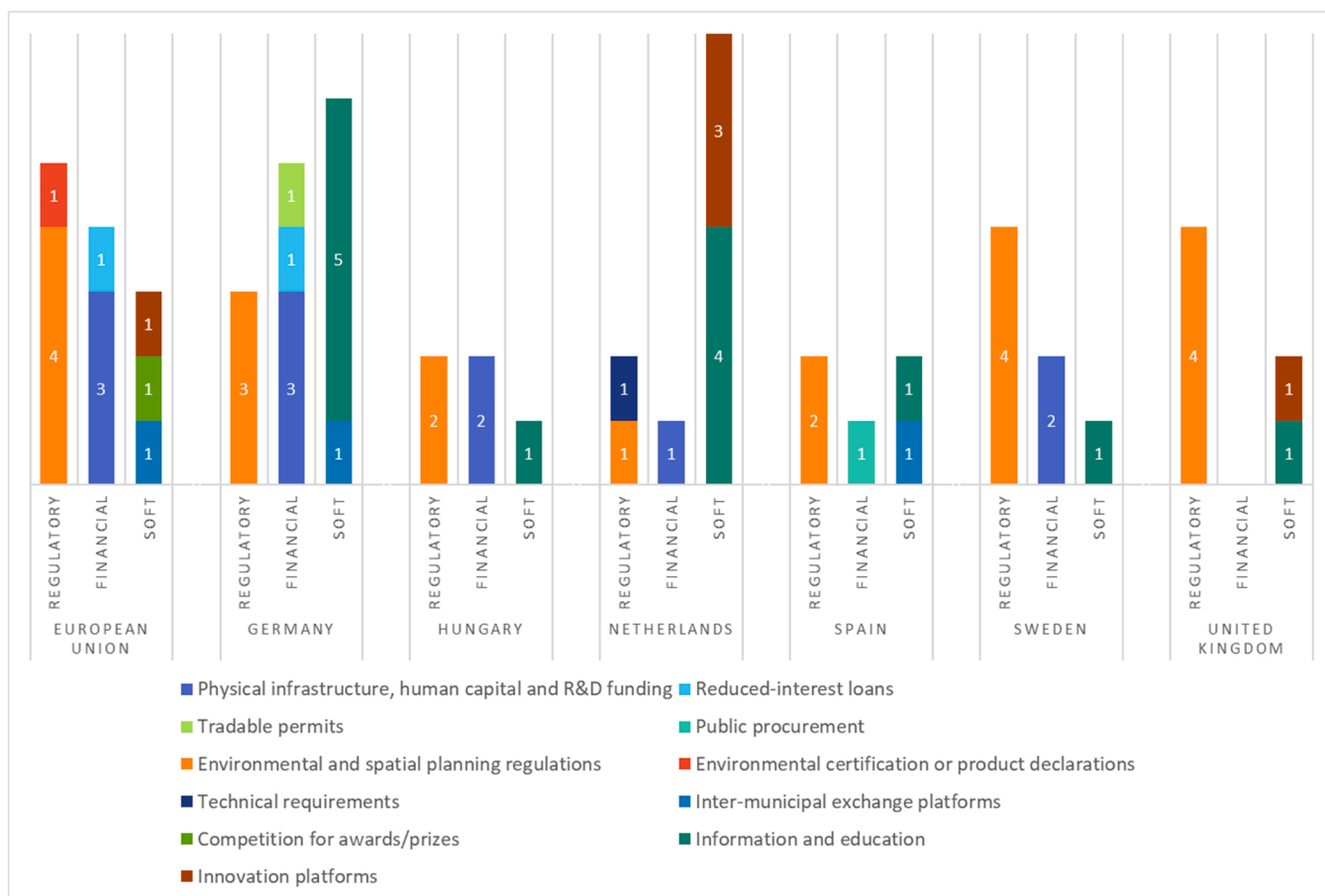


Fig. 2. Graph showing the distribution of different (supra)national policy instrument types and subtypes across each of the seven cases.

a comparatively high number of soft instruments (N = 6 & N = 7, respectively). Whereas in Germany this is largely down to the uptake of expert guides; the Netherlands also draws on decision-support tools and innovation platforms including City Deals. The distribution between regulatory, financial and supportive instruments is more balanced in Hungary, Spain and Sweden. The European Union is the case with the highest variety of different policy instrument subtypes (N = 7), indicating that urban NBS mainstreaming is stimulated through a range of interventions. The number of its financial instruments (N = 4) is particularly high when compared to most other cases. Finally, there is considerable variation between cases at the level of instrument subtypes, which demonstrates that policy approaches to mainstreaming urban NBS vary markedly across contexts. Environmental and spatial planning regulations is the only (sub)category of instruments that is used across all cases.

4.3. Policy comprehensiveness for mainstreaming urban NBS across the cases

The comparative case analysis of policy mix comprehensiveness using the seven urban infrastructure regime structures that are part of our analytical framework is visualized in Fig. 3. This shows that the EU is the only case employing a comprehensive policy mix that is targeting each of the seven urban infrastructure regime structures. There is no country case where all seven regime structures are targeted, suggesting scope for learning, and potentially policy transfer, between the cases. Hungary and Spain only target four and three of the seven regime structures, respectively, indicating low to medium policy comprehensiveness. The other countries are positioned somewhere in between the EU and these two cases, which is suggestive of medium-high policy comprehensiveness. Germany and The Netherlands have a relatively skewed distribution, doing comparatively well in targeting some of the regime structures but not showing any activity related to other structures.

5. Discussion

Drawing on a large dataset covering multiple sectors within the EU and six European countries, this research presented a structured overview of (supra)national policy instruments relevant to the mainstreaming of urban NBS for biodiverse, climate resilient and just cities. This complements previous research on policy instruments supporting (particular types of) urban NBS, which is mostly conducted at the level of cities and metropolitan regions or solely for the EU (Kirsop-Taylor et al., 2021), lacking a focus on the urban infrastructure regime. Records of national-scale analyses of policy instruments are often aimed at particular interventions (e.g. green roofs) subsumed under the NBS umbrella (e.g., Carter and Fowler, 2008; Mazza et al., 2011), whilst not studying these in combination across multiple countries.

5.1. The uptake of policy instruments for urban NBS mainstreaming

We provided a theory-driven argument for employing policy mixes combining different types of instruments in order to support urban NBS mainstreaming. Our empirical research showed that the studied cases generally achieved this, which suggests that multiple actors are enrolled into urban NBS mainstreaming efforts as a result of regulation supported with financial and soft instruments aimed at shifting social norms and cognitive routines (Jänicke and Lindemann, 2010). Interestingly, the studied cases varied in the extent to which policy instrument types were used relative to one another. The UK was found to rely relatively strongly on regulatory instruments, whilst not applying any financial instruments. This is in agreement with a policy style of ‘pragmatic opportunism’, where national government sets broad regulatory frameworks, with scope for lower scales of government and specialist agencies to set specific targets in consultation with industry (Wurzel et al., 2013). The central implementation of financial instruments have elsewhere been described as “alien to the guiding percepts and organizing structures of UK policy” (Wurzel et al., 2013, p.62). The relatively

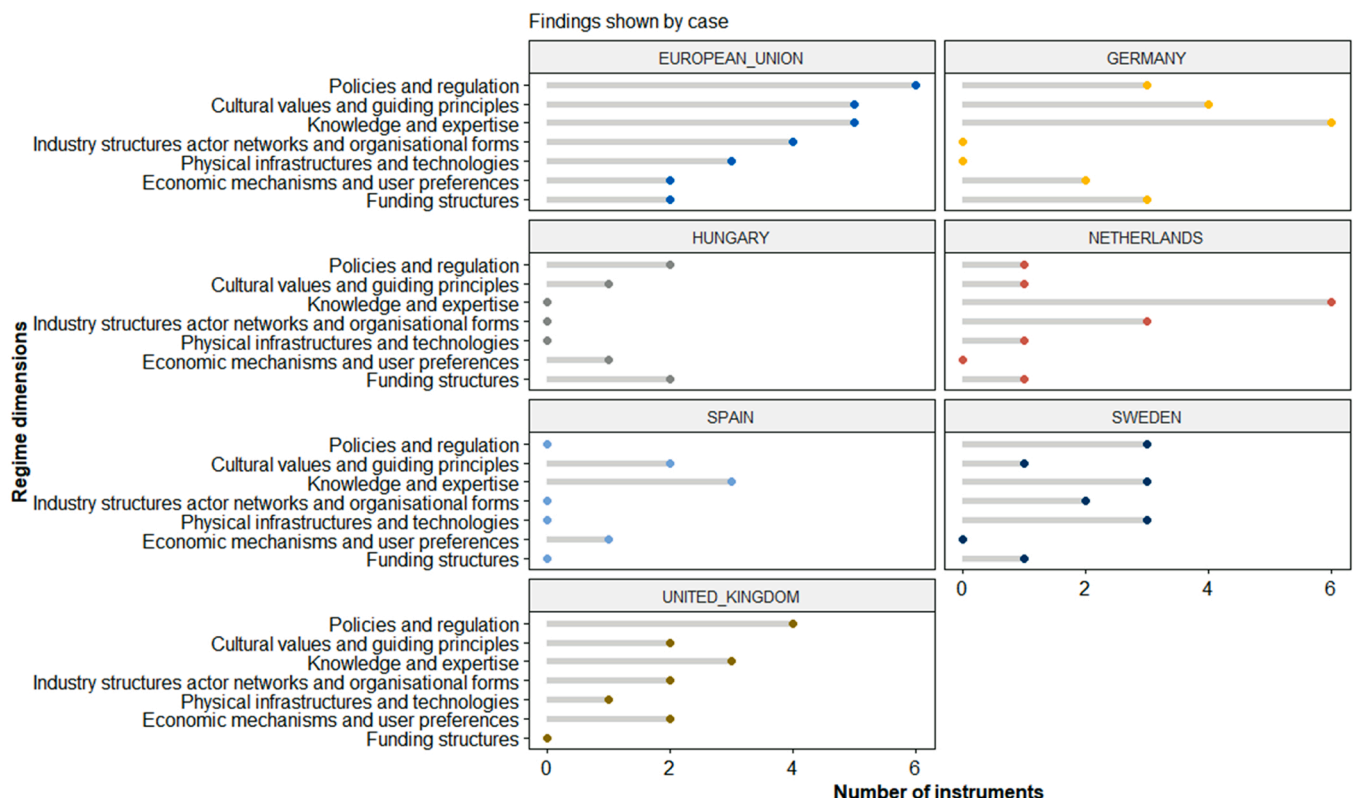


Fig. 3. Graph showing urban infrastructure regime structures targeted by (supra)national policy instruments across each of the seven cases.

high number of soft policy instruments found in The Netherlands is in line with the ‘Dutch governance model’ – where the state engages in extensive networking and public-private partnership working to stimulate self-regulation through consensus-building (Persson et al., 2016; Wurzel et al., 2013). The high number of policy instruments of different types used by the EU is in line with recent research indicating them to be a global leader with regard to policy-driven support of NBS (Davies et al., 2021).

5.2. Scope for introducing new types of policy instruments

Despite the variety of instruments recorded in this study, it appears that some types of well-established policy instruments in sustainability policy are not yet used to support urban NBS mainstreaming. For example, we did not find evidence of *voluntary agreements* negotiated between government and industry providing targets around the delivery of urban NBS. Although instruments such as City Deals and Green Deals give the impression of being voluntary agreements, they do not include commitments by industry actors to change their practices. *Eco-taxes* represent another well-known category of environmental policy instruments, which was not employed in any of the studied cases. This is a surprising observation given that NBS such as green roofs generate public services (e.g. water buffering and filtration) for which property and water-related tax incentives could be provided, while unsustainable alternatives could be taxed more heavily. It is therefore promising that we were able to identify one (unsuccessful) attempt at lobbying for national-level sewage tax breaks for green roof implementation (based on water buffering benefits) by the Green Deal Green Roofs coalition in The Netherlands. Likewise, in Germany NGOs such as NABU are lobbying the federal government to overhaul the property tax system to address land speculation and foster sustainable urban development. Also, while we found examples of policy-driven (trans-)national networks with a sustainable development mandate that could potentially include urban NBS mainstreaming, these networks tend to focus on other more prominent topics, in particular climate mitigation. Examples of this include the Hub for Sustainable Finance set up by the German Council for Sustainable Development, as well as the Central Bank and Supervisor Network for Greening the Financial System (NGFS) initiated by the Dutch Central Bank.

Although environmental and planning regulations featured prominently in the analysis across all cases, we found relatively few examples of mandatory requirements, involving coercion and sanctions (Wurzel et al., 2013). Although instruments such as The Federal Nature Conservation Law in Germany provide municipalities with the powers to do so, the only observed example of a command-and-control instrument in this study was the UK’s Biodiversity Net Gain instrument. In some cases, we found that such mandatory requirements are implemented at a lower government level with scope for improving the uptake through support by the national government. The Green Space Factor is an example of such an instrument used by a number of frontrunner cities (e.g. Malmö, Stockholm & Berlin) in the studied cases. This is a point-based system to evaluate if spatial planning proposals meet minimum requirements around the quantity and quality of NBS provision. Different types of green space are weighted differently in relation to the social and environmental features, while taking into account the ratio of greenspace to the size of the plot. There is also scope for (supra)national government to learn from lower levels of government in other areas. In Spain, for example, the national government was considered a laggard on policy-based support for NBS when compared to some cities. For example, Barcelona committed to an additional 1 m² of greenspace per inhabitant (1.6 km² in total) by 2030 as part of its 2015 Commitment to the Climate, evidencing policy integration, while it also produced a green infrastructure plan and green roof guidance ahead of national government strategy development.

5.3. Observed policy comprehensiveness

The analysis of policy comprehensiveness served to build an understanding of the extent to which policy mixes employed in each of the cases target the full range of relevant urban infrastructure regime structures (Fig. 1). Whereas the EU targeted each of the seven structures, this was not replicated in the country cases. Consequently, there are likely missed opportunities for urban NBS mainstreaming. The analyzed country cases could draw on the information in Fig. 3 to help target policies to inactive areas. For example, some of the documented best-practice technical guides are likely at least partially transferable between countries to support the development of ‘knowledge and expertise’, or at a minimum could support (soft) learning by technicians, even if the instrument is not actually transferred (Dąbrowski et al., 2018). This also applies to state-of-the-art urban NBS assessment tools such as the green-benefit planner spatial planning support tool piloted in The Netherlands (‘physical infrastructures and technologies’ regime structure). Other structures might be more difficult to change because these are the result of political decisions or outcomes of planning traditions, e.g. the lack of national-scale funding structures in the UK referred to previously. Another example is the devolution of national nature policy in The Netherlands since 2010. This resulted in the loss of previously established national-scale guidance and standards for greenspace in and around cities (NATURVATION, 2020) – a legacy still reverberating in the relative lack of ‘cultural values and guiding principles’ supporting urban NBS mainstreaming today. In agreement with research suggesting that market formation for urban NBS might be less straightforward than for other types of innovations (van der Jagt, Raven et al., 2020), a number of countries did not yet employ measures to target the ‘economic mechanisms and user practices’ regime structure. Some examples of demand-side regulation are promising in this regard, such as the EU Taxonomy and the UK’s biodiversity net gain policy. Market formation can also be stimulated by directly subsidizing SMEs to experiment with NBS, such as done in the EU’s Horizon 2020 programme.

5.4. Directions for future research

This study documented different types of policy instruments employed by European countries and the EU and mapped these onto regime structures. Our assertion that employing a diversity of policy instrument types targeting all regime dimensions supports urban NBS mainstreaming, however, provides a simplification of a much more unruly reality. First, because of the possibility for favourable conditions enabling urban NBS mainstreaming to pre-exist for some of the regime structures, which implies that a policy instrument targeting that dimension would provide little to no added benefit for urban NBS mainstreaming. For example, the Netherlands has strong expertise in ‘building with nature’ (van der Jagt, Toxopeus et al., 2020), so there appears to be no immediate incentive for policy to prioritize further strengthening this knowledge (which does not mean that knowledge in other relevant areas should not be improved). Second, we did not control for the sectoral breadth and reach of instruments, which might vary considerably (e.g., compare a single short-term living lab with a handful of public and private actors to a nation-wide programme involving multiple long-term interdisciplinary partnerships). We also did not study the cumulative effects of different instruments targeting the same structural dimension on mainstreaming potential. Moreover, we predicted policy mix effectiveness based on its comprehensiveness rather than directly measuring it. Future research could address this by undertaking e.g. Impact Assessments or Cost-Benefit Analyses of similar policy instruments implemented across different contexts. Third, we have not scrutinized how instruments relevant to urban NBS mainstreaming interact with each other and related policy in other domains and at other levels. For example, green infrastructure policy is likely more effective if combined with policy *unmaking* grey infrastructure, and some national-level policies may be redundant if already

implemented at a regional level across a country. Future research could explore the role of coherence in policy goals and of consistency in instruments on policy impact (for an example on energy efficiency, see Kern et al., 2017). Finally and most importantly, we acknowledge that policy instruments are only one of many possible stepping stones to urban NBS mainstreaming, albeit an important one (Xie et al., 2020). The seeds of change, however, come from multiple sources with practices manifested at (supra)national scale being enabled, shaped and transformed by dynamics and events at other scales, including the local (Bouzarovski and Haarstad, 2019; Hodson and Marvin, 2010). Therefore, there remains an ongoing need for research that explores the reflexive interactions between the different components of the socio-material networks that together shape the city.

6. Conclusion

Given that the need for governments to take the lead in guiding transitions to urban sustainability has never been more urgent, this study explored the use of (supra)national policy instruments supporting urban NBS mainstreaming across six European countries and the EU. We showed that (supra)national policy instruments for mainstreaming urban NBS can be divided across the three main groups of regulatory, financial and soft instruments with eleven subtypes, which we illustrate with case study examples. However, there is scope for adopting a broader range of policy instruments, e.g., eco-taxes, particularly for actors in the finance domain. We argued that in order for governments to target all relevant actors and influence regulations, norms and routines, combinations between diverse types of instruments need to be made. The studied governments generally adhered to this, with the exception of the UK, but it is a precarious achievement given that the majority of studied countries did not have more than one policy instrument of a particular type. In addition, we reasoned that for NBS to be mainstreamed into the urban infrastructure regime, employed policy mixes need to address all relevant regime structures. We found that the EU was the only case successfully doing so. Consequently, the policy mix comprehensiveness across the six studied countries is lower than it could be. This likely creates openings for incumbents to maintain investment in unsustainable alternatives competing with NBS for limited urban space. (Supra)national governments could use the generated insights to inform the design of more comprehensive policy mixes that push for change from multiple directions simultaneously, which would likely help to shift momentum to developing nature-based cities benefiting both people and the planet.

CRedit authorship contribution statement

Alexander van der Jagt: Conceptualization, Methodology, Investigation, Formal analysis, Data curation, Writing – original draft, Writing – review & editing, Visualization, Project administration. **Laura Tozer:** Investigation, Formal analysis, Writing – original draft, Writing – review & editing. **Helen Toxopeus:** Investigation, Formal analysis, Writing – original draft, Writing – review & editing. **Hens Runhaar:** Conceptualization, Methodology, Writing – original draft, Writing – review & editing, Supervision, Project administration.

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

We have shared the link to our data in the reference list.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.envsci.2022.10.011.

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