

EU's roadmap for implementing nature-based solutions: A review

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Abstract

The present paper reviews the chronological history, or roadmap, of the documentation produced by the European Union (EU) for promoting and implementing nature-based solutions (NBS) as an innovative approach in the context of scientific research, environmental practice, and public policy to establish socially inclusive, economically vibrant and ecologically resilient society. With an ambition of positing Europe as the world leader in NBS theorisation and operationalisation, considerable efforts have been made by the EU as featured in a number of documents, funding programs and Horizon 2020 (Research and Innovation) projects that span the period from 2012 to 2020. While the EU's commitment to promoting NBS within its Member States and beyond is still an ongoing process, we aim to review the efforts undertaken, knowledge gained, and practices accomplished. This roadmap intends to provide interested practitioners, policymakers, researchers, as well as civil organisations with an updated, comprehensive understanding of NBS conceptualisation and operationalisation, which can inform future directions of NBS research and practices facing both acute and chronic environmental and social challenges prompted by urbanisation/re-urbanisation, globalisation/de-globalisation, climate change and, more recently, the COVID-19 pandemic.

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31 **Keywords:** Nature-based solution; European Union; Conceptualisation and operationalisation;
32 Sustainable development

33

34 **1. Introduction**

35 As human beings embark into a new era marked by the intensification of global-wide social,
36 economic and environmental problems and overt disconnection from nature (Lehmann, 2019;
37 Vasenev et al., 2020), it is evident in academic and practical arenas that the sustainability transitions,
38 which have traditionally been oriented by technological innovations, are gradually shifting to the
39 multifunctionality of nature (as an innovative form of soft technology) to address and mitigate both
40 acute and chronic social, economic, and environmental/ecological challenges simultaneously,
41 especially in urbanised and re-urbanising cities across the globe (Lafortezza and Sanesi, 2019;
42 Hanson et al., 2020; van der Jagt et al., 2020). This strategic, yet cost-effective, intervention has
43 manifested as an innovative conceptualisation and operationalisation of “nature-based solutions”
44 (NBS) initiated, guided and promoted by influential inter-governmental institutions such as the World
45 Bank (The World Bank, 2008, 2019), the International Union for Conservation of Nature (IUCN,
46 2009, 2012), and particularly the European Union (EU) and its executive branch: the European
47 Commission (EC) (European Commission, 2015a, 2015b). The explicitly envisaged aims include (but
48 are not limited to) restoring and rebalancing relationships between nature and human society (Hanson
49 et al., 2020; Randrup et al., 2020; van der Jagt et al., 2020), constructing resilient and adaptive urban
50 ecosystems (Cohen-Shacham et al., 2016; Kabisch et al., 2016; Faivre et al., 2017; Raymond et al.,
51 2017a), revitalizing and stimulating business and economy (Nesshöver et al., 2017; Mussinelli et al.,
52 2020; Swart and Groot, 2020), as well as improving quality of life, health and wellbeing (Panno et
53 al., 2017; Dick et al., 2019; Lafortezza and Sanesi, 2019).

54 Amongst various NBS concepts defined in existing documents and literature, the one proposed
55 by the EC is widely recognised and commonly adopted (Hanson et al., 2020). In its most signature
56 document, NBS are clearly conceptualised as “*solutions that are inspired and supported by nature,*
57 *which are cost-effective, simultaneously provide environmental, social and economic benefits and*
58 *help build resilience. Such solutions bring more, and more diverse, nature and natural features and*
59 *processes into cities, landscapes and seascapes through locally adapted, resource-efficient and*
60 *systemic interventions*” (European Commission, 2015a). This concept serves as an overarching
61 framework (Nesshöver et al., 2017; Pauleit et al., 2017; Krajter Ostoić et al., 2018), encompassing a
62 wide variety of interpretations and applicative interventions (Dorst et al., 2019). With an ambition of
63 positing Europe as the world leader in NBS theorisation and implementation (European Commission,
64 2015a; Bourguignon, 2017; Zwierzchowska et al., 2019), considerable efforts have been made by the
65 EC, as featured in a number of EU documents, funding programs and particularly Horizon 2020 (EU-
66 funded Research and Innovation) projects pertaining to a broad set of NBS interventions, to advance
67 and disseminate relevant knowledge and best practices.

68 NBS concepts, components, and aims have been constantly evolving (Dick et al., 2019) with the
69 advancement of relevant knowledge and the emergence of new environmental and social challenges
70 (such as the most recent COVID-19 pandemic). This paper presents a timely inventory and prudent
71 reflection of NBS documents and projects, with a focus on the EU’s efforts as a determined promoter
72 and active actor (Kronenberg et al., 2017) during the period from 2012 to 2020. It traces the state-of-
73 the-art and presents the communities of policymakers, scientists, public/private bodies and
74 institutions with a roadmap of what has been accomplished until now. This review is of pivotal
75 importance to articulate NBS more clearly, avoid ineffective implementation, and provide a direction
76 of travel forward towards sustainable society (Nesshöver et al., 2017; Dorst et al., 2019; Randrup et
77 al., 2020).

78 **2. Materials and methodology**

79 The EU's promotion and support of NBS manifest in three major strands as its publications
80 (including expert reports and theme-based conference proceedings, Table 1), funded projects (mainly
81 the flagship Horizon 2020 scheme under the Framework Programme for Research & Innovation), and
82 embedment in policy instruments. To collect all materials pertaining to NBS theorisation and
83 operationalisation, we mainly rely on e-resource provided by two key websites: (1) the EU web portal
84 for NBS (<https://ec.europa.eu/research/environment/index.cfm?pg=nbs>), which covers a wide range
85 of projects, documents and reports, and policy files, and (2) the Oppla information hub
86 (<https://oppla.eu/>), which is an open platform serving as the EU repository of NBS knowledge and
87 exemplar cases.

88 All materials are consolidated to evaluate available evidence on the state-of-the-art of NBS
89 thematic coverage, challenges to be addressed, and goals to be achieved. Especially, the qualitative
90 information is synthesised iteratively through rounds of discussions amongst all authors, as well as
91 with project leaders/participants and EU-funding officers so that consensus on the summative
92 assessments can be developed.

93 **3. NBS in EU publications**

94 Prior to 2015, when the EC formally and explicitly conceptualised NBS in its guiding document
95 (Towards an EU Research and Innovation Policy Agenda for Nature-Based Solutions & Re-Naturing
96 Cities), several precursors have sporadically appeared. The first one is "EU Research-Natural Hazards
97 and Disasters", published in 2012 (European Union, 2012a). Although this document focuses on a
98 series of topics including hazard assessment, triggering factors and forecasting, vulnerability
99 assessment and societal impacts, risk assessment and management, and multi-risk evaluation and
100 mitigation, a key concept which places nature and nature's functions in the spotlight is highlighted:
101 resilience, being defined as "*the ability (of nature) to resist, absorb, accommodate and recover from*
102 *the effects of a hazard in a timely and efficient manner*". In the same year, another report "Soil and
103 Sustainable Land Use Management" was issued (European Union, 2012b), which lays out "how soil

104 systems are influenced by human activities” as a major research theme aiming to develop innovative
105 and effective ways for mitigating damage and combatting desertification in Europe and worldwide.
106 The last, yet important, publication is entitled “Biodiversity” (European Union, 2014). Based on the
107 premise that human beings depend entirely on what nature provides (i.e., ecosystem services), this
108 document emphasises the importance and necessity of international collaboration in generating
109 transdisciplinary knowledge and designing feasible action plans to slow down or stop biodiversity
110 loss. While these different forms of nature have entered into the EU’s research scope, primarily being
111 regarded as important components of achieving sustainable civilisation, whether and how they can
112 be integrated into NBS remain largely ambiguous.

113 Even though a clear definition for NBS is still lacking (Droste et al., 2017), a series of forums and
114 meetings were organised by the EC and relevant proceedings drafted on the theme of “NBS and Re-
115 Naturing Cities” in 2014. These events discussed different aspects of NBS amongst multiple
116 stakeholders (e.g., EU agencies, representatives from Member State governments, research
117 institutions, public authorities, private companies, and international organisations) in Brussels,
118 Belgium, (European Commission, 2014a) and Milan, Italy (European Commission, 2014b). Using
119 these events, NBS, as a cost-effective intervention to address diverse environmental, economic and
120 social challenges, have been extensively discussed, debated and deliberated, with an aim to explicitly
121 conceptualise NBS and promote it amongst the EU Member States.

122 A breakthrough emerged in November 2014 when the EC published “In-depth Report: E-
123 Consultation on Nature-Based Solutions” (European Commission, 2014c). This report is based on
124 extensive consultation with diverse stakeholders administered by an expert group (commissioned by
125 the EU on “Nature-Based Solutions and Re-Naturing Cities”) to assist the EC’s tasks associated with
126 the Framework Programme for Research and Innovation. The consultation centered on four topics:
127 improving risk management and resilience, restoring degraded ecosystems, climate change adaptation
128 and mitigation, and sustainable urbanisation. Some recurrent, topical points are summarised in this

129 report, including (1) the need to adapt a broader systemic/holistic thinking which goes beyond “green
130 engineering” and includes risk management; (2) the requirement to clarify the NBS concept; (3) the
131 need for a clear operational framework that includes a multi-level stakeholder spectrum and
132 perspective; (4) the need to increase awareness of NBS and their multiple benefits among the public
133 and policymakers for which information/knowledge and education are key; and (5) an economic
134 dimension (which is yet to be clearly identified), stressing the need to make a business case for NBS.
135 Even though it appeared difficult to form consensus on NBS operational approaches and steps
136 forward, two recommendations were raised to the Directorate-General for Research and Innovation:
137 (1) the absolute need to establish a clear framework in which further research and policy guidelines
138 can be established, and (2) the necessity for broad systemic thinking and a multi-level stakeholder
139 perspective, which lay the foundation of the EC’s flagship funding stream, Horizon 2020: Nature-
140 Based Solutions.

141 In 2015, a final report was produced by this expert group, entitled “Towards an EU Research and
142 Innovation Policy Agenda for Nature-Based Solutions & Re-Naturing Cities” (European
143 Commission, 2015a), which has since then become one of the most important documents guiding and
144 driving NBS research and operationalisation (Dumitru et al., 2020). It comprehensively examines
145 how NBS can address a variety of environmental, social and economic challenges facing human
146 society. Four key goals are clearly specified: (1) enhancing sustainable urbanisation, (2) restoring
147 degraded ecosystems, (3) developing climate change adaptation and mitigation, and (4) improving
148 risk management and resilience. Particularly, seven NBS actions are recommended, including (1)
149 urban regeneration through NBS; (2) NBS for improving wellbeing in urban areas; (3) establishing
150 NBS for coastal resilience; (4) multifunctional, nature-based watershed management and ecosystem
151 restoration; (5) NBS for increasing the sustainable use of matter and energy; (6) NBS for enhancing
152 the insurance value of ecosystems; and (7) increasing carbon sequestration through NBS. This report
153 also emphasises that NBS should be regarded as an iterative, evidence-based process that entails the
154 co-generation of knowledge and co-implementation of tools involving researchers, practitioners,

155 businesses, and civil society. The publication of this document signifies an inherent feature of NBS:
156 dynamic, mutual enrichment of NBS conceptualisation and operationalisation.

157 In the same year of 2015, an international conference was organised by ALTER-Net (European
158 Ecosystem Research Network) under the auspices of the Latvian Presidency, with a focal theme on
159 “Nature and Urban Wellbeing: Nature-Based Solutions to Societal Challenges”. Experts from various
160 research and public policy institutions (e.g., business and solution providers, health professionals,
161 policymakers and governing authorities) attended this two-day event. The conference facilitated
162 broad dialogue across multiple fields of research, policy and practice engaged in nature and urban
163 wellbeing, centering on “how the NBS concept can be used to address current gaps in knowledge,
164 policy and practice”.

165 In 2017, the EKLIPSE (a Horizon 2020 project based in the UK) Expert Working Group was
166 requested by the EC to draft a report with a specific focus on NBS implementation and assessment
167 dealing with climate change in urban areas (Raymond et al., 2017a, 2017b). Along with a set of
168 indicators and assessment methods to monitor and evaluate the multi-dimensional, cross-
169 temporal/geographical effectiveness of NBS projects, knowledge gaps and future research and
170 practice directions are summarized, including: (1) international/national legislation; (2) multi-
171 stakeholder international networks to facilitate participatory planning and governance and NBS
172 transferability; and (3) legal, policy and financial instruments to promote NBS uptake. This report
173 signifies the integration of NBS knowledge generation and operationalisation.

174 This integration is also highlighted in a conference held the same year, co-organised by the
175 Estonian Ministry of the Environment, Tallinn University, and the EC (European Union, 2017). More
176 than 400 scientists, key policymakers, and nature enthusiasts mainly from EU Member States were
177 attracted. Diverse topics were discussed, such as blue-green infrastructure in smart cities, integrated
178 water management, ICT (information and communication technologies) as a supporting tool for NBS,
179 ecological restoration through eco-innovation, NBS in the circular economy, social wellbeing and

180 public engagement, and linking NBS to Sustainable Development Goals. This conference served as
181 an important platform for popularising NBS with a focus on its operationalisation.

182 Next in the timeline of the roadmap is a report titled “The EU-Brazil Sector Dialogue on Nature-
183 Based Solutions: Contribution to a Brazilian roadmap on Nature-Based Solutions for Resilient
184 Cities”, drafted in 2019 by the EU in collaboration with the Ministry of Science, Technology,
185 Innovation and Communications, Federative Republic of Brazil. Using 25 NBS good practice
186 examples from European Member States to illustrate possible adaptation to the Brazilian context so
187 as to form a unique NBS strategy for Brazil, this report highlights how to unlock NBS potentials not
188 only in Brazil but also in other Latin American countries (Herzog and Antuña Rozado, 2019). Clearly,
189 NBS, being an innovative idea and a feasible tool, has expanded from within the EU to cross-
190 continental knowledge generating and sharing.

191 **4. NBS in EU-funded projects**

192 Reflecting its leading role in NBS theorisation and implementation with overall aims to improve
193 competitiveness, raw materials security, and human wellbeing, the EU has also been actively
194 engaging with the research community to better address NBS knowledge and technology gaps (Sarabi
195 et al., in press) through its Framework Programmes and Research and Innovation strategy, notably
196 Horizon 2020.

197 As a priority area, it is strategically paralleled and intertwined with the other four themes: climate
198 action (informed decisions for a climate-resilient and low-carbon society), cultural heritage (engaging
199 a new cultural heritage agenda for economic growth), earth observations (crucial information on
200 climate, energy, natural hazards and other societal challenges), and systemic eco-innovation
201 (generating and sharing economic and environmental benefits). Hitherto, a total of 35 projects
202 (sourced from the EC’s CORDIS website that contains all information on the EU’s research projects
203 since the 1980s; see Appendix A) have been financed to consolidate the NBS knowledge base and

204 collect evidence on the effectiveness of NBS operationalisation in addressing various key social,
205 environmental and economic challenges (Sarabi et al., in press). A full list of NBS-related projects
206 for comparison is given in Appendix A, for which approximately 240 million Euros have been
207 allocated (Cohen-Shacham et al., 2019). Herein, six ongoing projects are presented to highlight their
208 diverse objectives in knowledge generation and operationalisation, and performance monitoring and
209 assessment, as well as their expansion from within EU Member States to other key regions for
210 sustainable development across the globe.

211 4.1 Nature4Cities: Nature Based Solutions for re-naturing cities: knowledge diffusion and decision 212 support platform through new collaborative models

213 This project aims to: (1) develop complementary and interactive modules to engage urban
214 stakeholders in a collective learning process about re-naturing cities; (2) develop and circulate new
215 business, financial and governance models for NBS projects, as well as (3) provide tools for the
216 impacts assessment, valorisation and follow-up of NBS projects. Various modules (i.e., NBS impacts
217 assessment toolbox, set of innovative businesses, financial and governance models, database of
218 generic NBS, and NBS best practices/case studies) will be integrated in a NBS dissemination/
219 assessment self-learning platform to assist NBS project developers along the entire life-cycle of their
220 projects from opportunity studies, project definition, down to performance monitoring.

221 4.2 URBAN GreenUP: New Strategy for Re-Naturing Cities through Nature-Based Solutions)

222 This project focuses on a tailored methodology, which can (1) support the co-development of
223 Renaturing Urban Plans pertaining to climate change mitigation and adaptation, and efficient water
224 management, and (2) assist in the effective implementation of NBS. It also seeks to foster the creation
225 of a global market and EU international cooperation by enacting a wide Exploitation and Market
226 Deployment procedure for NBS solutions and engaging in an Impact-based Communication and
227 Dissemination strategy. A large-scale and replicable demonstration action of NBS accompanied by

228 innovative business models would provide evidence about the benefits of NBS with regard to new
229 market opportunities for European companies.

230 4.3 CONNECTING Nature: COproductionN with NaturE for City Transitioning, INnovation and 231 Governance

232 The main objective of this project is to position Europe as a global leader in the innovation and
233 implementation of NBS. The project will co-develop the policy and practices necessary to scale up
234 urban resilience, innovation and governance via NBS from within EU Member States to worldwide.
235 The project will provide a reference framework for a new generation of urban NBS processes and
236 empower transitioning ambassadors who will globalise these new NBS tools.

237 4.4 proGIreg: productive Green Infrastructure for post-industrial urban regeneration

238 This project attempts to integrate NBS into business models that are economically self-sustaining
239 and provide multiple benefits for the economic, ecological and social regeneration of deprived urban
240 areas that have been suffering from the consequences of de-industrialisation. Innovative NBS-
241 orientated economies would be developed and shared amongst public authorities, civil societies and
242 industry, through co-designing, co-creating and co-implementing NBS and combining NBS with
243 market-ready business models. A training programme for the cooperative planning, implementation
244 and management of NBS will be designed to nurture global impacts.

245 4.5 CLEARING HOUSE: Collaborative Learning in Research, Information-sharing and Governance 246 on How Urban tree-based solutions support Sino-European urban futures

247 The main objective of this project is to analyse and develop the potential of urban forest NBS
248 (UFBS) to enhance the adaptive capacity and resilience of cities facing major ecological, socio-
249 economic, public health and human wellbeing challenges across China and Europe. This will be
250 achieved through the delivery of five objectives, as follows: (1) connecting existing academic with
251 practical knowledge on restoring, reconnecting, monitoring, managing, and governing UFBS across

the urban-rural interface; (2) analysing paired case studies on UFBS in China and Europe; (3) building a Collaborative Learning Architecture; (4) developing decision support tools and guidelines; and (5) increasing awareness on the benefits of UFBS for urban resilience, liveability, public health and wellbeing within governments, businesses, civic society, and academia. Intended outcomes include replicable business models and investment cases, decision support tools linked to urban development, topic-specific thematic guidelines and UFBS field laboratories.

4.6 INTERLACE: INTERnational cooperation to restore and connect urban environments in Latin AmeriCa and Europe

This project aims to advance knowledge and awareness of restorative NBS, foster more ecologically coherent and integrated city planning processes, and lay the foundation for multi-directional cooperation and exchange between the EU and Latin American cities for wider transformative impacts. Partner cities will provide and share experiences with other cities globally, building technical and procedural capacities. It envisions a wide dissemination and application of project outputs through effective pathways to impact. A web-based Innovation Hub will be established for disseminating NBS tools (comprised of integrated assessment systems, a catalogue of policy and governance instruments, city impulse papers, business cases, guidance documents, and other evidence generated by the project) to assist urban ecosystem restoration and rehabilitation and promote project result exploitation in the EU and Latin American cities and beyond.

5. NBS in EU policies

The successful uptake of NBS is underpinned by effective policy and legislation (Zwierzchowska et al., 2019; Frantzeskaki et al., 2020; Sarabi et al., in press). Presently, concepts that allude to NBS can be found in several important EU strategies; however, the potential of NBS remains to be achieved when it can be specifically mainstreamed in EU's high level policies. There is already significant recognition of the importance and need for policy and legislation instruments, and the "working with nature" approach has gained increasing prominence across EU policies (Faivre et al.,

277 2017; Calliari et al., 2019; Kumar et al., 2020). Anticipated early adopters for NBS delivery include
278 strategies on biodiversity, green infrastructure, resource efficiency, disaster risk reduction, and green
279 public procurement.

280 The first EU Biodiversity Strategy was adopted in 1998, and then followed up by an action plan
281 and succeeding strategies in 2006 and 2011, with a clearly specified objective to halt the loss of
282 diversity and degradation of ecosystem services in the EU by 2020 (Kettunen, 2018). Instead of
283 pursuing the classic protected area approach (as with Natura 2000 sites), a shift in the political
284 paradigm from focusing solely on nature *per se* to focusing on the interaction of people and nature
285 has been witnessed over the past two decades (Cohen-Shacham et al., 2019). As a result, NBS
286 interventions have been embedded as an innovative pathway, a key complement and an inclusive and
287 adaptable framework to conserve and restore nature and find ways to thrive by harnessing nature's
288 contribution to human beings (European Commission, 2015c; Xie and Bulkeley, 2020). One example
289 is the EU Action Plan for nature, people and the economy adopted in April 2017, which includes the
290 development of guidance for further supporting the deployment of EU-level Green Infrastructure
291 projects towards realising the EU's biodiversity targets for 2020 (Faivre et al., 2018).

292 The EU Green Infrastructure Strategy (European Commission, 2013a), with a clear focus on the
293 delivery of multiple ecosystem services and as an important part of the EU Biodiversity Strategy, has
294 strongly promoted the development of green infrastructure (defined as "*a strategically planned*
295 *network of natural and semi-natural areas with other environmental features designed and managed*
296 *to deliver a wide range of ecosystem services*", according to Mazza et al., 2011) throughout the EU
297 at transnational, national, regional, and local levels (Faivre et al., 2018; Schneider et al., 2020). The
298 EU policy position on green infrastructure is closely linked to NBS by proposing that healthy natural
299 and/or semi-natural ecosystems provide cost-effective alternatives to traditional "hard" and "grey"
300 engineering infrastructure (https://ec.europa.eu/environment/nature/ecosystems/index_en.htm). In
301 principle, the implementation of green infrastructure aims for a sustainable use of nature (Schneider

et al., 2020). Thus, green infrastructure has been regarded as an NBS for mitigating contemporary social and environmental problems associated with urbanisation/re-urbanisation (Davies and Laforteza, 2017; Sanusi and Bidin, 2020) and achieving sustainable urban development (European Commission, 2015a; Ferrari et al., 2019).

The Roadmap to a Resource Efficient Europe (European Commission, 2011) emphasises the importance of natural capital and ecosystem services for the prosperity and wellbeing of Europe and its citizens. The basic elements of the roadmap include several areas where NBS have been identified as interventions to make a direct contribution, most notably in respect of a “circular economy”. In essence, NBS embrace nature conservation norms and principles (Cohen-Shacham et al., 2019) and connote the deployment of various natural features and processes in a resource-efficient and sustainable manner (Somarakis et al., 2019). Thus, the concept forms the central plank of thinking and acting to create a resourceful circular economy across Europe (Katsou et al., 2020).

The European Strategy on Adaptation to Climate Change (European Commission, 2013b) and the EU’s Action Plan on the Sendai Framework (European Commission, 2016) are two examples of EU policy initiatives with strong embedded NBS components as positive and cost-efficient ways of supporting ecosystem-based disaster risk reduction and adaptation to climate change (Faivre et al., 2018; Cohen-Shacham et al., 2019; Kumar et al., 2020) as a response to the increase in frequency and intensity of natural hazards such as floods, heatwaves, droughts, storm surges, and others (Kumar et al., 2020). The implementation of climate-proof, resource-efficient, resilient and systematic NBS has been promoted in various ways, directly or indirectly, to counter natural hazards, adapt to climate change, and maintain physical, chemical and biological conditions (Calliari et al., 2019) such as the adoption of retention ponds and wetlands to reduce flood risks in the EU’s Flood Directive (Albert et al., 2019).

Green Public Procurement (GPP) is a policy that recognises the EU’s public authorities as major consumers of nature and ecosystem services (https://ec.europa.eu/environment/gpp/index_en.htm).

327 In November 2019, the EC issued a staff working document (European Commission, 2019) setting
328 out new criteria for GPP for public space maintenance. The document is essentially a technical guide
329 about how GPP could effect change in public space maintenance. Although not directly stated, some
330 of the measures listed in the procurement of gardening services are, in fact, NBS, notably in relation
331 to gardening practices that enhance biodiversity. The importance of GPP is increasingly recognised
332 and is also the subject of research coordination within the EC's Research and Innovation agenda,
333 especially in the Commission's Task Force 3, which deals with governance, business models and
334 financial mechanisms.

335 **6. Discussion**

336 Hitherto, the EU has firmly positioned itself as the world leader in Research and Innovation on
337 NBS and in the global market for NBS (European Commission, 2015b; Bourguignon, 2017; Albert
338 et al., 2019; Calliari et al., 2019; Zwierzchowska et al., 2019), via its considerable efforts and funding
339 support devoted to generate robust and scientific evidence so as to theorise NBS knowledge, promote
340 its social acceptance, and enable effective NBS operationalisation. This chronological roadmap of
341 NBS from the EU's perspective (as summarised in Figure 1) illustrates an evolving pathway of NBS
342 from an embryonic academic concept towards the increasing uptake and operationalisation within EU
343 Member States and beyond (e.g., Latin America and China), underpinned by cross- and multi-sectoral
344 coordination and partnerships (including businesses, industries, environmental governance, natural
345 resource management, ecological conservation and restoration, disaster and risk reduction, urban
346 planning, public health, and others), by greater synergy of science, practice and policy, as well as by
347 the extensive collaboration of scientists, policymakers, communities, and other stakeholders in
348 learning, design, implementation, performance monitoring and assessment.

349 The EU conceptualises NBS as an innovative term explicitly linking positive outcomes (solutions)
350 for society with a traditional notion of 'nature' (Nesshöver et al., 2017), aiming to harness the power
351 and sophistication of nature, turning environmental, social and economic challenges into innovation

352 opportunities (European Commission, 2015b) and achieving the full range of Sustainable
353 Development Goals (United Nations, 2015; Cohen-Shacham et al., 2019; Kumar et al., 2020). This
354 concept signifies a transition from the traditional “grey” and “hard” approaches to “green” and “soft”
355 solutions (Davies and Laforazza, 2019; Schneider et al., 2020), and from the resource-intensive
356 growth model towards a more resource-efficient, inclusive and sustainable growth model (Kabisch et
357 al., 2016; Faivre et al., 2017). Such a transition is multifaceted, spanning from science and knowledge,
358 societal views and values, to organisational structure and decision-making processes. Thus, its
359 success can only be driven by multiple actors from various domains and from different socioeconomic
360 and cultural contexts across the globe (Neuens et al., 2013; Frantzeskaki, 2019; Xie and Bulkeley,
361 2020). This point has been clearly recognised in the EU, but requires to be further expanded to build
362 a concerted and systematic effort to collate NBS evidence and operationalise NBS to tackle local and
363 global challenges.

364 Despite the good intentions behind and considerable efforts put into NBS theorisation and
365 operationalisation, some challenges exist in NBS conceptualisation (and relevant knowledge
366 generation), operationalization, and particularly institutionalisation (Nesshöver et al., 2017;
367 Frantzeskaki et al., 2020; Sarabi et al., in press). Firstly, it remains implicit how the NBS concept
368 differs from other concepts associated with improving human wellbeing by managing natural
369 elements, ecosystem services, and natural capital in appropriate ways, such as ecological engineering
370 as “actions using and/or acting for nature” (Rey et al., 2015), ecosystem-based adaptation as
371 “mobilising the role of ecosystem services in reducing the vulnerability of society to climate change,
372 in a multi-sectoral and multi-scale approach” (Vignola et al., 2009), and the ecosystem services
373 framework as “an approach to understand how ecosystems can benefit human beings” (Daily, 1997;
374 Millennium Ecosystem Assessment, 2005). While the EU’s NBS concept allows flexibility and
375 adaptability to define “solutions” suitable for varying practical contexts (Krauze and Wagner, 2019),
376 it is necessary to refine NBS knowledge and concept to ensure consistency, allow cross-disciplinary

377 and cross-sector communication and sharing, and avoid redundancy or confusion (Nesshöver et al.,
378 2017; O’Hogain and McCarton, 2018).

379 Secondly, the knowledge and principles of the NBS concept do not always make it into practice
380 (Rounsevell et al., 2019). How to transform NBS from a heuristic framework and mostly thematic
381 scientific evidence into unambiguous, systematic, impactful practices and business cases is
382 challenging (Nikolaidis et al., 2017; Frantzeskaki et al., 2020). Ways and instruments to form and
383 sustain partnerships amongst scientists, municipalities, businesses, and communities need to be found
384 and adopted to share NBS knowledge, understand societal expectations and needs, design feasible
385 solutions, implement and maintain those solutions, and monitor and assess NBS performance
386 (Frantzeskaki, 2019; Neto et al., 2019). While challenging, years of practical experiences in many
387 European cities have delivered exemplar elements of NBS best practices, as those that can be found
388 on open knowledge-sharing platforms such as OPPLA, <http://info.oppla.eu/>, and Urban Nature Atlas,
389 <https://naturvation.eu/atlas>. Some exemplars are provided in Appendix B. Nevertheless, their
390 replicability, scalability (upwards and/or downwards), and transferability require to be further
391 examined to streamline NBS knowledge and best practice models into actions on the ground.

392 Thirdly, progress in NBS adoption in the EU’s policies is evident. Nevertheless, the level of
393 integration of NBS within existing policy frameworks remains far from optimal (Rounsevell et al.,
394 2019), and NBS implementation can be significantly hampered by the misalignment between
395 municipal, regional, national and transnational policies and regulations (Li et al., 2019). Concrete
396 policy instruments (e.g., information and financial incentives, decision-making mechanisms, and
397 catalysers for public-private partnerships) are essential for implementing NBS successfully (Droste
398 et al., 2017). Translating the NBS concept into legal and institutional systems for supporting NBS
399 implementation (as a way to demonstrate political leadership and commitment) is needed to establish
400 a supportive institutional setting in favor of NBS operationalisation (Raymond et al., 2017a, 2017b;
401 Randrup et al., 2020; Sarabi et al., in press).

402 **7. Concluding remarks**

403 The NBS journey has already started but is not yet finished. It commences with a mutual
404 enrichment of conceptualisation and operationalisation, thus might only be concluded when NBS has
405 been widely adopted and successfully contributed to sustainable development, along with other
406 innovative solutions. Beyond that, the journey continues through processes of multi-level government
407 policy-making and the work of technocrats to embed NBS in policy and strategies; from our review
408 we conclude that this part of the journey largely remains to be undertaken. The EU can show further
409 leadership in this regard by mainstreaming NBS in its strategic policies, using the Research and
410 Innovation as a connective fabric to inform the integration of science-practice-policy.

411 It is already clear that the EU intends to continue its investment in NBS theorisation and
412 operationalization, which is expected to increase. Nevertheless, there are areas for further NBS
413 Research and Innovation, especially in respect of mechanisms for delivery and policy making as well
414 as the potential of NBS as a socio-environmental instrument, for urban resilience, climate adaptation
415 and green space management. Ideally, the discourse on NBS Research and Innovation should be reset
416 so that it is widely viewed, not least within the EU as more than a “product” but equally as a “process”.

417 Moreover, at some point the forward momentum can be expected to switch from one dominated
418 by the EU’s Research and Innovation to one that places an emphasis on mainstream policy and legal
419 framework. In this context, as researchers we recommend as a starting point that “NBS proofing” of
420 both existing and pending EU strategies be undertaken across all relevant fields, in particular
421 embedded NBS thinking across all EC directorates as well as seeking further political direction at the
422 European Parliament level. We support the idea that NBS should be made the “signature policy” of
423 a future presidency, since this has significant potential to advance “nature-based thinking”.

424 Furthermore, it is evident that a radical change, or transition, in political will towards NBS
425 implementation must be urgently put into action to effectively tackle the current challenges of climate

426 change that are severely impacting societies, the natural environment and economy. In this
427 perspective, it would be appropriate to quote the final statement pronounced by the UN's Chief and
428 Secretary-General, António Guterres, during the news conference on the eve of COP25, which in
429 essence is as follows: "Political will is still lacking; political will to put a break on the carbon and
430 fossil fuel industry and to shift taxation. We must stop digging and drilling and take advantage,
431 instead, of the possibilities provided by renewable energies and nature-based solutions". This should
432 become the new target, raising the bar for the EU from 2020 to 2050.

433 At the moment, the outbreak of the COVID-19 pandemic is anticipated to bring about crucial
434 impacts on the economy worldwide. NBS, as a potential solution contributing to sustainable economic
435 growth by creating new economic niches to generate employment (Cohen-Shacham et al., 2019; van
436 der Jagt et al., 2020), likely emerge as a key consideration in the 2020s. Portraying NBS as an
437 opportunity in "green recovery" is urgently needed and a "sine qua non".

438

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445

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447

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450

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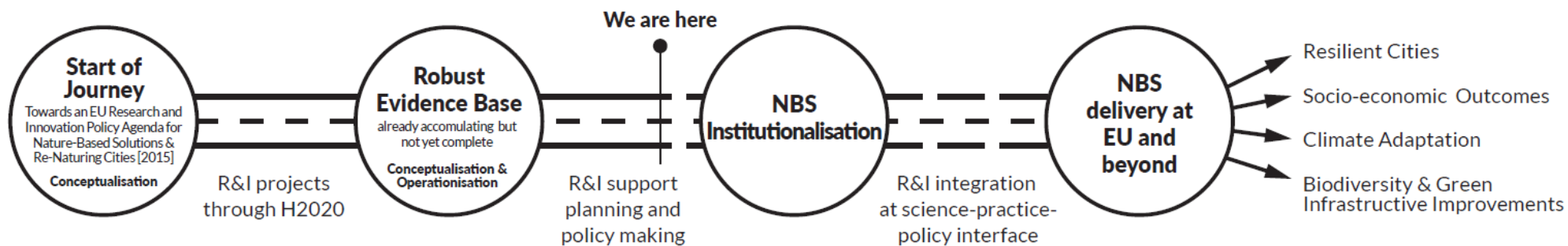
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662
663 Figure 1. EU roadmap for NBS implementation

Table 1. Documents published by the European Commission on Nature-Based Solutions

Year	Source	Title	NBS Thematic Goals	Re-naturing Actions	Impacts	Key Lessons
PUBLICATIONS						
2012	European Commission Research and Innovation	EU Research: Natural Hazards and Disasters	Hazard assessment, triggering factors and forecasting; vulnerability assessment and societal impacts; risk assessment and management; multi-risk evaluation and mitigation	Not available	Promoting communication of data and information among stakeholders, scientists, policy-makers and the general public	Well-grounded science and international collaboration for the development of credible forecasting and early warning systems of natural hazards
2012	European Commission Research and Innovation	EU Research: Soil and Sustainable Land Use Management	Address climate change, shortage of natural resources, and unsustainable urban growth; Build awareness and foster partnerships between policy-makers, researchers and local stakeholders	A combination of ground-based and remote-sensing approaches for evaluating soils and landscapes and take account of socio-economic conditions	Several projects help (1) identify pathways for a better future; (2) develop an integrated protocol on combatting desertification; (3) get an overview of resource and energy flows; (4) exchange knowledge and good practice, so as to find sustainable solutions	Policy-makers, researchers, local stakeholders and governments need to be informed on how soil systems are influenced by human activity and that research should pave the way for the development of innovative and effective ways to mitigate damage and combat desertification worldwide
2014	European Commission Research and Innovation	EU Research: Biodiversity	Promotion and conservation of biodiversity, covering a wide range of biodiversity, including marine, forestry, and freshwater	Overall actions to slow or stop the loss of biodiversity	Assess the dynamics of ecosystems and changes in biodiversity with greater accuracy; strengthen research on biodiversity cooperation in Europe and worldwide; understand the importance of creating knowledge networks to assist policy-makers and economic operators	Integrated assessment of social, economic and ecological issues via innovative transdisciplinary approaches is necessary
2014	European Commission	In-depth Report: E-Consultation on Nature-Based Solutions	Improve risk management and resilience; restore degraded ecosystems; climate change adaptation and mitigation; sustainable urbanization	Not available	Build a comprehensive EU Research & Innovation policy framework for nature-based solutions	Nature-based solutions is at its conceptualisation phase; further clarification is needed.

2015	European Commission Directorate-General for Research and Innovation	Towards an EU Research and Innovation Policy Agenda for Nature-Based Solutions & Re-Naturing Cities	Enhancing sustainable urbanization; Restoring degraded ecosystems; Developing climate change adaptation and mitigation; Improving risk management and resilience	Sustainable use of matter and energy; multifunctional watershed management and ecosystem restoration; coastal resilience; Increase of carbon sequestration; urban regeneration; human wellbeing in urbanized areas	Increase of ecosystem services provision; science-informed decisions	Position EU as a leader in world market, promoting NBS to address a variety of societal challenges, contribute to green growth, foster citizen wellbeing, and provide business opportunities
2017	European Commission Directorate-General for Research and Innovation	Nature-Based Solutions	Enhance NBS at EU policy level; develop a European R&I community for NBS; provide the evidence- and knowledge-base for NBS; advance the development, uptake and upscale of NBS; mainstream NBS within the international R&I agenda	Not available	Enhance the awareness and engagement of end-users, stir supply and demand towards the market and develop an EU-wide knowledge base on NBS	NBS brings together and capitalizes on major strands of knowledge from previous EU framework programs
2017	EKLIPSE Expert Working Group on Nature-Based Solutions	EKLOPSE-An Impact Evaluation Framework to Support Planning and Evaluation of Nature-Based Solutions Projects	Provide examples of indicators and methods for assessing impacts of NBS that may be applied in different ways across urban areas in Europe.	Creation of new vegetated surface waterbodies; conversion of brownfield to urban green areas; promotion of creative designs of adaptive NBS in cities	The report explores the multiple dimensions of impact that NBS projects may have when implemented at different scales, from individual building to a large region	Comparability is necessary to build an evidence-base on the benefits, co-benefits, synergies and trade-offs of different NBS applications
2019	European Commission Directorate-General for Research and Innovation	Contribution to a Brazilian Roadmap on Nature-Based Solutions for Resilient Cities	Harness the Brazilian potential for NBS and how the EU's experience can contribute; replicability, scalability and adaptation of NBS	NBS case studies	The challenges demonstrate how Brazil's mega-biodiversity could be the solution to a series of issues and provide inspiration to other countries	Each case study provides lessons to be learned (e.g., how to adapt NBS to the local urban environment and to social expectations)
CONFERENCE DOCUMENTS						
05/2014	EU conference under the auspices of the Hellenic Presidency of the Council of the EU (Brussels, Belgium)	Re-naturing Cities: Addressing Environmental Challenges and the Effects of the Economic Crisis through Nature-Based Solutions'	How renaturing cities can lead green economy; how urban developers and planners are re-naturing cities; how European cities are adapting to climate change and natural disasters using NBS; how to promote NBS	Examples are presented, e.g., an abandoned railway marshalling yard transformed into a large park to attract investment in residential and commercial land, and generate public support for regeneration	Best practices are compiled and disseminated	NBS should be inexpensive, attractive and efficient, systemic, multi-purpose and multi-stakeholder; R&I should provide the evidence and arguments for NBS

12/2014	European Union, under the auspices of the Presidency of the Council (Milan, Italy)	Renaturing Cities: Systemic Urban Governance for Social Cohesion	Exchange of experiences among stakeholders on the link between renaturing cities, social cohesion, resilience, and health and wellbeing in urban and peri-urban areas	Examples of best practices are presented	Using Milan EXPO 2015 to showcase how Europe is leading the process of re-naturing cities and how this European expertise could be applied at the international level	The need for a clearer definition, delimitation and explanation of NBS; new orientation of EU R&I policy towards Renaturing Cities through NBS to tackle diverse urban challenges
12/2014	European Union (Brussels, Belgium)	DEBRIEF - Stakeholder Workshop 'Nature-based Solutions and Re-Naturing Cities'	Sustainable urbanization; restoration of degraded ecosystems; climate change adaptation and mitigation; risk management and resilience	Examples are presented	Identification of R&I actions, strategic opportunity areas, areas for innovation, practical steps and key actors from each of the four NBS thematic goals	The need to adopt an integrated and holistic urban/spatial planning approach, innovate with 'living labs' and diverse stakeholders, conduct a valuation of the multiple benefits of NBS
05/2015	International conference sponsored by the EC and Latvian Presidency of the Council of the EU (Ghent, Belgium)	Nature and Urban Wellbeing: Nature-based Solutions to Societal Challenges	NBS in urban contexts, environmental justice, risk management and ecological restoration, health and wellbeing, public engagement and social learning	Not available	Not available	How the NBS concept can be used to address current gaps in knowledge, policy and practice
10/2017	Estonian Ministry of the Environment, EC, and Tallinn University	Nature-Based Solutions: From Innovation to Common Use	How to integrate NBS into urban environments and society, popularise NBS across Europe	Blue-green infrastructure in smart cities; integrated water management; ICT as a supporting tool for NBS; NBS in the circular economy; well-being and public engagement; NBS and sustainable development goals	Impacts on citizens and local governance; the future of NBS and the green economy specifically targeting legislation, economy, research and development and better communication	Develop concrete models; international cooperation and the dissemination of knowledge related; NBS as a tool to implement Sustainable Development Goals and feed into political debates; take European leadership on NBS to the global level
12/2017	Council conclusions on NBS	Eco-Innovation: Enabling the Transition towards a Circular Economy – Council conclusions	Reduce environmental impacts; efficient use of natural resources; climate change; vulnerability assessment and societal impacts; poverty eradication; food security; gender equality; biodiversity	NBS were recognized as innovative and multifunctional ways of addressing local challenges. The Council requested mapping potential NBS areas for improving environmental performance	Member States were called on to set ambitious and realistic targets for sustainability, to introduce NBS in regional development and spatial plans, develop partnerships and learn from best practices	The Council recognised that research and innovation are essential to boost the sustainable and efficient processes required to stimulate the transition to a circular economy
HORIZON 2020 FUNDING PROGRAMME						

2014-2015	Horizon 2020	Work Programme 2014-2015	Six thematic areas: economic instruments; education and communication; modelling business and consumer behaviour; policy; product /production design; waste treatment /management	Waste as a resource to recycle, reuse and recover raw materials towards a near-zero waste society; innovative water solutions; grow a low carbon, resource-efficient economy	Innovative waste prevention and management solutions to reduce impacts on health and Europe's dependency on the import of raw materials, and to reinforce its position as world market leader and look for opportunities to benefit the environment	Not available
2016-2017	Horizon 2020	Work Programme 2016-2017	R&I activities in the area of climate change, environment and resource efficiency to promote a greener and more competitive economy	Create multi-stakeholder and multi-level platforms to facilitate partnerships for deploying NBS; identify users' needs, market potential and knowledge gaps to create a policy agenda	Mainstream NBS in land use planning, landscaping and territorial policies	Not available
2018-2020	Horizon 2020	Work Programme 2018-2020	Moving toward a greener, more resource-efficient and climate-resilient economy	Build resilient societies, explore possible policies and communication strategies	Build a low-carbon, climate resilient future	Not available

*Retrieved from the EC's official website on NBS (<https://ec.europa.eu/research/environment/index.cfm?pg=nbs>); CORDIS - Community Research and Development Information Service (<https://cordis.europa.eu/projects>)

Appendix B. European exemplars of nature-based solutions (NBS)*

Year	Project description	Region/Scale	Objectives	Impacts	NBS Actions	Lessons learned	Project cost	Financing	Challenges
2010-2040 (city-region) 2015-2018 (Green Agenda)	Amsterdam - NBS for greening the city and increasing resilience	Amsterdam, Netherlands/local	Create a vibrant city, with an integrated public transport network, high quality urban planning, and investment in recreational green spaces, water and renewable energies	Green spaces created /renovated; flooding risks reduced; social awareness of and political support for water diplomacy and climate change adaptation increased	A variety of green-space initiatives	Public, not-for-profit organisations, companies and authorities had to invest money; a smartphone app was developed to engage public	€20 million for the period 2015-2018	Local government	Water-related hazards; densification; city attractiveness; quality of life; accessibility of green spaces
2007-2020	Bari - NBS for greening the urban space	Bari, Italy/local	Improve urban quality, improve green areas, reduce the urban heat island effect and manage storm water	Health benefits; UHI mitigation; air purification; restoration and maintenance of habitats and biodiversity; waterflow regulation	Revitalising residual urban areas as green spaces	The high building density places physical limits on greening, the land availability is hampered by the municipal authorities' limited resources	More than €9 million	Private investors	Land availability for re-greening, climate change, heat waves and wildfires
2004/2009	Berlin - NBS for urban green connectivity and biodiversity	Berlin, Germany/local	To create connectivity across the city and a 'green belt' as a border boundary for urban growth and protection against urban sprawl	Green/blue connectivity and functionality, biodiversity, cultural richness, infiltration/water storage, social learning of NBS, health benefits	BENE (urban gardening); Green Moabit; School gardens; Mixed forests programme; Green Walks; Nomadic gardening	Bottom-up citizen initiatives, the integration of bottom-up activities into mainstream policies	Not provided	EU's ERDF fund, national fund, private investors	Decouple the city's growth from negative impacts on climate and the environment
2016-	NBS for dealing with extreme temperature and rainfall events	Bilbao, Spain/local	Resilient city towards cold spells, heat waves, and frequent floods	Climate-change mitigation and adaptation in urban planning, new job opportunities; social and economic cohesion, health, and leisure opportunities, attractive city	Urban renewal project to promote the sustainable restoration of a derelict site, expansion and connection of the city's green areas	Awareness and support from local authorities	Over €6 million	Regional budgets, local budget, NGO funds	Projections from climate-change

2008/2009 /2011/2014	NBS for sustainable future	Bristol, UK/local	Socially inclusive and health environment, facilities for sport and leisure, urban regeneration and renewal, natural environment, climate change adaptation and mitigation, pollution control, green network	Protect, provide, enhance and expand green infrastructure, promote healthy lifestyles and social inclusion, enhancing connectivity for wildlife.	Bristol Development Framework Core Strategy; Bristol's Sustainable City Strategy; Bristol's Parks and Green Spaces Strategy	The Council's recognition of land's social and ecological values	Over £17 million	Statutory Authority, NGOs	
Not provided	NBS for climate resilience and pollution control	Budapest, Hungary/local	Address the issues of climate resilience and pollution control	Urban gardening for biodiversity, better air quality, water retention, social cohesion, public awareness of nature, health and recreational benefits	Pocket parks, renewing city parks, preserving forests on the city's outskirts and existing green areas	Involvement city authorities in urban sustainability, build stakeholder alliances, trust and capacity, integration of local knowledge into decision-making	Not provided	Municipal budgets, national sources and EU funding mechanisms	social and environmental challenges
2008-2013, 2015	NBS for sustainable urban transition	Dresden, Germany/local	Compact city to accommodate further development and include a network of functional green spaces	Bottom-up initiatives for community gardening for diverse environmental, social and economic benefits	Transforming former allotment gardens into community gardens; landscape plan	Participation on bottom-up initiatives facilitates a change of practice in local governance	Not provided	European Regional Development Fund, national funds, donation	River flooding, urban heat island, densely built historic center
2011-2022	NBS for a more sustainable city by 2030	Dublin, Ireland/local	Sustainable, Resilient Dublin based on economy, environment and equity	Boost in tourism, economic opportunities and financial investment in the city	NBS for sustainable urban drainage systems, green infrastructure	Dublin mapping tool for identifying vacant spaces for urban regeneration plans and meeting housing needs	Not provided	Developers of residential areas	Economy and lack of housing; climate change
2010-2017	NBS enhancing health, wealth and sustainability	Edinburgh, Scotland/local-regional	low carbon, resource-efficient city, delivering a resilient local economy and vibrant flourishing communities	Business opportunities, new knowledge, public awareness, connectivity and functionality of green infrastructures, biodiversity, cultural richness, sense of ownership, water	Pollinator Pledge project; Granton Community Gardens; Duddingston Field Group	The mapping of the city's green infrastructure, and its quality has led to developers paying for green space improvements across the city and to better coordination of green space investments by different departments	Green Network: £3 000 000; Smart Cities Scotland: €15 million	Scottish Enterprise; developers; businesses; grant aids, donations	Climate change, demographic change and sustainable economic growth

				management, climate adaptation					
2014-2019	NBS bridging green and industrial heritage	Genk, Belgium/local	Use Genk's natural and human capital for sustainable value creation	Social cohesion, economic opportunities and green jobs, sustainability transition	Urban farming; Bee Plan; Green Corridor; Heempark	NBS replicating, partnering, upscaling, instrumentalizing, and embedding	Not provided	Flemish Government, European Regional Development Fund, NGO, companies, private funders	Bridge the old and new working-class town with a knowledge-based economy and its green and industrial heritage
Not provided	NBS as a motor for urban growth	Linz, Austria/local	Enhancing and protecting urban green areas is a way to increase the city's attractiveness, and position it an important regional and international business location	Recreation, biodiversity, microclimate, traffic noise control, rainwater management, high quality urban landscape for real-estate value, air quality and reduce pollution	Landsaped park (Landschaftspark Bindermichl-Spallerhof); solarCity; Urban greening strategy	Conflicts between investment interests and the goals of protecting biodiversity and green spaces	Not provided	National funding, ERDF funds	Transition towards a post-industrial city by conserving and enhancing green spaces while providing opportunities for new development and housing
2007-2016	NBS enhancing resilience through urban regeneration	Lisbon, Portugal/local	Enhance resilience through urban regeneration	Urban agriculture and green infrastructure for climate change adaptation, improving drainage, reducing traffic, energy savings, cleaner air, property value	Creating green corridors, enhancing urban agriculture	Mainstreaming the idea that a healthy environment and urban regeneration must complement each other in innovative ways	€2.5 million	Municipal budget, European funds, private companies	Uncontrolled urban development
2009-2016	NBS for urban regeneration and wellbeing	Ljubljana, Slovenia/local	Protect and enhance the natural environment in the city	Mitigating urban heat island, accessibility for pedestrians and cyclists, vegetable allotments for recreation and relaxation, restores river Ljubljanica's function as an ecological corridor	Ecological Zone closing the city center to motorized traffic, biking and sustainable mobility, new green areas for social and sporting activities,	Availability of funding	€1.19 million	City budget, EU funds, private-public partnerships	Green initiatives to simultaneously regenerate the city, mitigate climate change, improve quality of life

					restoration of river Ljubljana				and boost tourism
2009-2020	NBS for a leading sustainable city	London, UK/local	Increase green space; improve air quality; reduce the UHI; prevent flash floods; climate change adaptation and mitigation	Opportunity to develop and market green infrastructure skills. NBS could address thermal stress, flood risk, air quality issues	Green walls and roofs, flood control measures; Barking Riverside project, Queen Elizabeth Olympic Park; and Beetle Bump, a brownfield nature reserve	Cost-benefit analysis, continued consultation with local community, flexibility, legacy management	Not provided	Land Trust	Public-private partnership to incorporate GI; community of interest company
2004-2016	NBS for urban regeneration	Milan, Italy/local-regional	Green infrastructure as the best way to achieve environmental targets, promote social development and improve social welfare	Bosco Verticale (Vertical Forest), urban gardening to encourage social contacts, Parco Agricolo Sud to offer inhabitants farming, forestry, cultural and recreational activities	Urban gardening, in particular public parks, gardens and urban forests, are created for multiple purposes	Upscaling and replicating Vertial Forest as a NBS	more than €2 billion.	The Lombardy Region, EU funds, private funds (Cariplo Foundation)	Abandoned areas in the metropolitan area of Milan; traffic pollution; reducing soil consumption
2030	Improving quality of life with NBS	Oradea, Romania/local	Improve quality of life for its citizens	Enhanced recreation; job creation; public-private partnership	Green area rehabilitation and development of green infrastructure; lake creation; creation of outdoor leisure areas	Quality green areas enable quality of life, business in the rehabilitation and creation of green areas, public-private partnership	Not provided	City budget, national and EU sources	Dense building coverage and deteriorating air quality due to traffic increase
2013-2030	NBS for a friendly, mobile city	Poznan, Poland/local	Improve quality of life for all inhabitants	Green wedge system, transforming car parks into green areas, riverside zone with seasonal beaches for recreation, high potential for tourism, new housing projects near green areas	Maintaining the green wedge system; planting 18 000 trees on the roadside; transforming car parks into green areas; community gardening; creating seasonal beaches	Dialogue amongst responsible sectors, showcasing the multiple benefits of NBS while at the same time employing technical solutions to enable NBS	Not provided	The city's budget, the national fund, and EU funding	Social challenges: develop a resident-friendly space and low environmental awareness

2025	NBS for building a waterproof city	Rotterdam, The Netherlands/local	100% climate-proof by 2025	Blue-green corridors to facilitate natural hydrological processes, enhance biodiversity and improve quality of life	Water storage capacity; Delta plan; Tidal park programme	Publi-private partnership, area-specific implementation	€4 to €5 billion		Flooding, population growth, climate change
2020	NBS for urban regeneration and adaptation to climate change	Szeged, Hungary/local	Improve the quality of green areas, restore natural habitats and ecological corridors for social and recreational purposes, and to mitigate the impacts of climate change	More recreation, public awareness, richer biodiversity and more stable ecosystems, better air quality; and reduced run-off and improved soil quality	Green area rehabilitation and increase in green infrastructure; urban gardening	Financial sources, knowledge and experience	Not provided	city's budget, and EU financing mechanisms	Complexity of public spaces, differing needs of residents, and 3) financial sources for complex urban renewal
2009-2030	NBS for for urban resilience and citizens' wellbeing	Utrecht, The Netherlands/local	Promote healthy urban living through an integrated and systemic approach that combines local climate regulation, noise reduction, recreation and cleaner air	Water system for diverse ecosystem services; street trees and street greenery contribute to the quality of life by the realization of a comprehensive green structure based on cultural-historical, spatial, environmental and ecological values	New Central Station Area: green roofs, stormwater retention measures; Leidsche Rijn: sustainable urban drainage systems; Street trees and street greenery	Mitigating UHI, aesthetic of street greenery	Various budgets available	City's budget	Spatial challenges as a transportation hub, climate change, health, a fast-growing city, densification

*More details available at: <https://oppla.eu/case-studies>

Appendix A. Suite of projects spearheaded by the European Commission within the Horizon 2020 Framework Program on nature-based solutions (NBS)*

ID No.	Period	Project Name	Full title	Funding Scheme	Lead Country	Objectives	Total Cost (EUR)	NBS
H2020-SC5-2014-one-stage	2015-2018	<i>ESMERALDA</i>	Enhancing ecoSystem sERVICES mApping for poLicy and Decision mAKing	CSA - Coordination and support action	Germany	Deliver a flexible methodology to provide the building blocks for pan-European and regional assessments	3 133 306	Mapping and assessment of ecosystems and their services
H2020-SC5-2014-one-stage	2015-2020	<i>BiodivERsA3</i>	Consolidating the European Research Area on biodiversity and ecosystem services	ERA-NET-Cofund - ERA-NET Cofund	France	Strengthen the ERA on biodiversity, provide policy makers and other stakeholders with adequate knowledge, tools and practical solutions to address biodiversity and ecosystem degradation	38 423 666	Pan-European research on biodiversity and ecosystem services
H2020-SC5-2016-OneStageB	2016-2019	<i>ThinkNature</i>	Development of a multi-stakeholder dialogue platform and Think tank to promote innovation with Nature based solutions	CSA - Coordination and support action	Greece	Develop a multi-stakeholder communication platform that will support the understanding and promotion of nature-based solutions at the local, regional, EU and International level	3 569 788	Bring together multi-disciplinary scientific expertise, policy, business, society, and citizens to build a platform covering all aspects of NBS in a clear, pyramidal methodological approach
H2020-SCC-NBS-1stage-2016	2016-2020	<i>Nature4Cities</i>	Nature Based Solutions for re-naturing cities: knowledge diffusion and decision support platform through new collaborative models	RIA - Research and Innovation action	France	Develop complementary and interactive modules to engage urban stakeholders in a collective learning process about re-naturing cities, to develop and circulate new business, financial and governance models for NBS projects, as well as provide tools for the impacts assessment, valorization and follow-up of NBS projects	7 499 981	Detailed mapping of urban challenges and relevant NBS

H2020-SCC-NBS-1stage-2016	2016-2020	<i>NATURVATION</i>	Nature Based Urban Innovation	RIA - Research and Innovation action	United Kingdom	1. Advance assessment approaches, 2. enable innovation to identify the most promising governance, business/finance and participation models, 3. generate momentum to realize the potential of NBS through co-design, co-development and co-implementation	7 797 877	Transdisciplinary approach working with 'urban-regional innovation partnerships' in six cities and a Task Force of international organisations to achieve a step-change in the use of NBS for urban sustainability (Urban) green/blue infrastructure
H2020-SC5-2016-OneStageB	2016-2020	<i>NAIAD</i>	NAture Insurance value: Assessment and Demonstration	RIA - Research and Innovation action	Spain	Operationalize the insurance value of ecosystems to reduce the human and economic cost of risks associated with water (floods and drought) by developing and testing the concepts, tools, applications and instruments (business models) necessary for its mainstreaming	5 081 176	
H2020-SC5-2017-OneStageA	2017-2018	<i>NBS2017</i>	Nature-based Solutions: From Innovation to Common-use	CSA - Coordination and support action	Estonia	Share knowledge on NBS multi-functionality and effectiveness and management options, improve policies and implementation of NBS in the European Union	274 516	Applied projects and case studies of NBS to facilitate the process to NBS at national and EU level
H2020-INNOSUP-02-2016	2017-2018	<i>INNOV</i>	Automate VertECO	CSA - Coordination and support action	Austria	Create an indoor, customized green wall system designed to significantly reduce drinking water consumption by providing a plant-based technology	119 225	Pump water from the topmost wetland stage of the system to subadjacent levels within the root zone
H2020-SCC-NBS-2stage-2016	2017-2022	<i>CONNECTING Nature</i>	COproductionN with NaturE for City Transitioning, INnovation and Governance	IA - Innovation action	Ireland	Position Europe as a global leader in the innovation and implementation of NBS	11 699 286	An open innovation ecosystem approach bringing together city governments, SMEs, academia and civic society
H2020-SCC-NBS-2stage-2016	2017-2022	<i>UNALAB</i>	Urban Nature Labs	IA - Innovation action	Finland	Develop a robust evidence base and European framework of innovative, replicable, and local	14 278 699	Innovative NBS: e.g., green spaces/walls/roofs,

						NBS to enhance climate and water resilience in cities		permeable pavements, alluvial meadows, etc.
H2020-SCC-NBS-2stage-2016	2017-2022	<i>URBAN GreenUP</i>	New Strategy for Re-Naturing Cities through Nature-Based Solutions	IA - Innovation action	Spain	Obtain a tailored methodology to support the co-development of Renaturing Urban Plans and to assist in the implementation of NBS in an effective way	14 777 185	Renaturing urbanization, green infrastructure, water management, non-technical interventions
H2020-SCC-NBS-2stage-2016	2017-2022	<i>GROW GREEN</i>	Green Cities for Climate and Water Resilience, Sustainable Economic Growth, Healthy Citizens and Environments	IA - Innovation action	United Kingdom	Provide a platform for a step change in the way NBS are embedded in the long-term planning, development, operation and management of cities around the world	11 458 133	Demonstrating a replicable approach for the development and implementation of city NBS strategies
H2020-MSCA-IF-2017	2018-2020	<i>ADAFARM</i>	Small scale farmers' sustainable adaptation strategies to climate change based on ecosystem services	MSCA-IF-EF-SE - Society and Enterprise panel	Spain	Analyze ecosystem-based climate adaptation options and nature based solutions for small farmers in sub-Saharan Africa	170 121	Performing new qualitative data collection through interviews and focus groups on the adaptation of small scale farmers to climate change
H2020-WIDESPREAD-05-2017-Twinning	2018-2021	<i>RENATURE</i>	Promoting Research Excellence in Nature-based solutions for innovative economic Growth and human well-being in Malta	CSA - Coordination and support action	Malta	Establish and implement a strategy and research cluster to step-up and stimulate scientific excellence and innovation capacity in the area of nature-based solutions for sustainable development	995 905	Nature-based solutions for sustainable development
H2020-MSCA-IF-2017	2018-2021	<i>Mind4Stormwater</i>	Innovative stormwater asset management in future cities	MSCA-IF-GF - Global Fellowships	France	Help cities achieve sustainable management of their "stormwater control measures"	270 918	Adapting existing low-cost technology sensors to the specific context of SCMs and developing an adaptation draft for European cities

H2020-SC5-2018-1	2018-2021	<i>EU-VNP-Net</i>	EU Valuing Nature Programme and Network	CSA - Coordination and support action	United Kingdom	Establish, support and energise an EU Valuing Nature Network of Networks (EU-VNN) and to implement a prioritized EU Valuing Nature Program	2 192 426	Mainstreaming NC assessment, NCA, NBS and GI in business decision-making frameworks and models
	2018-2021	<i>We Value Nature</i>	We Value Nature	EU Horizon 2020-funded three-year campaign	Europe (IUCN)	Identify and address key barriers and opportunities to business uptake of natural capital thinking and related training	—	Uptake of the use of natural capital thinking, natural capital accounting, nature-based solutions and green infrastructure by businesses across Europe
H2020-SC5-2017-TwoStage	2018-2022	<i>OEPRANDUM</i>	OPEn-air laboRatories for Nature baseD solUtions to Manage environmental risks	IA - Innovation action	Italy	Reduce hydro-meteorological risks in European territories through co-designed, co-developed, deployed, tested and demonstrated innovative green and blue/grey/hybrid NBS, and push business exploitation	14 696 501	NBS in seven European countries and three in China and Australia are implemented to address specific risks
H2020-SC5-2017-TwoStage	2018-2022	<i>PHUSICOS</i>	According to nature' - solutions to reduce risk in mountain landscapes	IA - Innovation action	Norway	Fill the knowledge gap related to NBSs for hydro-meteorological hazards (flooding, erosion, landslides and drought)	9 633 000	The concept cases of NBS will be used for testing innovative ideas at local scale
H2020-SCC-NBS-2stage-2017	2018-2023	<i>proGInreg</i>	productive Green Infrastructure for post-industrial urban regeneration	IA - Innovation action	Germany	Integration of nature-based solutions (NBS) into business, to develop new NBS orientated economies shared between public authorities, civil societies and industry/SMEs	10 907 916	Renaturing landfill sites, regenerating soils, community-based urban farming, aquaponics; green walls and roofs, pollinator biodiversity and citizen science projects, protocols for environmental compensation
H2020-SCC-NBS-2stage-2017	2018-2023	<i>EdiCitNet</i>	Edible Cities Network Integrating Edible City Solutions for social resilient and sustainably productive cities	IA - Innovation action	Germany	Explore the wealth and diversity of existing Edible City Solutions(ECS), and to adapt, plan and implement successfully proven ECS in their specific urban context	11 921 624	Five Front Runner Cities will demonstrate their experience with Living Labs and transfer their knowledge to 7

								dedicated Follower Cities
H2020-SCC-NBS-2stage-2017	2018-2023	<i>CLEVER Cities</i>	Co-designing Locally tailored Ecological solutions for Value added, socially inclusive Regeneration in Cities	IA - Innovation action	Germany	Co-create, -implement, and -manage locally tailored NBS to deliver tangible social, environmental and economic improvements for urban regeneration.	14 864 688	The project applies a city centric approach to foster sustainable and socially inclusive urban regeneration locally in Europe and globally
H2020-SCC-NBS-2stage-2017	2018-2023	<i>URBiNAT</i>	Healthy corridors as drivers of social housing neighbourhoods for the co-creation of social, environmental and marketable NBS	IA - Innovation action	Portugal	Co-plan a healthy corridor as an innovative and flexible NBS, which itself integrates a large number of micro NBS emerging from community-driven design processes	13 742 228	Partners will contribute their innovative NBS experience deployed through an array of transdisciplinary knowledge, methodologies and tools, as nature-based solutions
H2020-SC5-2017-TwoStage	2018-2023	<i>RECONNECT</i>	Regenerating ECOsystems with Nature-based solutions for hydro-meteorological risk reduction	IA - Innovation action	Netherlands	European reference framework on Nature Based Solutions (NBS) via demonstrating, referencing and upscaling large-scale NBS	15 412 579	A network of Demonstrators and Collaborators to upscale NBS throughout Europe and internationally
H2020-SwafS-2018-1	2019-2021	<i>MICS</i>	Developing metrics and instruments to evaluate citizen science impacts on the environment and society	RIA - Research and Innovation action	United Kingdom	Support NBS research by developing strategies and tools to evaluate impacts on science and society resulting from the integration of citizen science	1 944 428	MICS will use novel impact-assessment metrics and instruments to measure costs and benefits of citizen science in relation to the NBSs
H2020-SC5-2018-2	2019-2023	<i>CLEARING HOUSE</i>	Collaborative Learning in Research, Information-sharing and Governance on How Urban tree-based solutions support Sino-European urban futures	RIA - Research and Innovation action	Finland	Provide evidence and tools that facilitate mobilizing the full potential of urban forest-based solutions (UFBS) for rehabilitating, reconnecting and restoring urban ecosystems	7 687 863	The project will provide evidence and create tools that encourage rehabilitating, reconnecting and restoring urban ecosystems

H2020-SC5-2018-2	2019-2023	<i>REGREEN</i>	Fostering nature-based solutions for smart, green and healthy urban transitions in Europe and China	RIA - Research and Innovation action	Denmark	Generate evidence for how NBS can integrate ecosystem services and biodiversity and advocate NBS benefits and values in urban planning to meet societal challenges	5 222 604	Co-creation with urban planners, citizens and business in urban living labs and educational programs for children ensure long-term sustainability of solutions
H2020-MSCA-IF-2019	2020-2022	<i>Green CURIOCITY</i>	Green CURE In Overheated CITY spaces: An investigation of childhood heat-related health impacts and protective effects of urban natural environments	MSCA-IF-EF-RI - RI – Reintegration panel	Spain	Provide evidence for improved knowledge about how heat exposure during pregnancy affects birth outcomes and how long-term exposure to heat may influence children's neurodevelopment	172 932	Development of vulnerability maps, demonstrating urban "hot-spots" where the risk of negative impacts of heat is aggravated to predict impact of urban natural environments on childhood heat-related health outcomes
H2020-INNOSUP-2019-01-two-stage	2020-2023	<i>METABUILDING</i>	METAclustering for cross-sectoral and cross-border innovation ecosystem BUILDING for the European Construction, Additive Manufacturing and Nature-Based Solutions industrial sectors' SMEs	IA - Innovation action	France	ICT, Additive Manufacturing, Nature Based Solutions, and the Recycling industry, to underpin and fuel the emergence of new cross-sectoral, cross-border industrial value chains	5 160 875	Build an EU level enlarged innovation Ecosystem and value chain with actors involved from across the innovation chain from EU R&D platforms, RTOs/UNIs, funding bodies, to regionals SMEs
H2020-SC5-2019-3	2020-2023	<i>NetworkNature</i>	NetworkNature - Advancing nature-based solutions together	CSA - Coordination and support action	Germany	Establish a European and global platform allowing all interested stakeholders to access and contribute cutting-edge, innovative knowledge and expertise on NBS	2 189 833	Provide support to and strengthen the NBS community to foster market uptake and the transfer and application of innovative NBS

H2020-SC5-2019-2	2020-2024	<i>CONEXUS</i>	CO-producing Nature-based solutions and restored Ecosystems: transdisciplinary neXus for Urban Sustainability	RIA - Research and Innovation action	United Kingdom	Co-produce, structure and promote access to the shared, contextualised knowledge needed to support cities and communities to co-create NBS, and to restore urban ecosystems, to help drive the required step-change in urban policy and practice in EU and CELAC countries	6 203 619	Using nature-based thinking to bring together community, private, public and research partners as well as experiments with novel co-production methods to deliver NBS innovations in 'Life-Lab' pilots
H2020-SC5-2019-2	2020-2024	<i>INTERLACE</i>	INTERnational cooperation to restore and connect urban environments in Latin America and Europe	RIA - Research and Innovation action	Germany	Empower and equip European and CELAC cities to effectively restore and rehabilitate (peri)urban ecosystems towards more liveable, resilient and inclusive cities	5 476 165	Innovative forms of inclusive participation will optimise the collection knowledge and experiences and the co-production of governance instruments and tools for restorative NBS
H2020-LC-CLA-2019-2	2020-2024	<i>MaCoBioS</i>	Marine Coastal Ecosystems Biodiversity and Services in a Changing World	RIA - Research and Innovation action	United Kingdom	Ensure efficient and integrated management and conservation strategies for European marine coastal ecosystems to face climate change	6 980 657	Fill the lack of knowledge on the impacts of climate change on the most important marine coastal ecosystems
H2020-LC-CLA-2019-2	2020-2024	<i>FutureMARES</i>	Climate Change and Future Marine Ecosystem Services and Biodiversity	RIA - Research and Innovation action	Germany	Provide socially and economically viable nature-based solutions for climate change adaptation and mitigation to safeguard ecosystems' natural capital, biodiversity and services	8 555 905	Physical, ecological, social and economic analyses will be integrated to develop climate-ready NBS
ERC-2019-STG	2020-2025	<i>Niche4Nbs</i>	Beyond assuming co-benefits in Nature-based Solutions: Applying the niche concept for optimizing social and ecological outcomes	ERC-STG - Starting Grant	Israel	Develop and test a new approach that optimises NBS co-benefits	1 500 000	The project will offer the capability to predict and plan the best NBS implementation

*Retrieved from the Community Research and Development Information Service (CORDIS)
web portal

