



PHUSICOS

According to nature

Deliverable 5.4

Learning from NBS implementation barriers

Work Package 5 – Governance Innovation

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Summary

Reaching the ambitious United Nations goal of tripling investments in nature-based solutions (NBS) by 2030 will require a multi-faceted understanding of the enablers and barriers to NBS implementation. This deliverable identifies the factors that make NBS distinctly difficult to put into operation as opposed to conventional infrastructure, mainly focused on disaster risk reduction (DRR), and what we can learn from the long experience of ‘grey’ solutions. Infrastructure commonly refers to physical facilities, including but not limited to transportation networks and structures, buildings, water and waste-related networks and facilities, energy networks and plants, and communications networks and facilities. To dive deeper into NBS barriers and enablers, focused largely on DRR, we elicit the views of Norwegian policymakers, as well as NBS contractors, including nature-based enterprises (NBEs), in addressing two barriers: i) lack of knowledge about the effectiveness of NBS and their ability to deliver co-benefits and ii) the lack of qualified contractors who have specialized experience on constructing NBS compounded by a lack of standards, technical guidelines and legal norms. Throughout we document experience of PHUSICOS projects as they have confronted barriers in NBS implementation. We also document selected views of participants of the PHUSICOS Policy Business Forum.

The methodologies include:

- A systematic literature survey and meta-analysis of ‘grey’ infrastructure implementation, including 201 screened reports/papers that identified 18 for analysis, followed by a quantitative content analysis using NVIVO version 1.7, and the classification of 12 barrier clusters;
- The analysis of the 12 ‘grey’ barriers compared with their NBS counterparts as documented in PHUSICOS Deliverable 5.2;
- 13 semi-structured interviews with public-sector entities across Norway, including municipalities, county governors and national directorates;
- 20 semi-structured interviews with private-sector professionals working in the provision of NBS services across Europe, including designers, construction companies and consulting firms.

As we show in this deliverable, the barriers to NBS implementation are manifold. Poorly staffed municipalities with little experience or expertise with NBS, combined with a dearth of evidence on their effectiveness and co-benefits, appear to be dominating barriers. Lack of capacity and knowledge is compounded by a lack of funds earmarked for NBS, and there is a fundamental problem in attracting private financing given the public-good nature of NBS and thus the shortage of bankable projects and business models. The essentiality of valuing and funding NBS co-benefits means that implementation cuts across multiple institutions, jurisdictions, levels of government, policy areas and professional disciplines, which makes it difficult to coordinate and

finance. Moreover, politicians focus on short-term goals that bring voter support; yet NBS infrastructure has long-term impact and gestation periods. Given these and other hurdles documented in this deliverable, it is not surprising to witness a formidable ‘grey’ infrastructure path dependency.

Four (of 19) PHUSICOS demonstration interventions fell victim to NBS implementation barriers and were cancelled. As one case in point, the largest of the proposed NBS interventions in the Norwegian demonstrator site at Jorekstad, a receded flood barrier, confronted two main barriers: a detailed design of the project revealed that the cost would be significantly more, even double, that of the original estimate and, to compound the situation, there was strong opposition from riparian stakeholders who profited from the gravel deposited by floods.

With few exceptions the identified NBS barriers also plague ‘grey’ infrastructure, which means the NBS community can learn from how hurdles have been addressed and how innovation has been institutionalized in conventional policy processes. Our literature review, interviews and experience from the PHUSICOS Policy-Business Forum have provided a rich set of lessons. The list is extensive, but the most salient lessons emphasize the importance of:

- innovative co-generation stakeholder processes,
- smart uses of CBA that account for long-term impacts,
- novel ‘blended’ financing to extend the portfolio of bankable NBS projects,
- the EU taxonomy that can promote divestment from nature-negative projects,
- mechanisms to transfer infrastructure risk, and
- whole-of-life contracts that include long-term maintenance and monitoring.

As critical as these and other lessons are, they fall short of addressing three especially intransigent barriers that to large part differentiate NBS from ‘grey’, including:

- lack of expertise and knowledge
- lack of evidence on performance and co-benefits, and
- path dependency of ‘grey’ infrastructure.

Interviews with Norwegian policymakers and NBE contractors provided an on-the-ground perspective to these and other barriers. Many contractors, including designers, construction companies and consultants, emphasized the problems they face due to the lack of evidence on NBS performance and co-benefits:

People such as water companies always say: “I know if I buy concrete, the engineers can tell me exactly what it will stop, but you guys (NBS proposers) cannot. So that is a big problem. (Consulting firm)

This went hand in hand with a sense of path dependency in contractor daily business:

...Design engineers in this company have always been doing the same thing. They just use the same design approach and it is easier that way. We know the cost, we know how to estimate the costs, we know how to put a business case together. Going through a new approach means thinking outside the box,... (NBS designer)

To tackle these and other challenges, this report concludes by suggesting six policy reforms that we suggest can contribute to reshaping the NBS governance system and importantly to enabling NBS at scale. Each of the policy reforms is based on existing legislation or precedent, most recently related to implementing renewable energy projects. The suggestions reflect only the authors' views and not those of the PHUSICOS partners or the European Community. Moreover, they have not been vetted in a stakeholder process or discussed with policymakers for their practicality, rather, they are put forward to motivate further research and discussion. They include:

- Extend the scope of the EU Environmental Impact Assessment (EIA) Directive
- Switch the burden of proof from NBS to grey infrastructure
- Exempt selected NBS from the EIA
- De-risk NBS with public instruments
- Support public and private NBS financing
- Promote divestment from nature-negative assets

If EIAs become mandatory for a much larger set of infrastructure proposals, and if proposers are obliged to provide extensive accounting of NBS negative impacts, including to biodiversity and climate change, over an appropriately lengthy time horizon at a low discount rate, this will effectively switch the burden of proof. If, in addition, selected NBS are exempt from the EIA process, this will help tackle grey path dependency. Moreover, increasing public financing for NBS, even beyond what is currently planned (e.g. by the EU Green Deal), will help circumvent the NBS public-good challenge by enabling both public and private investment. Reducing liability risk to NBS owners will further contribute to the urgent scaling of NBS. Perhaps most importantly, strengthening implementation of the EU Taxonomy to identify and even require nature-negative divestment can critically redirect financing to NBS.

Reshaping NBS governance is crucial for making the urgent NBS investments necessary for meeting the EU biodiversity and climate goals. We hope this research and the suggested reforms will spur further research and, most importantly, deep deliberation across all affected and interested persons and institutions on transformative pathways forward.

Contents

1	Introduction	9
2	Part 1: Barriers to NBS implementation: a comparison with conventional ‘grey’ infrastructure	11
2.1	Background	11
2.2	Methods	13
2.3	Results of the comparative analysis	16
3	Part 2A: Knowledge on NBS effectiveness, benefits and co-benefits	43
3.1	Introduction	43
3.2	Background	44
3.3	Methodology	45
3.4	Interview results	46
4	Part 2B: Contractor expertise	50
4.1	Introduction	50
4.2	Background	51
4.3	Methodology	52
4.4	Interview results	54
5	Learning from implementation barriers	64
5.1	Learning from barriers across the NBS policy process	64
5.2	Learning from barriers: six suggestions for policy reform	67
5.3	Summary	73
6	Acknowledgements	74
7	References	75

Tables

Table 1:	Scopus search terms for peer-reviewed literature search.	15
Table 2:	Overton search terms for ‘grey’ literature search.	15
Table 3:	Google services search terms for peer-reviewed/’grey’ literature search	15
Table 4:	Categories used for NVivo coding and analysis followed by number of references	15
Table 5:	Overview of contacted public entities in Norway	92
Table 6:	Summary or types of NBS information/resources considered helpful by the interviewees	49
Table 7:	List of NBS contractors interviewed per type of experience.	53
Table 8:	Barriers and potential solutions for enhancing contractor expertise as identified by interviewees	55

Figures

Figure 1:	Major reasons why infrastructure projects fail to proceed according to global professionals as of 2018.	12
Figure 2:	The green-grey continuum of grey to green infrastructure approaches	13
Figure 3:	The selection process yielding 18 documents included in the meta-analysis	14
Figure 4:	Main NBS (a) and grey (b) barrier clusters as identified in the literature	17

Figure 5: Examples of private contractors/service providers involved in the life cycle of NBS projects	52
Figure 6: Share of reported NBS experience of interviewees	53
Figure 7: Coding framework illustrating broader themes	54

Boxes

Box 1: Stakeholder opposition to NBS at Gudbrandsdalslågen	23
Box 2: Lack of stakeholder support for ‘grey’ landslide measures in Nocera Inferiore	24
Box 3: Path dependency in the Serchio River Basin (Italy)	26
Box 4: Failed financing at Jorekstad	27
Box 5: Delays in the Norwegian procurement process	31
Box 6: Norwegian guidelines on NBS	32
Box 7: Conquering silos: the Isar river re-naturalization	34
Box 8: Compensation to farmers in the Serchio valley	36
Box 9: River owners protest loss of business in Norway	36
Box 10: Landowners in Jorekstad reject compensation for loss in crop land	37
Box 11: Lack of political support for NBS in Bastan Valley, France	39
Box 12: NBS owners confront maintenance barrier in Gudbrandsdalen	41

Appendices

Appendix A	Norway Interview Protocol
Appendix B	Norwegian Interview Responses
Appendix C	Interview Protocol for Construction Companies, Designers and Consultants

1 Introduction

According to the European Commission (2022b,c) roughly half of the world's GDP is moderately or highly dependent on nature; societies and economies depend on healthy ecosystems. According to UN Environment Program "If the world is to meet the climate change, biodiversity and land degradation targets, it needs to close a USD 11 trillion financing gap in nature by 2050. The current investments in nature-based solutions amount to USD 153 billion – most of which comes from public sources [...]. Investments in Nature-based solutions need to double by 2025 and triple by 2030" (UNEP, 2022, p.10).

Reaching this ambitious goal will require a multi-faceted understanding of the enablers and barriers to NBS implementation. This deliverable identifies the factors that specifically inhibit NBS as opposed to conventional infrastructure, mainly focused on disaster risk reduction, and what we can learn from the long experience of 'grey' solutions. To dive deeper into NBS barriers and enablers, we elicit the views of Norwegian policymakers, as well as NBS contractors, addressing two particularly complex barriers identified in PHUSICOS deliverables 5.2 and 5.3: i) lack of knowledge about the effectiveness of NBS and their ability to deliver co-benefits and ii) the lack of qualified contractors who have specialized experience on constructing NBS compounded by a lack of standards, technical guidelines and legal norms. Throughout we document experience of PHUSICOS projects as they have confronted barriers in NBS implementation.

We build on and extend extensive prior research in PHUSICOS WP2 and WP5 (the M36 PHUSICOS review specifically recommended that the work being performed in WP2 should be linked more systematically to the governance analysis conducted in WP5). As the below WP and task descriptions detail, previous research has i) identified factors behind the cancellation of four proposed PHUSICOS demonstration projects and behind the implementation difficulties confronting several others, ii) identified NBS project enablers through in-depth case studies of successful NBS projects in Europe and China, iii) provided an overview of enablers and barriers of NBS with a systematic literature review, and iv) proposed new ideas for governance, policy and financing structures that can lead to greater success in the implementation of NBS by convening three Policy Business Forums. Below are more details on PHUSICOS activities that serve as the basis for this deliverable:

- **WP2:** PHUSICOS includes three large-scale demonstrator sites located in the valley of Gudbrandsdalen in Norway, in the Pyrenees of France and Spain and in the Serchio River Basin in Italy. The hazards comprise snow avalanches,

various types of landslides, rock fall, flooding and erosion. A total of 19 NBS activities were proposed to the Steering Committee during PHUSICOS. Of these, 15 are physical interventions at sites. Four are educational- and outreach activities (webinar and spring school of the Isar case are treated as one activity). Of the 19 proposals, four were called off (Solheim et al., 2021).

- **Task 5.1** Case studies of governance models for designing, financing and implementing NBS, is completed (D5.1; Martin et al., 2019). It provides a comparative analysis of the enablers and barriers for co-designing and implementing NBS across three successful cases: flood protection on the Isar River, Munich, Germany; landslide protection in Nocera Inferiore, Italy; and flood/landslide protection in Wolong nature park, China. Important enablers included secure public financing, polycentric governance arrangements, and inclusive stakeholder engagement.
- **Task 5.2** Scoping study of opportunities and barriers to NBS is nearing completion. Based on a systematic literature review including workshop findings and grey and peer-reviewed literature, Deliverable 5.2 provides an overview of enablers and barriers of NBS across multiple governance contexts. Findings from the meta-analysis of 264 barriers and 252 enablers confirm that lack of knowledge and expertise on NBS and lack of evidence on performance and co-benefits represent the most important barriers to NBS implementation (Martin et al., forthcoming).
- **Task 5.3** NBS Policy Business Forum (PBF) for Governance Innovation is also nearing completion. One of the ambitions of the PBF is to propose new ideas for governance, policy and financing structures that can lead to greater success on the acceptance and implementation of NBS. Over seventy NBS experts have been involved in the Forum deliberations by participating in interviews, surveys, e-consultations, and workshops. The three PBF workshops have focused respectively on NBS policy and governance innovation, the role of the public and private sector in mainstreaming NBS, and private sector upscaling and capacity building. In these workshops, NBS policy, finance and capacity building innovations have been identified and discussed including e.g., reducing fragmentation and fostering policy synergies (e.g., by linking NBS policies to well-being and preventative health care policies); divesting from nature negative projects without greenwashing; and promoting the creation of NBS project preparation facilities and benefit/co-benefit catalogues for the private sector (Scolobig et al., forthcoming).

Part 1 of this deliverable extends the above research results by identifying salient differences in implementing NBS infrastructure as compared to their conventional counterparts based on a large literature review on the governance and implementation of ‘grey’ infrastructure. Infrastructure commonly refers to physical facilities, including but not limited to transportation networks and structures, buildings, water and waste-related networks and facilities, energy networks and plants, and communications networks and facilities. Our focus is mainly on infrastructure for disaster risk reduction, including floods and landslides. We do not judge success or failure of NBS projects, but rather we delve into what makes NBS especially difficult to put into operation compared to ‘grey’ infrastructure. We also show how the NBS barriers have ‘played out’ in the PHUSICOS demonstration projects.

Once the NBS distinguishing implementation barriers are identified, a second motivating question for **Part 2** is what governance innovations can mitigate the identified barriers. We thus take a ‘deep dive’ into selected barriers that, from our research, appear especially difficult to overcome: i) lack of knowledge about the effectiveness of NBS and their ability to deliver co-benefits and ii) the lack of qualified contractors who have specialized NBS experience compounded by a lack of standards, technical guidelines and legal norms.

In section 5 we summarize the identified lessons as they pertain to the NBS policy process. We distinguish three especially distinctive NBS challenges, and in response we suggest six systemic policy reforms that can contribute to transforming the NBS governance system and importantly to enabling NBS at scale.

2 Part 1: Barriers to NBS implementation: a comparison with conventional ‘grey’ infrastructure

2.1 Background

That infrastructure projects fail is not unique to NBS. Indeed, a large percentage of planned or even partly constructed projects fail to be completed. Nor are all implemented projects considered a success. As reported in project management statistics, the percentage of large infrastructure projects that fail to meet expectations is high. In one survey it is reported that 70% of all projects fail to deliver what was promised to customers, and 55% of project managers cite budget overruns as a reason for project failure (TeamStage, 2023).

As shown in figure 1, a survey of global professionals carried out by Statista in 2018, showed that many conventional infrastructure projects across all types (e.g., highways, hydropower stations, etc.) don't proceed mainly because of funding shortages and capital costs but also because of public opposition, erroneous government decisions, restrictive regulation, outdated procurement approaches, land issues and talent shortages.

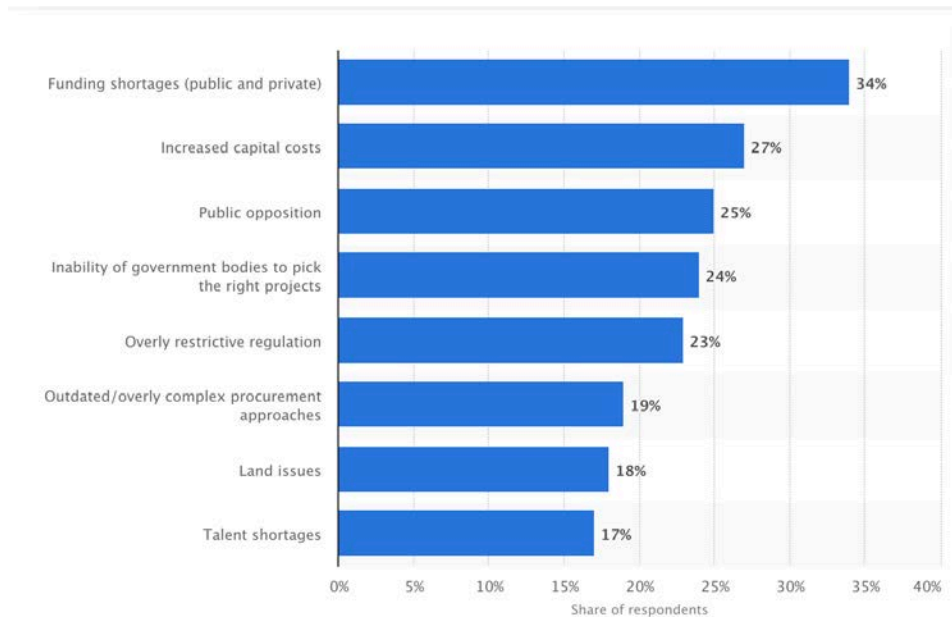


Figure 1: Major reasons why infrastructure projects fail to proceed according to global professionals as of 2018. Source: Statista, 2018

A motivating question for this deliverable has been: **Can failures to implement NBS projects be explained by similar factors as for ‘grey’ infrastructure failure, and, if not, what characteristics differentiate them?** Beyond understanding and comparing the respective barriers for realizing ‘grey’ versus NBS projects, a second motivating question is: **What can we learn from the implementation of conventional ‘grey’ infrastructure that can help us to address the barriers facing NBS and their scale up?**

Before proceeding, it is important to recognize that the ‘NBS-grey’ divide is not clearly delineated. As shown in figure 2, there is a continuum between fully ‘grey’ infrastructure, which are engineered projects constructed with little consideration of their impacts on biodiversity, climate and other ecological consideration (e.g., concrete dams or seawalls), to projects that re-create or strengthen the naturally occurring habitat (e.g., mangroves to lessen storm surge). In between, there are ways of ‘greening’ ‘grey’

infrastructure – what in some cases can be labelled ‘greenwashing’ – and hybrid NBS projects that combine both grey and green elements.

To make possible a comparison, we use the term ‘grey’ without distinction of the various shades of ‘grey’, although we have chosen literature of disaster risk reduction, where dams, levies, sea walls, landslide barriers and other concrete-based infrastructure have dominated.



Figure 2: The green-grey continuum of grey to green infrastructure approaches (adapted from: Naylor et al., 2017. Sources: Mangrove by ruliani, wall by AlyaNafisa, dune by Daan, sea plant by Agne Alesiute, Seaweed by Vladimir Belochkin from the Noun Project; Design: Juliette Martin.

2.2 Methods

Identifying barriers to NBS infrastructure

With a primary focus on DRR, we compare ‘grey’ infrastructure barriers with NBS barriers identified in PHUSICOS deliverable 5.2 (Martin et al., forthcoming), where a detailed description of methods can be found. In short, D5.2 carried out a systematic literature review and meta-analysis based on PHUSICOS project workshops, ‘grey’ literature and peer-reviewed literature. A total of 83 records were screened, from which 264 NBS barriers were extracted from 26 data sources. Enablers and barriers were classified, coded and evaluated using NVIVO (Edwards-Jones, 2014).

Identifying barriers to ‘grey’ infrastructure

To compare NBS barriers identified by Martin et al. (forthcoming; Deliverable 5.2) with those identified in the literature for ‘grey’ infrastructure, this task carries out a similar systematic literature review and meta-analysis for ‘grey’ infrastructure using NVIVO 1.7. Peer-reviewed articles were extracted with an advanced search on Elsevier’s Scopus, a search for ‘grey’ literature using Overton, followed by a search using google services (google search and google scholar). The search focused on barriers to the implementation of ‘grey’ infrastructure mainly for disaster risk reduction and mitigation (especially for landslides and floods), but articles addressing barriers to the implementation of public and ‘grey’ concrete-based infrastructure in general, if suited, were not excluded. Only articles published after 2010 were included in the search, and only articles published after 2014 were selected in order to represent the most recent literature.

A total of 201 records were screened in September of 2022, from which a total of 18 data sources were selected to be analysed in depth using the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) method (Moher et al., 2009). The data selection process is detailed in figure 3. Emphasis was given to scientific reviews in order to maximize data entries. The selection criteria and thus search terms and keywords used for this study are presented in Tables 1 to 4.

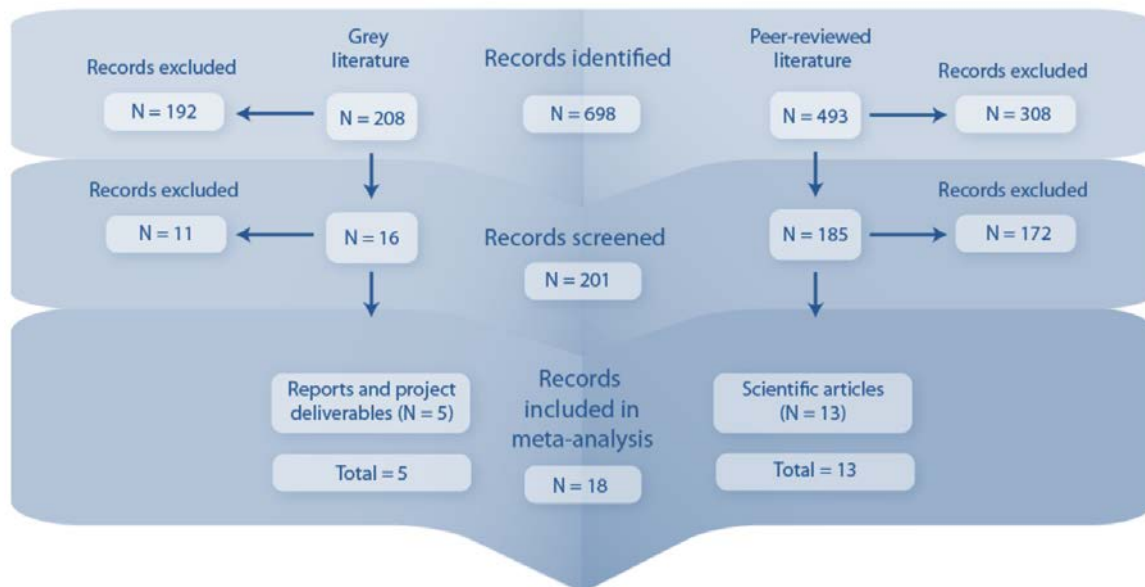


Figure 3: The selection process yielding 18 documents included in the meta-analysis

A quantitative content analysis of the selected records was undertaken using NVIVO version 1.7. (Manning et al., 2002). A total of 194 barriers to the implementation of grey

infrastructure were extracted from the 18 selected sources systematically. Subsequently, the barriers were identified and classified according to different clusters listed in table 4. In addition, each identified barrier or code was classified according to its phase or infrastructure stage as listed in Table 4, meaning the (planning or operating) stage/context at which the barrier comes into effect. This deliverable will not provide an in-depth analysis of the stage at which grey infrastructure barriers occur, which will, instead, be provided in a forthcoming publication.

Table 1: Scopus search terms for peer-reviewed literature search

Theme	Scopus search terms
'grey' infrastructure	("'grey' solution*") OR ("'grey' infrastructure*") OR ("gray solution*") OR ("gray infrastructure*") OR (landslide*) OR (dam) OR (levee*) OR (dike*) OR ("flood protection*") OR ("metal* net*") OR ("retaining wall*") OR ("slope protection*") OR ("soil* nailing*")
Barriers	(barrier*) OR ("obstacle*") OR (challenge*) OR (bottleneck*) OR (limitation*)
Enablers	(enabl*) OR (opportunit*)
Exclusion criterion	(SUBJAREA, "ENGI") OR LIMIT-TO (SUBJAREA, "ENVI") OR LIMIT-TO (SUBJAREA, "EART") OR LIMIT-TO (SUBJAREA, "SOCI") AND (LIMIT-TO (DOCTYPE, "ar") AND (LIMIT-TO (LANGUAGE, "English"))) PUBYEAR > 2010

Table 2: Overton search terms for 'grey' literature search

Theme	Overton search terms
'grey' infrastructure	'disaster risk reduction infrastructure enabler barrier landslide flood'
Exclusion criterion	PUBYEAR > 2010

Table 3: Google services search terms for peer-reviewed/'grey' literature search

Theme	Google search terms
'grey' infrastructure	'Financial challenges for public infrastructure' 'Governance/administrative challenges for public infrastructure' 'Public infrastructure challenges'
Exclusion criterion	PUBYEAR > 2010

Table 4: Categories used for NVivo coding and analysis followed by number of references

Category	Codes	Source
Barrier cluster	Lack and/or complexity of financing (42); sectoral and/or administrative silos (38); stakeholder conflicts and/or equity issues (21); lack of political will and/or long-term commitment (17); risk aversion (17); evidence on performance, co-benefits and maintenance (14); potential negative impacts (14); land ownership and availability (14); lack of supportive policy and/or legal frameworks (13); lack of expertise and knowledge (3); other (1); path dependency (0)	Adapted from: Martin et al., 2021
Barrier phase	Pre-condition (24); initiation, planning and design (114); implementation (2); benefit realization (39) and monitoring and maintenance (14)	Adapted from: Martin et al., 2021

2.3 Results of the comparative analysis

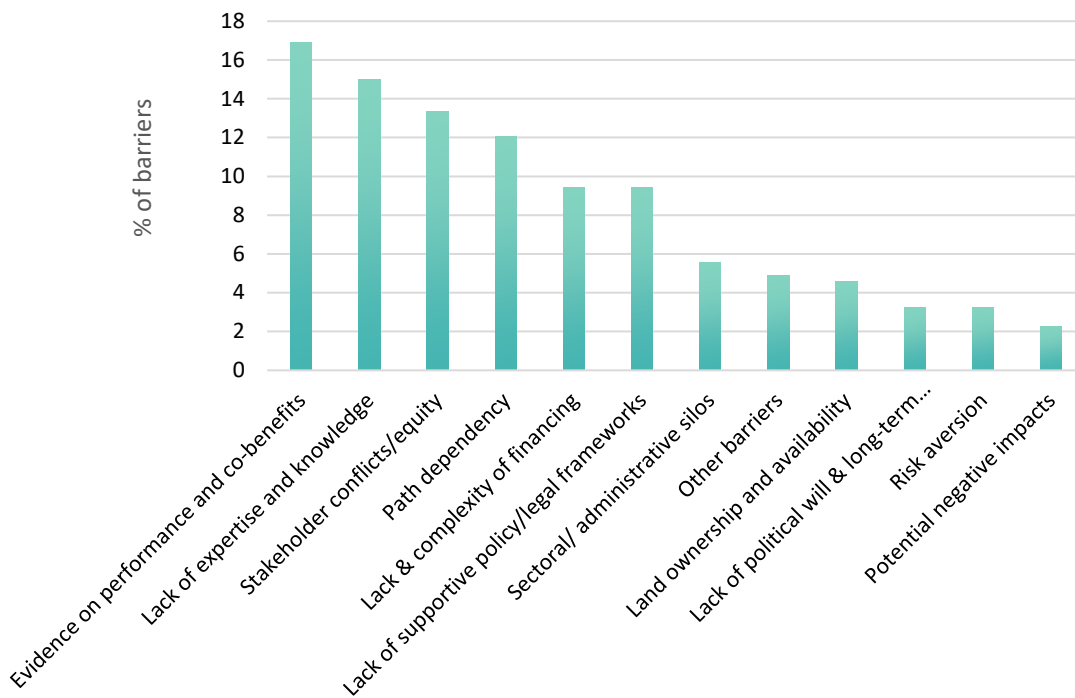
In this section, we illustrate the comparative results of the analysis across 12 main cluster headings (figure 4(a) and (b)). The NBS/grey infrastructure barriers are described in detail based on the literature and, importantly, illustrated with experience from PHUSICOS demonstration projects (Solheim et al., 2021, based on clusters from Sarabi et al., 2020), PHUSICOS in-depth case studies (Martin et al., 2019) and the PHUSICOS Policy-Business Forum (Scolobig, et al., forthcoming).

Figure 4(a) and (b) shows the relative rankings of each barrier cluster for NBS and ‘grey’ infrastructure, respectively, as they are mentioned in the literature, i.e., the percentage of ‘mentions’ given to each barrier. From this comparative analysis, one can identify what barriers are most distinctive for NBS compared to ‘grey’ according to the literature. What is notable from the relative rankings of barriers is that NBS appear somewhat unique (relative barrier ranking is more than double that of ‘grey’ infrastructure) across three clusters:

- Lack of expertise and knowledge (ranks 1st with NBS and 10th with ‘grey’)
- Lack of evidence on performance and co-benefits (ranks 2nd with NBS and 7th with ‘grey’)
- ‘Grey’ path dependency (only a barrier for NBS)

This does not mean that the other barrier clusters do not have some distinctive features, which will be discussed in more detail in what follows. However, it does indicate that addressing these three distinctive barriers may require special attention. Indeed, in the concluding section, we argue that addressing these barriers will require policy reforms across the NBS governance regime.

a)



b)

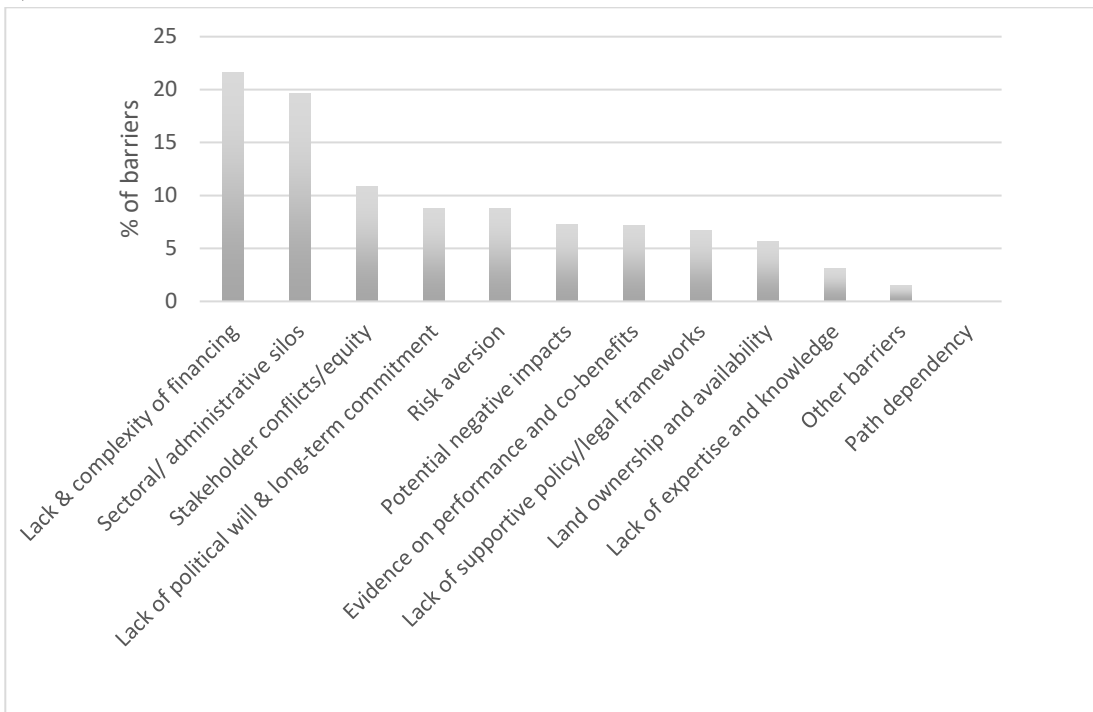


Figure 4: Main NBS (a) and grey (b) barrier clusters as identified in the literature (results given in % of total barriers identified in literature) (Source for NBS barriers: Martin et al., forthcoming)

A surprising result of the analysis is the comparatively low ranking of NBS barriers, *lack and complexity of financing* and *sectoral and administrative siloes*. Because NBS benefits and co-benefits are typically public goods, such as clean air, fresh water, fertile soil, sustainable natural resources, biodiversity and climatic conditions, there has been far greater reluctance on the part of private investors to provide financing (Sekulova and Anguelovski, 2017; Davis et al., 2018; UNEP, 2022; Mayor et al., 2021), which apparently has not been fully taken into account in the literature. Another distinguishing feature of NBS is the extent of co-benefits. In our analysis, we considered the main benefit of NBS to be disaster risk reduction, and the extensive co-benefits typically relate to biodiversity and health. Often public financing will require cooperation across the multitude of responsible agencies; thus, siloed administrative bodies is a significant challenge.

Another important observation from the analysis is the great learning potential that can be exploited by examining ‘grey’ infrastructure experience, i.e., asking the question of how the challenges presented for NBS have (or have not) been tackled in the implementation of more conventional infrastructure projects. This will apply mainly to infrastructure that has similar barriers.

Several caveats, however, should be kept in mind in comparing ‘grey’ vs NBS. First, the barrier clusters are correlated, that is, there are no fully clear boundaries, which means that the relative rankings depend to some extent on difficult subjective judgements in the coding process. For example, the barrier, *path dependence of ‘grey’ infrastructure*, is correlated closely with many others such as the *lack of (NBS) expertise and knowledge*. The availability of relevant literature also introduces a selection bias since much of the literature on ‘grey’ infrastructure pertains to barriers in developing countries, and mostly focuses on large infrastructure projects. Finally, caution is called for to avoid comparing apples and oranges given the different interpretations of barriers under the same cluster heading. Taking the cluster, *lack of supportive policy/legal frameworks*, as an example, for NBS the concern is lack of clear standards and regulations, but for ‘grey’ infrastructure the concern is over regulation. For all these reasons, the comparisons shown in figure 4 (a) and (b) should be considered a framework for discussion rather than an empirical comparison of barrier importance.

In what follows, we discuss each of the 12 barrier clusters, describe lessons learned from the comparison, and illustrate with examples from PHUSICOS experience.

2.3.1 Lack of expertise and knowledge

By far, the most cited barrier in the NBS literature is the *lack of (specialized) expertise and knowledge* regarding the performance, benefits and co-benefits of NBS. This ‘knowledge’ barrier has been identified as a major concern across many cases of NBS project implementation (Chausson et al., 2020) and across the whole NBS policy cycle – planning, design, procurement, construction and maintenance (Bernardi et al., 2019). It is compounded by limited standards, technical guidelines and legal norms (Sarabi et al., 2020) as well as the lack of long-term data on NBS performance (Bernardi et al., 2019). Site-specific evidence is needed to support the political shift towards employing NBS. It is also needed for public awareness and support, especially knowledge on the manifold environmental, social and ecological co-benefits.

Quite the opposite would appear to be the case with conventional ‘grey’ projects, which typically have long operating histories, detailed standards, guidelines and legal norms, as well as a pool of available expertise. Thus, as shown in figure 4(b), knowledge and expertise are infrequently mentioned in the literature as a barrier to ‘grey’ infrastructure implementation. In those cases where the ‘knowledge’ barrier does appear, it relates, for instance, to uncertainty in the risk estimates (e.g., for dam safety) or emergency operations (Scolobig, 2016), the performance of materials, e.g., concrete in submerged sea barriers, or the performance of infrastructure given climate change.

Yet, the reviewed literature may understate the salience of this barrier for engineered ‘grey’ infrastructure. Operating experience is plentiful, but there appears to be a lack of systemic data collection and publication. According to many observers there are insufficient open-access databases that could provide an overview, which also hinders the development of performance indicators for effectively monitoring the performance of infrastructure projects (Castalia Strategic Advisors for Evidence on Demand, 2014; OECD, 2017; Scolobig, 2017).

Because the ‘knowledge’ barrier appears similar, yet notably different in its manifestation for ‘grey’ infrastructure, Part II of this report takes a ‘deep dive’ to explore NBS knowledge and expertise on the part of Norwegian public authorities, especially concerning NBS effectiveness and co-benefits when applied to disaster risk reduction.

What can we learn from ‘grey’ infrastructure experience?

Expertise for developing and implementing infrastructure technologies covers a multitude of disciplines - perhaps most dominant are engineering and management. Indeed, throughout Europe there are high quality engineering and management schools. Most engineering universities are offering specialties in environmental engineering with

courses in, for instance, biology, chemistry, ecology, geology, hydraulics, hydrology, microbiology, and mathematics. It is reported that graduates from these programmes have good career prospects, but at least in the US the occupation is not expanding. According to the Bureau of Labor Statistics (2023) employment of environmental engineers is projected to grow four percent from 2021 to 2031, about as fast as the average for all occupations. Notably, the highest paid are petroleum engineers specializing in oil and gas extraction.

The NBS community can learn from how engineering has been promoted as a highly paid and attractive occupation, and it can capitalize on this reputation to promote specialties in environmental engineering with a focus on NBS, as well as multi-disciplinary courses. Moreover, trained technicians and other skilled workers can be facilitated through vocational training and apprentices. Importantly, NBS related jobs require multidisciplinary competencies and skills, such as knowledge on NBS planning, co-design, policy and legislation, as well as skilled workers in carrying out the NBS designs (Vera-Puerto et al., 2020). Lack of expertise was a dominant theme in our interviews with NBS contractors (see Part 2, Barrier 2), who reported that the growing interest in NBS has not translated into junior professionals with practical knowledge, which according to many interviewees was the main barrier hindering their ability to meet demand. Of the 20 interviewees, 50% mention the importance of hands-on learning in the field, attendance in conferences and the progressive assignment of small responsibilities.

To build NBS competencies outside of in-house learning, innovative capacity building options emerged in the PHUSICOS Policy-Business Forum (Scolobig et al. D5.3, forthcoming), which included not only the higher education sector, e.g. promoting specialties in environmental engineering, but also the private sector, e.g. developing project preparation facilities, creating and facilitating capacity building for NBS contractors and skilled workers, and creating communities of practice for NBS contractors and workers involving the public sector, academia, and civil society. As a complementary approach, accelerator programs could offer learning and development opportunities through intensive but brief funding and mentoring (*ibidem*).

2.3.2 Lack of evidence on performance and co-benefits

There is a serious lack of evidence on NBS effectiveness and delivery of co-benefits (Scolobig et al., 2021; Nelson et al., 2020). As seen on figure 4(a) and (b) this barrier is ranked second for NBS, and only about 7th place for 'grey' infrastructure. Indeed, the lack of historical data and evidence on NBS is one of three barriers that contributes most to differentiating NBS in their implementation. There are many reasons for the NBS evidence gap. Foremost is that the effects of NBS may not be experienced until many

years after their implementation, and there is little monitoring, thus little historical data. While monitoring and data are also problematic for grey infrastructure as noted below, evidence is often produced with models.

The literature on ‘grey’ infrastructure focuses largely on project performance since co-benefits, or what economists call positive externalities, have played a smaller role in project appraisal. While there is ample historical experience with many types of ‘grey’ infrastructure projects, there is still little data to quantify performance metrics. According to the OECD (2017)

A lack of systematic data collection on performance undermines evidence-based decision-making and disclosure of key information. Central infrastructure units tend to focus on delivering the asset, while auditors are not usually tasked with following performance. Lack of disclosure of data on contracts and subsequent operation tends to reinforce concerns about fraud and lack of transparency. (p.1)

For policy makers, the public and other stakeholders the lack of performance and co-benefit evidence is particularly problematic since without this information it is difficult to justify NBS over traditional infrastructure (Welden et al., 2021). This was witnessed in the interviewees with Norwegian municipalities and county officials (see section 3, part 2B), who noted that while the co-benefits don’t decide the investment, they do help in its justification over conventional options. Indeed, the benefits of NBS above and beyond their primary function, in our case reducing disaster risks, appear to be an important, although seldom decisive, selling point to policymakers and stakeholders.

More robust assessment of NBS efficiency in reducing disaster risks and the environmental/social co-benefits are also essential for applications of cost-benefit analysis (CBA). Although supported by the European Commission (2015), the use of CBA across Europe is varied but generally limited (Andersson, 2018). Wegrich et al. (2017, p.4)) comment on the early enthusiasm for ‘rational’ infrastructure decision making:

... infrastructure projects should be implemented by professionals, and the task of developing and maintaining the backbone of any economy needs to be ‘smartened up’ by making use of state-of-the-art tools of economic analysis, by drawing on the private sector’s superior expertise in and resources for infrastructure financing and provision, and by engaging in integrated and long-term infrastructure planning for prioritizing investments. On the delivery end of infrastructure, modern tools for risk assessment and management are available to rationalise project planning and implementation.

What can we learn from ‘grey’ infrastructure experience?

In reality, most of these instruments and tools have been around for a while, but they have not always yielded the promised effects. CBA, for instance, is controversial for

assessing and monetarizing non-tangible benefits, such as biodiversity, safety, health and many other positive impacts, although metrics for this purpose, e.g., valuing ecosystem services or lives, have been developed and applied (Campbell and Brown, 2001)). Critics point to fundamental problems, such as discounting future values or valuing safety, even in some cases as unethical (Sunstein, 2018). Josephs and Humphries (2018) note that we still have a long road ahead to be able to move beyond ecological definitions of NBS success, particularly when it comes to integrating socioeconomic and non-monetary co-benefits in NBS assessments. Still, since NBS' multifunctionality is a critical and distinctive NBS selling point, it is critical to ask how best to bring a holistic assessment to public decision processes.

Decision tools cannot provide an 'optimal' social decision, which ultimately will need to balance multiple and conflicting social values. Cost-benefit analysis (CBA), as the most used policy assessment tool, is distinctly different from a financial or rate-of-return analysis used by businesses to calculate the profitability or 'bankability' of their investments. The underlying normative principle of CBA is to estimate the project's impact, not according to a financial accounting sheet but according to its impact on social welfare or wellbeing, which presents difficult, some argue intractable, challenges in aggregating costs and benefits across groups holding different values and accounting for long-term global impacts given global warming (IPCC, 2018) and ecological breakdown (IPBES, 2019). Yet, the inclusion of the environment and incorporating sustainability sciences (OECD, 2018) has led to an explosion of studies addressing the many challenges of CBA, including refining the valuation of negative impacts, increasing the inclusion of co-benefits, developing new equity weightings, incorporating major changes to discounting practices, and extending the time horizon of the analysis (e.g., France now uses 75 years, Norway 100 years, and the UK 300 years (O'Mahony, 2021)). Indeed, the OECD (2018) is unequivocal that 'strong sustainability' guidance must be the focus of the process of CBA, necessitating integration across system levels (international-national-regional-local), and valuations that can account for irreplaceable natural and social capital -such as a stable climate and resilient social and ecological systems. It also requires that the limits of CBA are repeatedly flagged.

Thus, while CBA and other assessment tools cannot, alone, determine whether a project should or should not be employed, NBS can benefit from its wealth of experience. Most importantly, CBA and other assessment tools can provide a transparent input to stakeholder deliberation even in situations of high or 'deep' uncertainty and in 'wicked' policy settings (Lempert and Turner, 2021; Linnerooth-Bayer, 2021). The necessity to include intangibles, such as biodiversity impact, at different scales and across long time horizons can bring serious attention to the co-benefits of NBS.

2.3.3 Stakeholder conflicts/equity

Stakeholder conflict, often associated with perceived inequities in sharing NBS costs, burdens and benefits, is a major factor inhibiting or delaying the implementation of both NBS and ‘grey’ infrastructure. As shown on figure 4(a) and (b), stakeholder conflict and equity issues rank as one of the top three barriers for both types of interventions.

Consider, for instance, an urban park, for which the NBS can have a positive effect on property values; however, this positive effect can lead to neighborhood gentrification to the detriment of poor residents. At the same time, large dams, as a ‘grey’ case in point, not only can displace persons from fertile inundated areas, but the influx of workers can cause local food and other prices to increase, negatively impacting the poor. A large literature exists on public opposition not only to dams, but also to nuclear power plants, highways, waste incinerators, and even wind turbines (Statista 2018). The debate or conflict typically pits environmental NGOs and civil society actors against industry and government experts (Wegrich et al., 2017).

Often the opposition is driven by changes to property ownership, property values and other interest-based concerns that underlie the so-called NIMBY (not-in-my-backyard) characterization, but increasingly it is driven by ideological opposition or ‘worldviews’ (not-in-anyone’s backyard). As an example, opposition is mounting against the climate impacts of highways that enable fossil-fuel based transport. This might be described as a worldview clash between ‘grey’ and ‘green’ paradigms, which, however, leaves out an important third worldview that is rooted in procedural rationality, or hierarchy (Thompson and Rayner, 1998; Thompson et al., 1990). It might be expected that value-based worldview conflict is less prominent in NBS projects given their mainly positive socio-ecological impacts. Interest-based conflict, however, is evident. An example is the failed PHUSICOS project in Gudbrandsdalen (Box 1).

Box 1: Stakeholder opposition to NBS at Gudbrandsdalslågen

Stakeholder economic interests played a pivotal role in the flood-mitigation NBS proposed for Jorekstad and other interventions in the Norwegian valley of Gudbrandsdalen. The catchment of the river, Gudbrandsdalslågen, and its tributaries drain large areas of glacial tills. This results in severe erosion leading to transport and deposition of large amounts of sand and gravel downstream, which is the basis for firms retrieving and selling this resource. Gravel out-take after flooding events is therefore an important additional income for landowners along the rivers, and this has given rise to a potential barrier for implementing flood-reduction measures of any type. *Source: Innlandet County Authority, personal communication, 2019*

On the other hand, stakeholder opposition, especially value-based opposition to the negative impacts of ‘grey’ infrastructure, can work in favor of NBS. This was illustrated in a PHUSICOS case study (D5.1) of a landslide-prone town in southern Italy, where stakeholders opposed a ‘grey’ solution to their landslide problem (see Box 2).

Box 2: Lack of stakeholder support for ‘grey’ landslide measures in Nocera Inferiore

On 4 March 2005 the highest risk area of the southern Italian town, Nocera Inferiore, experienced a landslide that caused three deaths and extensive property damage. Three years later, a €24.5 million risk mitigation project prepared by the Regional Emergency Commissariat was rejected by the Municipal Council. This was largely in response to widespread opposition of residents and other stakeholders to the planned ‘grey’ infrastructure measures. The opposition was based primarily on considerations of the cost and environmental impact of the measures. Six years after that, in 2011, decisions about risk mitigation in Nocera Inferiore were still pending. This policy stalemate shows how the lack of stakeholder support can be a barrier for landslide risk mitigation. After an ensuing public deliberation process, an alternative NBS solution was eventually implemented. *Source: Scolobig et.al., 2016*

What can we learn from ‘grey’ infrastructure experience?

An important consideration for employing NBS for disaster risk reduction (DRR) is the emerging interest in co-production (stakeholders working together with experts and policymakers) of plans, design and implementation of public projects. Indeed, there is a rich experience of public participation in all types of public infrastructure (Renn, 2006). There have been important innovations, for instance in co-design, which is the approach of actively involving stakeholders throughout the planning and permitting stages. Even before a project is on the table, it can be useful to involve stakeholders in framing the problem and co-producing relevant knowledge. It can be equally useful to involve stakeholders in the assessments as well as in overseeing the construction of infrastructure projects, and often citizens are part of the monitoring process.

Still, in Europe and elsewhere, investment and regulatory decisions aimed at reducing risk of landslides, floods and other disasters are typically made by policymakers, e.g., municipalities, in consultation with their planners and other expert networks with little, if any, direct input from stakeholders at least in the early stages (once the project is proposed, most European countries require a public comment process or environmental impact assessment). As shown by the (failed) attempt to implement a ‘grey’ landslide mitigation measure in Nocera Inferiore (box 2), the one-way flow of knowledge from experts to policymakers can prove problematic. For several decades, critics have argued

that top-down, expert-driven processes risk being viewed as illegitimate by those ultimately affected, resulting in a loss of trust in public institutions (Agrawala et al., 2001; Thompson & Gyawali, 2007; Jasanoff, 2004 & 2011; Pielke & Byerly, 1998).

Shortcomings of the one-way model have reinforced calls for greater public participation (Thompson and Gyawali, 2007 Jasanoff, 2004 & 2011) even in dealing with sensitive matters of high public concern and inevitably associated with uncertainty and considerable scientific and political complexity (Gluckman, 2014), or what has been referred to as ‘wicked’ problems. Thus, the engagement of stakeholders along with experts, potentially supported by decision-analytical tools (Lempert and Turner, 2021; Linnerooth-Bayer, 2021), is becoming more and more crucial to improve the quality, efficiency and effectiveness of infrastructure decisions. Indeed, this critique has led to many innovative processes for stakeholder involvement throughout Europe, especially for large infrastructure following requirements of the EIA process (Renn, 2006).

The importance of wide and inclusive stakeholder engagement has proven to be a key success factor of NBS implementation by entailing stakeholder buy-in, ownership and dissipating potential skepticism towards NBS (Raymond et al., 2017; McVittie et al., 2018; Martin et al., 2021). However, the addition of stakeholders to what have hitherto been expert-driven processes is not straightforward, and there is little explicit guidance on how to design participatory processes that involve stakeholders and scientific experts in such a way that they co-produce useable knowledge for the policy process. An exception can be found in PHUSICOS Deliverable 5.1, which describes two seminal examples of a co-production processes for an NBS: the Nocera Inferiore process (box 2) and the long-running Isar river naturalization process in Munich (Martin et al., 2019). Living labs for NBS co-design have also been activated in the PHUSICOS Serchio river basin, Italy and in the Pyrenees mountains, which have contributed importantly to the implementation of NBS in the Serchio basin as well as in Santa Elena and Erill-La-Vall in Spain and Artouste and Capet in France (Scolobig et al. forthcoming).

2.3.4 Path dependency of ‘grey’ infrastructure

A major factor limiting NBS implementation appears to be the difficulty in breaking away from current and deeply ingrained legal and social norms that still favor ‘grey’ infrastructure, or breaking away from habit in the choice of infrastructure delivery and responsible persons or entities (OECD, 2017; Sarabi et al., 2020). Explaining this phenomenon is the concept of path dependency (Barnes et al., 2004), which denotes a system in which pathways are irreversibly ‘locked-in’ due to habituation (David, 1985). For example, Bernardi et al. (2019) found that landscape designers are more familiar with traditional infrastructure, both from a technical point of view and with respect to legal compliance. As remarked by Davies and Laforteza (2019), many institutions have

evolved in a deeply-set ‘grey’ infrastructure culture, which means that reforms of these systems are rare and require substantial agents of change and transformations. Unfortunately, NBS are not an exception and remain a neologism within many institutions (Box 3).

The strong prevalence of ‘grey’ path dependency as a barrier to NBS is evidenced by the meta-analysis shown in figure 4(a), where this barrier ranks third place. Whereas path dependency is a barrier for NBS, it is an enabler for conventional infrastructure. Thus, of course, it does not appear on the ‘grey’ ranking shown in figure 4(b).

Box 3: Path dependency in the Serchio River Basin (Italy)

In the PHUSICOS Serchio river Basin case, the responsible authority, the Autorita' di Bacino Distrettuale dell'Appennino Settentrionale (ADBS) maintains that to avoid grey measure path dependency it is essential to simplify the procedures for NBS approval. Presently these procedures are the same as for grey measures. To exit this “lock-in”, the recommendation is to promote technical self-certification schemes to be provided by the authorities in charge of NBS implementation.

What can we learn from ‘grey’ infrastructure experience?

Research on niche innovation (including green-niche, e.g., Lie and Sorensen, 1996; Lounsbury et al., 2001) identifies challenges hindering development of projects that are in line with our findings, e.g. high costs compared to existing solutions, lack of markets for radical innovation, "liability of newness" mechanisms, and scientific uncertainty, all of which reduce access to financial resources. Yet, many technological innovations have defied path dependency and gained market prominence, for example, with regard to mobility, heating, power, agro-food, water, sanitation, music, renewable electricity, to name only a few. According to Geels (2019) radical innovations tend to emerge in small niches at the periphery of existing systems through pioneering activities of entrepreneurs, start-ups, activists or other relative outsiders. While transitions take several decades to happen (this is critical since the transition to NBS is urgent), an historical analysis of case studies shows four recurring phases: experimentation, stabilization, diffusion/disruption, and institutionalization/anchoring.

2.3.5 Lack and complexity of financing

Lack and complexity of financing was among the top five NBS barriers shown in figure 4(a) and the highest ranked barrier for conventional ‘grey’ infrastructure. This does not mean that financing NBS projects is less problematic or complex than financing ‘grey’ projects. The ranking is relative, and higher ranked barriers for NBS may dwarf financing. Indeed, complexity is manifest in the assorted portfolio of public and private

instruments (debt, equity, parametric or indemnity-based insurance, green bonds, resilience bonds, contingency credit, and more) made more complex by sectoral silos leading to ‘silo budgeting’ and the consequent disregard of NBS’ co-benefits (Bernardi et al., 2019).

Financing is especially problematic because of the heavy load on public authorities. Most NBS (around 83% according to UNEP) (Sekulova and Anguelovski, 2017; Davis et al., 2018; UNEP, 2022), meaning that the pressure on public finances is intense with often limited municipal spending autonomy on budgets (Toxopeus and Polzin, 2021) and the incapacity to co-finance NBS (Bernardi et al., 2019).

Public bodies thus have high demands on their budgets, and politicians are typically attracted to highly visible projects with short-term benefits (Coelho, Ratnoo, and Dellepiane, 2014) that award them credit and votes; yet, infrastructure governance is very much about long-term investments that remain difficult to sell politically. We see this challenge contributing to the failure of an NBS planned for the PHUSICOS demonstration site at Jorekstad (Box 4). The municipality was reluctant to pursue additional financing given the current unpopularity of the project.

Box 4: Failed financing at Jorekstad

The largest of the proposed NBS interventions in the Norwegian demonstrator site at Jorekstad, a receded flood barrier, was called off mainly because a detailed design of the project revealed that the cost would be significantly more, even double, that of the original estimate. The municipality was reluctant to pursue financing possibilities, not only because of the already stressed budget, but also because of further complications. The already skeptical farmers and landowners were asking for compensation for loss of crop land, a demand that arose during the public hearing that was carried out for a new regulation plan for the area.

That the municipality did not pursue other means of financing is typical. According to the OECD (2019):

Subnational governments make little use of external financing options for public investment. Municipalities and local governments – in particular the smaller ones – are often limited by their capacity to use innovative financial tools, manage complex public procurement procedures, combine different streams of financing and funding, and by the lack of appropriate skills to design and manage Public-Private Partnership. (p. 10)

A similar but importantly different picture emerges with conventional infrastructure. Like with NBS, public bodies have limited resources for making long-term and large capital investments or for absorbing the high running costs of maintenance. Especially for poor countries, the costs of major infrastructure can be high, user charges can be low or non-existent, and government contributions may be insufficient to close the gap. The lack of cost recovery is one of the main barriers to scaling up provision of infrastructure services (Castalia Strategic Advisors for Evidence on Demand 2014, p. 12).

However, a crucial difference emerges. The shortage of private financing for ‘grey’ infrastructure has led to a trend, beginning in the 1980s, towards privatization of a range of infrastructure services such as telecommunication, energy, water services, public transport, road transport and most recently, renewable energy. And while the size of private sector investment varies substantially cross-nationally, it is now recognized (beyond the early enthusiasm) that the role of the state for regulation and delivery of infrastructure remains critical (Wegrich, et al., 2017). Still, many services from grey infrastructure are priced; this is not the case for most services from NBS including benefits from, for example, biodiversity, climate mitigation, pollinators, and flood control.

What can we learn from ‘grey’ infrastructure experience?

Unfortunately, the euphoria over private investment in infrastructure, especially the recent trend toward renewable technologies, cannot be transferred unequivocally to nature-based infrastructure. According to Bhattacharya and Stern (2021) far too little private finance is being mobilized today for sustainable infrastructure due to shortcomings in the policy and regulatory framework, a lack of well-prepared, bankable projects, inadequate risk transfer mechanisms, and by a lack of financial channels connecting deep sources of funds with investments. For NBS, emphasis might be put on ‘bankable’. In contrast to investments in renewable energy infrastructure with positive rates of return, many, if not most, NBS cannot provide a profitable revenue stream to the investors, i.e, they are public goods.

At the same time, municipalities are not prepared to fill the gap. Due to their financial stress, the market is gravitating away from conventional municipal bond financing toward public-private partnerships (PPPs), which opens the door for institutional investors such as insurance companies. PPP projects are most commonly employed in the construction of social projects, such as hospitals, schools, and courthouses. The model has also been extensively applied to civil projects, such as roads and bridges, as well as to other infrastructure elements.

Still, private investing even for ‘grey’ infrastructure has not been fully forthcoming. According to the OECD (2017), private investment in infrastructure on the part of long-term institutional investors remains relatively limited. This riddle of under-investment in the face of capital availability suggests that other factors are likely holding investor returns too low in many infrastructure markets (Blundell-Wignall and Roulet, 2015), which raises a central challenge for governments to effectively mobilize further private investment into domestic infrastructure markets. One way forward suggested by the OECD is to create a separate asset class for infrastructure, and to improve the availability and quality of data and information on infrastructure investments, which could broaden its appeal to a larger base of investors.

Turning to NBS, one encouraging trend is that investment in ‘green’ funds has increased dramatically, and this can improve financing for a small share of ‘bankable’ NBS. However, the public-good nature of NBS infrastructure raises the frequently discussed question of how the private sector might take more financial responsibility; however, it also raises the not-so-frequently discussed question of how the public sector can take more responsibility. Much can be learned for both questions by examining ‘grey’ experience on public-private partnerships, blended financing, subsidies, and other public financing schemes (see, e.g. <https://connectingnature.eu/innovations/financing-and-business-models>). Yet, no matter how you cut the cake, the message is that we need to pay more attention to increasing public budgets for NBS. This message was apparent even in a wealthy country like Norway, where a County Governor, who oversees municipal activities, notes the lack of financing at the municipal level:

... the capacity, both in terms of personnel and finances, is not present [...] When you have such small municipalities, the administrative resources are also small, and therefore I do not have much faith that this type of solution (NBS) can be achieved in these municipalities [...] (County Governor 1 (see Part 2, Barrier 1))

An encouraging recent development for increasing public budgets is the EU Biodiversity Strategy for 2030 (European Commission, 2021a), which includes detailed plans for funding and financing NBS to conserve, enhance and restore biodiversity. It foresees nature restoration to make up 25% of the EU climate action budget. As such, the strategy plans for at least €20 billion per year to be unlocked by mobilising private and public financing as part of the European Green Deal Investment Plan (ibidem).

Although the scope of bankable NBS projects is limited, it is important to exploit private finance for those that can yield sufficient revenues. In this vein the NBS Accelerator Project sponsored by the HSBC, World Resources Institute (WRI) and WWF develops models that can be scaled and replicated, and which blend different sources of finance

to become financially sustainable.¹ There are a diverse set of instruments to finance private NBS, like bank loans, equities, payments for ecosystem services, ESG investing, and green/resilience bonds. There are also controversial offsets for encouraging biodiversity investments, as well as philanthropic spending and private contributions to conservation on the part of non-governmental organisations. Global carbon credit markets, both regulated and voluntary, are offering significant incentives to governments and the private sector to invest in nature. This is in addition to direct public (taxpayer) support for private entrepreneurs including subsidies, tax advantages, public-private partnerships public guarantees, and funding provided through the EU like the Horizon Europe research program. Investment fund managers and private persons can be encouraged to invest in bankable NBS, perhaps by designating a separate NBS investment asset class (in addition to green funds) as has been proposed for public infrastructure more generally (Inderst, 2010). Finally, we should mention innovative insurance products that help finance NBS by insurance customers who gain in reductions in their premiums (Bechauf, 2020). As one interesting example of a novel financing scheme, Belize restructured its sovereign debt made possible by a blue bond. The savings from the restructuring will enable Belize to invest in an ambitious marine conservation program.²

Finally, it may be equally or more important to divest from investments in nature-negative 'grey' projects. The classification of unsustainable investment will be made more transparent with the extension of the EU taxonomy to include nature-negative activities. Another effort in the direction of divesting from nature negative solutions is the establishment of the Task Force on Nature-related Financial Disclosures (TFNDs) supported by Global Canopy, the United Nations Development Programme (UNDP), the United Nations Environment Programme Finance Initiative (UNEP FI), and the World Wide Fund for Nature (WWF) (Calliari et al., 2022).

2.3.6 Lack of supportive legal/policy frameworks and standards

One glaring difference between NBS and 'grey' infrastructure is the lack of regulatory guidelines and standards for NBS compared to their 'grey' counterparts. The newness and novelty of many (but not all) NBS interventions and the accompanying scientific uncertainty are major factors for the dearth of standards and the integration of NBS in legal systems (Davies and Laforteza, 2019). This is viewed as a formidable hurdle for designing and constructing NBS. For 'grey' infrastructure, the OECD (2017) points to the lack of clarity in rules and regulations (e.g., for procurement and bidding practices)

¹ <https://www.wwf.org.uk/who-we-are/who-we-work-with/nbs-accelerator>

² <https://www.nature.org/content/dam/tnc/nature/en/documents/TNC-Belize-Debt-Conversion-Case-Study.pdf>³ REACH (europa.eu)

as not only negatively impacting the willingness to invest in infrastructure (specially for private investors seeking PPPs) but also the quality-of-service delivery.

Standards are also essential for reducing financial liability, which is usually limited if the contractor has ‘built to standard’. This means that the absence of standards is a formidable challenge, even limiting insurance that could help de-risk NBS investments. This was a much-discussed topic at the PHUSICOS 3rd Policy-Business Forum (Scolobig et al. D5.3, forthcoming), where many academic and business attendees noted that, compared to ‘grey’ solutions where the standards are clearly defined, it is more difficult for companies to foresee and prepare for the challenges that NBS often bring. According to a participant from a technology company, the lack of NBS criteria affects the procurement process for nature-based enterprises. While legally binding standards and design criteria are generally absent, the IUCN Global Standard for NBS has been developed as a general framework to guide NBS (IUCN, 2020).

It is not only the dearth of NBS guidelines and legal standards, but also the lack of mandatory policy instruments that constitute a barrier for NBS. For instance, the procurement process can lead to long delays and even the cancellation of projects, as occurred in Norway (Box 5).

Box 5: Delays in the Norwegian procurement process

In Norway as well as in some EU countries, public procurement is regulated by national legislation, including sometimes necessary but often long deadlines, rules for the evaluation of tenders, and response to all comments and objections. In the procurement process for the PHUSICOS demonstration project, Jorekstad, the proposers experienced an official complaint from one of the losing bidders, resulting in a full new procurement round. This presented a serious delay, which can be critical in a time-limited project like PHUSICOS.

Most NBS policies at the EU scale are characterized by ‘soft’ measures with little to no means for their enforcement at the EU scale (Scolobig et al., 2020). However, even legislation that is non-binding at the EU scale can be binding on national governments with respect to the ends or targets to be achieved, and governments can be subject to national or regional court cases for non-compliance. Furthermore, the Commission has a duty to enforce EU legislation, eventually bringing matters to the European Court of Justice if necessary (Haigh, 1991; Treaty on European Union (TEU), 2012, Article 17).

As a forerunner, although not in the EU Norway has passed pioneering legislation in the form of guidelines that instruct public authorities to consider NBS in planning,

conservation or restoration activities (box 6). Unfortunately, to date the legislation has not been rigorously implemented. Still, if deemed enforceable, it can be a game changer. In our discussion in section 4, interviewed contractors indicated that in the absence of an explicit requirement for the consideration of NBS in calls for tenders, contractors are not stimulated to create or expand their capacity. The responsibility for proposing NBS rests with the applicant, but interviewees indicate that they are limited by lack of information and data to support NBS over grey or traditional solutions.

Box 6: Norwegian guidelines on NBS

In paragraph 4.3 of the 2018 Norwegian regulation "National guidelines for climate and energy planning and climate adaptation",¹ it is stated that nature-based solutions must be explicitly addressed as an alternative to be assessed along with any grey solution. Should the NBS solution be dismissed, the reason must be substantiated. In 2022, the Norwegian Environment Agency (NEA) published more detailed guidelines for climate adaptation that built strongly on this regulation. <https://www.miljodirektoratet.no/ansvarsomrader/klima/formyndigheter/klimatilpasning/veiledning-til-statlige-planretningslinjer-for-klimatilpasning/vurdere-naturbaserte-losninger/>

Given the recent attention to NBS legal and policy frameworks, it is somewhat surprising that this barrier ranks only 6th in its mention in the reviewed NBS literature (figure 4(a)). One consideration is the difficulty in distinguishing this barrier cluster as separate from related clusters, such as the earlier mentioned *path dependence on 'grey' infrastructure* or *lack of funding*. Not surprising, however, is its 9th rank in the 'grey' infrastructure literature, which in sharp contrast to NBS is mainly due to concerns about over regulation, or the myriad of rules and regulations across the whole policy cycle of infrastructure implementation. In many countries, the rules have evolved as a response to wide-scale corruption in the procurement and implementation of infrastructure investments (World Bank, 2021). Another consideration for the low ranking of legal and policy frameworks is the inherent difficulty in devising standards for NBS due to lack of knowledge, but also due to their variability with weather and other conditions.

What can we learn from 'grey' infrastructure experience?

The distinguishing characteristic of 'grey' infrastructure is 'over regulation', which has not been an issue in the NBS implementation literature. However, this may change as NBS scale up and infringe on permitting and other regulations that are in place for 'grey' projects. Indeed, providing planning and legal security and cutting red tape (i.e., reducing bureaucratic obstacles) are vital in eliminating investment blockages.

An important lesson is that legal procedures and frameworks can change if the need arises, particularly if the infrastructure is seen to be in the public interest. The most recent example is renewable energy infrastructure, including wind turbines, photovoltaic, heat pumps, etc., which faced extensive red tape for approving and siting facilities in many EU countries. This barrier is being urgently addressed by the Council of the EU in a draft regulation laying down a temporary framework to accelerate the permit-granting process and the deployment of renewable energy projects (52022PC0591 - EN - EUR-Lex - European Union).

2.3.7 Sectoral and administrative silos

As shown on figure 4(a) and 4(b) the impediment to infrastructure realization caused by siloed administrative authorities operating across governance scales and sectors is a frequently cited barrier in the ‘grey’ literature (2nd in rank) but less frequently mentioned in the NBS literature (7th in rank). This is somewhat surprising given that NBS – in contrast to ‘grey’ infrastructure - are typically characterized by co-benefits that impact different sectors; thus, their financing can (and frequently does) require contributions across administrative bodies. Apart from financing, institutional fragmentation and siloed administrations present a formidable and somewhat unique challenge to NBS employment in terms of expertise (Sarabi et al., 2019; Scolobig et al., 2020; Suleiman, 2021). As one example, reducing risk of heat extremes in a city by planting trees may require approval from multiple municipal bodies with separate mandates for landscape planning, parks/gardens, roads, sewer and water pipes, underground electric cables, and maintenance (e.g., watering). Each will have different procedures for granting permits and different requisite expertise including, for example, ecologists, biologists, waste engineers and city or landscape planners. Suleiman (2021) highlights in particular a disconnect between water and landscape planners for blue-green infrastructure implementation in Stockholm.

The stark difference in the relative rankings of the silo barrier may be partly due to the bias introduced by the ‘grey’ infrastructure literature predominantly focusing on larger projects than those in the selected NBS literature. Undeniably, however, ‘grey’ infrastructure realization, especially large projects, suffers from a lack of coordination across different institutions, jurisdictions, levels of government, policy areas and professional disciplines (OECD 2017, p. 2), making it a significant barrier for national and regional infrastructure projects. Apart from financing, which for large projects is typically a single administrative budget, the challenge appears to be coordination in project planning and approval due to a dispersion of powers and responsibilities across public administrative bodies, and due to increased powers awarded stakeholders, including NGOs, civil society actors and private businesses (Wegrich et al., 2017). According to Scolobig (2016, 2017), the excessive number of authorities, involved

parties (also civil society and PPPs) and the politics of scale between the national and the local level, lead to unclear and fragmented distribution of responsibilities, causing significant barriers (mainly in form of delays due to difficulties of coordinating policies and regulations across systems and scales) to the successful completion of large public infrastructure projects. Ultimately, these organisational and institutional silos reduce the adaptation capacity of governance systems (Rosenbloom, 2018).

Siloed organizational structures have been the subject of literature promoting more polycentric governance structures with multiple autonomous centers of decision making away from centralized authorities (Ostrom, 2009). While the advantages of polycentricity include more flexible opportunities for learning, trust building, and enhanced adaptive capacity (Carlisle and Gruby, 2019), commentators have also pointed out the problem of dispersed responsibility when no one organization can be held accountable (Cleaver, 2007). Indeed, as reported in PHUSICOS D5.1, centralized authority and budget proved to be an advantage in the re-naturalization of the Isar River (the stretch through Munich) but only after the emergence of a cross-sector working group that exploited expertise across multiple municipal and state authorities (Box 7).

Box 7: Conquering silos: the Isar river re-naturalization

In 2000–2011, an eight kilometer stretch of the Isar river in Munich (Germany) was restored using a hybrid of green and grey measures. It was jointly implemented by the State of Bavaria and the City of Munich and is widely acclaimed for having successfully turned a formerly concrete and unsafe riverbank into a green/blue recreational space, and an emblem of the city (Binder, 2010; Sartori, 2012; Düchs, 2014). The project's aims were threefold: flood protection, environmental restoration (both of these fulfilling the Munich Water Agency's main mandates) and creating an urban recreational space (fulfilling the City of Munich's mandate and the demand of local councils and Munich's inhabitants). Indeed, the Isar River in Munich falls into several overlapping jurisdictions and legal mandates, mainly at the State (Bavaria) and City (Munich) scales, which created the need for cross-scale and cross-sectoral coordination and cooperation. This collaboration was initiated by ecologically committed staff of the municipal government and the local water authority, who formed the multidisciplinary Isar working Group that was unprecedented for flood management (Zingraff-Hamed et al., 2019), and which was crucial for the eventual implementation of the Isar re-naturalization project. The working group members collaborated to advocate a far broader vision for the Isar than their customary focus on grey infrastructure for flood protection. This collaboration broke down the silos of water and urban planning and was unprecedented for projects of this magnitude.
Source: Martin et al. 2019 (PHUSICOS deliverable 5.1)

What can we learn from ‘grey’ infrastructure experience?

It appears from figure 4(a) and (b) that siloed administrative authorities are a major challenge, not only for NBS, but also for ‘grey’ infrastructure, for which the long experience has led to important suggestions. For instance, Oseland (2019) suggests centralized planning institutions that are anchored beyond the municipal or other authority in charge. Bundred (2006) calls for public sector leadership which rewards a culture of knowledge sharing within the organization and with other public sector bodies. Scolobig et al. (forthcoming) call for semi-permanent institutional frameworks that are adaptive, multi-scale, cross-sectoral, and well enough established to guarantee the delivery of NBS, for instance, the creation of new institutions devoted to NBS promotion with their own budgets and a clear political mandate (Runhaar et al., 2018). An example could be the establishment of climate/biodiversity offices or secretariats to assist agencies in the implementation of NBS strategies. Successful examples are provided, for example, in Braunschweiger and Pütz (2020).

Wegrich and co-authors (2017) take this idea further:

...as a variety of experts have suggested, the governance of infrastructure should be left neither in the fickle hands of politicians nor in silos of turf-defending, inward-looking bureaucracies (see Hammerschmid and Wegrich 2016: 31–2). Instead, infrastructure projects should be implemented by professionals, ..., and by engaging in integrated and long-term infrastructure planning for prioritising investments.(p.3)

2.3.8 Land ownership and availability

‘Grey’ infrastructure, especially large projects like highways and dams, as well as NBS (e.g., floodplains, urban parks, and wetlands) require space, which is becoming increasingly limited and expensive (Scolobig et al., 2020). While this barrier is ranked consistently low (figure 4(a) and (b)) for implementing both ‘grey’ and NBS projects, in specific contexts it can be irresolvable (Sarabi et al., 2020). Not only is it complicated to confiscate private property for public use, but it can also involve a myriad of stakeholders. In our survey of Norwegian policy makers (Section 3.4.1), this barrier was often mentioned, for example:

But when it is to be nature-based, you must set aside land, and then there are many more actors who have a say in what should happen [...] so my impression is that the processes to bring about nature-based solutions are more complicated. (Municipality 1)

PHUSICOS demonstration cases that have been located on private and public property can serve to illustrate. In the Pyrenees one intervention located in a public forest ran into delays in meeting all the special requirements and regulations. In the Serchio case, it appeared that farmers would resist the idea of locating buffer strips on their fields, which would reduce their productive land. As discussed in box 8, this barrier was overcome with negotiated compensation for crop loss.

Box 8: Compensation to farmers in the Serchio valley

Farmers in the Italian Serchio river basin agreed to give up cropping on parts of their fields and to construct buffer strips along the small waterways. This will reduce erosion on their own fields and reduce contaminated runoff into the Massaciuccoli Lake. Since the buffer strips will be populated with selected native plant species, it will also improve biodiversity in the basin. The farmers first resisted the idea of giving up productive land for the buffer strips, but after a successful stakeholder negotiation, it was agreed that the buffer strips would be three meters wide and that the farmers would be paid for providing these ecosystem services by the public authorities (Consorzio di Bonifica). Farmers receive payments to plant and maintain NBS and also compensation for their harvest loss.

Moving to another example, in Norway, private persons - the riparian landowners - own the river, which presents a rather unique barrier to NBS as shown in box 9.

Box 9: River owners protest loss of business in Norway

The influence of landowners in Norway in mining the gravel deposited in the Gudbrandsdalslågen river and its tributaries is heightened by the river ownership in Norway. Contrary to most European countries, where rivers are the property of the public, in Norway they are the property of the riparian landowners. This river ownership arrangement enables private property owners to have great influence on measures that impact the river, and in this case, gravel deposition in the river.

What can we learn from ‘grey’ infrastructure experience?

Taking private land for public use has been a long-standing legal issue in European countries and North America. In the United States *eminent domain* refers to the power of the government to take private property and convert it into public use, but the government may only exercise this power if it provides ‘just compensation’ to the property owners. Europe appears to have more protection against direct expropriation of private property (van Aaken, 2017). Most EU member states have legislation allowing the ‘taking’ of private property if it is deemed in the public interest and if there is compensation, albeit rules governing ‘fair’ compensation vary across countries (van Aaken, 2017; Kuban et al., 2018)

Fair compensation, however, can be difficult to negotiate as was the case in Jorekstad (box 10).

Box 10: Landowners in Jorekstad reject compensation for loss in crop land

Stakeholder and political skepticism were apparent in the Jorekstad case, a flood mitigation plan in the Norwegian valley of Gudbrandsdalen, which consisted of a receded natural flood barrier to allow more space for flooding on private property to protect agricultural land, farms and sports facilities. Initially, the affected farmers were generally positive. However, a public hearing of a new landuse plan raised a number of issues, including compensation to farmers for confiscating their land for construction of the barrier and allowing their fields to be flooded. The hearing also revealed a lack of knowledge on NBS and skepticism on whether the proposed receded flood barrier would reduce the flood risk as well as, or better than, the traditional “grey” measures. This combined with cost considerations (Box 4) and stakeholder opposition resulted in a cancellation of the project (see Boxes 4, 5 and 9).

Land use can also change in the other direction, that is, from public or restricted use to development, further limiting the land for NBS. As an example, the Italian city of Genova experienced poor land use planning, causing uncontrolled development and building in high-risk areas. As present laws and regulations were violated, inadequate control systems were used during their construction (Scolobig, 2016).

2.3.9 Lack of political will and long-term commitment

In the words of Wegrich and colleagues (2017, p.9), a core issue for green and ‘grey’ infrastructure is the ‘tension, if not clash, between the time frame of political decision making and the needs and requirements for long-term and economically sound priority setting’. Both NBS and ‘grey’ projects are characterized by long-term impact and gestation periods, requiring predictability and sober analyses, although many observers have pointed out the longer gestation periods for NBS, for example, a tree takes anywhere from 10 to 180 years to mature. Policy makers and business leaders at the PHUSICOS Policy Business Forum also discussed the notion that NBS operate differently than ‘grey’ alternatives, in most cases they require a longer time frame to deliver benefits. Restoration projects, for example, were noted to require between 10 and 15 years and considerable maintenance efforts before they can produce a long-lasting impact (Scolobig et al. Deliverable 5.3, forthcoming).

Understandably, policymakers are reluctant to devote resources to projects that will only provide benefits long after their term of office. This was evidenced in our survey of Norwegian policy makers (section 3.4.1.), where a municipality official put it this way:

[...] NBS are considered, and then they do not have good enough effect in the short term, and are perhaps more complicated, and may require other measures, e.g., moving infrastructure. So then [...] it is easier with a more classic solution.
(Municipality 6)

NBS and ‘grey’ infrastructure are highly sensitive to short-term attention cycles of political actors and economic cycles that vary over time, creating also tension with longer-term perspectives of (private) investments (OECD, 2017; Wegrich et al., 2017). As Scolobig (2017, p. 18) points out, this mismatch between short-term visibility of benefits and long-term social interests is particularly pronounced for projects that reduce disaster risks (see Box 11): “elected representatives and risk managers can have different priorities, visions, interests concerning disaster risk reduction.” Political priorities often determine budgetary choices and not cost-benefit analyses (Castalia Strategic Advisors for Evidence on Demand, 2014). Indeed, the proposed NBS interventions at Jorekstad (Box 4, Box 7) were called off, partly because of economic reasons, but also partly because of political prioritization, where the intervention was competing with other projects, which were considered more urgent (Solheim, personal communication, 27 Feb, 2023).

That the relative ranking of the barrier, *political will and long-term commitment*, is significantly higher for ‘grey’ infrastructure than for NBS (figure 4(a) and (b)) is puzzling given the long gestation period of many nature-based projects. It may be explained by the immaturity of NBS on political agendas. Indeed, the Norwegian survey (section 3.4.1) revealed that although the term, NBS, was known among potentially responsible municipalities and county officials, there was little direct NBS experience. The immaturity of NBS on policy agendas mitigates any attempt to delineate ‘political will’ as a barrier, which could help explain the near absence of its discussion in the literature. However, it is apparent that the long-term commitment necessary for NBS political decision making is equally, if not more, prominent for NBS than ‘grey’ infrastructure. For example, Toxopeus et al. (2021) mention the need for governors to make popular decisions to win subsequent elections, which naturally decreases their willingness to take risks on NBS. Additionally, frequent changes in local authorities or administrations can hamper the political will to implement NBS (Kuban et al., 2018). This was illustrated by the cancellation of two PHUSICOS demonstration interventions in France as described in Box 11.

Box 11: Lack of political support for NBS in Bastan Valley, France

The cancellation of two major PHUSICOS demonstration interventions in the Bastan Valley, France, illustrates the criticality of political support. Together, the two Bastan interventions - both intended to reduce flood risk by making more space for the river and increasing the river's natural flow- constituted the largest of the proposed NBS interventions in the Pyrenees. While several factors led to their cancellation, including the prospect that potential delays would make the projects ineligible for PHUSICOS funding, an upcoming local election introduced the prospect of a government less in favor of NBS, which became a key motivation for the proponents to fully cancel the plans. According to Solheim et al. (2021), closer involvement with the public administrations as well as other relevant stakeholders, such as farmers, prior to the planned implementation might have mitigated some of the opposition and increased political support.

2.3.10 Risk aversion

In economics and finance, risk aversion is the tendency of people to prefer outcomes with low uncertainty to those outcomes with high uncertainty even if the expected outcome or 'win' from the high-uncertainty choices is greater. Risk aversion, especially on the part of investors, was more prominent in the 'grey' literature than in NBS discussions. This is likely because 'grey' infrastructure has attracted far more private capital, and also because of the prominence of developing country literature in our review, where political risk, currency risk and institutional risk (including frail institutions, weak administrative, accounting and procurement systems, as well as internal conflicts that affect the local capacity to maintain and operate infrastructure) feature strongly in international and domestic investor decisions. The risks also limit available capital for investing since the cumulative risks to invested capitals set a difficult-to-overcome bar for attracting financing (Ehlers, 2014; Castalia Strategic Advisors for Evidence on Demand, 2014). Finally, negative social and environmental impacts may also hinder investments and contribute to increased investment/capital risks (Yankson et al., 2018).

Kuban et al. (2018) noted risk aversion on the part of private companies, which have a higher incentive to provide standard solutions at reliable profits than to implement or invest in innovative solutions, such as NBS. This is related to the perception of risk or uncertainty. NBS often face skepticism, as stakeholders tend to attribute a higher uncertainty to NBS than traditional infrastructure (Sarabi et al., 2020; Solheim et al. 2021; Toxopeus and Polzin, 2021). Risk featured strongly in NBS contractors' decisions to expand their business. As reported in Section 4.4.2 of this document, while 88% of the 17 contractors interviewed admit that they have noticed a growing interest in the

application of NBS, slowly translating into demand, notably from public authorities, they prefer to be cautious when taking decisions on the growth of their company.

Until the market is less uncertain, until it is clearer and NBS are becoming the future business as usual, we cannot take too much risk to increase too much.
(Interviewee 17, Design/construction firm)

What can we learn from ‘grey’ infrastructure experience?

The classic tool for dealing with risk aversion is insurance, and there has been ample experience with insurance for infrastructure projects. Insurers are increasingly turning their attention to natural capital (Surminski et al., 2022; National Association of Insurance Commissioners, 2022; University of Cambridge Institute for Sustainability Leadership, 2022) and asking how they can support NBS, as well as how the decline in natural capital can impact their investment portfolios (double materiality). As an example, Swiss Re, working with the Nature Conservancy (TNC), the Government of Quintana Roo, and the National Commission of Protected Areas (CONANP) has issued the world’s first insurance policy for a natural asset by insuring a coral reef in Quintana Roo, Mexico (Golnaraghi & Mellot, 2022). Other products include underwriting risks of NBS construction and insuring against NBS market risks. However, to our knowledge there are no products that insure NBS performance or the resulting liability, for example, if an NBS does not effectively provide protection against floods or other hazards.

Given the lack of insurance for NBS performance and liability, it is prudent to ask if governments could provide this protection, or (since governments, themselves, need protection) if they might form NBS risk pools. Indeed, there is experience with public insurance against natural hazards, e.g., in Norway, the US and Spain (although the arrangements differ), as well as national risk pools, e.g., the EU Solidarity Fund. These ideas are currently explored in two recent Horizon Europe research projects: Naturance (<https://www.naturanceproject.eu/>) and Firelogue (<https://firelogue.eu/>).

2.3.11 Maintenance

The cost of maintaining public infrastructure can exceed the initial investment, a fact that is too often neglected in infrastructure policy deliberations and even in formal policy analyses. Indeed, this was emphasized by an interviewee with an urban contractor:

The challenge is that no one likes to pay for maintenance. Investment is not that big of an issue most of the time, but in nature-based solutions, working with plants on buildings, investment is just half of it. If you build a garden and you do not look after it, it will be a jungle after two or three years, and vertical gardens need even more maintenance, you need to look after it. (Interviewee 8, Construction company)

One reason often cited for the neglect of maintenance in the early assessment stages is that new projects bring more visibility to the politicians in charge, putting maintenance and upgrade of existing assets low on priority lists (OECD, 2017). Moreover, for developing countries interested in implementing any type of infrastructure, donors generally prefer to fund capital and consultancy projects, rather than finance recurrent expenditures such as maintenance that is perceived as a governmental obligation (Castalia Strategic Advisors for Evidence on Demand, 2014).

This topic was discussed by policymakers and business leaders at the PHUSICOS Policy-Business Forum, where participants emphasized the need to consider the monitoring and maintenance requirements and clearly define the corresponding budget early on in the process, as lack of maintenance may negatively impact the performance of NBS, affecting the perception and acceptance of the measures for future projects (Scolobig et al. Deliverble 5.3, forthcoming).

The importance of including maintenance costs early on in the planning of NBS was illustrated in an on-going PHUSICOS demonstration site described in box 12.

Box 12: NBS owners confront maintenance barrier in Gudbrandsdalen

The PHUSICOS NBS measure proposed for the tributary river Skurdalsåa in the Norwegian demonstrator case site, Gudbrandsdalen, entailed the improvement of a small retention dam. The case illustrated the salience of cost barriers imposed by maintenance. Under current Norwegian regulations the dam, as it was classified, would require annual inspection, which would be ill affordable for the small private association comprising the local landowners and farmers, who would be responsible for the investment and upkeep. Fortunately, the dam was reclassified to open the way for implementation of this NBS.

Source: Anders Solheim, personal communication, Feb 27, 2023

What can we learn from ‘grey’ infrastructure experience?

The World Bank encourages contracts with private contractors and operators to take an upfront commitment to the whole-of-life approach, which typically considers all aspects of the use, operation and maintenance of the project from concept development, design and construction, through to infrastructure redundancy and demolition. This commitment strengthens budgetary predictability over the life of the infrastructure and reduces the risks of financing not being available for maintenance after the project is constructed. This might usefully be considered for NBS procurement of private contractors and operators (Castalia Strategic Advisors for Evidence on Demand, 2014).

2.3.12 Negative impacts

One notable difference in NBS and ‘grey’ infrastructure is the nature of the negative impacts of conventional infrastructure on climate, biodiversity and land degradation, many of which are co-benefits of NBS. Unsurprisingly, the negative impacts of ‘grey’ infrastructure are given only moderate attention in the selected literature and are hardly represented in the NBS results shown in figure 4(b). Mainly, NBS negative impacts pertain to potential ‘ecosystem disservices’, such as eco-gentrification (Nesshöver et al., 2017; Kuban et al., 2018) or increased use pressure in the wake of an NBS implementation (Martin et al., 2021). Additionally, the use of non-sustainable materials for constructing NBS has gained attention (Bernardi et al., 2019).

In addition to impacts on the environment, the potential negative effects of NBS on jobs unless ‘just transition’ policies are put into place have been raised in a recent report by the International Labor Organization (ILO), the UN Environment Programme (UNEP) and the International Union for Conservation of Nature (IUCN) (ILO, UNEP and IUCN, 2022). Currently nearly 75 million people are employed in NBS, the vast majority (96 per cent) in Asia, the Pacific and in lower-middle income countries, although the majority of global NBS expenditure occurs in high-income countries (*ibidem*). The report warns that there is currently no guarantee that NBS employment will meet the ILO’s standards for decent work, and there is a danger of scaling up decent work deficits, such as the informal work, low-pay and low-productivity conditions that many workers in NBS currently face.

What can we learn from ‘grey’ infrastructure experience?

The barrier caused by *negative impacts* of grey interventions suggests a stronger focus on the approval process for ‘grey’ infrastructure. Instead of focusing on estimating, even quantifying, the effectiveness and co-benefits for NBS, one might wish to switch the burden of proof to require more strict documentation of the negative impacts of traditional grey infrastructure. The rationale for this shift is the near-intractable problem of estimating NBS effectiveness and co-benefits given the current lack of experience and data, a problem that will improve over time but only if NBS are streamlined for their urgent implementation. This problem was emphatically flagged by our interviews with NBS contractors (see Part 2, barrier 2). A total of 59% of respondents stated that the lack of solid information and data to demonstrate the effectiveness of NBS is a difficulty they face continuously. Without concrete evidence for demonstrating to potential customers that their proposed solutions are the preferred option, it is challenging to build a business case. Particularly crucial is when NBS are measured against grey measures with a broader range of readily assessable evidence and industry standards against which to measure them.

In legal terms, the burden of proof means that one party has the burden of proving that they are correct, while the other party is presumed to be correct. Accordingly, NBS would be assumed to be the preferred option unless the grey solution is proven superior. In cases where an NBS is considered alongside a ‘grey’ intervention, which is required under the Norwegian guidelines (box 6), the basis for the decision would be the grey infrastructure assessment and not an assessment of the highly uncertain NBS effectiveness and co-benefits. This would make it far more difficult to approve grey projects especially if a cost-benefit analysis is required based on a lengthy time horizon and low discount rate (see the discussion on CBA, Part I, section 2.3.2), thus favoring the NBS as the default option.

‘Burden of proof’ is a core concept underlying the EU’s precautionary principle. Traditionally, the person claiming that an activity could cause harm should produce proof to back up that claim. The precautionary principle reverses this. The individual or entity proposing the activity must prove that the activity is not harmful. As an important precedent, this principle was embedded in the 2007 European Regulation on Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH), which shifts the responsibility from public authorities to industry with regards to assessing and managing the risks posed by chemicals and providing appropriate safety information for their users.³ By requiring extensive testing of specified chemicals, REACH shifts the burden of proof to industry.

3 Part 2A: Knowledge on NBS effectiveness, benefits and co-benefits

3.1 Introduction

As reported in section 2, the analyses of barriers for implementation of NBS (Martin et al., forthcoming; Solheim et al., 2021) show that, by far, the most cited barrier to NBS implementation is the *lack of specialized expertise and knowledge regarding their performance, benefits and co-benefits*. This ‘knowledge’ barrier has been identified as a major concern across many cases of NBS project implementation (Chausson et al., 2020). Given the importance attributed to evidence on and knowledge of NBS performance, benefits and co-benefits in the literature, this section delves deeply into on-the-ground experience and views on the ‘knowledge’ barrier, including how it manifests in public decision making and how to overcome it. We focus on NBS for natural hazard mitigation, and we examine how it is viewed and confronted by responsible authorities in Norway. For this purpose, interviews were conducted with

³ REACH (europa.eu)

public entities responsible for disaster risk reduction at the municipal, county and national scales across Norway.

3.2 Background

NBS for natural hazard mitigation is a relatively new concept. Surveys among stakeholder groups in the PHUSICOS project have shown that the level of knowledge varies widely, from not knowing the concept at all to being familiar with it. Another recent survey to linear infrastructure owners (roads, railways, powerlines) in the Nordic Countries found that 5 of 7 surveyed owners are not familiar with either the concept of nature-based solutions or hybrid solutions (Capobianco and Palau, 2022). In both cases the survey responses showed a need for technical standards and guidelines, for illustrative examples, and success stories including the efficiency and co-benefits of NBS, and for cost-benefit analysis approaches useful for the selection of mitigation measures.

Ommer et al. (2022) have argued that the lack of evidence on NBS efficiency and their wider benefits is partly due to the shortage of comprehensive assessment frameworks for assessing and quantifying the co-benefits, including slowing climate warming, supporting biodiversity and securing ecosystem services (Seddon et al., 2019), all of which can have positive impacts on the economy (e.g., tourism), on social systems, (e.g., recreation), among many others (Ommer et al., 2022). There are also disbenefits (e.g., equity considerations if NBS improve and gentrify neighbourhoods forcing poor residents to vacate), which are often under-communicated (Ommer et al., 2022).

Seddon et al. (2019) and other authors (e.g., Nelson et al., 2020; Chausson et al., 2020; Bernardi et al., 2019) conclude that despite these benefits and co-benefits, the potential of NBS has not been rigorously assessed, and they point to concerns over reliability and cost-effectiveness compared to traditional engineered 'grey' initiatives. Policy makers and private decisionmakers need to justify investments in NBS as opposed to grey engineered measures. Increasingly throughout Europe this requires a framework for full accounting of multifunctionality of NBS and quantitative information about the value of co-benefits and disbenefits (Nelson et al., 2020). (For a discussion of cost-benefit analysis (CBA) and multi-criteria analysis (MCA) see section 2.3.2).

The lack of knowledge drives another factor inhibiting the take up of NBS, namely, limited standards, technical guidelines and legal norms (Sarabi et al., 2020) as well as the lack of long-term data on NBS performance (Bernardi et al., 2019). NBS performance and co-benefits are typically not experienced until many years after their implementation, nor are they generally monitored.

3.3 Methodology

Emails were sent to 47 identified public entities across Norway to request an interview, in some cases, emails were sent to multiple employees. The selection was purposeful to assure a good representation from different locations across Norway. As shown on table 5, the public entities included municipalities, county authorities, (national) county governors and national directorates. Norway is a unitary versus federal state, meaning that the national government is the only legislative entity. The county governors ('statsforvalter'), which are an arm of the national government, ensure that goals, decisions, and guidelines adopted by the Norwegian Parliament ('Stortinget') and the government are implemented in the counties. The county authorities operate on a more regional level and do not directly implement NBS but are closely connected with the municipalities. The directorates are entities under Norway's ministries.

In total, 13 public entities agreed to the interviews. No response was received from the majority of the contacted entities, even in those cases for which the mail was forwarded within the organization. One frequent response was inadequate knowledge to carry out the interview on the part of the invitees or others in their organization. The 13 interview responses are not statistically sufficient to be representative of Norwegian public entities, and the participation of only 'willing' entities introduces a bias in the reporting. For these reasons, the analysis only gives an indication of the knowledge and other barriers confronting the implementation of NBS.

The interviews were carried out with Teams, in two cases with a group (2-3 people from one public entity) and the remaining as one-to-one interviews. The interviews were open-ended; the interview protocol was sent to the participants beforehand as a guide. The interviews were recorded and transcribed using the built-in record- and transcription-function in Teams. Quality control and corrections of the automatic transcription were assured by going carefully over the transcription while listening to the recordings. All interviews are anonymous. The interviewed public entities have been grouped, and are given a number (e.g., Municipality 1, 2 and Directorate 1). A list of the entity numbers can be found in appendix A.

Table 5: Overview of contacted public entities in Norway

	N = 13 Agreed to participate	N = 4 Declined	N = 30 Did not respond
Public entities			
Municipality	6	1	18
County Governor	2	2	5
County authority	3	1	4

Directorate	2		3
Municipality type			
Larger > 20 000 persons	5	1	8
Smaller <20 000 persons	1		10
Roughly location (directorates not included)			
North	1		5
South	2	1	2
East	4	1	10
West	4	2	10

The interview protocol (available in Appendix A) consists of ten questions; it covers a range of issues including but not limited to those addressing the knowledge barrier. The full questionnaire, the entities that responded, and selected representative responses can be found in Appendix B. This section focuses mainly on those questions (2-7 in Appendices A and B) that address the knowledge barrier; responses to other questions are cited in Part I.

Where possible, the responses to the questions have been grouped into the subsections found below along with the most pertinent and representative responses. In some of the interviews not all the sub-questions were asked, and for some of the questions the person(s) did not answer the question they were given but responded more broadly.

3.4 Interview results

In many ways the Norwegian interview results mirror the literature reviews discussed in Part I. Indeed, they bring the literature to life in the sense of showing how the knowledge barrier affects public authorities in their everyday infrastructure deliberations. The importance, even dominance, of this barrier became apparent. Many interviewees mentioned ‘lack of knowledge’, including difficulties in quantifying risk and risk reduction, as the distinguishing feature when deciding on NBS. The lack of knowledge is also closely related to responses mentioning that NBS often require more multidisciplinary work. Beyond knowledge, the interviewees offered opinions on other barriers. For example, since an NBS can require more space than traditional solutions, and hence affect more landowners, it is more challenging to implement in densely populated areas (see section 2.3.8 on land ownership and availability). Greater uncertainty regarding costs of NBS (see section 2.3.5 on lack and complexity of financing) and less data compared to a grey solution were also mentioned by interviewees from different responder groups. Overall, grey solutions are well known, and hence easier and safer to implement (path dependency).

3.4.1 Awareness and experience with NBS

Do you have any experience with projects where nature-based solutions have been considered, yet a traditional solution was chosen?

Do you have experience with projects where nature-based solutions have been implemented, and, if so, and what factors led to the choice of a nature-based solutions?

The interviews revealed limited direct experience with regard to considering and ultimately implementing NBS. This is partly due to the responsibilities and mandates of the interviewees. The county authorities only advise the municipalities and thus are not directly making investment decisions. While the national directorates, e.g., the public road authorities, can implement NBS, interviews were only conducted with the railroad directorate, which makes financial investment decisions. They reported having sparse experience with NBS. Four of the interviewed municipalities, on the other hand, were in the planning stage of implementing NBS, and many appeared to have some NBS experience and knowledge. However, only one municipal interviewee cited an example of implementing NBS, albeit before the terminology of NBS was known.

[...] But the municipality has done many things that are nature-based in the past, without really thinking about that term, [...] perhaps without being so aware of these additional values. (Municipality 1)

Two municipalities had been involved in NBS planning stages, but the NBS were not brought to fruition, in one case because the developer withdrew:

We have been involved in several regulatory plans and technical plans, that have been ambitious at the planning stage[...] when it comes down to it the developer withdraws. (Municipality 1)

3.4.2 Knowledge and resources to employ NBS

Do you have the necessary knowledge and resources to implement NBS?

While there was little direct experience with planning and implementing NBS on the ground, there did appear to be some knowledge of and resources for employing NBS. Authorities at half of the interviewed municipalities (3) and half of the directorates (1) stated that they have knowledge. According to a municipal interviewee:

I get a lot of knowledge about it, about the problems and possible solutions, so I certainly have the knowledge to contribute. (Municipality 6)

A further two municipalities, a county authority and county governor reported having some NBS knowledge, e.g., one county authority stated:

[...] I would like to think that I might have the knowledge, to sort of order right (type of NBS), and that's what I think many municipalities struggle with, that they may not have the knowledge to get the whole thing together [...] that you get the solution you need. (County authority 3)

When asked where they had gained this knowledge, responses included *'through education and through working on several projects'*. However, lack of knowledge also appeared and even dominated as a problem, making it difficult to understand when, where and what type of NBS would be appropriate to use. As one interviewee put it, if you are unsure about what you need, it is challenging to hire a consultancy firm. Not only does the municipality need knowledge to frame the terms for contracting or even designing NBS, but also for managing and overseeing the work:

[...] was supposed to have a nature-based urban runoff solution where they established a rain garden higher than that area (the project area), so all the water flowed down to an unwanted location. [...] there you could say that the developer should have had the competence, but you also need that competence internally to be able to go through the plan to see if it will work as intended. (Municipality 3)

A very cogent statement from a county governor, who mainly oversees activities of municipalities from the national perspective, summarizes the challenge:

No, I think that the capacity, both in terms of personnel and finances, is not present [...] When you have such small municipalities, the administrative resources are also small, and therefore I do not have much faith that this type of solution can be achieved in these municipalities [...] (County Governor 1)

3.4.3 Knowledge and salience of co-benefits

(In addition to DRR) Which positive side effects would you say are most important when considering implementing NBS?

With few exceptions, the public entities viewed biodiversity, recreation and health as NBS co-benefits that are aimed primarily at reducing flood, landslide or other disaster risk. Two entities (municipality and county authority) added water and environmental quality to the list. Noticeably missing was any mention of climate change mitigation.

For the most part, and this is the positive news, many entities reported that co-benefits are considered when thinking about implementing NBS, albeit qualitatively given the difficulties in quantifying especially the benefits of biodiversity. However, the co-benefits appear to be an ‘add on’ and not decisive for the decision:

Yes, it (co-benefit) will be included although it may not be the primary thing. Flood prevention measures are expensive so if it has some more positive effects then that's good. (Municipality 6)

As another municipality put it:

[...] It (the co-benefit) will probably end up at the bottom of the list, cost will always override a lot here. (Municipality 4)

3.4.4 Information and resources needed to implement NBS

What information or resources would be most useful in deciding whether to implement nature-based solutions instead of traditional infrastructure? e.g., cost-benefit analysis or other statistics?

Table 6 summarizes the types of information/resources that the interviewees mentioned as potentially helpful in their decision to implement NBS. Particular emphasis was given to an accessible data base of NBS reference projects from Norway and other countries, which would help in the identification of the most promising NBS for their case, as well as inform them on what can go wrong.

Table 6: Summary or types of NBS information/resources considered helpful by the interviewees

Type of information/resource	Description	Public entity mentioning
Collection of reference projects	Easily accessible collection of NBS examples: what did the implementers do?; how was it done?; what worked?; what didn't?	County authority 3, County Governor 2, Municipality 2, 3, 4, 5, 6, and Directorate 1
A planning tool for initial analysis	A tool that takes the initial conditions of an area (land coverage, settlements... etc.), and suggests a suitable type of NBS (such as NGI's Larimit (www.larimit.com))	County authority 2, and County Governor 2
Quantification	A method for quantifying NBS effects for comparison with 'grey' solutions	Municipality 6
Cost-benefit-analysis	Routine cost-benefit-analysis, which will make it easier to justify an NBS	County authority 1, 2, County Governor 2, and

		Municipality 3, 4
Conferences	NBS conferences to increase and spread knowledge, also by inviting several persons from the same entity	Municipality 2, and Directorate 2
Knowledge among consulting firms	When you hire a consulting firm for a job, it should suggest an NBS when possible	Directorate 2

4 Part 2B: Contractor expertise

4.1 Introduction

In the implementation of nature-based solutions, contractors play a crucial but often overlooked role. Contractors include a wide range of private sector companies, such as consultancy and engineering firms, construction firms, landscape architects, material suppliers, and data collection firms, which employ a wealth of expertise, including, for instance, ecologists, hydrologists, foresters, IT, gardeners, and many more. They are commonly tasked with the design, construction and/or maintenance of solutions following a bidding process initiated by the project initiators or owners (usually public entities). Results from Martin et al., (forthcoming) indicate that a lack of experience and knowledge on the part of contractors is one of the principal barriers affecting the successful implementation of NBS. This is also emphasized by Mačiulytė & Durieux (2020), who found that difficulties in finding skilled NBS suppliers from the private sector is a common challenge in the implementation of urban NBS. Deepening the understanding of the existing competences and limitations of contractors is essential to identify potential strategies capable of avoiding cost and improve quality and, simultaneously, to build confidence in NBS, as well as promote their upscaling and replication. Furthermore, by gaining a broader view of the challenges faced by contractors, correlations can be established with other barriers for NBS implementation (see Martin et al., D5.2, forthcoming) for an overview), and multi-benefit policy innovations can be proposed.

In this section we present a brief overview of the current literature on the expertise of NBS contractors, followed by a summary of the results obtained from interviews with private sector companies involved in NBS design, construction and maintenance. Twenty semi-structured interviews were conducted to address questions like, what barriers and opportunities do conventional construction firms see in expanding their expertise? what NBS capacities need to be built? how can public authorities foster synergies between different types of expertise? how do contractors define gaps for NBS project preparation? what type of facility could support them? are there policies in place

that hinder or support NBS private sector upscaling? The interview protocol and a short description of the interviewee's profile can be found in Appendix C.

4.2 Background

Because NBS projects require a wide range of multidisciplinary competencies, their deployment calls for manifold skills and knowledge, often by exploiting local knowledge on the part of stakeholders to ensure an acceptable performance (ILO et al., 2022). Private sector actors can participate at different phases of the NBS realization process, most frequently assuming the roles of implementers (18%), neutral mediators (25%) and knowledge providers (15%) (Zingraff-Hamed et al., 2020). Private agencies commonly act as temporary contractors hired through direct contracting or following a bidding process to perform a specific job for a given period of time. They encompass a diversity of firms such as landscape architects, material suppliers, consulting firms, data collection companies, managers, and engineering and construction companies (ILO et al., 2022; Kooijman et al., 2021; Zingraff-Hamed et al., 2020) (see fig 5). Despite a lack of clarity in the literature, the decision-making authority of contractors can be dependent on the discretion of project owners or managers and the timing of their engagement, which should be stipulated as part of a plan developed during the feasibility phase of the project (Brill et al., 2022).

By providing expertise and resources to the often less experienced project authorities, contractors are key enablers of NBS implementation (Tilt & Ries, 2021). However, recent studies (as well as this research, see fig. 3) show that the lack of NBS expertise and knowledge by private service providers is one of the main barriers that solutions currently face (Kuhlicke & Plavsic, 2021; Martin et al., forthcoming). NBS knowledge gaps vary in nature, for example, enterprises with strong technical/ecological skills can have poor business and communication capabilities (McQuaid et al., 2021). The effects of such knowledge and skill gaps include, to name a few, difficulties in finding skilled providers (Mačiulytė & Durieux, 2020), low response to project tenders (McQuaid et al., 2021), poor data collection and difficulties in conducting robust project evaluations (European Commission, 2021b), and negative impacts on the cost and quality of the deployed measures (Mačiulytė & Durieux, 2020).

NBS Project Stages				
Assessment and planning <ul style="list-style-type: none"> •Consultants 	Design <ul style="list-style-type: none"> •Designers •Landscape firms •Consultants 	Implementation <ul style="list-style-type: none"> •Construction/engineering firms •Material suppliers •Landscape firms 	Monitoring and evaluation <ul style="list-style-type: none"> •Data collection firms •Data analysts 	Maintenance <ul style="list-style-type: none"> •Construction companies •Landscape companies

Figure 5: Examples of private contractors/service providers involved in the life cycle of NBS projects. Adapted from (Brill et al., 2022, p. 5). Sources: (Brill et al., 2022; Kooijman et al., 2021; Moreau et al., 2022; Zingraff-Hamed et al., 2020)

Developing appropriate skills can enable enterprises to implement NBS more efficiently while fostering the creation of just (fairly compensated) employment opportunities (ILO et al., 2022). This requires equitable learning opportunities for those in charge of executing the solutions on the ground (Mabon et al., 2022). As emphasized in Part I, NBS knowledge and exchange platforms are also needed to develop clear standards and safeguards to guide the design and construction of NBS (UNEP, 2020), as well as to enable NBS upscaling (Fastenrath et al., 2020).

4.3 Methodology

For this qualitative research, 20 semi-structured interviews were conducted with private-sector professionals working in the provision of a diverse range of NBS services from disaster risk reduction measures (DRR) to the installation of vertical gardens or the design of landscape restoration areas, in both rural and urban areas. The interviewees were initially identified from among the participating companies at the PHUSICOS demonstration sites, as well as from the Connecting Nature Business Platform, an online database providing contact information of nature-based enterprises (NBE) (Kooijman et al., 2021). For a list of countries of the interviewees, see Appendix C. Selection criteria included geographic location (Europe) and language (English or Spanish) to facilitate communication with the researcher. Of the 49 experts contacted by e-mail, 20 from 20 different companies agreed to be interviewed remotely. Most participants fell into two contractor categories: consultants and construction firms (table 7). Questions were tailored accordingly for the design of two different questionnaires, one for consultant firms and one for construction firms (Appendix C). In both cases, the questions focused on i) the company's experience with NBS, ii) perceived internal and external barriers

and facilitators linked to NBS implementation, and iii) perceived opportunities for future involvement with NBS. Construction company interviewees were also questioned about their interest in continuing to participate in NBS projects and the actions they take to be competitive in the sector. The semi-structured nature of interviews allowed the researcher to clarify responses and ask unscripted questions when pertinent.

It should be kept in mind that most of the interviewees could be classified as representing nature-based enterprises (NBE) according to the typology designed by (McQuaid et al., 2020); yet we do not make use of this classification as a number of the participating companies are traditionally engaged in economic activities far removed from NBS projects and have only recently participated in NBS projects.

Table 7: List of NBS contractors interviewed per type of experience.

Type of expertise	Count
Consultant	6
Construction	4
Design, Construction	3
Consultant, Design	2
Design	2
Environmental	
Organization	1
Insurance	1
Researcher	1
Grand Total	20

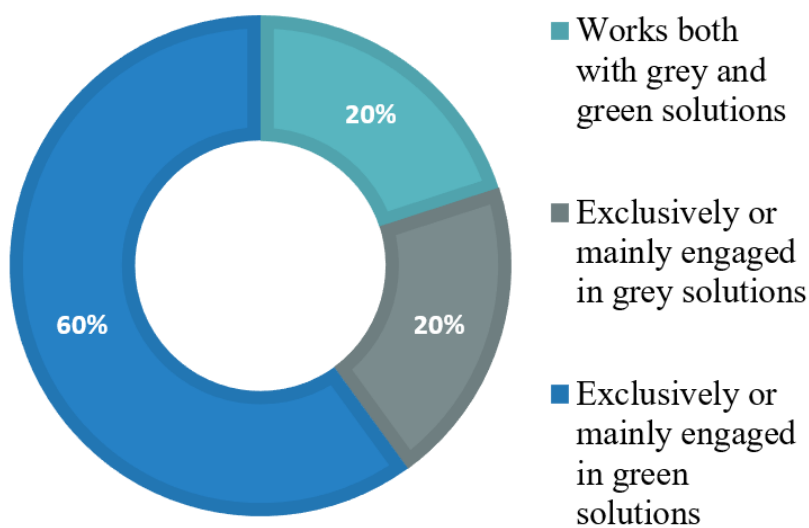


Figure 6: Share of reported NBS experience of interviewees.

Following familiarization with our data by re-listening to and transcribing the interviews (as well as translating when necessary) the anonymized transcripts were subjected to a thematic analysis (Jason & Glenwick, 2016) using the QSR International’s Nvivo software. First, guided primarily by the topics covered in the interview questions, initial codes were generated manually with the objective of organizing the data into meaningful units. Subsequently, all codes were reviewed, refined and hierarchically organized into broader themes and sub-themes (figure 7) to generate consistency of information to allow for greater clarity of the results.



Figure 7: Coding framework illustrating broader themes

4.4 Interview results

Table 8 summarizes the barriers and potential solutions to overcome the barriers identified by interviewees that could directly or indirectly influence their ability to acquire or expand their expertise in offering nature-based solutions. The barriers and their potential solutions are clustered into "factors" and further discussed below.

Table 8: Barriers and potential solutions for enhancing contractor expertise as identified by interviewees

Factor	Barrier	Potential solution
Economic/market	<ul style="list-style-type: none"> ○ Uncertainties over future demand/ lack of demand for NBS projects ○ Grey path dependency ○ Lack of funding ○ Competition (for small companies) 	<ul style="list-style-type: none"> ○ Collaborations ○ Increased competition ○ Growing market ○ Networks ○ Temporary outsourcing of services

Knowledge / education	<ul style="list-style-type: none"> ○ Lack of measurable evidence/data supporting the benefits of NBS ○ Lack of practical NBS experience ○ Difficulties in finding/retaining qualified employees ○ Need for multidisciplinary skills ○ Complexity of NBS projects 	<ul style="list-style-type: none"> ○ Building multidisciplinary work teams ○ Use of local knowledge ○ Reference projects ○ Attending NBS-related events and trainings
Legal/ regulatory	<ul style="list-style-type: none"> ○ Incomprehensible regulations and legislation ○ Lack of NBS-specific regulations and standards ○ Bureaucracy 	<ul style="list-style-type: none"> ○ Creation of legislative obligations ○ Non NBS-related regulations in place
Socio-cultural	<ul style="list-style-type: none"> ○ Silo mentality 	<ul style="list-style-type: none"> ○ Positivism regarding the future development of the market ○ Environmental consciousness within the company/willingness to learn
Technical technological /		<ul style="list-style-type: none"> ○ Access to innovation ○ Modelling tools
Others	<ul style="list-style-type: none"> ○ Liability ○ Economic risks/ risk aversion 	

4.4.1 Financial/market factors

Uncertainties over future demand/ lack of demand for NBS projects

Findings from our interviews indicate that factors related to the demand for NBS are among the potential influences on the increase in NBS experience by contractors. While 88% of the 17 contractors interviewed admit that they have noticed a growing interest in the application of NBS, slowly translating into demand, notably from public authorities, they prefer to be cautious when taking decisions on the growth of their company.

Until the market is less uncertain, until it is clearer and NBS are becoming the future business as usual, we cannot take too much risk to increase too much.
(Interviewee 17, Design/construction company)

According to a member of a Spanish-based construction company with little NBS experience (having only participated in one NBS project), investing in expanding their

NBS skills and knowledge would only be deemed valuable if there is certainty of a higher need for such expertise in the future. In this scenario, they would allocate resources (monetary or time) until more NBS projects are promoted and launched.

The training is usually at the same time or posteriori. You cannot say 'I am going to train because I am going to implement these projects later', because you do not have the capacity to decide. I would not train people in this solution because if the administration does not carry out works or does not tender this type of project, it would be useless. (Interviewee 10, Construction company)

Furthermore, respondents indicate that in the absence of an explicit requirement for the application of NBS in calls for tenders, contractors are not stimulated to create or expand capacity. The responsibility for proposing NBS rests with the applicant, but interviewees indicate that they are limited by lack of information and data to support NBS over grey or traditional solutions. Moreover, small companies find themselves disadvantaged by larger competitors with more experience or capacities. Here, collaboration and networking are strategies that appear successful in boosting market share. According to 70% of the participant contractors, collaborating with peers allows them, among other things, to take part in more projects and increase their knowledge and practical experience.

Grey path dependency

Our results also reveal that the market's tendency to stick with traditional 'grey' approaches constrains the expansion of NBS and, therefore, on broadening experience of companies engaged in their implementation. Even though many project owners perceive that green initiatives can be equally or more productive, the desirability of carrying out standard procedures often wins out. In the opinion of some interviewees, this is related to other aspects, such as the lack of incentives (e.g., legal obligations or financial support) to encourage the private sector to opt for NBS or the ease of the public sector to use existing equipment and knowledge and avoid out-of-the-ordinary considerations. At the same time, interviewees indicate that this problem also characterizes contractor experience:

What I see is that both designers and construction companies are used to pouring concrete, but they are not used to using the solutions that nature often offers and that are equally or even more efficient. (Interviewee 2, Construction company)

Lack of knowledge can be an internal challenge. Design engineers in this company have always been doing the same thing. They just use the same design approach and it is easier that way. We know the cost, we know how to estimate the costs, we know how to put a business case together. Going through a new approach means thinking outside the box, working out a business case together for my boss, and convincing

him. How do I cost this or that? So, knowledge and staying in the comfort zone I think are two issues. (Interviewee 13, Consultant/design company)

In the opinion of respondents, this barrier might be overcome with greater efforts to raise awareness about the possible applications and benefits of NBS, for example, through training and education of public officials who usually possess more power measures.

Lack of NBS financing/funding

Keeping costs to a minimum remains a major concern for infrastructure proposers, which is also reflected in earlier findings (see section 1.3). For example, an interviewee carrying out EIAs for infrastructure projects had this to say:

They [infrastructure proposers] just ask what's the bare minimum to get them through planning. There will be very conscientious applicants that you know are considerate of the environment. But if it's not legally required, then they don't ask us to quote a price for that (the assessment), or they don't ask us to do it. (...) We have proposed options that are good for biodiversity, and sometimes they'll go "yes, but if it doesn't cost a lot of money, then that's fine". But mostly, clients will complain if it's costing more money or delays. (Interviewee 11, Consultant)

Echoing recent literature, participating companies explicitly mentioned the need to develop their market and expertise for more sufficient and long-term investment in NBS projects, and 41% of the contractors cited the need for greater funding. Information provided suggests that insufficient funding is attributable to other barriers such as the lack of adequate knowledge, limitations to clearly establish the effectiveness of NBS, and failure to integrate their multiple benefits across sectors and over the long term. On this topic, contractors recommend reconsidering the way in which public funds are allocated to these projects. As an example, one respondent suggests that multiple administrations, such as water, infrastructure, and education among others, merge together to finance joint projects that would deliver benefits to all. An interviewee from France expressed the opinion that tourism taxes should be used to finance, for example, reforestation initiatives.

I think that moneywise, public sectors need to start thinking about coupling or joining multiple benefits to a project. (Interviewee 1, Design company)

The importance of long-term financing to ensure the effectiveness of NBS measures was also emphasized. Because a longer time frame is required to observe NBS impacts and to recover the initial investment, long-term financing is cited as necessary for maintenance issues. Judging from the information provided by interviewees, documenting the success of NBS projects is vital to provide assurances on both the

demand and supply side. A respondent from Germany, who works for both the private and public sectors, states that this situation is observable in both cases:

“The challenge is that no one likes to pay for maintenance. Investment is not that big issue most of the time, but in nature-based solutions, working with plants on buildings, investment is just half of it. If you build a garden and you do not look after it, it will be a jungle after two or three years, and vertical gardens need even more maintenance, you need to look after it. (Interviewee 8, Construction company)

Competition (for small companies)

Small construction companies report that bidding on projects is often hampered by competition from larger or more experienced companies, which can be exasperated by NBS high operating costs. According to an interviewee working at a firm that provides water purification services by plants and microorganisms, legal regulations increase the costs of laboratory analyses. In this case, clients may prefer contracting a ‘grey’ competitor.

Clients in the end decide that they do not want to have such high operation costs. So, it means that sometimes we lose to other solutions that are cheaper...easier and simpler to implement and maintain. (Interviewee 7, Design/construction company)

Nevertheless, NBS-oriented firms report engaging in collaboration to gain access to projects, that is, linking with universities and local companies already familiar with the topic, local regulations and the implementation environment.

4.4.2 Knowledge related factors

Lack of measurable evidence/data supporting the benefits of NBS

A total of 59% of respondents stated that the lack of solid information and concrete data to demonstrate the effectiveness of NBS is a difficulty they face continuously. Without concrete evidence for demonstrating to potential customers that their proposed solutions are the preferred option, it is challenging to build a business case. Particularly crucial is when NBS are measured against grey measures with a broader range of readily assessable evidence and industry standards against which to measure them. As one of the interviewees providing consultancy services expresses:

Having proof is a barrier. People such as water companies always say: “I know if I buy concrete, the engineers would tell me exactly what it will stop, but you guys cannot”. So that is a big problem. (Interviewee 16, Consultant)

An important feedback loop seems to exist in this regard. Having credible evidence to support NBS would lead to increased demand and enable contractors to build further

expertise. At the same time, gaining greater expertise and awareness of such solutions would help in acquiring evidence.

The fact that solutions that implement living plants are a bit harder to calculate accurately is a bit of a problem. But with more research and with more experience that should improve as well. (Interviewee 7, Design/construction company)

One interviewee noted that demonstrating to the public what works or does not work with NBS should be accelerated to drive the market.

Definitely, I think we have to use data science to assess what is working and what is not. And that needs to be linked. Because market should grow faster, and to make it faster we need to have more information. A database of example cases that work for given situations and scenarios. (Interviewee 14, Consultant)

Finally, the participants in this study also point out the necessity for past successful projects to be promoted so that they can serve as a reference for service providers and the general public to learn from them. Reference projects are seen by interviewees as an opportunity to increase confidence in the use of NBS. However, they also stress the importance of maintaining and monitoring past initiatives over the long term after implementation to supplement evidence of their impact with verified information.

Lack of practical NBS experience

A further reported barrier is the lack of practical experience in implementing NBS. For two of the companies interviewed, both of which are involved at the construction stage, their experience is limited to a single project. According to the information they provided, their participation was driven by the invitation from a project coordinator to apply for the projects in questions. The invitations were motivated by the fact that one local company was considered to have the required skills and the other local firm was tackling similar problems with grey approaches. One interviewee reported having little former experience due to lack of training:

People are not used to it (NBS) because they don't have any training in this field. Unless it is someone with an environmental background or a forestry engineer, as in my case, a civil engineer, they have not had any of this in their training and in fact they are all those who carry out the works, those who do the projects. So, the problems come more from there (Interviewee 2, Construction company)

Difficulties in finding/retaining qualified employees

When questioned about the challenges they face to recruit or train new staff with the skills and knowledge that NBS implementation or design requires, five contractors explicitly indicated it to be a struggle. In most cases, contractors expressed that the

growing interest in NBS is not necessarily translated into junior professionals with practical knowledge rather than purely research skills. As earlier cited, the interviewees report using in-house training as the solution. Of the 20 interviewees, 50% mention that the company focuses on training new employees by means of constant hands-on learning in the field, the attendance of conferences and by the progressive assignment of small responsibilities. On this subject, an interviewee from a company specialized in the design and execution of landscape restoration, conservation systems and the naturalization of urban spaces (mostly by means of NBS), depicts this barrier as one of the main difficulties encountered by the company, sometimes hindering its ability to meet the demand for projects. In his words:

Still today our main problem is having people that can work with us and sometimes we need to tell our customers that we cannot do the work because we do not have people. So, this is one important thing. (Interviewee 19, Design/construction company)

A contractor specialized in the design and construction of NBS also noted his company's difficulty in retaining personnel. In his opinion, the problem is that employees look for alternative jobs offering more promising careers and salaries.

It would be nice if we could find more engineers, electricians that would be interested in this area, which they are, but they are probably offered better salaries elsewhere, or more promising or safer careers perhaps elsewhere. That is a bit rough for us. That is a bit difficult. (Interviewee 7, Design/construction company)

Need for multidisciplinary skills

Interviewees emphasized that the implementation of NBS requires developing an understanding of their different uses, benefits and variants, which requires significant communication and coordination across the company. This, in turn, can entail delays for NBS implementation as compared to other types of solutions.

One problem is that nature-based solutions are very multidisciplinary projects. All the different partners must work in areas that are outside their comfort zone, that are new to them, which causes them a little bit of hesitation. This also lengthens the design process or the preliminary works as requires coordination and finding a solution in which everybody has clear what they need to do. That is always our perception when nature based solutions come into play, that all partners need a few extra loops until they are ready to go with the solution. (Interviewee 7, Design/construction company)

We use a multi professional team approach because there are a lot of aspects to be covered. So, the agronomical part, the geological part, the engineering part, and all must be naturalistic because you are involved with the environment. So, usually our

team, the architecture for the landscape, we have a team that it is always five, six different professional figures. (Interviewee 20, Designer)

Complexity of NBS projects

The complex nature of NBS as compared to other widely known 'grey' solutions seems to be yet another aspect with the potential to impact the ability of contractors to operate effectively. To illustrate, an interviewee making use of plants for water, air and soil purification, refers to the challenges they face given the dependence of living organisms on climatic factors. In his opinion, not only is it complex to work with this NBS, but also to effectively calculate the benefits. As they are "not as straightforward" solutions (interviewee 13, consultant, designer) consultancy firms or designers, who often have a greater influence on final project decisions, may at times be hesitant about integrating NBS into projects.

The other thing is interesting about it is that we tend to see solutions as being very basic, okay, we just plant one type of tree, you know, and now we're starting to dig deeper into the complexity of these nature's solutions. (Interviewee 14, Consultant)

4.4.3 Legal/regulatory factors

Lack of NBS-specific regulations and standards

Findings indicate that contractors are concerned about the lack of clear standards and requirements to assure NBS quality or compliance at the design and implementation stages.

Traditional engineering solutions usually have codex that you can use, and which is admitted by law. While on the other hand, nature-based solutions can have more variable results and are not codified. (Interviewee 20, Design company)

While respondents recognize that guidelines may be under development, some favour the creation of industry standards for greater reliability and to keep improving their expertise.

Having industry standards will help improving as it would build experience and permit getting better proof that these things [NBS] do work. (Interviewee 16, Consultant)

Furthermore, according to the interviewees, legal requirements might encourage risk-taking on the part of contractors, who, in the view of one of the consultancy firms, would be more willing to take risks and invest in training. as confidence would arise in that they would have enough work to cover the costs of acquiring the new knowledge.

That [legal requirements] would put the training on to the contractor. But because they have got enough contracts, they can take a risk of doing the training, investing in new tools because the public sector would go "here's a call contract for 100 units", and then they decide, "Okay, well, I am going to make this much profit. So, I am doing it" (Interviewee 13, Consultant/designer)

Bureaucracy

To a lesser extent but still mentioned is the issue of bureaucracy and the long procurement process of NBS. Although not specific to NBS, interviewees emphasize that if their client is the public sector, companies must learn to deal with administrative bottlenecks. In accordance with a consultancy firm in Ireland, acquisition times for planning permissions, for example, are lengthy for both grey and presumably green solutions (in their case, they work mostly with grey). In Italy, according to another NBS design firm, working for the public sector means that project completion can take several years even in the case of small projects.

Public projects have an administrative process that is quite different from the private one, it is more difficult and more constrained. The administrative part is different, not the design which is almost the same...In the private sector we have to deal with public authorization. So, it is bureaucratic from that side, but in all the process there are many constraints and bureaucratic stops, especially when you work for the public sector. (Interviewee 20, Designer)

Again, as with most of the other challenges mentioned, the main link between barriers to NBS adoption and contractor skill level is that the reduction in the number of NBS projects deployed translates into barriers to developing hands-on experience - a feedback loop.

4.4.4 Socio-cultural factors

Silo mentality

Another common response from interviewees, both from construction and design firms, is the need to change the silo mindset of project owners. According to one designer respondent, a main obstacle to increasing demand for NBS is not necessarily a lack of funding, but rather a failure to change the mindset of project owners so that the multiple benefits of these types of solutions are integrated and properly weighed against the costs of the measures.

I think we should start looking at the budget from a different angle in that respect, it will not be like "Oh, we don't have money". It is just investing your money differently and in a more intelligent way. (Interviewee 1, Designer)

In the case of construction companies, having little influence on the type of projects and their specifications could in some cases affect the level of NBS that is incorporated. Interviewees indicate that depending on the mindset and priorities of project owners (e.g., preference given to grey solutions due to greater familiarity, or vice versa), the measures carried out may be more or less environmentally friendly. Although in many cases the contractors may offer suggestions, the project owners take the final decision.

4.4.5 Technical factors

Our interviews yielded little discussion of technical or technological aspects for NBS implementation. While none of the companies referred to these elements as barriers, four respondents emphasized that technology is instrumental in providing information about the effectiveness and performance, including the modelling, of NBS. Two interviewees stressed that technology is useful for monitoring NBS measures, such as trees planted in a newly reforested area, or for monitoring the performance of green water purification systems.

I think technology does help. When we are in the project stages, our design stages, it help because we can ask our hydrologists or ecologist, for example, to model certain territories to observe where the water flows, where do we have to drain, where do we have to infiltrate, and so on. (Interviewee 1, Designer)

4.4.6 Other challenges encountered by contractors

Liability

Finally, the issue of liability linked to NBS performance appears important and complex for both design and construction companies. The distribution of responsibility appears unclear. One French design company mentions that their projects must be reviewed and approved by insurers due to potential liability risks for which they are responsible over a period of 10 years. Other companies note, however, that in case of an incident linked to the functioning of the measures (particularly in the case of projects aimed at reducing the risk of natural disasters), identifying the responsible party would be a complicated task. Interviewees from construction companies, for example, indicate that they only follow the project architecture provided by designers and engineers:

There we would have to see who is responsible, it would probably be responsibility of the engineering firm that made the calculations, because in the end we just execute what we are asked to do. If we are asked to build a three-meter wall, then we build a three-meter wall. (Interviewee 10, Construction company)

Moreover, the interviewees agree that maintenance is of paramount importance during the first years to ensure a satisfactory performance. In this case, it would also be relevant

to establish whether the maintenance activities have been carried out correctly, as well as to establish the responsible party.

Economic risk

Like the owners or initiators of NBS, contractors are also risk averse, especially given the multitude of recent crises affecting businesses:

But with the many crises we are having recently, and everybody is scared. I don't know if people are willing to take risks on nature-based solutions or invest for the benefit of everyone but with a smaller economic marginal profit. (Interviewee 7, Design/construction company)

5 Learning from implementation barriers

If the European Union is to meet its ambitious biodiversity and climate goals, it will need to greatly expediate and scale up the implementation of nature-based solutions. The conclusion of this analysis, which has focused on DRR infrastructure, is that NBS implementation faces almost intractable challenges requiring incremental changes as well as a transformation in how we assess, value, finance, and permit nature-based infrastructure.

The barriers to NBS implementation are manifold: Poorly staffed municipalities with little experience or expertise with NBS, combined with a dearth of evidence on their effectiveness and co-benefits, appear to be the norm across Norway and, no doubt, across many countries in Europe and beyond. Lack of capacity and knowledge is compounded by a lack of funds earmarked for NBS, and there is a fundamental problem in attracting private financing given the public-good nature of NBS and thus the shortage of bankable projects. The essentiality of valuing and funding NBS co-benefits means that implementation cuts across multiple institutions, jurisdictions, levels of government, policy areas and professional disciplines, which makes it difficult to coordinate and fund. Moreover, politicians focus on short-term goals that bring voter support; yet NBS infrastructure has long-term impact and gestation periods. Given these and other hurdles documented in this deliverable, it is not surprising to witness a formidable 'grey' infrastructure path dependency.

5.1 Learning from barriers across the NBS policy process

The 12 barrier clusters identified in the NBS and 'grey' infrastructure literature, complemented and extended by the deep dives into Norwegian as well as contractor experiences, have revealed important lessons on NBS implementation across all NBS implementation phases. Without being comprehensive, in this section we briefly list and

summarize a few of the most salient lessons that can lead to governance reforms for NBS planning, design and permitting, financing, procurement, construction, maintenance and monitoring. In section 5.2, we focus on those barriers most unique to NBS and venture six systemic reforms that can potentially overcome ‘grey’ infrastructure path dependency, and ultimately enable NBS at scale.

Planning, design and permitting

Initiating NBS through planning and design processes and, above all, permitting their construction, are riddled with hurdles. Yet, many barriers have been successfully addressed in the history of ‘grey’ infrastructure, especially through co-design, the ‘smart’ application of decision support tools, the development of standards/guidelines, the simplification of permitting procedures for urgent infrastructure, and the availability of skilled experts. Lessons for the NBS community include:

- **Polycentric arrangements**, especially for merging financing sources across multiple administrations, will be necessary for comprehensively including NBS co-benefits.
- **Cost-benefit analysis and other decision support tools** cannot be the sole input for permitting infrastructure, but can assess highly uncertain and intangible impacts and in so doing provide transparent input to stakeholder deliberations; they should be considered as input for NBS planning, design and permitting decisions.
- **Skilled experts** for ‘grey’ infrastructure design and planning are in good supply given the wealth of universities offering top-quality engineering, urban planning and other relevant courses. These university courses can be straightforwardly extended for training specialists, for instance, in environmental engineering with a focus on NBS and also in much-needed interdisciplinary fields. Moreover, as emphasized by interviews reported in section 4.2.2, trained technicians and other skilled workers are in short supply. Here, too, the NBS community can learn from implementation of ‘grey’ infrastructure, where the supply of skilled workers has been facilitated through vocational training, apprentices and hands-on learning on the job.

Financing

The large gap in EU financing for NBS as well as financing at the local (municipal) scale can benefit from taking a close look at ‘grey’ experience, especially the upsurge of private financing for renewable energy. While this experience cannot be fully transplanted to nature-positive investment (given its public-good nature), there are lessons including:

- **Standard and novel financing mechanisms** include bank loans, bonds and equities, which can be usefully built upon for financing NBS; less used instruments include payments for ecosystem services, green/resilience bonds, possibly a new asset class for NBS to encourage more investment, and recent novel insurance instruments.
- **Taxpayers** have supported private companies investing in grey infrastructure, e.g., with subsidies, tax advantages, public-private partnerships, blended finance, and public guarantees, all of which are being extended to NBS.
- Extending the **EU taxonomy** will encourage divestment by classifying nature-negative investment, which is a powerful instrument insofar as it encourages NBS by discouraging nature-negative investing.

Procurement and construction

A predominant and frequently referred to barrier for procurement and construction is the lack of clear guidelines and standards to guide contracting firms and judge private company bids, as well as the legal requirements that often cause long delays. Again, the history of public infrastructure can provide insights in overcoming these barriers.

- **Industry and government standards** like Codex and ISO standards have proven essential for providing contractors a safe operational space with reduced liability risk; efforts should continue in developing NBS standards and guidelines.
- **Insurance** is an important tool for transferring the risk of ‘grey’ infrastructure construction and damage from storms and other hazards, and recent new products have extended novel types of cover for NBS; however, there appears to be little appetite on the part of private insurers for liability products, which may be best offered by governments.

Maintenance and monitoring

- NBS maintenance and monitoring are two of the more neglected costs of NBS implementation that can introduce a significant cost barrier. Still, it is important to include both activities in costing investments in nature.

One lesson is valuable across the entire NBS implementation process, that is, the importance of stakeholder involvement. Co-design is the approach of actively involving stakeholders throughout the planning and permitting stages. Even before a project is on the table, it can be useful to involve stakeholders in framing the problem and co-producing relevant knowledge. It can be equally useful to involve stakeholders in the

assessments as well as in overseeing the construction of NBS, and often citizens are part of the monitoring process.

5.2 Learning from barriers: six suggestions for policy reform

In this final section, we build on the many lessons learned from this research by suggesting a reform pathway that we argue could contribute to changing the NBS governance regime to enable NBS adoption at the scale needed. In many ways, our suggestions may lead to system transformation, which has been defined as change that challenges the status quo, namely alterations in a system's fundamental nature, state, structure, or function (Smith & Stirling, 2010; O'Brien, 2011; Béné et al., 2012). However, transformation is not a one-off institutional change (Scolobig et al., in review) but a dynamic process. According to Geels (2019) it involves four phases: experimentation, stabilization, diffusion and institutionalization. By focusing on the final stage, 'institutionalization', we hope that our reform suggestions might spark discussion and contribute to a transformational process that would begin experimentally.

In this spirit, we suggest institutional reforms at the EU and national scales. The suggestions have not been vetted in a stakeholder process or discussed with policymakers for their practicality; rather, they are put forward to motivate further research and discussion. The suggestions reflect only the authors' views and not those of the PHUSICOS partners or the European Community.

Our suggested reforms respond particularly to what we identified (in Part 1) as barriers that distinguish NBS from conventional infrastructure and that therefore make NBS uniquely difficult to put into operation, namely,

- Lack of expertise and knowledge
- Lack of evidence on performance and co-benefits
- 'Grey' path dependency

Our aim is to contribute to ending path dependency, as well as circumventing the near-intractable issue of demonstrating the efficacy and co-benefits of many NBS based on current evidence. Each of the suggested policy reforms is based on legal or practical precedent, most recently related to implementing renewable energy projects.

Six suggestions for policy reforms

At its core, 'grey' remains the default option or accepted policy pathway for investments in disaster risk reduction. This was witnessed most convincingly in the NBS contractor interviews:

...Design engineers in this company have always been doing the same thing. They just use the same design approach and it is easier that way. We know the cost, we know how to estimate the costs, we know how to put a business case together. Going through a new approach means thinking outside the box... (Interview 13, Designer)

Indeed, the most fundamental characteristic of the NBS governance system is its ‘grey’ path dependency. Institutions, legal frameworks and expertise often constrain actors from moving out of their established practices. This is due in large part to the tacit assumption that the burden of proof needed for prioritizing an NBS over a ‘grey’ project rests on NBS proposers, which was a major concern among NBS contractors. As one consultant put it, the responsibility for proposing NBS rests with the applicants, but they are limited by lack of information and data to support NBS over grey or traditional solutions.

Six suggested policy reforms to address distinctive NBS hurdles follow:

#1 Extend the scope of the EU Environmental Impact Assessment Directive

Fortunately, a far-reaching and stakeholder-inclusive EU directive exists for assessing the environmental impacts of proposed infrastructure projects, the Environmental Impact Assessment (EIA) procedure, which requires project proposers to assess the direct and indirect effects of a project on environmental factors, including human health, biodiversity, land, soil, water, air, climate, landscape, material assets and cultural heritage.⁴ While an EIA is not carried out until an environmentally relevant project enters the approval process, a strategic environmental assessment (SEA) is carried out at the planning stage. The EIA Directive (2014/52/EU) has been amended four times since its implementation, most recently in 2014. The last amendment (amongst others) aimed to simplify its administrative process and increase consideration of biodiversity and climate change impacts (Lonsdale et al., 2017). While the EIA Directive is legally binding, it is transposed into national law, where its regulators are Local Planning Authorities (ibidem). This has led to inconsistencies in how and when the Directive is applied in different European countries (Pinho et al., 2010), which would have to be considered for this proposed reform.

The Directive, however, is aimed at large-scale infrastructure projects with a significant potential impact on the environment (Annex A), such as nuclear power plants, large dams, motorways, etc. Other project categories (Annex II) include, *inter alia*, urban development projects, inland waterways, canalization and flood-relief works. For these projects, Member States have discretion in requiring an EIA. Since NBS are often an

⁴ https://www.era-comm.eu/EU_Legislation_on_Environmental_Assessments/part_1/part_1_4.html

alternative for mitigating small but cumulative impacts on biodiversity and other environmental impacts, the ‘grey’ solutions they replace typically fall through the EIA net. It is revealing, for instance, that the interviewees with Norwegian public authorities did not mention EIA as an enabler or barrier for NBS.

Our suggestion is to consider extending the list of mandatory EIAs to encompass a greater number of proposed grey infrastructures. Currently, the screening of projects for EIA is in the hands of national governments and their planning authorities. As a second suggestion, while amendments to the EIA have put more emphasis on impacts to climate and biodiversity, a more stringent and long-term assessment may be called for. Hence, another possibility, which would further shift the burden of proof, is to specify an assessment methodology, e.g., CBA, which takes account of impacts on future generations by incorporating a long time horizon (as, for instance, in Norway with 100 years) and a zero or close-to-zero discount rate. This would increase the transparency of the EIA for stakeholder deliberations.

A third suggested revision of the EIA Directive is to consider requiring proposers of ‘grey’ and hybrid projects to systematically compare their proposal with a best-option NBS. Indeed, the current directive requires that the proposer or developer describe the reasonable alternatives to the project, at least those that were considered. A systematic comparison with an alternative is considered by some observers to be the most crucial element of an EIA, but the element most often absent from the assessment (Wood, 2002). This suggestion is consistent with, yet extends, the 2018 Norwegian guideline, where it is stated that NBS should be explicitly addressed as an alternative to be assessed along with any grey solution (see Sec. 2.3.6). However, instead of ‘guidelines’ this suggested revision of the EIA would institute a mandatory requirement for all EIAs across public and private proposed infrastructure projects.

The practicality of this proposition will depend in large part on the capabilities of municipal planning and permitting authorities and other responsible agencies, which are currently not equipped to carry out significantly more EIA processes and which are hesitant to expose themselves to risks from permitting uncertain NBS projects (see policy reform #4). Indeed, throughout the interviews in Norway, which conforms with the EU EIA Directive with responsibility for DRR at the municipal level, there is concern that the municipalities are understaffed and without sufficient expertise to assess NBS. The EIA reform would put additional stress on planners and permitting authorities at all scales. If the scope of the EIA is expanded, responsible authorities would require additional budget and staffing. Considering the number of municipalities across Europe (over 400 in Norway alone), the provision of capabilities across all relevant authorities would greatly strain already stressed local, regional and national budgets.

An alternative is to place long-term decisions on infrastructure into an autonomously funded institution, possibly at the national scale, with the required expertise (such institutions, in part, exist, e.g., the Environment Ministry in Italy). This would also circumvent the pressure on local politicians to implement projects with short-term benefits to their constituents. In fact, the OECD (2017) among others (Scolobig et al., in review; Runhaar et al., 2018; Braunschweiger and Putz, 2020; Wegrich et al., 2017) have called for formal mechanisms or bodies for the coordination of public investment across sectors and government scales, with some observers calling for separate institutions with autonomous budget and decision authority.

#2 Switch the burden of proof from NBS to grey infrastructure

Instead of focusing on estimating, even quantifying, the effectiveness and co-benefits for NBS, one might wish to reverse the burden of proof to require more stringent documentation of the negative impacts of traditional grey infrastructure. In legal terms, the burden of proof means that one party has the burden of proving that they are correct, while the other party is presumed to be correct. The rationale for this shift is the near-intractable problem of estimating NBS effectiveness and co-benefits given the current lack of experience and data, a problem that will improve over time but only if NBS are streamlined for their urgent implementation. Despite important handbooks and guidelines to provide this evidence (e.g., Somarakis et al, 2019; Raymond et al., 2017; World Bank, 2021), the necessary data and methods will require many years of NBS operation and monitoring.

‘Burden of proof’ is a core concept underlying the EU’s precautionary principle. The individual or entity proposing the activity must prove that the activity is not harmful. As an important precedent, this principle was embedded in the 2007 European Regulation on Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH)⁵, which shifts the burden of proof to industry.

#3 Exempt selected NBS from the EIA

Perhaps most importantly for changing the burden of proof, the European Commission might consider exempting a set of NBS infrastructure projects, including pre-specified hybrids, from the EIA procedure and replacing it with a streamlined permitting process. This would be in line with the recent European Council recommendation on speeding up permit-granting procedures for specified renewable energy projects (European Commission, 2022a). Each member state could determine the process of specifying

⁵ Regulation (EC) No 1907/2006 of the European Parliament and of the Council of 18 December 2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH),

which NBS and hybrids qualify for exemption (note, not all renewable energy projects are exempt from the EIA process). The screening process could take into account the importance of assuring safety for those DRR projects that protect against loss of life, in which cases NBS assessments might not be exempt. It could also guard against greenwashing.

#4 De-risk NBS with public instruments

While private insurers have embarked on products for transferring risks from NBS construction and for restoring NBSs damaged by storms or other hazards (e.g. coral reefs and mangrove forests), they have shown little appetite to insure NBS performance with regard to their provision of primary and secondary benefits. In other words, the risk of liability from non-performing NBS are to our knowledge not easily transferrable to private insurers. This suggested reform would transfer this risk, or a layer of the risk, from municipal and regional governments, private entrepreneurs and other NBS ‘owners’, as well as permitting authorities, to an appropriate vehicle at the national scale. This same protection would not be necessary for national governments in Europe as NBS owners since sovereign risk can be absorbed by a large tax base. Risk transfer instruments can include government guarantees, government-backed liability insurance or public-private partnerships. Reinsurance arrangements for national governments could be made at the EU scale.

There is precedent for governments taking on risk that others cannot to protect the population or provide an environment for investment in the public interest, what some refer to as the insurer of last resort. Governments and government-backed entities have provided guarantees for risky but socially desirable investments at all scales. For example, the European Investment Fund (EIF), as part of the European Investment Bank Group and an implementing partner of InvestEU, provides product support for investors in EU’s policy priorities, including the climate and infrastructure fund, in the form of a capped or uncapped guarantee to partly cover the credit risk of eligible debt financing transactions.⁶

While a government guarantee or other public arrangement can reduce the liability risk that municipalities and other NBS owners face, they cannot fully de-risk NBS. This is especially the case for those NBS projects that are expected to protect against risk of fatalities. In this case, the liabilities cannot be fully compensated. Politicians are understandably reluctant to take on uncertain mortality and morbidity risk. For this reason, as mentioned above, the institution responsible for screening projects for an EIA

⁶ https://www.eif.org/InvestEU/guarantee_products_calls/index.htm

may decide not to exempt NBS which protect against high risk of life. There is precedent for this in the flood risk area, where flood risk is rated taking account of risk of life.

These reforms, however, do not solve the problem of extremely limited funding and financing for NBS. Our final two suggestions include:

#5 Support public and private NBS financing

An increasing number of funding opportunities have been put into place for supporting NBS globally and in Europe (Baroni et al., 2019). Perhaps the most ambitious is the EU Biodiversity Strategy for 2030, which plans for at least €20 billion per year to be unlocked by mobilising private and public funding/financing as part of the European Green Deal Investment Plan (European Commission 2022b, c). A recent assessment of the Biodiversity Strategy for 2030, however, puts funding needs including baseline expenditure at around EUR 48 billion annually from 2021-2030, a significantly higher amount than the EUR 20 billion/year (Baroni et al., 2019). Taking account of other EU and national budgets, as well as a selection of private funding sources, the study estimates the remaining financing gap at around EUR 19 billion annually, which implies a significant financing gap also for NBS as they are an integral part of the biodiversity agenda (Martin et al., forthcoming, Deliverable 5.2).

According to many commentators, especially at the EC, this gap cannot be filled with public funding alone, which still represents 83% of global NBS investment efforts (UNEP, 2022). Indeed, driven by the recent upsurge of private investments in renewable energy projects, there is optimism that the biodiversity and NBS financing gap can to large part be filled by private investment. However, it should be kept in mind that unsubsidized private investment was only forthcoming after renewable energy became competitive with fossil fuels, in other words, only after renewable energy became profitable or 'bankable'. The picture is different for other 'non-bankable' types of public infrastructure. For instance, the World Bank (2021) estimates that in developing countries 83% of infrastructure projects in 2017 were sponsored by government entities and state-owned enterprises.

There is little reporting and thus data on the share of NBS that are bankable. Given this uncertainty and the recognition that the market will not provide public goods without (or in many cases, even with) public support, it may be prudent to greatly increase public funding opportunities at all scales even beyond those recently in place at the EU.

At the same time, although private financing will remain a challenge, at the same it is crucial to encourage businesses to invest in 'bankable' NBS for which there are a diverse

set of instruments (see section 2.3.5). These include privately financed instruments, e.g., payments for ecosystem services, green/resilience bonds, biodiversity offsets and philanthropic spending. Taxpayer supported instruments include subsidies, tax advantages, public-private partnerships, public guarantees, subsidized insurance products and funding provided through the EU like the Horizon Europe research program.

#6 Promote divestment from nature-negative assets

Finally, and perhaps most critically, current efforts to discourage investment in fossil fuels are being extended to nature-negative grey solutions. The EU taxonomy for sustainable activities is a major step in this direction by clarifying those investments that are environmentally sustainable in the context of the European Green Deal.⁷ This classification and the work of the Task Force on Nature-related Financial Disclosures (TFNFD) will provide needed transparency for ESG and ‘green’ investing as well as encourage divestment from nature- and climate-negative assets. As important as this direction is, it could become more effective if it were accompanied with an enforcement mechanism for banks and other financial agents, perhaps by extending the mandate of the European Central Bank (ECB) beyond financial stability or furthering current lending policies of the European Investment Bank (EIB) and European Bank for Reconstruction and Development (EBRD), each of which has embarked on strong sustainability policies. The ECB, for instance, issued its *Guide on Climate-Related and Environmental Risks*⁸ in 2020, recognising the loss of biodiversity as a risk and setting non-binding supervisory expectations pertaining to climate and environmental risk management and disclosure.

5.3 Summary

The literature, interviews and experience, also from the PHUSICOS Policy-Business Fora, have provided a rich set of lessons that can help address the barriers facing NBS and their scale up. Many are incremental, and include lessons for planning, design, permitting, financing, procurement, construction, maintenance and monitoring. The list is extensive, but perhaps the most salient are

- innovative co-design stakeholder processes,
- knowledge creation through documented examples, quantification of co-benefits, decision support tools

⁷ https://finance.ec.europa.eu/sustainable-finance/tools-and-standards/eu-taxonomy-sustainable-activities_en

⁸ https://www.bankingsupervision.europa.eu/legalframework/publiccons/pdf/climate-related_risks/ssm.202005_draft_guide_on_climate-related_and_environmental_risks.en.pdf

- smart uses of CBA that take account of long-term impacts,
- novel ‘blended’ financing to extend the portfolio of privately-funded NBS projects,
- an extension of the EU taxonomy that can promote divestment from nature-negative projects,
- whole-of-life contracts that include long-term maintenance and monitoring.

As crucial as these and other lessons are, all of which have been shown to enable conventional infrastructure implementation, they fall short of addressing those barriers that differentiate NBS from ‘grey’, including the path dependence of grey infrastructure. To tackle the especially distinctive and thorny challenges, we suggest six systemic policy reforms that can contribute to enabling NBS at scale. Each of the policy reforms is based on precedent or legislation, most recently related to implementing renewable energy projects. The suggestions reflect only the authors’ views and not those of the PHUSICOS partners or the European Community. Moreover, they have not been vetted in a stakeholder process or discussed with policymakers for their practicality but are put forward to motivate further research and discussion. They are:

- Extend the scope of the EU Environmental Impact Assessment (EIA) Directive
- Switch the burden of proof from NBS to grey infrastructure
- Exempt selected NBS from the EIA
- De-risk NBS with public instruments
- Support public and private NBS financing
- Promote divestment from nature-negative assets

Reforming NBS governance will be crucial for making the investments necessary for meeting the EU biodiversity and climate goals. We hope the suggested reforms will spur further research and most importantly debate on transformative pathways forward.

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Appendix A

Norway Interview Protocol and list of interviewees

Main question for interview

What is missing (information, resources, standards, etc. other?) for public entities to be able to decide on a Nature-based solution (NBS) instead of a traditional grey measure for disaster risk reduction (DRR) (floods, landslides, avalanches)?

Opening script

I would like to thank you once again for deciding to participate in this interview today. My name is xxxxxxx and I work as a researcher at NGI. I am currently working in the PHUSICOS project together with (person from Organization) interviewee is familiar with (e.g. NGI for Norway).

The PHUSICOS project is an EU funded project with 15 European partners, with the aim of demonstrating the functionality and co-benefits with NBS for mitigating various natural hazards in Europe. The project is actually implementing interventions in Norway (Sites in Gudbrandsdalen), The Pyrenees (both Spain and France) and in Tuscany in Italy. The focus is on rural areas, as much is already done in urban areas.

As I briefly introduced to you by email, the objective of this interview is to better understand the opportunities and challenges for public entities working on nature-based solutions. We also want to learn about the capacities and the needs required for those purposes.

The information you provide in this interview will be very useful to us for the generation of knowledge materials such as reports and other deliverables within the framework of PHUSICOS, and might also serve as background material for a future scientific publication to increase knowledge in this field.

Before we start, I would like to ask your permission for recording our call, this will help me later in the analysis of the information you will provide me.

Do you have any questions or concerns before we begin? *[Discuss questions]* If any questions (*or other questions*) arise at any point of our interview, please feel free to ask.

Now, with your permission we will start with our first question...

Questions

1. Are you at all familiar with the term Nature Based Solutions (NBS)?
2. Could you describe your experience with NBS for DRR (floods, landslides, avalanches)? Have you been involved in the implementation of NBS or been involved in any other NBS project?
 - a. What type of project(s) have you been involved in? (Type of NBS, aim of the measure, part of the process of decision-making/implementation)
 - b. How often do you work with NBS? / How much of your time is spent working on NBS(main part / 50% / rarely)?
 - c. How much does your organization / department work with NBS?
3. What would you consider are the main differences in the decision process for NBS as opposed to deciding on traditional infrastructure?
 - a. What do you see as the biggest challenge/barrier in implementing NBS for DRR?
 - i. (mention liability and ask if that has been considered)
 - b. If you have experience from projects where NBS was considered, but not implemented, why was this in your opinion?
 - c. If you have experience from projects where NBS was implemented, what factor(s) made you choose the NBS measure?
4. Given that risk reduction is the main aim (benefit), which co-benefits would you say are the most important for to decide on implementing a NBS? (Examples: biodiversity, economic-, aesthetics-, health- and well-being of inhabitants etc.)
 - a. What in your opinion is the most important co-benefit for the **public**?
 - b. Potentially: What is the most important co-benefit for other stakeholders?
 - c. Does the importance of various co-benefits vary between different applications of NBS? (Discuss examples from projects they have worked on earlier or know about – if any)
 - d. Is your organisation assessing co-benefits? If yes, how (qualitatively or quantitatively)? If no, why?
5. Do you believe that you have the necessary knowledge and resources to implement NBS for DRR?
 - a. If so, how did you gain that knowledge?
 - b. If not, what information/resources would be the most useful in deciding whether to implement an NBS instead of traditional infrastructure? (*Examples: Cost-benefits analysis, any particular numbers?, experience from other projects, general information on the co-benefits, standards on how to design and implement NBS, Liability issues (insurance etc.)...*)

- c. What institutions do you think could provide this information?
6. What (innovative?) policy or legislative reforms could support you in implementing NBS?
 - a. Are you aware of the requirement set from the Environment Agency about the use of NBS in climate adaptation actions?
 - i. If yes, has this affected your decisions on which intervention to apply?
7. What (innovative?) financing/liability/insurance measures could support you in implementing NBS?
8. Can you think of anyone else we should talk to who might have insights about this topic?

Closing script

Thank you very much for your responses and for your time. You have provided me a lot of relevant insights that will be very relevant in our study. These are all the questions I had to ask you, would you like to add something else?

At the end of our call I will share with you a consent form where you will be able to indicate, among other things, whether you wish to be identified or remain anonymous. I would appreciate if you can sign it and send it back to me when you find it possible please.

Thank you again. Have a nice day.

Interviewee list

County authority 1 (East)
County authority 2 (West)
County authority 3 (South)
County Governor 1 (North)
County Governor 2 (South)
Municipality 1 (West, large municipality)
Municipality 2 (East, large municipality)
Municipality 3 (East, large municipality)
Municipality 4 (West, large municipality)
Municipality 5 (East, large municipality)
Municipality 6 (West, small municipality)
Directorate 1
Directorate 2

Appendix B

Norwegian Interview Responses

Interview questions and responses

Question 1

What would you say are the most important differences when deciding to choose /consider a nature-based solution as opposed to deciding on traditional infrastructure?

Many interviewees mentioned that the lack of knowledge as an important difference when deciding on NBS, as opposed to traditional infrastructure. The lack of knowledge may also be seen in context with the answers mentioning that NBS often requires more multidisciplinary work. A NBS also requires more space, and hence affects more landowners, making it more challenging to implement in densely populated areas. Difficulties in quantifying the risk reduction in the case of NBS is also mentioned by some, as a difference from traditional grey measures. Greater uncertainty regarding costs of NBS, compared to a grey solution is also mentioned by interviewees from different responder groups. For grey infrastructure one has more data to base decisions on. Overall grey solutions are well known, and hence easier to use and feel safer. All the answers are given in Table 2.

Table 1 Overview of the different answers, grouped together, on the most important differences when deciding to choose a NBS as opposed to a traditional solution. Quotes, translated from Norwegian by the authors, are provided when suitable.

Answer	Who	Quote
Grey solutions feel safer, as it is possible to perform different calculations	County authority 1, 2	
Grey solutions are well known, and hence easier to use and feel safer	Municipality 1, 3, 5	<i>[...] my experience with that field (water supply and sewerage) was, "here we put it in pipes, that's what we do"</i> – Municipality 3
NBS requires more collaboration and interdisciplinarity	Municipality 1, and Directorate 1	
NBS requires more (new) knowledge	County authority 2, 3, and Municipality 1, 3	
NBS require larger space and affects more landowners	County Governor 1, 2, Municipality 1, 3, 6, and Directorate 2	<i>But when it is to be nature-based, you must set aside land, and then there are many more actors who have a say in what should happen [...] so my impression is that the processes to bring about nature-based solutions are more complicated</i> – Municipality 1
Finances, more uncertainty of the NBS cost	County Governor 1, Municipality 2, 4, and Directorate 2	
There are routines for maintenance on grey solutions, NBS requires that you create a new maintenance standard	Directorate 2	
NBS also serves multiple purposes	County authority 1	

Question 2

Do you have any experience with projects where nature-based solutions have been considered? But then traditional has been chosen instead?

The majority of the interviewees have not come to the stage where they have considered the use of NBS for a specific project, and hence they could not answer this. Two of the

municipalities had experience with NBS initially been planned, but eventually it was easy for the contractor to cut the NBS. Traditional solutions have also been preferred as they take up less space, are easier to implement, and one can see the effect fast. All the answers are given in Table 3.

Table 2 Overview of interviewee responses on experience with projects where NBS have been considered, but traditional solutions have been chosen instead. Quotes, translated from Norwegian by the authors, are provided when suitable.

Answer	Who	Quote
No	County authority 1, 2, 3, Municipality 2, 4, 5, and Directorate 1, 2	
Experience that NBS has been planned, but is easy to remove during the process	Municipality 1, 3	<i>We have been involved in several regulatory plans and technical plans, that have been ambitious at the planning stage[...] when it comes down to it the developer withdraws - Municipality 1</i>
Considered but not enough space, or that conditions were not right	County Governor 3, and Municipality 6	<i>[...] such NBS are considered, and then they do not have good enough effect in the short term, and are perhaps more complicated, and may require other measures, e.g., moving infrastructure. So then [...] it is easier with a more classic solution- Municipality 6</i>

Question 3

(Do you have) experience with projects where nature-based solutions have been implemented and what factors made you choose nature-based solutions ?

Most of the interviewees from the different entities do not directly have experience with the implementation of NBS. However, several are in the planning stage of implementing NBS, and throughout the interviews it also appeared that some of the interviewed municipalities had some experience with NBS, even though this was not

clearly stated as an answer to this question. It is worth mentioning that several of the entities (e.g. county authorities) work at a higher level, and do not directly work with the implementation but instead guide the municipalities. The one municipality where the interviewed person(s) could mention an example of implementing NBS, did this before NBS was a common term, see quote in Table 4.

Table 3 Overview of interviewee responses on their experience with projects where NBS have been implemented. Quotes, translated from Norwegian by the authors, are provided when suitable.

Answer	Who	Quote
No	County authority 3 Municipality 2, 4 Directorate 2	
Implemented, but before it was known as NBS	Municipality 1	<i>[...] But the municipality has done many things that are nature-based in the past, without really thinking about that term, [...] perhaps without being so aware of these additional values - municipality 1</i>

Question 4

(Do) you have the necessary knowledge and resources to implement NBS?

Several of the interviewees think that they have, or to some extent have, the knowledge needed to implement NBS. These answers are given from all four types of entities, this can be seen in Table 5. When asked where they had gained this knowledge some of the answers were 'through education and through working on several projects'. However, lack of knowledge within the different entities also seems to be a problem, making it difficult to understand when, where and what type of NBS would be appropriate to use. When you are unsure about what you need, it is also challenging to hire a consulting firm. Financial problems have also been mentioned by several as an answer to this question and has also come up in other questions. In general, the financial situation is tight, and the cheapest and most financially predictable solution is usually preferred.

Table 4 Overview of the different answers, grouped together, on if they have the knowledge and resources to implement NBS. Quotes, translated from Norwegian by the authors, are provided when suitable.

Answer	Who	Quote
Have knowledge	Municipality 4, 1, 6, and Directorate 1	<i>I get a lot of knowledge about it, about the problems and possible solutions, so I certainly have the knowledge to contribute</i> – Municipality 6
Have some knowledge	County authority 3, County Governor 2, and Municipality 5, 3	<i>[...] I would like to think that I might have the knowledge, to sort of order right (type of NBS), and that's what I think many municipalities struggle with, that they may not have the knowledge to get the whole thing together [...] that you get the solution you need</i> – County authority 3
Problem with finances	County authority 1, County Governor 1 Municipality 4, 2, 1,	<i>No, I think that the capacity, both in terms of personnel and finances, is not present [...] When you have such small municipalities, the administrative resources are also small, and therefore I do not have much faith that this type of solution can be achieved in these municipalities [...]</i> – County Governor 1
Lack of Knowledge	County authority 2, County Governor 1 Municipality 2, 3, Directorate 2	<i>[...] was supposed to have a nature-based urban runoff solution where they established a rain garden higher than that area (the project area), so all the water flowed down to an unwanted location. [...] there you could say that the developer should have had the competence, but you also need that competence internally to be able to go through the plan to</i>

		<i>see if it will work as intended–</i> Municipality 3
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Question 5

What information or resources would be most useful in deciding whether to implement nature-based solutions instead of traditional infrastructure? e.g., cost-benefit analysis or other statistics?

Table 6 summarizes the type of information/resources, mentioned by the interviewees, that would be helpful in the decision to implement NBS. It can be mentioned that a collection of reference projects, both from Norway and other countries, is highly desired as it would help them figure out the most promising NBS for their case and make them aware of what can go wrong.

Table 5 Summary of the types of useful information/resource mentioned by interviewees

Type of information/resource	Description	Who
Collection of reference projects	Easily accessible collection with examples of NBS implementations, what did they do, how was it done, what worked, what didn't	County authority 3, County Governor 2, Municipality 2, 3, 4, 5, 6, and Directorate 1
A tool for initial analysis	A tool that takes the initial conditions of an area (area, land coverage, settlements... etc.), and suggest a suitable type of NBS	County authority 2, and County Governor 2
Quantification	A way of quantifying the effect of a NBS, which will make it easier to be compared to a grey solution	Municipality 6

Cost-benefit-analysis	Regular cost-benefit-analysis, which will make it easier to choose NBS...?	County authority 1, 2, County Governor 2, and Municipality 3, 4
Conferences	Conferences about NBS to increase and spread the knowledge on NBS, and focus on inviting several people from the same entity	Municipality 2, and Directorate 2
Clarify responsibilities	With the implementation of NBS it is not quite clear who is responsible for what, as it is more multidisciplinary than traditional infrastructure	County authority 2
Economic support	Economic incentives, making it lucrative to decide on NBS	County authority 2
Knowledge among consulting firms	When you hire a consulting firm for a job, that the firm in addition to suggesting a grey solution also suggest NBS when possible	Directorate 2

Question 6

(In addition to DRR) Which positive side effects would you say are most important when considering implementing NBS?

Several of the entities mention that co-benefits are considered when thinking about implementing NBS.

Yes, it will be included although it may not be the primary thing. Flood prevention measures are expensive so if it has some more positive effects then that's good (translated from Norwegian by the authors) – Municipality 6.

These co-benefits are considered qualitatively, as it is difficult to set a number on, for instance biodiversity. However, for some the co-benefits are not really in focus.

[...] It will probably end up at the bottom of the list, cost will always override a lot here (translated from Norwegian by the authors) – Municipality 4

Table 7 summarizes the co-benefits mentioned by the interviewees.

Table 6 Co-benefits mentioned by the interviewees.

Type	Who
Biodiversity	County authority 1, 2, 3 County Governor 1, 2, Municipality 3, 5, and Directorate 2
Water environment/quality	County authority 3, and Municipality 2
Recreation and public health	County authority 1, 2, 3, County Governor 2, Municipality 2, 3, and Directorate 2
The solutions are less invasive	Municipality 5
One solution can serve several purposes	Municipality 6

Question 7

What policies or legislative reforms do you think can support the implementation of nature-based solutions?

To this question there are several different views and suggestions, which are summarized in Table 8. Some want stricter legislations, while others think that stricter legislations are probably not the solution. Some suggested to make the statement/recommendation by the Environment Agency on the use of NBS more known. This might be a good idea, given that four of the municipalities, and one of the directorates were not aware of this statement/recommendation, when asked.

Table 7 Summary of policies or legislative reforms thought to support the implementation of NBS. Quotes, translated from Norwegian by the authors, are provided when suitable.

Answer	Who	Quote
Make the statement from the Environment	County authority 1, 2, County Governor 1, and	

Agency about the use of NBS in climate adaptation, and information in general, better known	Municipalities 4, 5	
Stricter legislation is not necessarily the solution	County authority 2, County Governor 1, Municipality 4	It could help if it had been [...] a legal requirement that one preferably should use nature-based solutions but in practice I see a problem with that, because it will lead to a rather large increase in costs quickly, so without having financial support in place you quickly end up like today, that you do nothing but just sit and wait and hope that you won't have an unforeseen event. (Translated by the author) – Municipality 4
Stricter legislation	County authority 3, Municipality 1, 6, and Directorate 2	<i>[...] but then it also must be well justified, [...] so for me it is not so difficult to understand that it is wise to use nature-based solutions, but I need help to sell it.</i> (Translated by the author) – Directorate 2
Make sure laws do not contradict each other	Municipality 3	
Get NBS into several fields	County Governor 2	<i>I would like if it entered a few more fields not just nature- and societal security, but that for example health. It could be a little clearer that NBS has an important health effect</i> (Translated by the author) – County Governor 2

Question 8

What kind of institutions do you think can provide the information that one needs to make these choices?

Table 9 summarizes the different kind of institutions mentioned by the interviewees that could provide the needed information. It was also mentioned by several that a lot of information is probably already there, but is difficult to find, better coordination is requested:

Some information exists, but it is difficult to find. You must actively search and know where to look [...]. The Norwegian Water Resources and Energy Directorate makes a lot of technical reports and reports after they have carried out things, but it is not necessarily clearly stated "here we have chosen NBS", so it requires that you know what you are looking for. (Translated from Norwegian by the authors) – Municipality 4

Table 8 Summary of institutions mentioned by the interviewees that could provide information to support the choice of implementing NBS.

Answer	Desired information	Who
Research and educational institutes	Need to communicate their knowledge and research.	County authority 1, County Governor 2, Municipality 5, 6, and Directorate 1, 2
Consulting firms	The consulting firms start to advertise for and suggest the use of NBS as an alternative to grey-solutions	County authority 3, Municipality 2, Directorate 2
Environmental agency	Better to communicate information, and make it easier accessible	County authority 2, County Governor 1, 2
Norwegian Water Resources and Energy directorate (NVE)	Improved communication of information, and make it easier accessible	County Governor 1, 2, Municipality 4, 5, 6, and Directorate 1

Question 9

(Have you) encountered any challenges in that it has been difficult to say who is responsible if the solution should not work?

Again, most of the interviewees from the different entities do not directly have experience with the implementation of NBS, however several are in the planning stage. Some have not encountered any challenges regarding the responsibility if a solution should not work. Whether this is not a problem in general, or if they have not encountered it yet due to the lack of experience with implementing NBS is not clear. Some are unsure but think it might be a relevant issue in the future if they are to implement NBS. It was also mentioned that responsibility in general is a problem if a

municipality is to create safety measures for "older" (existing, rather than planned) buildings. The answers can be found in Table 10.

Table 9 Overview of the different answers, grouped together, on if they have encountered any challenges in that it has been difficult to say who is responsible if a NSB should not work. The table gives; the answer, who answered what, and when suitable a quote, which is translated from Norwegian by the authors.

Answer	Who	Quote
no, not mentioned	County authority 1, and Municipality 6	
Yes	County Governor 1, 2, and Municipality 4	<i>Yes, it is a big obstacle, but insurance and liability are big problems in general. Often, for both landslides and floods at least, the municipality does not necessarily have any clear responsibility for existing buildings that were built 60 years ago that now are within a hazard zone [...]. But if the municipality should suddenly step in and start doing some security measures, then we become responsible.</i> – Municipality 4
Unsure, but think it is a relevant issue	County authority 2, 3	

Question 10

Which financing, liability or insurance measures can support you in the implementation?

From the responses (Table 11) it is quite clear that some sort of financial support would be helpful for the implementation of NBS. The financial support must be organized in a way to make NBS more lucrative than grey solutions that it becomes cheaper for the municipality to go for NBS. Some suggested solutions included lower interest rate on loans, or reduced payment by the municipality for the solutions.

Yes, I think we definitely need better reinforced financial support in this field. I strongly believe that all municipalities should have their own pilot project. In other words, you learn a lot from pilot projects, so if national authorities can strengthen the work with financial support so that all municipalities, not just the largest, but all municipalities can work with it and gain more competence. (Translated from Norwegian by the authors) - County authority 3

As NBS is quite new and can affect a larger area than a grey solution, there are some uncertainties about who has the different responsibilities for the measure.

I think it would have been necessary to clarify the law for the municipalities so that they know what they are allowed to add requirements in a planning process, for example, whether they can transfer that responsibility to the developer or to those who will live there, or how they can avoid sitting with all the responsibility for maintenance. (Translated from Norwegian by the author) – County Governor 3

Table 10 Overview of interviewee responses on financing, liability or insurance measures that can support public entities in the implementation of NBS

Answer	Description	Who
Financial support	Make it financially lucrative to choose NBS. The support must be easy to apply for.	County authority 2, 3, County Governor 1, Municipality 1, 2, 4, 5, 6, and Directorate 2
Clarify responsibility	As NBS often affects a larger area one needs to clarify the responsibility with regard to what happens if it goes wrong, who will pay for the measure, who will do the maintenance, who owns the safety measure	County authority 3, County Governor 2, and Municipality 4,
Change the Natural Damage Compensation Act §5¹⁰	If your house is damaged by natural damage, it should not be necessary to rebuild exactly the same as before, but get support to make it more resilient to new damage	Municipality 1

¹⁰ Where it is written: *Compensation shall be determined based on the cost of necessary measures to return the damaged object to the same condition as immediately prior to the time of damage* (taken from an unofficial translation of the Norwegian version, found at lovdata.no)

Appendix C

Interview Protocol for Construction Companies, Designers and Consultants

Interview protocol for construction companies

Objective

To gather information on the opportunities and challenges faced by companies dedicated to providing services (at any stage from the design to the implementation or monitoring of measures) for nature-based solutions as they seek to expand or increase their market share. To learn about their capabilities and needs for such purposes.

Questions

I would love to start by asking you if you are familiar with the term nature-based solutions?

1. Are you familiarized with the term Nature-Based solutions?
2. Can you please briefly describe your company and your experience with nature-based solutions?
3. What percentage of your work involves nature-based solutions? And what fraction of this work is financed by the public versus the private sector?
4. Do you experience competition in the bids for this line of work, and if so, how much?
5. Is it in your interest to increase your participation in this type of projects?
6. Do you collaborate with other companies in these types of projects, and if so, what type of organizations?
7. Do you see any legal/liability issues for your company linked to your participation in NBS? If so, how do you deal with them?
8. What training do you currently conduct to be competitive in this market? What training do you foresee as being needed for designing or implementing nature based solutions? Who would be responsible for such training?
9. Can you recommend what changes would need to take place in order to increase the number of nature-based solutions that are implemented? (e.g. increase the number of NBS versus grey interventions)
10. How do you see the NBS sector developing in the future? What business opportunities do you see for nature-based solutions?

Interview protocol for designers and consultants

Objective

To gather information on the opportunities and challenges faced by companies dedicated to providing services (at any stage from the design to the implementation or monitoring of measures) for nature-based solutions as they seek to expand or increase their market share. To learn about their capabilities and needs for such purposes.

Questions

- 1 Can you please describe your company experience with nature-based solutions? (*e.g. how did you first get involved with NBSs? The type of NBS you are usually involved with?*). Have you ever participated in the implementation of NBSs with disaster risk reduction purposes?
- 2 Are NBS the main services/ products that your company provides? Do you provide NBS mainly in response to calls/funding from the public or the private sector?
- 3 How do you see the NBS sector developing in the future?
- 4 Do you see any legal barriers or policies in place that could prevent the NBS market development? Have these issues ever prevented you from getting involved in a project?
- 5 Are there any liability issues for your company linked to NBS design or implementation? If so, how do you deal with them?
- 6 What type of economic reforms do you consider necessary to increase private or private-public demand in the future?
- 7 What type of competition are you experiencing?
- 8 How difficult is it to recruit or train staff to have the needed expertise or skills for participating working with NBS? If you do train your staff, in which type of training do you focus the most?
- 9 Do you make use of any facility to help you participate in NBS projects? (*e.g. networks to find funding for projects development or other useful information*)
- 10 According to your company experience, what are the main challenges that enterprises working with NBS face for growing their market? Are they mostly linked to external or internal factors?
- 11 What do you consider are the main aspects that could help your company upscaling?
- 12 Overall, what are the principal gaps for NBS projects preparation and implementation? (*from the private sector perspective*) What are the priorities? What capacities need to be mostly supported? Why and how?

Descriptive information of NBS contractors interviewed

ID #	Interviewee Location	NBS-related services	Short description	NBS expertise
1	France	Design	Landscape design company	Works both with grey and green solutions
2	Spain	Construction	Construction of wooden structures and treatment of wood	Exclusively or mainly engaged in grey solutions
3	Norway	Consulting	Civil engineering. Independent company offering advice on issues related to floods and landslides. Mapping and design.	Exclusively or mainly engaged in grey solutions
4	Switzerland	Construction	Landscape restoration. Tree planting	Exclusively or mainly engaged in green solutions
5	Ireland	Researcher	Researcher with large NBS-related knowledge	Exclusively or mainly engaged in green solutions
6	Switzerland	Environmental Organization	Environmental Organization	Exclusively or mainly engaged in green solutions
7	Austria	Design, Construction	Nature-based technology providers for water, air and soil purification	Exclusively or mainly engaged in green solutions
8	Germany	Construction	Vertical gardens	Exclusively or mainly engaged in green solutions
9	Netherlands	Consulting	Consultancy on ecosystem restoration, biodiversity, water management	Exclusively or mainly engaged in green solutions
10	Spain	Construction	Construction company. Installation of road	Exclusively or mainly engaged in green solutions

			infrastructures, bridges, etc.	
11	Ireland	Consulting	Engineering consultancy firm.	Exclusively or mainly engaged in grey solutions
12	Switzerland	Insurance	Insurance company	Works both with grey and green solutions
13	Germany	Consulting, Design	Large international infrastructure consulting company	Exclusively or mainly engaged in grey solutions
14	France	Consulting	Smart technology developers. Data collectors.	Exclusively or mainly engaged in green solutions
15	Norway	Consulting	Planning, architecture and engineering	Works both with grey and green solutions
16	United Kingdom	Consulting	Technology providers. Modelling and mapping.	Exclusively or mainly engaged in green solutions
17	Italy	Consulting, Design	Sustainable water management services	Exclusively or mainly engaged in green solutions
18	Ireland	Design, Construction	Green roofs and IT monitoring	Exclusively or mainly engaged in green solutions
19	Spain	Design, Construction	Design and execution of systems for landscape restoration and conservation	Works both with grey and green solutions
20	Italy	Design	Waste treatment	Exclusively or mainly engaged in green solutions