Characterizing nature-based solutions from a business model and financing perspective

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Abstract

Nature-based solutions can help overcome urban sustainability challenges by providing services, creating benefits and holding value for different urban actors. However, the development of nature-based solutions is hampered by a number of barriers that relate to the value proposition, value delivery and value capture of NBS business models and sources of (public/private) finance to tap into. Value created from nature-based solutions which provide marketable products that can be privately appropriated, such as urban agriculture, can be more easily privately finance and delivered through business models than NBS such as urban forests which deliver nature-based value with mostly public good characteristics (e.g. improved air quality, CO2 abatement). We find that the level of finance and business models needed for different types of NBS varies. Policy makers can intervene at various administrative levels to encourage finance and business models for NBS innovations, for example through changing accounting frameworks, adjusting procurement rules and providing risk guarantees. The main challenge surrounding the scale up of urban NBS will be matching commitment from heterogeneous urban constituents to different types of nature-based solutions through appropriate finance and business models.

1 Introduction

This paper reviews the diverse body of literature in innovation and urban studies in order to gain insight in current business model and finance arrangements for urban nature-based solutions (NBS). Building and financing (public/private) business models for urban transformation has been highlighted as one of the major challenges of NBS (Kabisch et al., 2016; Keivani, 2010). Khare et al. (2011) even state that initiatives tackling climate change in cities must be financially beneficial to all stakeholders. However the 'core' literature surrounding NBS or other green/blue innovations (ecology, planning, urban studies etc.) focus on technological feasibility and sustainability assessment and has been largely disconnected from the discussion about (financing) sustainable business models, with a few exceptions (Park & Page, 2017; T.T. Sousa-Zomer & Cauchick Miguel, 2016; Specht, Weith, Swoboda, & Siebert, 2016). At the same time, the (sustainable) business model literature can benefit from concrete application to the development of business models for urban NBS.

Hence, this paper aims to fill this gap by structuring the literature which identifies challenges and opportunities for NBS business model development and suitable financing mechanisms. It addresses research shortcomings in three different areas. *First*, NBS literature lacks a clear understanding of valuing NBS and the potential of exploring and exploiting commercial opportunities and stakeholder impact that will affect these business models. *Second*, the business models for sustainability lack an understanding about cooperative arrangements and/or power struggles likely to occur in the NBS space. Furthermore, tools to support specific types of NBS innovations and how to measure their performance and societal impact are currently missing (Bocken, Short,

Rana, & Evans, 2014; Schaltegger, Hansen, & Lüdeke-Freund, 2016). *Third,* the innovation finance literature remains fuzzy on the public-private relationship in sharing risks and gains through the application of new innovation, such as NBS (Mazzucato, 2013; Mazzucato & Semieniuk, 2017; Polzin, 2017; Polzin, von Flotow, & Nolden, 2016).

The remainder of this review is structured as follows. We first explain how the relevant literature is assembled. Then the findings are portrayed, first characterizing NBS and introducing the relevant business model and financing literature before mirroring existing evidence about green/blue innovation to these frameworks. The structured findings section forms the basis for discussion and conclusion in the final sections.

2 Methodology

In contrast to a narrative literature review, this paper aims to be transparent, replicable and comprehensive, limiting potential selection biases. We follow an two-step approach increasingly used in the social sciences (Pittaway, Robertson, Munir, Denyer, & Neely, 2004; Reim, Parida, & Örtqvist, 2015).

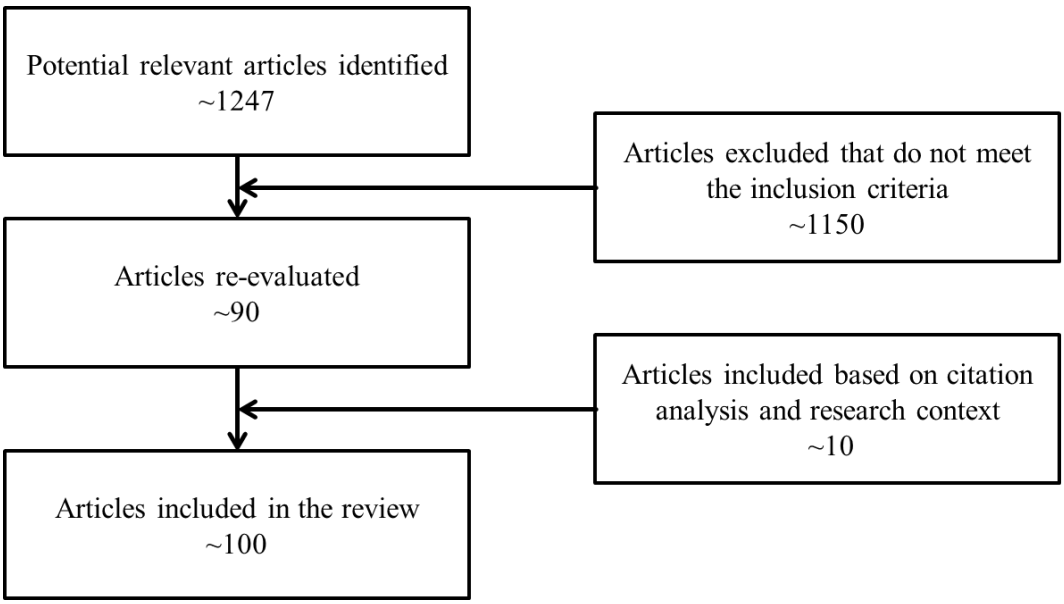

Figure 1: Methodology

After an initial selection of literature by using keyword search (title, abstract and keywords) in a comprehensive literature database (SCOPUS[1]), we systematically exclude articles based on exclusion criteria. Afterwards, the narrower article base is screened for re relevance to the research topic based on which we decide whether to add the article to the final list (Reim et al., 2015).

[1] https://www.scopus.com

2.1 Selection of keywords

We start with an overview of main keywords per theme. Furthermore, in scanning the primary literature, we add keywords as we become more familiar with the literature relevant to our research question (see Table 1). In our search, we combine NBS keywords with (a) business model keywords and (b) finance-related keywords. For example we searched for 'Financ* AND urban sustainable innovation' or 'urban AND business model innovation'. Since we aim to include both conceptual literature and case study literature, we use both high level search terms (such as nature-based innovation) and search terms that refer to specific cases of nature-based innovation (such as green roofs or urban forests).

Table 1: Themes for literature search and corresponding longlist of keywords

Theme	Keyword longlist (to be combined in searches)
Urban nature-based innovation	Urban, nature-based, innovation, urban nature-based solutions, socio-technological change, experimentation, living labs, urban sustainability transition, socio-technical, resilient cities, infrastructure, nature, innovation, urban infrastructural regimes, sustainable cities
Finance	Financial structure, financing, public-private finance, investment, investing
Business model	Business model, business model innovation, value capture, stakeholder engagement, profits, revenue model, for-profit, entrepreneurship, economic development
NBS examples (case studies)	Urban forests, green roofs, green-blue infrastructure, urban water systems, sanitation

2.2 Selection of literature for longlist (based on keywords)

We create a longlist of potentially relevant literature based on our key search terms[2] which led to 937 references for business model-related NBS literature and 210 references for finance-related NBS literature. We first exclude articles which use the word 'sustainable' or 'nature' in a more business-like (i.e. sustainable cash flows) or social sense (i.e. sustainable wage rates). Second, we do not consider articles that do not mention anything nature-based (examples include medical research, light pollution, electric / air mobility, technological noise monitoring, social housing, education in general, health insurance, housing for the poor). If the title was too vague, we scanned the abstract to decide whether the topic of the paper fits our purpose. This procedure reduced the number of articles to ~90.

2.3 Citation analysis and additional literature

We also included papers published in a special issue on urban transition in the Journal of Cleaner Production[3] as well as more general articles that directly relate to NBS but do not explicitly focus on business models and/or finance. The total literature base amounts to ~100 research articles. Articles have been published between 1998 and 2017.

3 Findings

3.1 Characterizing nature-based solutions

Nature-based solutions are a form of 'eco-innovations' that specifically 'promote nature as a means for providing solutions to climate change (mitigation and adaptation), bad air quality, loss of biodiversity,

[2] Search terms used: TITLE-ABS-KEY ((urban OR city) AND (innovation or 'business model') AND (nature OR forest OR green)); TITLE-ABS-KEY ((urban OR city) AND (financ* OR invest*) AND innovation AND (nature OR forest OR green))

[3] http://www.sciencedirect.com/science/journal/09596526/50/supp/C

vulnerable coastlines and other threatened ecosystems, food insecurity and health, social and economic deterioration/injustice (Kabisch et al., 2016, p. 2; Nesshöver et al., 2017, pp. 1216–1217).
NBS consist of different 'green' ecological domains such as building facades and roofs, urban green space connected to grey infrastructure (green playgrounds, street green), parks and urban forests, allotments and community gardens as well as of different types of green-blue spaces such as lakes, urban drainage systems, permeable surfaces and wetlands. Finally, derelict and industrial areas are counted as ecological domains that can serve as NBS. Each of these ecological domains can potentially provide a unique set of services, benefits and values for different urban stakeholders, ranging from ecological services such as climate mitigation and water management to social and economic benefits such as social cohesion and economic development.

From an economic point of view, NBS has been conceived through the lens of natural capital, eco-system services and ecological footprint to calculate the delivered value of ecosystems (Monfreda, Wackernagel, & Deumling, 2004; Nesshöver et al., 2017; Wackernagel et al., 1999). Here, we will take ecosystem services as a defining concept for describing the benefits flowing from NBS. Accounting for value of ecosystems is undertaken both at a national level (Wackernagel et al., 1999) and firm level (Milne & Gray, 2013) aimed at improving governance and management of natural resources. The services delivered by NBS can be of public (common) or private nature which has implications how they are governed and managed (Ostrom, 2010).

The provision of ecosystem services serve as a starting point for our analysis on business models and finance for NBS. Following the TEEB categorization, NBS can provide several types of ecosystem services. The first is *provisioning services*, such as food, raw materials (i.e. tree biomass), fresh water and medicinal resources. Second, NBS can provide *regulating services* such as local climate regulation (i.e. combating heat island effect), air quality regulation, coastal protection, noise reduction, carbon storage, flood regulation, water purification and pollination. Third, NBS provide *habitat* for species, thus supporting biodiversity. Finally, *cultural services* are provided through recreation space, support of mental and physical health, tourism, aesthetic appreciation and inspiration for arts, culture and design. On top of these services categorized by TEEB, *social and economic services* may also play a role, since NBS provide public meeting spaces and locations for (commercial or not-for-profit) economic activities such as outdoor sports, parties and games.

In the literature, financing arrangements and business models for NBS are discussed in several ways. Stakeholder involvement is mentioned by some as a tool to speed up the uptake of NBS, ranging from citizens to businesses to policy makers (Nesshöver et al., 2017; Ugolini, Massetti, Sanesi, & Pearlmutter, 2015). Others argue that specifically the business community has to take up a significant role in the process as they possess the necessary resources for scaling-up (New Climate Economy, 2014, 2016). Some discuss the success of for-

profit business models in the provision of basic needs such as fresh drinking water (Loftus and March, 2016) or the employment of new business models such as product-as-a-service versus sales (T.T. Sousa-Zomer & Cauchick Miguel, 2016).

In this paper, we wish to provide a structured overview of business model and financial arrangements for NBS as discussed in the existing literature base. This serves as a starting point to understanding the possibilities to for building business models based on ecosystem services of NBS and for suitability of financing arrangements. In the following paragraphs we cover the business models and financing literature relevant to NBS drawing from disciplines such as ecology, urban planning, business, economics and finance.

3.2 Sustainable business models (for nature-based solutions)

The concept of business model innovation (BMI), a potential enabler of NBS and sustainability, in general, has been extensively discussed and recently reviewed in the management literature (Foss & Saebi, 2017; Osterwalder, Pigneur, & Tucci, 2005; Teece, 2010; Wirtz, Pistoia, Ullrich, & Göttel, 2016). Four core areas emerge: conceptualizing business model innovation, BMI as an organizational change process, BMI as an outcome and outcomes of BMI processes (Foss & Saebi, 2017). The business model innovation literature distinguishes three main components of a business model: the value proposition (to customers in a form of a marketed product or service), the value delivery architecture (notably resources, partners, network) and the value capture component (revenues and costs) (Wirtz et al., 2016).

Building on this literature stream, the sustainable business model (SBM) literature assesses the ability of certain business models to contribute to sustainability development (Bocken et al., 2014; Boons & Lüdeke-Freund, 2013; Schaltegger et al., 2016; Stubbs & Cocklin, 2008). It links ecological, social and economic performance of businesses to their technological, organizational and social innovation activities (Boons & Lüdeke-Freund, 2013). Bocken et al. (2014) differentiate this work into archetypes of sustainable business models, which can be overlapping. Archetypes relevant for the assessment of NBS can be found in all three types of innovation. Creating value from waste (e.g. circular economy) and substituting the use of finite resources with renewable and natural processes (e.g. biomimicry) are *technological* innovations. Adopting a stewardship role (e.g. biodiversity protection, consumer health and wellbeing) is a form of *social* innovation. Repurposing business activities for society and environment (e.g. cooperative ownership models and social and biodiversity regeneration) represents a form of *organisational* innovation (Bocken et al., 2014). These sustainable business model archetypes serve as an initial framework for our analysis of different business models found in urban NBS. These archetypes can be assessed using the value proposition, value creation/delivery and value capture models to uncover opportunities and explore barriers to business models

for NBS as found in the literature review. We give an overview of NBS found in each sustainable business model archetype in Table 2, including the value proposition, delivery and capture.

3.2.1 Sustainable business model archetypes found in each NBS ecological domain

Buildings, facades and roofs

NBS related to buildings, facades and roofs are related to several sustainable business model archetypes. Firstly, green roofs provide isolation and protection of buildings and their roofs, leading to *maximizing material and energy efficiency.* For a building owner, the investment of placing a green roof pays off if the increased longevity of the roof (double the lifetime) is taken into account, which is the largest defining benefit in terms of cost savings realized by the private building owner (Claus & Rousseau, 2012). Furthermore, green roofs lead to greater energy efficiency by providing building isolation (Carter & Keeler, 2008; Claus & Rousseau, 2012). Building-integrated agriculture (on roofs, indoor or on facades) also *creates value from waste,* since it uses the water, heat and organic waste of the building can be re-used as input for delivering agricultural produce (Specht et al., 2014, 2016). Finally, green roofs, buildings and facades, including roof agriculture, fit within the business model *substitute with renewables and natural processes* due to their contribution to decreasing rain/stormwater run-off and improving air quality through natural (green) processes (Claus & Rousseau, 2012; Kok et al., 2016; Niu, Clark, Zhou, & Adriaens, 2010a). However, these ecosystem benefits are of a public nature and therefore are difficult to capture through private investments (Claus & Rousseau, 2012).

Urban green spaces, parks and urban forests

Tree cover in cities, such as alongside streets, has been associated with multiple ecological and social benefits such as improved air quality, stress reduction and habitat provision (Dimke, Sydnor, & Gardner, 2013). This relates first and foremost to the business model archetype *substitute with renewables and natural processes.* As an example, one study shows that patients in hospitals with a view of green space were discharged quicker and needed less medication than patients without a window or a 'green' view, thus reducing the need and cost of medicines and hospital visits (Ulrich, 1984). Using native plants in the urban environment also relates to the business archetype of *adopting a stewardship role*, if local tourist attractions use native plants which serve conservation purposes and improve the visitor's experience through environmental education and by providing a 'sense of place', integrating tourist facilities into the local setting (Andereck, 2009). Studies find that nature-oriented tourists are most appreciative of environmentally responsible innovations such as native plant landscaping (Andereck, 2009; Henderson, Koh, Soh, & Sallim, 2001), implying that this particular group of visitors may grow faster because of such an NBS, leading to a potential increased income for these particular tourist attractions (and their cities, more generally). Value can be captured through professionalization of tour guiding and related services (Rønningen, 2010).

Tree cover in residential areas seems to fit the business model archetype *adopting a stewardship role,* as well. A positive valuation of tree cover in resident areas seems evident from some studies which show a positive correlation between property prices and tree cover (Tyrväinen, 2001), in particular for more affluent residential areas (Dimke et al., 2013). Some of the benefits ascribed to urban tree cover are improved air quality, aesthetics, health benefits, habitats for birds and other wildlife and recreation opportunities (Y. Zhang & Zheng, 2011). At the city level, these benefits are expected to translate into improved employment and economic growth, by attracting talented people and business (Y. Zhang & Zheng, 2011). This fits with the value capture potential in this business archetype through premium pricing (i.e. higher residential value). At a macro level, governments could invest in community tree development programmes in less affluent areas since the willingness to pay for tree cover here appears to be lower (Dimke et al., 2013) whereas the positive valuation of trees seems to be unrelated to affluence (Y. Zhang & Zheng, 2011). Public hearings could improve participation of local residents into the municipal forestry planning process as tried in Finland (Tyrväinen, 2001).

Finally, marketing tree cover as CO_2 abatement in urban areas fits the *develop scale-up solutions* business model archetype, since urban tree cover could be stimulated by developing specific, high value markets for *urban* CO_2 offsets (Poudyal, Bowker, & Siry, 2015). Consumer willingness to offset CO2 are found to be higher when offsetting activity takes place in urban areas, due to the expected higher benefits of urban tree cover as opposed to tree cover, in general (Poudyal et al., 2015). Creating markets specifically for urban offsetting could capture this improved willingness to pay.

Allotments and community gardens (including urban agriculture)

Allotments and community gardens, encompassing urban agriculture, are delivered in line with many different sustainable business model archetypes. First, the delivery model of many urban agricultural initiatives is to *repurpose for society/environment*, when social enterprises or local cooperatives and networks are set up to deliver urban agricultural projects (Ghose & Pettygrove, 2014; Specht et al., 2016). Urban agricultural projects which combine commercial with social and ecological goals seem to achieve the highest level of social acceptance, whereas purely production and technology-driven urban agriculture (such as aquaponics) receives much less support (Specht et al., 2016).

Urban agriculture also leads to *maximising of material and energy efficiency* by decreasing 'food miles' (transport of food from production to consumption locus) and lowering the need for packaging (Specht et al., 2014; Vogl, Axmann, & Vogl-Lukasser, 2004). Furthermore, integration with buildings (as mentioned in

ecological domain 'buildings, facades and roofs') can also produce the *make value from waste* business model archetype, by using waste heat, water and organics from building activity (Specht et al., 2014).

The archetype *develop scale-up solutions* is present in this ecological domain in entrepreneurial concepts such as "Selbsternte" (self harvest), where organic farmers prepare and rent out small plots of land to local residents in order to self-harvest, providing recreation, education and organic nutritional value at the same time (Vogl et al., 2004). Organic farmers in this way facilitate a cheaper way of accessing organic produce than in specialty shops, allowing both farmers and residents to capture private value from this model. However, the work diversification and good relationships with customers were mentioned as more pressing reasons to engage in Selbsternte by farmers (Vogl et al., 2004). Furthermore, urban agriculture can also *adopt a stewardship role* by providing education and insight into the food chain to local urban residents (Specht et al., 2014; Vogl et al., 2004).

(Integrated Green-)Blue spaces

Within the ecological domains that deal with managing water flows in urban areas, the business model archetype *substitute with renewables and natural processes* is most prominently visible. Nature-based drainage systems provide solutions to managing excessive rainwater in highly developed, urban areas (Perales-Momparler et al., 2016; Xia et al., 2017). Instead of creating grey, pipe-based water infrastructure to manage urban water and prevent flood risk, nature-based water management approaches such as Sustainable Drainage Systems (SuDS) can generate multiple types of benefits under both flood and non-flood conditions (O'Donnell, Lamond, & Thorne, 2017). This multi-functionality (i.e. delivering recreation, air quality at the same time) is seen as a key source of value for using nature as a drainage system as opposed to pipes, however the lack of awareness and quantification of these added benefits currently act as a barrier for adaptation by local authorities (O'Donnell et al., 2017).

From a different angle, delivery of high quality drinking water through local purification and pick-up points is seen as the business model archetype *deliver functionality rather than ownership.* In regions where sale of bottled water is widespread due to low quality of the public water infrastructure, local purification processes and (unbottled) pick-up points can also *stimulate material and energy efficiency* through re-use of bottles and lower transportation costs, and provide increased access to high quality water at a lower cost than through bottles (T.T. Sousa-Zomer & Cauchick Miguel, 2016) Although this is an example in urban water infrastructure that is linked clearly to the sustainable business model archetypes, it is not totally nature-based. Nevertheless it is included to inform our understanding of variations of business models that may help spread NBS.

Table 2: Plotting Urban NBS to sustainable business model archetypes using (Bocken et al., 2014)

BM archetypes	Value proposition	Value creation & delivery	Value capture	Literature
Maximize material and energy efficiency	• Green roofs prolong life span of roof and reduce building energy need • Urban agriculture reduces 'food miles' for urban food demand	• Adapting gardening / agricultural expertise to rooftop environments. Commercial and private consumers / roofs. • Commercial / social enterprises delivering roofing and maintenance or running entire farms. Expertise needed to increase yield levels for agriculture.	• Green roofs are an attractive investment if building owners take into account doubled roof longevity and if subsidies are available. • Subsidies can improve adaptation of green roofs (to cover investment cost) • More planning certainty due to integration with building lifespan than e.g. brownfield.	(Carter & Keeler, 2008; Claus & Rousseau, 2012; Niu, Clark, Zhou, & Adriaens, 2010b)
Create value from waste	• Use of building waste (water, heat, organic) by rooftop and building-integrated agriculture • Unused brownfield, set aside for development, can temporarily be used for urban agriculture	• "Zfarming" (zero-acreage farming) is an approach that allows for the non-use of farmland or open space for agricultural production and instead reuses/recycles resources from buildings. • New material and technologies needed (innovation) for building-integrated agriculture.	• Building-integrated agriculture provides more planning certainty on the long-term than brownfield use due to integration with building lifespan (versus uncertainty about development plans of brownfields) but face high investment costs. • Brownfields often associated with high decontamination costs.	(Specht et al., 2014, 2016)
Substitute with renewables and natural processes	• Decreasing rainwater run-off with green roofs; • Improving air quality using tree cover and green roofs • Reducing heat island effect through green urban spaces • Reducing flood risk through different NBS (green roofs, tree cover, sustainable drainage systems)	• Applying green roof expertise (usually delivered through business) • Delivery through tree care firms • Measurement / quantification is a challenge to enable delivery • New partnerships and collaboration needed to set up sustainable drainage systems	• Green roof owners receive reduced storm water tax rate in some municipalities for their contribution to decrease flood risk; value of green roofs/ sustainable drainage systems is particularly high in highly developed areas	(Carter & Keeler, 2008; Kok et al., 2016; O'Donnell et al., 2017; Xia et al., 2017)
Deliver functionality rather than ownership	• Reducing environmental cost of bottling and improving health by access to (unbottled) clean water.	• Delivering drinkable water as a service (unbottled) at a local level and providing pick-up points. A filtering facility is placed in local communities	• Fee for water service at local filtering and pick up points. Cost of water is lower than bottled water for citizens (and higher quality than public water supply).	(Thayla T. Sousa-Zomer & Cauchick Miguel, 2016)
Adopt a stewardship role	• Involving local residents in urban community farming educates them about the food chain. • Landscaping with native plants caters to preferences of nature-inclined tourists, integrating tourist facilities into the environment and providing environmental education • Tree cover in residential areas leading to health, aesthetic and biodiversity benefits	• 'Selbsternte', an Austrian concept where an organic farmer sublets plots of land to residents of the urban surrounding area. • Landscaping of tourist attractions and urban surrounding with native plants • Planting of trees by private citizens in affluent areas and public support for urban forestry. Public hearings can be part of the municipal forestry planning process	• Farmer receives rents from renting out plots • Residents obtain produce from the land as well as social and educational benefits. • Enhanced visitor experience can lead to higher tourist income for cities or attractions • Potential for higher property values relating to tree cover, as well as macroeconomic benefits (attracting talented people and business) at a city level	(Andereck, 2009; Dimke et al., 2013; Tyrväinen, 2001; Vogl et al., 2004; Y. Zhang & Zheng, 2011)
Encourage sufficiency	• Family / local agriculture to combat poverty and social exclusion and provide recreation and green space	• Development of supportive networks for community gardening in marginalized communities on vacant lots	• Increased resident / family nutrition	(Ghose & Pettygrove, 2014)

BM archetypes	Value proposition	Value creation & delivery	Value capture	Literature
Repurpose for society / environment	• Social enterprises set up to facilitate self-sustaining urban agricultural initiatives	• Cooperative, business and network structures used	• Willingness to pay (in-kind) and volunteer embedded in networks	(Ghose & Pettygrove, 2014; Specht et al., 2016)
Develop scale-up solutions	• Urban farmers coordinating and facilitating involvement of local residents (i.e. Selbsternte) • Providing green roof subsidies to encourage private investment in green roofs • Creating markets for urban CO_2 abatement	• Creating a standardized approach for subletting plots of organic farmland helps scale up residential urban farming • Municipal subsidies based on green roofs • Selling urban CO2 certificates for urban tree cover	• Farmers create better customer relationships and receive land rent; residents receive good nutrition, recreation and education • Green roof owners can recoup their investments over the roof lifetime. Municipalities have lower storm water costs • Increased value of urban tree cover through specialized markets	(Claus & Rousseau, 2012; Poudyal et al., 2015; Vogl et al., 2004)

3.2.2 Sustainable business models for NBS: an overview

Based on the existing literature on NBS we are able to find sustainable business model archetypes for most of the ecological domains (combining some due to similarities and leaving out others due to lack of literature). The sustainable business model archetypes therefore seem to be quite applicable to NBS and helps us understand the different types of value propositions, delivery and capture approaches that could be provided. However, they seem to be able to capture the 'private' business model better than the 'public' business model (i.e. delivering the rationale why governments should engage in certain types of NBS).

Not surprisingly, the business model archetype *substitute with renewables and natural processes* is widespread in urban NBS, delivering value by replacing 'grey' infrastructure with 'green-blue' infrastructure (such as green roofing and sustainable drainage systems). In this business model, value capture is mostly from ecological / physiological benefits such as isolation, increased roof longevity and reduced flood risk. *Adopting a stewardship role* is a business model archetype found in quite some NBS, as well, which takes a more social / educational angle on the business model creating other types of opportunities for value capture through willingness to pay of residents and tourists (through education, recreation and self-harvesting, for example). The business model archetype *develop scale-up solutions* is important in the context of our larger question: how to speed up the uptake of NBS. Standardized urban farming concepts such as 'Selbsternte' improve scale-up, as does more structured access to subsidies to stimulate private investment (in the case of green roofs). Finally, setting up an earmarked CO_2 market for urban emission abatement could structurally increase the value of urban tree investment. Scale-up solutions are partly related to the financing question of NBS, to which we move next.

3.3 Financing urban sustainable (nature-based) innovation

Private finance for sustainable innovation in general faces two fundamental challenges: (1) payoffs are for some part public and therefore cannot easily be reaped by investors, and (2) payoffs are often long term and high risk due to their innovative character, making it less attractive for investors. This has also been referred to as the double externality problem (Faber & Frenken, 2009; Polzin, 2017). Innovation finance faces key challenges as opposed to regular finance such as high technological risk, lack of collateral and investment into R&D which is generally highly insecure and difficult to capture (Cincera & Santos, 2015; Hall, 2010; Hall & Lerner, 2010). When projects are not just innovative but also sustainable, this adds the difficulty to reap a private payoff from 'green' public goods that are created or, on the flip side, ease with which environmental costs can be externalized (Carter & Keeler, 2008; Faber & Frenken, 2009). Furthermore, infrastructural investments are likely to suffer from their often long term, illiquid character and are therefore traditionally seen as the domain of public policy into which private investors do not enter naturally (Campiglio, 2016).

In line with the above, securing finance is pinpointed as a key (and understudied) challenge for nature-based solutions and for sustainable urban transformation in general (Huston, Rahimzad, & Parsa, 2015; Nesshöver et al., 2017; Specht et al., 2014). We review the key topics discussed in the literature related to financing of urban nature-based innovation, including the slightly broader literature on urban regeneration and sustainable transformation, to ensure enough high quality literature on this topic. WE present our findings in two steps. First, we report on any specific financing issues and strategies found for separate ecological domains (similar to the sustainable business model review). Second, we report on findings in the literature review that are useful for NBS, in general (partly from the urban infrastructure finance literature), namely public-private partnerships, valuation and accounting frameworks and innovation in financial mechanisms.

3.3.1 Different financing strategies for different types of urban NBS

We find evidence of different financing strategies (and challenges) for different ecological domains in which urban NBS occur. The differences in financing strategies seem to vary along with the extent to which private value can be captured from the NBS approach, as well as with the scale (investment amount and longevity) of the investment. We discuss financing strategies for four main ecological domains in a similar way as we discussed the business model archetypes for each domain. We focus in particular on the financial players which are involved in financing a specific NBS and note the challenges and opportunities that are mentioned in the literature.

Buildings, facades and roofs

When NBS are connected to a building (i.e. green roofs, building-integrated agriculture), the investment decision takes place primarily at a decentralized level with the building/home owner or with the entrepreneur carrying out building-integrated agriculture, for example when adapting to low waste or low carbon alternative consumer products such as toilets, lighting, transportation or green roofs (Carter & Keeler, 2008; Khare et al., 2011). The upfront investment at a consumer level can be stimulated by a tripartite model in which costs and benefits are shared equally between citizens, government and businesses/developers. This means for example that the government quantifies and provides information on savings at the household level and retailers are stimulated by the government to sell low carbon products (Khare et al., 2011). Clear communication of the benefits to both society and the individual customer may drive adoption of NBS such as green roof systems (Carter & Keeler, 2008). Some studies calculate the expected cash flows (NPV) from investing into a green roof, and find that incentives such as municipal subsidies can potentially be very effective in increasing the returns of green roof investment to trigger larger scale green roof adoption (Carter & Keeler, 2008; Claus & Rousseau, 2012). They also find that the increased longevity of the roofing system due to a green roof (doubling of the lifetime) is the main benefit to the private building owner from investing in a

green roof, however this benefit materializes only after twenty years which means that building owners need to have a long-term vision (Carter & Keeler, 2008). However the private benefits do not in themselves make a green roof an attractive enough investment (NPV-positive), therefore public subsidies (Flanders, Rotterdam) or storm water tax cuts (some regions in Germany) can stimulate private investment into green roofs (Carter & Keeler, 2008). To ease access to and knowledge of these type of public incentives, standardization is recommended (Carter & Keeler, 2008).

In the context of building-integrated agriculture, the high upfront investment cost is mentioned as a challenge (Specht et al., 2014). Rooftop farms can be organized in a collective or private manner, as cooperatives or private businesses (Specht et al., 2016). When examining the economic dimension of "Zfarming" (zero-acreage farming), the economic challenges mentioned most often were costs of construction and engineering and investment cost and financing (Specht et al., 2014). A key economic issue for building-integrated farms is how to increase the expected yield from the farm, in order to make the upfront investment more attractive (Specht et al., 2014). In this early stage of development of building-integrated farming, investment costs are high and secondary benefits are difficult to quantify (Specht et al., 2014), which is a constraint in line with the innovation finance literature. Whereas small scale rooftop agriculture can use proven, low-cost technologies, scaling up rooftop / building integrated agriculture will require investment into the development of new lightweight materials / techniques (Specht et al., 2014). Although expectations are that roof top farms can be profitable, many are now in a pilot stage and lack investment funds for scale up (Specht et al., 2014). Insight is needed not only into initial cost, but also operation and maintenance costs (life cycle cost) as well as integration of financial measures with social and environmental criteria (Nelms, Russell, & Lence, 2005).

Urban green spaces, parks and urban forests

The ecological domain of green space / tree cover type NBS, either related to grey infrastructure (such as playgrounds, street trees) or in the form of urban forests and parks appear to profit from citizen investment (trees in residential grounds), real estate developer investment (in urban development projects) as well as from public investment (in public spaces). Economic valuation of urban forest benefits, such as assessing citizen willingness to pay, can stimulate investment in urban forest construction and management, as well as prevent loss of urban forests to urban development projects (McPherson, 2007; Tyrväinen, 2001; Y. Zhang & Zheng, 2011). The contingent valuation method is most often used for assessing total value of urban forest benefits (Tyrväinen, 2001). Shadow pricing of rainwater collection (B. Zhang et al., 2011) or treating trees as fixed assets to calculate life cycle costs are ways to make the added value of urban forests measurable (Funk & Domke, 2008). Poudyal et al (2015) find that some carbon offset buyers are willing to pay a price premium for carbon credits sourced specifically from urban forests, due to the importance they place on additional

community, economic and environmental benefits due to their urban location. Targeting urban carbon credit sales to these specific buyers could provide additional financing for urban tree cover. On the flip side, liability in case of tree failure can lead to costs for the (public or private) tree owner. For example, the amount of compensation paid for property damage for residents has increased in recent years in The Netherlands (van Haaften, Meuwissen, Gardebroek, & Kopinga, 2016). Furthermore, fundraising amongst residents is expected to be most successful in a good economic environments and affluent residential areas since higher household income increases willingness to pay (Dimke et al., 2013; Y. Zhang & Zheng, 2011). Relatedly, tree cover / parks were shown to have a positive correlation with house prices in empirical studies in The Netherlands and the US (Luttik, 2000; Schilling & Logan, 2008), which can allow municipalities to recoup some of their public investment in trees through higher levels of real estate taxation and ground sales. Also, the potential of increased house prices can motivate home owners to contribute financially to local community forest projects (Dimke et al., 2013).

Allotments and community gardens (including urban agriculture)

Urban community gardening can overcome financial constraints in several ways which seem to be more bottom-up. Using social network theory, Ghose and Pettygrove (2014) show how urban community gardening use embeddedness in networks to organize grassroot agriculture in spite of minimal funding (often consisting of in-kind donations and/or grants). This can be compared to how small firms overcome a lack of funding through bootstrapping, using internal funds or by organizing themselves without funds (Ebben & Johnson, 2006). Opportunities to overcome a lack of funding through bottom-up collective action using sustainable (urban) crowdfunding strategies are pinpointed by others (Bieri, 2015; Calic & Mosakowski, 2016; Hörisch, 2015; Toxopeus & Maas, 2017). Examples of successful nature-based urban crowdfunding are discussed in mainstream media but lack academic analysis so far (NEwsworks.org, 2013; The Guardian, 2014). Although not in an urban context, Hein et al. (2013) address a funding need on the long term for biodiversity protection through coordination with local communities.

(Integrated Green-)Blue spaces

Some urban NBS have characteristics which are more similar to larger urban infrastructural projects, such as sustainable drainage systems, set up to use and enhance natural processes mimicking predevelopment hydrology (Perales-Momparler et al., 2016). In a qualitative study about barriers to implementation of green-blue infrastructure in Newcastle, securing funding - for initial investments and long-term maintenance - was mentioned as one of the main barriers by more than half of the respondents (O'Donnell et al., 2017). Also, they recognized that the initial funding requirement was lower or similar to 'grey' infrastructure but that longer term funding is needed to reap the full benefits of this blue-green infrastructure due to higher

maintenance costs as opposed to grey infrastructure. Some key ways to overcome the funding (and other) barriers were to find alternative (sustainable) funding mechanisms; working in partnerships from the outset; improved education and awareness raising of the local community (to put pressure on local government to choose a green-blue variant) and creation of multifunctional space as part of the investment while clarifying the multiple benefits associated with the specific green-blue infrastructure, such as improved air quality (O'Donnell et al., 2017).

3.3.2 Key general topics for financing urban NBS

To complement the literature on financing NBS, we look for useful lessons from the broader urban infrastructural finance literature. We focus on three main topics: public-private partnerships, valuation and accounting methodologies and innovation in financing mechanisms.

Public-private partnerships in urban infrastructure

The role of different financial players, notably public versus private investors, is an frequently discussed topic in the literature on urban infrastructure investments (Claus & Rousseau, 2012; Koppenjan & Enserink, 2009; Warner & Hefetz, 2008). Infrastructure is traditionally seen as the domain of public players but lack of public funds make the entry of private and even citizen investors attractive or even necessary for cities (Helm, 2010). Furthermore, efficiency reasoning partly motivate private investment into infrastructure with expectations of smarter incentives. In line with this, user charges would create even better incentives between providers and consumers (Helm, 2010). Privatization of urban infrastructure on the other hand also creates multiple challenges (Helm, 2010), exemplified by the privatisation of London's desalination plant which led to higher water costs for London's citizens (Loftus & March, 2016). Based on three Dutch case studies of large public-private urban investment partnerships, (Klijn & Teisman, 2003) find that although long term cooperation between public and private parties are generally set up to allow for efficient risk, cost and benefit sharing, successful partnerships are often hampered by complexity of actor composition, institutional factors and strategic choices of both public and private actors. In particular, the appetite for new (improved) solutions, such as potential urban NBS, is not naturally high. Public actors need political support for their actions which hampers their risk appetite (fear of losing the next election), whereas private bodies have a higher incentive to provide standard solutions at reliable profits than to present innovative solutions (Klijn & Teisman, 2003). The quasi-market structure, often characterized by one buyer and a few sellers, is an imperfect substitute for internal control and requires active government involvement and citizen engagement to ensure efficient and fail-free delivery of public services and to prevent underinvestment by private parties (Warner & Hefetz, 2008). In order for private investors to invest adequately in delivery of public services, government needs to credibly commit that investors will get their sunk costs back (Helm, 2010).

Other drawbacks for private investors in urban regeneration are operational and bureaucratic challenges related to real estate and infrastructural investments, such as conflicting tax and grant schemes, uncertainty regarding contamination of sites and delay in planning schemes (Adair, Berry, McGreal, Deddis, & Hirst, 2000). Also, urban regeneration projects are often perceived by private investors as high risk due to a lack of information about the underlying value of assets (McGreal, Adair, Berry, Deddis, & Hirst, 2000). Furthermore, volatile rental markets create insecurity regarding expected profits. In reaction to these challenges, researchers find evidence of risk reducing measures such as public loan guarantee schemes (Schilling & Logan, 2008).

Creating a diverse group of partners and financiers, from state money to foundation grants and local bonds, is pinpointed as a key enabler for successful regeneration of US old industrial cities, as well as growing a project from a pilot phase into a larger scale building on initial successes (Schilling & Logan, 2008). Land banks can carry the initial risk of preparing land in weak or volatile real estate markets to encourage private investment and create momentum for area revitalization (Schilling & Logan, 2008). In the context of middle-income countries, public funds for biodiversity consist out of domestic, bilateral and multilateral instruments. In later stages of market development, mechanisms such as ecotourism, green commodities, hydrological services, REDD and voluntary carbon or biodiversity markets build on available public funds, some of which classify as Payment for Ecosystem Services or PES (Hein et al., 2013).

Valuation and accounting methodologies for urban NBS

A second major topic in the literature on finance for sustainable urban regeneration and NBS is adaptation of valuation and accounting methodologies in such a way that NBS/sustainable urban innovation is better accounted for, increasing its ability to generate funds. Researchers suggest adjustment of valuation procedures to include appraisal of factors such as quality of life and job creation (Adair et al., 2000; McGreal et al., 2000). A key question lying below this literature stream is weighing long-term public value against (lack of) private short-term cash flows.

The concept of natural capital and provision of ecosystem services can increase the ability of financial decision makers to allocate funds towards nature-based solutions by providing a clear accounting framework for communicating NBS benefits (Nesshöver et al., 2017). Example of a natural capital / ecosystem services accounting frameworks are “inclusive wealth”, which aims to measure human, social, manufactured and natural capital all together (Guerry et al., 2015). Improved performance metrics will allow better monitoring of ecosystem services and impact assessment of environmental policies and programmes (Schaefer, Goldman, Bartuska, Sutton-Grier, & Lubchenco, 2015). Furthermore, ecosystem service valuation is a crucial factor in

creating environmental markets, exemplified by sulphur dioxide trading, wetlands mitigation banking and nutrient trading (Schaefer et al., 2015).

In order to tackle long-term uncertainties present in large-scale investment in renewable energy infrastructures for smart cities in Japan and Vietnam, Ha & Fujiwara (2015) suggest applying real options valuation instead of simple Net Present Value (NPV) valuation procedures. Inclusion of present as well as future values into a natural capital accounting framework raises questions about how to aggregate these values over time, since discounting future values leads to economic, sustainability and ethical considerations (Anand & Sen, 2000; Guerry et al., 2015). Helm (2010) even argues that investments in infrastructure should not be depreciated like traditional asset investments, but instead should be treated as infinite, with renewal and maintenance replacing depreciation costs. Current application of environmental impact valuations by financial decision-makers are described by some as incomplete and disassociated, used for justifying nature-based wealth accumulation (Bracking, 2012; Milne & Gray, 2013).

3.3.3 Innovation in financial instruments

Several innovative private and public funding solutions for urban regeneration are suggested by Huston et al (Huston et al., 2015). First, capturing land value uplifting from urban NBS could occur either directly (through lease charges and connection fees) or indirectly using tax schemes (usually through a land property special purpose vehicle, SPV). Second, alternative financing schemes based on crowdfunding or bitcoin could play a role in creating sound public-private partnerships. Social Impact Bond (SIB) schemes can shift the risk of reaching social or environmental milestones from tax payers to private bondholders. Tax Increment Financing (TIF) allows for infrastructure induced property gains to be ringfenced to capture ex-post project benefit streams. More generally, they suggest extensive information harvesting for better risk analytics to cut information asymmetries. Relatedly, new sources of funding for biodiversity conservation should employ new information technology in order to improve monitoring and verifying contractual arrangements, which will make value more measurable (Hein et al., 2013).

At the same time, change in decision models for investment may go slower than expected due to persisting conventions and resistance to alternative investment strategies by traditional financial players such as pension funds (Clark, 1998). Lack of entry of large, traditional players such as these may slow the scaling up of sustainable housing and urban infrastructure investment (Clark, 1998).

3.4 Theoretical framework: Business models and financing arrangements for NBS

Based on our understanding of business model, financing and NBS-related literature we propose a theoretical model that generically describes the process by which NBS value can be created, delivered and privately captured (see Figure 2).

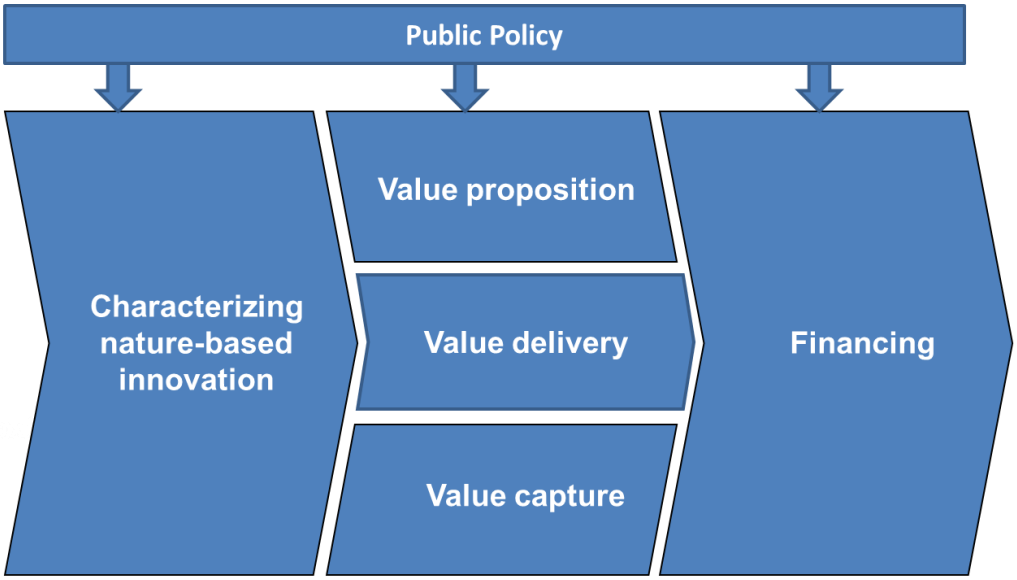

Figure 2: Proposed analytical framework

Specific characteristics of a nature-based urban innovation influence the proposed value (e.g. related to buildings, green spaces, community gardens or green/blue spaces) and the way it can be delivered by a government or business entity (e.g. through new concepts such as zero acre farming, landscaping tourist attractions with native plants, water as a service). Usually this step is linked to technical feasibility, measurability/accounting and ownership questions. Finally the value capture part reflects how the value can be monetised and appropriated through an organisation (e.g. increased rents, product sales or reduced costs for climate change adaptation). All three aspects of NBS-related business model impact the type and (public/private) and structure (equity/debt) of finance that can be obtained and fit the characteristics. Public policy can intervene at any stage in this process, e.g. by city planning, public procurement for innovation or financing guarantees for certain types of business models.

For example a community-based garden might build on social networks to finance their risky local vegetable business through crowdfunding whereas large-scale real estate development projects that include NBS elements can be best finance through corporate debt because of its low risk/return structure and stable cash-flows. Local administration can intervene in both cases: Public-private cooperation in real-estate district

planning or procurement of community initiatives on public green space heavily influence the (commercial) viability of the corresponding NBS innovations.

4 Conclusions and implications

4.1 Conclusion

Barriers to the commercial exploitation of urban nature-based solutions mostly lie in the socio-economic and political sphere rather than biophysical barriers. Successful nature-based urban innovation faces key challenges to obtain long term (private) financing due to inability to capture value from their delivery of ecosystem services, i.e. lack of a successful business model. Some applications such as urban gardening and urban tourism possess a clear value proposition, value delivery architecture and value capture part (financial payoffs) whereas others such as ecosystem services (air quality etc.) and green spaces create value that is difficult to appropriate for a private company. This difficulty is linked to: the public nature of the payoffs produced (traditionally the area of government); the absence of a clear accounting framework for ecosystem services; disconnect of central stakeholders to deal with these complex innovations and resulting difficulty in designing public-private cooperation with well-aligned incentives between all stakeholders (academic, business, government); valuation customs of private investors such as the tendency to discount/depreciate assets whereas sustainable infrastructural assets should instead be maintained/renewed; and uncertainty w.r.t. public-private contracting and commitments.

There are several avenues discussed in the literature for coping with these challenges, on both the business model and finance side. Firstly, financing should take place within diverse groups of (public and private) financiers, in order to balance incentives and improve the ability to value different types of payoff. Secondly, innovation in accounting and valuation/monetisation methodology (i.e. natural capital accounting) can allow for integration of NBS value delivery and benefits into decision-making processes of governments, businesses, investors and citizens. Citizen willingness to pay (such as for urban trees, green roofs or urban agriculture) could be captured using innovative business models and financing arrangements. Bottom-up self-organisation can sometimes sustain NBS (like community agriculture) in spite of lack of funds. Furthermore, technological and financial innovation (such as SIB's or blockchain-based funding arrangements) can facilitate collective bottom-up and public-private funding as well as offering potential for remote monitoring of natural assets which can improve contractual commitments.

4.2 Policy implications

As discussed above policy makers on the local, regional or national level possess various options to support NBS innovations in cities. On a national/supranational level CO2 abatement sinks that NBS provide need to be

incorporated in some sort of emission accounting and trading system. On a national level, accounting rules need to incorporate non-monetary values related to nature and relatedly procurement rules need to be adjusted to capture indirect benefits of NBS, such as improved air quality (Webb & Hawkey, 2017). Increasing private entrepreneurship around NBS through capturing citizen willingness to pay poses the challenge of social justice to keep spaces and services accessibly for everyone. Hence policy makers should establish clear boundaries for business models on a local level, in particular for access to basic needs.

4.3 Limitations and future research

Although this structured literature reviews aims to be transparent and replicable, there remain some limitations to the methodology used. First of all, we do not attempt to search for all possible combinations of keywords in the Scopus database. Second, Scopus itself is only one source to obtain scholarly work. Third, inclusion of additional studies and journal issues based on the authors' knowledge of the field is arbitrary but contributed to achieving a coherent picture of business models and finance considerations for urban NBS.

In spite of the literature analysed above, finance and business model literature on urban / sustainable/nature-based solutions remains nascent (T.T. Sousa-Zomer & Cauchick Miguel, 2016). We include literature that covers urban regeneration, sustainable urban transformation and biodiversity conservation, which is broader that just NBS but which capture different aspects of the finance and business model challenges that urban NBS face. A more structured approach is needed to understand exactly which aspects enter into NBS finance and business models. The literature could benefit from a more overarching framework for several reasons. Business models are almost never approached using the different components (value proposition, delivery and capture) nor linked to the sustainable business model literature which could inform the understanding of which business models may help which urban NBS to flourish. Also, the evolving types of entrepreneurial finance, such as crowdfunding, may be well positioned to assist scale-up of citizen and/or enterprise-led NBS (Calic & Mosakowski, 2016) and should be scrutinized for their ability and application to do so. Finally, choice of business models and financing options are interlinked (Toxopeus, Achterberg, & Polzin, 2017) and should therefore be viewed and strategized in sync. We therefore propose an initial framework for linking NBS to potential business and financing models which can also serve as a starting point for further theoretical and empirical analysis.

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