Chapter 4
Student Guide 2—How to Develop a Biophilic Design Framework

Abstract A biophilic design (BD) framework is a crucial component for using BD principles within an environmentally sustainable design (ESD) approach. One key challenge in developing a BD framework compatible with an ESD approach is the lack of systematic techniques with clear instructions to generate the criteria. To address this need, the process-bridging technique—a systematic method for developing biophilic criteria—is outlined in this chapter. The proposed system uses natural processes to bridge between biophilic and building performance criteria. The five elements—*earth*, *air*, *water*, *energy* and *habitat*—proposed in previous chapter are used to categorise the criteria. The process-bridging technique supports you in systematically generating biophilic criteria compatible with ESD approach We illustrate how a *place criteria* for BD and a *performance criteria* for ESD are generated using current BD and ESD frameworks respectively. These biophilic criteria can be used as a basis to develop and elaborate strategies for the architectural concept, geometrical model and building components and systems to be employed in the design. These, in turn, can then be integrated into your ESD framework, which we have termed as the 'success matrix'. There are two ways to integrate: (i) you can include them as a specific category in the matrix, hence your BD framework will become a sub-section of the overarching ESD framework, or (ii) they become the leading design targets in the matrix. We will give you some examples of each. Either way, you can synthesise the generated biophilic criteria, design strategies and building components into a self-assessment tool.

4.1 Introduction

This guide outlines a systematic method for developing a BD framework that you can use to enhance your biophilic response within an ESD project. To describe the development process, we use a number of specialised terms that we summarised in Table 4.1.

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Table 4.1 Definition of process-bridging technique terms

Term	Definition
Design framework	A design framework is a set of predetermined criteria that outlines what you want to achieve in your building design. In the practice of environmentally sustainable design, green building rating tools are used for this purpose; they set the criteria you aim to achieve through your design. Some examples are Green Star certification and Leadership in Energy and Environmental Design (LEED) certification
Biophilic design (BD) framework	When a design framework is developed to practise biophilic design, we call it a biophilic design framework. The *14 Patterns of Biophilic Design* developed by Browning et al. (2014) is an example
Success matrix	A success matrix is a design framework used within a studio design project. Similar to a design framework, you can include a set of predetermined criteria that you intend to achieve within your sustainable design
Category	These are the high-level categories, covering different aspects, presented in a design framework. For example, the Leadership in Energy and Environmental Design standards comprise eight categories: site management, energy, water efficiency, air quality, materials and resources, innovation and regional priority
Criteria	Criteria are given under each category. They are aspects of what is to be achieved within the category. For example, under the 'water efficiency' category, 'reduction of potable water use' is a criterion
Place criteria	Place criteria consist of a list of criteria that support biophilic design and contribute to sensory place-making aspects of a design. They include criteria given in the current biophilic design frameworks found in industry practice
Performance criteria	Performance criteria consist of list of criteria that support building performance. They include criteria generally found in green building rating tools currently used in industry practice
Natural process inventory	A natural process inventory is a list of natural processes that can be used to achieve certain building performance. This is generated by reviewing current academic literature and building case studies
Process	'Process' is short for 'natural process' within the natural process inventory
Biophilic criteria	Biophilic criteria is a list of criteria that is generated through the proposed technique. The criteria in this list contribute towards place-making and sustainable performance of a building

(continued)

Table 4.1 (continued)

Term	Definition
Design strategy	A design strategy outlines how a certain criterion can be achieved through design. For example, if 'use of natural elements to reduce heat gain is a criterion', then 'use of vegetation to reduce heat gain' and 'use of water features to reduce heat gain' are two design strategies
Building components	A building component is used to adopt a design strategy in the building. For example, if the 'use of vegetation to reduce heat gain' is a design strategy, then 'vegetated vertical window shading' is a building component
Implementation steps	Implementation steps are further instructions given in a design framework to realise the design strategies or building components. For example, if 'vegetated vertical window shading' is the building component, then 'calculate the dimensions of shading device' and 'use a simulation model to calculate the reduction through window' are implementation steps

Figure 4.1 shows the structure of a typical BD framework. It is based on our pilot of BD framework development (Wijesooriya et al., 2021) and an extensive literature review of academic and industry references (Wijesooriya et al., 2022).

As illustrated in Fig. 4.1, *categories* are at highest level. Under each category is a list of *biophilic criteria.* Each criterion can be further detailed in terms of *design strategies*, which can each be achieved in the building through *building components.* Elaborating the *biophilic criteria* with *design strategies* and *building components*

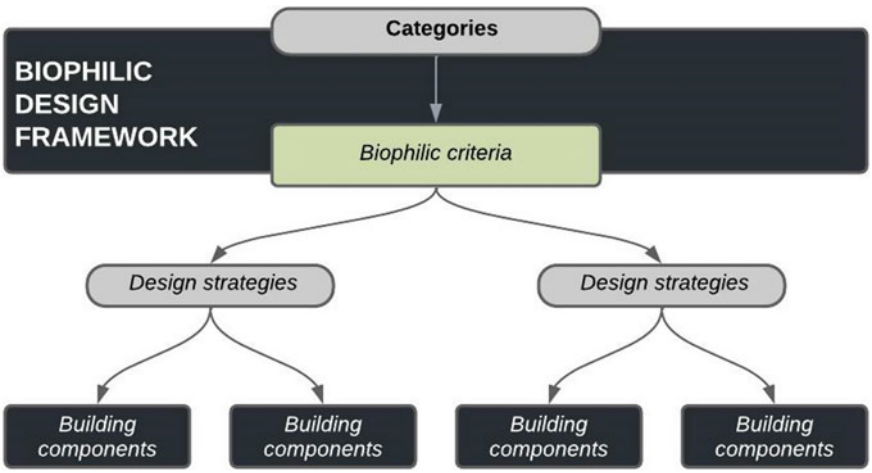

Fig. 4.1 Structure of a typical biophilic design framework

is an optional activity that improves the applicability of the BD framework. By investigating this structure and analysing current frameworks, we can identify the stages involved in developing a BD framework:

Stage I: deriving *categories* (Sects. 4.2 and 4.3)
Stage II: generating *biophilic criteria* compatible with the ESD approach (Sects. 4.2 and 4.3)
Stage III: identifying *design strategies* (Sect. 4.4)
Stage IV: proposing *building components* (Sect. 4.4)
Stage V: integrating the *biophilic criteria*, *design strategies* and *building components* into the success matrix (Sect. 4.5)
Stage VI: synthesising the BD framework into a self-assessment tool (Sect. 4.5).

The most challenging of these stages is generating *biophilic criteria* that are compatible with the ESD approach. We propose the Process Bridging Technique (PBT) for this purpose, which is more specifically detailed in Sect. 4.2. We have included an example of BD framework analysis (Wijesooriya et al., 2022) in Sect. 4.3, which may assist you understanding the process and generate your own framework.

We used the term 'success matrix' to identify the design framework in a studio setting. These generated *biophilic criteria*, *design strategies* and *building components* alone will not guide your design; instead, you need to integrate them into your success matrix. Instructions on how to integrate the BD criteria into your success matrix and further synthesise the framework as a self-assessment tool are given in Sect. 4.6.

Once the BD framework has been developed, it is necessary to validate its compatibility with the ESD approach. This step can be undertaken following the methodology used by Xue et al. (2019), presented in Sect. 4.5.

4.2 Stage 2–4: Process-Bridging Technique

The use of natural processes in building performance and ESD approaches is becoming increasingly popular. Identifying natural elements that support the sensory experience while contributing towards building performance is a strategic bridging point between ESD and BD. The PBT presented in this chapter is based on this concept. The PBT we outline here to generate the BD criteria comprises a few steps, as shown in Fig. 4.2.

As illustrated in Fig. 4.2, PBT requires additional steps expanding on the previously identified stage II:

Stage I: deriving *categories*
Stage II: generating *biophilic criteria* compatible with the ESD approach

II(a) develop the place criteria and performance criteria
II(b) develop a *natural process inventory* (NPI), meant as a list of natural processes that can be used for achieving building performance

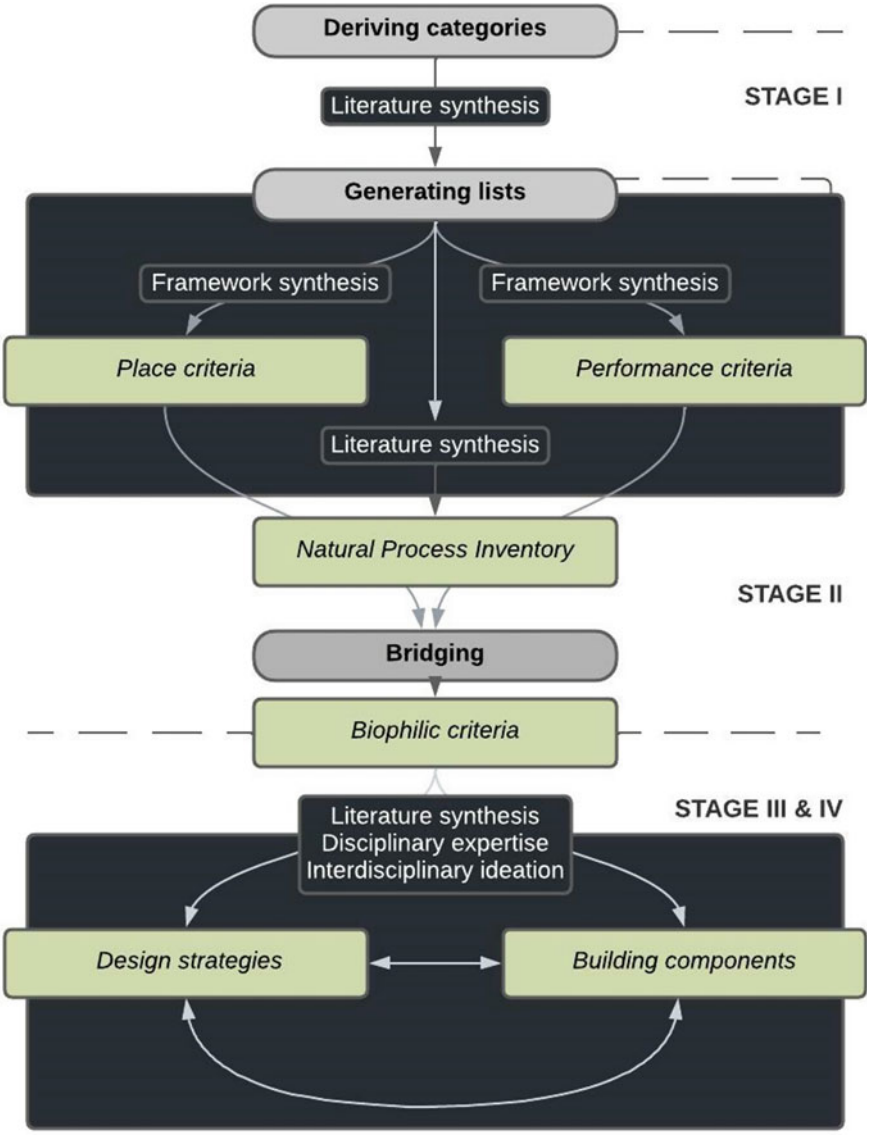

Fig. 4.2 Process-bridging technique steps

II(c) bridge between the *place* and *performance* criteria lists using the items from the NPI and develop the *biophilic criteria.*

Stage III: identifying *design strategies*
Stage IV: proposing *building components*

PBT has several stages, and, depending on the need and the scope of the project, this may differ. The figure provides the technique for development in between the steps and how these techniques are identified by analysing the exiting BD frameworks is reported in Sect. 4.2.1, while Sect. 4.3 provides a step-by-step guide to apply the PBT.

4.2.1 Techniques Used in the Stages of Biophilic Design Framework Development

To develop a systematic method for deriving BD frameworks it is important to refer to previous examples and applications. In literature, there are only a limited amount of BD frameworks that can be used at building level. All of them are outlined in following Table 4.2.

If we analyse each of these BD frameworks, we can notice that there are several common stages of BD. These stages include deriving *categories*, generating *criteria*, identifying *design strategies*, proposing *building components* and *outlining implementation steps*. Not all BD frameworks include all these stages, as these frameworks vary in terms on their aims, targets and expected outputs. However, it is possible to define four techniques common to BD frameworks at each stage: (1) literature synthesis, (2) framework synthesis, (3) interdisciplinary ideation and (4)

Table 4.2 Currently available biophilic design frameworks

Framework	Description
Kellert (2008)	the earliest design framework from Stephen Kellert (2008), which focused on the qualitative design principles of BD
Kellert and Calabrese (2015)	A shortened version of Kellert's design framework, based on the spatial experiences within a building, introduced as a guide for practical use of BD
Browning et al. (2014)	The *14 Patterns of Biophilic Design* provides a framework with 14 BD criteria, that can guide a BD design. The framework is detailed with references supporting each criteria
Abdelaal (2019)	A framework particularly developed for a biophilic campus by Abdelaal (2019)
Xue et al. (2019)	A framework by Xue et al. (2019) as an attempt to bridge the current ESD approach and BD principles
Wijesooriya et al. (2020)	A BD framework that focused on water, previously developed by the present authors
ILFI (2018)	The BD guide by the International Living Furniture Institute, developed to support the Living Building Challenge, remarkably the only guide found that provided instructions on developing a BD framework

expert knowledge. These are useful techniques that you may want to explore to develop your own framework.

Literature synthesis refers to the review of current literature to develop themes for a particular stage. Similarly, *framework synthesis* uses existing design frameworks to develop themes. When the development of the themes is a communal effort of a professional interdisciplinary team, it is refer to as *interdisciplinary ideation*, while, if the development is based on the internal expertise of the development team, it is referred to as *expert knowledge*. Table 4.3 summarises the use of each technique at different stages across the seven BD frameworks analysed.

We further summarised Table 4.2 to understand which techniques are more commonly used at each stage for each of the framework (Table 4.4).

According to Table 4.2, *literature synthesis* is the basis of most of the frameworks, except from the guide by ILFI (2018), which uses *interdisciplinary ideation.* Table 4.4 reveals that *literature synthesis* and *framework synthesis* are more predominant during the development process. *Expert knowledge*, although not a technique per se, can contribute when the framework is novel by building on the existing expert knowledge base. Table 4.5 summarises which of these techniques we used to construct the BD framework presented in this book.

4.3 Step-By-Step Use of the Process-Bridging Technique

This section presents a step-by-step guide to PBT. We start by deriving categories that can be applied to both an ESD and BD approach (Stage I). We use the nature-centric sustainability manifesto developed in Chap. 3, which defines *the built* and *nature* as comprising five elements: *earth*, *air*, *energy*, *water* and *habitat*. The following are the definitions given in Chap. 3 under 'Biophilic Thought' (Table 4.6).

These five elements are used as the main categories for both *place* and *performance* criteria lists. For each category, *place criteria* and *performance criteria* are required to bridge them and to derive a *biophilic criteria.* An NPI is developed to associate *place criteria* with *performance criteria.*

4.3.1 Developing the Place Criteria

In developing the *place criteria* (Stage II(a)), we suggest you use the *framework synthesis* and to take inspirations form the existing BD frameworks already in use. These frameworks are primarily qualitative, and, in many instances, some criteria found in them will fall into multiple categories. For example, consider three frameworks: Kellert (2008), Kellert and Calabrese (2015) and Browning et al. (2014). For clarity, we use only one category, *earth.* If you refer to these frameworks and you select the criteria used for *earth*, you will generate a list that contains the criteria presented in Table 4.7.

Table 4.3 Use of techniques for developing themes at different stages in biophilic design frameworks

	Stage				
Framework	Deriving categories	Generating criteria	Identifying design strategies	Proposing building components	Outlining implementation steps
Kellert (2008)	Expert knowledge	Literature synthesis	Expert knowledge	Expert knowledge	Not applicable
Kellert and Calabrese (2015)	Literature synthesis	Expert knowledge	Expert knowledge	Expert knowledge	Not applicable
Browning et al. (2014)	Literature synthesis	Literature synthesis	Literature synthesis/disciplinary expertise	Literature synthesis/disciplinary expertise	Literature synthesis
Abdelaal (2019)	Literature synthesis	Framework synthesis	Literature synthesis	Literature synthesis	Not applicable
Xue et al. (2019)	Framework synthesis	Framework synthesis/literature synthesis	Literature synthesis	Literature synthesis	Not applicable
Wijesooriya et al. (2020)	Literature synthesis	Framework synthesis/literature synthesis	Literature synthesis	Literature synthesis	Not applicable
ILFI (2018)	Not applicable	Framework synthesis	Interdisciplinary ideation	Interdisciplinary ideation	Interdisciplinary ideation

Note ILFI = International Living Furniture Institute

Table 4.4 Summary of techniques used during framework development stages

Stage	Literature synthesis	Framework synthesis	Interdisciplinary ideation	Expert knowledge
Deriving categories	✓	✓		✓
Generating criteria	✓	✓		✓
Identifying design strategies	✓		✓	✓
Proposing building components	✓		✓	✓
Outlining implementation steps	✓		✓	

Table 4.5 Techniques used for the development of biophilic design framework at different stages

Stage	Adopted technique
Deriving *categories*	Literature synthesis
Developing *place criteria* and *performance criteria*	Framework synthesis
Deriving a *natural process inventory*	Literature synthesis
Bridging to derive a *biophilic criteria*	Expert knowledge
Identifying design strategies	Literature synthesis, expert knowledge, interdisciplinary ideation
Proposing building components	Literature synthesis, expert knowledge, interdisciplinary ideation
Synthesising framework as a self-assessment tool	Expert knowledge

Table 4.6 Categories and definition of biophilic thought

Category	Definition
Earth	*Earth* is the materiality of the building that brings it into existence with colours and textures
Air	*Air* is the space that is trapped within the building to allow for ventilation and air quality performance and which contributes to the sense of space and light
Energy	*Energy* is the power of the building that brings warmth, comfort and light into the building; the visual attributes of daylight; and the perceived heat in the building
Water	*Water* is the fluidity within the building, serving aesthetic and utilitarian purposes
Habitat	*Habitat* is the living forms in and around the building that interact with humans, including flora and fauna that connects the inside with the outside

Table 4.7 Place criteria for earth

Earth place criteria sections	Earth place criteria themes
Natural material selection	Material connection with nature Natural material use Biomimicry Information richness Age, change and patina of time Growth and efflorescence
Place-making with earth resources	Visual connection with natural materials Non-visual connection with natural materials Materials for non-rhythmic sensory stimuli Connection with natural systems Prospect/refuge Mystery Risk/peril
Composition of material variability	Sensory variability Complexity and order in material variability Biomorphic forms and patterns Fractals in natural materials

This list is referred to as *place criteria* because, it is generated using BD frameworks focused on sensory attributes that contributes towards a sensory place experience within a building. The list is divided into 3 sections: natural material selection, place-making with earth resources and composition of material variability. Each section has themes for *earth* related *place criteria.*

4.3.2 Developing the Performance Criteria

Similar to *place criteria list*, it is recommended to use the framework synthesis technique for deriving the *performance criteria*. In this case, you can refer to common GBRTs that you might already be familiar with. In our example, we used four rating schemes detailed in Table 4.8.

Remembering that we are considering the category *earth*, the GBRTs are analysed to identify those criteria that can be related to our focus. In LEED, 'materials and resources' provide most of the criteria for *earth*, but some are extracted from the 'indoor air quality' and 'regional priority' categories. In BREEAM, 'materials' provides the majority of criteria, with a few from 'waste' category. Therefore, it is crucial to carefully go through the whole framework in selecting criteria items for each category.

Table 4.9 shows the list of *earth* criteria generated synthesising above four GBRTs. In this case, the list is called *performance criteria* because all criteria are generally quantifiable and commonly found in evidence-based design approaches.

Table 4.8 Details of selected green building rating tools

GBRT	Version used	Buildings certified	Year
LEED BD + C V4	LEED v4 Reference Guide for Building Design and Construction	More than 94,000	2013
BREEAM International NC 2016	BREEAM International New Construction 2016 Technical Manual	566,727	2016
WBS V2.1	WELL Building Standard v2 Pilot	1,166	2018
LBC V3.1	Living Building Challenge 3.1	386	2016

Note GBRT = green building rating tools; LEED = Leadership in Energy and Environmental Design; BREEAM = Building Research Establishment Environmental Assessment Method; NC = New Construction; WBS = WELL Building Standard; LBC = Living Building Challenge

Table 4.9 Performance criteria list for earth

Earth performance criteria sections	Earth performance criteria themes
Material selection	Low-emitting materials Regional priority Exterior materials and structures Responsible sourcing of construction products Designing for durability and resilience Material efficiency Rapidly renewable materials
Waste management	Net-positive waste Construction and demolition waste management Operational waste management Waste free safe and healthy surroundings
Impact management	Building life-cycle impact reduction Hazardous material abatement Enhanced material precaution and transparency Site remediation Avoiding pesticide use Hazardous material reduction Volatile compound reduction Long-term emission control Building life-cycle assessment

The *performance criteria* is directly associated with the materiality of the building and will not require design strategies to understand its implications. Again, with the long list, the criteria are categorised under three headings: material selection, impact management and waste management.

Table 4.10 *Natural process inventory* for *earth*-related processes

Associated place category	Natural process	Associated performance category
Earth	Earth walls for enhanced thermal performance	*Energy* (enhanced thermal performance)
Earth	Sand filters for water purification	*Water*
Earth	Clay as a thermal insulation	*Energy* (enhanced thermal performance); *Earth* (low-emitting materials; building life-cycle impact reduction)
Earth	Timber as a material for carbon offset	*Air* (carbon offset)
Earth	Timber as a rapidly renewable material	*Earth*
Earth	Earth as a low-embodied energy material	*Earth*
Habitat	Flora for air purification	*Air/Earth* (short-term emission control; long-term emission control)
Habitat	Flora for air quality enhancement	*Air/Earth*
Earth	Waste composting	*Earth/Habitat*

4.3.3 Deriving the Natural Process Inventory

Once the *place* and *performance* criteria lists have been derived, an NPI can be used to bridge the two. You can derive the NPI by selecting natural processes of preference from the literature. Unique *biophilic criteria* can be generated depending on the items included into the NPI. This step requires expertise in principles of building science, passive design and approaches for bioclimatic design. Your teacher will provide you with the references and resources necessary for this.[1] Table 4.10 shows an example of NPI derived using research on natural processes.

The list in Table 4.10 contains items associated with *earth* either in *place* and/or *performance*. For example, 'sand filters for water purification' has visible elements of sand that would mean it falls under *earth* in the place criteria, whereas its performance of enhancing water quality means it is in the *water* category. The associations between the two types of criteria under *place* and *performance* using NPI items depends on the user's interpretation, with an opportunity to individualise the final *biophilic criteria* list. This is further discussed in the next section.

[1] For educators: Please not that this step is highly customizable based on the overarching curriculum of your School. It is recommended that the studio will integrated the necessary knowledge to undertake this step with one of the modality described in Sect. 2.3.3.

4.3.4 Bridging to Derive Criteria List Items

With two criteria lists and the NPI compiled, bridging these list items generates the *biophilic criteria* list. Bridging is a unique step introduced in the PBT that also supports individualisation of your *biophilic criteria* list, depending on what items are included in the NPI and how the *biophilic criteria* items are written. Your expertise and personal preferences will shape which natural processes are selected and how they are associated with *place* and *performance* criteria. While writing the *biophilic criteria* descriptions, the proposed design strategies and elements allow for another level of individualisation that can reflect your architectural style and gusto.

Bridging can be done in three ways: (1) *place pathway*, (2) *performance pathway* and (3) *process pathway*. 'Process' is a shorter term used in this context to refer to NPI items. As the terms indicate, each path is identified based on where the bridging starts and its direction for association with other criteria items. Each pathway is shown below with examples using the generated lists.

4.3.4.1 Place Pathway

Place pathway bridging starts from *place criteria*. It is then associated with *process*, which is in turn is associated with *performance* (Fig. 4.3).

In this pathway, *place criteria* can be associated with multiple processes, as they contain abstract concepts that focus on the sensory experience in the built environment. Since the NPI items are specifically written for natural processes that contribute to building performance, the association with *performance* will give at least one link. This one link can lead to multiple *performance* items (Fig. 4.4) since one natural

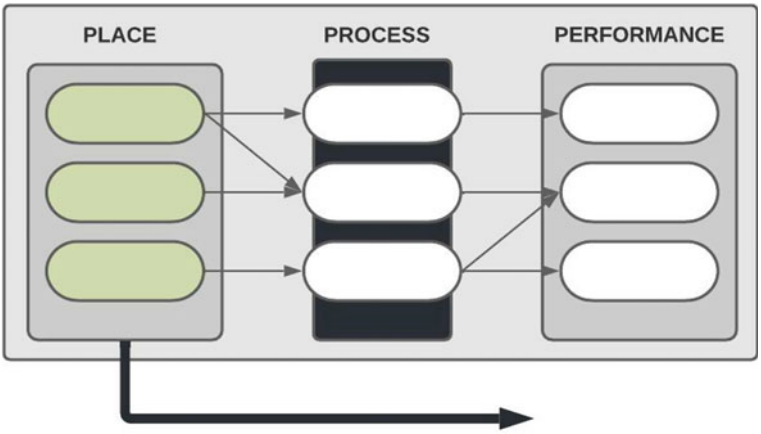

Fig. 4.3 Place pathway

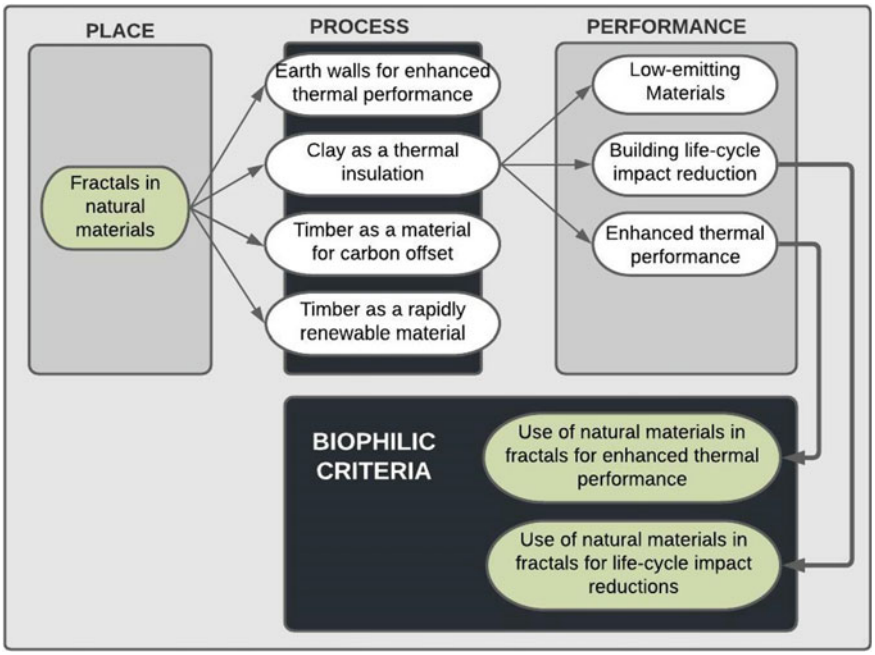

Fig. 4.4 *Place pathway* bridging for 'fractals in natural materials'

process can be used to achieve many building performances. Figure 4.4 demonstrates one example of a typical *place pathway* bridging.

As illustrated in Fig. 4.4 'fractals in natural materials', from the *place criteria list*, is associated with 'earth walls for enhanced thermal performance', 'clay as a thermal insulation', 'timber as a material for carbon offset' and 'timber as a rapidly renewable material' within the NPI. To associate this further with *performance criteria*, 'clay as a thermal insulation', as an example, can be associated with 'low-emitting materials' and 'building life-cycle impact reduction' from the *performance criteria list* for *earth*. *Earth* category mainly focuses on materials and the knowledge around the shift towards circular use of resources emphasised in concepts such as cradle-to-cradle, circular economy, circular construction processes are crucial. In this example use of clay support the cradle-to-cradle approach where clay is biodegradable material that can be disposed back to nature with no environmental consequences.

However, the direct implication of 'enhanced thermal performance' can be assumed to be in such a list derived for *energy*. This is quite a common phenomenon when the *place pathway* is used.

The *biophilic criteria* item for 'enhanced thermal performance' can, as an example, be written as 'use of natural materials in fractals for enhanced thermal performance'. By using the generic term 'natural materials' rather than the more specific term 'clay' in the criteria, there is more opportunity during design stages to respond with multiple design strategies.

The *place pathway* is recommended when place-making aspects are in focus and the design is required to improve upon its building performance without compromising on the BD considerations.

4.3.4.2 Performance Pathway

The *performance pathway* starts the association from an item within the *performance criteria list*. With some *performance* items including management aspects, it is difficult to associate with any natural processes. Due to this, there can be some items in the *performance* list without a link to a natural process. This can result in a *performance* criterion not contributing to the overall BD approach in the design. The potential associations are illustrated in Fig. 4.5.

This pathway can result in one of three potential associations: a *performance* can be linked to both *process* and *place*, *process* only or have no links at all. An example is given in Fig. 4.6 to demonstrate this.

The *performance* item 'long-term emission control' is associated with 'flora for air purification' and 'flora for air quality enhancement'. When attempting to associate these to *place criteria*, numerous items can be linked due to their abstract level. It takes disciplinary expertise to determine what aspects should be covered by a particular NPI item and what should be included in the *biophilic criteria* list. In this example, 'information richness', 'age, change and patina of time' and 'growth and efflorescence' are selected from the *place criteria list* to associate with 'flora for air purification'.

The *biophilic criteria* items are written as 'use of flora contributing to information richness (or 'age, change and patina of time' or 'growth and efflorescence') for long-term emission control'.

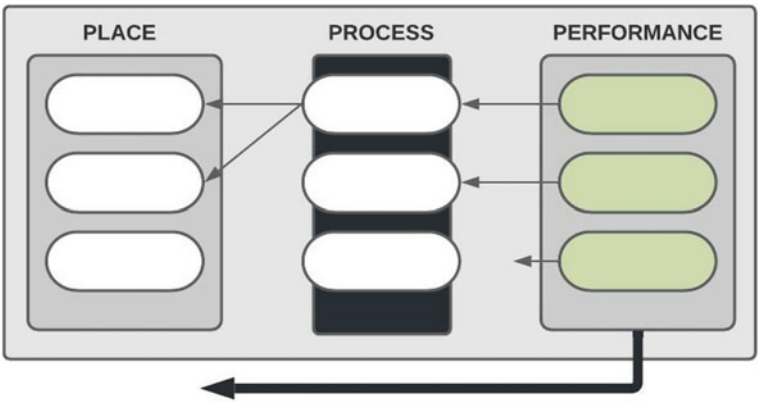

Fig. 4.5 Performance pathway

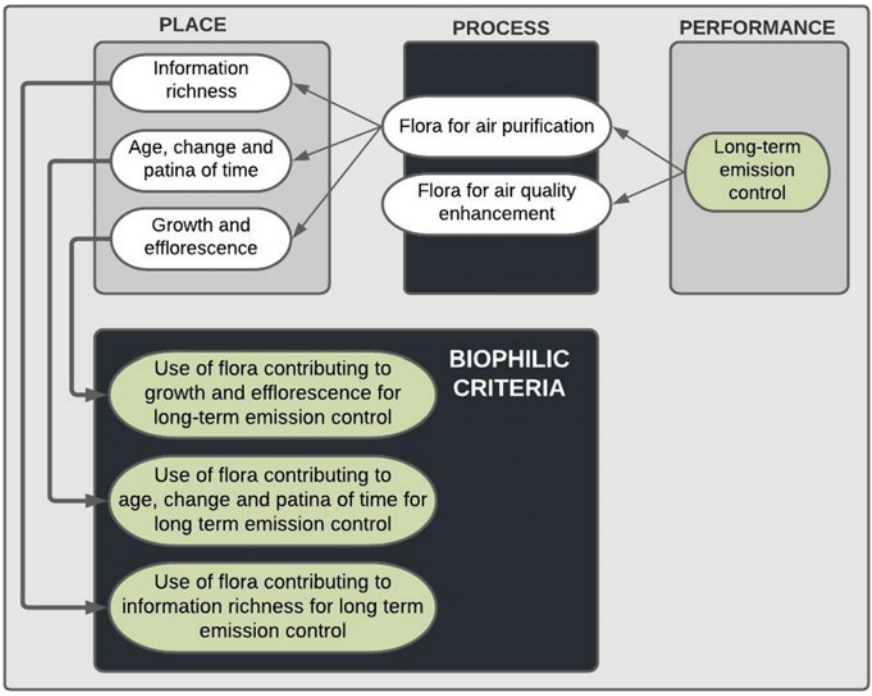

Fig. 4.6 *Performance pathway* bridging for 'long-term emission control'

This pathway is useful when the design is focused on building performance and there is a need to improve its BD response.

4.3.4.3 Process Pathway

The *process pathway* starts at the NPI by selecting a natural process and then associating it with both *performance* and *place*, as shown in Fig. 4.7.

This pathway usually results in one of two types of associations: links to both *place* and *performance*, or with a link only to *performance.* 'Solar electricity' from the NPI is one example of the latter, as there is no visible natural element to associate with the *place criteria* list. A pathway is shown in Fig. 4.8 using the generated lists for *earth.*

In this example the *process* item 'timber as a rapidly renewable material' is selected, and the item description itself indicates a *performance* item within *earth*: 'rapidly renewable materials'. Associating the *process* item with *place criteria* is not as direct, since the use of timber in *place* can link with multiple items; however, we have selected 'information richness', 'growth and efflorescence' and 'fractals in natural material'. All of these qualities can be achieved by using timber as a material.

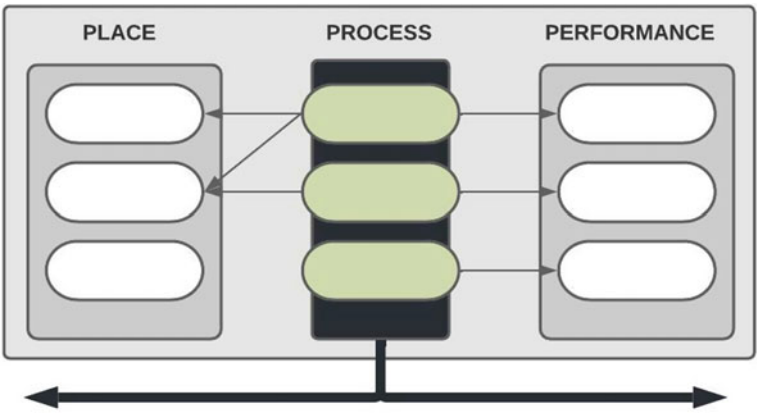

Fig. 4.7 Process pathway

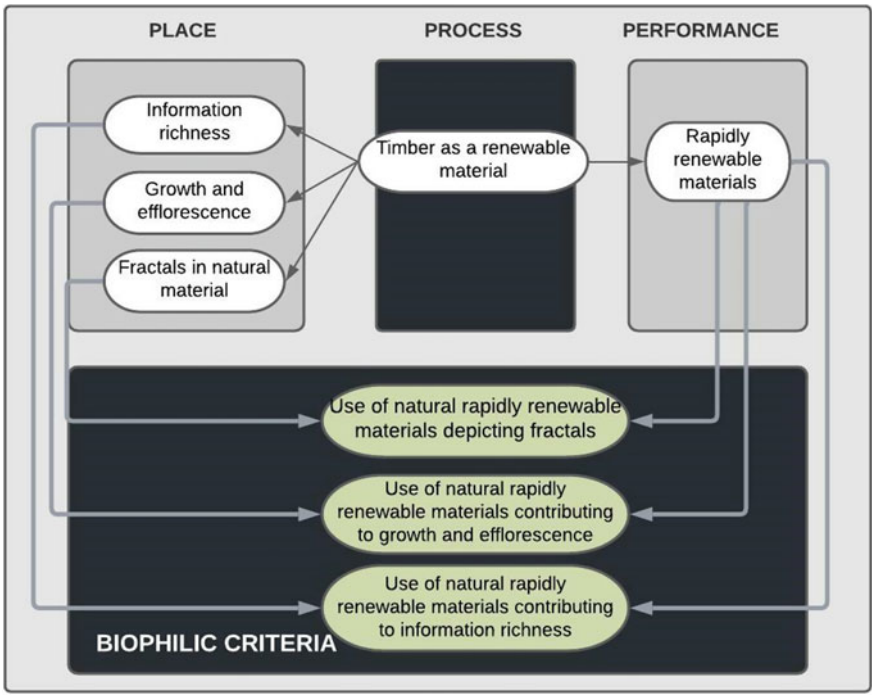

Fig. 4.8 Process pathway bridging for 'Timber as a renewable material'

Hence, *biophilic criteria* can be written as 'use of natural rapidly renewable materials contributing to information richness', 'use of natural rapidly renewable materials contributing to growth and efflorescence' and 'use of natural rapidly renewable materials depicting fractals'. Again, this shows that writing *biophilic criteria* can vary according to user knowledge, with immense opportunity for original interpretations.

4.3.5 Design Strategies and Building Components

This is an additional step that is used to derive a more elaborated BD framework. A good example of associating with *design strategies* (referred to as 'design considerations' in the BD framework) and proposing *design elements* is given in the *14 Patterns of Biophilic Design* (Browning et al., 2014). Figure 4.9 shows this step for 'use of flora contributing to information richness for long-term emission control'.

It is worth differentiating between *design strategy* and *building component* at this point. As shown in this example, a *design strategy* is an overall idea for achieving a certain criterion, whereas a *building component* is an actual feature included in the

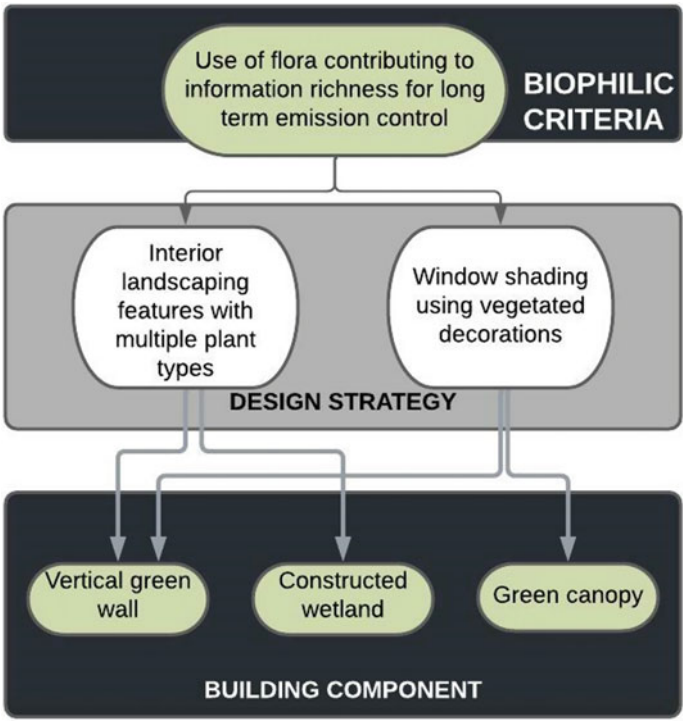

Fig. 4.9 Design strategies and building components for 'use of flora contributing to information richness for long-term emission control'

building. In this example, 'interior landscaping features with multiple plant types' is a broader-level *design strategy*, while 'vertical green wall' and 'constructed wetland' are two *building components* used to achieve this. Sometimes, one *building component* can be used to satisfy multiple *design strategies*. Similarly, one *design strategy* can guide several *building components*, as shown in Fig. 4.9.

Expert knowledge, literature synthesis and interdisciplinary ideation can be used for this step. To use literature synthesis, you can review the current literature, to find *design strategies* and *building components* for each criterion. Alternatively, you may draw upon your expertise to do this task. If you are working in a group, you can each assume the different roles of stakeholders involved in the design and then generate ideas for *design strategies* and *building components* from different disciplinary viewpoints. By doing this, you are using interdisciplinary ideation. This is an opportunity to explore role-play to support your interdisciplinary learning.

4.4 Synthesising a Biophilic Design Framework

We use the term 'BD framework' to identify a guiding framework that includes a *biophilic criteria* list, *design strategies* and *building components* that can be easily used for your ESD project. This is similar to an industry GBRT. This section outlines how the generated themes for the *biophilic criteria* list, *design strategies* and *building components* can be developed into a BD framework. You can also develop a BD framework with only *biophilic criteria*, since the two other themes are follow up stages of the PBT (Fig. 4.2).

Your generated themes can be integrated into the success matrix as a separate category; this category will then become your BD framework. Alternatively, you can use the BD framework itself as the success matrix. We highly recommend that you use the latter option, since, building performance is already considered in writing *biophilic criteria* and is compatible with ESD criteria. You can further synthesise the BD framework into a self-assessment tool regardless of your integration option. Both options are discussed below.

4.4.1 Use of BD Themes Within the Success Matrix

With this option, your generated themes are integrated into the success matrix as a separate *category* of a *criteria.* This is very much similar to current ESD practice, where, in GBRTs, you would find either a separate category for BD or credits that can be achieved through other existing criteria. For example, the Living Building Challenge has BD as one of its 20 imperatives (Fig. 4.10). In LEED, there is a separate credit for BD that can be achieved through other categories.

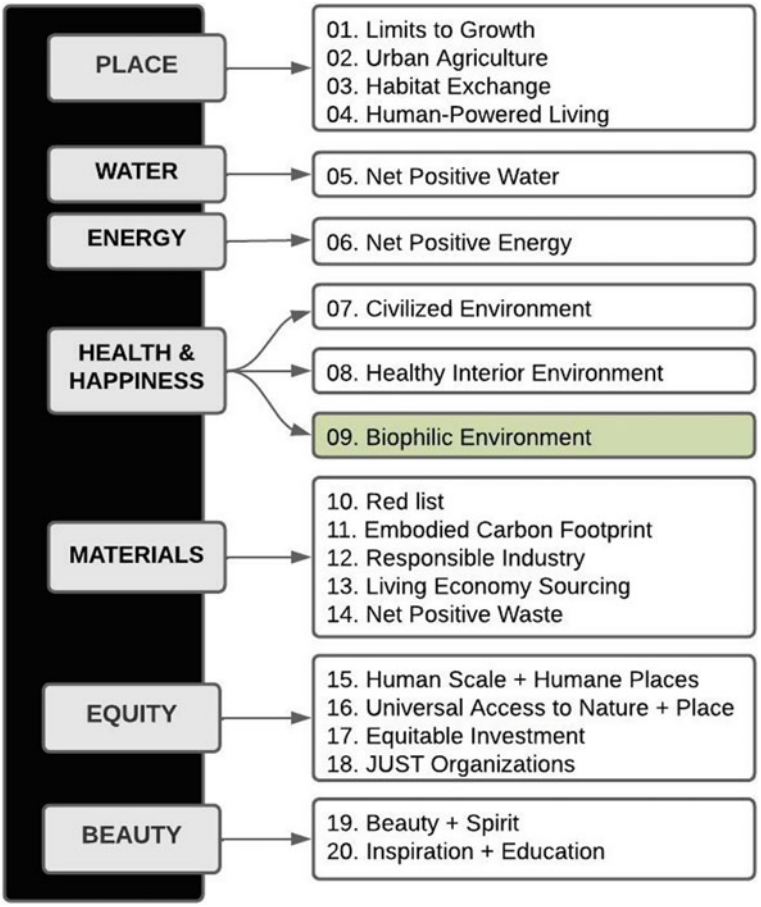

Fig. 4.10 Living building challenge's 20 imperatives. *Source* Adapted from International Living Future Institute (2018)

If you are to include your generated BD criteria list into your success matrix, you can also use either one of these methods. Figure 4.11 shows a sample success matrix that uses BD as a separate category.

In this example, the success matrix has five categories: site management, energy, air quality, water efficiency, materials and resources and biophilic quality. The BD framework only consists of *biophilic criteria* without *design strategies* and *building components.*

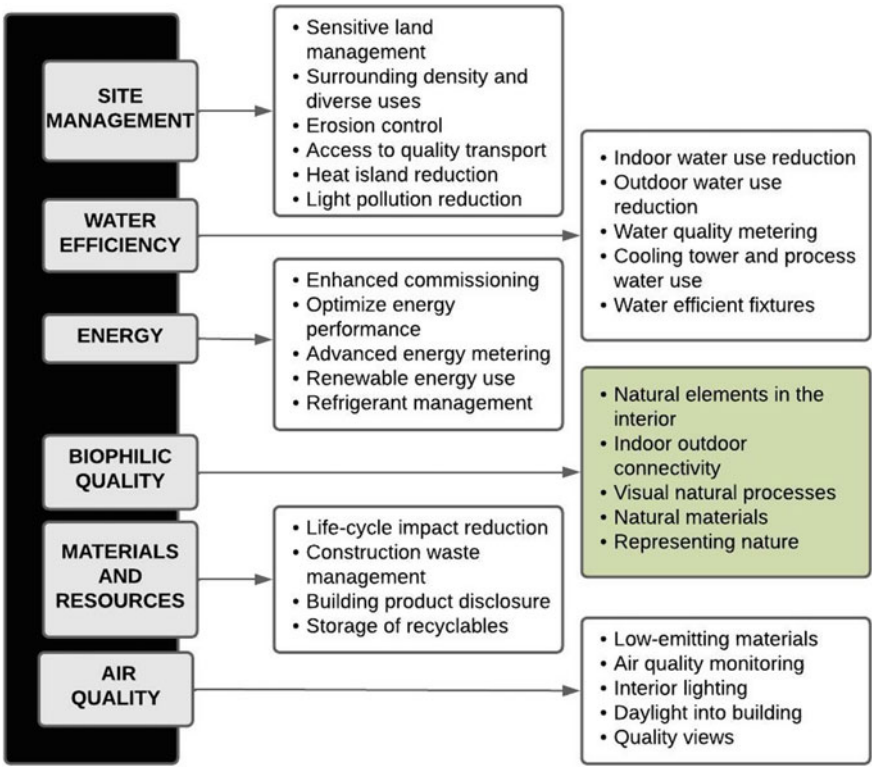

Fig. 4.11 Biophilic design framework as separate category

4.4.2 Use a Biophilic Design Framework as the Success Matrix

With this option, you can use the generated themes developed as a BD framework as your success matrix. This is similar to using a current BD framework, such as the *14 Patterns of Biophilic Design*, to guide your design (see Appendix B). The example given in Table 4.11 illustrates how a BD framework is used as a success matrix with the *earth* category. The total BD framework with five categories of *earth*, *air*, *water*, *energy* and *habitat* is given in Appendix C.

As shown in Table 4.11, categories used for PBT are repeated with *biophilic criteria*, with elaboration up to *design strategies*. During the *place* and *performance criteria* development, all the ESD criteria are mapped against the same categories. Therefore, it is sensible to use the same categorisation used in generating *biophilic criteria* for the success matrix.

Table 4.11 Biophilic design framework used as a success matrix

Category	Criteria	Design strategy/building components
Earth	Exposed natural materials	Materials use in natural forms for floors, walls, doors and windows etc. Exposed brick work Natural stone paving
	Low embedded energy natural materials	Use of natural materials with low embedded energy such as timber, clay etc. for floors, cladding and finishes
	Rapidly renewable materials	Rapidly renewable timber use in its natural form Bamboo for cladding and partitions
	Recycled natural materials	Use of materials recycled with low technology such as clay
	Sustainable finishing of materials restoring natural quality	Using finishing techniques to retain natural colours and textures for diversity of experience Use of non-toxic finishing materials

4.4.3 Developing the Biophilic Design Framework into a Self-Assessment Tool

This step is highly recommended: it will allow you to learn to judge the quality of your work and which is a necessary skill for using BD within an ESD approach. By synthesising your BD framework into a self-assessment tool, your success matrix will automatically become part of this tool. Whether you have BD criteria within the success matrix, or it is used as the success matrix itself, the method to be used to synthesise a self-assessment tool is similar.

The use of a design framework as a self-assessment tool is seen consistently in industry GBRTs. If you carefully investigate LEED, every category has certain criteria with assigned credit values. GBRTs generally provide design strategies and indicators to achieve these credits. Using a similar structure, you can convert your success matrix into a tool that can be used to assess the achievement of your sustainable design. You will need to assign credits to each criterion within the categories, which may result in differing weightings for each category. Figure 4.12 shows three key GBRTs and their weightings for each category.

Assigning credits and providing weightings for each category depends on your perception of sustainability. At this point, you can refer to your sustainability manifesto to decide which categories should have higher weightings.

The way you have integrated the *biophilic criteria* list will also lead to one of two different outcomes. If you used the BD criteria as a separate category, you could attain a building with higher biophilic quality only if you provide a higher weighting for the BD category. If you are using a BD framework as the success matrix, your design outcome will have a higher biophilic quality. In the second option, how you

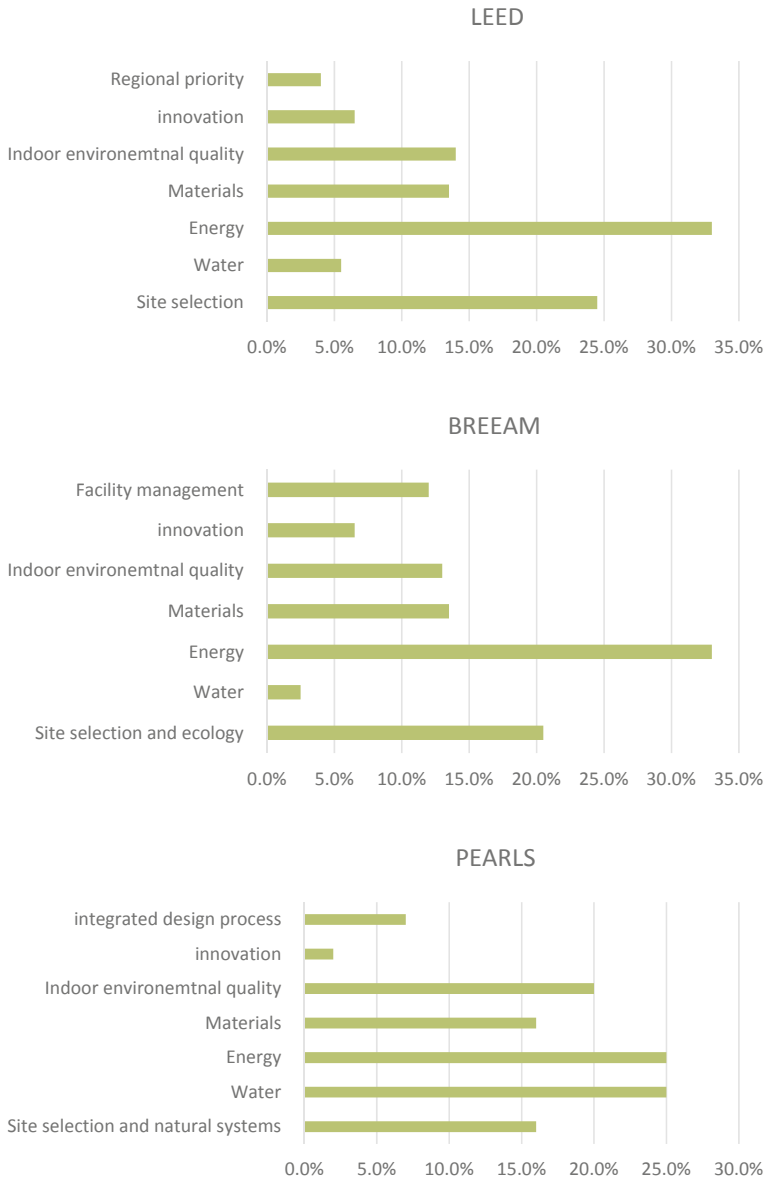

Fig. 4.12 Weightings across categories among green building rating tools. *Note* LEED = Leadership in Energy and Environmental Design; BREAAM = Building Research Establishment Environmental Assessment Method

assign weightings for each category may determine the focus of your BD response. Say, for example, you give more weight to water-related categories—your design may become focused on achieving BD principles using water as an element. Table 4.12 shows a BD framework that is developed to be used as a self-assessment tool with differing weightings across the categories.

Table 4.12 Biophilic design framework developed as a self-assessment tool

Category	Criteria	Credits	Total for category	% for category (%)
Earth	Exposed natural materials	6	24	11
	Low embedded energy natural materials	5		
	Rapidly renewable materials	4		
	Recycled natural materials	4		
	Sustainable finishing of materials restoring natural quality	5		
Air	Natural processes for air quality management	6	20	9
	Natural ventilation	4		
	Sensory air flow variation	4		
	Natural elements for carbon offset	3		
	Low-emitting natural material	3		
Water	Nature for water quality management	6	24	11
	Water for thermal comfort	6		
	Enhanced water area	3		
	Water saving in landscaping	4		
	Water elements for restoration	5		
Energy	Passive solar heating	6	26	12
	Circadian lighting design	4		
	Sensory thermal variation	4		
	Renewable energy use	6		
	Natural elements for heat reduction	6		

(continued)

Table 4.12 (continued)

Category	Criteria	Credits	Total for category	% for category (%)
Habitat	Restore natural habitat	6	27	13
	Restorative natural habitats	5		
	Bio-diversity	6		
	Experience direct nature	5		
	Inter-species connectivity	5		

4.5 Validating the Biophilic Design Framework

An important step in the process is the validation of the developed BD framework in terms of its compatibility with ESD criteria. For this step, you can use the method proposed by Xue et al. (2019). This method is simple, and it provides clarity by visualising the results. The key objective of the validation is to assess the success of the developed *biophilic criteria* in achieving the building performance anticipated by the selected GBRT. Each criterion in the GBRT has a credit-awarding points assigned to it. By using a *design strategy* within the building design, the credit point will be awarded to the criteria. Hence, the method is simply to find how many credits can be achieved in a certain criterion by using the *design strategies* in response to the developed *biophilic criteria.*

As an example, select LEED as the GBRT and provide all the *performance criteria* items from LEED and which are categorised into *earth* (Table 4.13). The credits assigned to the LEED items are shown in the second column, 'LEED credits'. Once the *biophilic criteria* are derived, an evaluation is performed to ascertain how much credits can be gained by using this *biophilic criteria*, and the credit value is given under the third column, 'biophilic criteria potential credits'.

After the credits are assigned, a radial diagram is generated to compare and visualise the achievement (Fig. 4.13).

The radial diagram in Fig. 4.13 illustrates how generated *biophilic criteria* can be used to achieve the credits in LEED credit-awarding systems. Further conclusions can be drawn by totalling the credits from LEED and finding what percentage can

Table 4.13 Comparison of LEED credits and potential achievement through *biophilic criteria*

Performance items from LEED	LEED credits	Biophilic criteria potential credits
Building life-cycle impact reduction	2	2
Construction and demolition waste management	2	1
Low-emitting materials	1	2
Regional priority	1	1
Building product declarations	2	0

Note LEED = Leadership in Energy and Environmental Design

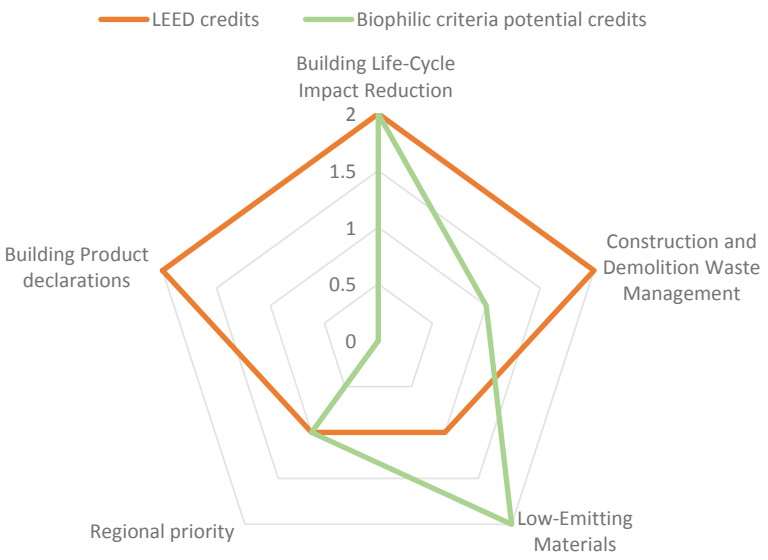

Fig. 4.13 LEED credits achievement through Biophilic criteria. *Note* LEED = Leadership in Energy and Environmental Design

be achieved using the *biophilic criteria*—in this example, the result is 75%. The same validation and analysis can be repeated for each GBRT using this process. When multiple GBRTs are used, the analysis can also indicate which GBRT is more supportive towards developing a BD framework for enhanced human–nature connectedness.

4.6 Concluding Remarks

This chapter provided a methodology for developing a BD framework. The strategic step in this is generating the *biophilic criteria* using PBT. We showed how to develop a *place criteria list*, a *performance criteria list* and the NPI required for this technique. You will need a sustainability manifesto to generate these lists so that you have the same categories in the *place*, *performance* and *process* lists.

You need to integrate the criteria into your success matrix, a design framework used in sustainable design studio. We showed how to synthesise the *biophilic criteria* as a BD framework, with additional instructions for using it as a self-assessment tool. You can also use the validation method if you are working with a standard GBRT. You may have to refer to Student Guide 1 (how to develop sustainability manifesto) to start with the PBT, and Student Guide 3 (how to model your BD thinking process) to understand how the BD framework is used in your design thinking process.

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