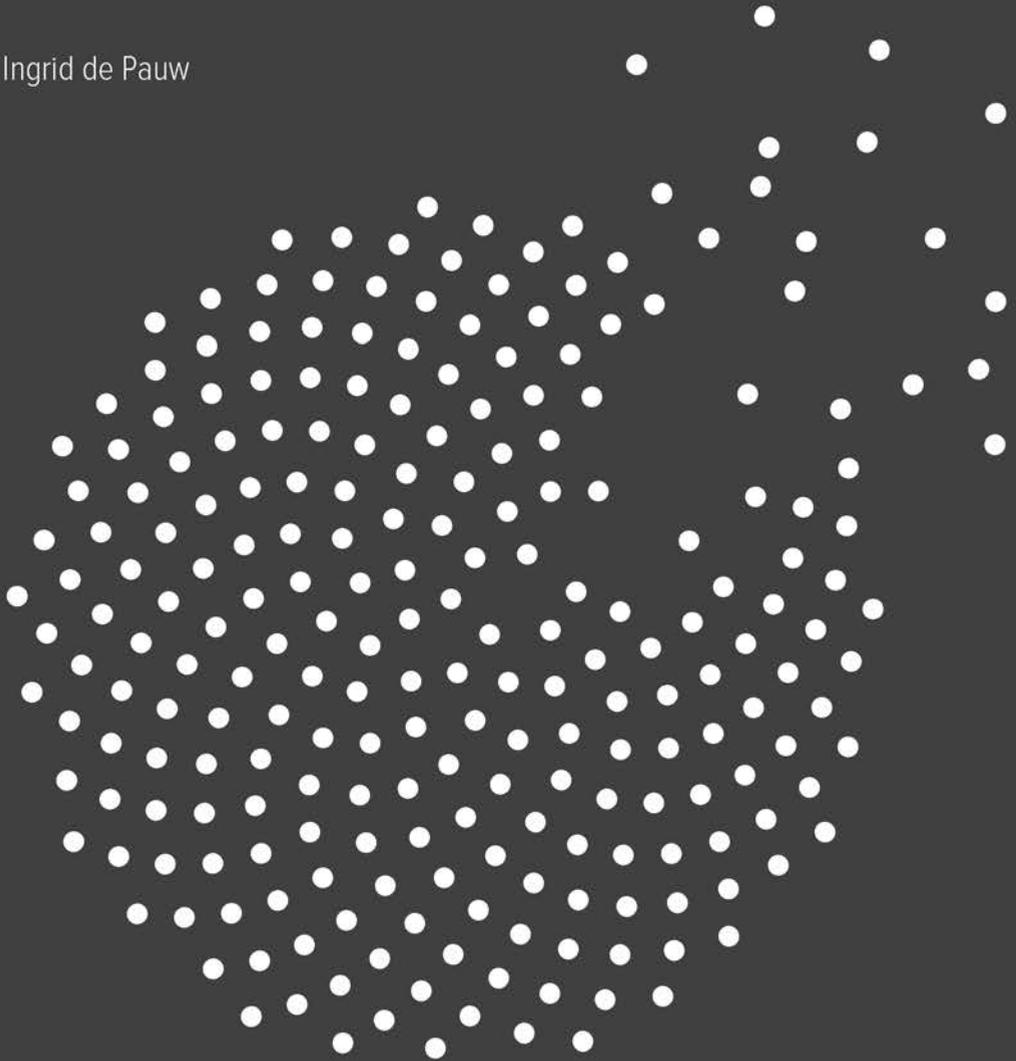


# Nature-Inspired Design

Strategies for Sustainable Product Development

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# SUMMARY

Product designers can apply different strategies, methods, and tools for sustainable product development. Nature-Inspired Design Strategies (NIDS) offer designers a distinct class of strategies that use ‘nature’ as a guiding source of knowledge and inspiration for addressing sustainability. Biomimicry and Cradle to Cradle, two NIDS, are already being applied in product development practice and have been integrated in the curricula of higher education. However, little research has been conducted on *how* NIDS are applied and how they actually help designers with sustainable product development. Consequently, these design strategies are not supported by an empirical understanding of their applicability, benefits, and limitations. To facilitate the effective application of NIDS for sustainable product development, a first step is to explore and understand the current NIDS design practice. Accordingly, the main research question of this thesis is:

**How do Nature-Inspired Design Strategies (NIDS) help designers in developing ‘sustainable products’?**

To answer the research question, a multiple case study approach was adopted, analysing NIDS-projects to reveal how the application of the design strategies affected the design process and its outcomes. First, a comparative study was performed using student design projects, to explore which effects could be attributed to the application of NIDS. The results were used in the subsequent study of four ‘real-life’ design cases. Based on the analysis of in-depth interviews and project documentation, this second study generated a thorough understanding of the effects of applying NIDS in design practice.

The first three chapters of the thesis describe the research leading up to the case studies. In **Chapter 1**, we first frame the wider context of sustainable design thinking within which

NIDS have been developed. We argue that NIDS support a changing perspective towards the aim of sustainable design which has been described as a move from 'reducing unsustainability' towards 'achieving sustainability'. Both Biomimicry and Cradle to Cradle build on this perspective of achieving sustainability and share key characteristics. In **Chapter 2** we define the term Nature-Inspired Design Strategies (NIDS) as design strategies that "base a significant proportion of their theory on 'learning from nature' and regard nature as the paradigm of sustainability". Following the definition, we analyse which design strategies can be classified as NIDS and what these strategies offer for product design, resulting in the selection of Biomimicry and Cradle to Cradle as suitable NIDS for case study research.

To be able to assess how NIDS help designers in developing 'sustainable products', we evaluate the sustainability of the case-study designs. However, as described in **Chapter 3**, current life-cycle based assessment methods are not geared towards capturing some of the main results that NIDS strive to accomplish. Consequently, for the purposes of this study, we developed an adapted method, presented in Chapter 3, which evaluates the extent to which a product (benefits) a sustainable environment, using assessment criteria for (environmental) sustainability.

In **Chapter 4**, we describe the case study findings from the student design projects. We compared Biomimicry and Cradle to Cradle with a more established design strategy (Ecodesign) and elicited differences specific to the application of NIDS. The results from these case-studies show how the application of different design strategies coincides with differences in a) the design focus of the student groups, b) the level at which the design assignment was interpreted, and c) the resulting solution levels. NIDS helped the design students to broaden their solution space and to include designs that provided alternative ways for fulfilling product functions, system functions, and user needs. The analysis highlighted two distinct features of NIDS contributing to these findings. Both Biomimicry and Cradle to Cradle offer challenging 'absolute' design principles for guiding the design process, and both strategies trigger the integration of context-specific solutions that reach beyond the design of the product, for instance solutions that include a recycling infrastructure coupled to specific local companies. In addition, the study showed that the student groups did not apply all steps offered by the design strategies, which may have led to partial implementation of the design philosophy on which the strategies are based. In the case of NIDS, this finding is particularly relevant, as Biomimicry and Cradle to Cradle currently lack quantitative design tools for evaluating the environmental impact of the designs, when compared to Ecodesign.

**Chapter 5** presents the results from the case-studies of real-life projects. These cases confirm that application-level is an important variable to consider: designers have their ‘own way’ of applying the design principles, methods, and tools that NIDS offer and do not apply all of the strategy elements. However, the design principles they applied activated the designers to set ambitious targets and to adopt a ‘systems approach’. In each of the four real life cases, the designer/design teams engaged in designing parts of the ‘material cycle’. These results were achieved by cooperating with suppliers, by selecting different materials or even developing new material combinations, and in some cases by implementing functional innovations that eliminated materials containing potentially harmful ingredients for which no cycle could be established.

In **Chapter 6**, we evaluate the outcomes of the real-life cases using the assessment method and criteria for environmental sustainability developed in Chapter 3. The assessment shows that NIDS helped designers meet specific sustainability criteria on the level of product components and, to a limited extent, achieve beneficial impacts. The designers thus achieved more than a reduction of environmental impacts for specific components. These results indicate that, in principle, NIDS are capable of helping designers to ‘achieve’ one or more criteria for environmental sustainability, especially with respect to establishing material loops. However, at a product level, none of the case study projects succeeded in meeting all criteria; the designers focused on specific principles at the expense of others. This poses the risk that the solutions, while realising break-through solutions in terms of specific issues such as cycling of resources, may generate increased environmental impacts within the current system in which they are produced, used, and cycled.

**Chapter 7** presents the main conclusions from the study. They capture the understanding of NIDS we generated from this study, which we summarize here:

- Nature-Inspired Design Strategies offer a design philosophy for integrating environmental sustainability in product development, building on the perspective of ‘achieving sustainability’. This perspective challenges designers to develop products that, like their natural counterparts, fit within and even benefit the ‘ecosystem’ of which they are part.
- At an operational level, Biomimicry and Cradle to Cradle provide design principles and tools conveying ecosystem knowledge for implementing this philosophy within the design process. This study illustrates how the principles helped designers to set ambition levels and to guide the design process.

SUMMARY

- The cases included in this study show that NIDS helped designers to achieve solutions that include more than the design of the product (the artefact), thereby tackling hurdles for realising environmental sustainability, especially concerning the cycling of resources.
- However, NIDS offer no tools that help designers to pinpoint potentially adverse impacts of their designs across the product life cycle. The study demonstrated how the partial application of NIDS by designers can lead to such impacts.

This PhD study has generated several propositions for the way in which NIDS affect the design process and its outcomes, thereby providing starting points for follow-up research. Furthermore, the findings gave rise to recommendations for the development of tools that can remove current obstacles in the application of NIDS. The thesis ends with the author's recommendations for designers who are currently putting NIDS into practice, and for the educators who are encouraging the next generation of designers to learn from and be inspired by nature.



Figure 7.1: Visualisation of the differences in the primary objectives of eco-efficiency strategies and nature-inspired design strategies (NIDS) in terms of resource flows (based on Braungart et al., 2008)

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This thesis is about Nature-Inspired Design Strategies; strategies that use 'nature' as a source of knowledge and inspiration for sustainable product development. Biomimicry and Cradle to Cradle, two Nature-Inspired Design Strategies, have already been implemented in product design practice and in curricula of higher education. But how are these strategies applied, and how do they help designers in developing 'sustainable products'?

Based on case-study research of multiple design projects, this study shows how the design philosophy, principles, methods, and tools of Biomimicry and Cradle to Cradle have inspired and guided product designers in their work. The findings demonstrate the value, as well as the current limitations, of Nature-Inspired Design Strategies. The insights and recommendations provided in this thesis are valuable for researchers, designers, and educators with an interest in Nature-Inspired Design, and help to clearly position Nature-Inspired Design in sustainable design practice.