CHAPTER 3
TOOLBOX

About this toolbox

"A collection of hands-on tools."

The following section describes a collection of tools that support you in filling in the NID Wheel. It is both a selection from the tools that were used by the pioneering companies to integrate NID in their practice as well as slightly altered or even new developed tools by our team. All tools have been evaluated and optimized in design cases at various companies. Many examples used in this section come from these cases.

We deliberately choose to include those tools we feel are unique or instrumental for a successful NID project. The collection can of course be expanded, however we prefer this strong selection over an exhaustive long list. Because NID can be used within your own design process, we invite you to add your favourite design tools in the process.

Finally, with NID we like to "Adapt and Evolve to Changing Conditions", and the same can be said for the tools: we expect these will improve with every project in which they will be used. What follows are the best practices currently available, and in the near future we will make them even better.

VALUE

- Competitor Benchmark

Determining the specifications on which your product can compete in the market.

I. List competing products

II. List most valued properties that product type can have

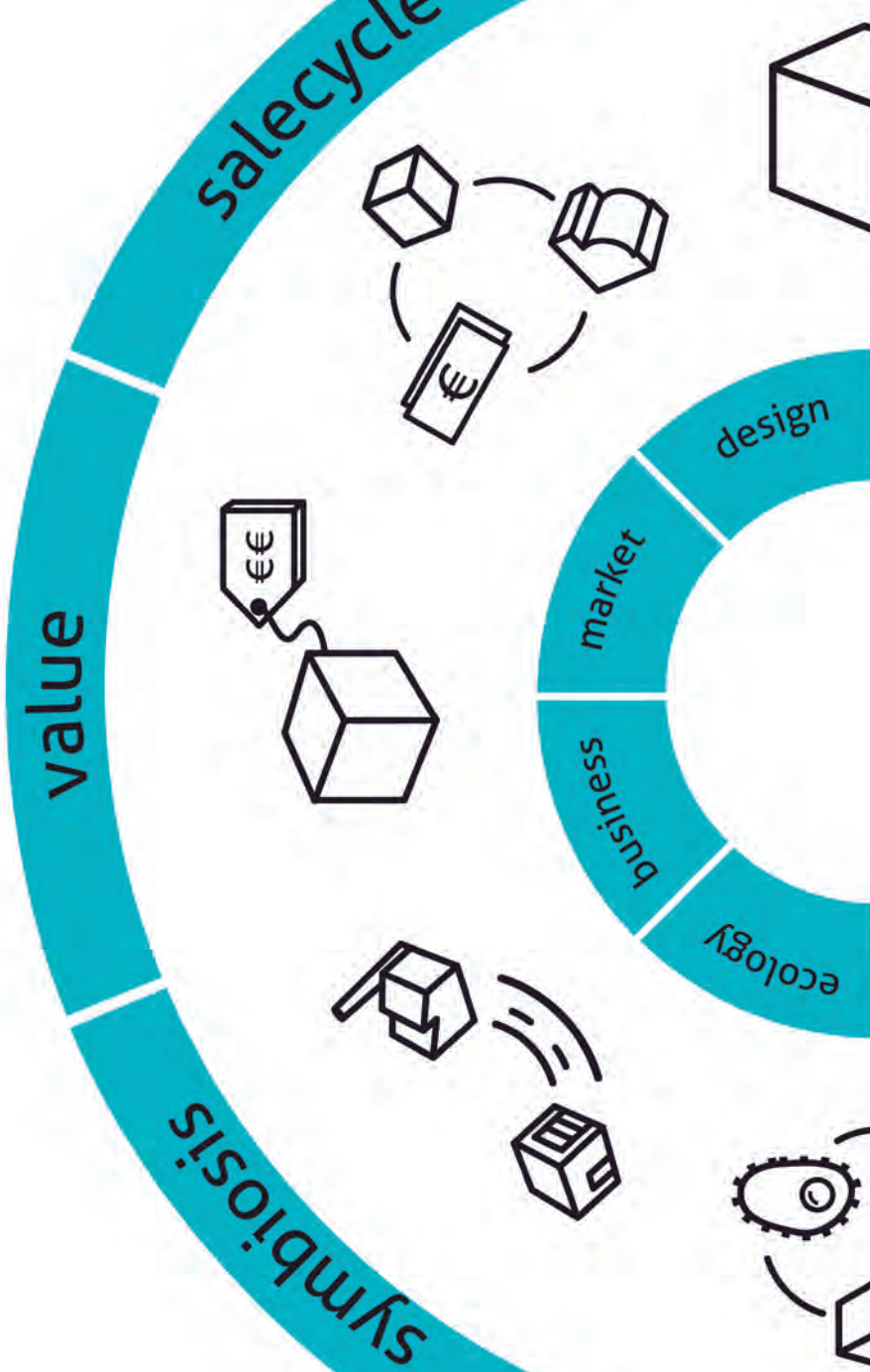
III. Rank competing products on the key properties

IV. Note the blanks and groups

V. Choose one key quality that separates you from the crowd

It is most likely that you want your product or service to be competitive. Common strategies to compete are outperforming the alternatives on the market, or occupying a niche in the market. The natural parallel is evident, and from Nature we can see how competitive strengths rely on specialization. According to Mader (1996) no two species compete for the exact same niche. A niche, defined as the relationship between a species and its environment, is described in the field of ecology in three parameters: Physical factors (temperature, soil, sunlight, etc.), Biological factors (food, parasites, competitors, etc.) and Behaviour (season, time of day, social organization, etc.). Chipmunks and squirrels for example compete for the same food in the same seasons, but they have different nests (underground and in trees).

So where could you specialize to have the competitive edge in the market? The goal of a Competitor Benchmark is to visualize the market and the existing gaps that you can fill. The result is a short-list of specifications and performance targets that sets you apart from the market, and a long list of specifications where a 'best in class' reputation is less important. It is based on Quality Function Deployment (QFD) (Akao 1994), which is a more comprehensive method than the tool described here. QFD translates user quality perception into functional and measurable characteristics, offers tools for concept selection, and deploys quality assurance for detailing and production. The Competitor Benchmark only looks at the translation of user quality perception into functional characteristics, emphasizes distinction of your product in the market, and provides a visual aid for decision making and communication. The result is a list of key requirements that, as with QFD, can be used at will for concept selection and quality assurance. Competitor Benchmarking ties into the Circular Business Model Canvas, as these specifications are key to the value proposition.



Steps of the tool

I. List competing products

Find out who your competitors are for your type of product or service, for instance via a web search. Look for direct competitors and also for indirect ones. In case you are working on a coffee machine as in the example, include other coffee machines of different types, cafés, and perhaps coffee delivery as well. The Intention Statement may inspire you to widen the scope even further by including other ways to get the end result.

II. List the most valued properties that these products can have

Looking at the inventory of competing products made in step 1, list the qualities or properties that these have. Properties can be functional (such as volume, temperature, ...) aesthetic (colour, finish, ...) emotional (evoked feelings, desirability, ...) economic (price point, running costs, ...) and so on. You don't need to be exhaustive as this is about finding the key properties that influence the value perception.

III. Rank competing products on the key properties

For each property, draw a horizontal line and indicate the values at the left, middle, and right end of the line. Use quantified scales whenever possible (1kg..5kg..9kg) and use a qualified scale otherwise (poor..modal..best). Then place images of the competing products or services at their appropriate places along the lines.

IV. Note the blanks and groups

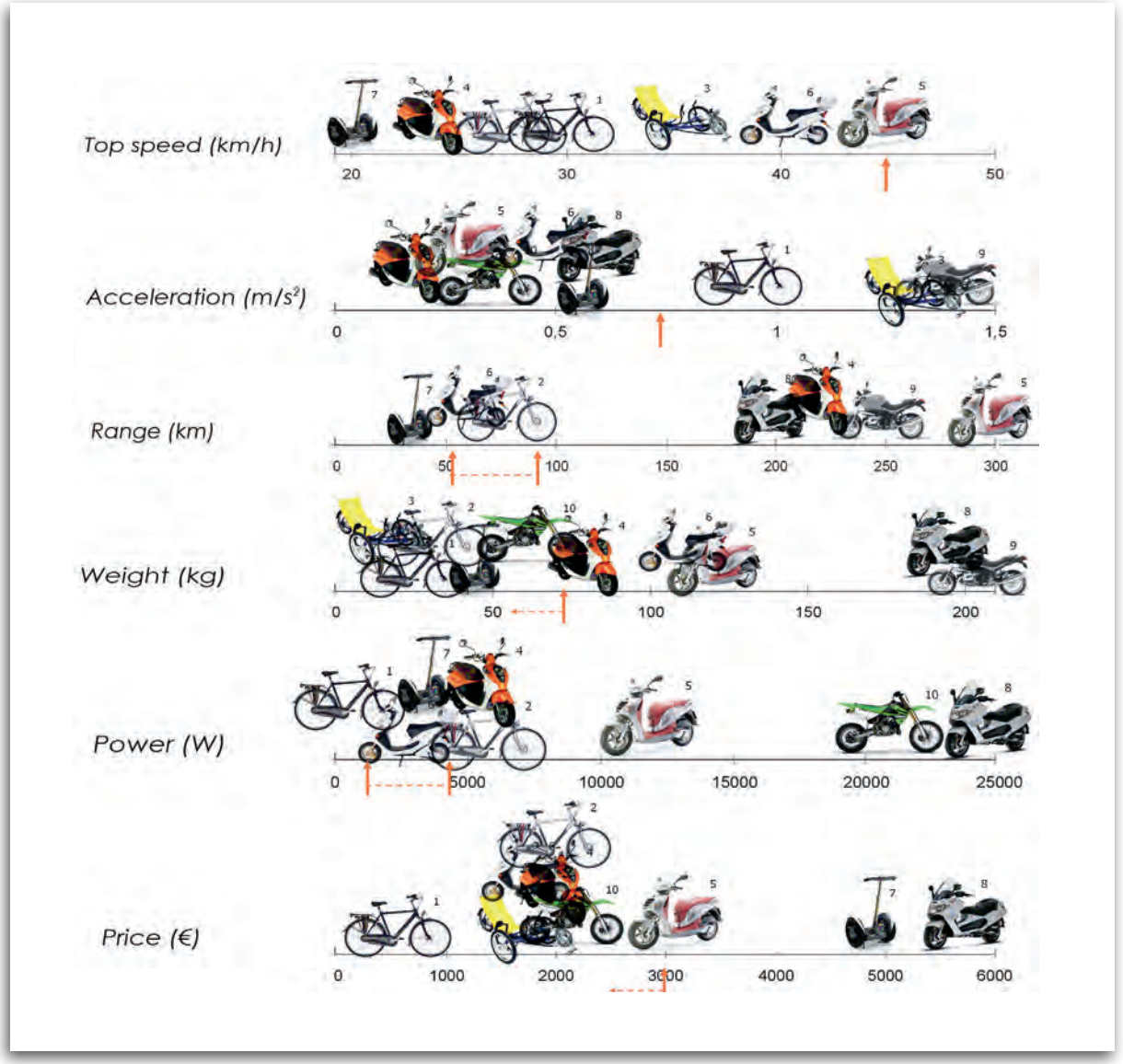
In the distribution of competitors on the key properties, you are likely to see clusters of products with comparable performance and gaps where no products are ranked. Also, the highest, lowest and modal score for each property are immediately visible. This gives you a bandwidth for key requirements and the gaps are unfilled niches that you may consider to fill.

V. Choose one key quality that separates you from the crowd

Choose one or very few properties that distinguish your offering and to aim for agreeable performance on the other qualities. In other words, on one line, you choose one gap and on the other lines, you choose a cluster. Conclude by specifying performance ranges for all of the key requirements, using the lines to illustrate where this puts you in relation to competitors.

Example

Here you see a Competitor Benchmark for an electric scooter. Besides direct competitors (popular electric scooters), other products are taken into the comparison (bike, e-bike, e-motor, Segway, petrol scooter, etc.). The key quality target for acceleration is what should separate this product from the crowd. For top speed, the product should be top-end and for the other qualities, it conforms to the market.



VALUE

- Certification

Identifying relevant and value adding sustainability certificates.

I. Read the certification resources

II. Observe the certification criteria

III. Aim for a chosen certificate

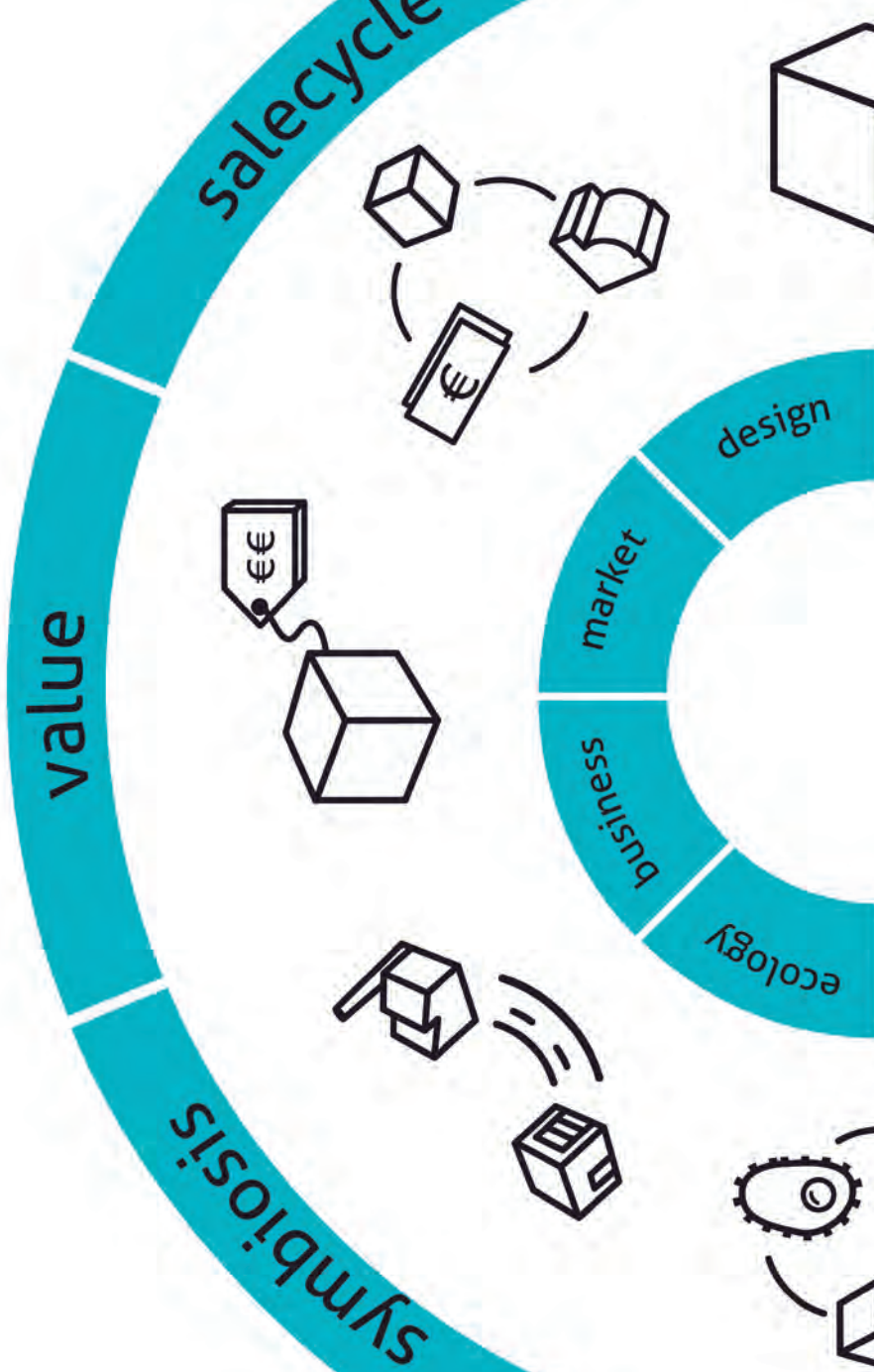
IV. Initiate the certification procedure

V. Use your certificate for marketing

Nature Inspired Design products can be eligible for cradle to cradle (C2C) certification (Cradle to Cradle Products Innovation Institute 2012). NID integrates and operationalizes many aspects of cradle to cradle, as well as Biomimicry. All aim for healthy products made with positive environmental impact and producing no waste, and C2C certificates are a way to get external validation for (working towards) these qualities. This tool summarizes C2C certification, and it links to the Quick Scan ABC-X Inventory tool that is needed for proper certification. It can be helpful if you are preparing to get certified, and also when you want to use the certification criteria as an additional check of your design without actually applying for a certificate.

It is worth mentioning that C2C certification is subject to criticisms: 1) certified products are not necessarily cradle to cradle, 2) the certification protocol is owned and exclusively sold by cradle to cradle institutions and 3) the certification requirements are not compatible with the standards for Life Cycle Assessment.

The following tool description is about the steps to take for the certification of your product. Another way to use the C2C certificates is in the search for C2C materials, products and producers. At C2Ccertified.org you find the registry of certified products, ranging from plastics to PV panels and from textile to toys.



Steps of the tool

I. Read the certification resources

Through the website of the cradle to cradle products innovation institute on C2Ccertified.org you can find the resources on the product standards (certification requirements), material health methodology (ABC-X Inventory), fees and policies. We advise you to study those documents and summarize them here.
The certification applies to materials and products and does not apply to processes, food and drinks, buildings, countries and cities. In the certification of a product, all involved processes are reviewed but the processes themselves cannot be certified. Cradle to cradle buildings do exist, as well as the ambitions for cradle to cradle cities. These use C2C certified materials and products whenever possible but are not certified themselves. Furthermore, products with harmful intent or apparent safety concerns will not be certified, for example weapons, tobacco, ivory, blood metals, nuclear technology or products that are otherwise in contradiction to the cradle to cradle principles.

II. Observe the certification criteria

The certification criteria are categorized in material health, material re-utilization, renewable energy and carbon management, water stewardship and social fairness. The following table contains the key criteria for each category and for each level of certification. For an explanation of the ABC-X abbreviation, read the ABC-X tool description.

Material Health	Basic	All materials in the product are known, defined as either technical or biological nutrient and free of chemicals in the banned substances list.
	Bronze	75 mass% of the product is ABC-X rated, or 100% if the entire product is a bio-nutrient, and there is a strategy to phase out any 'X' materials.
	Silver	95 mass% is ABC-X rated (or 100% for bio-nutrients) and no X rated materials occur in the product.
	Gold	The product is ABC-X rated for 100%, no 'X' materials are used and the product does not emit hazardous volatile organic compounds.
	Platinum	The product complies with the gold standard for material health and all process chemicals are ABC-X rated without occurrence of X ratings.

Material Re-utilization	Basic	All materials are designated to the biocycle or technocyle as covered in the basic level material health criteria.	
	Bronze	The product's material re-utilization score ≥ 35	The material re-utilization score (MRS) averages the mass percentage of recyclable/ compostable content (a) with a weight of two recycled/ renewable content (b) with the weight of one: **MRS = (2a+b)/3**
	Silver	The product's material re-utilization score ≥ 50	
	Gold	MRS ≥ 65 and there is a 'nutrient management strategy'	
	Platinum	MRS = 100 and the product is actively recovered and cycled.	

Renewable Energy and Carbon Management	Basic	Annual purchased electricity and on-site emissions comprising the energy for manufacturing are quantified.
	Bronze	A strategy to use renewable energy and manage carbon emissions is made.
	Silver	5% of the energy used for final manufacture is either renewable or the carbon emissions are offset (CO_2 neutral)
	Gold	50% of the energy used for final manufacture is CO_2 neutral.
	Platinum	Final manufacture uses 100% CO_2 neutral energy, creates excess clean energy and there is progress in clean energy use across the value chain.

III. Aim for a chosen certificate

Use the summary table to identify a certificate that you think you can attain and study the relevant section of the product standard in full detail. Make a list of all the criteria that you would need to comply to and highlight those that are at this point a challenge. Initiate measures that work towards compliance with design assignments, management directives or audit planning. You can use the certification program documents to prepare for audit, or choose to initiate the certification procedure before putting the assignments, directives and planning into effect.

IV. Initiate the certification procedure

Again through c2ccertified.org you can find an assessor to perform the certification protocol for you, and they will give you advice on how to improve your compliance. At the time of writing, there are such firms in the United States of America (2), Germany (2), the Netherlands (2), Belgium (3), Switzerland, Spain, the United Kingdom (2), Denmark and Brazil (2). You will find contact persons and contact details to initiate the following procedure.

a) Data is collected and the assessor evaluates this data on the certification requirements
b) This data and strategies for improvement are reported to the C2C products innovation institute for review
c) You sign a license agreement and pay the certification fee
d) The institute makes their decision and if all goes well, issues the certificate

Water Stewardship	Basic	Company specific water issues (e.g. scarcity, sensitive ecosystems) are identified and was is no violation of the discharge permit for two years.
	Bronze	All water inputs and outputs on all facilities are quantified, all sources and discharge channels are known and reported in a water audit.
	Silver	Chemicals in discharged water are characterized or a positive impact strategy is developed if there is no product related water discharge.
	Gold	Discharge water does not contain problematic chemicals or, in case of no discharge, there is progress towards positive impact through water.
	Platinum	All water that is discharged from manufacture facilities is clean enough to be used as drinking water.

Social Fairness	Basic	A self-audit is performed to protect human rights and procedures are developed to address any of the identified issues.
	Bronze	A self-audit for full social responsibility is performed and a positive impact strategy is developed.
	Silver	Across the value chain, social responsibility is guaranteed by external certification (e.g. fair trade) or with a social project to improve lives.
	Gold	External audit of social responsibility and active life-improving initiatives are in place.
	Platinum	A third party audit on internationally recognized social responsibility requirements (e.g. SA8000) is completed.

Credit: Cradle to Cradle Products Innovation Institute.

e) Your product is put into the C2C certified product registry
f) Every two years you must show progress to be re-issued the same or higher level certificate.

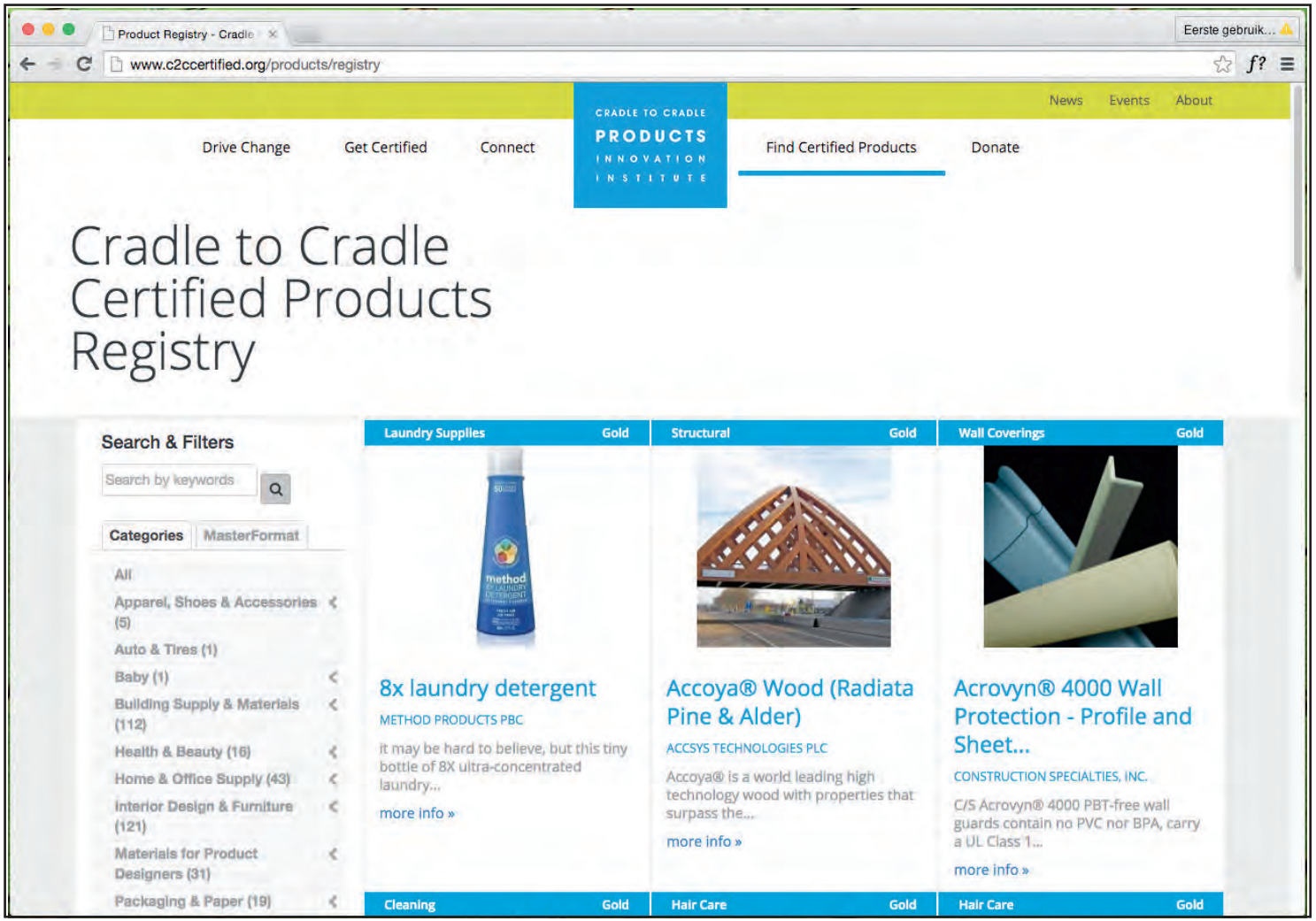
The certification fees mentioned in step 3, are € 2000,- for new products and € 500,- for recertification (V3.0 product standard, Cradle to Cradle Products Innovation Institute 2013). This is however not the full price tag of a certificate. The data collection and the consulting needed to make improvements are charged by the assessor and depending on the complexity of your product, range between a few thousand to a few ten-thousand Euros.

V. Use your certificate for marketing

You are likely to want to boast your certificate through your advertising media, packaging, and product details page. After the very involved process of optimization and certification, you might need to be reminded that not everyone knows what a C2C certificate entails, so make sure you clearly mention your positive impacts and the quality improvements that you made.

Example

For various up-to-date examples of c2c certified materials and end products, we recommend you visit www.c2ccertified.org.



Credit: Cradle to Cradle Products Innovation Institute.

VALUE

- Circular BMC

Creating business models that support closed or open loop product service systems.

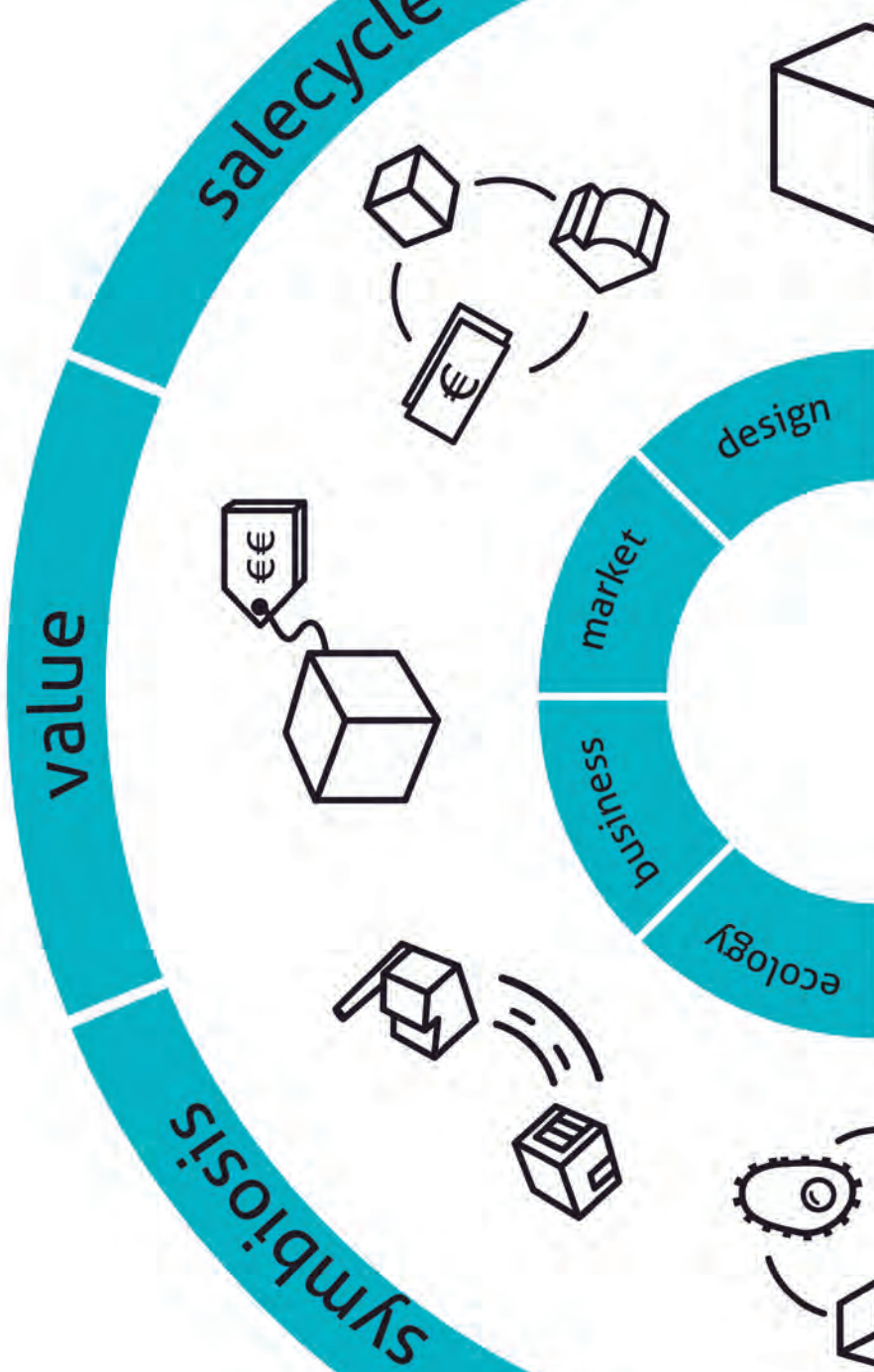
I. Set up the first iteration business model

II. Add inputs and outputs

III. Close value cycles

IV. Iterate the canvas with circular business model archetypes

In many cases, a new business strategy will help to profit from a product developed with Nature Inspired Design. For instance by recovering value from a closed loop system (a product-service system that closes material loops through recovery, reuse, remanufacture, recycling and biological regeneration). Or by creating revenue from beneficial impacts. The business model canvas is a tool to outline and iterate the plan for a business, identifying the offering, revenues, cost structures, target group and the activities of the company. With the addition of input and output fields, it can be used to come up with circular business models. After several iterations the result will be a business model, which touches many other aspects of the NID wheel. The concept you develop is the embodiment of the offering developed in the Value Element, the Salecycle explores the channels and customer relationships, and key partners are considered in the Symbiosis Element.



Steps of the tool

I. Set up the first iteration business model

The best explanation of using the business model canvas can be read in the book "Business model generation" by Osterwalder and Pigneur (2010) that can be previewed at businessmodelgeneration.com. The Delft Design Guide provides a summary of the traditional Business Model Canvas (van Boeijen, Daalhuizen et al. 2013). It will guide you through nine aspects of a business; key partners, key activities, key resources, the value proposition, customer relationships, channels, customer segments, cost structure and revenue streams. Fill out the canvas once before adding two more fields and iterating in the next steps.

II. Add inputs and outputs

The bottom line of the traditional canvas represents financial inputs and outputs: costs and revenues. Now create two more fields below them, representing the material and energetic inputs and outputs. Populate the input field with the main materials and the energy you think go into making the product or delivering the service. Use the output field for the expected 'waste' flows including production leftovers (like clippings, water used for cleaning and sawdust), end of life products, consumables to use with products and remaining energy (usually heat). As with the other fields of the canvas you can be very detailed, but for the first iterations, it is more important to have a good overview of the main issues.

III. Close value cycles

In a linear product system, materials move from left to right on the canvas whilst money moves from right to left in exchange. There are expenses made to acquire new materials in the left half of the canvas, the profit is made on the right side, and the waste materials are not featured in a typical canvas. With the input and output fields in place you may find that some of the outputs may be suitable for recycling or remanufacturing back into the input field. Getting materials from the output into the input requires a channel and a relationship with the customer, and perhaps an incentive that could be regarded as part of the value proposition. You may even need additional key partners, activities and resources to close the materials loop. Other effluents like production waste, heat and solvents are unlikely to pass through the customer segments, but you might come up with new customers that are willing to pay for them.

IV. Iterate the canvas with circular business model archetypes

Now that you have set up the first canvas, it is important to do it a few times over on a blank sheet, creating five to ten versions that you can choose from. The business model canvas is a tool to design business models. Inherent to design is following different directions to see where they take you, than choosing the most promising one and exploring it in more detail in a next round. In short; diverge, converge, iterate. In this step, iterate the canvas to seek a business model that creates savings or additional revenues from the input and output fields. The book "Products that Last" (Bakker and den Hollander 2014), describes five archetypes of business models that support circular products (see also www.productsthatlast.nl). Three of them are applicable in the context of this tool:

The hybrid model: combination of a durable product and short-lived consumables (e.g. Océ-Canon, printers and copiers). Main revenue stream from repeat sales of the fast-cycling consumables.

The access model: provides product access rather than ownership (i.e. the Dutch company GreenWheels' shared car use). Main revenue stream from payments for product access.

The performance model: delivers product performance rather than the product itself (e.g. hours of thrust in a Rolls- Royce, 'Power-by-the-Hour' jet engines). Primary revenue stream from payments for performance delivered.

The other two, Products that Last, archetypes extend the life of products without the necessary return of products to the manufacturer. They may not support your iteration in this tool but are mentioned here for completeness:

The classic long-life model: primary revenue stream from sales of high-grade products (e.g. the German company Miele's washing machines) with a long useful life. The main revenue stream comes from sale of the product.

The gap-exploiter model: exploits 'lifetime value gaps' or leftover value in product systems (e.g. printer cartridges outlasting the ink they contain, shoes lasting longer than their soles). The manufacturer takes revenue from selling products, third parties make profit on service to prolong the product lifetime.

Example

Figure 1 provides an example of a Circular Business Model Canvas. Besides just selling bikes, the model wants to extend the product life with repairs and upgrades. A new market segment is served with second hand bikes with factory refurbishment.

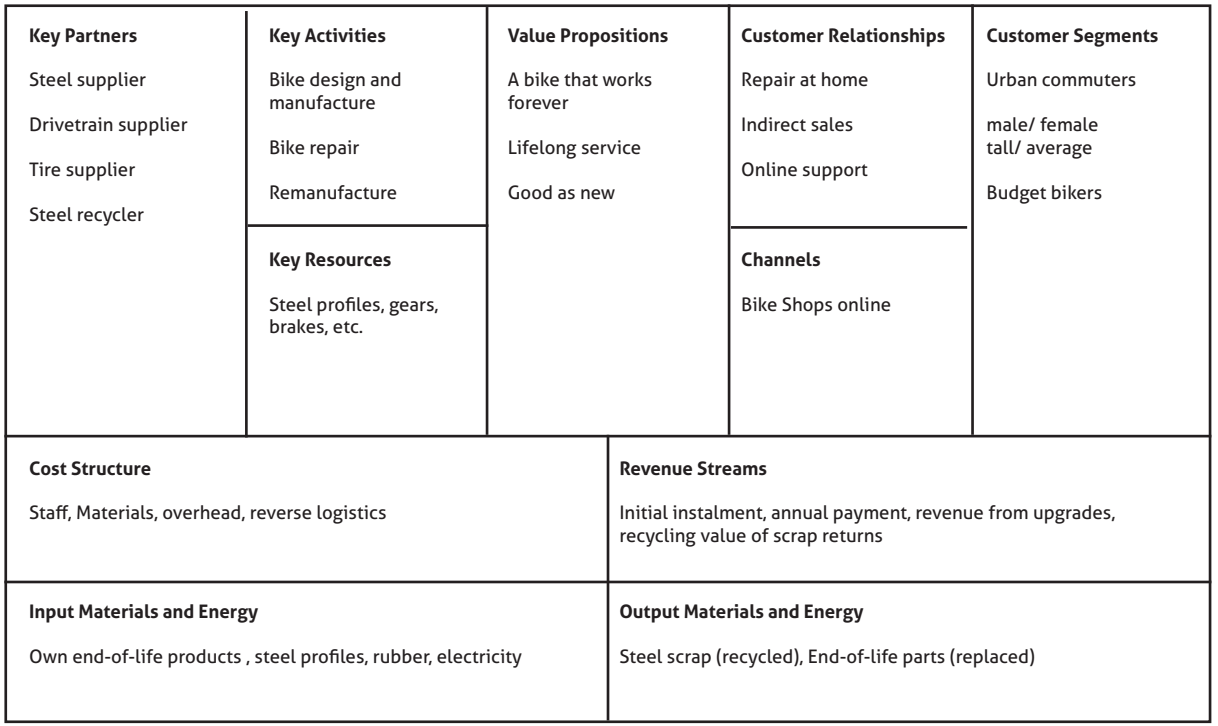


Figure 1: Circular Business Model Canvas (based upon Osterwalder and Pigneur 2010).

SALECYCLE

- Service cycles

Creating recurring revenues and customer benefits through extended product services.

I. Create the baseline

II. Optimize towards the Circular Economy

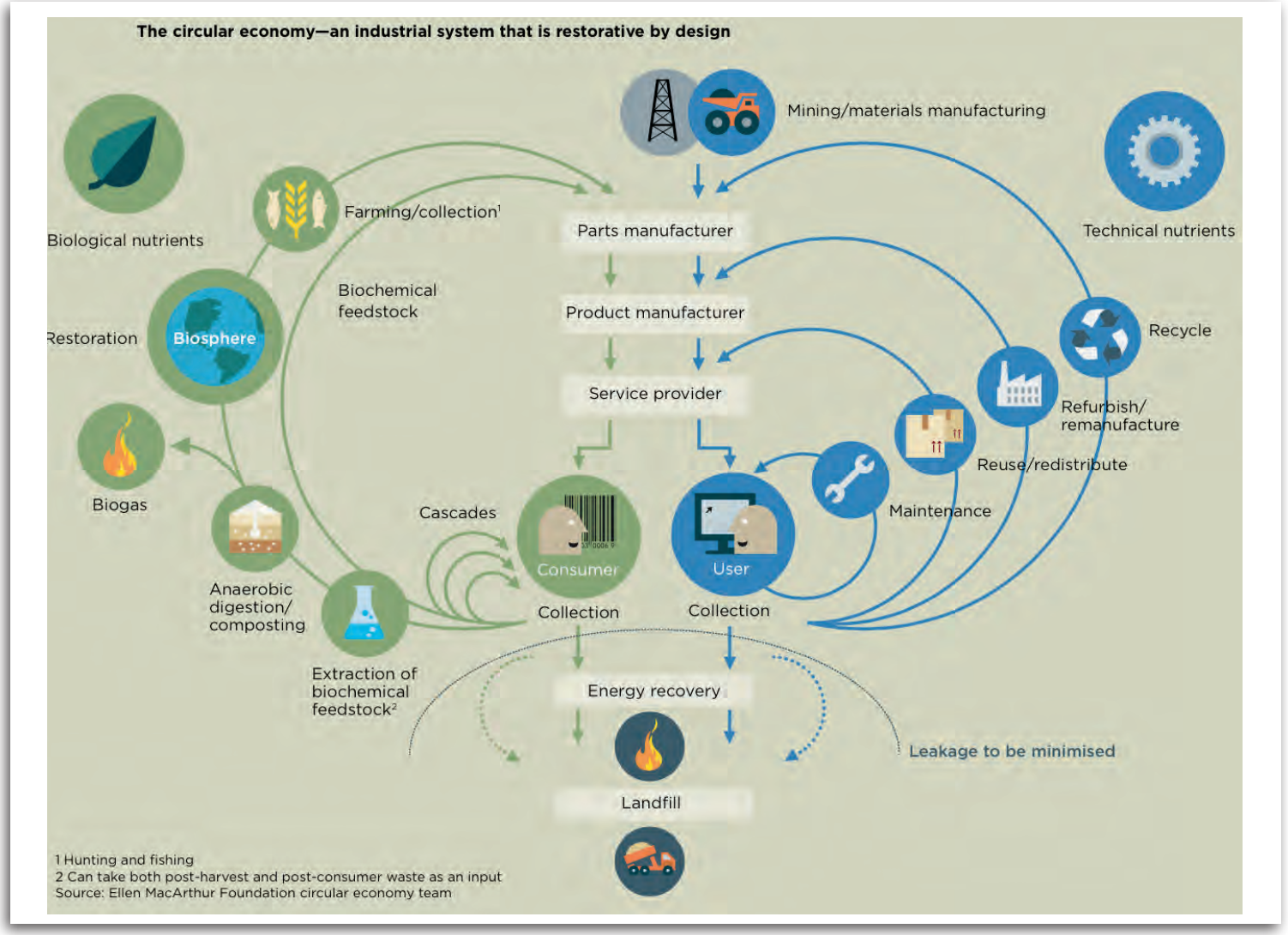
III. Check with the baseline

To date, three reports of the Ellen MacArthur Foundation (EMF) describe the Circular Economy (CE) and the benefits it can have for the environment, economy and users (Ellen MacArthur Foundation and McKinsey 2012, 2013, 2014). Akin to the two cycles of cradle to cradle, EMF's 'butterfly model' divides technical and biological materials into cycles. Two important differences are the addition of inner circles in EMF's model and the input of virgin materials and an output of waste (to be minimized).

These are no trivialities or mere graphical style, but pointers to a difference between CE and C2C. The Circular Economy is a model for transition whereas cradle to cradle is a model for a desired state. Also, the butterfly model makes more explicit that not just materials can be recycled, but components and entire products as well. Through inner circles of maintenance, redistribution and remanufacture more value can be recovered because more of the added value is maintained.

This tool can serve as an introduction to circular design, whilst the Circular Economy also comprises innovative business models, reverse logistics and cascades. Using the four principles described in EMF's first CE report, this tool helps you explore services to promote inner cycles. It ties in with the Salecycle, and links with the Value Element of the NID wheel. In this tool the emphasis is on the incentives and channels that enable the product to be cycled. Other aspects such as recyclable materials and modularity are topics dealt with in the Nutrient Pathways and Design for Disassembly tools.

Steps of the tool



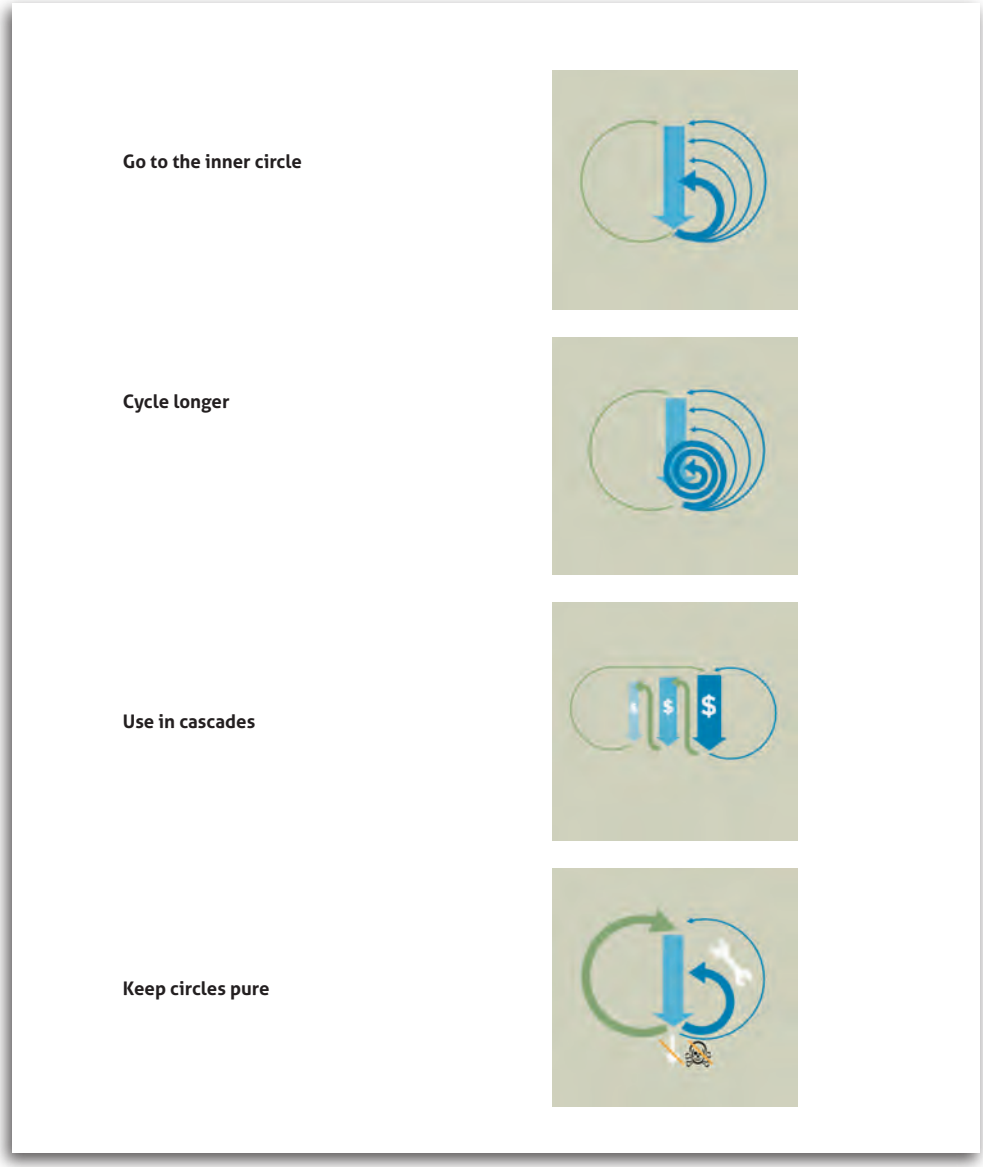
Credit: Ellen MacArthur Foundation.

I. Create the baseline

For the most likely scenario, determine the percentage parts in which your product is destined to be...

a) wasted (landfilled or incinerated)
b) recycled (materials are reused)
c) remanufactured (parts and sub-assemblies are reused)
d) repaired/ upgraded (the product is used multiple life cycles)
e) biodegraded and regenerated (for bio-based parts)

These percentages are a starting point and reference for improvements. Represent them in a diagram similar to the butterfly diagram; putting the percentages on the representative arrows.



Credit: Ellen MacArthur Foundation

II. Optimize towards the Circular Economy

Go to the inner circle
Try to minimize waste by envisioning service concepts that make more use of the inner circles. For example, rental options or upgrade plans. Estimate the value that can be captured when the product could be entirely remanufactured (recovering the value added by manufacture) and reused (also recovering the value added by assembly and packaging). This gives you a budget for the operations required for the inner circles.

Cycle longer
Try to maximize the number of cycles with timeless design, upgradable features and component durability. Higher quality components can become more economical that short-lived, cheap alternatives when used in more than one product. Product features that are technologically mature, not subject to serious aging and relevant to future versions of the product are eligible for multiple life cycles.

Use in cascades
Natural materials can be recycled in decreasing quality before being degraded and regenerated, replacing virgin materials and increasing the time for regeneration. Cascades like timber > fibre board > cardboard, or fabric > fibre filling > insulation use wood and cotton a few times over. Could this be true for your product and can the used product be offered as materials for downstream applications?

Keep circles pure
The value of returns and efficiency of recycling are impacted by contamination. To secure clean return flows and zero waste, you may need to provide (reusable) packaging and a pick-up service.

III. Check with the baseline

Make a second diagram showing the percentages you claim to attain for the various flows in the butterfly diagram. Hopefully you have found changes that can be implemented in the design to make better use of the inner circles.

SALECYCLE

- Design for diversity

Gearing the same basic product towards different customer segments and individual users.

I. Segment your customers

II. Identify conflicting desires

III. Assess the ranges of differences

IV. Create a portfolio of variants

One size fits no one and this tool recognizes the diversity of your customers. The Surroundings Scan deals with the diversity of surroundings and the Context of Use deals with the diverse products, places and people in the life of the product, but this Salecycle instrument is focused on tailoring the product to a large audience of potential buyers. If a (circular) business model canvas is in place, you will have defined one or more customer segments. Customers in different segments have different needs for the product or service, and also within segments there may be individual preferences. Serving a wide audience with a platform product makes it easier to reuse components between versions and opens opportunities to change the product when preferences change. This relates to the Concept Element where resulting options for customization can be conceptualized.

Design for diversity will help you aim for the NID Principle:

"Being locally attuned and responsive."

Steps of the tool

I. Segment your customers

Divide your target audience in groups with similar interests, demographics, and needs. Often, two parameters can be used to separate your clientele into four or more meaningful segments. For instance, geographical location plotted against predominant use for your product, high vs. low status sensitivity plotted against traditional vs. postmodern values, or desire for new things vs. enduring quality plotted against high or low involvement with sustainability (Hanks, Odom et al. 2008).

II. Identify conflicting desires

Assess what the different segments are demanding from the product and make any differences explicit. Imagine how the different customer segments can be served by manipulation of one product characteristic, or as few characteristics as possible. These can for instance be aesthetic or performance characteristics.

III. Asses the ranges of differences

For each characteristics, determine the range of the different needs per customer segments. For a bike for example, customer segments can be made based on the length of the user. If these users have heights between 150 cm and 210 cm, the range of the characteristic will be 60 cm.

IV. Create a portfolio of variants

Create a platform with the product characteristics that serve all of the customer segments, and show how limited changes can make that platform applicable to your diverse audience.

Example

This children's bike seat design, made by Van der Veer Designers for Yepp, is designed for diversity in two ways. The diversity of growing children is accommodated with adjustable footrests and buckle. The foam seats also come in many fashionable colours. Furthermore, the design embodies the Salecycle Element very well by allowing resale of wear-sensitive parts. An added benefit is that it requires only very little storage space for the retailer while still offering the full range of options for colours and accessories to customers.

Children's bike seat design, made by Van der Veer Designers for YEPP

CONCEPT

- Context of Use

Fitting into the mesh of people, products and places that the product encounters during use.

I. Inventory

II. Misfits and fit options

III. Ideation

Products work in a context, and this tool seeks ways to work with that context. This helps you to "be locally attuned and responsive". As this is a tool for the Concept Element of the NID wheel, we target the use phase context. Other contexts are explored in the Recycling, Foodweb, and Symbiosis Elements.

In the use context, there will be people, other products, the natural and man-made setting. What does the product take from this context, what does it bring and how does it rely on a context that changes over time? Products can be beneficial to their setting, extend the life of surrounding products and bring people together. Smart product constructions help the upgradability and serviceability of products, such that they will fit in over a longer period. On the other hand, a product that pollutes does not fit its setting and working products get discarded when they don't fit other products anymore. By applying this tool, you aim to develop products, that generate value, for instance by being beneficial to their setting, by extending the life of surrounding products and by bringing people together. The question is: how to make the product fit in?

A logical next step after describing the Context of Use is to find benefits within that context, see the tool Use Life Benefits.

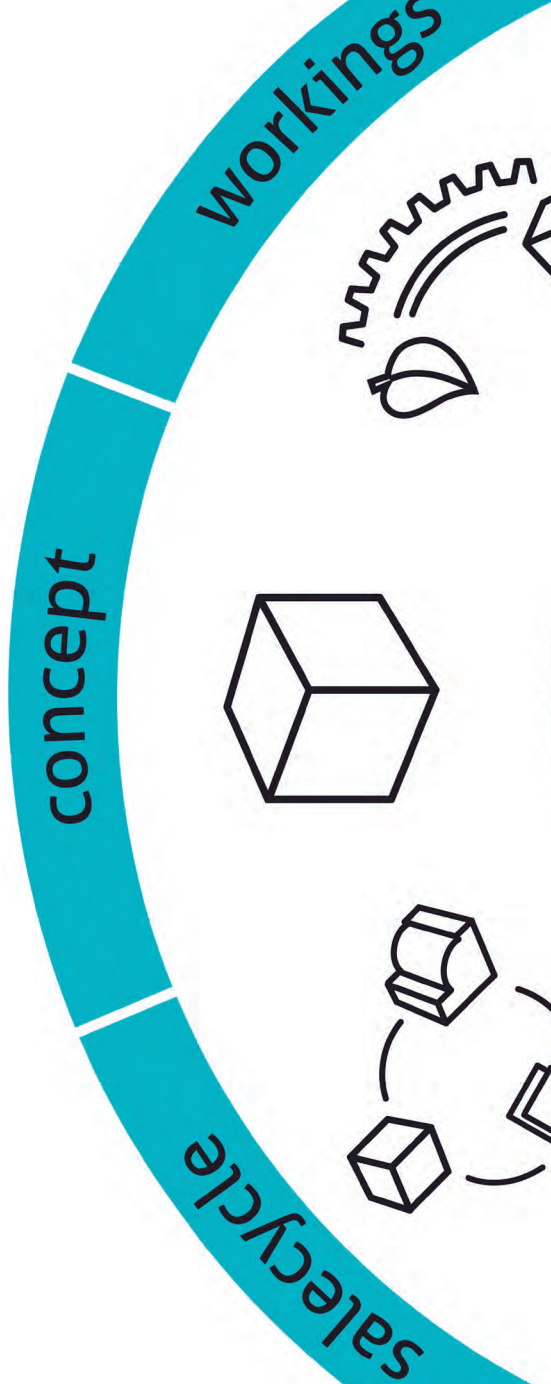
The fittest survive, the fitting-est thrive.

As Braungart and McDonough put it in their book on cradle to cradle:

"Popular wisdom holds that the fittest survive, the strongest, leanest, largest, perhaps meanest – whatever beats the competition. But in healthy, thriving natural systems it is actually the 'fitting-est' who thrive. Fitting-est implies an energetic and material engagement with place, and an interdependent relationship to it." (McDonough and Braungart 2002, p. 120)

Take mobile phones for example. Feature phones (you might know them better as dumb phones) are fitter than smartphones; they are more rugged and the battery lasts longer. But smartphones thrive because they fit the use context better than feature phones; they can connect with your computer, smart appliances and online resources, apps enable smartphones to keep up with new developments and how much battery life do you need when you can charge it almost everywhere?

Bear in mind that we are not considering Recycling, Health, Foodweb and Symbiosis at this point. In some of those respects the feature phones might fit better than smartphones. A good fit with the use context does not guarantee low environmental impact, although negative impact and a bad fit often go hand in hand. This tool can help you find positive impacts in the use phase by, being locally attuned and responsive, and by celebrating diversity, making your product meaningful in more places for a longer time. The end result is a scenario or story that captures how the product fits its use context.
The Design Discipline is leading in the use of this tool, and for products that are used outdoors or in conjunction with plants or animals it is advised to take in the biologist's perspective as well.



Steps of the tool

I. Inventory

Take the perspective of your product and look around you. What do you see? Go through the product's use life and ask yourself who, what and where; which people, products and places are encountered. Fill out the Use context inventory table (see the example on the next page), preferably with photos, sketches, or icons instead of words; images are easier to associate with in the next steps. Notice the bottom row of the context inventory table. The use context will change with the seasons, with day and night, with aging users and advancing technology for example. Capture the changes that you think your product can respond to, and the range of these changes (from light to dark, from +30°C to -10°C). You may have data from the Surroundings Scan tool already to start your inventory.

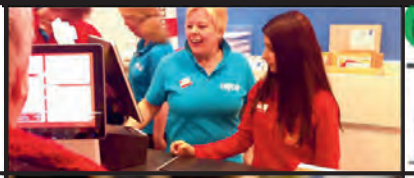
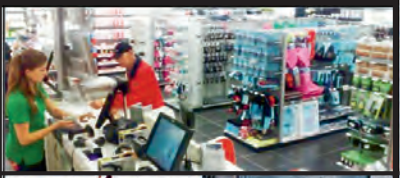
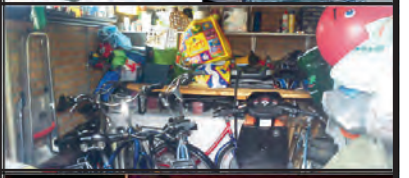
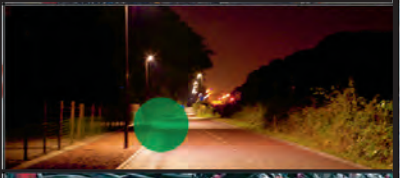
II. Misfits and fit options

Now ask yourself how well the product would fit its context. It does not matter if you are making a redesign or something completely new, the context already exists. Mark potential misfits in red. In the example of the bike light, people in the installation context of a bike light may not be handy enough to fix the light to the bike in the proper manner. Furthermore, the end of use for a bike light is likely a trash bin, and a battery will contaminate its environment when it is discarded like this. Mark fit options in green. For instance, people on bikes become healthier and are more likely to do other sports where they might want to use a light (changes/people); a light may be combined with a bell and flash as well as ring (first use/products); or the bike light could be attached to backpacks and clothes as a way of bringing it home (transport/place).

III. Ideation

When placing the red and green marks you might already come up with some options to fit your product in its use context. Dive deeper into these options by asking how, and generating many answers. How to make it fit domestic waste streams, how to use it in the summer, how to use it for other sports, how to attach it to a bag? Conclude with visualizing the best ideas and hopefully you hit on something that sets your product apart in both sustainability and usability.

Example

	People	Products	Places
Buying/ getting the product			
Transport to the place of use			
Installation/ first use			
Typical use			
Approach of the end of use/ discarding			
Changes over time			

context inventory table

CONCEPT

- Function Analysis

Find the underlying functions of your product to prepare for AskNature; the search in Nature for strategies to realize these functions.

I. Ask: "what does the product do?"

II. Start asking "why does it do this"?

III. Keep asking this question until you arrive at the fundamental answer

IV. Describe the function(s) in verbs plus subject

V. Stay concrete and separate different functions

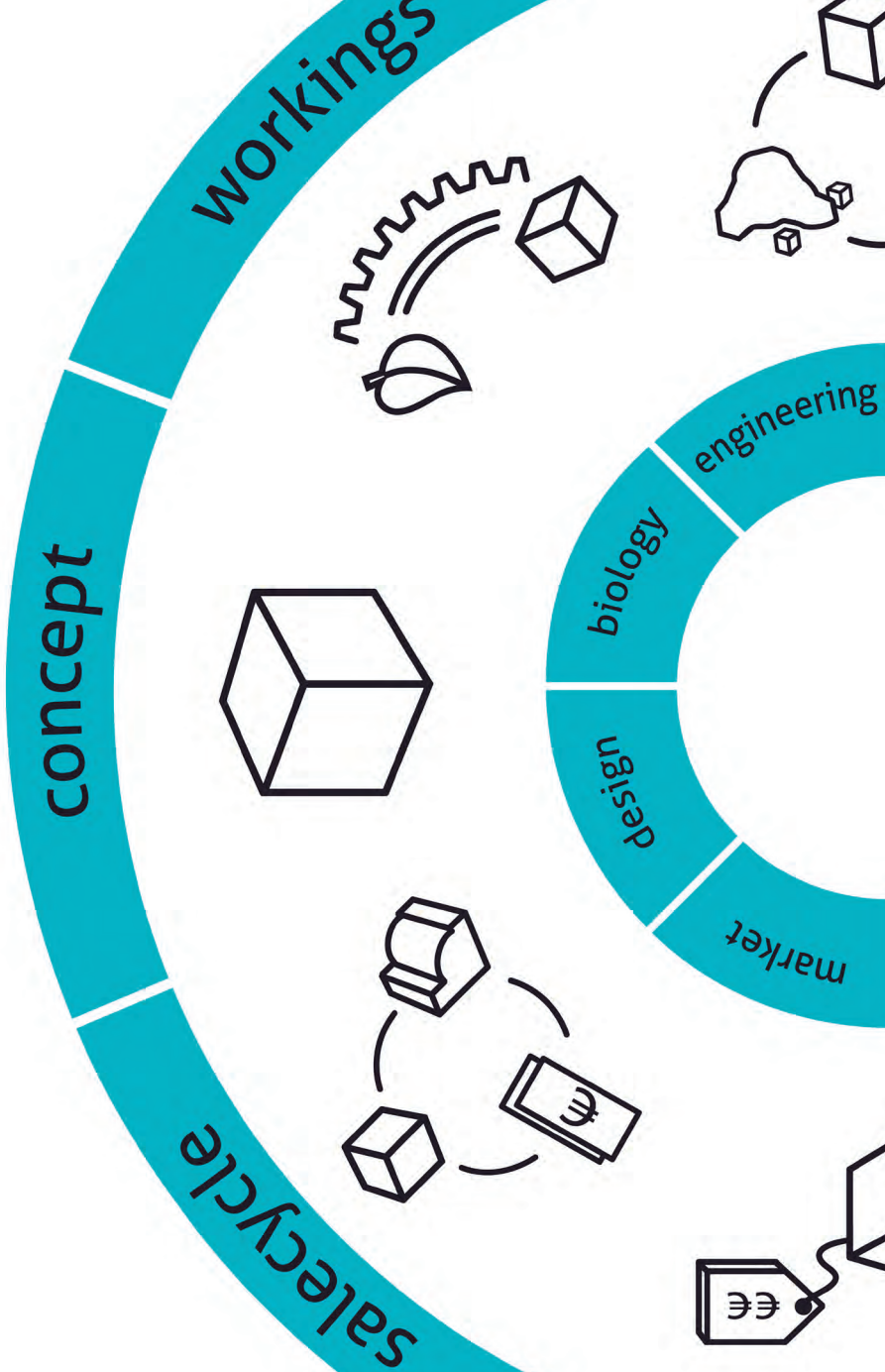
VI. Check if and how your function(s) fits into this question: "How would Nature provide this [function]?"

Credit: Biomimicry 3.8.

Have you ever seen a squirrel using a digital camera? Obviously not: most man-made products do not exist in Nature. However, their underlying functions often do: light is focused in muscle-driven lenses, images are processed in brains, and fragile eyes are protected in strong eye sockets and shock-absorbing layers of tissue, to give a few examples. If you define the underlying functions of your product well, it becomes possible to propose a product as how Nature would make it, even though it does not exist as such in the natural world. Use the Function Analysis tool to make a crucial step before you start asking: "How would Nature do these functions?"

Timing and linking with NID Principles

Outcomes of the Function Analysis feed into the program of requirements and into AskNature. The tool should therefore be used in the goal definition phase. For best effect, use it before making an Surroundings Scan and Use Life Benefits, to get a general impression on the role(s) of your product in its surroundings. Through Use Life Benefits you may find additional functions for your product to improve its fit with its surroundings, so you are advised to re-do the Function Analysis after using this tool. Finally, once you dive into the detailed design of a product system, the outcome of the Function Analysis is a good resource to understand exactly what you want each part of your product to do.



Steps of the tool

I. Ask: "what does the product do?"

Write down your answer. For example: "make cups of coffee".

II. Start asking "why does it do this"?

In our example: "so that people can drink a cup of coffee".

III. Keep asking this question until you arrive at the fundamental answer.

Stop when the answer becomes too generic. In the example: to enjoy a hot drink > to be relaxed. Or, to get caffeine > to be alert. Now go back to your first answer and ask: "how does it do this?" An answer could be "by boiling water, mixing it with ground coffee and running it through a filter".

IV. Describe the function(s) in verbs plus subject.

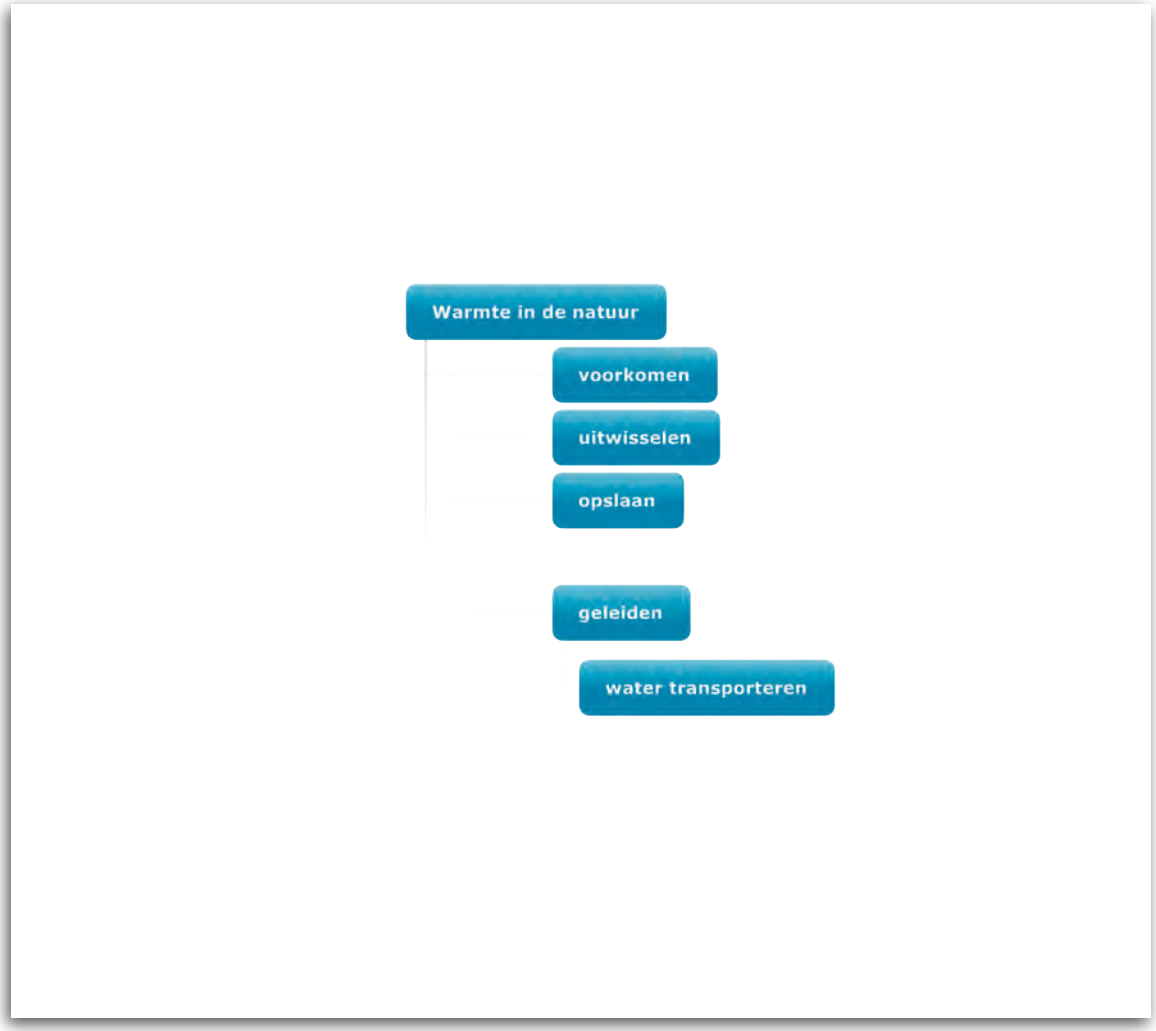
The functions in our coffee example are: become relaxed, become alert, heat water, perhaps grind beans, mix solutions, filter a suspension, pouring liquid. Stay concrete, and ensure to separate between different functions.

V. Check if and how your function(s) can be put into this form: "How would Nature [verb noun]?".

For examples of functions, you can take a look at the Biomimicry Taxonomy which organises biological solutions by function (http://www.asknature.org/article/view/biomimicry_taxonomy).

Example

How would Nature keep a hockey field cool? The answer is that it doesn't, as there are no fixed rectangular fields made of synthetic polymers in Nature. However, there are many natural strategies for cooling down.
For the company TenCate a Function Analysis was made for cooling a synthetic soccer field. Initially, the description of the functions did not seem to be that meaningful for a hockey field. However, it became important later on. With this analysis, a long list of natural strategies deployed to cool large bodies, such as elephant ears were explored (also see the AskNature tool description).



Example of a functional structure related to 'cooling', translated into: "how would nature [verb] heat" (Lamers, MuL 2011).

CONCEPT

- Use Life Benefits

Creating positive impacts on the Context of Use.

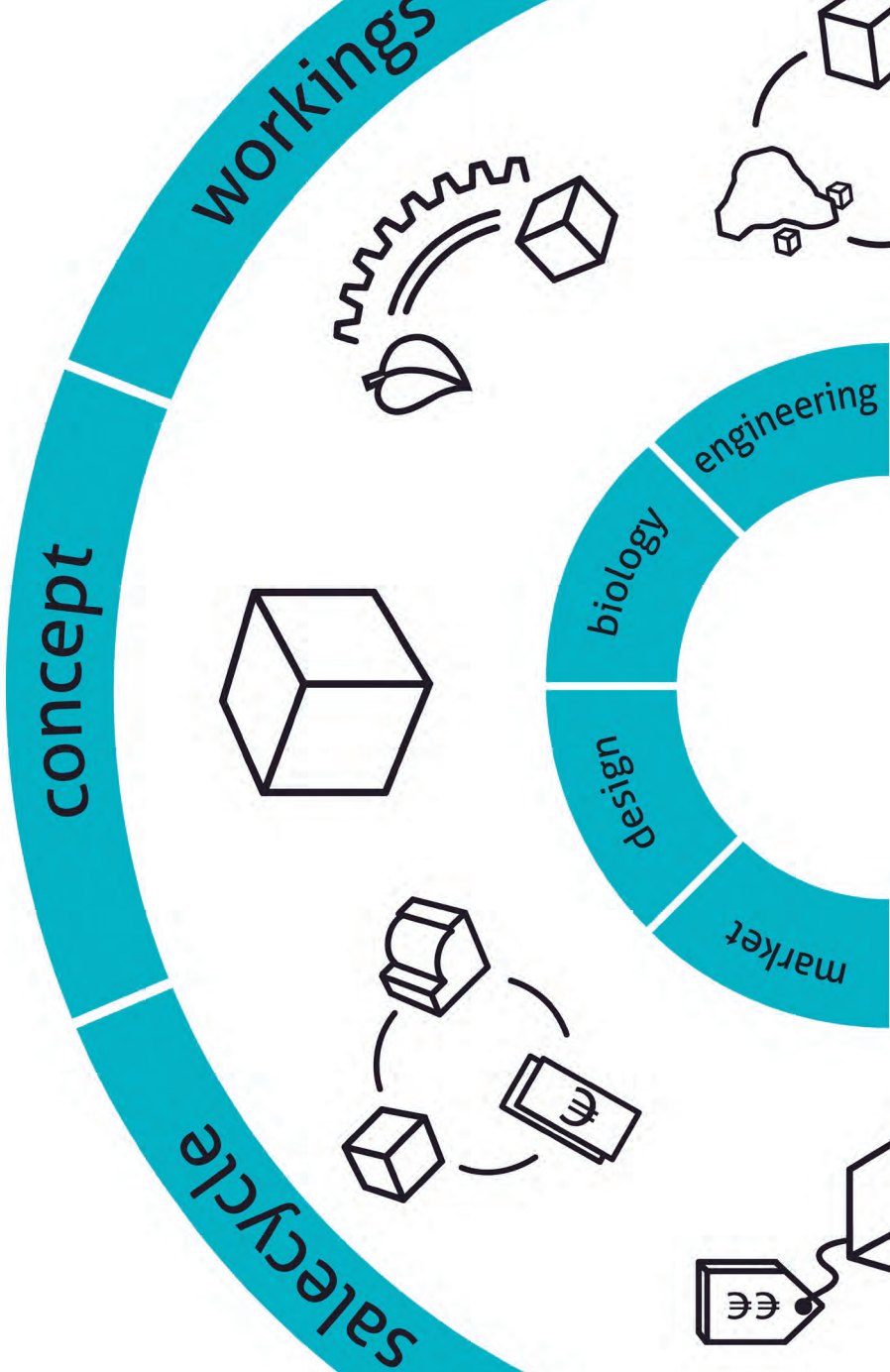
I. Visualize the story of use

II. Add what is given to and taken from the Context of Use

III. How to... create benefits

If Ecodesign is about making products less harmful, Nature Inspired Design is about making products more beneficial. The Use Life Benefits tool is a quick brainstorm guided by twelve questions that helps you to invent benefits, which may serve as unique selling points and as proof that you aim to enrich the lives of your clients by offering additional value. Let there be no mistake that the enrichment of your company goes hand in hand with a thriving audience for its products or services; life creates conditions conducive to life and business as well can create conditions conducive to business.

The Use Life Benefits tool is a way to deepen the outcomes of the Context of Use tool. It can equally well serve as an alternative to the Context of Use tool that takes less time to execute, but with a less detailed view on the Context of Use, the outcomes of the Use Life Benefits tool will be more general and less reliable, but useful nonetheless. As you will see later on, the questions help you to aim for several NID principles, such as: waste equals food, use current solar income, and be locally attuned and responsive and adapt to changing conditions. The benefits in the use life feed into the value proposition of the Circular Business Model Canvas as they create added value to the customer.



Steps of the tool

I. Visualize the story of use

If you have used the Context of Use tool you have this covered. Otherwise, visualize on a time-line how the product or service is acquired, transported to where it is used, perhaps installed, used for the first time, used with experience and eventually discarded. You can use the same life cycle as with the Surroundings Scan and Context of Use tools here, if you have applied those tools earlier.

II. Add what is given to and taken from the Context of Use

On the time-line, indicate where energy and material is used or expelled, and where ecological and social contexts may be affected by the use of the product. At this point, you are merely compiling the known and expected effects; inventing new and beneficial effects is the next step. Again, input from the Surroundings Scan and Context of Use can be used here.

III. How to... create benefits

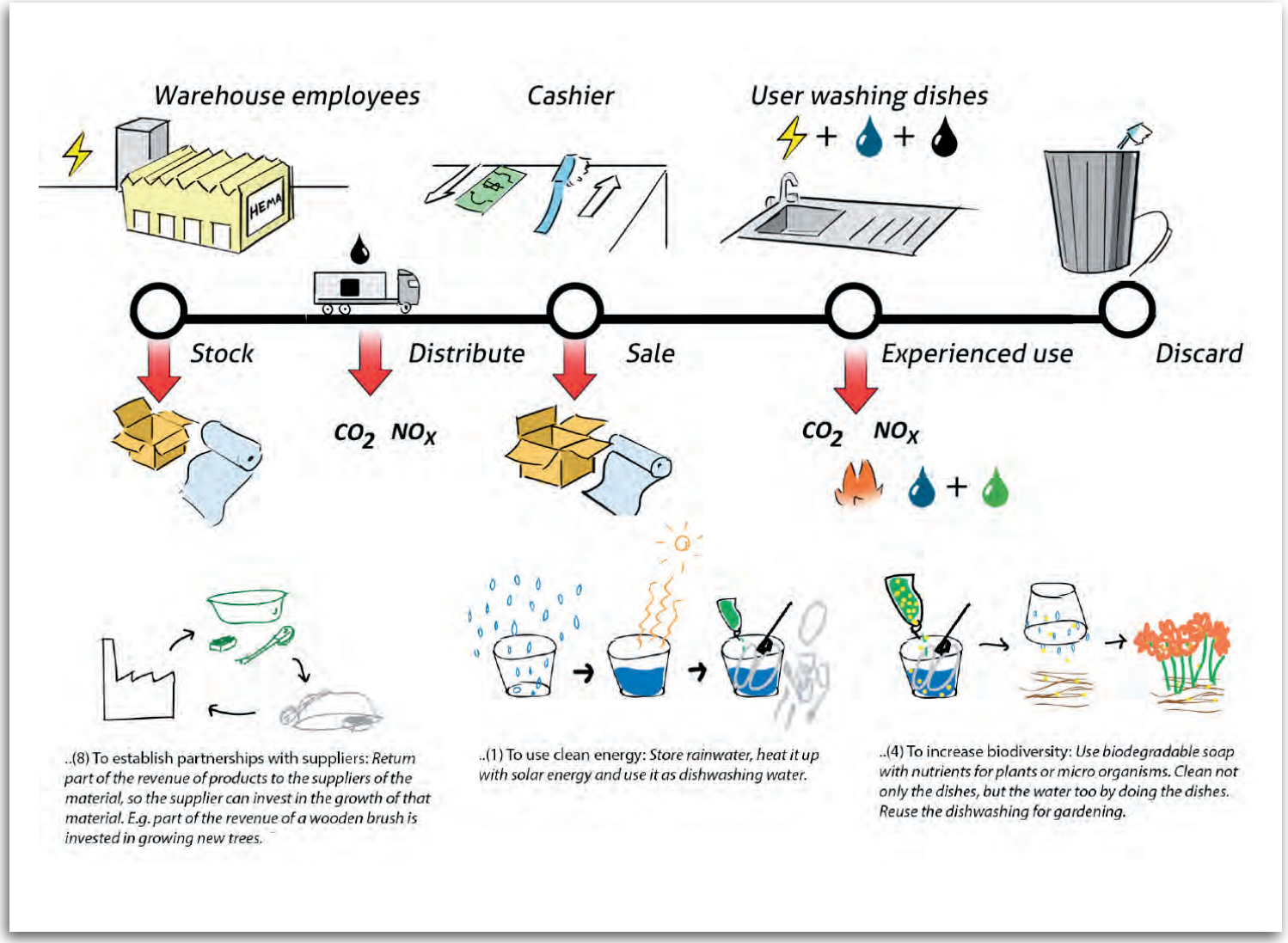
Remind yourself of the Intention Statement and observe the time-line with inputs and outputs you created with this tool. Go through all of its stages and use these twelve questions (you may add more) to come up with wild and wonderful out-of-the-box ideas:

How to make the product or process...

- use or create clean energy?
- use or create clean and recycled materials?
- support ecosystems?
- increase biodiversity?
- strengthen communities?
- improve peoples' health?
- clean air, water or soil?
- lead to partnerships with suppliers?
- supply companies with a resource?
- strengthen the local economy?
- link to other developments to achieve economies of scale?
- lead to developments that other industries could benefit from...

Example

Design students developing a NID package of dish-washing products used Use Life Benefits to make a wooden brush that is returned to the factory, whilst the soap is enriched with nutrients for favourable micro-organisms in garden soil. Using rainwater and sunlight to make the tub of hot water was another idea that for practical reasons did not make it into the final design.



Credit: Benefit ideation: J. Bianchi, C. Frijde, I. Stolk, A. van Vliet

WORKINGS

- Ask Nature

Explore specific strategies in Nature for how to fulfil the underlying functions of your product.

Discover the underlying working principles of these natural strategies.

I. Formulate a key design problem as a question: "How would Nature [do this function]?"

II. Go to www.asknature.org and type the function in the search bar

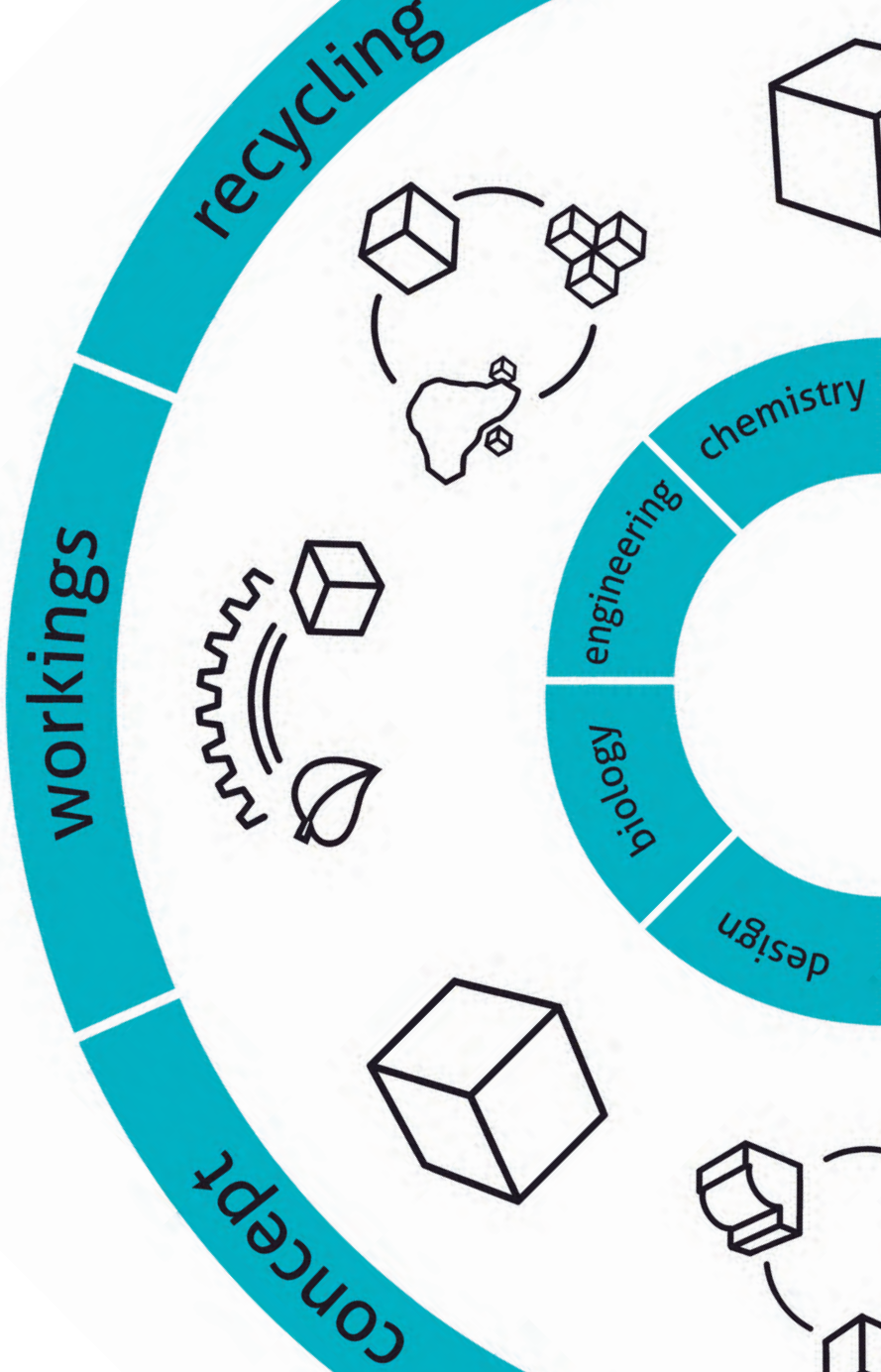
III. Select interesting strategies, and describe the underlying working principle of these strategies in a diagram.

IV. Collect the strategies in a morphological chart, combined with regular technological strategies that fulfil the function

Using the outcomes of your function analysis, you can study solutions in Nature to discover how a design problem may have already been solved in organisms. The best way to do this is to work together with a biologist. For instance, the Biomimicry Institute offers a service called 'Biologist at the design table', or you can consult a nearby biologist. However, this is not always feasible under time pressure and it can be difficult for a designer or engineer to engage with a biologist. For the daily design practice, a hands-on tool is the online database AskNature.org, that has been developed by The Biomimicry Institute (2008). This database points you to interesting natural solutions and with those solutions in mind, it is easier to find a specialized biologist to help you understand the working mechanisms better.

Timing and linking within NID Principles and process

Ask Nature helps to develop design ideas by learning from strategies in Nature. It can be done after the Function Analysis and before consolidating your design ideas into concepts. Ask Nature works best early in the idea generation phase, when you are exploring all possible solutions and when there is still time left for additional research into these strategies. At the detailed design level, the strategies from Ask Nature are usually too complex to realize or may take too long to validate.



Steps of the tool

I. Formulate a key design problem as a question: "How would Nature [do this function]?'

II. Go to www.asknature.org and type the function in the search bar.

Select 'strategies' to find only strategies of organisms to fulfil the function, or select 'products' to be inspired by existing products that were Nature Inspired for your function. If the strategies that Ask Nature returns do not fit your function, or if there are only very few strategies, then try different words to describe the same function. Ask Nature uses a specific taxonomy to describe functions that you will need to learn over time. For example, "making a strong structure" is described in Ask Nature as "maintaining structural integrity" (notice how this involves the 'means-versus-ends' discussion that often comes up in design processes).

III. Select interesting strategies, and describe the underlying working principle of these strategies in a diagram.

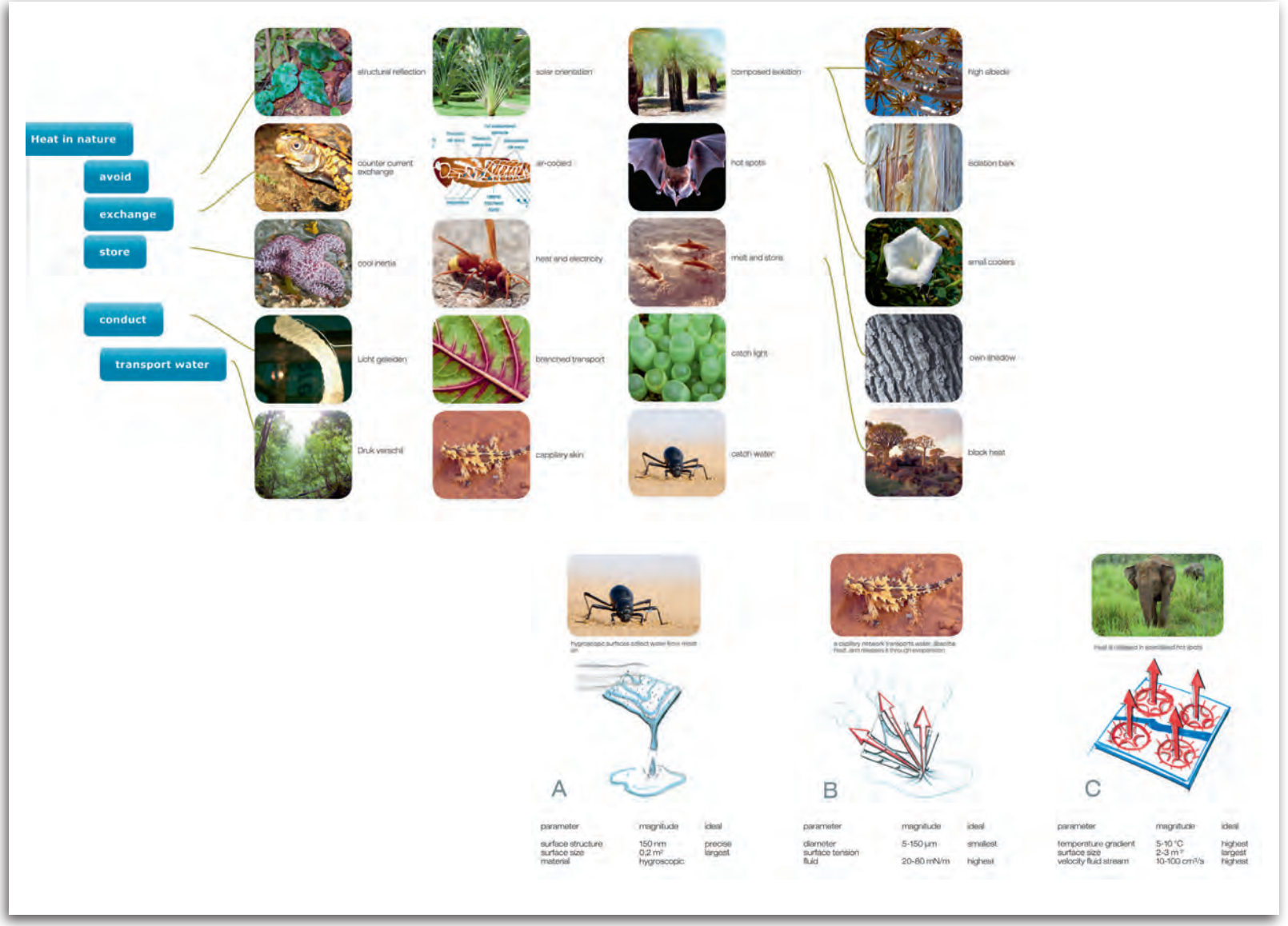
Go deeper than just describing the organism and stating the function, and try to understand in (some) detail how the organism does this. Only then, you will be able to translate this into technology. At times, the exact working mechanism is not known yet, or too complex to translate into technology: then we recommend you select other, more feasible strategies.

IV. Collect the strategies in a morphological chart, combined with regular technological strategies that fulfil the function.

In a next step, this morphological chart can be used to create concepts of the product system that fulfil every desired function.

Example

For manufacturer of technical textiles TenCate (based in Nijverdal, the Netherlands), designer Ernst-Jan Mul and biologist Niek Lamers used biological literature and Ask Nature to find a variety of strategies that are used in Nature to fulfil the functions for a product, as were found in the Function Analysis they performed earlier. A morphological chart was made, with the rows listing the functions of the product, and the columns containing the different strategies. The most relevant strategies were selected based on their fit with the core capabilities of TenCate, and for these, diagrams were drawn of the underlying working mechanisms (partial example shown). The proposed concept was a combination of strategies found in the Quiver tree, the Thorny Devil Lizard and Elephant Ears.



Credit: Lamers & Mul.

WORKINGS

- Biomimetic Construction

Use guidelines for smart construction strategies as found in Nature.
Specifically useful for lightweight design.

I. See how Nature constructs

II. List your main construction challenges

III. Scan Nature's guidelines to brainstorm

IV. Reflect on the ideas

V. Integrate these solution in your main design

The guidelines in this tool are derived from constructions in living systems. Nature's constructions are resource efficient yet physically resilient and "Integrate development with growth". For us, this makes it possible to developed products to "Be locally attuned and responsive". These guidelines can be seen as good practice for designing structures like Nature would. The list of guidelines is not fixed and will probably be revised over the years. Several similar lists were compiled by Steven Vogel (1998), Autodesk (2014), Tributsch (1982), Philip Ball (2011), and Hoagland , Dodson et al. (2001) and many other textbooks on biological morphology. This particular list is our compilation of the above.

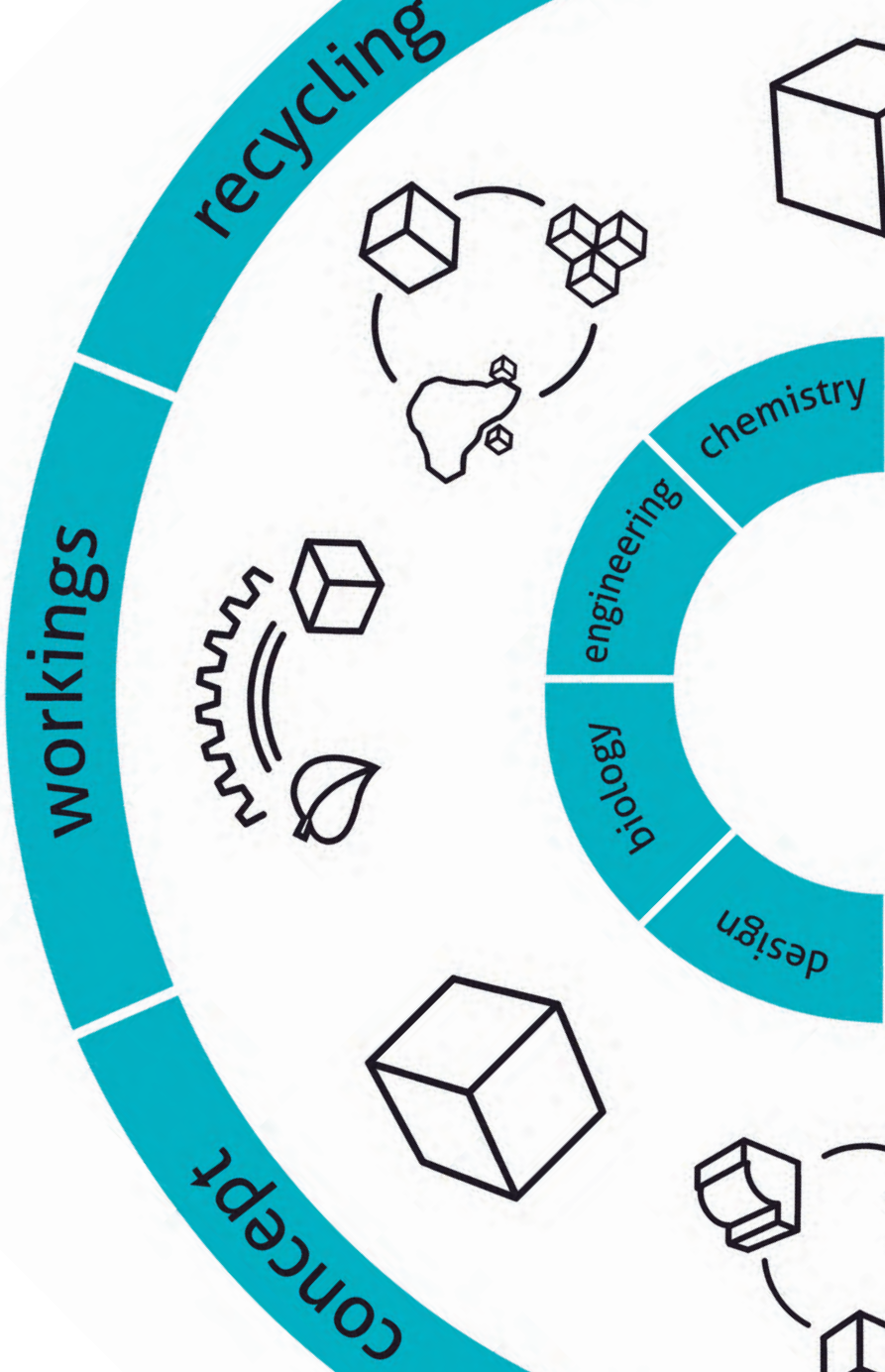
Timing and linking within NID Principles and process

Biomimetic construction can be used when generating ideas how to construct your product. They have a different timing than the NID Principles, which are primarily used in the goal definition phase. The principles of Biomimetic construction can be used once the goals are defined and when the ideation has begins.

Nature's construction guidelines

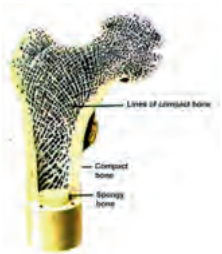
I. Curves over straights

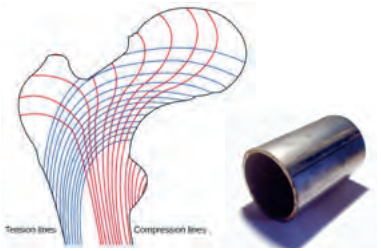
Nature uses curved surfaces and rounded corners, instead of flat surfaces and straight corners. Smooth transitions result in lower stress concentration, allowing for optimization of lightweight structures.



II. Structure over material

In Nature fewer different materials are used with more complex varying internal structures, whereas in technology more different materials are used which are internally homogeneous. Compare the internal structures of bones and bicycles.





Credits (from left to right): www.itmonline.org artsfemur.htm/ openstax cnx/ commonswikimedia.org

III. Tough over stiff

In Nature, structures tend to be strong and tough, and allow for a degree of bending. Failure of such structures is gradual. Technology in general is stiff and rigid and bending is being avoided. Such structures are very strong until they fail without warning or time to take preventative measures.

Credits commonswikimedia.org (left) ONJCS (right)

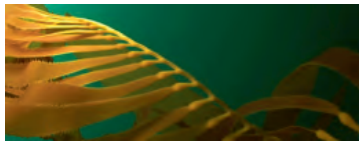
IV. Flexing over sliding movements

Nature's objects bend, twist, or stretch at predetermined places with little friction. Technology uses rigid pieces moving on sliding contacts that need high precision and lubrication to prevent friction.

Credits Pseudopanax (left) James Selesnick (right)

V. Adapting over fixing in the flow

When in a flow, Nature's flexible bodies change shape to become streamlined and to stay streamlined, even in unpredictably changing flows. Although they may be less optimal in stable flows, in the reality of changing flows such bodies are overall more streamlined. Technology uses bodies with fixed streamlined shapes optimized for one specific flow only. In changing flows however, these bodies are dramatically less streamlined.



Credits Greg Boland (left) Kendra Karr (right)

VI. Structural resilience over ductility

Industry uses ductile metals in parts with homogeneous internal structures to avoid failure. Nature however uses the resilience of structures such as foams and composites to transform brittle materials into ductile constructions with improved failure behaviours.

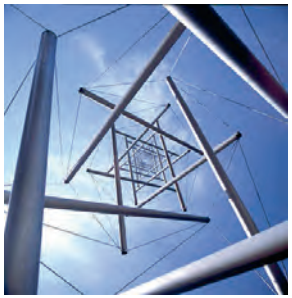
VII. Tensegrity over compression

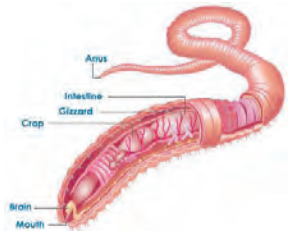
In Nature, constructions are loaded in Tensegrity: the main strength comes from elements loaded in tension, which are held together by only few elements in compression. In technology, materials are more often loaded in compression. Materials often are stronger in tension, therefore tensegrity structures need less material for a given strength. Tensegrity makes product lightweight.

Credits Econcern.ie (left) Afloral (right)

VIII. Sheets over cables

Tensegrity constructions in Nature are often made with tensile sheets on the outside and pressurized fluids on the inside. An example is the hydrostatic skeleton of worms. In technology tensegrity constructions generally use cables as tensile elements. Even if technology uses tensile sheets, like in our pneumatic tires, they contain pressurized gasses, where Nature often prefers to use water, because it is incompressible and useful as a transportation and storage medium for energy, nutrients, and informational molecules (such as hormones)

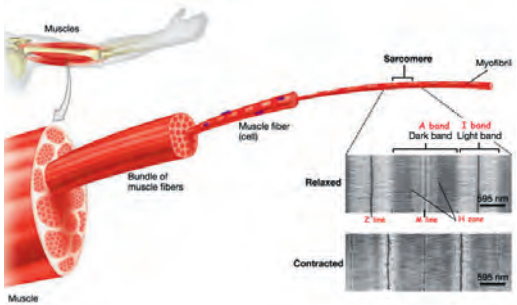




Credits: tutorvista (left) tensegritychiro.com (right)

IX. Sliding over rotating actuation

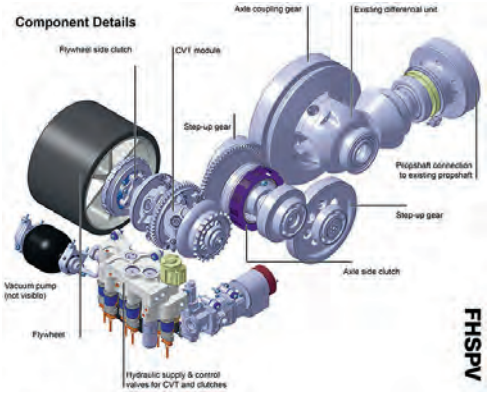
Muscles create movement by sliding fibres along each other. In contrary to technological engines, hardly any movement in Nature is generated by rotating actuators.



Credits: https://cyhsanatomy1.wikispaces.com (left)

X. Elastic over electro-kinetic

Mechanical work in Nature is often stored elastically resulting in relatively simple constructions where materials are used functionally. In technology often this is done electrically or kinetically resulting in constructions that are more complex.



Credits: UOFM (left) FHSPC (right)

Credits: Isuzu (right)

Steps of the tool

I. See how Nature constructs. Read Nature's construction guidelines.

II. List your main construction challenges.

Where would your design typically be straight, material heavy, stiff, sliding, ductile, compressed, cabled, rotating and electro kinetic? Which of these design aspects are problematic (i.e. causing difficulty in manufacture, failure points, risks, or high costs)? Select a handful of constructional design aspects that you may improve by looking at Nature's construction guidelines.

III. For each main construction challenge, scan Nature's guidelines to brainstorm on ideas how it might apply for this situation.

If the principle does not trigger ideas, move on to the next. It is a brainstorm, you can move quickly. Go for quantity of ideas instead of quality, you will select in the next step.

IV. Reflect on the ideas; be critical on the benefit that applying the principle brings.

Will a biomimetic construction add benefits for other requirements as well? Reconsider the necessity of these construction principles carefully, and avoid applying them merely as styling. For each construction challenge, circle the best solution you found.

V. Integrate these solution in your main design.

RECYCLING

- Harvest Map

Representing locally available materials on a map to find recycled resources.

I. Wish list

II. Bike/ car tour

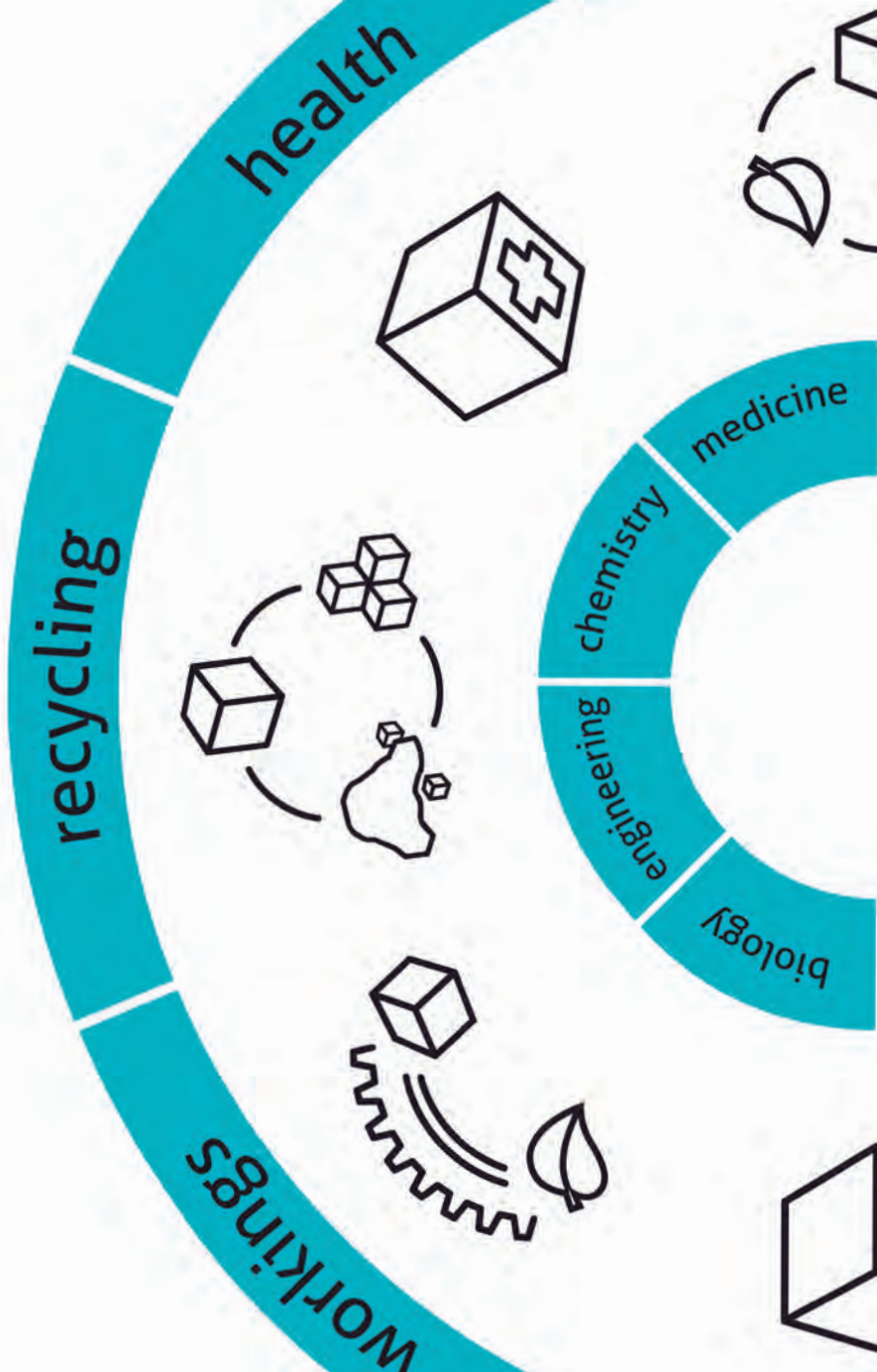
III. Plot the map

IV. Select and contract suppliers

When defining materials for a product it is good practice to consider recycled content and resource proximity. Recycled content is of course all that Nature ever uses, and just like organisms, industrial production requires a steady supply of high quality nutrients (technical nutrients in this case). A good way to secure recycled materials is to find nearby sources that produce these materials in excess. The proximity of this source or recycled material supplier prevents the transport of virgin of recycled materials over needlessly great distances, and having this partner nearby also benefits any collective efforts to maintain quality. The same counts for energy sources that may be available in your vicinity in the form of waste heat or overcapacity of sustainable energy generation.

In the context of buildings, the Harvest Map tool was originally created by the architecture firm Superuse Studios. They used Harvest Maps to find sources of building materials and energy in Utrecht, Amsterdam, Rotterdam, Eindhoven, New York and other cities. Take a look at their maps and the buildings they were used for via www.recyclicity.org/toolsharvestmap.html. Superuse Studios also created an interactive Harvest Map showing currently available resources, take a look at www.oogstkaart.nl. These tools are geared towards the Dutch building industry and may not suffice for your production location and the materials or energy you need. Not to worry, below are the steps to create a Harvest Map dedicated to your project.

To make a Harvest Map, you want to know the main parts of the product and the materials that are currently proposed for them. If the Harvest Map helps you to identify possible suppliers, you can add these to the Stakeholder Network tool in the Symbiosis Element. This tool can be seen as a more focused version of the Surroundings Scan. Whereas the Surroundings Scan is best used in the goal definition, the Harvest Map can also be used up to the detailed design phase.



Steps of the tool

I. Wish list

Start with a (preliminary) bill of materials (BOM) and mark parts that could be made with or completely from recycled content. Make a wish list that mentions for each part the required material, the amount needed for a production volume and the boundary specifications for the material. Add any energy requirements quantified in kWh of heat and electricity to the list and use this list to create the inventory in the next two steps.

II. Bike/ car tour

Explore the area around the production site at low speed and note any visible piles of materials, cooling towers that expel heat and companies that may have wish list resources indoors. To prepare for this tour, study an online map and identify points of interest. Make photos of resources you come across. You may be able to inquire about attractive 'waste' streams on site, and you can follow-up with phone calls in other cases.

III. Plot the map

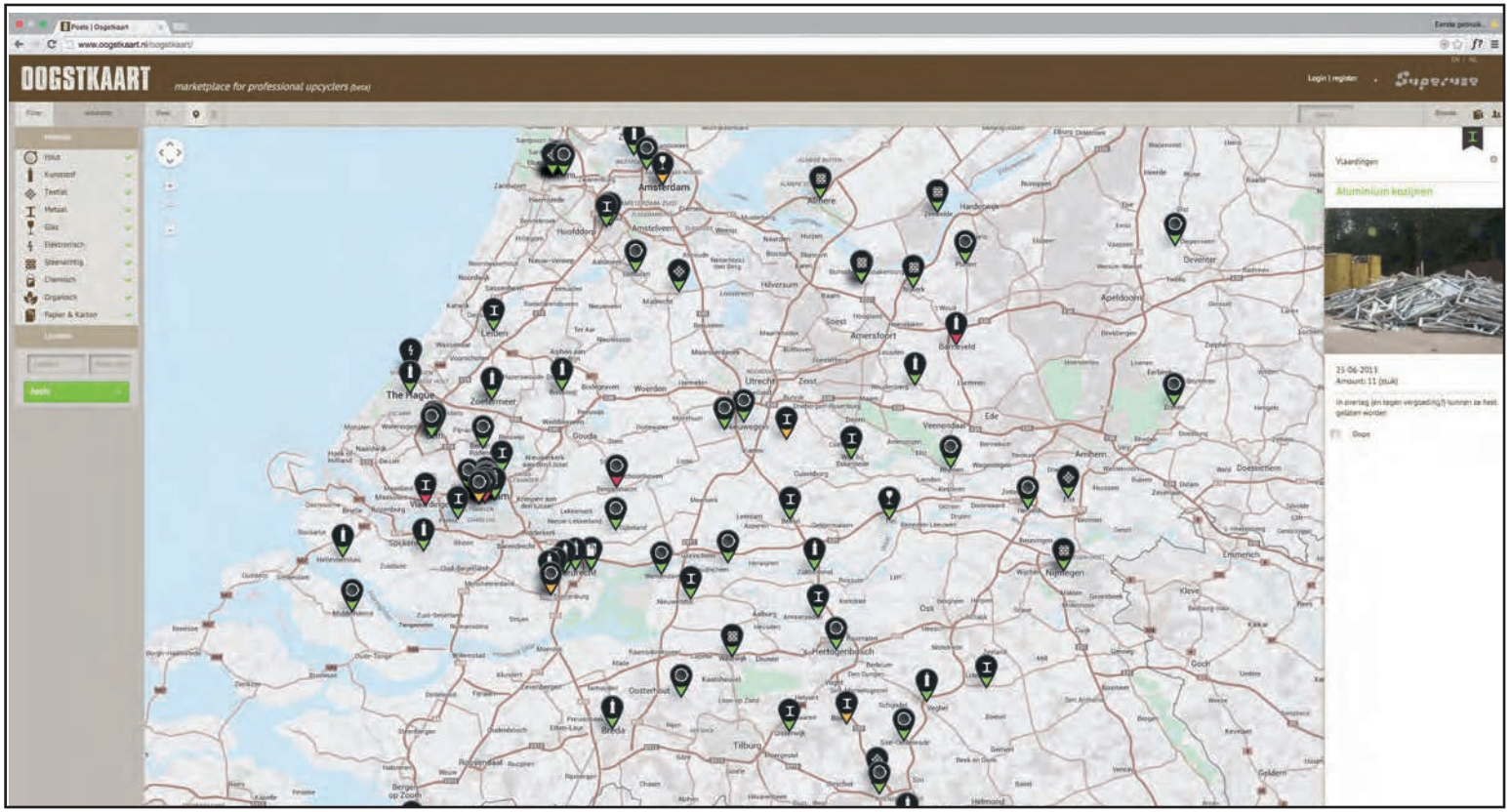
To visualize the readily and locally available resources you can use the online 'oogstkaart' (harvest map) or create a map of your own with graphic software. This map will help you to communicate about and choose between resources.

IV. Select and contract suppliers

When you found one or more potential suppliers of materials or energy, establish contact and negotiate your terms for volume, quality and price. If all goes well you will tap into a cost-effective and sustainable resource whilst reducing the costs that your neighbours make to resolve their waste.

Example

In this online tool, stocks of used materials are put on a map. Filter for the materials on your wish list and click on the available resources near you, to make better use of what is available.



Credit: Superuse Studios.

RECYCLING

- Nutrient Pathways

Outlining the activities required to close material loops.

I. Choose one or two cycles

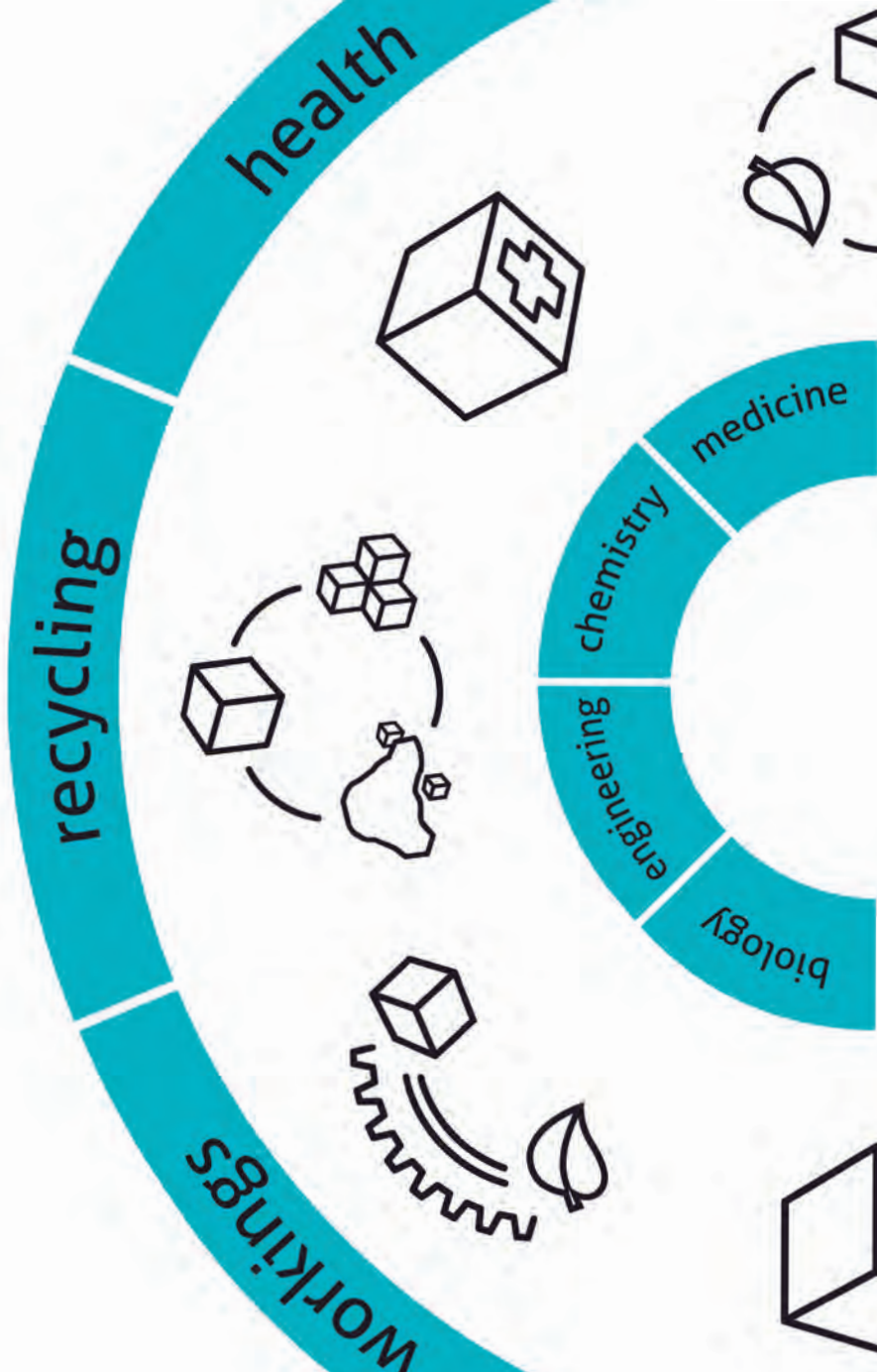
II. Define the pathways

III. Plan for action

Recycling can be easier said than done. Many materials are recyclable, but the process needed for the recycling to happen will involve separation, transport and a number of mechanical and chemical steps to break down and restructure the material (Tempelman et al. 2014). Therefore, getting your effluent materials recycled and using the recycled material for new production requires some planning. You may be able to outsource most of the actual recycling work, or decide to do it yourself alongside the production work. Either way the Nutrient Pathways tool creates insight into the work behind effective use of recycled materials. The outcomes include (un)selected materials to be reviewed in LCA or ABC-X. If you need partners for the recycling , include these in the Stakeholder Network

Cradle to cradle famously defined two cycles: In the biocycle materials are digested trough biological pathways and support growth of new materials in the biosphere. In the technocyle materials are recycled trough technological pathways and end up as technical resources. If materials from both cycles are combined in a product they have to be separable in a realistic process or it becomes a 'monstrous hybrid'; a mix of materials that is useless as a resource (McDonough and Braungart 2002).

As we are dealing with both cycles in this tool, it touches both the Recycling and Foodweb Elements of the NID wheel. The Nutrient Pathways can be seen as a detailing after you have established the Circular Economy service cycles. The Harvest Map can be a starting point to determine the Nutrient Pathways, together with the Local Ecology Map tool.



Steps of the tool

I. Determine: bio- or technocycle

Any material that 'disappears' and enters the environment during use (for example tires which wear down and shampoo that enters water treatment) has to cycle in the biosphere. These materials can be fully used as a nutrient in a realistic context and time frame, are renewable and completely non-toxic or beneficial to humans and ecosystems. They have to be, because there is no control over where they end up.
Any non-renewable material has to cycle in the technosphere. Non-renewable means is comes from a source that does not regenerate the material, a mine for example, even if there is ample stock. The materials in the technosphere need to be recycled endlessly at the same or higher quality, or they will eventually be depleted. Technical nutrients flow exclusively in man-made systems and are non-toxic unless it can be absolutely guaranteed that no leakage is possible under any circumstance.
With this in mind, determine if your product belongs in the biocycle, technocycle, or both (in case it has parts that must be made from non-renewable materials whilst other parts wear down for instance).

II. Define the pathways

List the main materials and do the following for each material:

a) For technocycle materials, list the infrastructure that you need to reclaim the materials, such as collection bins and transport services. For biocycle materials, list the organisms involved in digesting the materials and the organisms responsible for the regeneration of the material you used.

b) Envision a (possibly multi-stage) process that improves the usefulness and quality of the material to at least the quality that you need for your product. For biocycle materials, this would be the shortest food chain between the digesters and regenerators.

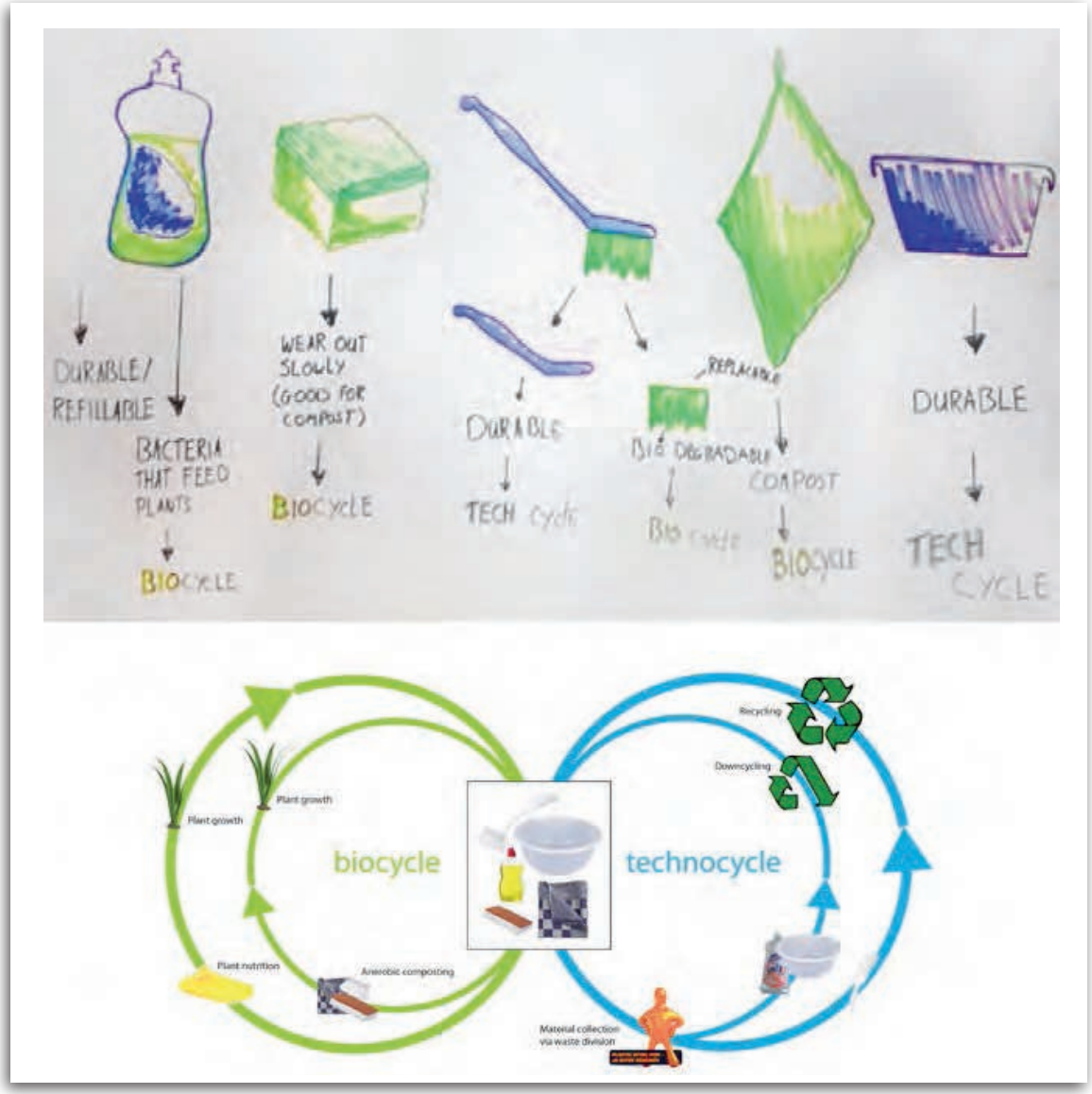
c) Visualize the Nutrient Pathways by drawing them as circles that touch at one point, which is where you would have the product. By convention, the biocycle is drawn on the left whereas the technocycle is drawn on the right. Draw one circle for each material and, communicate the processes it goes through along the circle.

III. Plan for action

The Nutrient Pathways you have drawn will help you communicate with supply chain partners who are able to complete these cycles with you. Sit with these suppliers and recyclers to determine the recycling process in further detail. Also set requirements for the separation of technical and biological materials (fast, affordable, using simple tools or prevalent infrastructure, etc.).

Example

In this execution of the Nutrient Pathways tool, a dish-washing set is divided into durable technocycle components and dissipating biocycle components. The technocyle is closed with a 'Plastic Heroes' recycling system and the biocycle combines re-nutrition and composting to regrow the materials used.



RECYCLING

- Design for Disassembly

Ensure that products can be optimally disassembled to allow for upgrading, repair, reuse and recycling.

I. Understand that there is no fixed approach to Design for Disassembly, but good pointers are:

II. Consider product architecture

III. Consider which components might fail prematurely

IV. Consider which components are eligible for upgrading

V. Consider who will do the disassembly

VI. Smartly choose fasteners

Design for Disassembly, or DfD for short, is an established tool for product design and engineering. Here we share with you some pointers for how we have come to regard the topic: we hope you will find them to be of value in letting you decide which of the existing DfD tools are any good.

The aim of DfD is to ensure that your product can be disassembled in the most optimal way for your specific situation, and for any or all of the following contexts of use:

a. Repair: your product broke down during (mis)use and must be repaired to retain its original functionality;

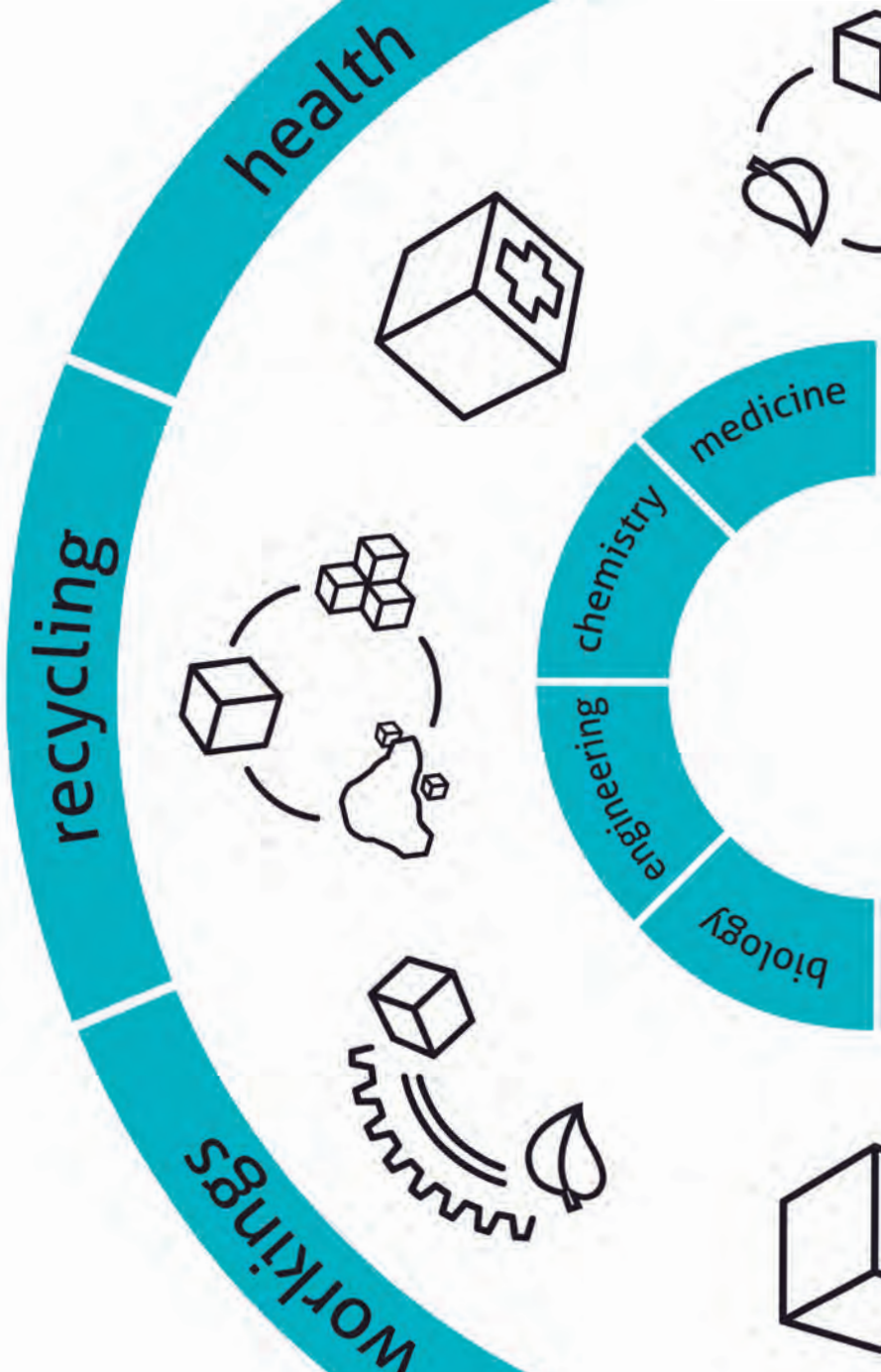
b. Upgrading: your product can gain new components (that you, or others, put on the market) that allow it to become faster, more efficient or some other increase in functionality;

c. Refurbishment: your product is disassembled (by you or by your partner companies) and then reassembled, using a mix of new and old parts, and used for a second life;

d. Recycling: having spent its useful (second) life, your product is partially disassembled for spare parts, and the remainder is shredded for material recovery.

Whatever the context, bear in mind that DfD addresses a secondary issue at best: a TV that does not work will not sell, no matter how easy it is to take it apart – and if DfD adds sizable costs that do not lead to substantial value, it will not sell well either.

As Design for Disassembly ensures that products can be recycled, this tool supports, the NID Principle "Waste equals food". Usually modular designs are easy to disassemble. By doing DfD, you may support the NID Principle of "Integrate development with growth."



Steps of the tool

Understand that there is no fixed approach to design for Disassembly. It is essentially a process of optimization, in which you aim to balance the (secondary) requirement for a product to be easy to disassemble against its primary requirements, such as function, quality and cost. The outcome of this process depends on so many variables that no single method should claim to provide the end-all solution. Below, we present a set of common and uncommon pointers to help shape the process: use these to determine if the method you found in literature or on the Internet "makes sense". Note that this set is not exhaustive, but it will set you on your way for sure.

I. Consider product architecture

For the overall product architecture i.e. its layout, we recommend you use a modular structure, with the majority of parts mounted onto a simple frame and in plain view of the user, or hidden from view behind easy-to-replace (non-structural) covers if looks are essential.

II. Consider which components might fail prematurely

If your product is to have a long life, make sure that components that are likely to fail prematurely, are easy to replace. Batteries are a good example: the infamous case of Apple iPhones, where the battery loses functionality after just 18 months yet is fiendishly difficult to replace, comes to mind as a scenario to avoid. These "short-life components" should be easy to locate and replace; moreover, make sure that it is easy to determine if they are indeed in need of replacement. Classic car designs generally make good examples: in most cars from the 1980s, an indicator light that blinks too rapidly signals its impending failure, and can be pre-emptively replaced in mere seconds (in modern cars, not quite so anymore).

III. Consider which components are candidates for upgrading

Upgrading can boost product performance , and thereby can generate business as well as goodwill, as customers generally appreciate it if they do not need to replace the entire product. Such upgradable components should also be easy to take out. Again, it will pay off if it is easy to determine if an upgraded version is available, and how exactly performance is boosted. Web-based communities are great media here.

IV. Consider who will do the disassembly

In parallel to step III, consider who will dis- and re-assemble the product, and how this limits the (tooling) options: consumers have more time than professionals have, but have much fewer tools at their disposal, and are generally less experienced. Also, if you consider printing DfD instructions onto your product (or in the manual), then also consider that some users may not understand your language (indeed, are unable to read at all). Icons work better.

V. Smartly choose fasteners

When it comes to the choice of fasteners, your first DfD rule is to use as few different types as possible. Every tool change takes time, so if your product is held together fully by M4 screws, it will be much quicker to dissemble than one where a range of screw sizes is used. And speaking of screws: if you can replace them with snap-fits that allow repeated opening and closing (so, NOT the permanent ones!) or form closures, then you can do away with tools altogether. Wing nuts, quick-release catches and the like also make for good "tool-less" DfD fastening solutions. Avoid welding and soldering for components that are likely to fail or be upgraded, as only very few people can restore these types of joints, and none of them fast. Likewise, avoid thermosetting adhesives in favour of "hot melts" (which loosen with heat) or dispersion systems like ordinary wood glue (which loosens with moisture), if you have to resort to adhesives at all. And in all cases, ensure proper access to fasteners – this, like standardization of fastener sizes, will in fact also drive down assembly cost.

Worthy of special mention here is: active disassembly. A recent addition to the decades-old arsenal of DfD solutions is formed by several types of fasteners that open automatically under the right conditions. Heat is one of these "triggers", vacuum another. Industrial-sized vacuum chambers are remarkably cheap to operate and enable DfD solutions that are stunningly effective. On the website of the UK-based Agency of Design, you can see this solution (along with several other great examples of DfD) in action: just search their site www.agencyofdesign.co.uk for the "Realist Toaster".

To give a last pointer (remember – this set is not exhaustive), always consider safety. Brake systems of trains are not to be "serviced" by non-professionals, let alone come under easy attack from vandals or saboteurs. Dedicated fastener types, only operable with special tools, can be a solution for such parts and components.

Need further reading? We recommend Afterlife: an essential guide to design for disassembly by Alex Diener (2010). This well-read document, freely available on-line, succinctly complements our own text here.

Example

An excellent example of Design for Disassembly is the Herman Miller Mirra chair. It can be quickly disassembled into its components and different materials, making it for 96 % recyclable. Therefore, the seats can be upgraded to the users liking as well. For example, the backrests can be replaced with one of seven different colours. And, being a product developed in the C2C philosophy, these backrests are fully recyclable (Rossi, Charon et al. 2006).

Credit: Herman Miller 2007.

HEALTH

- Quick Scan Life Cycle Analysis

Determining places to improve the efficiency of the product system that give the largest improvement in eco-efficiency.

I. Make a diagram of the lifecycle of your product system

II. Determine a relevant functional unit for your product system

III. List and quantify the main materials and processes present in your product system for the given functional unit

IV. Use the Eco-Indicator, the EcoLizer 2.0, or similar tool to find the impacts of the materials and processes

V. Evaluate the outcome for several design alternatives and select the most eco-efficient product system

Once you have designed a product system that has a circular structure and is functionally fulfilling the NID Principles, it is time to optimize it and make it more efficient.

A Life Cycle Analysis (LCA) shows the potential environmental impacts of your product system throughout its entire life cycle (ISO 2006). With this analysis, it becomes possible to pinpoint the stages and materials through which the product system generates the largest environmental impact. This allows you to target the right aspects of the product system to reduce its impact.

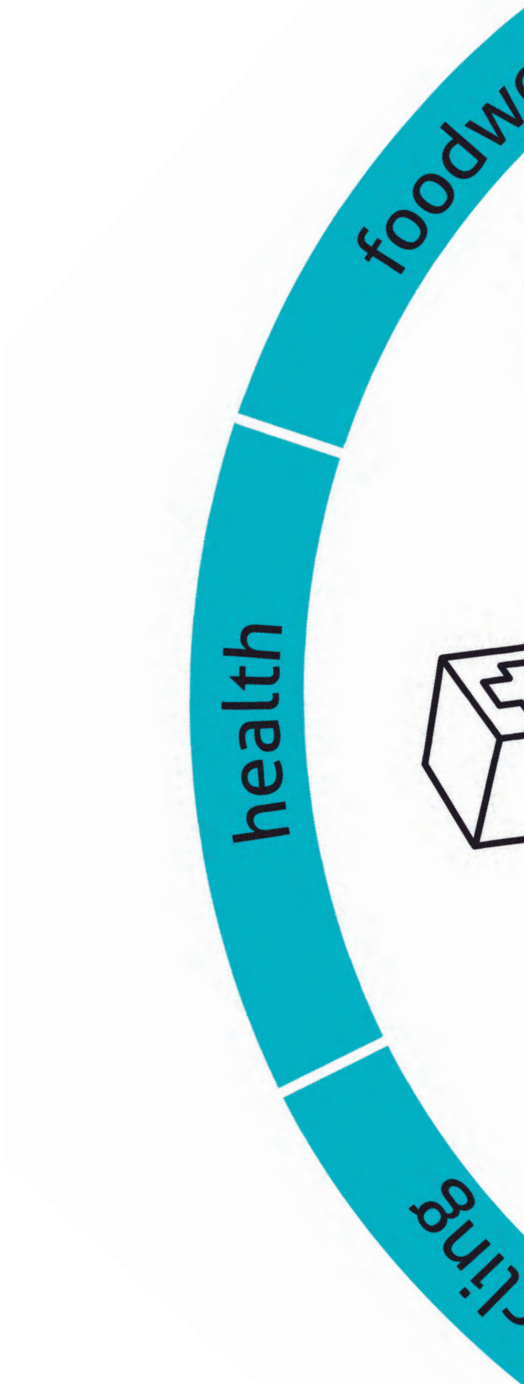
LCAs come in several different forms. A full LCA of a product system can take years (!) to execute and is generally not feasible within a real-world design process. Such analyses become especially unwieldy if instead of only the product system, the equipment for making it is included as well ("machines to make machines..."), i.e. so-called higher order LCAs. More simplified forms of LCA, increasingly common since around 2000, are the 'Fast track' LCA and the Quick Scan LCA, of which we propose and describe a version here: this can be a feasible yet powerful tool for design. It is rough, by definition incomplete, and prevents you from identifying all possible impacts. Therefore, it cannot be used as a basis for making (public) statements about the absolute impact of your product. However, it can be used quite well to select the design alternative of the product system with the highest efficiency, or to prioritize between different options for optimization. To learn more about LCA for design purposes, Vogtländer (2010) offers highly practical guidelines.

Link with Nature Inspired Design

Any LCA focuses on reducing the negative impact of your product system on the environment. So, it is not suited for measuring any positive impacts, which is what NID is all about. Another drawback is that LCAs do not take into account the local context: the impact assessment system behind LCAs assumes that for instance all harmful emissions are somehow directed at the regional or even global ecosystem. However, LCA remains the best-developed tool available to track all material and energy streams of product systems from and towards the environment, and to quantify the negative effects these streams have (in terms of e.g. loss of biodiversity, greenhouse gas emissions and resource depletion), i.e. the impact assessment. ISO 14040 (2006) provides a framework for making LCAs in a standardized manner, with conclusions that are much less vulnerable to criticism than many people may think. Plus, it is a powerful tool to compare design alternatives; in particular, the LCA helps your design to be Resource Efficient – which is one of the six NID Principles.

A Quick Scan LCA is preferably made when some first concepts have already been developed and not too late after that point: there is enough information, yet there is still room to improve the concept.

In the goal definition stage, a Quick Scan LCA can also be used to indicate where the major impacts of existing product systems are –for benchmarking. However, be careful when doing so: the intention behind any NID project should never be to merely reduce impacts of existing systems, but to go for positive impacts and the best contextual fit. So, at this stage, LCAs can only have a different goal, which is to communicate the necessity for change, not as a means to find the focus for redesign. For that purpose, this handbook offers other tools such as translating the NID principles into requirements, Use Life Benefits, and the Harvest Map.



Steps of the tool

I. Make a diagram of the lifecycle of your product system.

Consider at least production (including extraction of raw materials), usage, and discarding, and include major transportation steps as well

II. Determine a relevant functional unit for your product system.

A functional unit defines and quantifies the service delivered by the product service system that allows fair comparison with other solutions. In the infamous case of the Hummer having a better LCA score than the Prius, the functional unit was erroneously defined as 'a car' (Tempelman 1999). If you compare the two alternatives for "personal transport for 20.000 km/year during 20 years", the gas-guzzling Hummer has a much bigger environmental impact than the Prius. The Prius has a higher impact in the production phase, but this is more than offset by its fuel efficiency during the 20-year lifetime.

III. List and quantify the main materials, manufacture processes and energy required in your product system for the given functional unit.

IV. Use the Eco-Indicator, the EcoLizer 2.0 or similar tool to find the impacts of the materials and processes).

The Eco-Indicator is a database used in LCA software like Simapro, Idemat, ECO-it, EcoScan and many others (Goedkoop and Spriensma 2001). The EcoLizer (OVAM 2010) is an easy to use booklet with the Eco-Indicator data that is most relevant for designers, which you can find at ecodesignlink.com.

V. Evaluate the outcome for several alternatives for the functional unit of your product system.

A common way to do this is with a bar chart, showing bars for the impact of alternatives in the phases of production, use and disposal. Select the most efficient product system, and define the parts with the highest impact as points for further improvement.

Example

In passenger car design, a key choice to make is the materials for the structural shell, or body-in-white (BIW). Aluminium can produce a lighter BIW than steel and hence, realize fuel savings during the use phase, but at the expense of increasing the energy needed for manufacture. Carbon-fibre composites (used e.g. in the BMW i3 electric city car, shown right) can reduce even more weight but again at a cost during manufacture; also, within the existing car recycling system, these materials present a recycling problem. Quick Scan LCAs can show how the relative sizes of these benefits and drawbacks, thus helping you to make the right choice. Also, they reveal the key variables at work, such as the secondary weight savings (lighter BIW means lighter engine), the lifespan in km, and installed power. For more information on reducing energy use in passenger cars, refer to Tempelman (2011).

The 2013 BMW i3 represents a breakthrough in BIW design, but its lightweight carbon composite body does present recycling challenges

HEALTH

- Quick Scan ABC-X inventory

Identifying sub-optimal materials and prioritizing material replacement options.

I. Define interactions

II. Define risks

III. Determine cyclability

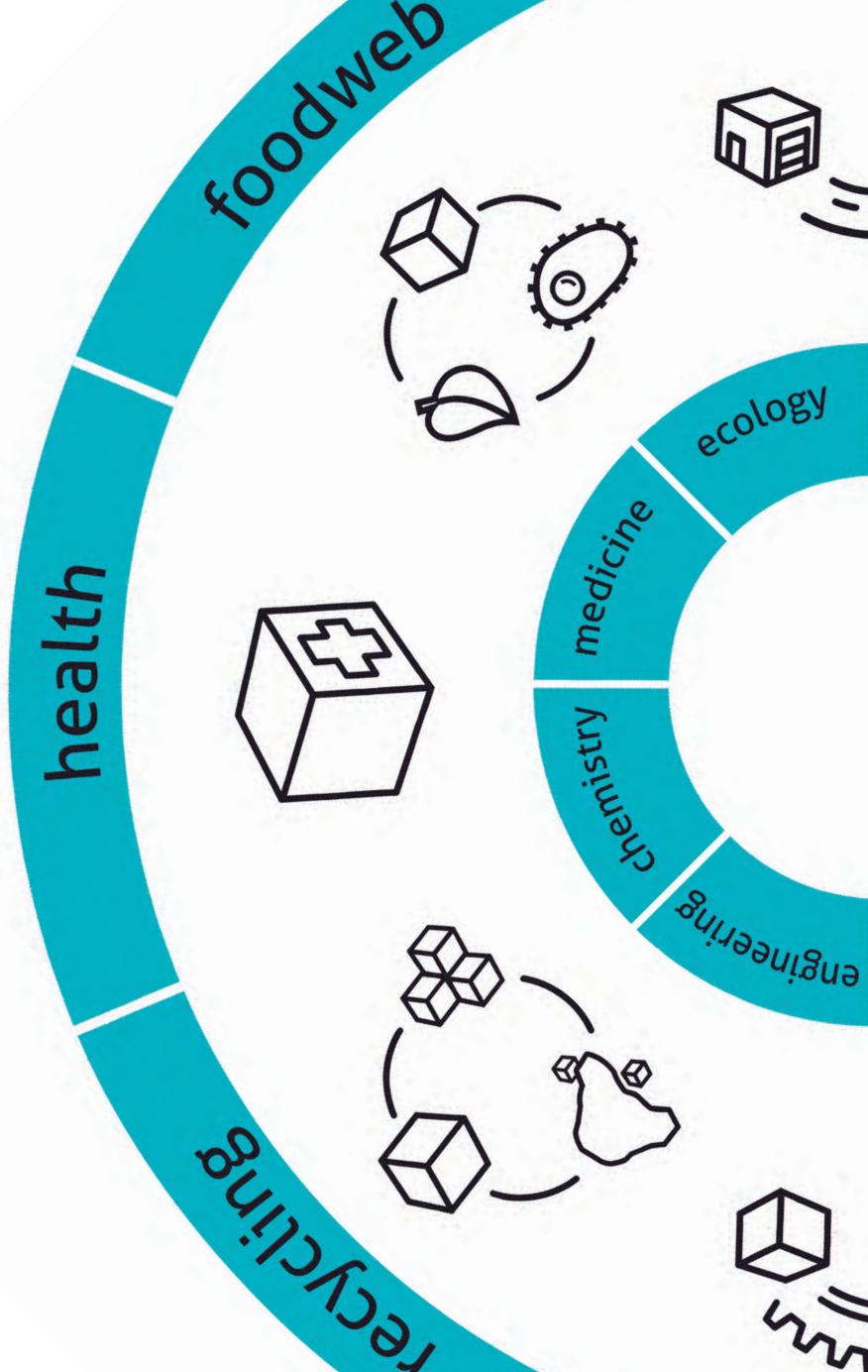
IV. Check against the banned substances list

V. Give the final ABC-X classification for each material

VI. Prioritize improvements

ABC-X Inventory is the tool used in cradle to cradle to assess the toxicity and cyclability of a product . The assessment fits the design philosophy of C2C and is quite different to toxicity assessment in LCA, even though both evaluate materials and provide direction for improvement and means of measuring those improvements (see Bor, Hansen et al. 2011 for a detailed analysis of the differences). ABC-X is a shorthand for the Material Health Assessment Methodology that classifies materials in A; optimal, B; safe, C; acceptable, X; problematic, Grey; unknown or 'Banned'; materials on the cradle to cradle banned list. The full assessment methodology is described in detail in the cradle to cradle V3 product standard (Cradle to Cradle Products Innovation Institute 2012). It can take weeks to carry out a proper ABC-X, as the assessment requires for instance mass spectrometry to read the chemical composition of materials in parts per million precision (0.01%). We cannot do this methodology justice in these short pages, for that we refer to the standard. What is described here is a quick scan inventory, addressing the main criteria for material health classification for the most relevant materials while assuming their composition by using a materials database. This quick scan toxicity inventory has been helpful in classes to determine priorities with limited information and no more than an hour, and to teach about impact assessment in cradle to cradle.

The result is a Quick Scan inventory table with the classification of each material and areas for improving their impact in your product. This contributes to material selection and is tied with the Elements Recycling and Foodweb. The output from the Surroundings Scan can help to identify exposure risks of the materials. To perform a cradle to cradle ABC-X analysis, we refer to the cradle to cradle certification standard.



Steps of the tool

I. Define interactions

When and where are the materials exposed throughout the product life cycle? For the most important materials, describe the exposures to humans and other organisms downstream from production. The source of materials is usually not rated in the Material Health Assessment Methodology. In a table, account for the interactions through contact, air, water and soil for the phases of production, use, unintended use, the standard post-consumer scenario and when burnt or buried.

II. Define risks

Make an informed assumption on the hazards that the materials may pose and rate them on a four point scale from short term hazardous (3) to long-term safe or healthy (0). Also assess the likelihood that the corresponding route of exposure happens on a four point scale, from certain (4) to highly unlikely (1). The two scores are multiplied to make the single material risk assessments in four classes; a, b, c, and x. With the four point scales we use in this tool those classes correspond with the risk assessment as follows.

a) 0; ideal for humans and environment
b) 1-2; no moderate risks
c) 3-5; some moderate risks
x) 6-12; significant risks

III. Determine cyclability

This time on a three-point scale, rate the recyclability or degradability as:

b) Recyclable or rapidly degradable
c) Downcyclable or slowly degradable
x) Not recyclable or degradable

Recycled content may contain trace elements. If applicable, rate the material and the residual material traces.

IV. Check against the banned substances list.

The C2C products innovation institute has published the V3 banned substances in the C2C certified resources and in the material health methodology. These materials are carcinogenic, endocrine disruptive, mutagenic, bio-accumulative, toxic to inhale, to digest or to touch for humans, animals or plants. It takes a chemist to understand most of the chemicals on the banned substances list, designers will recognize some materials like PVC, mercury and cadmium. If a material contains (traces of) banned substances, the final ABC-X score is automatically 'Banned'.

V. Give the final ABC-X classification for each material

Compare the risk and cyclability scores for each material and assign, in capitals, the lowest score as the final score . For example, b & c = C and a & x = X. Since cyclability is not rated 'a', A is an impossible outcome or as stated in the C2C methodology: "Note that the A designation is unlikely to occur at present" (MBDC 2012, p. 70). It is reserved for the materials that are ideal from every cradle to cradle perspective, utterly harmless and even beneficial.

VI. Prioritize improvements

From the materials you have rated, the lowest ranking materials are the highest priorities. But also B and C rated materials allow for improvement. Choose the materials you need to optimize or replace and adjust the design accordingly.

Example

In this Quick Scan ABC-X Inventory a product comprising four materials is analysed. From the defined interactions with these materials (see tables on the right), the risk of exposure is rated in table #bottom. Combined with the cyclability of these materials, a final rating is provided for each material, which in this case makes the replacement of filled Nylon a top priority, and the replacement of Low alloy steel a second priority.

Material	Interactions				
	Production	**Use**	**Unintended use**	**Post-consumer**	**Burnt or Buried**
ABS, red colouring	Emission of of-gassing process chemicals	Touch, inhalation of volatile components	Inhalation of fumes from burning	-	Emission of CO_2 and complex organic chemicals
Low alloy steel	Exposure to heavy metals nickel and chrome	-	-	Fumes and heavy metals in recycling	Emission of (heavy) metals and oxides
Wood	Inhalation of sawdust	Inhalation of of-gassing components	Splinters entering the skin	-	CO_2 emission or emissions of bio-degradation
Nylon, glass fibre filled	Inhalation of and skin contact with glass fibres	-	-	-	Emission of CO_2 emission and residues

Material	Risk	Cyclability	ABC-X score	Improvement Priorities
ABS, red colouring	b	b	B	
Low alloy steel AISI 4300	c	b	C	Replace with silicon manganese alloy AISI 9200
Wood	a	b	B	
Nylon, glass fibre filled	b	x	X	Use recyclable material such as unfilled Nylon or ABS

HEALTH

- Eco-Effectiveness Test

Finding evidence for positive impact of your product.

I. List and check the benefits you defined so far

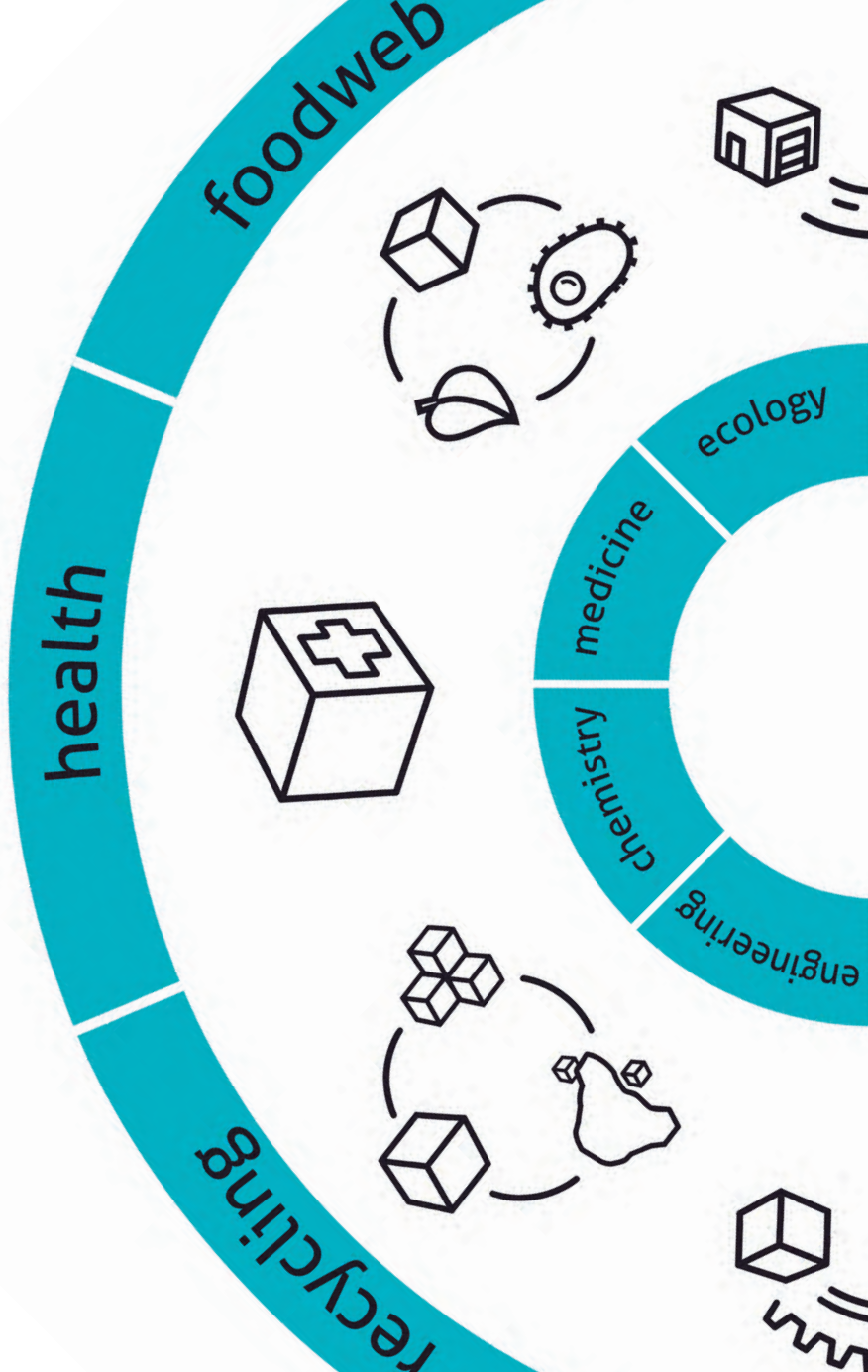
II. Pick your battle

III. Describe the test

IV. Do the test and boast about it

Eco-Effectiveness is not a criterion for certification, but it is a property of a truly NID product. Your Intention Statement will give some hint about the intended benefit(s) of your product or service. Additionally you can use the outcomes of the Use Life Benefits and/ or the positive eco-effects found in the NID Elements Symbiosis or Health in this Eco-Effectiveness Test tool to help you communicate those benefits.

The goal is to provide evidence for and communication of the benefits or positive impacts of your product or service. The target audience depends on your project and can be managerial staff, sales team, potential customers and even sceptics, competitors and researchers. A good way to show them that your design has a positive impact, is to provide measurable test results. The best way to do that is to describe and carry out a single and simple test, and not all possible benefits lend themselves to that, so the first step is to choose. The outcomes of your test feed into the Value Element as a testament of quality and competitive edge.



Steps of the tool

I. List and check the benefits you defined so far

a) Simply list the benefits you have defined and check, for each of them, whether the following properties are true: does not affect a complex system, or the positive and negative influences for the system are well understood and generally accepted.

A complex system is a system with many interacting components that, when combined, produce behaviour that cannot be derived from the behaviour of the individual components, like organizations, organisms, societies, ecosystems and markets. For example a car is not a complex system and the effects of a fuel with healthy emissions can reliably be measured. What is healthy for a person is much more sensitive to the initial state of the person, which is unique to him or her. But there are known effects on complex systems, for example, it is generally accepted that collaboration benefits organizations, fine dust harms organisms, inclusion benefits societies, chlorinated water harms ecosystems and spending benefits markets.

b) This benefit is a sign of perceived quality.

This depends on what the audience knows. Since a lot of bad press, Bisphenol A is known amongst many parents as something you don't want near you child and 'BPA-fee' is now a quality hallmark. With a substance such as Chromium VI, the level of awareness is much lower and CrVI-free will not be perceived as an indication of quality unless you are able to explain why you think it is. Clean energy is another case where the consensus is in your favour, but (depending on the product) the case of batteries replacing a fuel tank is much more convoluted.

c) This benefit can be expressed as a quantity.

Evidently, quantification means that you can put a number on it, and that you can hence compare it to other solutions that offer similar qualities. A few examples are Phtalate-free (0.00 grams), fine-dust levels (16.8 µg/m3 compared to a typical concentration of 67.2 µg/m3) and fair wage (150% of local minimum wage). Qualities like good working conditions, animal welfare and clean production are much harder to quantify and not suitable for an Eco-Effectiveness Test. In such cases, consider measuring indicators like average days of sick leave, milking cow productivity, and pollutant levels respectively.

d) This benefit creates significant positive impact, preferably over some agreeable threshold.

You want the measurement outcomes to be impressive, enabling you to state that a problem is fixed instead of just diminished. Ideally you are able to show the effect with a secondary indicator. In the example case, the Airmaster carpet tile significantly reduces indoor fine-dust concentration at breathing height (generally accepted positive impact on the complex system of a human body) ánd there is a quantified financial return coming from increased productivity.

II. Pick your battle

Hopefully you will have at least one benefit that checks all the boxes. If not, ask yourself if you have designed a benefit that does justice to your Intention Statement and perhaps take a step back and create new ones. If you have more than one benefit checking all boxes, pick the one that you think creates the most value from your client's perspective.

III. Describe the test

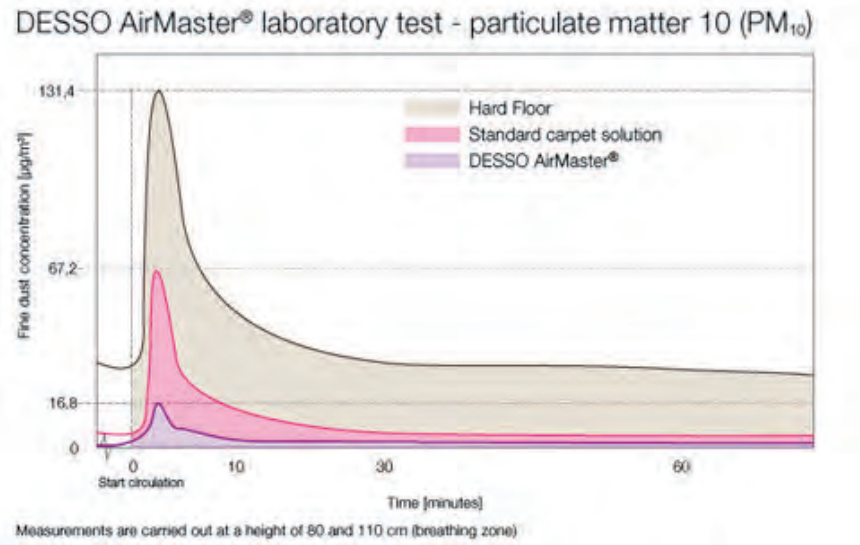
As if writing a scientific paper (and perhaps you are doing so), define the method and equipment for testing such that the results from your test can be reproduced by other researchers. Ideally, you can use a method described in a scientific publication to increase the chance of general acceptance of the results. Also, define upfront how you will interpret the results, for instance in terms of thresholds or statistical relevance. Aim for appealing real-world tests that can be done with the simplest means, to ensure that the outcomes are accepted as credible and externally valid.

IV. Do the test and boast about it

The best way to be sure of your results is to do the test a few times over. If you design delivers on its promise, the outcomes are a sales argument. That is what you would be after in an Eco-Effectiveness Test: You already knew you were creating positive impact, but now you have a powerful marketing instrument to make that case with any outreach opportunity that you have.

Example

Desso used three similar office spaces, one with a hard floor, one with their normal carpet tile and one with the Airmaster carpet tile, and they measured fine particle matter concentration in different places between 80 and 110 cm from the floor, which is where people breathe. Indeed fine-dust levels were dramatically lower. These are the graphics they created to tell this story:



Credit: Desso.

FOODWEB

- Surroundings Scan

Find, list, select, and estimate the size of the opportunities in the direct surroundings of your product.

I. Visit the places where your product will be throughout its lifecycle

II. Make a long list with all the items that are in those places

III. Select those items you consider potentially useful for your product

IV. Range and Change: make 'guesstimates' of the range in which these items are present

The success of any animal or plant depends on its interaction with the surroundings it lives in. This is the key message of Herbert Spencer's famous statement "survival of the fittest" (see the Deep Dive section of the handbook for a discussion on this statement). Those who fit best within their surroundings (so, not those who are somehow the 'strongest') will do more than just survive: they will thrive.
Fitting well within your surroundings offers plenty of opportunities to become better at what you want to do. To make your Intention Statement a reality, start by looking at the surroundings in which this product will function. Find opportunities for your product to cleverly cooperate with other products and organisms, and find ways to use available energies and materials in the direct surroundings. Also, observe how the availability of all these resources changes over time (e.g. how sunlight varies with the seasons, local weather, and times of day), and use this insight to your advantage. The Surroundings Scan guides you through that process.

Timing and linking within NID principles and process

The Surroundings Scan supports you in following these two NID principles:

- Be locally attuned and responsive
- Adapt to changing conditions

This tool can already be used in the earliest stages of a product development process. Even in the fuzzy front end: to determine what opportunities exist in the surroundings of the product for new functionalities, or even for entirely new products. The Surroundings Scan can be used as input for Design for Diversity, Context of Use, Use Life Benefits and Harvest Map. If a clear and detailed design brief is already present, then you can use the Surroundings Scan during the goal definition phase to determine what functional requirements are of key importance, and which requirements might be added. Although this tool is a key NID tool to use, it also sees some use in very other contexts of use. For instance, survival experts also learn how to systematically scan their surroundings in order to maximize their chance of making it through. Closer to 'home', for designers, is the practice of certain architects, who also deliberately explore the location of buildings they are commissioned to design so that the right fit can be created. A nice example is the Louisiana Museum of Modern Art in Humlebæk, just North of Copenhagen in Denmark, designed by Vilhelm Wohlert and Jørgen Bo (Wikipedia 2013).

Louisiana Museum of Modern Art in Humlebæk

Steps of the tool

I. Visit the place, or more likely: places, where your product will be used.

We advise to visit places together with an expert of the surroundings: this can be an ecologist, or the owner of a building, or the maintenance employee of a factory. Do this for each phase in the product lifecycle, so go to and photograph the places where it will be when it is:

- Built
- Used, reused and refurbished
- Recycled and discarded/disposed

II. Make a long list of all the items that are in those places.

Do not forget to check for blind spots! Can't find anything in your surroundings? Zoom out or zoom in: go into detail about what happens in specific locations of the surroundings, or zoom out to see what is going on in a larger area. Do you see just a field of green grass, and nothing more? Zoom in: how can the grasses be green, and stay green? What do these plants need to be green, and therefore, what other resources are apparently present? Or zoom out: is the forest next to the grass field important? What happens beyond the walls of the factory? Or on the parking spot? Use the following categories to help you look in the right place:

- Energies
- Materials
- Organisms
- Products

NB: 'energy' comes in many different forms, e.g. sunlight, wind, water waves and tides, geothermal heat and salinity gradients (used today in as 'blue energy'), but in the built surroundings, you may also have access to waste heat, electricity, chemical, kinetic and potential energy (e.g. items stored at height) and you might even be able to use ambient radiation through energy scavenging. Sometimes, even process noise can be used in a beneficial way!

III. Select those items you consider potentially useful for your product.

These can could be energy streams that your product can harvest to function, or materials that it can be built with, or other products it can work together with to complement its functionality. Draw and map the results in (a schematic representation of) the actual surroundings you have analysed. Do not go into endless detail: it is easy to go too far. Any situation can be modelled in an infinite level of detail. You will never be 100% certain if you've found all relevant items. If you cannot be complete then you might as well stay within your time budget for this step.

IV. Range and Change: for the selection you made in step 3, make informed guesses (i.e. 'guesstimates') of the magnitude, or range, in which this material, energy, organism etc. will be present: e.g. 100W/m2 of solar energy. Also, estimate the change: how will the availability of this item change over time? What will this place look like in a year from now? How will it change? What processes are at work, and what energies and materials drive these processes? Per resource, you may want to select a different time scale. For instance, for "kinetic energy from passengers at the train station" a timescale of 15 minutes might apply (assuming that a train stops nearby every 15 minutes). For solar energy a daily cycle, but as well a monthly or even seasonal timescale is more relevant. Plot the range and change on a graph that shows when how much of the resource in the surroundings of your product is available.

For energy, also consider energy cascades: use residual energy from already occurring processes that generate unused heat or other forms of energy to power your product. When looking for energy available in the product's (local) surroundings, see if you can identify such sources for energy harvesting.

For bio-cycle materials: consider cascading and fractionation: use a part of the material (wooden planks from a tree) and think of uses for the by-product (branches) or try and identify sources of such cascades and fractions that are useful for your products. Especially in the food industry, you may encounter effluents of wastewater streams filled with by-products that can possibly be used to grow other biomass.

Example

In her graduation project for FESTO, student Puck Bos analysed the surroundings of an actuator used in food production machines. These machines are used in a fresh-cut vegetable production hall in The Netherlands (Puck Bos, forthcoming).

In these surroundings, around 1,500 tons of vegetables are processed every week. There is a day and night cycle of 24 hours: every night the production hall is sanitized to be able to start the production with clean machines every morning. This is a period of 24 hours chosen to show the changes in the presence of different resources.

These data were gathered through observations and interviews with the employees. The interviews with employees were, next to the observation, an important way for finding out how the surroundings changes over time. The materials-in-time diagrams are made to roughly show the changes of materials over time. If during the design of the product one of the materials is found to be interesting, the exact amount can be determined.

If you would want to use the wastewater that gets spilt over the floor, the diagram shows that there are significant variations in the availability of this stream over time. This depends on the timing of cleaning the machines.
There are also constant values to design with, such as the temperature in the room that is continuously kept at 4ºC, no matter what the outside temperature is – and if we factor in that this outside temperature also changes with the seasons, we get a temperature gradient that itself again becomes a variable.

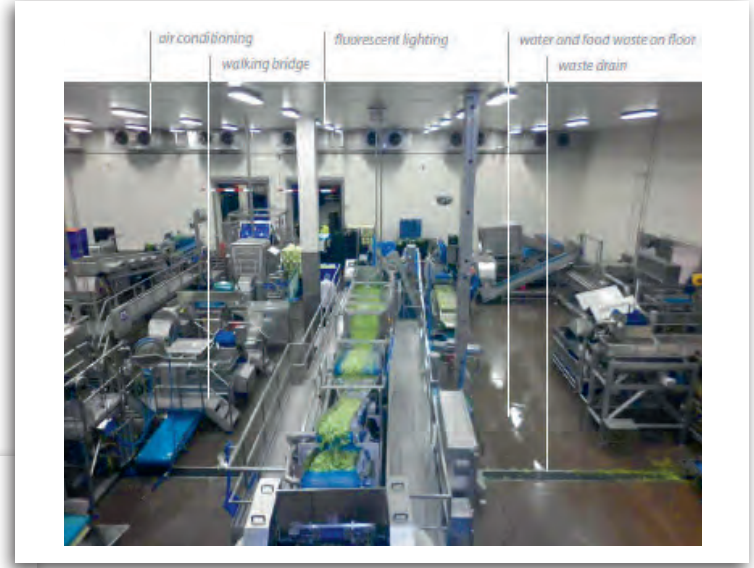


Figure 1: part of a production hall of Vezet. Credit: Puck Bos

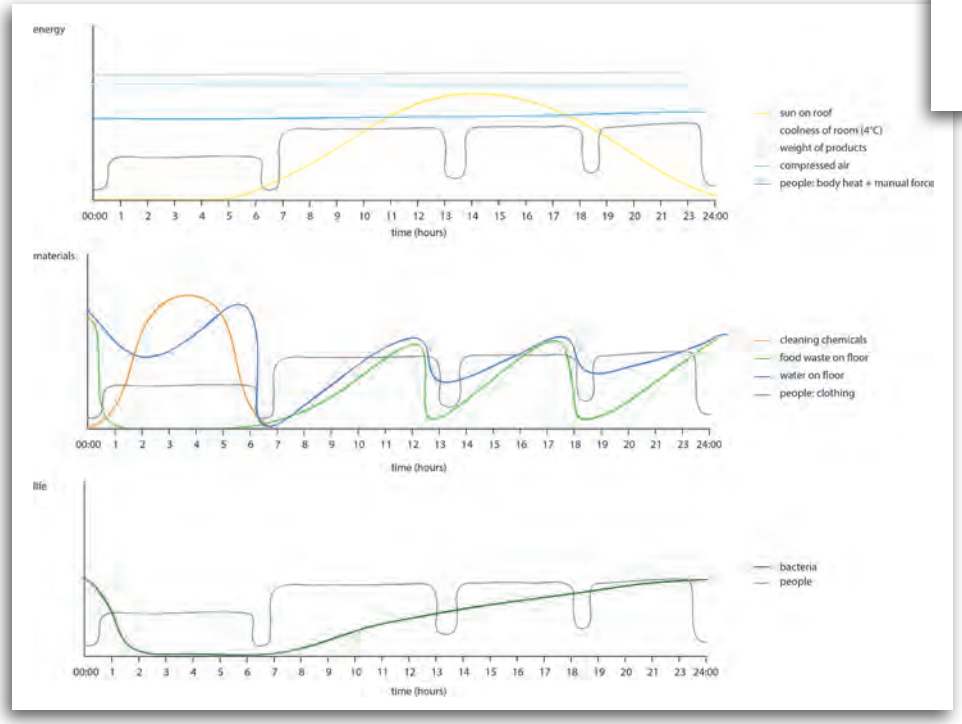


Figure 2: Estimation of amounts of resources present over time in a fresh-cut vegetable production hall in The Netherlands.

FOODWEB

- Local Ecology

Find the structure and main actors of the ecology around the product system.

I. Find an ecologist that is specialized in your specific environment

II. Take the list of organisms, materials and energies from the Surroundings Scan

III. Put each actor and resource on a post-it, or use mind mapping software

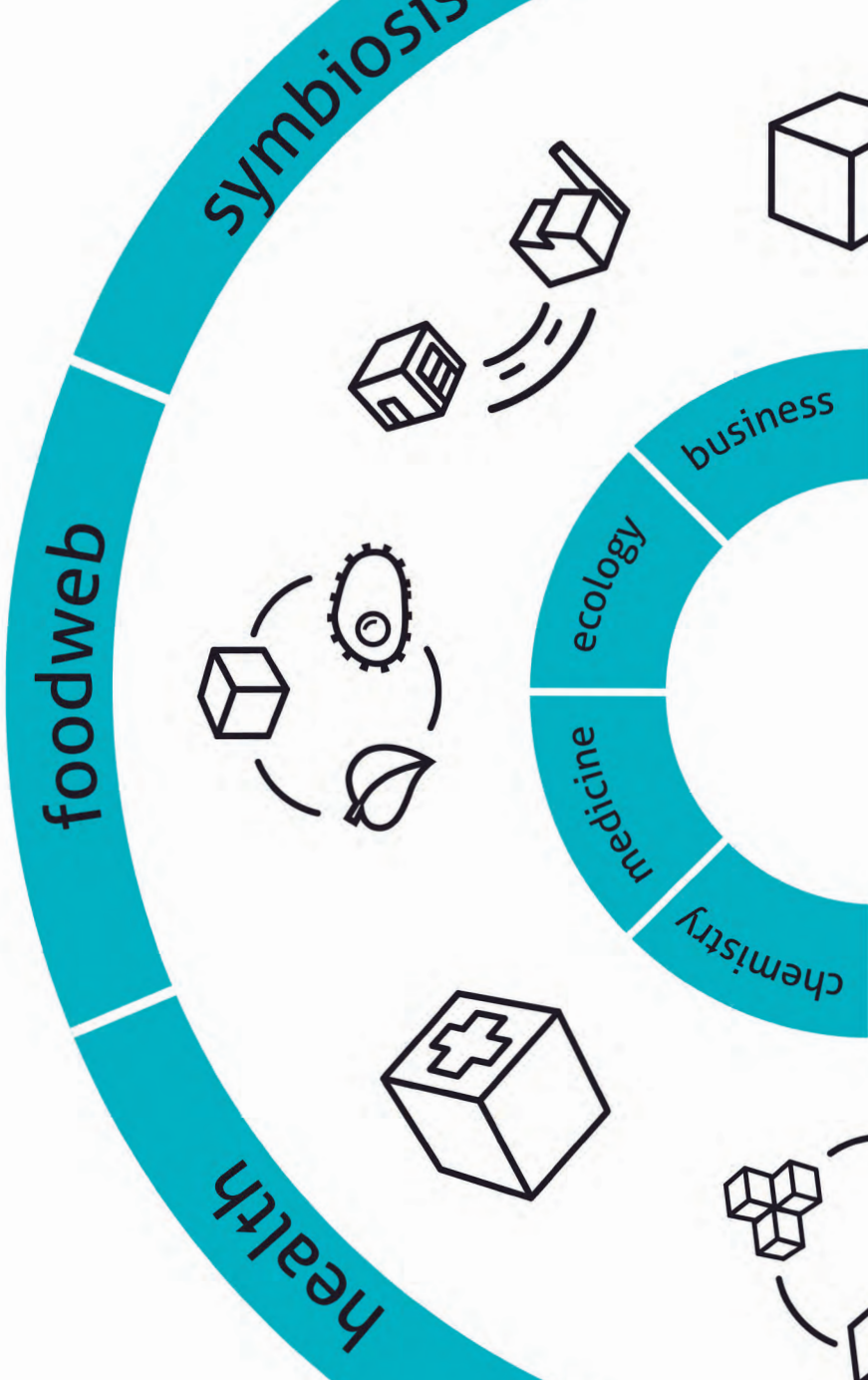
IV. By using arrows, indicate how materials flow from one actor to the other

V. Identify material or energy flows that may support the function of your product, or that your product may support to strengthen the local ecology

After you have made a long list of organisms around your product in the Surroundings Scan, it is time to analyse this information. How do the organisms interact, who eats who, who work together, and what energy, nutrients and climate do they need? Local Ecology is the tool to do that. Product developers usually ignore surrounding ecosystems since products that are almost exclusively found in non-natural contexts. We think. Nevertheless, ecologies exist everywhere. They are in the forest, but just as well in the city. Even in your living room there is a specific climate where certain plants, animals, insects, healthy and malicious microbes thrive or perish. An NID product strives to be locally attuned and responsive, to promote health, and will seek interaction with actors within the ecology surrounding it.

Timing and linking within NID principles and process

Knowing the local ecology can inform you on the role a product could play within its environment. Perhaps the product has to fit on the branches of a tree, or contribute to a micro climate in which specific insects grow best. The Local Ecology tool comes after the Surroundings Scan and between a first and second iteration of the Function Analysis. As the design becomes more detailed, you may want to refine the Local Ecology as well, adding specific descriptions and amounts of nutrients for example, or detailing the dynamics of interactions between actors.



Steps of the tool

I. Find an ecologist that is specialized in your specific environment.

You can look for them in universities, and in many cases you may find ecology research institutes specialized in the city, climate, material source or waste channel that constitutes your product's context.

II. Take the list of organisms, materials and energies from the Surroundings Scan

III. Put each actor and resource on a post-it, or use mind-mapping software, to visualize the ecological playing field.

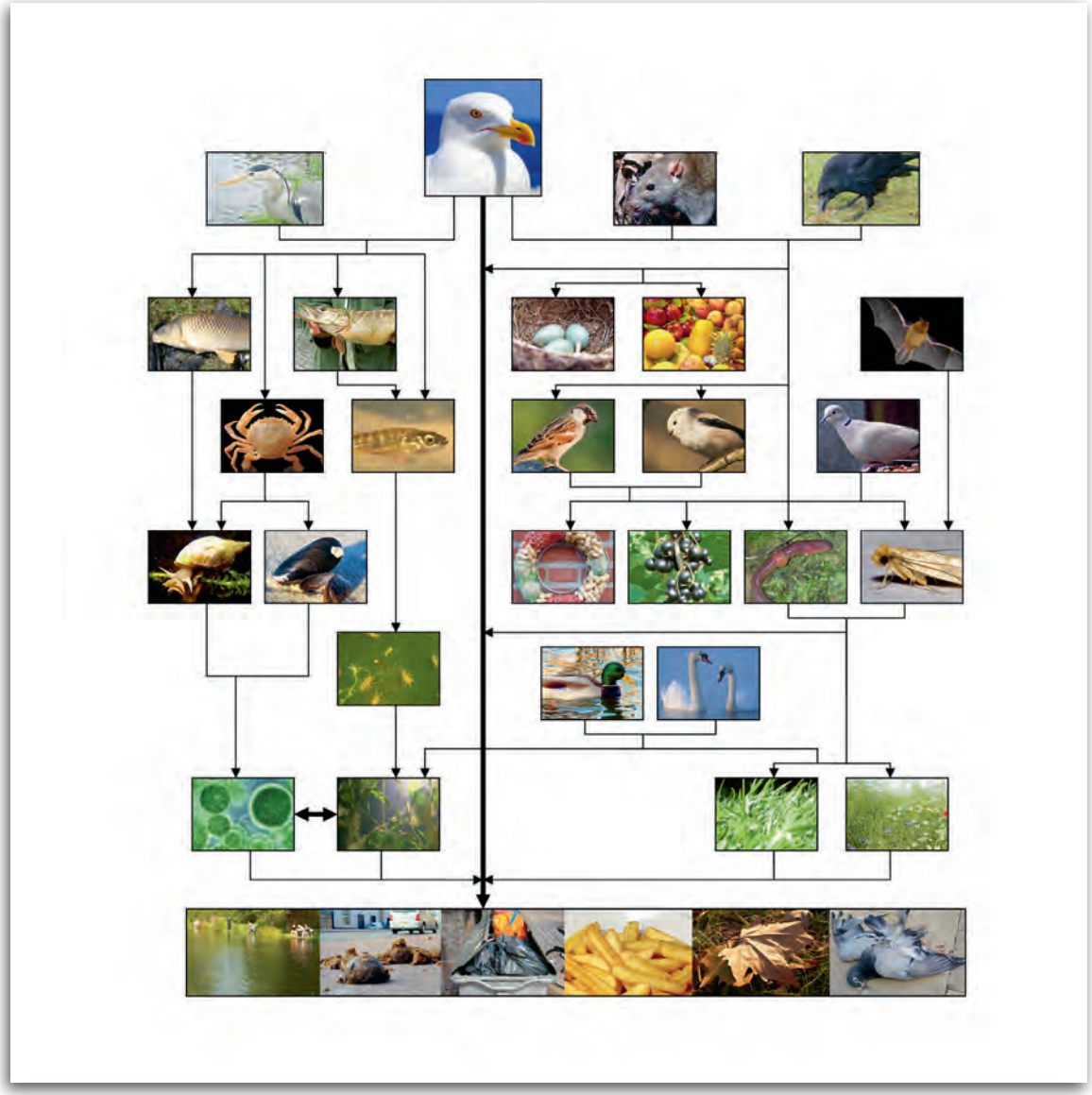
IV. By using arrows, indicate who eats what (e.g. how nutrients flow from the ground into a plant). If an owl eats a mouse, the arrow goes from the owl to the mouse.

V. Identify inorganic energy streams, for example solar energy into plants, or thermal columns used by flying birds, or body-heat used by mice to warm each other.

VI. Identify material or energy flows that may support the function of your product, or that your product may support to strengthen the local ecology.

Example

For the design of a play item with a positive impact for the city of Rotterdam, cradle to cradle specialist Bram van der Grinten mapped the Local Ecology in the diagram below. The target location, a park alongside the river, was a barren, windy place with seagulls and pigeons feeding on garbage and fast-food. He formulated the design goal to attract more songbirds. The Local Ecology tool gave him the insight that birds are attracted by insects, who thrive in wild grasses, which in turn grow best in soft-banks, which need plenty of clean water. The final design is a play item dubbed Fitness Fountain, which pumps river water onto the banks, so that grasses can get a better foothold, so that more insects can feed and live there, attracting birds and in turn the people of Rotterdam.



Credit: Bram van der Grinten.

SYMBIOSIS

- Stakeholder Network

Identify and involve the right people to develop an industrial symbiosis.

I. Identify stakeholders

II. Determine needs and wishes

III. Map stakeholders

IV. Select stakeholder(s)

Developing a new product is something you do together with many different people. Many people will need to be convinced of the value of your plans. You might have a manager that should allow you and your colleagues to spend time on the project. He or she has to sell the choices to the CEO, who again has to convince investors. Outside the company, there are other people who have a stake in the product: legislators and (local) authorities, retail owners, advertising companies, as well as producers and suppliers of the product. There are transporters, distributors, consumer organizations, environmental agencies, industry associations: once you start to think about the issue, it quickly becomes clear that product development projects involve many different people. For all of them there is something at stake, such as money or quality of life. In other words, they are all stakeholders in your project.

Every new project involves many stakeholders. Particularly in NID, your objective is to seek alliances with strategic partners, like in the symbioses of natural ecologies. How can you determine which people, companies, organisms and institutions (in one word: actors) are involved, what is at stake for them, and how they can achieve what they want? Even more importantly: how can you tell which ones matter most and must be involved at any cost, and conversely, which ones you can quite safely ignore?

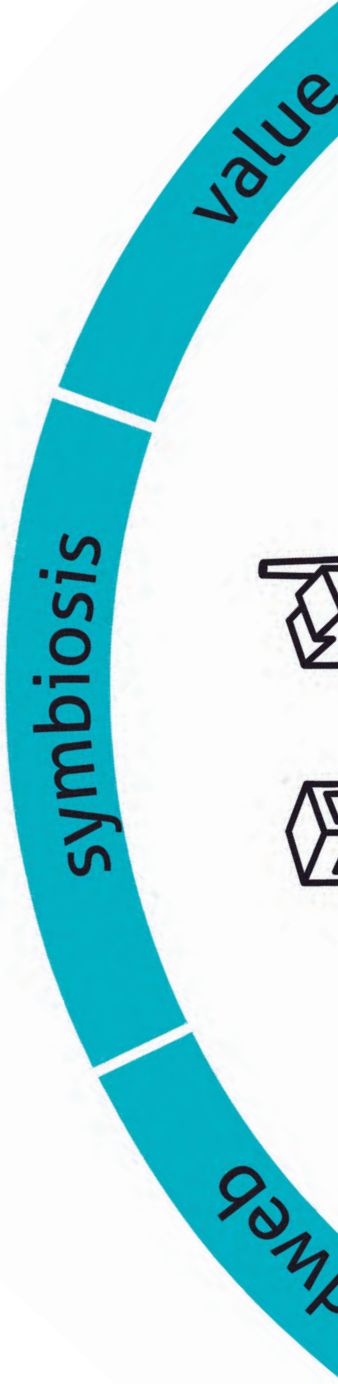
Stakeholder Network is an easy schematic to help identify all relevant players (companies, organizations, people etc.) in a product development project and sort them by power/interest level. Thereby you can manage that only those who matter most are directly involved and that those who are not as important can be ignored, or simply be involved on a less intensive level. It is recommended to perform such an analysis early on in the project, preferably when the program of requirements is not yet fully fixed.

Timing and linking with NID principles and process

As the Stakeholder Network influences the design goals, this network is developed in the goal definition phase. Doing a Stakeholder Network is good practice in any product development process. In Nature Inspired Design, this activity is linked to the NID principles "Locally attuned and responsive": to make products with positive impacts on specific environments, you need to know what is considered a positive impact by all parties that are exposed to the product. For NID, organisms in the local ecology of the product are as important as the user of the product. This is where Stakeholder Network connects with the Surroundings Scan, the Use Lifecycle Benefits and Local Ecology tools.

Steps in Stakeholder Network

Stakeholder Network is an established tool in the world of business. A good source for details (and the one we use here as the main reference) is "Exploring Corporate Strategy" by Johnson, Scholes and Whittington (2008). But the tool is really quite simple and easily summarized: in Step 1, you identify the stakeholders, in Step 2, you determine what they need and want, in Step 3, you map them in a two-by-two matrix, and in Step 4, you use this matrix to select the ones you will address during your project, and determine how to 'deal' with them.



Steps of the tool

I. Identify stakeholders

We assume you are working for a company that plans to develop a new product and market. Some of the stakeholders in this project are easy to identify, such as the prospective clients, suppliers, retailers and distributors. Others can be easy to miss. Here are some suggestions (not exhaustive):

- Your competitors, developing and selling comparable products
- Companies making products that can be used together with the one you are developing
- Organisms in the direct environment of your product
- The government (on all its levels: local, regional, national and international)
- The various bureaus and organizations issuing relevant product standards
- Branch organizations of companies making or selling similar products
- Consumer interest groups (e.g. Consumentenbond or the BBC program Watchdog)
- Insurance companies (i.e. who insure against costs arising from product accidents or misuse)
- Environmental protection agencies (warning: there will be more than you think, ranging from Greenpeace to local 'save the geese' foundation)
- Academic institutions interested in how your product is developed, sold and used
- Direct users of the product
- Indirect users, i.e. family, colleagues
- Your staff
- Staff of the suppliers, logistic company, waste manager etc.

Important advice: in companies larger than around 100 people, always treat different departments, such as marketing, product development, etc., as separate stakeholders. Although all cooperate with the interests of the company at heart, practical experience shows that in reality their needs and wants are often quite different. Similarly, you are advised to differentiate between the various levels of government (e.g. national, regional and local).

To structure the 'long list', sort the stakeholders into (1) companies and other profit-driven entities, (2) NGO's (non-governmental and not for profit organizations), (3) governments, and (4) people, either individuals or collectives. Furthermore, we recommend you use a spreadsheet program to document your analysis.

II. Determine needs and wishes

Once you have the long list, it is time to find out what your stakeholders need and want. Based on prior experience, existing contacts and common sense, you can usually take a good guess or consult some public source (e.g. annual reports, mission statements on websites etc.), and it works best to actually talk to a stakeholder's representative too. So, get on the phone and start calling. Here's a tip: particularly in larger organizations, the spokesperson you find may not be entirely happy with the line that his or her organization is taking. A good approach is to first ask for the 'official position', then follow up by asking something like "how do you think your organization's views will evolve in the near future, with respect to our product?" If you're a good listener, such diplomatically-phrased open questions can bring you a wealth of knowledge.

It will be a lot of desk work, but you will end up with the full set of needs and wishes. This will already give all kinds of suggestions for other products you could develop, or how to change it for extra success, but we recommend you withhold making such changes until you have finished the full analysis.

III. Map stakeholders

Make a two-by-two matrix with 'power' on one dimension and 'interest' on the other:

- 'Power' refers to how easily a given stakeholder can get what it needs and wants. For instance, if you are market leader or the government, you usually can get your way, but if you are a small environmental lobby group, you are much less in control.

- 'Interest' refers to how much the product matters to a given stakeholder. Will it make a lot of difference to people's lives, to company profit margins, to governmental objectives, and so on? Then the interest level of these stakeholders is high. Conversely, if your product does not make much difference to a given stakeholder, then it will have a low interest level.

Next, make a power/interest map: sort all stakeholders into the four categories of A: high power/high interest, B: high power/low interest, C: low power/high interest and D. low power/low interest (see Figure 1). When in doubt, you can choose to either 'round down' (i.e. putting a stakeholder down as low power unless you are sure this is wrong) or 'round up', as long as you are consistent in your decisions to do so.

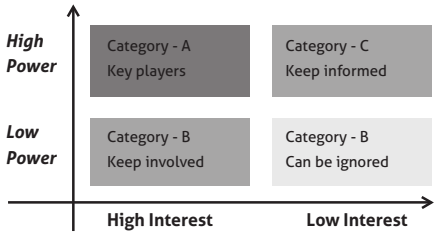


Figure 1 - Power/interest map with four categories of stakeholders

IV. Step 4: select stakeholders

All category-A stakeholders are to be de facto included and actively addressed during your project: they are the key players. Category-B are stakeholders you do not need to actively address, but you could find a low-cost ways to keep them satisfied. Category-C (low power/high interest) stakeholders are just to be informed, and those from category-D you can ignore. Now you see why you better withhold judgment on any suggest on for product change you received during Step 2: if these come from high power-stakeholders (A/B) you should follow up on them, but if they are from low power-stakeholders (C/D) then it is really a case of 'someone else's problem'.

Example

This example illustrates the generic value of stakeholder identification within a design project that co-author Erik Tempelman was involved in.

Not too long ago, the association of Dutch jewellery shops became concerned about the increase in so-called crash-burglaries. In this type of crime, thieves use a heavy car or truck to crash into shop façades, bypassing common anti-theft defences, such as bullet proof glass and reinforced doors.

Wanting to put a stop to this type of burglaries, the association commissioned TNO, The Netherlands Organisation for Applied Scientific Research, to find a of solution. What they had in mind were strong poles sunk into the ground in front of the jewellery shops to block the vehicles (in Dutch: 'anti-ramkraak-paal'). In the assignment, building specialists were also involved, as were representatives of local governments and town planners. The initial assignment: prevent crash-burglaries, no matter what, was complemented with the requirements that the price was right and that the solution was not too intrusive for the street life and traffic.

TNO also involved product designers in the project and they quickly spotted the "question behind the question", leading to the real issue at hand. Their stakeholder analysis brought to light a 'category-A stakeholder' hitherto unnoticed: the jewellery shop insurance companies.

Once a representative from their branch organization was invited, it emerged that the issue was not to block the crash-burglaries per se, but to do so with certifiable performance of whatever the solution would be (poles, fences, etc.), since this certification would allow the insurers to lower their premiums. This eventually led to a very effective solution.

Figure 2- Anti-crash burglary pole (can slide into the ground when not in use)

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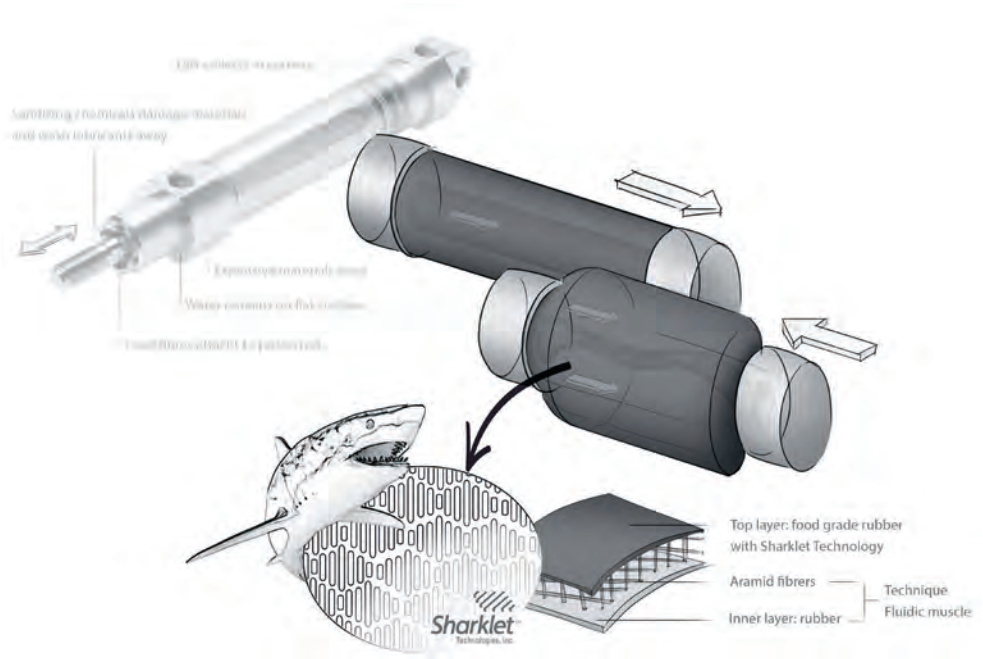
Case 5

- FESTO



Based in Esslingen, Germany, FESTO supplies industrial automation equipment. With an annual turnover of 2.2 B. Euro and 15,500 employees world-wide they classify as a multinational, with an unusually strong outreach towards teaching and education in its working fields of pneumatics, actuation and mechatronics. Through its bionic learning network, FESTO has been pursuing various NID projects since 2006, resulting in stunning technology showcases, such as the dragon fly-inspired 'bionicopter', first shown to the public on the Hannover Messe in 2013.

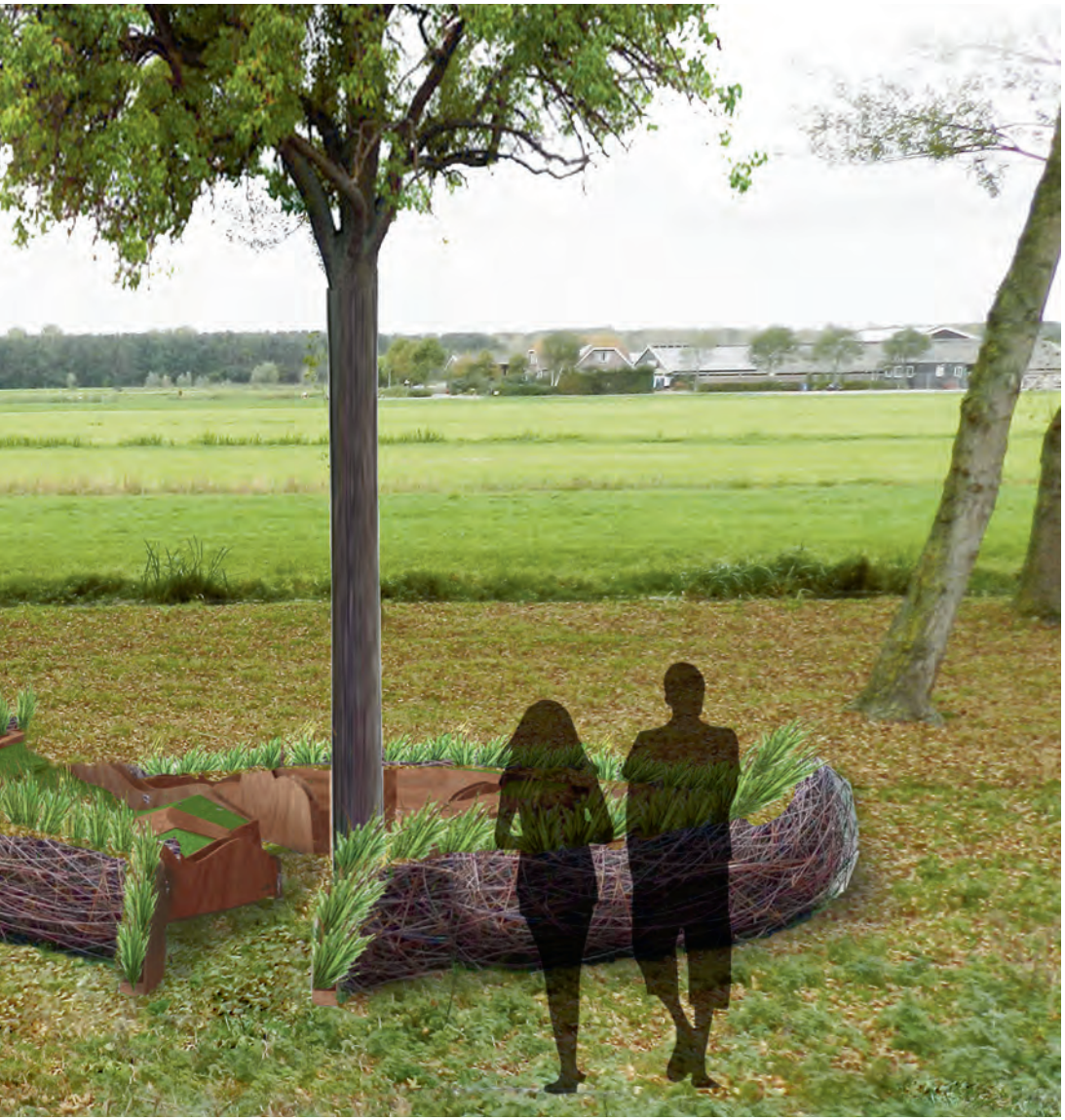
In the NID Project, the Delft branch of FESTO has been involved and has created two NID solutions. One, put forward by TU Delft graduate Dionisos Klavdianos, involved a drone that repels birds at airfields much like how a predator bird scares away birds. This way, bird strikes are avoided without needing to kill any birds (which is sadly how the problem is often solved at airfields today). The drone itself flies on electricity generated with PV panels and is stored in a 'nest' that is built using locally-obtained materials. It receives its target data from a Robin Radar system. Testing is on hold due to the current lack of legislation around drones; however, the potential is there.

FESTO's second NID solution, designed by TU Delft graduate Puck Bos, concerns the hygiene of machines used in food production. FESTO's client build complex machines used for the production of fresh foods. Their moving parts have many nooks and crannies: ideal places for microbes to thrive. To prevent contamination of the fresh foods, machines are now cleaned with harsh chemicals. Puck Bos develops a solution for FESTO's component with the following Intention Statement: Creating an environment that adds value to food during its processing process.

At the moment of writing the project is well under way but not finished. Puck Bos has developed solution directions ranging from shark-skin inspired anti-microbial surfaces, to enhancing the growth of beneficial microbes as a natural detergent against harmful microbes.

STATUS: design concepts

CREDITS: Dionisos Klavdianos, TU Delft Industrial Design Engineering 2013.



Case 6

- Tauw

The Netherlands are well-known for their waterworks. Under Dutch law, such infrastructural projects must go accompanied with 'natural compensation': if you build infrastructure in one place, you must assess the degree of natural damage it does, and realize some form of Nature-enhancement elsewhere along with the project. As a result of this regulation, Dutch infrastructure is increasingly designed to provide not just safety for people, transport conduits of whichever primary functionality in question, but also to minimize ecological drawbacks. For the 'Kampen Bypass', the Tauw company decided to take things to a much higher level by integrating this compensation right into the project. This bypass acts as a high water overflow between the river IJssel and the lakes near the Dutch city of Kampen. Thanks to its fully-natural banks (as opposed to typical 'canal-style' banks) it combines its primary buffer/overflow function with providing high-value real estate, enhancing wildlife and water quality, and even allowing recreational use. This super-large scale NID project is being realized from 2014 onwards and proves that even in these huge designs, an all-round positive impact can be made (see also: www.tauw.nl).

A smaller Tauw project concerns resting shelters for cyclists along bike paths. For such shelters, local trees are routinely felled to provide appealing lines of sight that invite cyclists to stop and enjoy the view – thus (presumably) stimulating cycling. TU Delft graduate Alexandra Izeboud was disappointed to see that trees have to die in order for people to cycle more, and working for Tauw she came up a very different solution. Inspired by the NID principle of being locally-attuned and responsive, Alexandra decided to leave the trees where they are and let them be the view themselves: in her design, the resting cyclists look up into the tree crown, and literally change their perspective. This way, they see something they would otherwise perhaps drive by, and come to appreciate the natural environment along their route even more. Furthermore, the shelter's benches are deliberately shaped to relieve a sore back, making the most of chiropractic advice obtained for this occasion. Alexandra's design is currently being realized by Tauw in the Dutch province of Zuid-Holland.

STATUS: prototype built and tested

CREDITS: Alexandra Izeboud, TU Delft Industrial Design Engineering 2015