Guardian by Nordgreen environmental screening and life cycle study

The Thinking

The concept of watches goes back to the XVI century. Back then, watches were already used as accessories to complement your style. Nowadays, a common behaviour in the fashion industry is to cheaply and rapidly mass-produce pieces that respond to the fast-changing trends. The products are conceived to expire and that comes with huge environmental impacts. This is where Nordgreen aims to take a step forward. We have a long-term vision to change the watch industry from within. Could we be the brand to develop the world's most sustainable watch?

We wanted our flagship product to be a stunning example of the true meaning of Scandinavian design. Guardian is a manifestation of Nordgreen. It is the physical exploration of all the values which lie at the heart of the brand.

The thinking behind Guardian is to extend the life of the watch to the maximum, as much as 100 years. To create a timepiece that withstands the passing of time and the everyday use, with the right maintenance and a responsible use. From an environmental perspective, it is 'the next best thing to not wearing a watch´. The reason behind this goal is to reduce the environmental impact caused by the production of each watch.

As less watches are produces, the extraction of raw material is reduced and, thus, there is less use of natural resources.

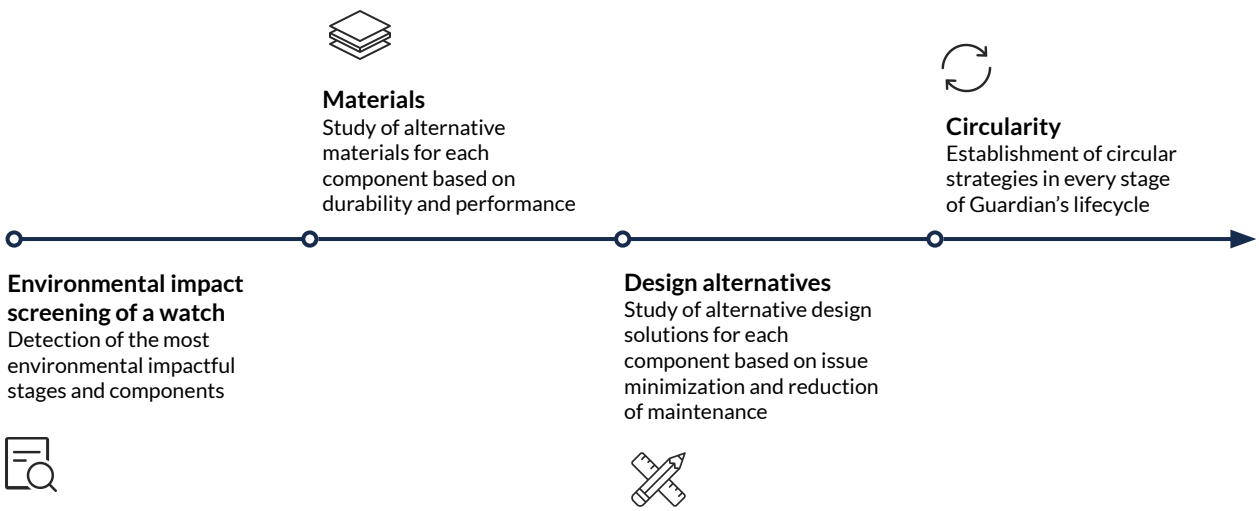
Secondly, operations are minimized. In terms of transportation, consumers will not have the need to purchase a watch after short periods of time meaning less required transport. Emissions are reduced, both in terms of transport and manufacture. And a decrease in energy consumption is produced for extraction of resources, manufacture and storage.

Finally, the end of life of the product is delayed, reducing waste as the disposed of products are reduced.

Together with circularity and sustainability experts, a lifecycle research and development project was conducted. This paper gathers the main phases that took place in the scientific and creative process of Guardian, as shown in Figure 1. The intention of making it available to the public is to offer full transparency to our customers and stakeholders and to share knowledge with the watch industry so we can lead it towards more sustainable practices.

The study started by an environmental screening of a watch to detect the stages of the lifecycle and components of the product that exert the most environmental damage. Guardian is designed to the essential, where every individual element has a distinct role to play. Thus, materials and design alternatives were studied specifically for each component. Then circular strategies were introduced for the complete lifecycle.

Figure 1
Stages of the creation process of Guardian



GUARDIAN

BY NORDGREEN

Strap

Material: 85% recycled SS 316 LN
Design: H-link, butterfly lock

Glass

Material: Sapphire crystal
Design: Flat crystal

Crown

Material: 85% recycled SS 316 LN
Design: T-bar, crown guards, low placement

Dial

Material: Painted Brass

Movement

Miyota Caliber 9039
Design: Automatic Movement

Case back

Material: 85% recycled SS 316 LN
Design: Screw case

Case

Material: 85% recycled SS 316 LN
Design: round, high thickness case

Lock

Material: 85% recycled SS 316 LN
Design: Butterfly lock

The creation process of Guardian

When we conceived Guardian, we knew we wanted a watch that lasted a century and represented our values of respect and responsibility to people and the environment. However, we had to figure out how to translate our vision of the watch into technical and executable specifications. The process that was carried out to achieve the final product design is documented in this section.

Environmental screening of a watch

To be able to design a responsible watch, it is essential to understand first which are the stages of the lifecycle and components of the product that exert the most environmental damage. A life cycle screening based on a Nordgreen watch was performed to identify opportunities for environmental impact reduction and to obtain environmental knowledge about the watch.

The inputs for modeling this assessment come directly from Nordgreen's production and suppliers to guarantee the representativeness of the data.

However, the study presents a number of **limitations**:

1. It has focused on environmental screening, which only considers **environmental impacts in terms of carbon footprint and energy consumption**. Other impacts such as air pollution, acidification or ozone depletion are not included in the results.

2. It is limited to **'Cradle-To-Gate'**. In other words, from resource extraction to factory gate. That means not including stages like transportation which potentially could have a significant impact.

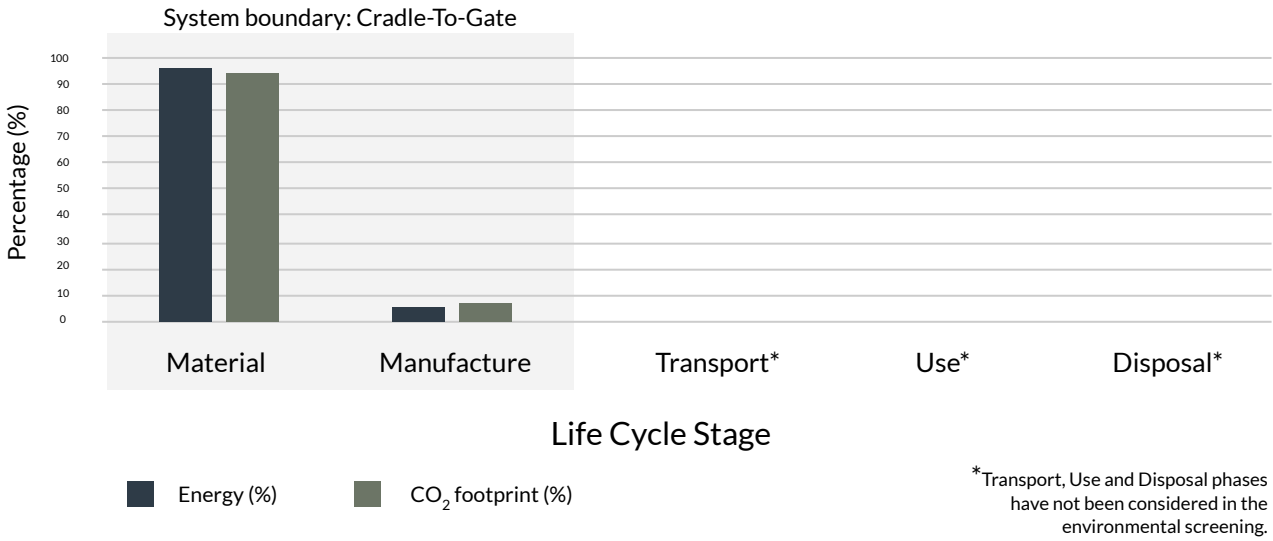
Results

The results show that the **material extraction stage has a more significant impact both in terms of energy consumption and CO_2 footprint** than the manufacturing phase. As it can be seen in Figure 2, it represents 95% of the energy consumption and 92% of the carbon dioxide emissions.

Regarding the parts of the product with a bigger contribution, results in Figure 3 show that the **strap** is the part that consumes the most energy, followed by the cases, the crystal and the dial. On the other hand, in terms of CO_2 footprint, it is in the **case body** production where the most CO_2 is emitted; followed by the strap, the case back, the crystal and the dial.

Figure 2

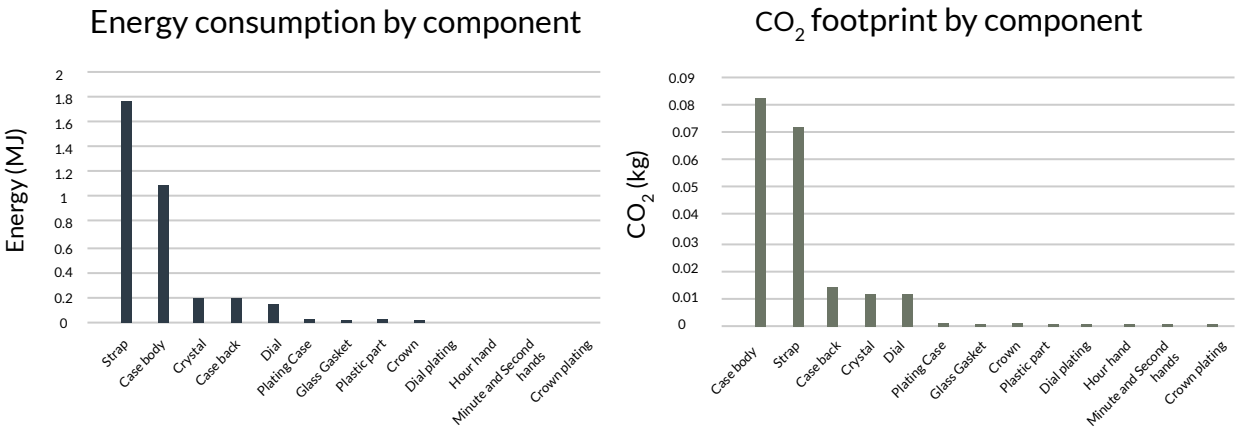
Environmental impact by Life Cycle Stage



*Transport, Use and Disposal phases have not been considered in the environmental screening.

Figure 3

Environmental impact by component



Materials

A responsible use of resources is a key aspect of circular product design and, according to the previously mentioned results, the material extraction is probably the most impactful stage in the life cycle. Thus, a study of alternative materials must be conducted in order to select a sustainable option.

For each critical part, several material alternatives have been assessed according to a number of evaluation criteria. These criteria, aimed to measure the life expectancy and environmental impact, have been specifically chosen for each part depending on their function.

This study presents a number of **limitations**:

1. The life expectancy has been defined by experts in the watch industry and indicate the **lifetime as an interval with some uncertainty** - as it is highly dependent on other factors which are not intrinsic to the material.

2. The **estimations are based on virgin materials**. Hence, uncertainties need to be checked for recycled materials.

Case and case back

Material options

The alternative material options studied for the cases have been the following:

SS 316L without IP	SS 904L + recycled
SS316L recycled	Titanium + recycled
ABS	Azobe wood
Aluminum + recycled	Oceanix rHDPE
Polycarbonate	Bamboo
SS 304L + recycled	

Evaluation criteria

The evaluation criteria to determine the sustainability of the case's materials are the following:

- Environmental impact: **CO_2 footprint, energy consumption**.
- Life expectancy and performance:
  - **Baseline lifetime**. Interval of lifetime given by experts in the watch industry based on their own experience.
  - **Resistance to weak acids**. As the cases are exposed to the exterior, it should resist exposure to weak acids present in daily life scenarios.
  - **Resistance to water.** The case is not only exposed to water but needs to seal the movement so water cannot penetrate the case.
  - **Hardness.** The exterior of the watch is exposed to events such as hits that may occur from daily use, thus the material should be as hard as possible so these events do not cause any scratches in the surface.

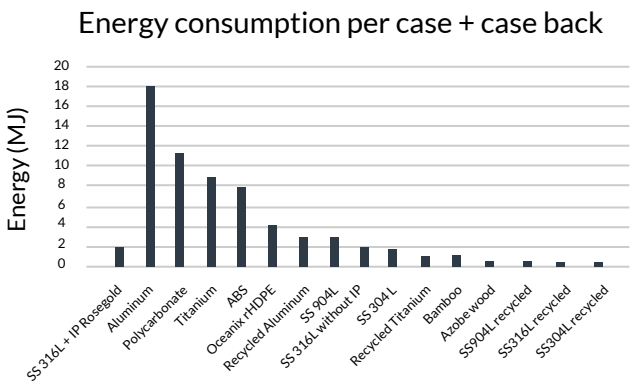
Figure 4

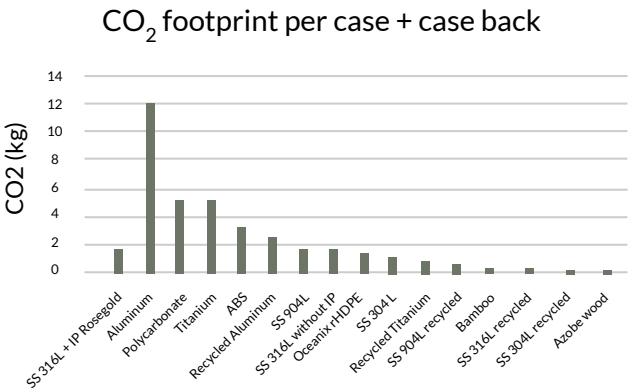
Evaluation of material **alternatives for the cases** according to properties and lifetime.

		Properties				
Material type	**Material composition**	**Resistance to weak acids (pH 4-7)**	**Resistance to water**	**Hardness [HV]**	**Baseline lifetime**	**Units per 100 years**
Natural	Azobe wood	Limited use	Limited use	17.3	3 years	33 units
	Bamboo	Limited use	Limited use	N/A	3 years	33 units
Thermoplastics	Polycarbonate	Excellent	Excellent	19	2 years	50 units
	ABS	Excellent	Excellent	9	2 years	50 units
	Recycled Ocean Plastics (Plastix)	Excellent	Excellent	8	1 year	100 units
Metals	Aluminum 6061, T6	Excellent	Excellent	100	5 years	20 units
	SS316LN	Excellent	Excellent	214	50 years	2 units
	SS304L	Excellent	Excellent	170	50 years	2 units
	SS904L	Excellent	Excellent	148	50 years	2 units
	Titanium, Grade 2	Excellent	Excellent	155	50 years	2 units

Figure 5

Evaluation of material **alternatives for the cases** according to impact





Results

The results in Figure 4 show that the best choice to build the case in terms of durability are metals. SS 316LN presents the best balance between durability and hardness, while thermoplastic and wood parts have significantly lower hardness.

Focusing on the environmental impact of metals shown in Figure 5, recycled stainless steel (SS 316LN) has the lowest impact in terms of both energy consumption and CO_2 footprint.

In conclusion, recycled stainless steel performs the best in terms of durability and environmental impact and thus, it has been selected as the material for the cases.

Decision

Recycled SS 316L. Guardian is produced with the most sustainable stainless steel in the world, provided by the leading world producer of this material, Outokumpu, who also has a commitment with sustainability. According to ISO 14021, the material supplied has a steel recycled content rate of at least 85%, the highest rate that could be found in the market.

Dial

Material options

The alternative material options studied for the dial have been the following:

Recycled brass
SS316L + Recycled
ABS
Aluminum + Recycled
SS 304L + Recycled
Bamboo

SS 904L + Recycled
Titanium + Recycled
Azobe wood
Oceanix rHDPE
Polycarbonate

Evaluation criteria

The evaluation criteria to determine the sustainability of the dial materials are the following:

- Environmental impact: **CO_2 footprint, energy consumption**.
- Life expectancy and performance:
  - **Baseline lifetime**. Interval of lifetime given by experts in the watch industry based on their own experience.
  - **Durability for UV radiation.** Resistance to UV radiation is relevant to evaluate color degradation over time due to sunlight.
  - **Resistance to water**. Might not be relevant as the dial is sealed, however the material is evaluated if potential leak in the watch.
  - **Plasticity.** The dial is one of the elements of the watch that more post processing requires, to be customized to the design demands. Thus, the material should preferably have the capability to receive well the most common processes such as plastic deformation or painting.
  - **Hardness.** Might not be relevant as the dial is sealed, however the material is evaluated if potential breakage of the glass or case.

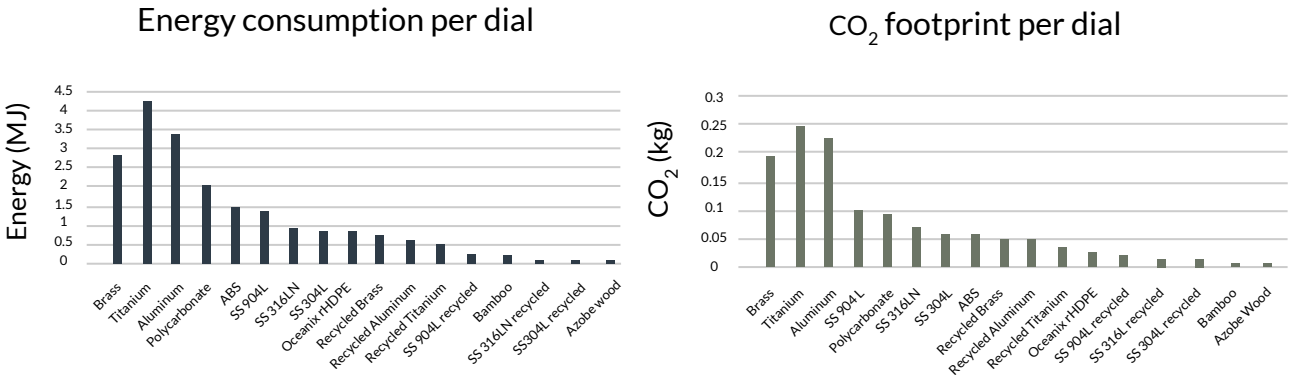
Figure 6

Evaluation of material **alternatives for the dial** according to properties and lifetime.

		Properties					
Material type	**Material composition**	**UV Radiation**	**Resistance to water**	**Yield Strength [MPa]**	**Hardness [HV]**	**Baseline lifetime**	**Units per 100 years**
Natural	Azobe wood	Good	Limited use	N/A	17.3	3 years	33 units
	Bamboo	Good	Limited use	50	N/A	3 years	33 units
Thermoplastics	Polycarbonate	Fair	Excellent	64	19	2 years	50 units
	ABS	Fair	Excellent	45	9	2 years	50 units
	Recycled Ocean Plastics (OceanIX)	Excellent	Excellent	13	8	1 year	100 units
Metals	Aluminum 6061, T6	Excellent	Excellent	276	100	5 years	20 units
	Brass, CuZn33, C26800	Excellent	Excellent	97	64	5 years	20 units
	SS316LN	Excellent	Excellent	245	214	50 years	2 units
	SS304L	Excellent	Excellent	210	170	50 years	2 units
	SS904L	Excellent	Excellent	220	148	50 years	2 units
	Titanium, Grade 2	Excellent	Excellent	140	155	50 years	2 units

Figure 7

Evaluation of material **alternatives for the dial** according to properties and lifetime.



Results
As it can be seen in Figure 6, most materials perform excellently to resist UV radiation (sunlight) except plastics and wood. Regarding plasticity, plastics and wood have the lowest yield strength, while brass is the easier metal to deform. Wood, recycled stainless steel and ocean plastics perform the best in terms of carbon footprint and, in relation to energy, wood, recycled stainless steel and other recycled metals have the smallest consumption, as shown in Figure 7.

The dial is however a part that must be sealed from the exterior and thus, the life expectancy of the material can be extended. Based on the material properties and ease to be customized, the selected material is Brass.

Decision
Painted Brass.

Glass

Material options

The alternative material options studied for the glass have been the following:

Mineral Glass Sapphire crystal

Evaluation criteria
The evaluation criteria to determine the sustainability of the glass are the following:

- Environmental impact: **CO_2 footprint, energy consumption**.
- Life expectancy and performance:
    - **Baseline lifetime**. Interval of lifetime given by experts in the watch industry based on their own experience.
    - **Fracture toughness.** Property which describes the ability of a material containing a crack to resist further fracture.
    - **Hardness.** The exterior of the watch is exposed to external events such as hits that may occur from daily use, thus the material should be as hard as possible so these events do not cause any scratches in the surface.

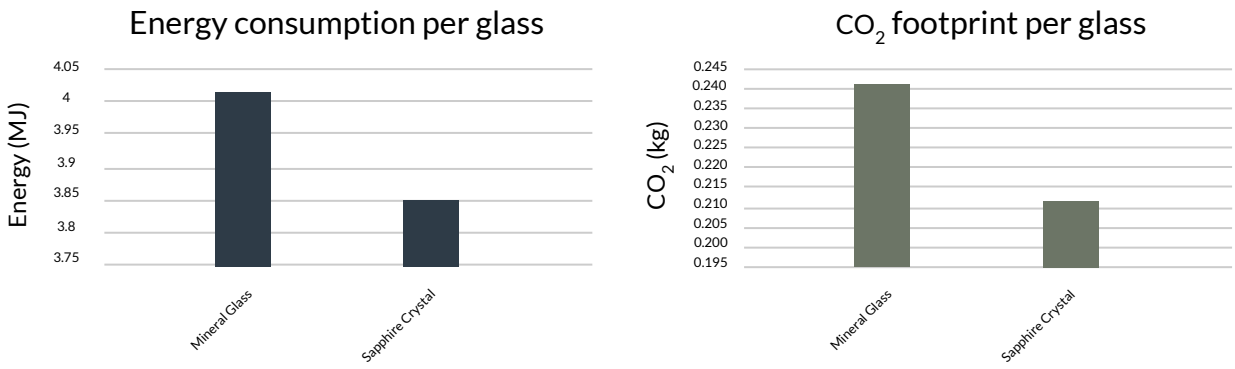
Figure 8

Evaluation of material **alternatives for the glass** according to properties and lifetime.

		Properties			
Material type	**Material composition**	**Fracture Toughness**	**Hardness [HV]**	**Baseline lifetime**	**Units per 100 years**
Glass	Mineral Glass	0.6	952	2 years	50 units
	Sapphire Crystal	1	2500	5 years	20 units

Figure 9

Evaluation of material **alternatives for the glass** according to impact.



Results

The results in Figure 8 show that sapphire crystal is significantly better at resisting scratches and fracture than silica (mineral glass). They also indicate that not only it has better mechanical properties but also requires less units over 100 years. On top of that, it provides significantly better environmental performance (Figure 9). For these reasons, sapphire crystal has been the selected material for Guardian.

Decision

Sapphire crystal.

Strap

Material options

The alternative material options studied for the strap have been the following:

Leather	Polyurethane rubber
SS316L + recycled	Oceanix rHDPE
SS304L + recycled	Natural rubber
SS904L + recycled	SB Rubber
Aluminum + recycled	ABS
Titanium + recycled	Polycarbonate
Azobe wood	Wool fiber
Bamboo	

Evaluation criteria

The evaluation criteria to determine the sustainability of the case materials are the following:

- Environmental impact: **CO_2 footprint, energy consumption**.
- Life expectancy:
    - **Baseline lifetime**. Interval of lifetime given by experts in the watch industry based on their own experience.
    - **Resistance to weak acids**. As the strap is exposed to the exterior, it should resist exposure to weak acids present in daily life scenarios.
    - **Resistance to water.** The strap is directly exposed to water and thus, should resist without deterioration
    - **Young's modulus.** The elasticity of the strap is important because a more elastic material deforms more and is more comfortable to wear than a stiff material. The elasticity and comfortability also depends largely on the design of the straps – the parameters are based on solid pieces of materials.
    - **Tensile strength.** The strap needs to support load without fracture while being stretched. Again the overall performance depends largely on the design of the straps, but in this analysis the parameters are based on solid pieces of materials.

Results

Most of the materials perform excellently in terms of resistance to water corrosion except leather, wool, wood. Rubbers and leather are more elastic (more comfortable to wear) while metals are harder to deform/rigid (more stiff and uncomfortable to wear). But elasticity and comfortability depends largely on the design of the straps. Regarding impact, recycled metals and woods perform better.

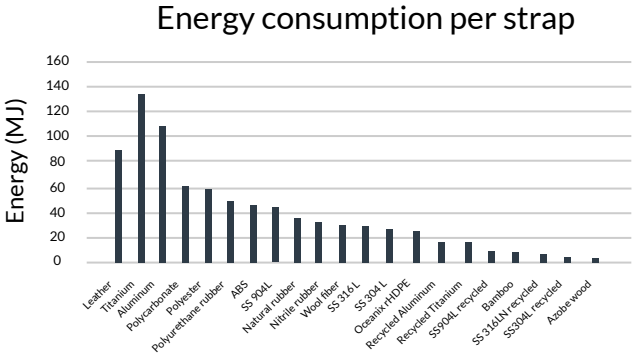
Figure 10

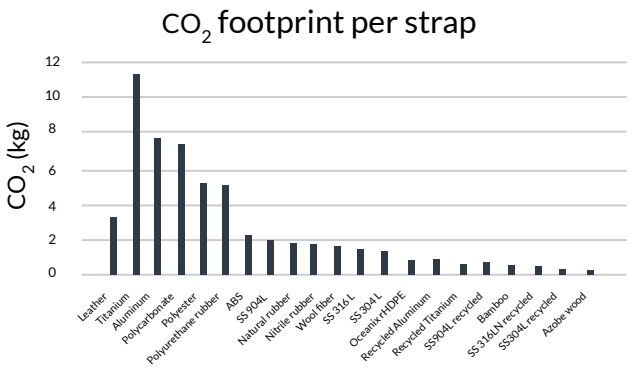
Evaluation of material **alternatives for the strap** according to properties and lifetime.

		Properties					
Material type	**Material composition**	**Resistance to weak acids**	**Resistance to water**	**Young's modulus [GPa]**	**Tensile strength [MPa]**	**Baseline lifetime**	**Units per 100 years**
Natural	Leather	Limited use	Acceptable	0.1	20	1 years	100 units
	Wool	Acceptable	Acceptable	2.3	50	2 years	50 units
	Azobe wood	Limited use	Limited use	18.1	165	3 years	33 units
	Bamboo	Limited use	Limited use	1.5	2	3 years	33 units
Elastomers	Natural rubber	Acceptable	Excellent	0.0012	21	2 years	50 units
	Nitrile rubber	Acceptable	Excellent	0.0018	4	2 years	50 units
	PE rubber	Limited use	Excellent	0.0025	40	2 years	50 units
Thermoplastics	Polyester	Acceptable	Excellent	3	573	2 years	50 units
	Polycarbonate	Excellent	Excellent	2.21	57.2	2 years	50 units
	ABS	Excellent	Excellent	2	30	2 years	50 units
	Recycled Ocean Plastics (OceanIX)	Excellent	Excellent	1.07	26	1 year	100 units
Metals	Aluminum 6061, T6	Excellent	Excellent	66.6	290	5 years	20 units
	SS316LN	Excellent	Excellent	195	580	20 years	5 units
	SS304L	Excellent	Excellent	191	485	20 years	5 units
	SS904L	Excellent	Excellent	191	575	20 years	5 units
	Titanium, Grade 2	Excellent	Excellent	100	345	20 years	5 units

Figure 11

Evaluation of material **alternatives for the strap** according to impact.





Decision

Recycled SS 316L. Guardian ia produced with the most sustainable stainless steel in the world provided by the leading world producer of this material, Outokumpu, who is engaged with moving society to sustainable solutions.

According to ISO 14021, the material supplied has a steel recycled content rate of at least 85%, the highest rate that could be found in the market.

Design choices

In addition to the selection of materials, design decisions for each component are essential for the achievement of a watch that meets the specifications and lives up to Nordgreen's vision and mission. The process followed to achieve an optimal balance between these two factors is mentioned below:

1. Definition of requirements: the requirements that the component must attend to when selecting the solution.
2. Definition of components: the main parts of the watch have been analyzed for deciding on the final solution.
3. Definition of typical issues: causes of damage or failure that the component can experience due to use and maintenance aspects.
4. Definition of alternative design solutions for each of the components.
5. Evaluation of design alternatives: the determined evaluation criteria are the compliance of the requirements and mitigation or prevention of the critical errors.
6. Final decision

The full process from identification of errors to the design decision has been carried out in collaboration with experts from the Product Development and Manufacturing team of Owago, manufacturer of Guardian. The following insights are extracted from the conducted interviews.

Requirements

"A watch designed to last for 100 years"
The "Nordic" and "green" identity inclines the brand to create useful and long-lasting solutions. Guardian is designed for a lifetime of 100 years which, from an environmental perspective, is "the next best thing to not wearing a watch".

"Respect and responsibility for people and the planet"
Guardian opts for a battery free power supply. Corrosion of these elements leads to the emission of chemicals, which reach the water supply causing potential toxic risks for the aquatic and terrestrial ecosystems.

"10 ATM water resistance"
Guardian should be able to withstand the pressure equivalent to 10 times the pressure at sea level over a prolonged period of time without suffering water damage.

Components

Movement

Typical issues

The typical issues for the movement are the following:

1. **Oiling:** the correct amount of oil should be applied for the movement, or else it can dry out or suffer from excess of oil. On the other hand using the wrong oil can also damage the mechanism.
2. **Impacts on the crown:** the crown is directly linked to the mechanism for which an external impact on the crown could be transferred to the mechanism and damage it.

Maintenance: mechanisms need a service check every five years to prolong its lifetime, adjust the time and adjust the oil levels.

Design alternatives

The following are the options considered for Guardian's movement:

1. Automatic winding
2. Manual winding

Evaluation of design alternatives

The alternatives for the movement are evaluated according to the determined evaluation criteria:

1. **Automatic winding:** the mechanism is winded with its use, it does not require a battery.
2. **Manual winding:** requires no battery, but must be manually winded every day. The constant winding can cause the sealing between crown and movement to wear prematurely.

Decision

An automatic movement, particularly the Miyota Caliber 9039 movement, is the final solution, being respectful to the environment using no batteries as power supply. It offers a higher user satisfaction, as the consumer does not have to worry about winding the watch, and less maintenance, as the sealing is more reliable. With proper maintenance the life expectancy of the mechanism can last 100 years. Particularly, the Miyota Caliber 9039 is a very new movement, introduced to the market in 2018, requiring less oiling and, thus, less frequent maintenance than other movements. In addition, a good choice in the design of the crown will decrease the vulnerability of the mechanism.

Glass

Typical issues

The typical issues for the glass are the following:

1. **Scratches and rupture**: The glass is one of the most exposed components of a watch. It can suffer different kinds of impacts due to the high exposure in daily life use, leading to generation of superficial scratches and ultimately shattering. As defined in Figure 8 and Figure 9, the selected material for the glass is Sapphire. Due to the hardness and fracture toughness of this material the possibility of scratches diminishes and fracture is almost none. There is a dependency between the life expectancy of the glass and the consumer's use of the product.

Maintenance: The generated scratches can be sanded down, however this can be an expensive process for which changing the glass completely can be a better option.

Design alternatives

The following are the candidate sapphire crystal geometries for Guardian:

1. Flat crystal
2. Double domed crystal
3. Single domed crystal

Evaluation of design alternatives

The alternatives for the glass are evaluated according to the determined evaluation criteria:

1. **Flat crystal**: leveled to the surface of the case of the watch, providing protection.
2. **Double domed crystal**: higher exposure to external incidents due to its geometrical characteristics. It is curved on both sides of the glass, meaning its highest point surpasses the edge of the case.
3. **Single domed crystal**: higher exposure to external incidents due to its geometrical characteristics. It is curved on both sides of the glass, meaning its highest point surpasses the edge of the case.

Decision

The decided geometry for the glass is Flat crystal. As the occurrence of scratches and breaks minimizes the lifetime of the product is extended. Flat crystal is the best solution to achieve a watch that can live 100 years.

Besides the benefits of the geometry per se, a good care of the watch by the consumer would extend the life of the component more than 10-20 years.

Crown

Typical issues

The typical issues for the crown are the following:

1. **Looseness**: the external location of the component increases its vulnerability. An extended use of the watch increases the occurrence of external impacts. This can cause the crown to lose tightness.
2. **Deformation or partial rupture**: the external impacts to the crown can cause it to get deformed or break partially.
3. **Damage in the mechanism:** the crown is a link between the exterior and interior of the watch. The potential external impacts on the crown can damage the mechanism.
4. **Detachment from the watch**: the crown can be impacted and experience deformation or rupture which can lead to it detaching from the watch.

Maintenance: In case of rupture, the crown would need to be changed for a new piece.

Design alternatives

The following are the considered types of crown for Guardian:

1. Screw crown
2. T-bar crown
3. Glued crown

In combination with the type of crown, there are different parameters that can be regarded in order to increase protection and minimize the critical events of rupture:

1. Location of the crown on the case
2. Crown guards

Evaluation of design alternatives

The alternatives for the crown are evaluated according to the determined evaluation criteria:

1. **Screw crown**: the best option for a crown, however to comply with the battery free requirement of Guardian, it must be discarded. Screw crowns are not an option for automatic watches.
2. **T- bar crown**: The crown is attached to the mechanism through a T-shaped link, providing more reliability on the steadiness of the crown.
3. **Glued crown**: It is the most unsteady option as the glue can come apart from an external impact or by natural effects, causing the crown to detach from the mechanism.

Regarding the protection parameters:

1. **Location of the crown on the case**: placing the crown at the glass level exposes the component to possible damages from external actions. The furthest the crown is from the glass surface level the higher protection the crown has.
2. **Crown guards**: the use of crown guards decreases the potential external impact received by the crown. The absence of guards increases the vulnerability of the crown to damage.

Decision

The final decision is a T-bar crown, for its compatibility with the design decision for the movement, an automatic watch, and the assurance of a long lifetime, through a mechanical link instead of an adhesive one. To increase the life expectancy the two protection factors have been considered, choosing a low placement for the crown on the case and to include crown guards.

Strap

The exploration of alternatives of this component has been narrowed down to link bracelets as there is a specification of Recycled SS 316L as the selected material. All critical points and design options are based on link bracelets only.
The strap consists of two parts, the links and the lock.

Typical issues

The typical issues for the link bracelets are the following:

1. **Looseness and break**: the screws and links can lose tightness over the use of the watch, leading to the rupture of the link bracelets.
2. **Abrasion of the lock**: the lock of the strap is vulnerable to abrasion due to the undesirable effect of friction from the use of the piece.

Maintenance: A service check is needed every five years to prolong the lifetime of the product and evaluate the state of screws and links. The service consists of an ultrasonic cleaning and tightening of links.

Design alternatives

The following are the considered alternatives for the link bracelet and the lock:

Links

1. H-link
2. 3 link
3. 5 link

Lock

1. Diver lock
2. Butterfly lock

Evaluation of design alternatives

The alternatives for the movement are evaluated according to the determined evaluation criteria:

The number of links is directly dependent on their vulnerability to looseness or rupture.

1. **H-link:** it is considered to be the best link. It has a low amount of links due to their particular geometry in H shape.
2. **3 link**
3. **5 link**

Lock

1. **Diver lock:** with safety clasp can be tightened by pressing on the side if it becomes loose.
2. **Butterfly lock:** more vulnerable with many small parts.

Decision

The H-link bracelet is the final decision for its high life expectancy. A correct use and maintenance of the strap together with its optimal characteristics will extend the durability of the component.

Case

Typical issues
The typical issues for the case are the following:

1. **Scratches and dents**: these can appear from use, from external impacts.
2. **Looseness of the gasket**: the gasket that seals the case and the case back can loosen and affect water resistance.

Maintenance: In order to extend the lifetime of the watch, the case must have a service check every five years. The gasket must be exchanged to assure good performance over the extended life of the product. And the scratches can be sanded off.

Design alternatives
For the case, different parameters have been considered, for which there are different alternatives under each of the following categories:

1. Thickness of the case
2. Ease of surface treatment

Evaluation of design alternatives
The alternatives for the movement are evaluated according to the determined evaluation criteria:

1. **Thickness of the case**: there is a direct relationship between thickness and strength.
2. **Ease of surface treatment**: the geometry of the case can ease the polishing and refurbishing of the component.

Decision
A round case, without nooks, to ease maintenance and refurbishment. A case in the higher end of thickness for better sturdiness and toughness. Together with a responsible use of the product by the user, the case can meet the goal of lasting 100 years.

Case back

Typical issues
The typical issues for the case back are the following:

1. **Looseness**: the component can experience loss of tightness due to:
    a. external impact
    b. looseness of screws; in the case that there are.

    This compromises the water resistance of the watch.
2. **Scratches and dents**: these can appear from use, from external impacts.

Design alternatives
The following are the considered alternatives for the case back:

1. Screw case
2. Case with screws
3. Clickback box

Evaluation of design alternatives
The alternatives for the case back are evaluated according to the determined evaluation criteria:

1. **Screw case**: this case back allows a maximum of 10 ATM.
2. **Case with screws**: having a screwed case back allows a much tighter seal than a clickback box. However, the screws can be loosened with time and use increasing one of the critical points mentioned before.
3. **Clickback box**: the sealing of a clickback box is limited compared to the other options, it allows maximum 5 ATM.

Decision
The decided case back is a screw case, avoiding screws which ensures a good seal and an extended lifetime. A responsible use from the customer's side will also increase its life expectancy. Lastly, it meets the requirement of 10 ATM water resistance.

Circularity

Circularity means that a product is designed keeping in mind its whole lifecycle, so when it reaches the end of its life it can be introduced into the supply chain again in some way. In the core of Nordgreen, and especially with Guardian, they aim to create a product that is not disposed of or replaced after every season. Thus, apart from the decisions on the product design, there are others to be made throughout the complete lifecycle, leading towards their goal of becoming carbon neutral.

Responsible suppliers

Every component of Guardian comes from a responsible supplier that has signed Nordgreen's Code of Conduct and Banned Chemical Declaration and that is ready to offer full transparency in its actions.

Code of Conduct

The standards of the Code of Conduct are based on internationally agreed conventions, including but not limited to: the International Bill of Human Rights, the International Labour Organisation's (ILO) Declaration of the Fundamental Principles and Rights at Work, the UN Guiding Principles on Business and Human Rights, the OECD Guidelines for Multinational Enterprises, the OECD Due Diligence Guidance for Responsible Business Conduct, the UN Convention Against Corruption, the Rio Declaration on Environment and Development; and the UN Global Compact's 10 Principles.

The standards constitute minimum requirements that all suppliers must meet and are based on above listed international standards. They focus on four areas:

1. **Human and labor rights**
2. **Environment and climate**
3. **Anti-corruption**
4. **Animal welfare**

All suppliers are expected to comply with national legislation, regulations, and applicable practices and industry standards as relevant to their business.

Ban of substances Declaration

The Cradle to Cradle Certified Product Supplier Banned Chemical Declaration contains a list of chemicals and substances selected for their tendency of accumulation in the biosphere and irreversible negative effects in the human health. There are two cycles, biological and technical. The listed chemicals are banned for Biological Nutrients but may be allowable in managed technical cycles.

By signing the declaration, suppliers provide transparency of the chemicals intentionally added to the homogeneous material and/or whether they are contaminants.

Stainless Steel

Guardian is produced with the most sustainable stainless steel in the world provided by the leading world producer of this material, Outokumpu, who has a commitment with moving society to sustainable solutions.

Manufacture

Watches are produced in OWAGO's facilities in Shenzen, where Danish partners ensure the accomplishment of the highest standards while following Danish labor practices.

Packaging

The packaging of Guardian lives up to the values of the watch, without compromising its uniqueness and premium quality. It is a 3D printed box, using recycled PLA in a specially developed filament. LostBuysLab is a cutting edge 3D print expert based in Malmo whose vision aligns with Nordgreen's. They practice circular design using biological or recycled materials, reducing transportation and manufacturing on demand from only online orders.

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Supply chain

An effective and sustainable strategy throughout the supply chain should be a balance between an efficient service to ensure consumer satisfaction and decisions that are responsible for the environment. Finding that balance can be challenging. Nordgreen has searched for accomplishing this in an optimal way.

Shipping

Nordgreen aims to minimize their environmental footprint regarding the transportation of their products. The design decisions of Guardian and its complete supply chain compromise the environmental choices. As the packaging is ordered on demand a considerable amount of deliveries must be shipped via air to ensure customer satisfaction. The carbon footprint of all transportation of Guardian, as all other Nordgreen products, is offset completely. However, Nordgreen works towards finding even more sustainable solutions for the future.

In 2021 728 tonnes CO2e2 were emitted via shipments (delivery and returns), which is an average of 8.1 kg CO2e2 for each package. These shipments include sea, air and land freight. This data can serve as a forecast of the scenario for Guardian.

The following are the phases in the products supply chain in which transportation is involved:

1. Assembled product to storage: the assembled Guardian is shipped from Hong Kong by sea and land to the warehouse in Denmark.
2. Packaging: the packaging is transported from Sweden to Denmark in electric vehicles.
3. Final product to delivery destination: the final product is shipped through air or land to the clients location, depending on the delivery market. Shipments to the US and Asia are made via air, while shipments inside the EU are made via land or sea. In specific cases, department stores collect their orders at the warehouse in Denmark. It is beyond Nordgreen's reach what means of transportation they choose for their shipment.
4. Product return: the same means of transportation are used in the return of the product from the users location to the warehouse in Denmark.

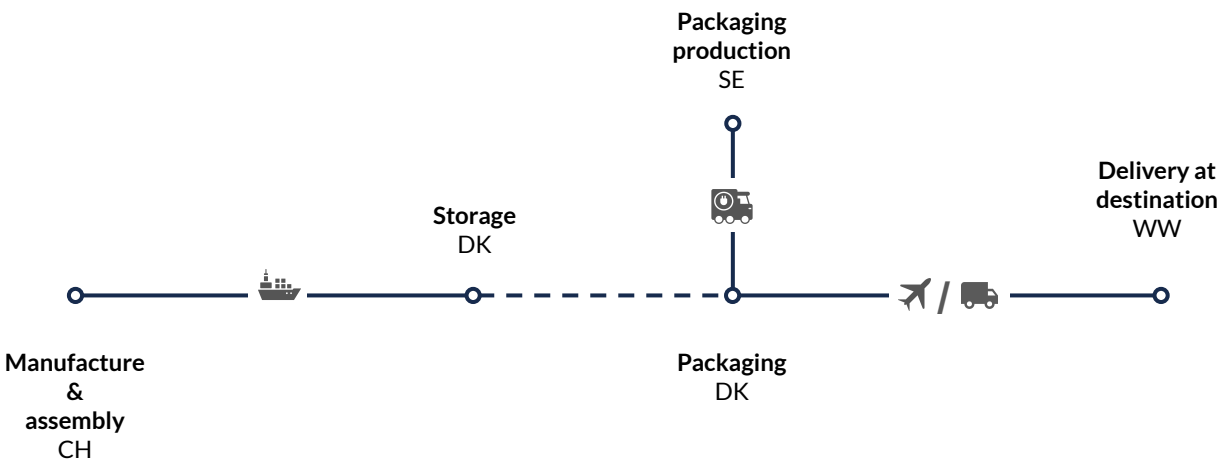
Figure 12 shows an overview of the supply chain from manufacture to delivery, including country and mean of transport.

Nordgreen works with responsible shipping companies for all transports of the product throughout the complete lifetime. Besides, express shipments are not allowed for Guardian when sea or land freight are possible.

Nordgreen has partnered with The Carbon Funds, an organization engaged in carbon reduction projects. Guardians carbon footprint will be offset by supporting several of their projects in one of the three areas: renewable energy, energy efficiency or forestry.

Figure 12

Overview of the supply chain of Guardian: from manufacture to delivery



Shipping packaging

For the shipment of Guardian it is seeked to reduce packaging as much as possible yet ensuring quality. An optimization of size and weight is accomplished.

The packaging is FSC-certified. The cardboard boxes are made out of paper extracted from responsibly managed forests and felt inside, made out of recycled plastic bottles.

- Labeling: Labels are thermal imprinted, no use of ink or plastics and adhesives is required.
- Sealing system: No plastic tape has been used, the sealing is obtained with the use of an adhesive strip in the top side of the box.

Use

Maintenance

Guardian pursues a responsible and respectful planet, both socially and environmentally. The design decisions have been taken regarding the durability of the watch, among other criteria, meaning the maintenance of the components has been minimized when possible. However, a good use of the watch from the consumer and the correct maintenance will extend Guardian's life expectancy.

Guardian will be able to be serviced for maintenance or repair in official watch service centers located in all the available purchase locations of Nordgreen. In this way, the transportation impact is reduced and the closeness to the customer ensured.

Warranty

Guardian is covered by a 100-years warranty which applies to the date of purchase. The right of complaint covers all production defects. It does not cover defects due to negligent or improper use, accidental damage and general wear and tear.

End of use

Buyback program

Guardian introduces a new strategy towards circular economy into Nordgreen: a buyback program that aims to take back to the supply chain as many resources as possible. At the end of the use life of the watch, users have the opportunity to have their Guardians bought back and get a percentage of the original price of the watch refunded. The percentage depends on the status and age of the product (e.g. 18% for a fully functional watch, 10% for a not working but well maintained watch, 7% for a damaged watch). Once the products are received, they are assessed and treated accordingly .

There are two options for the watches' life continuation: refurbishment and recycling.

Refurbishment

The watches that arrive in a fair condition are repaired and polished so that they meet the same high quality requirements as the new watches. Then, they can be purchased online in Nordgreen's refurbished store.

Recycling

In the case that the product is in a condition that prevents it from being refurbished, then the watch will be recycled. This process will be done within a specialist facility located in Europe and following data security, quality and health-and safety-focused certifications, such as NAID, ISO, and OHSAS to maximize the value and minimize the footprint.

Giving back

Guardian will be, as every Nordgreen product, part of the Giving Back program which donates money to a solidarity cause that the customer can choose. Using the serial and identification numbers found with the watch, the users can access and have the unique ability to choose which cause is most important for them and where their donation will go.

Nordgreen is currently working with three different causes: health, environment and education.

Conclusions

What has been done and not done

Guardian's ambition surpasses what has been possible to do until now and we are ready to keep collecting knowledge about our product to optimize it even further.

A life cycle screening of an existing product of our portfolio has been done, but the 'cradle-to-gate' approach only considered raw material extraction and manufacturing phases. Even though efforts have been made on the whole life cycle of Guardian, the lack of data on the logistics, use and end of life, could have underestimated the importance of some stage.

The assessment that has been carried out in order to select the best material for each of the components has great value for the industry. It has set principles regarding material durability, environmental damage and performance that can be used not only for Guardian but other watches in the future. However, there were some limitations to calculate the lifetime expectancy of the materials that could have had an impact on the results due to its high sensitivity. In the material study, the lifetime durability was defined based on experts personal experience, however in order to work with more precise data, physical and chemical tests that resemble the normal use of the watch need to be performed. In addition, the data properties considered in the analysis were defined for virgin materials, not taking into account discrepancies that could occur for being recycled materials.

The material alternatives for each component were defined based on internal knowledge of the industry and only considering responsible and unlimited resources. Nevertheless, the development of new materials has been revolutionary in recent years. It is therefore not surprising that the results will soon become obsolete as materials with higher recycled content rates or properties emerge on the market.

The design choices were defined and evaluated based on knowledge of experts of the watch industry. A balance between qualitative and quantitative data provides a higher contrasted assessment.

Measurable parameters can be defined in order to evaluate quantitative data of typical issues and advantages for each design alternative. On the other hand, for the most part, existing solutions have been used for the alternatives. Nordgreen could consider the design of novel solutions for Guardian's components, as has been done for the butterfly lock of the strap, tailoring completely the components to the specifications and needs.

Guardian considers sustainability throughout all stages in the life cycle. However, a holistic approach considering the process as a whole and not as subsequent steps would provide solutions that respond to respect and responsibility of an interconnected system. The decisions in each stage have an impact in previous and posterior ones, for which it is of great relevance to consider them as one.

Next Steps

Guardian is the first big step forward in the watch industry towards a better responsible environmental behavior. In all good projects and products the work does not end once it is launched, there are always actions to improve and others to embrace. Different matters of Guardian's circularity are in the process of analysis and improvement, hereunder some of these measures are described.

The first next step for the Guardian will be to have a Life Cycle Analysis (LCA) commissioned to evaluate what has been the real impact of these choices and to find new hotspots to improve. The LCA will follow the guidelines of ISO 141040 to make sure the results can be used for comparisons and in further studies. The functional unit proposed for this study is: 'to produce and commercialize worldwide one Guardian watch for an expected lifetime of 100 years'. Thus, the material and energy required by the system will be scaled to fulfill this function.

Unlike the environmental screening that has been performed in this study, the system boundary of the analysis will include all life cycle stages from production to disposal or upcycling as well as transportation. The data for the system modeling must be provided directly from Nordgreen and their suppliers, and it may be supplemented by LCA databases or calculated from provided values, to guarantee as much as possible the representativeness.

Nordgreen keeps working towards responsible and respectful solutions for both society and the planet along the full supply chain of their products. The different initiatives and strategies defined for Guardian in the previous sections support the brand's vision. Nevertheless, logistics is one of the processes in constant search of optimization. Of course, this further analysis places the established requirements and already taken decisions as a starting point. However, changes in these are an option if the new results indicate an improvement. The steps that will be taken are the following:

1. Assessment of the current concept of Guardian's supply chain and logistics to identify the hotspots in terms of environmental impact.
2. Assessment of sales across Guardian's markets.
3. Evaluation of different strategies that balance customer requirements and environmental responsibility.
4. Prioritization of strategies.

Some possible strategies that can be considered are the following:

- Reduction or elimination of bottlenecks from start to finish in the product's life.
- Relocation of storage facilities.
- Design of alternative transportation routes.
- Broaden suppliers network across Guardians different markets.