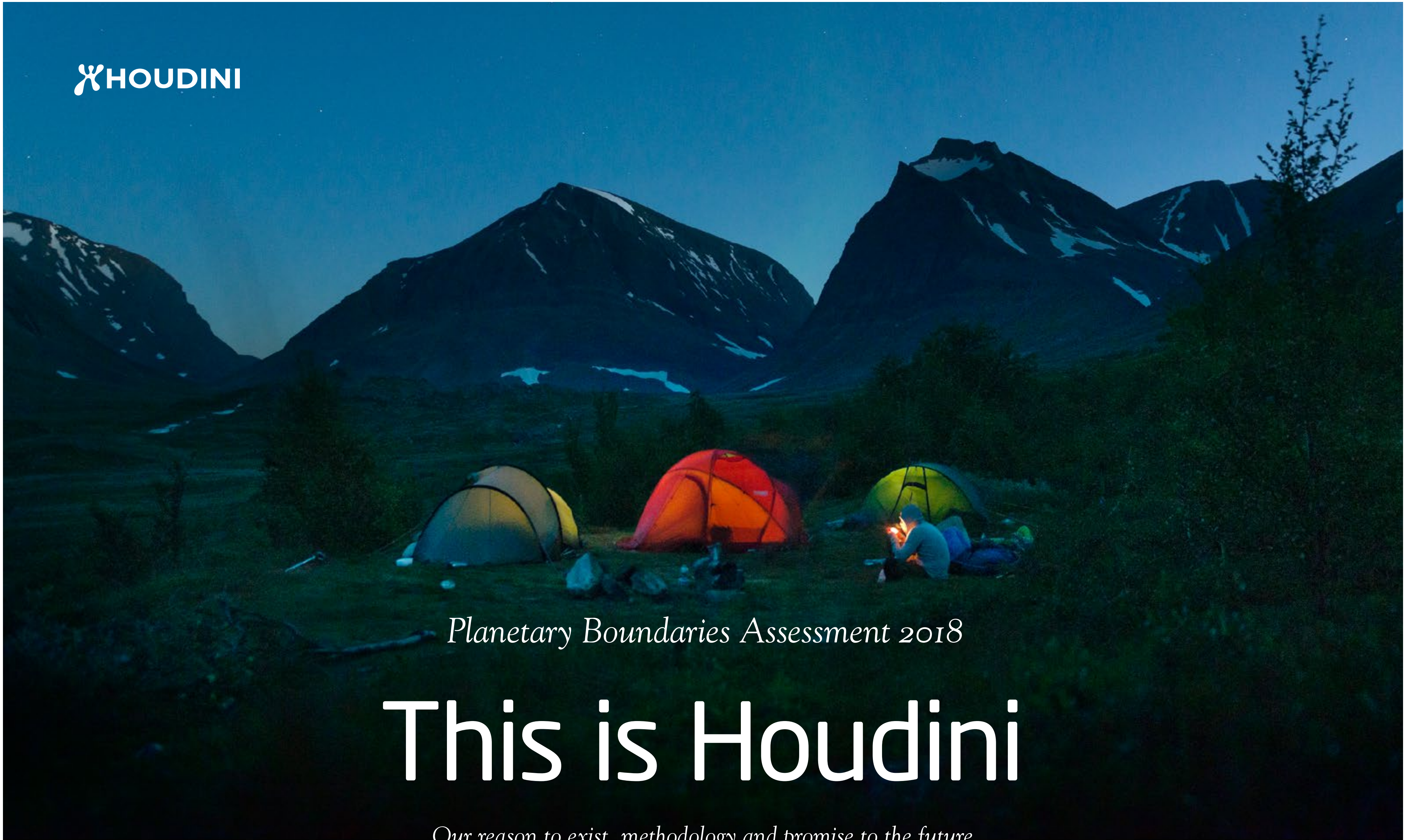


HOUDINI

Planetary Boundaries Assessment 2018

This is Houdini

Our reason to exist, methodology and promise to the future.

A cooperation between Houdini Sportswear, Albaeco and Mistra Future Fashion.

Since the early nineties, when Houdini started to evolve from a project among climbing buddies into a company, responsible business has been our way.

With the passion, determination, planning and execution of mountaineers, we took on the challenge of designing our business to become a force for good. Never compromising. Always smiling (almost).

We have come far in the transformation we envisioned but as a company we believe we can and must eventually move beyond zero and become a positive and regenerative force in society and for the planet. It's our obligation, or we have no business running a business at all.

We believe our vision, and the way we work towards it with uncompromising commitment and speed, motivates our existence as a company. Our sense of urgency is easy to understand when seeing the state of the planet and the prevailing lack of will power, guts and action to truly change course. Seeing the untapped potential, vast opportunities and abundant value in this transition, makes us all the more motivated.

In order to reach our vision, systemic change will be required. We need to embrace complexity, acquire holistic, robust and in-depth understanding of the complex systems we are part of in order to understand how to engage in, contribute to or change them.

The pilot study of Houdini's impact on the earth system using the Planetary Boundaries framework is one example.

In order to minimize and eliminate our negative impact on the planet we need a holistic understanding of it. How we not only have a carbon impact but a biodiversity impact, a novel entities impact and an impact on land-systems and fresh water, how the different parts of the systems affect each other and the system as a whole. How we can adjust and transform our way of doing business in order to eventually contribute to the planet rather than take from it.

We are well aware of the fact that this type of assessment is difficult and an endless project that will have to be refined and

By sharing our thoughts, knowledge, methodology and ambitions in this report, we hope to inspire you to join us in our quest.

expanded over time. This pilot represents the starting point and an explorative study that Houdini together with earth system scientists at Albaeco and Mistra Future Fashion have performed.

Our plan is to do full-scale third-party Planetary Assessment every third year and to go more in-depth with each assessment – moving from general LCA data to specific data for our value chain and later from past to real-time data. We will also need to go broader for each assessment – adding data and analysis on the user-phase and our impact and contribution to the societal system. In addition to the Planetary Assessment we will report yearly on our key performance indicators.

In the complementary qualitative report of our work we have included the sections Who we are – including our company heritage, philosophy, values and vision, What we do – including key strategies, methodology, business models and work flows. We have included Milestones for the 25 years Houdini has been in business. Last but not least, we have included our Promise for the future – our Roadmap Towards 2020 and beyond, our goals for the years ahead, stretching as far as 2066 which marks the 50th anniversary of our Roadmap Towards 2020 and Beyond and the 100th anniversary of the Stetind Declaration.

We are clearly not the biggest sportswear brand around. We don't aim to be the biggest, we simply aim to be the best. By sharing our thoughts, knowledge, methodology and ambitions in this report, we hope to inspire you to join us in our quest and welcome you to share your thoughts with us and contribute with your wisdom in the co-creation of a more beautiful tomorrow!

Let's keep moving mountains, climb others and celebrate the beauty of nature and the myriad of life it sustains.

Have a great read,
The Houdini Team

Houdini Friend Joakim Johansson swimming in the deep section of Courmayeur, Italy. Photo: Linus Meyer

01. Who we are

Planetary Boundaries Assessment 2018

Photo: Nakshe Ghalat


Photo: Nakshe Ghalat

Maximum experience. Zero impact. And beyond.

Our purpose and vision is about inspiring and enabling mankind to reconnect to nature, to lead a healthier and happier lifestyle in partnership with nature, to evolve as individuals and form a prosperous society on a thriving planet, for us and future generations.

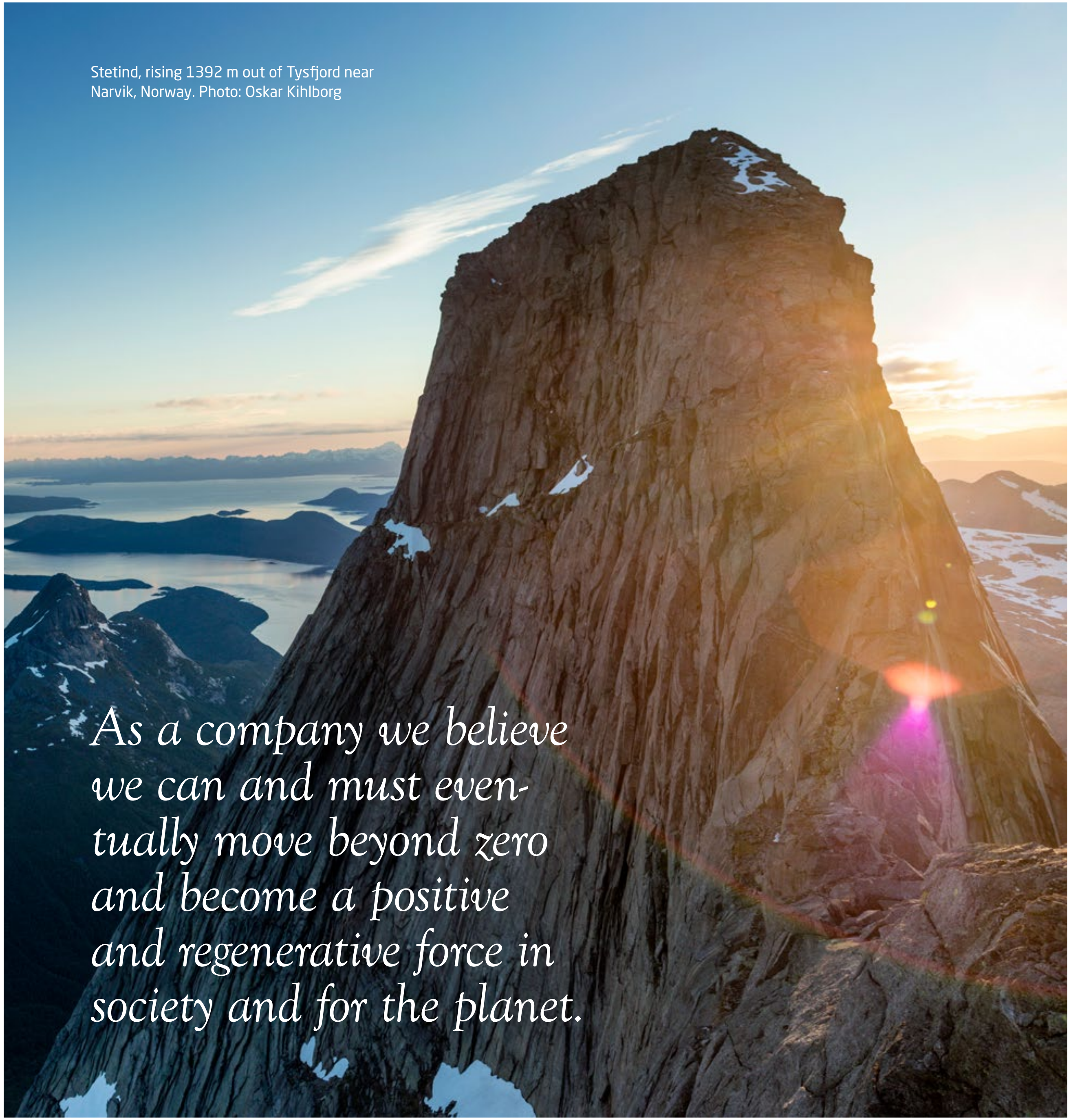
THIS IS WHY WE WORK HARD to provide state-of-the-art products and services designed for the great outdoors. That is why we connect and build our community together with conscious, active and engaged people like ourselves worldwide – people who want to enjoy nature, sports, camaraderie and culture while contributing to the world rather than causing any negative impact socially, ethically or environmentally.

In fact, as a company we believe we can and must eventually move beyond zero and become a positive and regenerative force in society and for the planet. It's our obligation, or we have no business running a business at all. We believe our vision, and the way we work towards it with uncompromising commitment and speed, motivates our existence as a company.

Ecosophy, our philosophical haven

We have our philosophical haven in ecosophy and the deep ecology movement. The Scandinavian tradition of "friluftsliv" is deeply rooted in ecosophy and was defined by a group of likeminded mountaineers and philosophers, among them Arne Naess, Sigmund Kvaloey Setreng and Nils Faarlund. At the essence of ecosophy lies the understanding of the intrinsic value of nature, how nature and humankind constitute a whole and share a common destiny.

Their edition of the ecosophy was created under and on the magnificent Arctic tower Stetind, rising 1392 m out of Tysfjord near Narvik, in the summer of 1966. Here they brilliantly manifested the need for a deeper and more harmonious relationship between place, self, community and the natural world and the urgency for society to change course. They declared the following in their Stetind Declaration:



Stetind, rising 1392 m out of Tysfjord near Narvik, Norway. Photo: Oskar Kihlborg

Nils Faarlund outside Oslo, Norway in 2016 as we met to bring new life into the Stetind Declaration, fifty years after its creation. Apparently we were the first company to sign it although Nils has worked for it relentlessly since 1966. Photo: Kristian Harby

The Stetind Declaration from 1966

We have gradually come to realize:
That our way of life has fateful consequences for nature and humankind, and thus for all life on Earth. The challenges we face as individuals and as a community are not merely of an economical and technological nature. They concern our basic values and our fundamental conception of what it means to be human.

We acknowledge that:
Nature and humankind constitute a whole and share a common destiny. Nature is the home of culture. Life is like a woven fabric of relations. To live is to be dependent. The value of nature and human dignity are intrinsically linked. What we do to nature, we do to ourselves. All life is vulnerable and therefore under threat.

We will:
Work to promote a renewed understanding of the relationship between nature and humankind. Strive to base our choices, both as individuals and as a community, on this understanding. Discover the joy of living in harmony with nature: There is no path to harmony with nature. Harmony with nature is the path.

Humankind possesses great capacity both to create and to destroy. At this crucial point in time we will take responsibility and commit ourselves to thinking and living in a way that promotes life. Concern for nature implies a concern for greater justice: Our way of life affects in particular the poorest among us, indigenous peoples, and future generations.

Do good. Play hard. Push boundaries and have fun.

The Houdini core values

Our core values form keel and rudder

Our core values of doing good, playing hard, pushing boundaries and having fun form keel and rudder at Houdini – in daily operations and strategic work alike. There is no parallel or hidden corporate agenda.

On the contrary, we work in accordance with our values without compromise, across the board and at every level. Paired with our shared passion for ”friluftsliv” and ecosophy these values make our vision and the journey towards it ”common sense” to us.

The Houdini team and a selected few inspiring dreamers, thought-leaders and change-makers in the beautiful nature reserve Nordmarka, just outside Oslo in our neighboring country Norway in 2016. Photo: Kristian Harby

Our company culture is constantly cultivated along these lines and one could argue that our ”common sense” and uncompromising approach makes our work self organizing, focused and effective, hence very powerful.

EQUALLY POWERFUL IS our willingness to take on great complexity where this is required. For Houdini this is business critical. To drive systemic change, which is what we believe is required in order to reach our vision, we need to embrace complexity, acquire holistic and in-depth understanding of a complex system in order to understand how to engage, contribute or change it.

We have found our “common sense” to be especially valuable when navigating complex systems. “The goal is not to crack the code but to catch the rhythm”, is a quote that comes to mind when attempting to describe our ways of navigating and staying on course. It is a quote from the essay “Practicality in Complexity” by Nora Bateson, the researcher, writer and founder of the International Bateson Institute who has devoted her life to systems thinking and patterns in living systems.

ONE SUCH EXAMPLE is the Planetary assessment of our company. In order to minimize and eliminate our negative impact on the earth system we need a holistic understanding of it. How we not only have a carbon impact but a biodiversity impact, a novel entities impact and an impact on land-systems and fresh water and an understanding of how the different parts of the systems effect each other and the system as a whole. It can seem overwhelming as a project but on the other hand it is business critical.

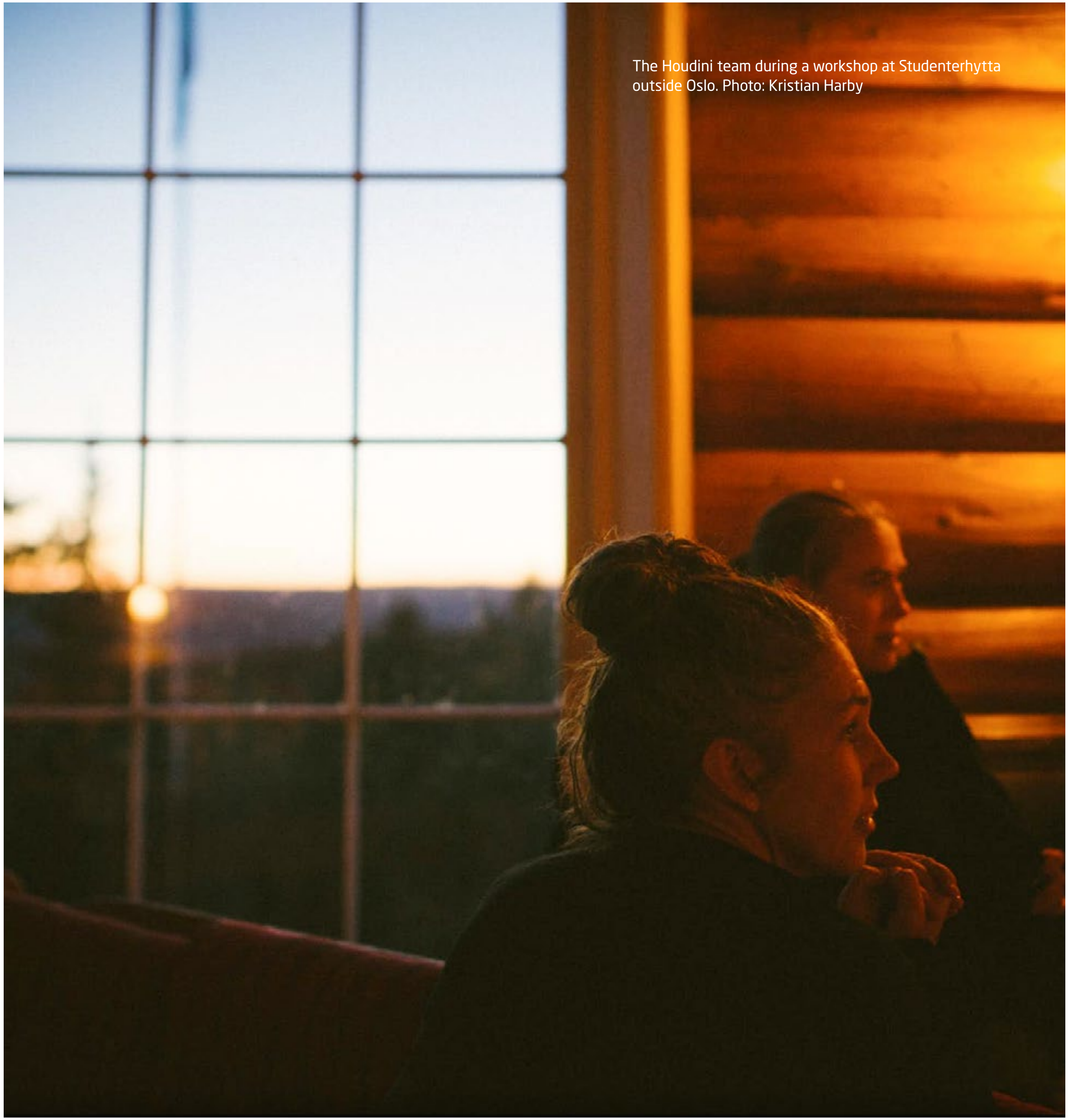
With this pilot we have initiated the project well aware of the fact that it is an endless project that will have to be refined and expanded year after year. Similarly, we look upon our own organization as an interconnected and interdependent system. We cannot work in silos if we want to create true change. Hence we do not view sustainability as a separate area within our operations – it is an integral part of everything we do. As we often describe it – *we have no sustainability work. Just a lot of work.*

WHEN ENGAGING IN challenges with great complexity a science-based methodology is important. We have chosen to base our environmental work on the Planetary Boundaries framework to understand the earth system and our impact and contribution within it. For the societal system and the social and ethical impact and contribution of our operations we have chosen to base it on Doughnut Economics by Kate Raworth.

In addition we find the Swedish Environmental Objectives important for our local Swedish perspective and inspirational considering its poetic descriptions of the ecosystems we love and depend upon. Although it is important to underline that each and every objective is equally important and that only together they constitute a whole, brilliantly visualized in the UN Global Goals symbol, a few examples:

Examples of the Swedish Environmental Objectives

8. Flourishing lakes and streams (Levande sjöar och vattendrag)
10. A balanced marine environment, flourishing coastal areas and archielagos (Hav i balans samt levande kust och skärgård)
11. Thriving wetlands (myllrande våtmarker)
14. A magnificent mountain landscape (storslagen fjällmiljö)
16. A rich diversity of plant and animal life (ett rikt växt- och djurliv)


The Houdini team during a workshop at Studenterhytta outside Oslo. Photo: Kristian Harby

Tone Bjordam's Biosphere Sculpture in Nordmarka, Norway.
Photo: Kristian Harby

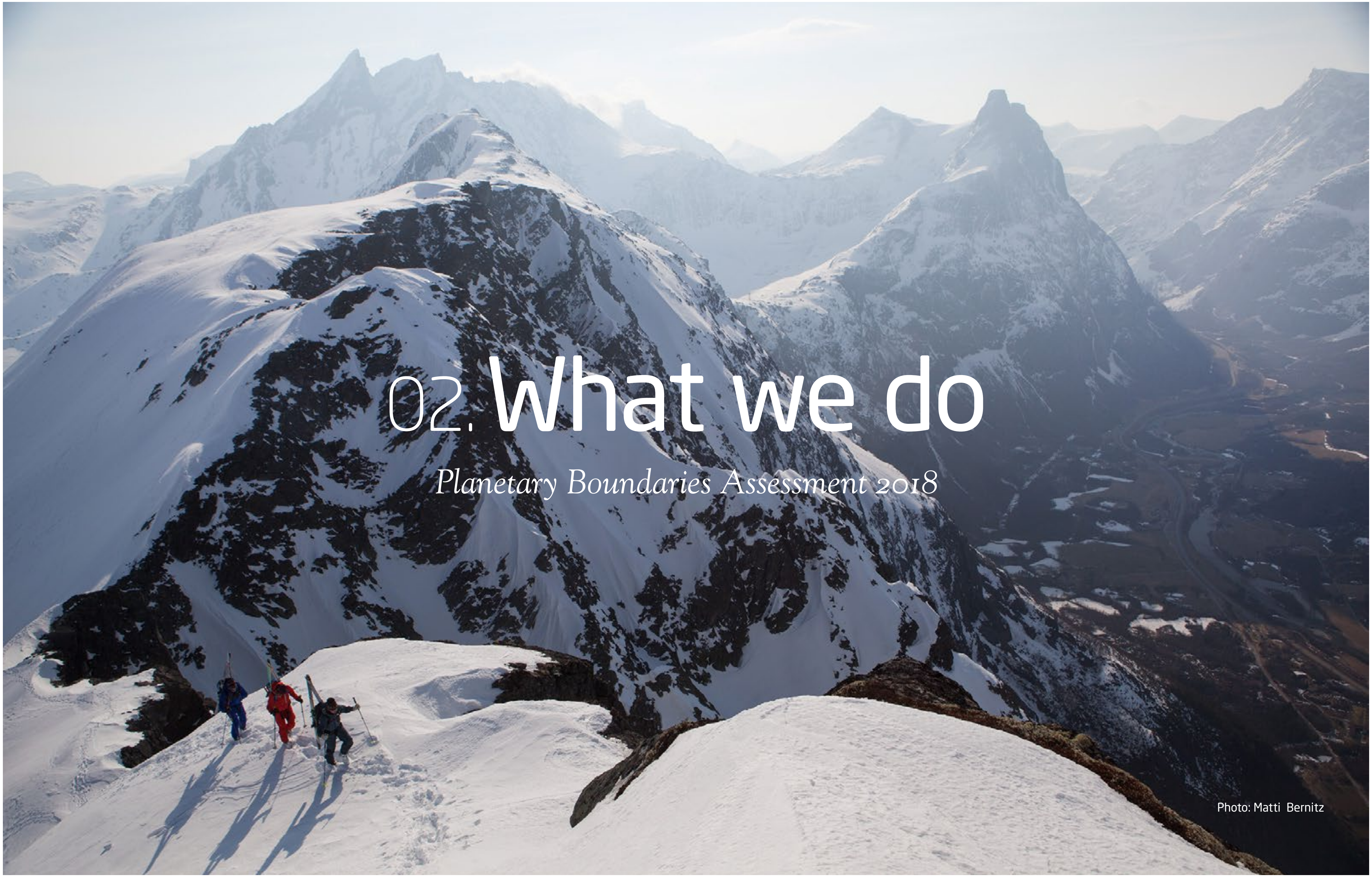
We have no sustainability work. Just a lot of work.

Also the UN Global Goals are worth mentioning, as they might become the strongest global force towards a sustainable world and are partially based on the Planetary Boundaries Framework and the Oxfam Doughnut.

The UN Global Goals also take the systemic perspective and emphasizes on how co-creation is important in order to reach them, by making partnerships for the goals a goal in itself.

ON THE SUBJECT OF science-based frameworks and methodologies we see culture and art as having an equally important role to play to balance common sense and hard facts, the emotional realm and scientific data.

The Norwegian artist Tone Bjordam created a sculpture visualizing how utterly dependent the economical system is on a healthy societal system and how dependent the societal system is on a healthy earth system. Only delicate threads hold the societal and economical systems from falling in case of a failing earth system. It portrays what we all know intellectually but for some reason don't manage to act on. The beauty and sense of urgency communicated in a work of art.



02. What we do

Planetary Boundaries Assessment 2018

Photo: Matti Bernitz

Our core strategies to become regenerative

IN OUR QUEST TO BECOME a regenerative force we have identified the following four core strategies:

1. DESIGN A CIRCULAR SYSTEM eliminating the concept of waste. With nature as the blueprint for the perfect circular system we strive towards designing a circular system.

We design circular products, made from recycled and recyclable materials alternatively from organic, renewable and biodegradable materials. We design circular business models extending product lifetime, securing that raw materials remain within the system and enabling product-as-a-service solutions radically improving resource efficiency at the systemic level.

We engage with the world around us based on circular principles, with a collaborative mindset, open source innovation and sharing knowledge, experiences and cameraderie.

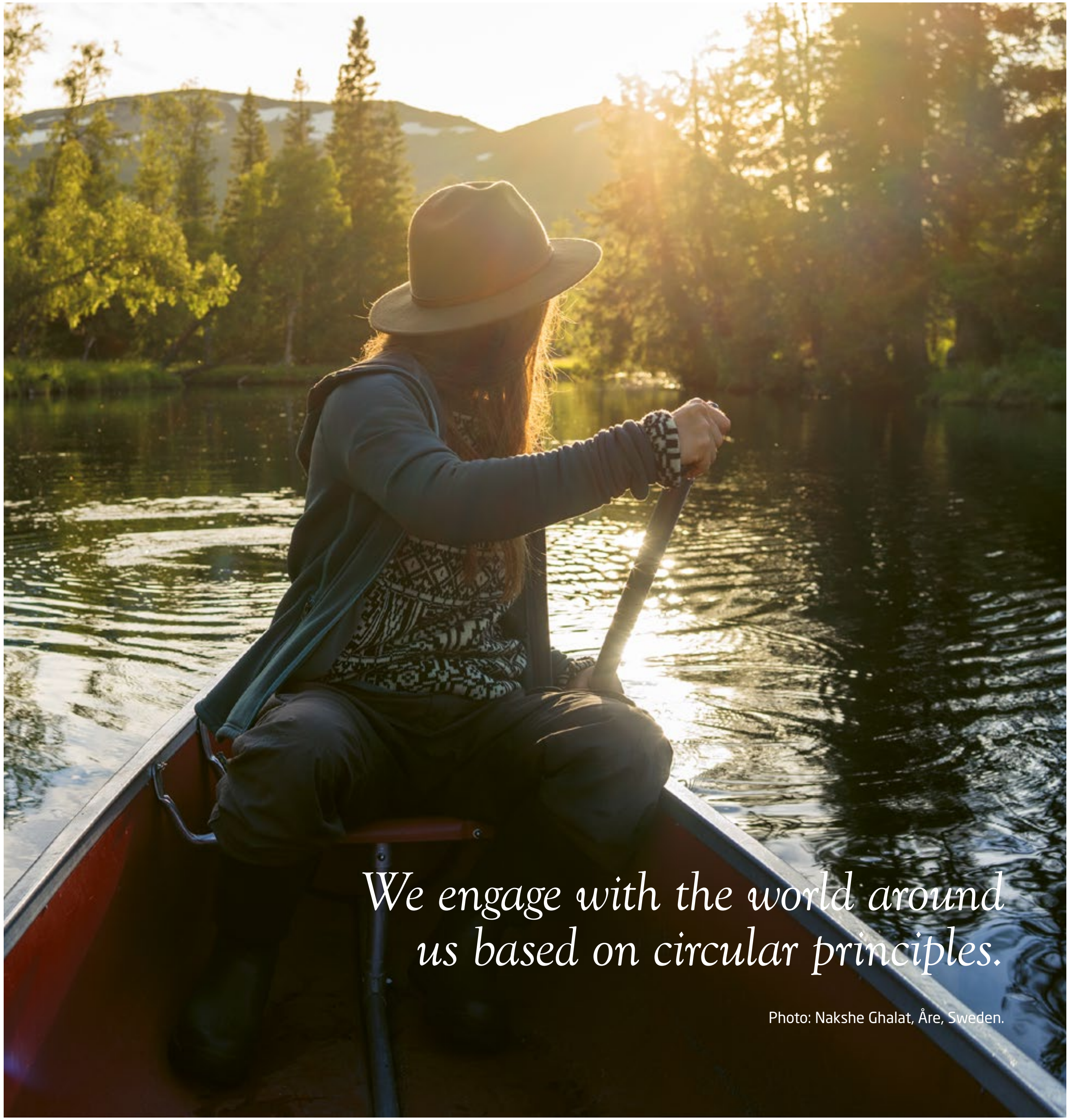


Photo: Nakshe Ghalat, Åre, Sweden.

Only by setting the example and sharing our work we can lead the way to change.

2. RECONNECT TO NATURE. For a multitude of reasons we strive towards reconnecting ourselves and our community of end users to nature. Biomimicry provides access to nature's 4 billion years of innovation enabling us to design smarter materials, solutions and systems. Our products provide comfort for all senses, for body, mind and soul enabling our end users to have the best possible outdoor experiences.

Our hangouts create a possibility for us to invite and guide people to outdoor experiences, strengthen their sense of wellbeing and their bond with nature. Our communication allows us to educate, inspire and speak for nature.

3. SET THE EXAMPLE. In order to create significant change it is not enough for us to transform ourselves but to contribute to the transformation of the entire business community.

Only by setting the example and sharing our work we can lead the way to change. Transparency and the sharing of knowledge, methodology and technologies is essential. Innovation and co-creation across disciplines and in between what would traditionally be called competitors is key.

There is no inherent contradiction between sustainability and good business; on the contrary, sustainability is a prerequisite for good business but the world needs more examples of it in order to reach a positive tipping point.

4. BUILD OUR COMMUNITY. Starting with the Houdini team, family, friends, partners and core end-users we are building a co-creative global community to inspire to reconnect to nature, to speak for nature, make informed decisions, design, enable and live a conscious lifestyle.

By enabling and encouraging interaction within the community, sharing knowledge, ideas and gear, inviting others to collaborate and co-create – we want to contribute to an exponential growth of activists for a sustainable lifestyle.

Our business model

We do not view sustainability as a separate area within our operations – it is an integral part of everything we do. We can see clearly how our way of doing business, more resource efficient solutions and new collaborative business models have resulted in us doing better business.

Without any traditional marketing we are growing with 20-30% per year and at double speed on our 15 export markets. One reason is of course that a change maker attracts attention. However, the trust and magnetism we experience from our partners, end-users, customers and followers is sprung also from the honest dialogue we have always had with the world around us, how we are open about the challenges we face combined with the fact that our products exceed expectations creating the strongest ambassadors and a grassroots movement.

WITH POTENTIAL government policy changes designed to speed up the transition to sustainable business practices we couldn't be better prepared as a company. We have built our entire business on the basis of responsible use of resources and social justice.

We already take responsibility for collecting and turning worn-out Houdini products into resources for new products and we are well prepared for a transition into an automated recycling process.

Our product and design philosophy

In a world of fast fashion and mass consumption where quantity and frequency often seem to matter more than quality and good design, our design philosophy stands out. We design every product with the intention of it making a difference for the end user and for the world, in the short- as well as long-term perspective. We see our innovation-, design and development process of each style as strategically important long-term investment for our company, with a clear vision of what we want to accomplish and no room for compromise.

This means we make sure to invest the adequate amount of time and effort into the ideation and product development process and eventually end up with the perfect product. Most of our products stay in the range for multiple years. Some core products have been in the range for more than 10 years and a few for more than 15 years.

This is a resource efficient, resilient and sustainable innovation and design process in itself, which results in a resource efficient, resilient and sustainable system – from sourcing, production and manufacturing, throughout the entire user-phase and to the end-of-life solution.

OUR END-USERS HAVE BECOME our strongest ambassadors calling their favorite Houdini products ”addictive” and recommending them to the extent that advertising and traditional promotional efforts have not been needed. Although we cannot yet present quantitative data, our qualitative estimate of average product lifetime in terms of use is 5 years and an average days of use per product per year is estimated to 50. (Quantitative user data will be added to the next assessment.)

Our products are designed to last for many years of hard use. Photo: Hampus Samuelsson, Häller, Sweden

Designer’s Checklist

The Designer’s Checklist is used in several phases during the product development process in order to safeguard that the product aligns with our product philosophy.

Does this product deserve existence?
Will it last long enough?
Is it versatile enough?
Will it age with beauty?
Nothing added that isn’t needed, right?
Will it be easy to repair?
Is it durable enough for our rental program?
Do we have an ”end-of-life” solution?

Some core products have been in the range for more than 10 years, a few for more than 15 years.

Our products must last a lifetime and age with beauty.

Our Product Philopophy

Less is more – versatile performance and minimalist constructions. Versatile product performance enables a smaller and smarter wardrobe for the end-user and one that creates possibilities rather than limitations, resulting in happier end-users and greater resource efficiency on the systemic level. Our designs are minimalistic – stripped from unnecessary details and simple by construction resulting in beautiful aesthetics, a longer product lifetime and product repairs becoming easier.

Built to last – both in terms of quality and style

The quality of our products is intrinsically linked to the fact that they must be reliable in extreme conditions but also that they must last a lifetime and age with beauty.

With timeless aesthetics we create styles that don't get outdated but rather iconic and with our unique color philosophy we stay above and beyond seasonality and trends.

Holistic comfort – for body, mind and soul

Our holistic definition of comfort embraces individuality and includes comfort for all senses, for body, mind and soul. The comfort of making an informed and sustainable choice is central in the way we define comfort.

How we choose our fabrics and technologies

In order to design circular product lifecycles our policy is to keep the raw material as pure as possible and never mix natural and synthetic fibres. Instead, we blend wool with other biodegradable fibres, such as silk and lyocell Tencel, making the products both recyclable and biodegradable.

Similarly, we mix a synthetic polymer with other synthetic polymers when performance requires it. Where we can we eliminate stretch fibres, as they currently make circularity impossible. This policy and methodology is based on current recycling technologies as well as promising technology development. If and when there is a technology breakthrough that motives a policy change we will act accordingly.

In addition to striving for circular materials our policy is to always choose the environmentally, socially and ethically superior alternatives. We continue our selection process by looking at factors such as quality, longevity, geography, supplier, facility, certifications, traceability and transparency.

Our policy is to always choose the more sustainable alternative when such exists and we favour suppliers with the best track record, the adequate internal framework and ambitions in line with ours, hence with the best potential to develop further in partnership with us.

THERE ARE NUMEROUS earth system impact estimations performed as well as silent considerations being made during the process. For fabrics and technologies in the organic cycle we have for instance opted to not use cotton because of clear performance limitations as well as its heavy use of water and monoculture land system use. Instead we use natural or cellulose based, sustainable and biodegradable performance fibres that support the organic cycle. The biodegradable wool yarns and fabrics we source were carefully selected to make sure also treatment and process chemicals belong in the organic cycle.

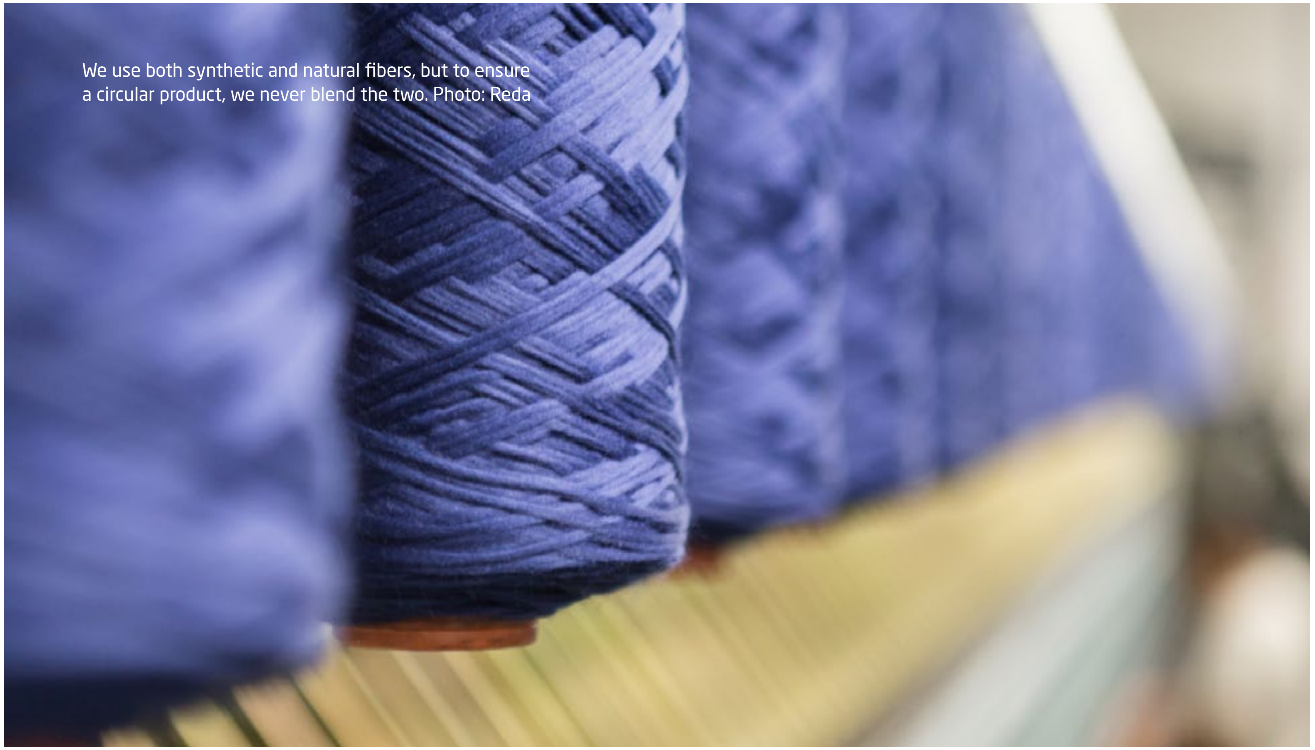
We source our merino wool mulesing free, preferably from certified ethically and environmentally sustainable farms with

Such a system could ultimately eliminate the need to take crude oil from the earth's crust.

traceability from farm to product. We take geography, hence land system use and water consumption into consideration, as wool although it is a natural fibre, can have a strong negative impact on the environment if not farmed appropriately.

For fabrics and technologies in the technological cycle we use mainly recycled synthetic fibres, preferably recycled polyester as the technology for closed-loop recycling enables a circular system without any loss of quality and without the need to add virgin fibres.

WE FIND CHEMICAL RECYCLING, enabling continuous textile-to-textile recycling, to be the superior alternative in terms of possibilities for up-cycling and designing a truly circular system. Such a system could ultimately eliminate the need to take crude oil from the earth's crust for the production of polyester entirely. However, the supply is scarce.



We use both synthetic and natural fibers, but to ensure a circular product, we never blend the two. Photo: Reda

Mechanical recycling is more common but requires an understanding of its current systemic limitations and possible risks, such as becoming an excuse to grow the plastic packaging industry further. Post Consumer Recycled PET-bottles is currently a key source. Potential for industrial symbiosis to evolve within an emerging circular plastics industry in order to recycle products designs for longevity rather than packaging is of great importance for us looking ahead.

Where we currently need to add virgin polyester we have implemented plans for how to transition to recycled alternatives. This is the case for the waterproof/breathable polyester membrane we use in our shell layers as well as for a few fibre types where demand for recycled versions is yet too low to motivate suppliers to produce them.

There is a recent development of circular polyamide that we are following closely, in order to transition to recycled and recyclable polyamide as soon as this is possible. Another development we are following closely is the emergence of high tenacity polyesters, which could enable us to shift current polyamide fibres to polyester, hence improving material purity and circular efficiency further.

SINCE 2013 WE HAVE had to take another consideration into account when developing and assessing our technological cycle – micro plastics. Synthetic garments shave off small fibres during production, during the user phase and at end-of-life if left in landfills. These micro fibres travel through air and runoff systems, often ending up in the ocean where they eventually move into the food chain.

Our ambition in this field is clear: to minimize and eventually eliminate our contribution to micro plastics. By recycling worn-out garments and keeping them from ending up in landfills we limit the release of micro plastics but as the release can occur throughout the cycle, we tackle this challenge in multiple ways:

1. The material choice down to polymer and construction is key. Where a poor quality polyester fabric will quite rapidly deteriorate when washed, a high quality will look, perform and weigh almost the same after 10 years of use, hence micro fibre release is low.

2. Through our Care Guide we educate and encourage our end users to discover the advantage of airing their garments rather than washing them as frequently. We have introduced a laundry guide and laundry bag collecting micro fibres that potentially release during the wash cycle.

3. We are collaborating with a home appliances firm in the development of improved care instructions and wash cycles to minimize micro fibre release and extend product lifetime further and possibly a filter solution that would capture stray fibres in the washing machine.

4. We keep developing next generation fibres and fabrics together with various partners in order to minimize and eventually eliminate the occurrence of micro fibres. To date we have developed alternatives such as C9, a novel 3-layer synthetic filament fibre construction, as well as organic and biodegradable alternatives, such as Wooler.

5. We engage with academia and across sectors in various research projects with the ambition of developing solutions and standardized measuring methods for increased data precision and transparency.

We keep developing next generation fibres and fabrics together with our partners.

Our sourcing by geography

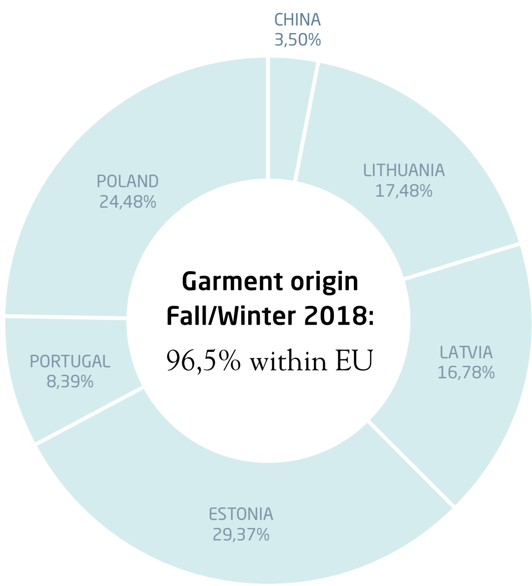
Fabric and technologies sourcing at Houdini is based on a highly selective partnership strategy, with long-term relations with world leading fabrics and technologies supplier partners

Organic, renewable and biodegradable Wooler Houdi. Pure enough to fit in our circular system where worn-outs can be composted and become fertile soil. Photo: Nakshe Ghalat

Our value chain is global and the number of supplier partners very few.

and manufacturers. Fabrics are sourced mainly from Japan, Italy and the US. This enables Houdini to provide the highest quality and best practice while also maintaining the highest environmental, social and ethical standards. Equally important, the partnership strategy results in improved trust and transparency, making analysis of current practices possible, improvement plans easier to implement and innovation projects comfortable to invest in.

Our value chain is global and the number of supplier partners very few. Most of them produce their fabrics in developed countries where high social standards are regulated by law, legal requirements environmentally are strict and federal control functions are in place.



Sourcing at Houdini for the Fall/Winter 2018 range, based on our partnership strategy with a selected few world leading supplier partners and manufacturers, enabling us to provide the highest quality products while pushing environmental, social and ethical standards to the next level.

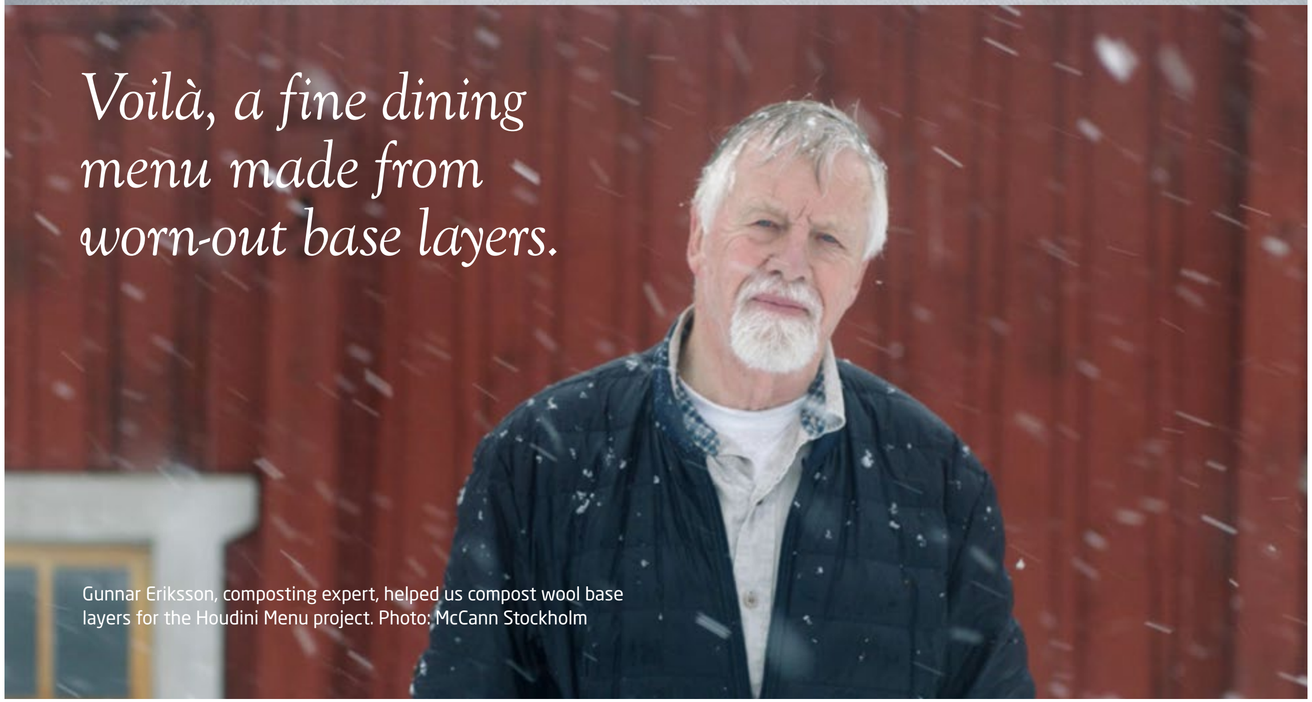
Manufacturing at Houdini mainly takes place at selected and specialized European manufacturing partners in Estonia, Latvia, Lithuania and Poland. This manufacturing network close to our global distribution center in Sweden (which could be considered “local” in a textile supply chain perspective) enables us to have a lean set-up with tight collaboration and an efficient way of working, meeting and shipping. In addition EU social and environmental standards apply, legal requirements and government control functions are in place, meaning our sustainability efforts are at a high level even at baseline.

Local manufacturing has multiple benefits and we see great potential in developing our local value chain further. On the other hand Houdini has the ambition to export its high social standards and practices to manufacturers elsewhere in the world, as we then would be able to push boundaries, especially social and ethical boundaries, further and on a global scale. We recently initiated a pilot with manufacturing at a selected Chinese manufacturer.

Our fabrics and technologies innovation

Our circular principles as well as our drive to radically enhance product performance and sustainability often result in innovation projects, development of entirely new fabrics and technologies or improvements of existing qualities - fibre compositions, treatments and production methods.

These innovation processes broaden our horizon and enable us to question conventions and design superior solutions. The result is often advancements in multiple areas



Voilà, a fine dining menu made from worn-out base layers.

Gunnar Eriksson, composting expert, helped us compost wool base layers for the Houdini Menu project. Photo: McCann Stockholm

even though our focus might have been in one specific area. For instance, the focus might have been material innovation for circularity but the end result is a circular lifecycle plus improved product performance, a smarter design of the value chain or the business model. Here are a couple of examples:

THE HOUDINI MENU and the development of our merino wool range is one example. While conventional merino is often mixed with synthetics and various treatments are based on synthetic polymers and other chemicals that do not belong in nature, we envisioned a circular system with merino garments pure enough to be composted and beneficial in the composting process. The project ran for four years before the first garments were launched. Since then the range has grown significantly and improved further.

To celebrate the beauty of the system we grew vegetables in the composed soil and had a star chef in Stockholm serve a fine dining menu to a few of our end users.

SHELL LAYERS FOR THE FUTURE is a similar project, where we questioned the chemical intense and linear technologies conventionally used for waterproof/breathable shells.

Whilst sustainable alternatives were readily available for several key improvements such as polyester based membranes enabling circular product lifecycles, innovation was needed elsewhere, for instance to develop sustainable Durable Water Repellent treatments (DWR) enabling the phasing out of PFC-based DWR's. After extensive field-testing we decided to use only pure and circular alternatives, featuring polyester membranes in combination with recycled polyester fabrics. In the shell layer innovation and development process we also refined and redefined the aspect of shell layer comfort, moving from stiff, static and noisy to soft, resilient and silent.

Open source innovation and co-creation

Most of our innovation projects are performed in partnership with leading innovation hubs and universities in addition to partnering up with our suppliers. Interdisciplinary collaboration across sectors has proven successful and we often partner up with likeminded conscious companies in various industries when searching for superior solutions to common challenges.

We believe in the power of reconnecting to each other, to technology and to nature in order to stay open, curious and constantly evolving. Albaeco and Mistra Future Fashion who performed the Planetary Boundaries Assessment for us are two examples, Chalmers University of Technology, Swedish School of Textiles, Sunfleet and Rosendals Trädgård a few others of our partners for co-creation. Our co-creative platforms in themselves are in constant evolvement with hubs, hangouts, co-creation labs and fireside talks. This is where we meet, co-create, innovate, plan, progress and hang out.

We prefer open source innovation as it aligns perfectly with our core values. When dealing with sustainable innovation open source is our policy, as we believe sustainable technologies should be shared for the common good.

Packaging, shipping and transports

Considering our global supply chain we need to assess, report and improve further in packaging, shipping and transportation. We will include assessments in these areas in our next

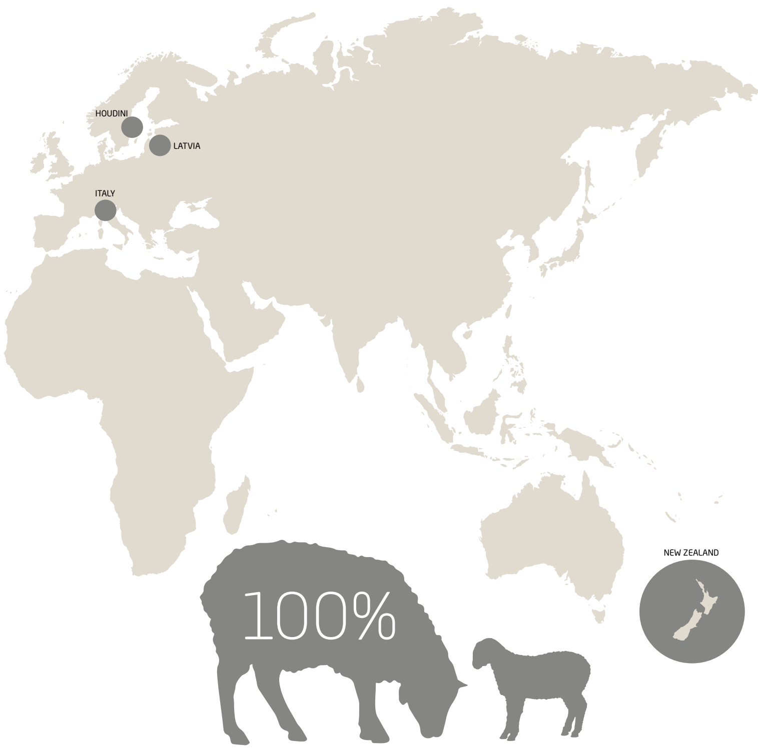
Open source is our policy, as we believe sustainable technologies should be shared for the common good.

Made to Move brings the design process closer to how and when we wear Houdini gear – in movement among mountains, rivers or wherever our adventures take us. By creating a 3-dimentional shape, using the natural diagonal stretch of the fabric and avoiding seams in friction areas, we managed to take the level of comfort and freedom of movement to a different level while enabling circular product life cycles.

The Wooler Houdi value chain: Merino wool sources from two beautiful ZQ-certified NZ farms, shipped to our supplier partner in Italy.

report. So far we have designed every product value chain as lean and effective as possible, reducing complexity in assembly, reducing the number of legs in the value chain and being selective in our choice of transportation. We use low-impact shipping alternatives ranging from regenerative local shipping solutions such as MovebyBike and Urb-it to shipping by sea, train and truck, avoiding air freight almost entirely.

When designing packaging we apply the same critical thinking, including the designer's checklist, as we do when designing our products.



Our Wooler Houdi value chain is an example of what we intend to reach for each and every one of our products.

Bluesign partnership

Textile processing and finishing is a critical part in our sourcing, production and innovation processes. In order to access experts in the field for knowledge, guidance, monitoring and development we are a Bluesign Systems Partner since 2009. The basic idea behind Bluesign is to combine the use of chemicals, air and water emissions, consumer safety and occupational health and safety under a single standard.

The Bluesign Input Stream Management method provides an efficient solution by stating the principles and monitoring the implementation of the Bluesign System. It guarantees that approved facilities, fabrics and processes do not contain components that are harmful to people or the environment and it guarantees the application of responsible chemistry in a clean process. Similarly, Bluesign Technologies guides and facilitates us in our innovation processes to push boundaries further.

Traceability and transparency

We strive towards a completely traceable and transparent value chain. We conventionally engage with our suppliers from tier 1 all the way to tier 3 or 4 but have our Wooler Houdi value chain as an example for what we intend to reach for each and every one of our products.

Furthermore, we have taken a stand against green washing generalization and have strict and transparent principals on what we call circular, recycled etc. For instance, we communicate recycled content in a transparent and detailed way. If a garment is made from only 45 % recycled fibres, we describe the garment "partly made from recycled fibres". Only if a product is made from more than 50% recycled fibres we count it as "recycled" in our range statistics and describe it as "primarily made from recycled fibres". Exact data is made available in various ways – from product range sustainability specification, to assessments such as the Planetary Impact Assessment and direct at request.

WE BELIEVE IT IS a great benefit for us as a company to be transparent, as it enables us to continuously build trust. The way we see it, it is also our obligation as a company to be transparent. We owe it to ourselves, our end-users, customers, our colleagues in the business as well as to the general public since at the end we are all interdependent in the local as well as global and planetary perspective.

Business model innovation

Apart from material and product innovation, which comes natural to most forefront outdoor companies, we have invested and continue to invest heavily in business model innovation, mainly within the field of the collaborate economy.

Our over arching idea is to find smarter solutions in the field of consumption that will keep Houdini garments in a slow, ever-extending and resource efficient circular system where our offering and growth is decoupled from the use of resources. Up until now this has lead to the introduction of several services catering to the extension of product lifetime such as Care, Repair and Reuse and "product as a service" solutions such as Rental.

The main platform for our business model innovation has so far been through our direct channels – the Houdini Hubs and eCom. Our hubs, as we call our brick and mortar retail locations, are physical hubs in our community and much more than commercial spaces.

Our hubs are key in innovating and co-creating our offering together with our customers and users. The retail hubs themselves are developed in line with the forefront of green building design and we apply the same design philosophy as with our products – less being more, built to last and providing comfort for all senses, body, mind and soul.


In our Houdini Hubs, like this one in Oslo, we offer rentals, repair services and second hand sales. Photo: Kristian Harby.

Through collaborative business models we can decouple growth from the use of resources.

Care, Repairs and Reuse

We extend product lifetime by inspiring, assisting and guid-

Morten Christensen putting our Mr Dunfri to the test during a winter of skiing and sailing in Norway.

We are committed to having our garments last as long as they're meant to.

ing to better product care, by providing repair service and by creating a marketplace for reuse, vintage yet fully functional Houdini products that deserve a 2nd or 3rd life companion.

THROUGH HOUDINI CARE we educate and encourage our end users to discover ways to take better care of their products – from airing as an alternative to washing, to providing a laundry and detergent guide, to instructions for how to re-boot water-repellent performance.

Regarding Repairs, we are committed to having our garments last as long as they're meant to, even if that sometimes involves a repair or two. Should a customer happen to tear their favourite hoody or jacket when skiing or climbing, all they have to do is visit a Houdini hub and have it repaired there or contact us for repair support.

Furthermore, with Reuse we challenge the norm of fast fashion and seasonality. By selling second hand clothing in our retail hubs, we provide entry-level price points without developing an entry-level product line where compromises to quality, performance and sustainability would be inevitable. Simultaneously we visualize how our products age with beauty and can become companions for life and emphasize the value of long lasting products.

We choose to see Houdini as the custodian of resources, responsible for handing them back to the planet in good shape.

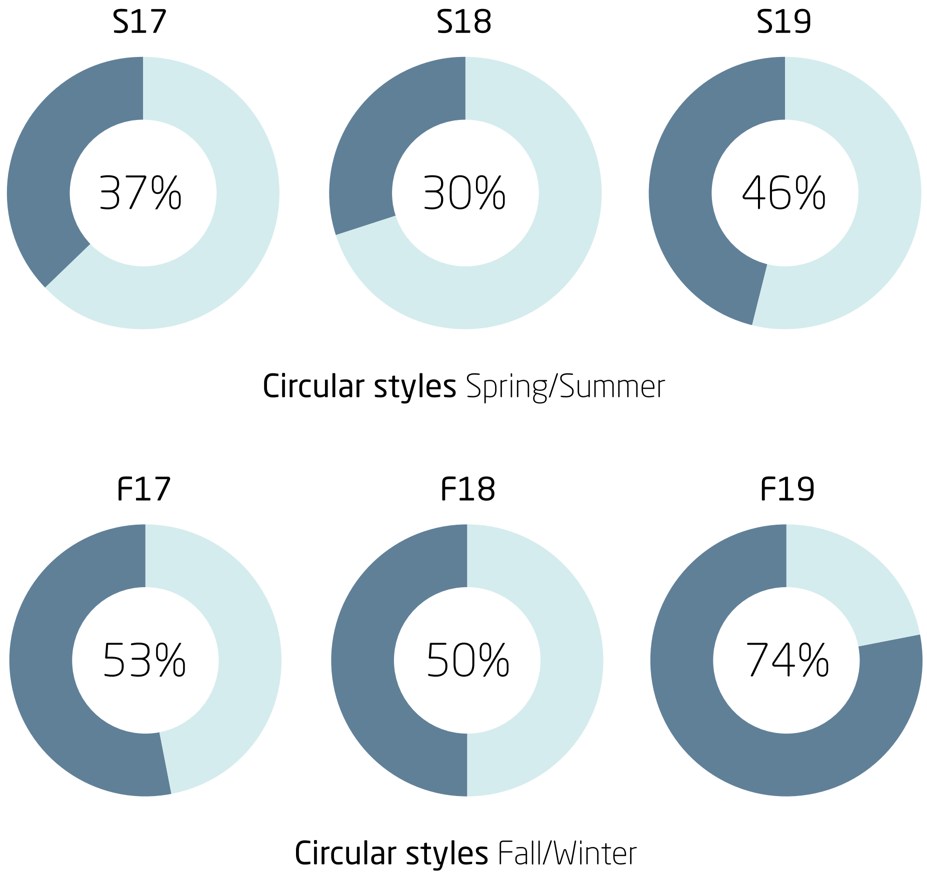
Our recycling system
We choose to see the resources we use as resources borrowed from the planet and Houdini as the custodian of these, responsible for handing them back to the planet in good shape. A take-back system for all Houdini products is therefore a given.

Together with our end-users we treat worn-out garments as they were intended when designed - as a resource to recycle rather than as waste.

As the first European brand we became partner in Eco-Circle, Teijin's closed-loop system for polyester recycling in 2006. The system enabled us to provide products made from recycled fibres that at end-of-life can go back into the system and become a resource for new garments. The system has since scaled and other solutions have been added in order for us to recycle all products. For the few products where we currently do not have a recycling solution we are working to get them in place and meanwhile store these garments.

TEXTILE RECYCLING is clearly a field that has the opportunity to develop further. The evolution since 2006 has been extremely poor. As an example, for the chemical recycling of polyester we still need to ship to Japan.

Considering the pricing of virgin compared to recycled polyester, where substantial planetary costs for virgin polyester are externalized, the incentive for further development is weak.



Share of completely circular styles in Spring/Summer 2017, 2018 and 2019 (top) and Fall/Winter 2017, 2018 and 2019 (bottom). Our goal is to reach 100% circular in 2022. (Definition of circular: styles designed to be recycled at end-of-life and made from recycled or organic, renewable and biodegradable fibres.)

The conventional way of selling and consuming goods has created business models and behaviours that are unsustainable and often unattractive.

With the rental program, we are reinventing our business model with access as an alternative to ownership.

Designing product-as-a-service solutions

Houdini believes sharing and services could and should play a larger part as an alternative in the near future. The conventional way of selling and consuming goods has created business models and behaviours that are unsustainable and often unattractive for all stakeholders involved. Looking to nature for answers – we are designing alternative solutions where resources are used more effectively and resilience is build into the system to properly match supply with demand.

Apart from sustainability advancements, the product as a service business model is one where the customer and user experience has potential to radically improve in comparison to the conventional. The success depends entirely on how well this novel and alternative system is designed and we are only in the early stages of this development.

OUR RENTAL INITIATIVE has been in place for five years. It's a great way of providing access to products as an alternative to ownership and to make life simpler for the end user while eliminating unnecessary resource use for garments that may not be used frequently. Also, being able to rent otherwise expensive gear offers a smart financial solution for individuals and families who might not have the possibility or desire to invest in owning their outdoor gear.

Looking ahead we will soon make rental available online and through selected partners. In parallell, we are developing additional product as a service solutions to be launched within the next couple of years.

Photo: Nakshe Ghalat

The milestones on our journey so far

Houdini founder Lotta Giornofelice on the left during a climbing trip in the Himalayas.

Late 80s: We're a group of Swedish ski- and climbing buddies traveling the globe in search of good skiing, good climbing and good fun. Gear improvements linger in our heads. Houdini, the escape artist, is our "House God".

Early 90s: On a trip to NZ we pioneer the development of progressive precision insulation garments that won't weigh you down or overheat you yet provide addictive comfort and exceptional freedom of movement. They soon get the name "the great Houdinis".

1993: The Houdini garments spread like wild fire within the mountaineering community, the brand is born and we open a small office in Stockholm. We continue spending most of our time in remote places and travelling the globe, leaving the office empty.

We launch "Dunfri" along with the statement that we don't believe in stealing birds' feathers but do believe in the advantages of modern technology.

The Dunfri synthetic down jacket.

1995: We introduce Houdini Repairs to extend product lifetime of all Houdini gear. We develop the early stages of the Houdini layering system with lighter weight performance base layers and precision wind block garments.

2001: Our quest to keep the great outdoors great begins. We decide to either become part of the solution rather than the problem or shut down business, no compromise.

2003: We launch the Power Houdi, a state-of-the-art mid layer featuring Polartec Power Stretch Pro - an iconic style that since have been claimed to be "addictive" by many. The Power Houdi is built to last, both in terms of quality and style.

2005: We are the first European brand to form a partnership with Teijin, the disruptive Japanese textile supplier. Now we can finally move from virgin to recycled polyester and to the circular system we had envisioned for closed-loop garment recycling.

2006: Our first products designed for circularity are developed – progressive and stylish performance base layers, tops and T-shirts. By moving to recycled polyester we manage to reduce CO_2-emissions by +60% and energy consumption by +60%.

2007: Our first products designed for circularity are introduced along with recycle units and the infrastructure for our garment recycling take-back system. Finally we can start collecting worn-out Houdini garments for recycling.

2008: We launch "Dunfri", synthetic down jackets featuring PrimaLoft, along with the statement that we don't believe in stealing birds' feathers but do believe in the advantages of modern technology. Dunfri is down-free, awesome and circular.

2009: We become Bluesign system partner to intensify our work on chemicals, energy and water use. As we source fabrics mainly from our partner suppliers in the US, Europe and Japan and have 100% EU manufacturing we start out at an already high level.

2010: After more than four years of innovation we introduce Airborn, a lightweight and luxurious range of merino wool-silk garments. Possibly the most advanced merino base layer around at the time and pure enough to put on the compost at end-of-life.

2011: We initiate Reuse, our program to bring vintage Houdini products to life. We introduce a platform for our customers to buy and sell their vintage Houdini gear in an effort to extend product lifetime, create awareness and enable entry-level price points.

We finally reached our goal 100% fluorocarbon-free.

2012: We open our first Houdini Hub in Stockholm and start exploring how we together with our customer and end-user can shape retail for the future and contribute to conscious consumption. We launch Rental, our first product-as-a-service solution.

2013: With the Cloud Nine project we are the first brand globally to introduce an air-permeable synthetic down featuring migration resistant PrimaLoft insulation. This is our first step in developing solutions to tackle microfiber pollution.

Field testing shell layers in the Andermatt backcountry. Photo: Linus Meyer

2014: We introduce shell layers for the future – our state-of-the-art waterproof/breathable shell layers with circular life-cycles. We win the ISPO Sustainability Award and begin the quest to transform the outdoor industry standard from polluting to contributing.

2015: As the first company globally we take the decision to use the Planetary Boundaries framework as the scientific base for our environmental work and to perform a pilot study in partnership with earth system scientists to assess our company footprint.

2016: The Houdini Menu project is initiated, putting our organic products to the ultimate test. By composting them we could prove they are pure enough to contribute to fertile soil for growing food. Voilà, a fine dining menu made from worn-out base layers.

2017: With Rollercoaster, we take on the holy grail of shell layers, introducing the Made to move concept, a progressive way of designing and cutting garments, creating groundbreaking freedom of movement and enabling us to eliminate stretch fibers.

2018: We finally reach our goal 100% fluorocarbon-free! After 8 years of innovation and co-creation, lab- and field-testing, transitioning and implementation we have succeeded with this critical transformation and joined forces with our partners to make it happen.

04. Our plan ahead

Planetary Boundaries Assessment 2018

Photo: Erik Nylander

HOUDINI

Our roadmap towards 2020 and beyond

Our goal is to have 100% circular products in our collection by 2022. Photo: Linus Meyer, Romsdalen, Norway

AT THE END OF 2016 we finalized a roadmap for our journey ahead. The final details to the plan, including some big, hairy and audacious goals, were co-created by the entire Houdini team and a selected few inspiring dreamers, thought-leaders and change-makers in the beautiful nature reserve Nordmarka, just outside Oslo in our neighboring country Norway.

We left Nordmarka with a bold plan and a promise to the future and to ourselves that will keep us busy the next few years.

WE HAVE COME FAR in the transformation we envisioned – to eliminate our negative footprint while enabling and inspiring a healthier and happier lifestyle on a thriving planet, for us and for future generations. Along the way we have come to realize that in order to reach our vision, we will have to break free from the status quo of the current system and co-create a new one, where our core values of doing good, playing hard, pushing boundaries and having fun form keel and rudder. Our sense of urgency is easy to understand when seeing the state of the planet and the prevailing lack of will power, guts and action to change course. Seeing the untapped potential, vast opportunities and abundant value in this transition, makes us all the more motivated.

Honoring our commitment to the Stetind Declaration and saluting its co-author and our friend Nils Faarlund, we will move towards our vision with uncompromising speed. We will keep moving mountains, climb others and celebrate the beauty of nature and the myriad of life it sustains.

We left Nordmarka with a bold plan ahead and a promise to the future and ourselves.

Our big hairy audacious goals towards 2020 and beyond:

Mimic nature in a digital eco system

In order to eventually reach our circular and regenerative vision we are building a digital eco system, mimicking the natural system. Only with an accurate and transparent flow of data can we build a value chain catering to the exact demand as well as assess value chain impact in a transparent and automated manner. By enabling an equally effective flow of products being accessed and shared rather than owned, we can provide a viable and truly superior alternative to ownership.

By enabling an all direction sharing of knowledge and ideas customers and end-users can turn into activists for the societal transition we envision.

By 2025 we aim to have eliminated all waste throughout our entire value chain. Photo: Anna Öhlund, Rapadalen, Sweden.

By 2022

- We will provide 100% value chain traceability and transparency.
- We will have an IoT solution in place to guide to product care, reboot and repairs and automate recycling.
- We will have a 100% integrated inventory solution in place.
- We will enable a100% connected community for end-users to turn activists.

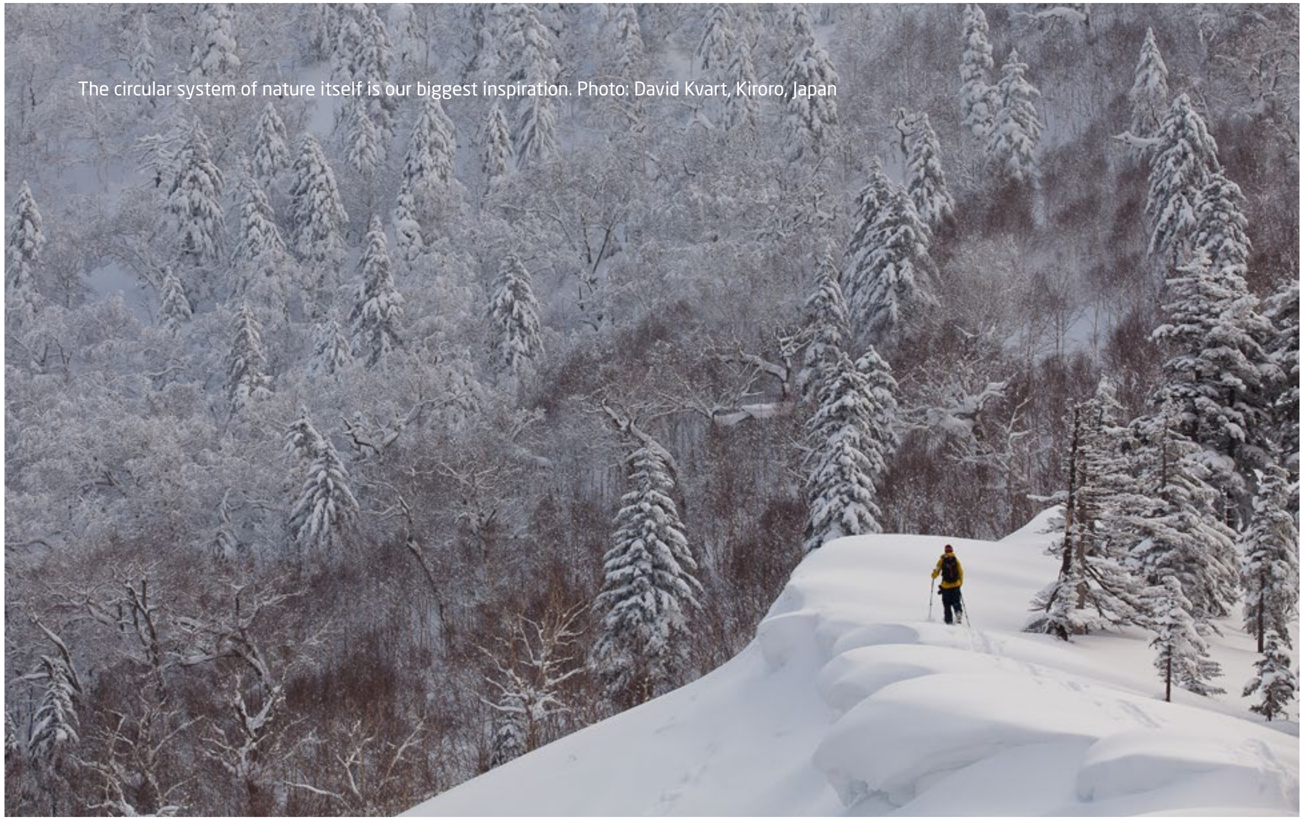
Reconnect humanity to nature

For a multitude of reasons we will strive towards reconnecting to nature – starting with ourselves and our community of friends and partners, inspiring society to do the same. We will develop our business in partnership with nature and technologies mimicing and supporting nature.

We will inspire and guide people into nature, spreading the tradition of ”friluftsliv” and the spirit of ecosophy and provide access to our products making the experience of the great outdoors great. We will manifest mankind’s freedom to roam just as we will speak for nature and its intrinsic value and awe-inspiring beauty.

By 2022

- We will have 100 000 end-users, followers and fans turned activists.
- We will have enabled exponential growth in the number of experiences of nature with the same use of resources through product-as-a-service solutions.
- We will have local hangouts to guide, educate and inspire to reconnect to nature worldwide.



The circular system of nature itself is our biggest inspiration. Photo: David Kvart, Kiroro, Japan

We will develop our business in partnership with nature.

Go 100% circular with nature as the blueprint

We choose to see the resources we use as resources borrowed from the planet and Houdini as the custodian of these, therefore responsible for handing them back to the planet and future generations in good shape. Therefore we intend to go 100% circular with nature as the blueprint for our circular principals.

By 2020:

- 100% of what we have identified as transitional fibres will be transitioned into recycled alternatives.

By 2022:

- 100% of our products will be circular – made from recycled or biodegradable fibers and recyclable or biodegradable at end-of-life.
- We will have initiated the use of novel regenerative textile fibers such as ocean, land and air PCR waste.
- We will have designed a next generation industrial symbiosis solution turning waste to resource.

By 2030:

- 100% of our value chain will be circular.
- 0% of our resources will be taken from the earth's crust.
- We will have eliminated the concept of waste throughout our value chain.
- +20% of our textile fibres will be novel regenerative, such as ocean, land and air PCR waste or from next generation industrial symbiosis solutions turning waste to resource.
- 100% of raw materials used for trimmings, dyestuff, process and treatment chemicals in our value chain will be recycled or renewable.
- We will have eliminated our contribution to micro plastics.
- 100% renewable energy will be used across our value chain.
- We will move beyond net zero towards a regenerative value chain in symbiosis with nature.

By 2066:

Celebrating the 100-year anniversary of the Stetind Declaration and the 50-year anniversary of the Houdini roadmap towards 2020 and beyond, we have disrupted the old and moved on to a new system where nature and society are in harmony and life flourishes.

05. Our promise

Planetary Boundaries Assessment 2018

Photo: David Kvart

The Houdini Manifesto

Stockholm, November 2017

We are driven by a deep love for nature and the experiences it gives us. We also believe that nature has an intrinsic value, regardless of human needs.

We acknowledge that human activities have created a dire situation for the planet we live on. Companies have a big part in this, and therefore a big responsibility.

The current system, where products are produced, used and discarded at an ever-increasing pace, is not working. Our mission is to transform into a circular system in harmony with our world. Nature itself is the blueprint.

Every resource we use is borrowed from nature and we will therefore treat it carefully.

We will fight overconsumption.

We will contribute to the development and implementation of sustainable technology.

We will collaborate with others and share our knowledge. We will speak for nature when no one else does.

We will question our own way of working and evolve to address the challenges we face.

We will encourage free thinking and individuality among ourselves.

Environmental, social and economic factors are interdependent and system change depends on all of them.

Our work is fueled by passion and therefore we take our passions seriously. We will keep exploring the world around us. When it snows, we will go skiing. When there's surf, we will go surfing. We will keep falling in love with nature, and we will bring our friends with us. We will never stop having fun.

We will keep working to minimize our negative footprint, move beyond zero, and leave an entirely positive impact on the world.

HOUDINI

albaeco

mistra future fashion

RISE

Planetary Boundaries analysis for Houdini Sportswear – a Pilot Study

Assessment of company performance from a planetary boundaries perspective

A cooperation between Houdini Sportswear, Albaeco and Mistra Future Fashion. **Authors: Marika Haeggman, Fredrik Moberg, Gustav Sandin**

Content:

1. Introduction

This is to our knowledge the first ever corporate Planetary Boundaries analysis. It is an explorative collaboration between Houdini Sportswear, Albaeco and Mistra Future Fashion with the long-term ambition to create an open-source approach that will provide Houdini and other similar companies with a more holistic view on their sustainability efforts. Albaeco is closely tied to the Stockholm Resilience Centre (SRC) an international research centre for sustainability science at Stockholm University, known among other things for its work on planetary boundaries, resilience and ecosystem services.

This report aims to operationalize the Planetary Boundaries framework in a business context. The framework was established in 2009 when a group of scientists (Rockström and others, 2009) identified nine global environmental boundaries we should remain within so that our societies can continue to develop in a positive way. As such the Planetary Boundaries provide a holistic way of analysing sustainability that has acquired international recognition and contributed to the UN's Sustainable Development Goals (SDGs). Rather than a narrow focus on for example water, chemicals or energy use, a planetary boundaries approach implies covering a larger set of critical environmental factors.

The manufacturing and consumption of clothes, like every other industry, plays a role in relation to all of the nine boundaries. For example, cotton is one of the most pesticide and water demanding crops grown; chemicals used when treating fabrics risk polluting water downstream from factories; and shell layer garments are often produced using compounds that stay in the environment indefinitely and accumulate in the fatty tissues of wildlife and humans.

Albaeco, Houdini and Mistra Future Fashion believe that analysing the textile industry from a Planetary Boundaries perspective is an important part of a larger ambition to integrate scientific analysis and resilience thinking into projects focused on accelerating business solutions for sustainability.

2. Background

2.1 About Albaeco

Albaeco has been working since 1998 with strategic environmental communication, science communication, consulting and environmental training for companies. The organisation is connected to an extensive network of international researchers from both the natural and social sciences, through close collaboration with the Stockholm Resilience Centre, based at Stockholm University. Albaeco is an active partner of the Centre and communicates research findings to the media, politicians, government agencies and resource users at local, regional and international levels. For more information: www.albaeco.se.

2.2 About Houdini

Houdini Sportswear is a Swedish company that designs, markets and provides gear and services to enable great outdoor experiences. The company is built around a passion for the outdoors and a commitment to preserving it. Houdini aims to meet challenges like global warming, novel entities pollution and biodiversity depletion head on, striving to create solutions. Houdini draws inspiration from nature and the circularity of ecosystems, and are working to become a regenerative company, with fully circular operations and production throughout the value chain, including everything from design and production to sales and distribution to use, reuse, remake and recycling.

2.3 About Mistra Future Fashion

Mistra Future Fashion is a research program on how to make the fashion industry more sustainable by a systemic change of design, production, use and recycling processes. Guided by the principles of the circular economy model, the program operates cross-disciplinary and involves 50+ partners from the fashion ecosystem. Its unique system perspective combines research on business models, policy, consumer behaviour, life cycle assessments, systems analysis, material chemistry, engineering, and more.

Mistra Future Fashion is funded by Mistra, The Foundation for Strategic Environmental Research, and coordinated by RISE Research Institute of Sweden, a leading international research institute. For more information: www.mistrafuturefashion.com.

2.4 The science behind the planetary boundaries

The Earth we live on and the world we live in are inextricably interconnected – though we might not always see the connections very clearly (e.g. Folke and others, 2011). In the urbanized and globalized world fewer and fewer people directly experience their fundamental dependence on a functioning Earth system (see box 1. for explanation) on a daily basis – yet there are no people who do not rely on ecosystems and the services they produce. Today it is also a fact that there are no longer any ecosystems that have not been affected and shaped by people (e.g. Steffen and others, 2011; IPCC 2013).

The term "Earth system" refers to Earth's interacting physical, chemical, and biological processes. The system consists of the land, oceans, atmosphere and poles. It includes the planet's natural cycles – the carbon, water, nitrogen, phosphorus, sulphur and other cycles – and deep Earth processes. Source: www.igbp.net

There is no longer scientific doubt that human activity is causing the Earth's biogeophysical systems to change. Geologists are arguing that humanity's impact on the Earth is now so profound that a new geological epoch – the Anthropocene (the age of humans) – needs to be declared (Waters and others, 2016). The epoch of the last 12,000 years, the Holocene, has been characterised by stable climate since the last ice age during which all human civilisation developed.

Science tells us that we for the first time ever face catastrophic environmental risks on a planetary level, but also that there seldom has been such great potential for shifting mindsets, transformative change and innovations that can allow us to avoid serious threats and change the world for the better (e.g. Figueres and others, 2017).

In 2009 a group of 28 prominent scientists (Rockström and others, 2009) identified nine global environmental boundaries we should remain within so that our societies can continue to develop in a positive way – without facing catastrophic threshold effects in the environment and climate. When the updated version of the framework was published in 2015 the nine boundaries remained the same, though some were given new names, and the research shows that we have crossed four of them (Steffen and others, 2015; see figure 2. below).

The nine Planetary Boundaries processes identified are: (1) climate change, (2) pollution by novel entities, (3) stratospheric ozone depletion, (4) alteration of atmospheric aerosols, (5) ocean acidification, (6) perturbation of biogeochemical flows (nitrogen and phosphorus inputs to the biosphere), (7) unsustainable freshwater use, (8) land-system change, and (9) changes in biosphere integrity (or destruction of ecosystems and biodiversity).

Out of the nine global processes they identified, the research team initially proposed boundaries for seven. For climate change, for example, they argue that carbon dioxide levels should not rise above 350 parts per million (ppm) in the atmosphere if we are to remain in what they term the "safe operating space." This boundary is consistent with a stabilization of global temperatures at about 1.5 degrees Celsius above pre-industrial levels. At this level research suggests that humanity faces climate adaptations, but that the risk of catastrophic shifts is not imminent. However, carbon dioxide

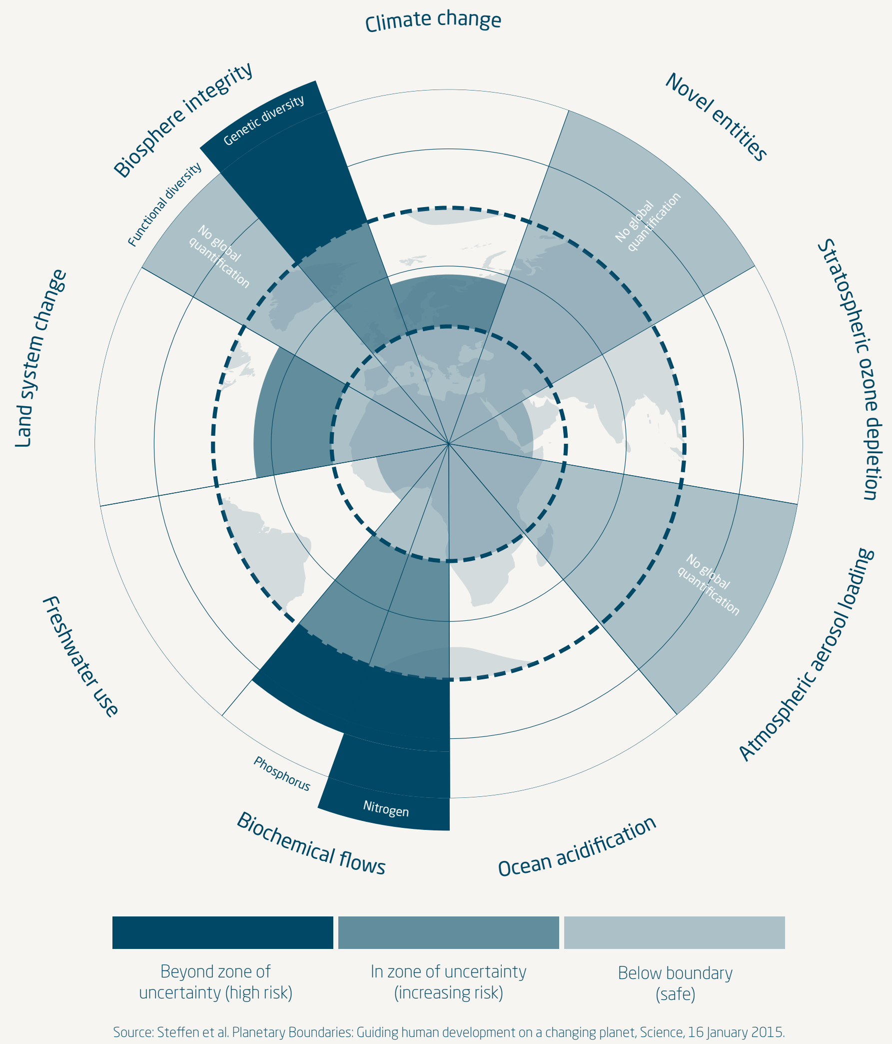


Figure 2: Planetary Boundaries The light blue zone is the safe operating space (below the boundary), medium blue represents the zone of uncertainty, with an increasing risk of disrupting Earth system stability; and dark blue is the high-risk zone, pushing the Earth system out of a stable Holocene-like state. The Planetary Boundary itself lies at the dotted line (Steffen and others, 2015).

levels have already risen into the more risky "zone of uncertainty." Atmospheric concentrations of carbon dioxide are currently about 400 ppm and growing at about 3 ppm per year.

But it is not just about the climate. In the updated planetary boundaries analysis Steffen and his colleagues (2015) point out that the boundaries for loss of plant and animal species and nutrient concentrations in the oceans and land, as well as the boundary for land system change through for example deforestation, have also been crossed. The researchers also emphasize that the boundaries are strongly interlinked – crossing one boundary is likely to threaten the ability to stay within safe levels for several of the other ones.

In the analysis from 2015 Steffen and colleagues also identified two boundaries, climate change and biosphere integrity, as "core boundaries". These core boundaries are affected by and drive changes in all the other boundaries, making them central to the concept.

The planetary boundaries concept is based in resilience theory and Earth system science (e.g. Folke and others 2011; Steffen and others 2011), and provides a new understanding of the most pertinent global environmental challenges by analysing the risk of crossing critical thresholds in the behaviour of the Earth's climate and ecosystems. The criteria for identifying planetary boundary processes was that they can be associated with some kind of threshold, or "tipping point", beyond which the planet and its ecosystems might enter new states, some of which are likely to be less hospitable to our current societies, and that this process is possibly irreversible. Boundaries were then set at what was considered to be a "safe distance" from the estimated threshold, using the best available science and the precautionary principle.

It is worth noting that the planetary boundaries framework is still evolving and that it has triggered some scientific and broader debates, where some criticisms have been presented (e.g. Lewis, 2012). Nevertheless, the planetary boundaries concept is increasingly perceived as a useful integrating framework for illustrating the risks of human interference with the Earth's climate, ecosystems and natural cycles through our patterns of consumption and production (WWF, 2016).

One benefit of working with the planetary boundaries framework is that it offers a more holistic approach than many other tools for analysis. Rather than focusing solely on for example water, chemical or energy use, a planetary boundaries assessment needs to cover a multitude of critical factors. It also sets new frames for what should be assessed and how. If the goal is, as we believe it should be, not simply to minimize negative impacts but rather move into a "regenerative economy" where human activity can be a positive force on the planet, the planetary boundaries can be seen as mapping out crucial space for such action.

2.5 Planetary boundaries and the outdoor clothing industry

The planet's climate and environment are of course affected by how we produce, transport, wash, dye and dry, as well as recycle and dispose, our clothes. In one way or another, the clothes we wear are connected to each of the nine planetary boundaries (e.g. Roos and others, 2015; Zamani, 2016; Roos and others, 2017).

Different materials will relate differently to the nine boundaries. Take for example a t-shirt or a pair of trousers, made of cotton. Cotton is one of the most pesticide (boundary 2) and water (boundary 7) demanding crops grown. To produce the large amounts of chemical pesticides and fertilisers (boundary 6) used in conventional cotton cultivation, generally requires a lot of fossil fuels. Crude oil is also used in the production of synthetic material like polyester, polyamide and acrylic. The resulting carbon dioxide emissions not only affect our climate (boundary 1) but also lead to increasing ocean acidification (boundary 5) and potentially increased concentrations of aerosols in the atmosphere (boundary 4). Since cotton farming is often very intense and based on genetically modified cotton grown in large monocultures, it also affects biodiversity (boundary 9) and land use (boundary 8). It is the same with many other fibers grown for manufacturing clothes. The use of fertilisers might also entail increased emissions of laughing gas (nitrous oxide), which has become the most important ozone-depleting gas (boundary 3) after chlorofluorocarbons (CFCs) were phased out in the late 1990s.

In addition to all this, and specifically linked to outdoor clothing, some textiles have been treated with substances like perfluorooctane sulfonate (PFOS). PFOS gives the garment water- and stain repellent properties, but is also a persistent pollutant (boundary 2). In the European Union, production and use of PFOS is illegal for most applications since 2006, but it has since been replaced with compounds with very similar chemical structures, whose potential environmental impacts are not fully known.

The clothing industry's effects on the nine planetary boundaries are further elaborated below:

1. Climate change

Climate change is accelerated by the emission of greenhouse gases, notably carbon dioxide and methane, from land use change and the burning of fossil fuels in for example industries, agriculture, homes and the transport sector. The increasing concentration of greenhouse gases traps heat in the atmosphere and is causing global warming.

Every year the global textile industry delivers close to 100 million metric tonnes of new products to the market (Roos, 2016). The sheer size of the textile industry and the high-intensity production of materials imply that textile manufacturing is one of the biggest emitters of greenhouse gases, accounting for nearly 10 percent of global emissions according to some analyses (Zaffalon, 2010). In Sweden, however, Roos and others (2016) come to the conclusion that Swedish consumption of clothes account for about 2.5 % of the country's carbon footprint. Climate effects from the clothing industry are complex and happen in many different places along the long and varied supply chains of production, raw material, textile manufacture, clothing construction, shipping, retail, use, recycling, and disposal of the garments. Most of the greenhouse gas emissions come from the fossil fuels used to produce energy along the supply chains.

Fast fashion and the enormous increase in the consumption of clothes means that the impact on climate (and impacts on the other planetary boundaries) is growing. The number of garments produced annually has doubled since the year 2000 and exceeded 100 billion for the first time in 2014: nearly 14 items of clothing for every person on earth (Remy and others, 2016).

2. Novel entities

Chemical pollution causes large scale disturbances in ecosystems worldwide. Major sources of pollution are industries and agriculture. The effects of the chemicals emitted and the levels at which they become toxic to humans and other organisms are often unknown, and taking synergy effects from different chemicals into account the lack of data is even bigger. Novel entities include chemicals emitted, but also particles such as micro plastics.

A range of chemicals are used in the production of clothes. Other than emissions to the environment, workers along the supply chain in the industry are also at risk of being exposed to toxic substances. (e.g. Munn, 2011). For example, several allergenic and carcinogenic dyes that are banned in EU are still used in many parts of Asia. Several potentially toxic substances are also used in the cultivation and spinning of fibres and in the weaving or knitting of fabrics. Fabrics are also treated with chemical substances to produce desirable properties in fabrics such as flame retardation and water and dirt resistance. To protect the fabrics during transport different kinds of anti-mold agents are also often added. Some of the most highlighted textile chemicals that might be toxic to humans and the environment are per- and polyfluoroalkyl substances (PFAS), nonylphenol ethoxylates (NPEO) and phthalates (Roos, 2016). In addition, chemical pollution by plastic waste, from e.g. micro plastics, tiny plastic particles released when washing synthetic fabrics (e.g. acrylic and polyester), is emerging as a serious human-driven disturbance to the Earth system. Plastic waste in the marine environment has become a global, ecologically systemic problem, and even though knowledge about the impacts on ecosystems is still incomplete, it is clear that both direct and indirect effects are causing damage (Persson and others, 2013; WWF, 2016).

3. Stratospheric ozone depletion

The ozone layer has an important function in that it absorbs harmful UV rays from the sun. In the 1980's researchers discovered that the ozone layer was thinning, and the cause could be traced back to the emission of chlorofluorocarbons (CFCs) at the time commonly used in cooling elements in refrigerators. The Montreal protocol banned the use of CFCs in 1987 and they have since been phased out, but certain compounds that have an ozone depleting effect are still in use today.

Synthetic fertilisers are often used in the production of textiles. As fertilisers are broken down by soil bacteria nitrous oxide (N_2O) is produced. Since the phasing out of CFCs, nitrous oxide has become the most ozone-depleting substance emitted by humans (Ravishankara and others, 2009). However, food production is responsible for most (80%) of the increase in atmospheric nitrous oxide (N_2O) in recent decades (Ciais and others, 2013). Since the late 1990s, Earth's ozone layer – both the polar hole and the atmospheric layer around the whole planet – has been on the mend. But the emission of nitrous oxide, which is not regulated by the Montreal Protocol, could reverse those gains – and could even make the situation worse. Another potential ozone depleting activity relating to the textiles industry is when clothes are dry cleaned, since dry-cleaning agents might still contain CFCs.

4. Stratospheric aerosol loading

Aerosols are small particles in the air that harm human health and affect the climate (Ramanathan and others 2005). They are often sulfur-based and are formed in particular in the combustion of coal.

All processes in textile production that require energy input, including transports, can to some degree emit aerosols. Import of clothes produced in countries where electricity is still produced from coal or diesel ultimately might mean that the dirty production has left the country where the clothes are consumed and that environmental impacts of aerosols and other emissions have moved far beyond the consuming country's borders. For instance, a large part of global textile production takes place in China where energy is often produced from coal causing severe human health and environmental problems. China's coal use has, however, decreased in recent years and its national carbon emissions are reported to also have decreased as a result.

5. Ocean acidification

The world's oceans are home to a vast number of species, produces half of the oxygen in the atmosphere and are important carbon sinks. As such, marine ecosystems maintain many vital functions that humans rely on. Carbon dioxide and other gases in the atmosphere are absorbed by the ocean to create an equilibrium between concentrations in air and water. As carbon dioxide is dissolved it forms carbonic acid, making the oceans increasingly acidic. This acidification can have detrimental effects on marine species and cause disturbances in marine ecosystems. The more acidic the oceans become, the harder it will be for corals and other organisms to build their skeletons or shells from lime. If carbon dioxide emissions continue at the same pace as now the oceans will become so warm and acidic that coral reefs will disappear almost entirely by 2050 according to some scientists' forecasts (Hoegh-Guldberg and others 2015).

As mentioned above, production of textiles tends to lead to large emissions of carbon dioxide and other compounds that could contribute to ocean acidification.

6. Biochemical flows

One of the major threats to oceans and lakes around the world is eutrophication, which, among other things, is causing algal blooms and dead (oxygen-deprived) zones (e.g. Carpenter, 2005). The textiles industry's impact on this boundary is mainly in the runoff of different nitrogen and phosphorus compounds from fertilisers used to grow different kinds of fibre crops. However, the washing of clothes can also be problematic, as laundry detergents sometimes contain phosphates. In response to the deteriorating health of the Baltic Sea Sweden and many other Baltic countries have banned detergents containing phosphates. Other than agriculture, transportation is another source of nitrogen as nitrogen oxides and ammonia are produced when fossil fuels are burned. This contributes to the formation of smog and acid rain, but excess nitrogen in the atmosphere is also deposited back onto land, where it washes into nearby water bodies.

7. Freshwater use

In many places in the world fresh water is a scarce resource. By 2050, at least one in four people is likely to live in a country affected by chronic or recurring shortages of fresh water (UN, 2015). The water that is used for cooking, drinking, washing and other household needs constitutes only a small share of the water we use and actually water for irrigation in agriculture constitutes one of the greatest pressures on freshwater resources. A balanced diet, for instance, represents a water use per capita which is 70 times more than the 50 litres per day used to indicate the basic household needs of water (SIWI-IWMI, 2004).

Producing the cotton needed to make a single small t-shirt requires, on average, more than 2000 litres of water. That is, typically 7,000 to 29,000 litres of water (averaging about 10,000 l) are required to grow one kilogram of cotton (Cherrett and others, 2005). How such extensive water use can affect the water supply in an area was severely felt by the people around the Aral Sea in the 1960s when the then Soviet leadership gave a directive that the region was to expand its cotton crops. To get enough water to irrigate the cotton cultivation two rivers, that had been supplying the lake with water, were diverted. The Aral Sea was since the fourth largest lake on Earth but by the 1960's it had decreased in size by 90%. As the water levels recede the salinity in the remaining water has risen, causing problems in the lake's ecosystems. Though some restoration efforts have been successful, in 2014 the entire eastern basin of the lake had dried up and become a salt desert. Other fibres also require water, of course, but cotton is the thirstiest of them all (Defra 2010). According to Roos and others (2016) an effective intervention to reduce water consumption is to replace cotton with either forest-based or recycled regenerated cellulose fibres.

8. Land-system change

Across the planet land is increasingly being converted for human use. Forests, wetlands or grasslands are turned into farmland, shrimp-ponds or cities. In the updated planetary boundaries report (Steffen and others, 2015) the research team could conclude that humanity has moved out of the safe operating space for land use change. This means that we have reached, or even crossed, a point where further deforestation and expansion of agricultural land and urban areas could seriously threaten biodiversity, climate and water resources at the global level.

Large-scale cultivation of textile fibres is one factor that drives land use. Cotton cultivation is one example where the impact is rather clear: cotton is often grown in large monocultures that require chemical pesticides, fertilisers and irrigation, creating a land system very different from what was there before, most often low in diversity and with few other values than the crop that is grown. Other fibre production may have a less clear impact on land systems. For example, wool production also requires large areas of land, but grazing sheep can in fact contribute to conservation values and restoration of grasslands if the production system is well managed. Wool and merino wool sourced from sustainably grazing animals can in that way even have a positive impact on land use as important and valuable landscapes might be preserved (e.g. Kviseth, 2011).

9. Biosphere integrity

Today, the extinction of plant and animal species is at least 100 to 1,000 times faster than the natural, baseline levels (Pimm and others, 2014). Many local species of plants have been lost and with them important ecosystem services and properties which could strengthen agriculture's chances to cope with environmental and climatic changes. Our clothes are one of the culprits. Not least, cotton plantations, often based on a few varieties of cotton grown in large monocultures. Biodiversity conservation and textile production can, however, be combined. One example is the often cited collaboration between Patagonia, The Nature Conservancy and Ovis 21 between 2011 and 2012. The original idea was that Patagonia would commit to buy sustainable merino wool as long as it was certified and the producers were keeping and restoring the biodiversity of the natural grasslands. This pilot project was never implemented in full-scale, but the intentions were promising and similar projects would certainly be worth exploring in the future. Shipping of clothes can also indirectly lead to the spread of invasive species in ballast water, that may cause ecosystem and infrastructure damage, economic losses and may pose risks to human health. Impacts on all of the other planetary boundaries have indirect effects on biodiversity, relating for example to habitat loss due to land system change or negative effects from climate change and emitted pollutants to land, air or water.

2.5 Social boundaries and the UN global goals

As a further development to the Planetary Boundaries, and to visualize sustainable development, the development economist Kate Raworth complemented the framework with 'social boundaries' to emphasize that realising the human rights of all is an equally important aspect of human flourishing. Raworth added the social boundaries to the planetary boundaries framework, so turning its circular 'safe operating space' into a doughnut-shaped 'safe and just space for humanity'. The planetary boundaries delimit the ecological ceiling within which humanity's collective activity must remain, and the social boundaries provide the basis of dignity and opportunity for every person.

The 12 social boundaries, which were derived from the 2015 UN Sustainable Development Goals, have been analysed for the textile and clothing industry and the results show that the most significant social risks are related to wage, child labour, and safe working conditions (Zamani and others 2016).

This study of Houdini Sportswear from a planetary boundaries perspective does not explicitly focus on the social aspects, but some basic social indicators for the company's suppliers were included in the questionnaire and are presented in Appendix II.

Building on the outcome from the Rio+20 conference the 193 countries of the UN General Assembly adopted the 2030 Development Agenda for Sustainable Development in September 2015 (United Nations, 2015). The agenda outlines 17 Sustainable Development Goals (SDGs) and 169 associated targets. Both the goals and the targets can be seen as a network, in which links between goals are reflected

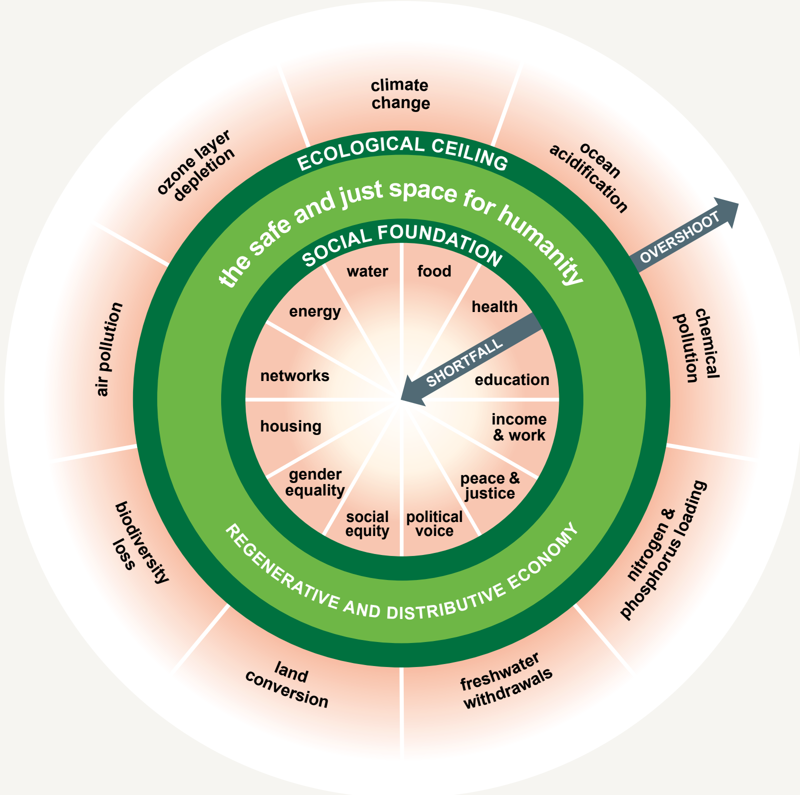


Figure 3: "The doughnut" illustrates the planetary boundaries humanity must remain within and the social floor which should be steady beneath everyone's feet. (image from: Oxfam, inspired by Rockström et al (2009)

in targets that refer to multiple goals. As such, the SDGs as a whole make up a more integrated system than their precursors, the Millennium Development Goals (MDGs), did. Hence, ecological and social goals are increasingly viewed as interlinked and part of inseparable social-ecological systems. Another difference between the MDGs and the SDGs is that the latter are universal goals and targets which apply to the entire world, developed and developing countries alike. The SDGs call for a new view on what development needs to be, and redefines all countries as developing countries.

Moreover, the SDGs explicitly call on all businesses to use their creativity and innovation to solve sustainable development challenges (United Nations, 2015). In order to guide companies in taking a strategic approach to the SDGs a tool called the "SDG Compass" has been developed jointly by (Global Reporting Initiative (GRI), the UN Global Compact and the World Business Council for Sustainable Development (WBCSD).

To clearly show that all human development must respect the planet's boundaries, Stockholm Resilience Centre has proposed a new way of viewing the economic, social and ecological aspects of the Sustainable Development Goals (SDGs). The resulting conceptual figure (see below) divides the 17 SDGs in a way that clearly illustrates that the goals associated with our economies and societies are embedded parts of the planet's biosphere (represented in the figure by Goals 6 on freshwater, 13 on climate, 14 on oceans, and 15 on biodiversity).

This figure changes our paradigm for development, moving away from the current sectoral approach where social, economic, and ecological development are seen as separate parts. It calls for a transition toward a world logic where the economy should serve society so that it evolves within the safe boundaries of the planet's climate and ecosystems. In this worldview we talk about social-ecological systems as integrated, rather than about socioeconomic systems on the one hand and ecosystems on the other.

In Sweden companies also need to take the 16 environmental quality objectives into account. These objectives have been adopted by the Swedish Parliament and describe goals that are crucial to our welfare, and that are intended to guide the Swedish efforts to safeguard the environment. To attain these environmental objectives, everyone has a part to play – individuals, companies and authorities at every level.

As stated by the Swedish Environmental Protection Agency (2012): "Efforts by business to improve environmental performance – in terms of production, transport and technology development – are crucial to the prospects of realising the environmental objectives".

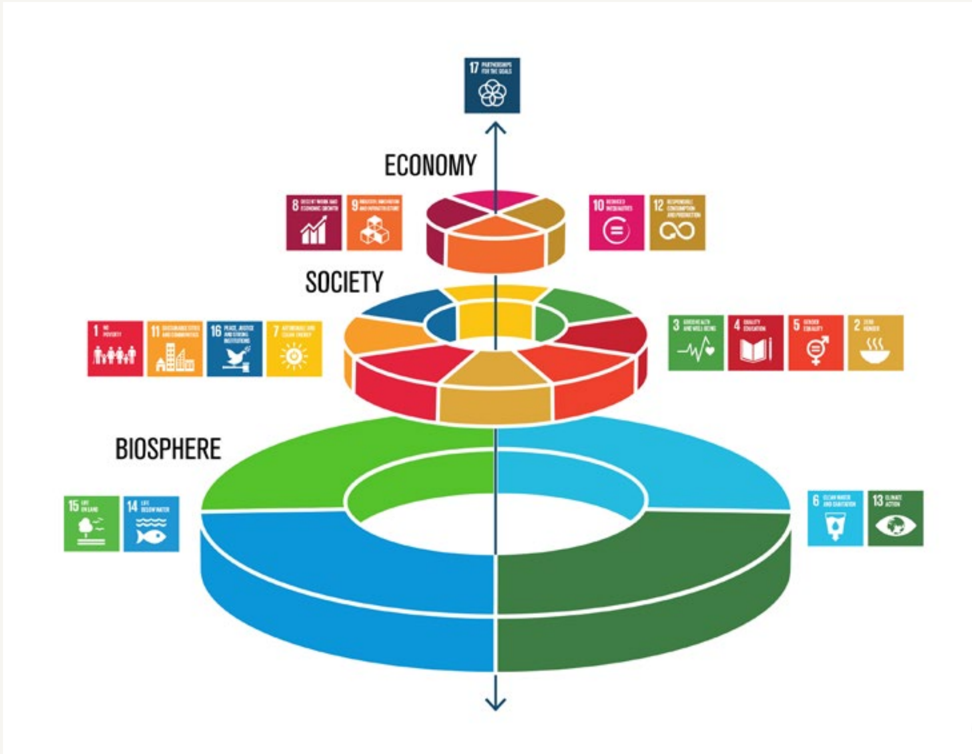


Figure 4: The 17 SDGs divided in a way that illustrates that the goals associated with economies and societies depend on the planet's biosphere (represented by Goals 6 on freshwater, 13 on climate, 14 on oceans, and 15 on biodiversity). (Illustration: Azote Images for Stockholm Resilience Centre)

The 16 environmental quality objectives are:

1. *Reduced Climate Impact*
2. *Clean Air*
3. *Natural Acidification Only*
4. *A Non-Toxic Environment*
5. *A Protective Ozone Layer*
6. *A Safe Radiation Environment*
7. *Zero Eutrophication*
8. *Flourishing Lakes and Streams*
9. *Good-Quality Groundwater*
10. *A Balanced Marine Environment, Flourishing Coastal Areas and Archipelagos*
11. *Thriving Wetlands*
12. *Sustainable Forests*
13. *A Varied Agricultural Landscape*
14. *A Magnificent Mountain Landscape*
15. *A Good Built Environment*
16. *A Rich Diversity of Plant and Animal Life*

In addition to the 16 environmental quality objectives there is an overarching goal in Swedish environmental policy, the so-called Generational Goal: "to hand over to the next generation a society in which the major environmental problems in Sweden have been solved, without increasing environmental and health problems outside Sweden's borders".

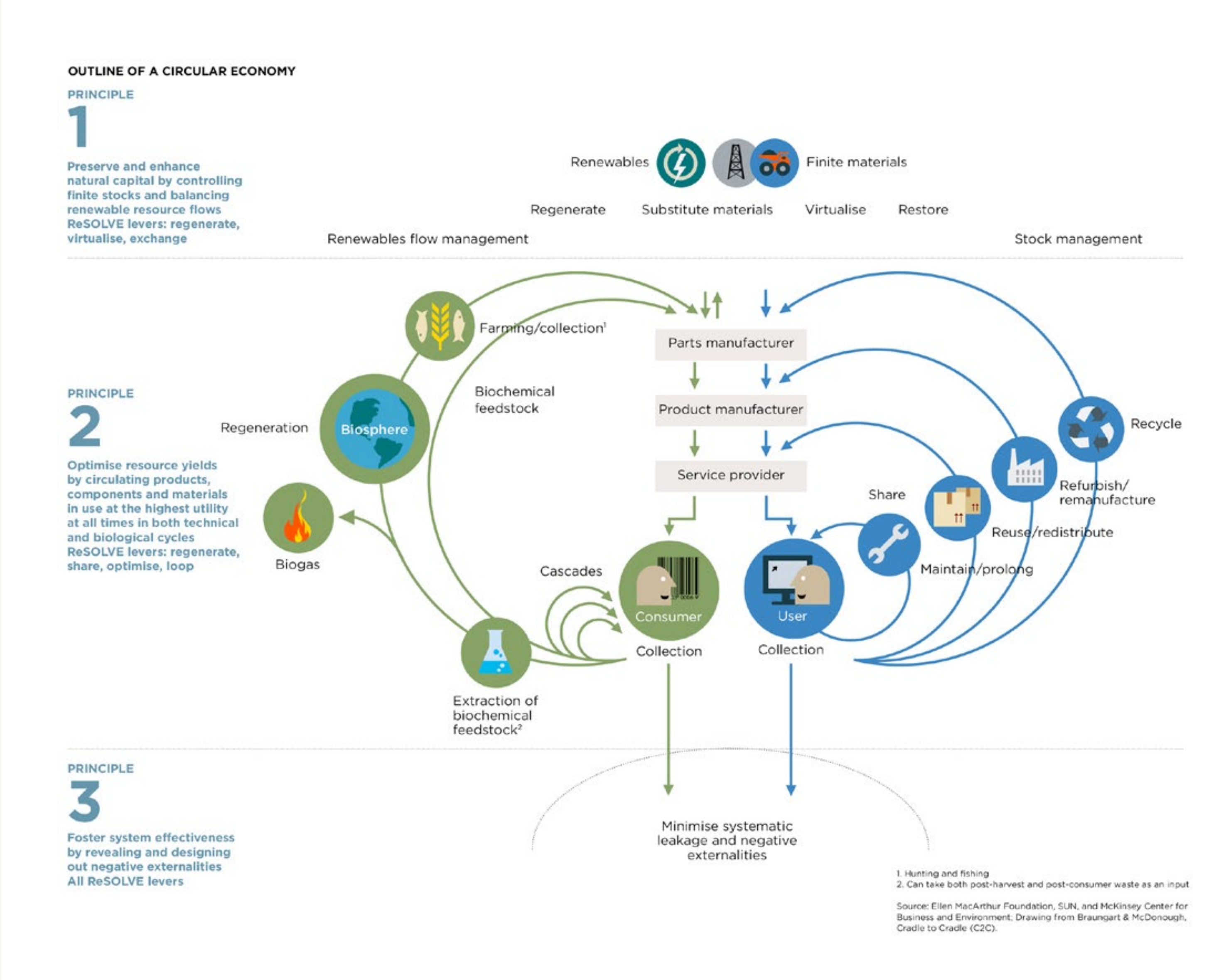


Figure 5: Outline of a circular economy framework, as depicted by Ellen MacArthur Foundation. This is the kind of business model that Houdini aims to be a part of striving for a 100% circular business focused on recycling, reuse, repair and rental.

3. Analysis

3.1 Current sustainability work at Houdini from a planetary boundaries perspective

Houdini Sportswear is already engaged in sustainability issues and view this work as an integrated part of their business model. Below we briefly describe a selection of their efforts, such as certification, rentals, repairs and recycling, and assess them qualitatively from a planetary boundaries perspective (table 1).

We base our assessment of the intended impact of a tool or method as relevant/positive (+) or very relevant/very positive (++) on the measures included and the stated intent. Bluesign®, for example, has as its stated purpose to decrease chemical use and energy and water consumption. Decreased chemical use reduces the pressure on the novel entities boundary and energy savings lead to lowered carbon dioxide (CO_2) emissions, which impacts the climate and ocean acidification boundaries. However, the label does not specifically take measures to protect biodiversity or minimise impact on nutrient flows or land-use change. As the boundaries are all connected, impacts on one will often have an effect for others as well, however we do not consider these kinds of positive by-effects enough to reward a positive impact in this qualitative assessment.

	Climate change	Novel entities	Stratospheric ozone depletion	Atmospheric aerosol loading	Ocean acidification	Biogeo-chemical flows	Fresh water use	Land-system change	Biosphere integrity
Recycled fibres	+	+	+	+	+	++	++	++	++
Repairs	++	++	++	++	++	++	++	++	++
Rental	++	++	++	++	++	++	++	++	++
Reuse	++	++	++	++	++	++	++	++	++
Long lasting products (style and endurance)	++	++	++	++	++	++	++	++	++
BlueSign	+	++			+	?	+		
pH Pure™		++							

Table 1: A selection of Houdini's sustainability efforts and their relevance for the different planetary boundaries. The intended impact of a tool or method is assessed as relevant/positive (+) or very relevant/positive (++) based on the measures included and the stated intent.

The first five of the efforts in the table are Houdini's main strategies for reducing impacts: repair, reuse, rentals, creating long lasting products and styles, and using recycled fibres. All these five strategies impact on all of the boundaries as they lower the pressure on resource extraction. We, however, consider the positive impact of using recycled material as lower than that of repair, rent, reuse and long-lasting products, since recycling doesn't necessarily lead to a lowered use of natural resources and reduced emissions.

We also base this assessment on the assumption that the recycling is done according to best practices as research has shown that poor mechanisms for recycling materials can in fact cause them to be more energy demanding than the production of virgin materials (Zamani, 2016).

3.2 Houdini's current fibre use

As seen in the pie chart and table below virgin and recycled polyester (from PET bottles) constitute 33% each of the total fibre use (in kg), polyamide is the second largest with 20%, followed by wool with 13%. Elastane use constitutes 5% of the total use. These numbers are used below when choosing which fibres to focus on in the further analysis.

3.3 Selection of materials for this analysis

A total of six fibres were included in this pilot study. Three fibres were chosen on account of being the most used in Houdini's collections: virgin polyester, recycled polyester and polyamide. In addition to these we also chose to focus on fibres that have been identified by Houdini as potentially interesting for the future, to investigate what an increase of use would mean: lyocell and wool. As a reference fibre, we also include cotton in the analysis, as it is often depicted as an environmental villain and Houdini has taken an active stand to not use it in any of their garments.

Figure 6: Pie chart showing the most important materials Houdini use (2014.05.01-2015.04.30). Houdini labels 27% out of the 33% polyester "transitional", since they are currently converting from virgin to recycled fibres. Similarly, 15% out of the polyamide is being converted.

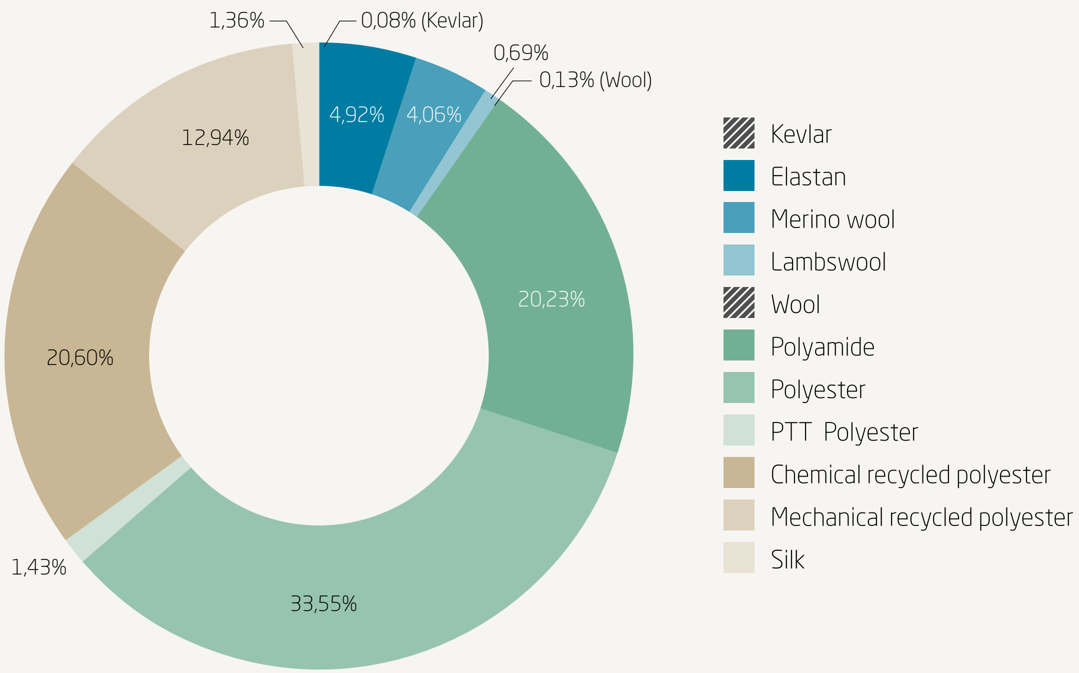


Table 2: Total consumption of fibres in kg and percent for Houdini during the period 2014.05.01-2015.04.30.

FIBRE	CONSUMPTION (KG)	CONSUMPTION (%)	FIBRE
Kevlar	44,72%	0,08%	Kevlar
Elastan	2846,14	4,92%	Elastan
Merino	2347,37	4,06%	Merino
Lambswool	396,24	0,69%	Lambswool
Wool	75,5	0,13%	Wool
Polyamide	11697,22	20,23%	Polyamide
Polyester	19401,34	33,55%	Polyester
PTT Polyester	828,13	1,43%	PTT Polyester
Chemical recycled polyester	11911,83	20,60%	Chemical recycled polyester
Mechanical recycled polyester	7484,64	12,94%	Mechanical recycled polyester
Silk	787,85	1,36%	Silk

3.4 Environmental impact of the selected materials:

Cotton

The environmental effects of cotton farming are notorious and have been investigated in a large number of previous studies (e.g. Cherrett and others, 2005; van der Velden and others, 2014). Conventional cotton is grown in large monocultures that cover vast areas of land and are treated with chemical pesticides and fertilisers to prevent crop losses to disease or pests and promote growth. Cotton is also a water-intensive crop often requiring extensive irrigation, and often grown in areas of the world where water scarcity is an issue.

When it comes to the release of greenhouse gases, LCA studies have reported considerable differences between different conventional cotton farms. For example, Wang and others (2015) studied farming in six different provinces in China, with impact per functional unit ("fibres for pure cotton shirt of weight 0.28 kg") spanning from 1.5 to 16.2 kg CO_2-eq. Other LCAs report numbers as low as 0.6 kg and as high as 6 kg CO_2-eq per kg of cotton (Muthu and others, 2012; Bevilacqua and others, 2014), and an attempt for a global average lands on about 1.9 kg CO_2-eq per kg (Cotton Incorporated 2012).

Organic cotton

In recent years several initiatives have emerged to find ways of producing cotton with a lower environmental impact. Organic cotton is produced from non-genetically modified seeds and without the use of pesticides or synthetic fertilisers, often using practices that aim to enhance biodiversity. Crop rotation and mixed cultivation are examples of methods that are used to increase soil fertility and decrease the occurrence of pests.

The Better Cotton Initiative (BCI) (bettercotton.org/) has attracted many larger clothing chains and other retailers who want to help move the industry towards more sustainable practices. BCI is not strictly organic, but is a step away from intensive conventional cotton farming. BCI promotes the adoption of Integrated Pest Management strategies, minimising input of synthetic pesticides and fertilisers but not necessarily eliminating them altogether. BCI-farmers are also required to care for the health of the soil, conserve natural habitats, use water effectively and promote decent work while promoting the quality of the fibre produced.

LCA studies have shown significant differences in impact between conventional and organic cotton. One study found that energy demands are reduced by 62% and the global warming potential, measured as CO_2 equivalents per tonne produced fibre, is lowered by 46% in organic compared to conventional cotton (Textile exchange, 2014). The acidification potential of organically grown cotton is also significantly lower, with a 70% decrease of SO_2 equivalents emitted, this could have implications for the ocean acidification boundary.

The same study (Textile exchange, 2014) concluded that water use, if rainfall is excluded, is reduced from 2120 m^3 per tonne cotton fibre in conventional cotton to 182 m^3 per tonne cotton lint fibre in organic production. As is stated in the study however, the need for irrigation is by and large a result of climatic factors and cannot be attributed only to organic farming methods. However, the big difference in irrigation shows that the geographic location of the production matters.

Polyester

In the textiles industry polyester is one of the most produced and used fibres. The fibre was produced for the first time in 1941 and because of properties such as stretch resistance, durability and low water absorption it has since then become a favourite synthetic fibre in fashion as well as industry. Polyester is used in everything from plastic bottles and tyre reinforcements to underwear and performance fabrics.

Virgin polyester is produced from crude oil through a process that is highly energy demanding and often causes emission of chemicals to both air and water, impacting several of the planetary boundaries: water, climate, aerosols, ocean acidification, and novel entities. The process includes breaking down long chains of hydrocarbons (cracking) in crude oil to make shorter and more useful chains; separating the different products of the cracking and chemically treating them to obtain desired polymers; and finally spinning the polymers into filaments, threads of fibre that can be used in fabric production.

Recent studies have highlighted potential dangers of microplastic emissions causing pollution in marine environments (e.g. Law and Thompson, 2014), for instance from tiny particles of polyester garments as they detach during laundry and are too small to be picked up in water treatment facilities.

Recycled polyester

Most recycled polyester is produced from plastic bottles. The general idea is to use plastic bottles that have passed through several cycles of consumer use and then been handed in and taken care of at a recycling station. In certain instances, however, it has been revealed that polyester recycling facilities have placed orders for unused plastic bottles to be delivered straight from the production industry (Oekotextiles, 2009). Needless to say, in this unfortunate case the environmental benefits of the recycled material are lost, and the resulting material has a worse environmental impact than virgin polyester due to the added production loop. There are two main ways of recycling polyester, mechanically and chemically.

Chemical recycling

DMT stands for dimethyl terephthalate, and it is the intermediate chemical in manufacturing of polyester. Patagonia has done a quantitative comparison of three possible "DMT manufacturing scenarios" together with Japanese supplier Teijin. The comparison evaluated the energy use and greenhouse gas emissions that result from the following three scenarios: (1) Virgin Process: Teijin's production of polyester from virgin materials; (2) Locally Recycled Process: Teijin's production of polyester using chemically recycled garments that were collected locally; and (3) Recycled Capilene Process: Teijin's production of polyester using Patagonia's chemically recycled Capilene garments that were collected in the US.

Their results for the production of fibres were:

- Virgin Process = 4.18 metric tons CO_2/metric ton of DMT
- Locally Recycled = 0.98 metric tons CO_2/metric ton of DMT
- Recycled Capilene Process = 0.98 metric tons CO_2/metric ton of DMT

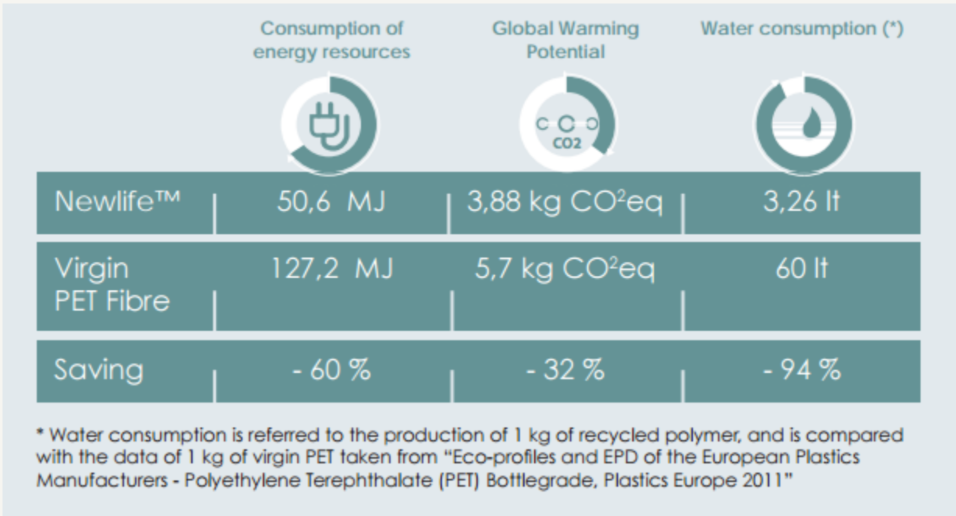
Mechanical recycling

For mechanically recycled polyester, most of the material Houdini used 2014-2015 comes from the supplier Newlife in Italy (54% in 2014). Newlife's recycling is based on a mechanical process to transform plastic bottles into a polymer, without the use of chemicals. According to an LCA carried out by the ICEA (Institute for Ethic and Environmental Certification) this allows significant savings in energy use (60%), water consumption (94%) and CO_2 emissions (60%) compared to virgin polyester fibres production (see illustration matrix below; numbers given for the production of 1 kg of polyester fibre) (Newlife, 2017). Others have also found environmental benefits with bottle-to-fibre recycling (Shen and others, 2012; Spathas 2017).

Though recycled polyester uses significantly less energy than virgin polyester, and also does not to the same extent contribute to extraction of non-renewable resources there are some issues with the material from an environmental point of view. The colour of recycled polyester before being dyed will vary, making it more difficult to achieve consistency in colour in the produced material. This can lead to a more excessive use of chemicals in the dye process or repeated re-dyes to achieve the desired result.

With current technology polyester fibres can be recycled numerous times, but not infinitely, and if not recycled they will eventually end up as waste in landfills or incinerators, or in nature. Moreover, the fact that fabrics are often blends, mixing polyester with other fibres (such as polyamide or elastane), makes recycling significantly more difficult. Mechanical recycling of polyester cannot yet separate different kinds of fibres to make new recycled yarn of 100% polyester (Oekotextiles, 2009).

Figure 7: The results from an LCA carried out by the Institute for Ethic and Environmental Certification, comparing virgin and recycled polyester fibre production.



Wool

The story of wool from a planetary boundaries perspective is complex. Even though wool is a natural fibre, in every stage of production, from breeding sheep to mothproofing garments, the wool industry does have a number of impacts on land, climate, air, and water. Most LCAs show that the greenhouse gases released from wool production, mainly as methane produced from the sheep's digestive system, by far exceed the numbers for other fibres (e.g. Wiedemann and others, 2016). As far as industry responsibility goes, the emissions should be divided between wool and meat production, but even so they remain high.

While the release of methane from sheep is not from a fossil source, but rather biogenic and, in a way, part of a natural carbon cycle, the question could be raised how many sheep there are room for in the world from a climate change perspective – and whether the many benefits of wool outweigh its climate impact. There is also a number of concerns when it comes to ethics, since a number of cases of animal cruelty have come to light in the wool industry, for example through mulesing, a practise that aims to prevent infection from parasitic blowflies known as "flystrike", by removing skin from the sheep's buttocks. In addition, unsustainable grazing in very high stock numbers can cause vegetation change and soil erosion. On the other hand, combining grazing with conservation efforts could become a way for businesses to not only decrease their negative impact, but in contrast have a positive effect on landscape, biodiversity and the ecosystem services it produces (Kviseth, 2011). Hence, sustainable levels of sheep farming can contribute to keeping landscapes open and even restore degraded grasslands. Such revival of grasslands could also be beneficial from a socio-economic point of view, e.g. help keep sheep ranching alive as an important, but currently threatened, livelihood. So, it is crucial to make sure that the scale of the operations does not outgrow the ability of the land to sustain them.

Given that wool is produced with high animal ethical standards and in a way that allows grazing and trampling to regenerate soils, strengthen ecosystem services and build biodiversity, a trade-off still has to be made between these benefits and the emission of the potent greenhouse gas methane.

ZQ-wool

ZQ is an accreditation programme designed to assure a higher standard of environmental, social and economic sustainability as well as animal welfare. The accreditation is awarded after an audit process that is performed by Asure Quality New Zealand Ltd, a government owned 3rd party auditing body.

To receive the accreditation, farmers are required to provide the ZQ organisation with land management plans that address water, soil and hazardous waste for a 3rd party audit. ZQ also requires that farmers provide for five animal welfare freedoms: 1. Freedom from thirst, hunger and malnutrition; 2. Provision of appropriate comfort and shelter; 3. Prevention, or rapid diagnosis and treatment of injury, disease or infestation with parasites; 4. Freedom from distress; and, 5. Ability to display normal patterns of behaviour. Mulesing is prohibited, as is international shipping of live animals, and the farmers are required to have an animal health plan.

Polyamide

Polyamide has long been seen as a cheap alternative to natural fabrics. Since it was invented some 80 years ago, it has been used in everything from violin strings to fabrics to automobile tires. However, manufacturing polyamide products depends heavily on large amounts of crude oil. This means that production of polyamide is energy and water intensive with impacts on the climate, water, aerosol and ocean acidification planetary boundaries. Another main ingredient is adipic acid. Producing the acid was once the largest source of industrial nitrous oxide (N_2O), a greenhouse gas nearly 300 times more potent than carbon dioxide. Since the phasing out of CFCs, N_2O has become one of the most ozone-depleting substances. Adipic acid emissions were reduced by 61% between 1990 and 2006, according to the U.S. Environmental Protection Agency (2008). But the chemical still accounts for 5-8% of global human-caused emissions of N_2O.

Another problem is that polyamide is more difficult to recycle than polyester. After years of research, development, and testing, there are now some recycled polyamide fibres that are suitable for apparel (Patagonia, 2017).

Lyocell/Tencel®

Tencel, one of the trademark names of lyocell fibres, is produced by Lenzing. The raw material for Tencel and other lyocell fibres is cellulose from wood. Wood is turned into wood chips and then to wood pulp mechanically. The cellulose in the wood pulp is then extracted using a solvent, in the case of Tencel the solvent used is a water soluble, biodegradable, solvent called N-Methylmorpholine N-oxide. The extraction process results in a solution from which water is evaporated. Lenzing produce their tencel in a closed loop process in which they manage to recycle more than 99% of the solvent used.

The production process for Tencel is described by Lenzing in the diagram below:

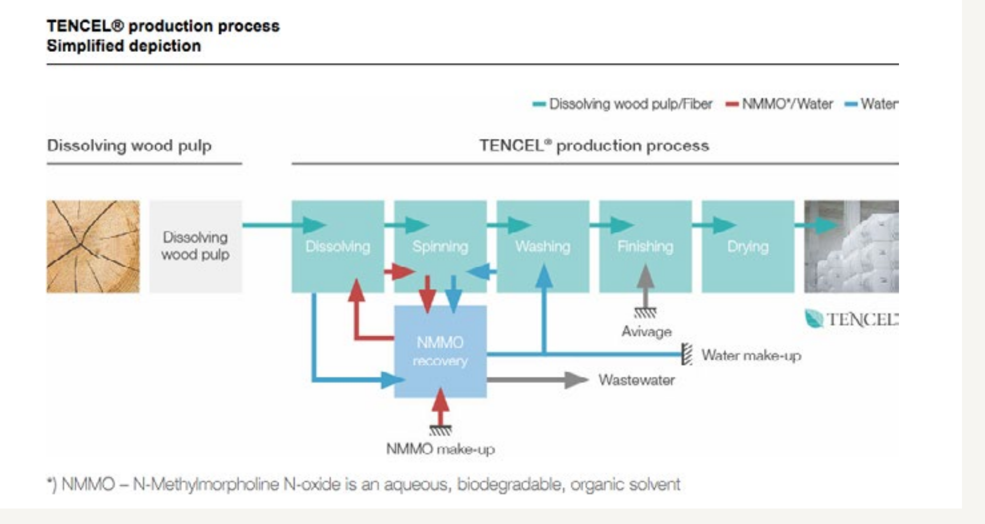


Figure 8: The production process for Tencel as described by Lenzing. (Image: lenzing.com, 2016-09-27)

3.5 Impacts of the fibres along the value chain

Houdini's impact on the planetary boundaries occurs along the many steps of the value chain:

Design
Raw material
Fabrics and yarn production
Garment production
Transport
Sales
Use
Recycling

In this planetary boundaries analysis we have concentrated on the first parts: raw material and fibre production, trying to assess whether fibres are sustainably sourced and produced. It is, however, important to note that for e.g. climate, the customer care, garment production and transportation steps can have as large, or even larger, impact than the other steps. Thus, it is crucial for future strategies to also include these steps in order for Houdini to be as sustainable as possible from a planetary boundaries perspective.

Regardless of what fibre is chosen, certain steps will be taken to turn the fibre into garments. These steps include for instance yarn spinning, weaving or knitting, dying, assembling and sewing the garment. These steps are important to consider in trying to decrease the impact on the planetary boundaries processes. For instance, yarn size

FIBRE	CLIMATE	BIO-DIVERSITY	PHOSPHORUS/ NITROGEN	LAND	WATER	OZONE	OCEAN ACID	NOVEL ENTITIES	AEROSOLS
Proxy	kg CO_2 eq/kg fibre	Happy/ neutral/ sad (q)	kg phosphate eq/ kg fibre	Happy/ neutral/ sad (q)	Litres water/ kg fibre	kg CFC11 eq/ kg fibre	kg CO_2/ kg fibre	Happy/ neutral/ sad (q)	?
Conventional cotton	1.9 (p)	☹	0.0038 (a) 0.022 (b)	😐	2130 (a)	3.1E-7 (n)	?	☹	?
Organic cotton	0.98 (a)	😐	0.0028 (a)	😐	182 (a)	?	?	😐	?
Virgin polyester	8.5 (d)	😐	0.0012 (b)	😐	130 (b)	0.7E-7 (b)	?	😐	?
Chemically recycled polyester	0.98 (f) – 2.59 (o)	😐	0.0023 (o)	😐	?	?	?	😐	?
Mechanically recycled polyester	0.96 (o) - 3.88 (k)	😐	0.0008 (o)	😐	?	?	?	☺	?
Wool	7-37 (c)	☹ ☺	0.012 (n)	☹ ☺	279-721 (h,g)	5.1E-7 (n)	0.6-1.8 (g)	😐	?
ZQ wool	11 (c)	☺	?	☺	?	?	?	☺	?
Polyamide (6/66)	9.5 (i)	😐	0.007-0.008 (h)	😐	663 (h)	0.9E-7 (m) (N6)	?	😐	?
Lyocell	1.1 (b)	😐	0.0018 (b)	😐	263 (b) 265 (j)	1.1E-7 (b) 0.07-0.11 g (b)	?	😐	?

Table 3: A summary of the data inventory, showing the impact of each fibre on the respective boundaries according to selected proxies. References are given in brackets for each measurement and listed below the table.The happy, sad, and neutral faces represent a potential positive, neutral or negative effect, according to the qualitative analysis. NB: this is a pilot study, meaning that the data and the qualitative assessments are preliminary and subject to discussions and future refinement. For polyester production the impacts on land use change are primarily linked to oil extraction. Unless it is produced from tar sands or fracking, oil extraction generally does not occupy vast tracts of land, in comparison to for example cotton or sheep farming. For biodiversity, some of the effects of polyester are linked to land use, but in addition there are issues to consider regarding the release of non-degradable waste and microplastics. These aspects are important both in the case of virgin and recycled polyester, at a later stage in the life cycle. The full scope of effects from microplastic waste is still unknown, but the research field is growing and there is good reason to adhere to the precautionary principle. In the qualitative analysis of these two boundaries we have considered the land use impact of all three types of polyester to be "neutral" or rather "intermediate". In comparison to the other fibres the production does not stick out, however it cannot be said to be beneficial either.

as well as production model (knitting or weaving) will lead to different impacts. A study by van der Velden (2014) found that knitting, overall, is a better option than weaving from an environmental point of view, but also that the total impact of yarn spinning and weaving/knitting is a function of yarn size. The thinner the yarn the higher the impact.

3.6 Data inventory

Initially the aim was to base this analysis on data specific to Houdini's suppliers. A value chain questionnaire was designed and sent out to the suppliers of the materials selected. The data returned from the suppliers were however deemed to be incomplete and not sufficient as a basis for this analysis. To account for impacts as accurately as possible, the comparisons below are based on an inventory of data in external reports, most often life cycle assessment (LCA) studies.

However, not all boundaries are accounted for in a sufficient manner in the existing data, and therefore some boundaries were qualitatively assessed and some had to be excluded from the assessment (see figure 9). Parallel, a next generation questionnaire was initiated to enable a more efficient and secure way of acquiring, processing and analyzing data.

Examples are presented in Appendix IV. The complete questionnaires can be made available at request.

Table 3 presents a summary of the results

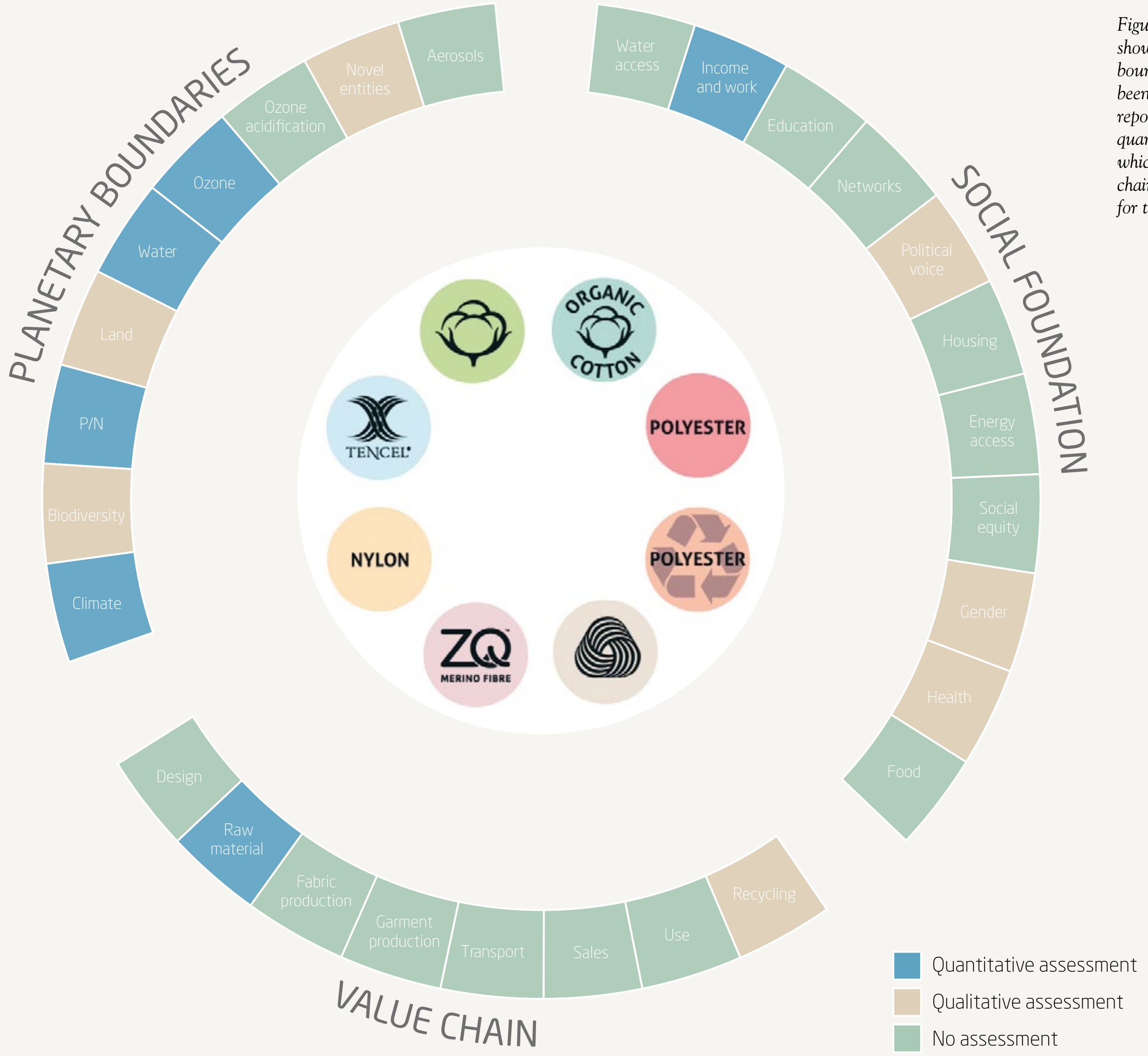


Figure 9: The figure shows which fibres and boundaries that have been assessed in the report, qualitatively or quantitatively, as well as which steps of the value chain have been covered for the respective fibres.

from the data inventory and the qualitative assessment. The numbers presented in the table are those deemed most suitable for this analysis based on the assessed accuracy of the LCA studies and their applicability to the case of Houdini. For example, the data on climate impact from wool production is a global average, as Houdini imports wool from more than one country, whereas that for ZQ wool represents wool from New Zealand, as the ZQ certification scheme is based there.

Two boundaries were excluded from the analysis: ocean acidification and aerosol loading. This was done due to a lack of data both on what the proxy for the boundaries should be and on impacts from the textile industry. For ocean acidification one possible proxy would be the same as for climate change, as CO_2 is the key compound in the process.

However, other emissions also play a part and were deemed significant enough to make discounting them in an assessment problematic. The assessment of impact on three of the boundaries (biosphere integrity, land system change and novel entities) are qualitative in nature, for a number of reasons:

Biosphere integrity: There is no known adequate LCA proxy, or collection of proxies for the boundary. Synergy effects of different impacts can be assumed but remain unknowable in size and significance. The qualitative assessment is a combination of insights and data around land transformation, farming practices and chemical use.

Land system change: A straightforward proxy might seem to be hectares/tonne fibre produced, however it is more complex than that. Wool provides an illustrative example: If sheep are kept on large enough areas of land, in an extensive production fashion, their grazing and trampling can serve to restore degraded land and even contribute to increasing biodiversity.

If, however, they are kept in narrow enclosures the impact on the land, long-term, is more likely to be negative. The reality is then the inverse of what the proxy hectares/tonne fibre would tell us.

Similarly, for cotton or lyocell production, extensive rather than intensive production could produce more benefits and be less harmful. Impact, in other words, depends largely on the management of the production system.

Novel entities: The novel entity planetary boundary has yet to be quantified. There is still great uncertainty regarding how much chemical and particulate pollution the Earth system can cope with.

However, it is known that chemical pollution is a growing problem. Therefore, the reasoning is that the precautionary principle should apply, and though no exact measurement can been found on the sum total of all toxic effects, the fibres have been assessed based on a qualitative estimate from the literature of how severe chemical pollution they contribute to.

References:
a) Textile Exchange, 2014.
b) Shen L, Worrell E, Patel MK, 2010.
c) Wiedeman et al. 2015.
d) Ecoinvent, 2016.
f) Patagonia: Patagonia's Common Threads Garment Recycling Program: A Detailed Analysis.
g) Wiedemann, S.G et al. 2016
h) DEFRA, 2010.
i) Van der Velden, N. M., Patel, M. K., & Vogtländer, J. G. 2014.
j) Textile Exchange. 2016.
k) Newlife 2017
m) Roos et al 2015 + databas Ecoinvent 2.2
n) Ecoinvent, 2017. Ecoinvent 3.3 database. Characterised in GaBi 6, using ReCiPe 1.08 Midpoint (H).
o) Shen L, Worrell E, Patel MK, 2010.
p) Cotton Incorporated, 2012.
q) These are qualitative assessments made by the authors of this report and based on a literature review and interviews with key stakeholders (scientists and practitioners). Key references include: DEFRA, 2010 (biodiversity, land-use and novel entities); Textile exchange, 2014 (novel entities, land use); Van der Velden and others, 2014 (land use, novel entities); Wiedemann and others, 2016 (land use); Roos and others, 2015, 2016, 2017 (biodiversity, land use, novel entities).

3.7 Comparison of Houdini's fibres from a planetary boundaries perspective

This section has compared the effects of different fibres on planetary boundaries, based on the inventory data presented in the previous section. This data serves as a proxy for the different fibres' potential large-scale impacts on planetary boundary processes, but does not make it possible to analyse the local level environmental effects of the actual fibres used in Houdini's own value chains.

The analysis is limited to the production of fibre. Where sufficient and specific data has been found, the fibres are compared quantitatively. For three of the planetary boundaries (novel entities, land-system change and biosphere integrity), the impact from fibre production is complex and currently not satisfactorily represented in LCA measures, in these instances we have conducted a qualitative comparison based on a range of information sources (see table 3). Two boundaries (atmospheric aerosol loading and ocean acidification) have been excluded from the analysis as data was insufficient and indicators not adequately known.

Impacts that result from transportation or garment manufacturing have more to do with decisions related to the choice of contractors; where should production take place and under what conditions? This is not necessarily directly related to the type of fibre and has therefore been excluded from this analysis.

The bar charts below (Figure 10-13) illustrate the data from table 3, comparing the fibres' impact on the four boundaries for which quantitative data was available. In the instances where the data presents a numeric span we have used the average in the table.

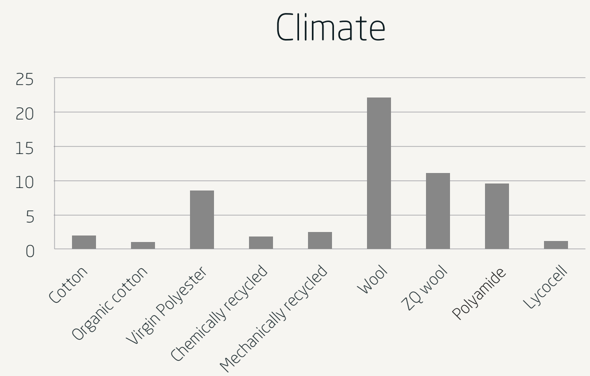


Figure 10: Bar chart comparing the climate impact of the nine analysed fibres in kg CO_2 eq/kg fibre.

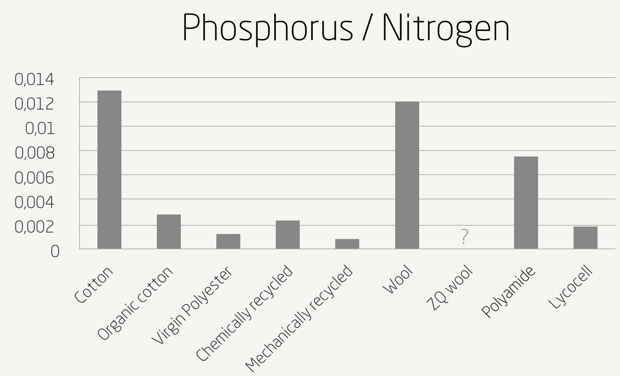


Figure 11: Bar chart comparing the eutrophication of the nine analysed fibres in kg phosphate eq/kg fibre. Data missing for ZQ wool.

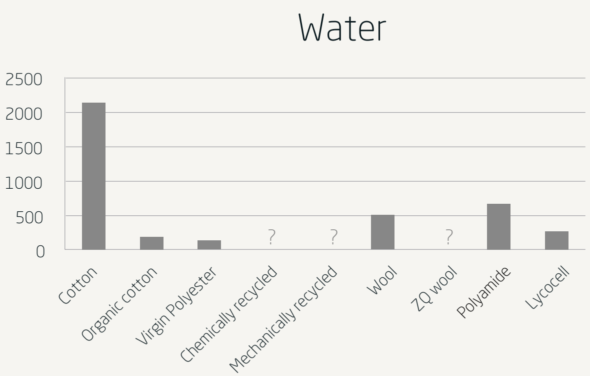


Figure 12: Bar chart comparing the water use (blue water withdrawal) of the nine analysed fibres in litres water/kg fibre. Data missing for chemically recycled polyester, mechanically recycled polyester and ZQ wool.

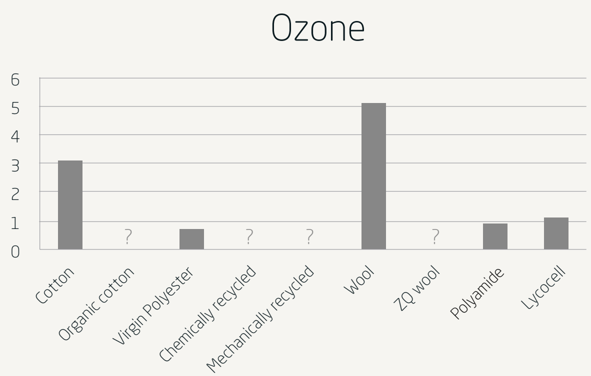


Figure 13: Bar chart comparing the ozone depletion impact of the nine analysed fibres in kg E-7 CFC11 eq/ kg fibre. Data missing for organic cotton, chemically recycled polyester, mechanically recycled polyester and ZQ wool.

4. Discussion

4.1 General discussion

Being the first of its kind, this pilot study must by necessity be considered only a first step towards a more robust method for analysing corporate impacts on planetary boundaries. A next generation value chain questionnaire based on block chain has been developed, enabling a more efficient and secure way of acquiring, processing and analyzing data. Examples are presented in Appendix IV.

Another important realisation is that it is at present very difficult to get sufficiently good and reliable data from all suppliers to conduct a complete quantitative comparison of the actual fibres in use in Houdini's production. From the data that was gathered it was clear that suppliers are not used to providing the kind of quantifiable data that was asked for in the questionnaire. The answers provided often contained incomplete data or inconsistent metrics. Because of these difficulties, we have in this study had to rely on data from external reports when analysing a selection of the fibres Houdini use. Even such data has proven difficult to find for metrics relevant to some of the planetary boundaries, and this will be elaborated further down in the discussion.

Nonetheless, it is clear that Houdini has already implemented an ambitious sustainability strategy. From a planetary boundaries perspective, it is promising that Houdini is increasingly implementing circular lifecycle approaches as these tend to have an overall positive effect, decreasing the company's impact on more or less all the planetary boundaries.

These circular economy strategies, which most often are positive for all the planetary boundaries, include: using recycled or renewable fibres, a closed-loop garment-recycling program; offering services such as rental and repairs as well as second hand resale (reuse). Timeless, durable design for multi-functionality is another key ingredient in this kind of thinking, which might contribute to more "slow fashion"-thinking and customers who prefer to buy a few loved garments, instead of promoting "fast fashion"-consumption as a way of living. The environmental benefits of prolonging the service life of clothing have been shown in numerous LCA studies (see e.g. Farrant and others, 2010; Roos and others, 2015; Schmidt and others, 2016; Dahlbo and others, 2017). It is, however, important to note that recycling of fibres does have effects on the planetary boundaries (e.g. water, novel entities, and climate change) every time the fibres go through the recycling loop of collection, transportation, manual/chemical recycling and fabric and garment production (see e.g. Zamani, 2016).

One benefit of using the planetary boundaries framework in assessing environmental impact is that it makes visible factors and aspects that have often been forgotten. Each one of the nine boundaries highlights an area to consider, and the addition of the social boundaries indicates what conditions are acceptable for people working along the production chain.

4.2 The comparison of different fibres

From this pilot study it is clear that no fibre is perfect from a planetary boundaries perspective. For example, virgin polyester tends to require small amounts of water to produce, but is very energy intensive and uses non-renewable crude oil as raw material. Using recycled polyester significantly decreases the use of energy as well as the emissions of greenhouse gases (as long as the "recycled" polyester is not made from unused bottles directly from bottle producing companies, which has been reported in some cases). Likewise, wool can be produced in a manner that contributes to enhancing biodiversity. However, from a climate perspective carbon dioxide and methane emissions are still high.

Throughout this study we have analysed fibres with data from various LCAs and it is worth noting that the world of LCAs includes differences and disagreements on e.g. metrics and system boundaries. Kviseth (2011) even claim that "LCAs can be manipulated within acceptable methodological limits to give a wanted result. You get what you pay for." Overly unjust manipulations are, however, supposed to be stopped by the commissioner if the LCA study follows the ISO standard in terms of transparency. Moreover, not all differences reflect disagreements. There is often a reason for different metrics and system boundaries in various LCAs, as they reflect different goals and scopes of the studies.

Moreover, LCAs might also underestimate the overall benefits of some natural fibres, as some ecosystem services provided by their cultivation are difficult to quantify. For example, "annual fibre crops such as flax or hemp, are valuable break crops in arable rotations and, with the exception of cotton, help to reduce the overall burden of agricultural production on the environment, as they have lower fertiliser and agrochemical requirements than most arable crops" (DEFRA, 2010).

Kviseth (2011) also points out that an LCA is dependent on specific scientific competence and data tools and is not a convenient tool for designers and small companies. Moreover, LCAs tend to be used to compare negative environmental impacts rather than as a basis for improvements and new designs. Another drawback is that differences in individual company performances are not necessarily visible in LCAs, since they are mainly performed with global data and industry averages. For example, energy-intensive fibres, such as polyester, are prone to variations in the means of electricity production (fossil fuels vs renewable) between different geographical locations. Similarly, natural fibres, such as cotton, are prone to variations in land management practices and water scarcity.

Some LCAs assess "abiotic depletion", that is the depletion of non-renewable resources, e.g. fossil fuels. For polyester, this means a divide between virgin and recycled material. The use of crude oil products as a basis for polyester production means that fossil resources are extracted from the ground. The use of a non-renewable resource in virgin polyester production is in other words an important factor, alongside the reductions in CO_2 emissions, water use and energy that recycled polyester can achieve compared to virgin, provided the best available recycling practices are adopted (as in the case of Newlife for example).

Another interesting result of this pilot study is the effect on land use from wool production. Using the simplistic metric of total land use/kg product results in a high value assigned to wool products made from the fibres of extensively grazing sheep. However, other important measures of land use may give very different scores, e.g. use of arable land. Often sheep can use land that is not suitable for crop production, and may even have a positive effect on biodiversity and ecosystem services from the land being grazed (e.g. Ripoll-Bosch and others, 2013).

There is also the matter of emission allocation. A study by DEFRA (2010) states that "[w]ool has a very high land demand, but wool is also a by-product of meat production and utilises land that is unsuited to crop production, particularly in extensively grazed systems". They refer to other studies that suggest that both energy inputs and land demand could be allocated by up to 60% to meat production. This significantly reduces the proportion allocated to wool production, but compared to fibres from other plant-derived sources, the land demand for wool is still very high. The study by DEFRA suggests that lyocell/Tencel and PLA (polylactic acid fibres; bio-based polyester replacements made by e.g. corn, sugar beets or wheat) would deliver the highest saving in CO_2 emissions/hectare because of their high productivity per hectare and their relatively low energy demands.

It is however important to note that even though lyocell production is associated with a relatively low land use requirement per tonne produced fibre, compared to wool production, this simplistic measure fails to include other important qualitative aspects of land use. DEFRA (2010) points out that "increasing eucalyptus plantations is not without problems as such plantations commonly have little other biodiversity value, and the leaf litter can be a potential fire hazard in dry climates."

Also, this measure does not capture time, which is a flaw for some measures of productivity used in LCA studies. When comparing different annual or bi-annual crops, this is not a problem, but when comparing for example regenerated man-made fibres made from wood pulp (e.g. viscose, Tencel) with cotton, time must be considered. For cotton, harvests are at least annual, whereas eucalyptus trees take several years of growth before they are harvested, and trees from temperate or boreal forests can take up to 100 years. Therefore, if a simple productivity-based metric is used to compare such fibres, it should be in terms of kg product/hectare/year.

The ability to satisfactorily measure land use, and particularly the subsequent impact on biodiversity, is in fact one of the main gaps in LCA methodology. There are many reasons for why it is difficult to measure biodiversity in an LCA framework, for example the fact that there are many kinds of biodiversity (diversity of species, genetics, functions, ecosystems), which do not necessarily correlate, and the inherent difficulty in finding universal metrics for impact that is local in nature and caused by a multitude of stressors (Curran and others., 2011; Koellner and others, 2013). Therefore, there is still little consistency and consensus in how to measure biodiversity in LCAs. Because of the lack of methods for accounting for land use change and biodiversity loss in LCA, it may be neglected in corporate sustainability decision-making (Egorova and others, 2014). Eventually, biodiversity might need to be assessed through a broad and diverse set of indicators. Another option is to settle with "mid-point indicators" (e.g. land-use or nutrient pollution) which influence biodiversity.

The climate effect of wool is also worth discussing in further detail. The effect is large because of the release of methane, but comparing it to the release of carbon dioxide from virgin polyester or chemical fertiliser production in conventional cotton is sometimes argued to be unfair because there is a difference between the greenhouse gases released from grazing sheep and those emitted when burning fossil fuels. Sheep actively participate in the carbon cycle by eating plants that have captured carbon dioxide from the air through photosynthesis. The burning of fossil fuels, on the other hand, adds carbon dioxide to the atmosphere that otherwise would have stayed in the ground. However, though grazing sheep are naturally occurring in landscapes, drastically increasing industrial wool production around the world would vastly increase the number of sheep with effects on global greenhouse gas emissions. Thus the climate impact from wool production is very much a question of scale; what could work at a limited scale is not necessarily a viable large-scale solution for the clothing industry. Thus the sustainability of wool use in an individual company, such as Houdini, cannot be assessed solely based on a simple metric compiled at a certain moment in time. It must be continuously evaluated based both on the circumstances surrounding a specific wool producer (the local perspective) and the development of the wool industry as a whole (the global perspective).

4.3 Comparison between boundaries

One of the strengths of a planetary boundaries approach in an impact analysis is its holistic nature, as has been pointed out before. It accounts for a range of processes and systems that have been identified by researchers as key to the stability and resilience of the Earth system. Having said that, prioritising between the boundaries might still be an important step in making strategic decisions for the future. In this analysis, we have compared the impact of nine fibres relative to one another, rather than assessing their quantitative impact on each respective planetary boundary. We chose this approach for several reasons: Several boundaries have not yet been quantified meaning that we would be at a loss in trying to position an impact against a boundary. There is also great difficulty in awarding "fair shares" to nations, industries, companies or individuals – rather than positioning a view on what Houdini as a company is "entitled to" we decided to compare the fibres to find the one with the lowest impact on each boundary. This also makes sense in light of Houdini's expressed goal to have zero or a positive impact in the end, and not to appropriate their entitled share of impact.

However, there is also a point in comparing the magnitude of the impacts and accounting for the urgency of each boundary. For example, the climate boundary has already been transgressed and has also been identified as a "core boundary", impacting on and being impacted by all the others. The impact on the climate boundary from the textiles industry also appears to be significant in a global perspective. We are however still in the "safe operating space" of the ozone depletion boundary, and the textile industry appears to be a relatively small contributor globally. Given this, a trade-off should be made when making decisions on investments for future production, taking into account not only the relative impacts of the fibres but also the relative urgency to decrease pressure on a boundary and the impact of the textiles industry as a whole on the boundary. Taking measures that result in decreased pressure on the climate boundary might then be prioritised over decreasing pressure on the ozone boundary.

4.4 Scaling down the boundaries

The planetary boundaries are just that – planetary. The boundaries are given on a global scale, and while some of them are truly global, for example climate change, others need to be looked at also on a more local scale. The boundary for freshwater use is an example:

On a global scale the Steffen and others' (2015) paper on the updated Planetary Boundaries concludes that we remain within the safe operating space for freshwater use. However, the water boundary is one that differs greatly on local scales, and though the world as a whole remains within the boundary, water scarcity and droughts are facts of life in many places on the globe. This is also emphasised by Steffen and others, whose (2015) paper features a world map of more regional water vulnerabilities associated with how much water can be claimed for human use at the river basin scale without risking irreversible ecosystem degradation.

In textile production, different steps in the production chain will lead to different kinds of impacts. In wool production for example, impacts on climate, biodiversity and land use are the biggest in rearing sheep, whereas impacts related to novel entities are bigger in the scouring and dyeing of the wool. Water will be required all throughout the chain, and for this boundary it becomes key to geographically trace and quantify the use. For a local assessment of the impact on the water boundary there are accounting tools, such as the World Resources Institute's Aqueduct, which can be useful and complemented by additional measurements.

Where water is taken from and used is important as it impacts both ecosystems and people locally. Even though company targets can benefit from using Sustainable Development Goals (such as SDG6 on water) as a reference point, it is crucial that they also account for the scientific understanding in a specific local basin. Such "context-specific water targets" must for instance take into account if company activities jeopardise the access to improved drinking water or adequate sanitation for people who rely on the same water source as the fibre production, garment manufacturing or dyeing of clothes. Hence, corporate water targets must not only be based on best available knowledge on hydrological and ecological conditions at the basin level, they also need to be informed by local people's needs, and aligned with local to global public policy objectives (CDP and others, 2016).

One result of this analysis was finding that this type of locally specific data is not easily accessible. While suppliers were generally cooperative in answering the questionnaire we sent out, gathering coherent data for comparison was a difficult task. It is obvious that there is currently no common practice of gathering or sharing this type of information.

Not having access to complete data from Houdini's suppliers we chose to use information found in LCAs and other external reports for our analysis. This type of LCA data do provide a first estimation of Houdini's impact on the planetary boundaries on a global scale, but does not make it possible to look at the specific impacts of the actual fibres used in their own value chain.

4.5 Interactions among the planetary boundaries

On a planetary scale, there are many interactions among the different planetary boundaries (see figure 14 where biosphere integrity [biodiversity] and climate change is placed in the middle to show the numerous linkages among boundaries). Steffen and others (2015) emphasise that the planetary boundaries research shows that Earth is a single, complex, integrated system where the boundaries interact in ways that can create stabilising or destabilising feedbacks. They go on to conclude that "this has profound implications for global sustainability, because it emphasises the need to address multiple interacting environmental processes simultaneously (e.g., stabilising the climate system requires sustainable forest management and stable ocean ecosystems)".

This of course has implications for the clothing industry's impact on the planetary boundaries as it shows that it is not enough to only concentrate on a few of the boundaries like climate, water and novel entities. While there may be a need to prioritise between boundaries this needs to be done based on an understanding of not only impact on and status of specific boundaries, but also of the interactions between boundaries. A narrow focus of the sustainability efforts of an industry might lead to unintended trade-offs if strategies are not based on a holistic understanding of the full set of boundaries (including social aspects of course). For example, fervently focusing on minimising the carbon footprint of a garment might lead to increased water use or negative effects on biological diversity. This is why this pilot study has tried to include as many boundaries as possible in the comparison of different fibres.

Figure 14: The interrelations between planetary boundaries, with biosphere integrity (biodiversity) and climate change in the centre.

5. Conclusions: The way forward

Based on this pilot study of Houdini Sportswear's sustainability efforts from a planetary boundaries perspective we see a number of important areas for future investigation and improvement. They include the following recommendations:

- According to the literature, the choice of fibre (once conventional cotton is taken out of the equation) tends to be less important from an environmental point of view than how the fibre is then turned into fabric and garments. However, as indicated by this study and others, it does matter which supplier you choose. Hence, parts of the production chain where Houdini could really make choices that make a difference are in choosing fibre suppliers and whether the material is knitted or woven, how it is dyed, what coarseness of fibre is used and how the garments are sewn together. In general, the thinner the fibre the higher the impact, and knitting has lower impact than weaving.
- The ambition of Houdini's work on planetary boundaries and overall sustainability should be to do more good, rather than to simply minimise the negative effects on planetary boundaries. Fibres that are climate positive (sequestering more CO_2 than is being released) are being developed, and in light of Houdini's history of driving processes for new materials (such as the PFC-free shells) a logical next step might be to see how Houdini could contribute to the development of fibres

that are biodiversity positive or to finding ways to remove excess nutrients or plastic particles from the oceans.

- In choosing between materials it may become necessary to make trade-offs and prioritise between boundaries. We suggest prioritisation is awarded to:
    - The core boundaries: Climate change and Biosphere integrity
    - Boundaries that have been crossed or are close to being crossed
    - Water, in the sense that water demanding activities should be located to areas that have sufficient water resources
    - Boundaries on which the textile industry as a whole has a large impact
- It is crucial to combine any future strategy to improve company performance from a planetary boundaries perspective with improved analysis of how each action contributes to reaching social boundaries. One way of doing this is to use Oxfam's doughnut approach and/or the newly developed SDG-compass which relates company performance to the global Sustainable Development Goals.
- Houdini should continue developing its circular/collaborative business model as circularity tends to reduce the overall impact on all planetary boundaries. The development of this business model should include a continued analysis of the effect of each new strategy on the planetary boundaries, e.g. how much better is a rental system from a climate change perspective?
- Looking more into planetary boundaries seldom covered by the clothing industry, like biosphere integrity and nitrogen/phosphorus flows, could give Houdini a competitive advantage when well-informed consumers start demanding better performance in these respects.
- By continuing to develop the questionnaire for suppliers (in dialogue with them) a full planetary boundaries analysis could eventually be conducted, based on the actual fibre, fabric and garment production of Houdini's value chain. This work will include a dialogue with the suppliers to follow up in various way and motivate why Houdini wants more elaborate answers. This is an important part of a co-learning process for Houdini and their suppliers in order to improve sustainability performance in the coming years. It could hopefully also trigger a change in the industry with regards to transparency and data accessibility.
- It is important to address all parts of the life cycle in order to improve future company performance from a planetary boundaries' perspective. This pilot study's analysis for climate impact, for instance, focuses on fibre production, but fabric and garment production, consumer care (washing and drying) and transportation are also important from a life cycle perspective when seeking to minimise the climate impact from textiles. The user's transportation to and from the store can be as significant as fibre production and for some fibres the consumer care of the garment can sometimes (e.g. in countries with a CO_2 intensive electricity mix) have a larger impact than the fibre and fabric production. In a further development of this pilot study, it would thus be important to assess not only fibre production, but also subsequent life cycle processes.
- Using renewable fibres like wool and lyocell instead of polyester is indeed worthwhile, but even these fibres can have large effects on some planetary boundaries. This should be further investigated in detail by Houdini before phasing out all polyester. Polyester garments can be made to be very durable, and if the potential for longevity is realised polyester could be good from a planetary boundaries perspective.
- For polyester, it is important to do more research on the impact of different ways of recycling fibres and to continue the efforts to minimise the leakage of plastic particles into the oceans, all the way from production to customer care and recycling.
- Considering that polyamide is one of the worst fibres from a climate change perspective, and climate change is one of the core planetary boundaries that has already been transgressed and should be prioritized, Houdini should look into how to replace polyamide and/or develop polyamide recycling on larger scale.
- Houdini should continue its efforts to design garments in a complete life cycle perspective, and the choice of materials must be related to function, aesthetics, expected life-time, care and end-of-life.
- From a novel entities perspective Houdini should continue their work to become completely fluorocarbon-free, e.g. by only selling shell layers that are weatherproofed with biodegradable components.
- As a large part of Houdini's collection is still polyester the issue of novel entities and microplastics is one to prioritise. Houdini should continue their work on developing methods to reduce the release of microplastics through, for example, improving fibres so they remain intact through wear and tear, and developing new washing instructions, filters and washing bags to decrease friction and potentially collect the released microplastics.

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Appendices

APPENDIX I: Existing methods for assessing the clothing industry's impact on planetary boundaries

This pilot study is an attempt to connect recent findings in Earth system science with efforts for impact reduction at the product scale in the clothing industry.

As a first step in our effort to study Houdini's operations from a planetary boundaries perspective we have conducted an inventory of existing methods and tools for measuring the clothing industry's impact on individual boundaries as well as bundles of boundaries (see Table 4). Some of the available tools aim to guarantee a certain standard, whereas others are ways of understanding the extent of a company's impact.

Clothing companies have the option of purchasing materials that are in different ways certified or labelled as organic or otherwise "environmentally better", by for example Bluesign® or GOTS. The certification schemes list different criteria in line with their respective goals, and the label on a certified product or material shows the customer that these goals are being met.

Companies can also conduct their own sustainability reports and assessments within existing frameworks such as the Global Reporting Initiative or the Higg Index, or conduct life cycle assessments to learn about the impact of a product. These reports can be made public to show sustainability efforts to customers, or they can be used as internal reviews or evaluations to gage performance (see e.g. Houdini, 2013).

While we haven't been able to find a framework that takes all nine boundaries into account, there currently exists a plethora of different tools that address different planetary boundaries processes, and bundles of boundaries, knowingly and, we think, sometimes as an unintended bonus.

Each boundary identifies a key aspect to account for, however, they are also inextricably interlinked, and while labels or certifications may state a rather narrow focus, measures that affect for instance climate can have an impact on other boundaries as well, for example aerosols: Each process step of textile production causes air emission. As mentioned above, production of fibres like cotton and the manufacturing of polyester and other synthetic fabrics are energy-intensive processes, often utilising large amounts of fossil fuels and releasing emissions like greenhouse gases and aerosols. This implies that tools for measuring and reducing the emissions of greenhouse gases from the clothing industry will in many respects be applicable also when it comes to aerosols.

The Bluesign® system is a certification scheme for materials that aims at reducing air pollution by directly targeting at the basis: the selection of the raw materials and the chemical products. It specifies strict selection criteria for substances and components having an emission impact, but the overall aim is to reduce carbon dioxide emissions rather than other air emissions, even though it specifies that "exhaust air has to be cleaned and recycled by adequate environmental technology". The Higg Index 2.0 complements this by also including the emissions of sulphur dioxides in its self assessment tools.

Another boundary that is closely linked to climate and emissions of carbon dioxide is ocean acidification. CO_2 emission is the main driver of ocean acidification and decreasing emissions will in other words have a positive effect on this boundary as well.

One of the tools with the broadest reach is the certification scheme Global Organic Textile Standard (GOTS). GOTS certifies products rather than materials meaning that their quality controls run along the whole production chain. For organic material, wool or cotton for example, they have two levels of certification, "made with organic" contains a minimum of 70% organic raw material and "organic" a minimum of 95%. GOTS prohibits the use of toxic chemical compounds that can damage consumer's health and places demands on social and working conditions. Wastewater treatment as well as target goals and procedures for reducing water and energy use are also required.

In textiles production water is used in many different phases from growing natural fibres such as cotton or other cellulose fibres to processing synthetic materials or dyeing fabrics.

As water security is an issue on local scale rather than global the impact of these processes will differ depending on where they are placed geographically. Other than water use, pollution of runoff water is also an issue for the textile industry and relates to the novel entities boundary and the emissions of nitrogen and phosphorus (the biogeochemical flow boundary). The Bluesign® system aims to control emissions to water, reducing it to a minimum by specifying requirements for water pollution control.

An example of a tool that helps businesses navigate their water consumption and impact on the water boundary is the Aqueduct Water risk Atlas. This tool was developed by the World Resources Institute and is a tool for measuring, mapping and understanding water risks. The mapping tool draws on data from science and climate models included in the Fifth Assessment Report from the Intergovernmental Panel on Climate Change (IPCC, 2013) to provide metrics for developing business and investments strategy.

The map allows the user to see the overall water risk of an area, and also to look more closely at different types of risks, such as physical risks related to for example droughts, seasonal variability or groundwater stress, or regulatory and reputational risks related to for example media coverage, threatened amphibians and access to water (www.wri.org/our-work/project/aqueduct). The footprint approaches aim at clarifying and quantifying a business' dependency on a resource, the water footprint focuses on water and the carbon footprint on carbon and CO_2 emissions.

Life cycle assessments aim at determining a product's environmental impact from cradle to grave, meaning they should account for all stages from raw material to waste management. LCAs typically account for different environmental impacts, such as water consumption, use of non-renewable resources, land use and nutrient flows. Certain aspects are however rarely or less extensively covered in LCAs, for example biodiversity. And though CO_2 emissions might be a focus area, ocean acidification might not be mentioned specifically.

The table below lists a number of different reporting tools and certification schemes and the planetary boundary processes they target. Processes that relate to the Planetary Boundaries and covered by the tools/certification schemes are marked with an x. Boundary processes that are not specifically or extensively targeted (but still in some way addressed) are marked in parenthesis. We can conclude that though a few of the reporting tools come a long way towards covering the planetary boundaries, none of them effectively does so completely. It is also clear that while a boundary might be addressed as an aspect of environmental concern, measurements or reporting is seldom, or never, done in relation to a quantification of impact related to a set boundary.

APPENDIX II: Social boundary aspects

Below is a selection of the questions posed by Albaeco and Houdini to Houdini's suppliers,

	Climate	Novel entities	Ozone layer	Aerosols	Ocean acidification	Biogeo-chemical flows	Fresh-water	Land use change	Bio-diversity loss
BlueSign[1]	x	x		(x)	(x)		x		
Global Organic Textiles Standard	x	x		(x)	(x)	x	x		
Oekotex	x	x			(x)	x	x		
Carbon footprint	x				x				
Water footprint							x		
Aqueduct water risk atlas							x		(x)
Life Cycle Assessment	x	x	x	(x)	(x)	x	x	x	(x)
Ecosystem Services Review	x						x	x	x
Global Reporting Initiative (GRI)	(x)	(x)	(x)	(x)	(x)		(x)		(x)
Higg Index	x	x	x	(x)	x	(x)	x		

Table 4: Summarising table showing a selection of existing methods or certification schemes for assessing sustainability performance and their relative applicability for the nine planetary boundaries processes.

[1] Bluesign only measures processing of the fibres, not origin, use or end of life.

regarding social aspects and working conditions. The selection shows the questions to which most of the responding companies provided answers that reflect that they interpreted the questions in the way they were meant to be interpreted.

The majority of the responding companies have a standard of not hiring persons under the age of 18. Company number 7, with the minimum age for employees of 16 is based in Taiwan where as a comparison the legal voting age is currently 18.

All who responded to the question follow national or industry standards for minimum wage, offer their employees health care and paid sick leave. Employees are also allowed to join or form unions. Most also appear to offer some form of paid parental leave, at least for women.

APPENDIX III: Suggested steps of a tentative 5-step methodology for a planetary boundaries analysis

Step 1: Select the scope (where in the value chain to focus)
Step 2: Identify priority planetary boundaries
Step 3: Analyse company impact on priority boundaries and interaction with social boundaries
Step 4: Identify business risks and opportunities
Step 5: Develop strategies for addressing risks and opportunities

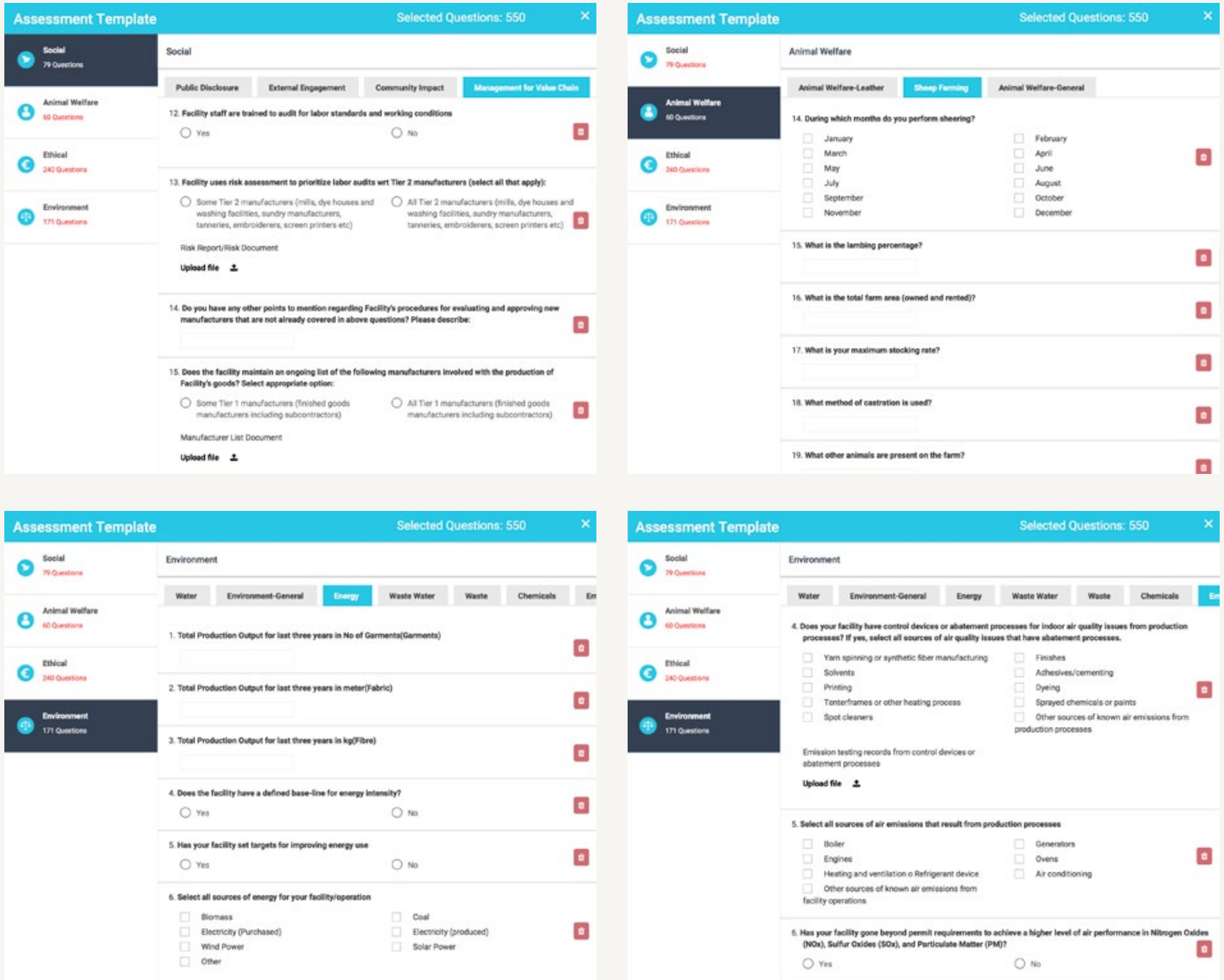

Figure 15: Examples of Houdini's next generation value chain questionnaire that has been developed to enable a more efficient and secure way of acquiring, processing and analyzing data. The questionnaire reflects the holistic perspective and consists of 550 questions covering environmental, social and ethical aspects in its entirety.

APPENDIX IV: Examples of the 550-question value chain questionnaire that Houdini has developed in partnership with tech partner TrusTrace, who are designing a blockchain powered collaboration platform to establish product and value chain transparency and traceability.

The more the merrier

WHETHER YOU'RE SAILING a boat, pitching a tent or starting a revolution, you will have better luck if you bring some friends. All people are different and that's why we're so good together.

Together with an odd band of scientists, artists, designers and engineers, we're pushing the boundaries of how outdoor clothing is made. Together with our customers, we are recycling, renting, repairing and reusing our way to a new, sustainable outdoor industry.

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Let's climb a mountain. Run a mile. Eat a cake. Start a band. Save the world. Call your best friend, your mom and all your cousins. The more the merrier!