European Master in Biological and Chemical Engineering for a Sustainable Bioeconomy

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SCIP implementation for the substitution of hazardous chemicals and towards a safer circular economy

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at : Vanderlande Industries

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Dr. Niina Dulova, Tallinn University of Technology

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THESIS TASK

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Thesis topic:

(In English) *SCIP Implementation for Substitution of Hazardous Chemicals Towards a Safer Circular Economy*

(In Estonian) SCIP rakendamine ohtlike kemikaalide asendamiseks ohutuma ringmajanduse suunas

Thesis main objectives:

1. To familiarisation with the literature and documentation on the subject
2. To develop a methodology for the implementation of the SCIP project
3. To collect data provided by Vanderlande's suppliers and analyse results

Thesis tasks and time schedule:

No	Task description	Deadline
1.	Familiarization with the literature and documentation of SCIP regulation and implementation processes	04.2023
2.	Engage with suppliers for data collection, analysis, and interpretation of results	05.2023
3.	Writing and formatting the thesis	06.2023

Language: English **Deadline for submission of thesis:** 15 June 2023

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PREFACE & ACKNOWLEDGEMENTS

In Vanderlande's journey to comply with applicable regulations and contribute its share to a more sustainable world, the SCIP project was born. This work was done at Vanderlande Industries, and it was such a pleasure to work with the team of the Product Environment Regulation Working Group and the HSE department to share all the ideas and challenges faced to fulfil this thesis.

I would like to thank the full support and guidance received from Daniela Angioletti and Patrick Miegielse, especially in those stressful moments when the progress was not as much as expected.

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This thesis means the end of a journey that took me far away from my family, but even being thousands of kilometres apart, they have always found a way to be close to me, cheering and supporting what I do even when I did not even believe in myself. The biggest thank you goes to my dearest mother.

Last, to my new friends who became my family in this journey called BIOCEB: All of you were scattered around the world, facing your own challenges with your thesis, but managed to be there when I needed you. Thank you.

P.S. *Se logró*

Eindhoven, Netherland. June 2023.

Erandy Correa Guillen

List of abbreviations and symbols

CE	Circular Economy
CLP	Classification and Labelling of Chemicals
ECHA	European Chemicals Agency
EEE	Electrical and Electronic Equipment
EU	European Union
GHG	Greenhouse gas
HRC	High-risk categories
ICT	Information and Communication Technologies
LRC	Low-risk categories
PER-WG	Product Environment Regulation – Working Group
PFAS	Per- and Polyfluorinated Substances
POPs	Persistent Organic Pollutants
REACH	Registration, Evaluation, Authorization and Restriction
RoSH	Restriction of Hazardous Substances in Electrical and Electronic Equipment
SCIP	Substances of Concern In articles as such or in complex objects (Products)
SDGs	Sustainable Development Goals
SSN	Simplified SCIP Notification
SVHCs	Substances of very high concern
TICO	Toyota Industries Corporation
TMHE	Toyota Material Handling Europe
UN	United Nations
WEEE	Waste electrical and electronic equipment
WFD	Waste Framework Directive

1 INTRODUCTION

Unsustainable production is known to be the cause of resource depletion all around the globe, which has become a pressing concern and incentive for the worldwide transition towards a sustainable and circular economy (CE). In the European Union (EU), to achieve this, a proper action plan was developed, stating strategies for the economic, social, and environmental pillars of sustainable development to achieve circularity. [1,2]

The environmental strategies focus on product design for long-lasting life, reducing waste production, and increasing recyclability for secondary raw materials, highlighting that those raw materials should be safe and not contain hazardous substances. To ensure it, the Waste Framework Directive (WFD) and the European Chemicals Agency (ECHA) created the Substances of Concern In articles as such or in complex objects (Products) (SCIP) database.[2–4]

These environmental goals and regulations push the companies to restructure their strategies to align with their sustainability goals and therefore develop the proper actions and processes to achieve those objectives. In the case of SCIP, companies need to focus on establishing a sustainable supply chain and fostering transparent communication with their suppliers.

This thesis uses Vanderlande Industries as a case study to assess the implementation of SCIP by identifying SCIP-listed articles within the company's supply chain to ensure compliance with their complex products, having a specific focus on promoting a CE and addressing the challenges faced by an assembler company in ensuring SCIP compliance. All of these to answer the following questions:

1. How has the SCIP regulation been implemented within Vanderlande?
2. What is the impact of SCIP implementation on Vanderlande's business model and operations, specifically in terms of sustainability practices and supply chain management?
3. What is the compliance status of suppliers, and how does it impact the CE?
4. What are the challenges and opportunities associated with SCIP implementation, and how can Vanderlande Industries enhance SCIP compliance and advance circular economy initiatives?

To provide a thorough understanding of the importance of how SCIP came into place to reduce the SVHCs in the market, the literature review will explore the European Union Circular Economy Action Plan and the European Chemical Strategy for Sustainability, which are critical frameworks guiding the implementation of SCIP. Additionally, to build a background for SCIP implementation, the WFD goals will be explained and a

comparison between SCIP, REACH (Registration, Evaluation, Authorisation, and Registration of Chemicals), and RoSH (Restriction of Hazardous Substances) regulations. Moreover, the thesis will provide an overview of Vanderlande Industries, including the company's background, solutions or products, and sustainability strategy, to better understand the company's operations, commitment to sustainability, and drive to assess the impact of SCIP implementation on its overall business model and operations.

To achieve the objectives set for this thesis, the methodology will outline the development of an action plan for the SCIP implementation in Vanderlande, with the support of external consultations with Royal HaskiningDHV, and Toyota Material Handling Europe (TMHE) for process validation and gathering experiences in sustainable chain management and SCIP implementation. Also, it will convey the phases followed and the evaluation of suppliers with SCIP requirements.

In the section on results and discussion, the findings of the Pilot phase and Phase II in the implementation process will be explained, especially on suppliers' engagement and compliance status, including where more SCIP-listed articles are found according to the type of articles' categories in Vanderlande. Furthermore, will be analysed the influence of the location and size of the suppliers in their compliance status with SCIP. Lastly, the impact of the SCIP implementation on CE will be evaluated, and the challenges and opportunities associated with the process will be explored, including recommendations and next steps for Vanderlande to ensure SCIP compliance and advance in their goals in CE by being a regenerative company.

In conclusion, it will be highlighted the takeaways and importance of SCIP implementation to tackle and decrease hazardous substances in waste streams and to promote and encourage recycling for CE. Also, it will review all the findings and achievements in this research with a special focus on the impact on Vanderlande's business operation to ensure compliance with SCIP and being a responsible player in the industry, ensuring a sustainable and transparent supply chain.

2 LITERATURE REVIEW

2.1 Sustainable Economy

The use of material resources grew from 27 billion tonnes (Gt) to 89 billion tonnes from 1970 to 2017, globally according to the Organisation for Economic Co-operation and Development (OECD), and it is expected to grow to 89 gigatonnes (Gt) due to the increase in population and economic development.[5] In consequence, the progress in environmental degradation has been correlated to excessive production activities, massive energy consumption, and economic growth.[1]

A sustainable economy has been pointed out as the solution to the situation. The World Wildlife Fund (WWF) states that a sustainable economy can provide a good quality of life for people while staying within the limits of the planet.[6] Although achieving this transition is challenging and requires a commitment to action, in 2015, all the countries in the United Nations (UN) adopted the 2030 Agenda for Sustainable Development.[7]

The 2030 Agenda for Sustainable Development is a global strategy designed to address and call for action to end poverty and inequality and protect the planet. It is made up of the 17 Sustainable Development Goals (SDGs), as shown in Figure 1 and they are integrated by 169 targets, balancing the three main dimensions of sustainable development: economic, social, and environmental.[7,8]

Figure 1. Sustainable Development Goals[9]

The current exploitation of resources is attributed to the traditional economic model system, known as the linear economy model. This model is also known as the "take-make-waste model," as shown in Figure 2[10], which consists of the extraction of raw materials to make products that will later end their life cycle as waste and be thrown away. This model moves only in one direction and is described as their products not being used to their full potential (not recycling or reusing) and pushing the Earth to its

limits, causing environmental degradation as a result, just to provide for and satisfy the needs of modern society.[10,11]

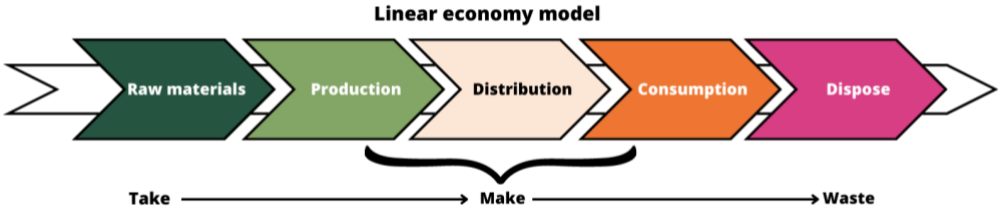


Figure 2. Linear Economy Model[10]

This model started during the industrial revolution, when resources looked infinite and allowed massive production, helping economic growth and global development. Although nowadays it is clear that these resources are finite and getting depleted, creating "massive anthropogenic erosion of biodiversity and of the ecosystem services essential to civilization".[12]

According to the UN, the current planetary crisis is caused by unsustainable consumption and production patterns, and it is expected that by 2050, the world will be consuming resources equal to the equivalent of three planets, leading to environmental degradation and threatening human well-being and therefore the achievement of the SDGs.[2,9] The 12th goal of the SDGs states the need for sustainable consumption and production, natural resources management and the development of urgent actions to tackle climate change and achieve a global sustainable development to guarantee and support the needs of the present and future generations.[9,13]

Additionally, under this goal, a short-term target was established to be fulfil by 2020, which consisted on a complete environmentally sound management of chemicals and all waste throughout their life cycle in accordance with international frameworks, with the aim of minimising the impacts on health and the environment by decreasing the release into the air, water, and soils.[8] While, for 2030, a waste generation reduction is expected through prevention, reduction, recycling, and reuse. For this urgent necessity to optimise the use of resources in a more efficient way, the idea of Circular Economy (CE) has gained attention, which is an alternative to the current linear model system, which has shown it is reaching its limitations.[14,15]

2.2 Circular Economy Model

The concept of (CE) arose as an alternative to the current linear economic system and was addressed for the first time in 1989 by Pearce and Turner, who described it as how natural resources influence the economy by providing inputs for production and

consumption and giving outputs in the form of waste.[16] Although they were inspired by Boulding's work in 1966, where he stated that the Earth is a circular and closed system with a limited capacity, he suggested that equilibrium should exist.[14,16]

In the latest EU Action Plan to achieve circularity, the EU defines the CE as a production and consumption model involving sharing, leasing, reusing, repairing, refurbishing, and recycling as long as possible the existing materials and products (extending the life cycle of products) and reducing waste to a minimum.[17] Nowadays, the concept has evolved, and the contemporary version shares the idea of a closed loop or cradle-to-cradle.[16] The most celebrated definition is the one presented by the Ellen MacArthur Foundation, in which CE is defined as a restorative and regenerative system by design in which input, waste, emissions, and energy leakages are minimised by closing and narrowing the material loops through long-lasting design, maintenance, repair, reuse, remanufacturing, refurbishing, and recycling.[12]

Therefore, the keywords to define CE are a closed-loop economy model that generates the minimum amount of waste by producing lasting products, which as the Ellen MacArthur Foundation mentions, has three main pillars:[18]

1. Regenerate nature – this pillar explains that shifting to a CE will allow nature to regenerate instead of just extracting from it by enhancing the use of renewable resources and avoiding the use of non-renewable resources (i.e., using renewable energy instead of just relying on fossil fuels).
2. Circulate products and materials – this second pillar supports the first one, which maximises the use and recirculation of material flows to eliminate or decrease waste.
3. Eliminate waste and pollution – by including, from the beginning phase, the elimination of "waste" or directing this flow to re-enter the process as a secondary raw material.

These pillars are summarised in Figure 3, from top to bottom, where the top shows the foundation for preserving and enhancing the natural capital, followed by the loops, which refer to the optimisation of resources yield by the circularity of the products and materials, and in the bottom, the need foster the effectiveness of the system by designing and minimising waste and leakages. This model was adapted from Braungart & McDonough's protocol Cradle-to-Cradle design by the Ellen MacArthur Foundation.[14,19]

Another highlight of the model in Figure 3, is the two complementary loops of the biological (green loop) and the technical (blue loop), where the first one refers to all the biological materials that can be decomposed by living organisms and, therefore, can go back to the biosphere, while the latter refers to all the materials that cannot be

decomposed by living organisms and need to be designed better to increase their circularity.[19] Additionally, these loops indicate the materials and resources that should remain functional in the economy as much as possible, increasing their life cycle to minimise waste.[20,21]

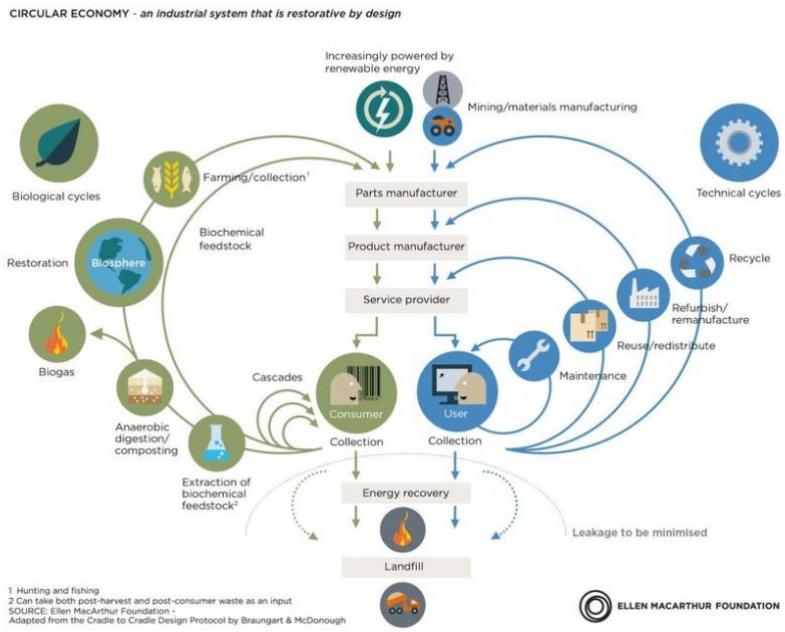


Figure 3. Circular economy butterfly diagram proposed by the Ellen MacArthur Foundation and adapted from Cradle Design Protocol by Braungart & McDonough[19]

Transitioning to this model will bring benefits for sustainable development, and it is suggested that it will contribute to its three dimensions: economic, environmental, and social.[22] The greater benefit comes from the economic aspect by the creation of new jobs and business opportunities leading to economic growth, as well as the fact that the CE is fostering innovation in product design; therefore, new technologies are being developed, allowing cost savings and increasing material efficiency for the companies. Moreover, CE is increasing its competitiveness and expanding into new markets, especially in the sectors of recycling, remanufacturing, and repair services.[2,22–24]

For the environmental aspect, CE promotes and equilibrates the use of resources through controlled extraction, allowing their conservation and regeneration.[24] Also, a reduction in pollution and greenhouse gas (GHG) emissions is achieved by decreasing the waste produced and by switching to renewable energy sources, promoting energy efficiency and sustainable production.[16,21] The social benefits are described as minimal compared to the economic and environmental benefits because they come as a consequence of the others. A higher level of social inclusion is caused by increased job opportunities, which also create a higher sense of community and cooperation through sharing the economy.[16,22,23]

On the other hand, several potential challenges have been addressed to achieve this change. The first barrier is a financial aspect in which economic support is required, especially for the implementation and development of new technologies (R&D) and processes, asset investments, infrastructure for new processes, and waste management.[21,25] Next, legal and regulatory barriers need to be sided for this transformation of the existing model of production and consumption, and they must be aligned to accommodate circular practices such as including CE principles of waste management, product design, and producer responsibility.[21,25]

The next barrier is the technological challenge, caused by the limited infrastructure and technology available to achieve the goals or requirements for a CE model to increase material durability, waste management, recycling materials, etc.[21] Another barrier is the lack of reliable information, skills, and knowledge, which demands more public awareness to promote the cultivation and teaching of required skills in the workforce to encourage and value the CE principles.[21,25]

Consumers are a key player in the transition towards a CE; therefore, cultural and consumer awareness needs to change from the take-make-dispose idea towards sustainable consumption by encouraging the adoption of behaviours of reuse, repair, and recycling. Furthermore, raising awareness, education, and knowledge among stakeholders, business owners, and policymakers will help them have a broader understanding of the benefits of CE principles and practices.[21,25] Additionally, this transition must be global; therefore, a multilevel governance challenge exists demanding the participation, and coordination of international, national, local businesses and individuals to achieve circularity.

Moreover, systemic challenges need to be considered (i.e., population growth, resource availability, and overconsumption) to accomplish a successful CE.[25] In the last few years, several actions have been taken to transition to a CE, and as mentioned, the SDGs are an important pillar supporting the need for this change. In Europe, the European Green Deal sets the baseline to achieve climate neutrality in Europe by 2050 and supports a sustainable CE. It recognises the model as a pillar for environmental sustainability and emphasises the need to decouple economic growth from resources and economic degradation; therefore, the EU CE Action Plan was developed to achieve a sustainable transition to this model.[26]

2.3 EU CE Action Plan

For the transition to a cleaner and more competitive Europe, the European Commission developed a Circular Economy Action Plan in December 2015, but until March 2020, the

plan was adopted.[27] This plan is composed of 35 legislative and non-legislative actions to accelerate the transition of the EU towards a CE model with the aim to assure that everybody participates and has a role in a CE and, along with the industries and communities, to push forward and work together to achieve climate neutrality by 2050 and safeguard the competitiveness of the EU in the long term.[2]

The way to accomplish it is by shifting and accelerating the transition towards a model focused on a regenerative approach with firm planetary boundaries in which more can be given back to the planet than taken from it, meaning reducing resource consumption, hence decreasing the consumption footprint, and duplicate the circular material use rate for the oncoming years.[2] This will allow Europe to not just accelerate circularity but also dematerialize, making it rely less on primary materials.

All the actions introduced in the plan can be grouped into seven key categories or groups, in which different frameworks, initiatives, legislation, regulations, directives, and policies were developed to achieve them, as summarised in Appendix 1.[2]

The first category focuses on a sustainable product policy framework because the EU found that 80% of the environmental impacts of a product are determined in the design phase; consequently, designing and eco-designing (eco-design framework) the products with the objective of delivering more climate-neutral and resource-efficient products.[2,28] Moreover, all the frameworks developed in this category are based on sustainability principles to improve durability, reusability, upgradability, and reparability, reducing single-use and premature obsolescence of the products in the European market. Priority is given to electronics, information, and communication technologies (ICT), textiles, furniture, and high-impact intermediary products (e.g., steel, cement, and chemicals).[2]

Furthermore, it looks to disclose the presence of hazardous chemicals in them, increase the recycled content without losing their high performance, and digitalize product information to reduce carbon and environmental footprints.[2] Making all the information available for the public buyers or consumers to empower them to make a more conscious decision including them in the transition for this circularity.[2]

The next category is the key product value chain, which oversees the important role played by the value chains to achieve the goals for a sustainable product policy stated in the previous category. The European Commission will collaborate with the key stakeholders to identify the barriers and how to overcome them for the expansion of circular products in the market. Impacting the most to:

1. Electronics and ICT fall into the "circular electronics initiative" to increase product recyclability by changing the mindset of repairing instead of thrashing the devices,

improving the waste streams, and reviewing the restriction of hazardous chemicals RoSH Directive [29] to align with REACH[30] and eco-design.[2]

2. Batteries and vehicles are pillars of mobility, and the Batteries Directive is aimed at enhancing the value chain of electro-mobility in a sustainable way, while the End-of-Life Vehicles Directive[31] incentives for the recycling of materials and their components, along with the strategy on smart mobility for the reduction of virgin raw materials and increasing the use of sustainable fuels.[2]
3. For packaging, the Packaging and Waste Packaging Directive is expected to reduce packaging waste, use more sustainable and recycled materials, and guarantee the safety of recycled materials for reuse (no hazardous chemicals in them).[2]
4. Plastics are affected by the EU Strategy on Plastics in the CE, which focuses on reducing litter and microplastics as well as the labelling and composition of bio-based plastics, biodegradable and compostable plastics, and single-use plastic products.[2]
5. The textile industry is one of the most polluting industries, therefore, the EU Textile Strategy is expected to increase recycling, boost innovation to develop new models to address fast fashion, ensure the take of secondary raw materials, tackle the presence of hazardous substances, and provide guidance to have a proper waste separation of textiles in each Member State by 2025.[2,32]
6. Construction and Buildings in which the Strategy for a Sustainable Built Environment aims to standardise the policies about climate, energy, and the efficient use of resources, and promote the circularity principles during the lifecycle of the construction, such as durability.[2]
7. Food, water, and nutrients aim to reduce food waste; therefore, the Waste Framework Directive (Directive 2008/98/EC) (WFD) and EU Farm-to-Fork Strategy set targets for waste reduction.[2]

The third category is "less waste, more value," which is divided into four main approaches to reducing waste and incentivizing circularity:

1. Enhanced waste policy - for waste prevention and circularity (from design). Also, increase the recycled content to promote cleaner and safer (no-hazard substances) waste streams to accomplish high-quality recycling. Additionally, in the action plan, a revision was proposed and done into the WFD in 2018, setting specific targets to reduce the total waste generated in the oncoming years.[2,3]
2. Enhancing circularity in a toxic-free environment – where the EU chemical policy, along with REACH, urges the shift to safe-by-design chemicals for the gradual substitution of hazardous substances for the protection of people and the environment. Also, this action encourages the development of proper

methodologies to minimise the presence of these hazards and a tracking system by the ECHA SCIP database (explained in detail in the following chapters) to identify them for future waste management and recovery. Also, it highlights that the Chemical Strategy for Sustainability will address in detail the association of chemicals, products, and waste legislation to reinforce the collaborations with the CE.[2]

3. Creating a well-functioning EU market for secondary raw materials - aims to face the challenges posed by recycled material or secondary raw materials to comply with the requirements of recycled material. It would be done by assessing the end-of-waste criteria and standardising them to create a well-functioning internal market for secondary raw materials.[2]
4. Addressing waste exports from the EU –the Commission aims to ensure the waste is recycled in the EU for secondary raw materials and stop sending waste challenges to third countries.[2]

The fourth category addressed in the EU CE Action Plan is Making the CE work for people, regions, and cities, which shows that the Commission is aware this transition cannot be achieved without social inclusion, therefore, the implementation of the European Pillar of Social Rights will support the green transition by creating jobs and preparing them with the right skills by updating the Skill Agenda and launching the Pack for Skills.[2] It has been forecast to create around 700,000 new jobs (recycling plants, repair services, and rebounds in consumer demand from savings) and increase the GDP by an additional 0.5% for 2030, especially for the manufacturing sector, by transitioning to a CE model.[33]

The next category is cross-cutting actions focused on three main actions: circularity as a prerequisite for climate neutrality, getting the economics right, and driving the transition through research, innovation, and digitalisation, as explained below:

1. The first action is to balance circularity and GHG emissions to achieve climate change by implementing modelling tools, promoting circularity in the energy and climate plans, and exploring regulatory frameworks for certifications for carbon removal.[2]
2. The Commission is implementing measures for circular financing. The CE Finance Support Platform offers guidance to projects to support financing and new funding mechanisms to enhance the environmental data disclosure of companies, as well as to improve companies' governance frameworks to integrate sustainability criteria into their business strategy.[2]
3. European Regional Development Fund and Horizon Europe want to bring to the table funding to support the cycle of innovation for a solution for the market, as well as the development and research of indicators and data, novel materials,

the substitution of hazardous substances using an approach of safe by design, new business models, new recycling, and production technologies, including the recycling of the chemicals.[2]

The sixth category is "leading efforts at the global level," which aim to include the neighbours of the EU to achieve a climate-neutral, resource-efficient, and CE as well. The Commission wants to achieve this through a global agreement on plastics, a Global CE Alliance, and a Safe Operating Space for Natural Resources to discuss an international agreement on the management of natural resources.[2]

And to properly track all the actions and achievements, the last category is monitoring the progress of the national plans in each member state and the framework for the CE, which relies on data, statistics, and indicators linked to circularity, climate neutrality, and zero pollution ambitions. Along with Horizon Europe and Copernicus, the expansion of data and official statistics is expected, including resource use, material consumption, material footprint, etc., all of which are used to assess the progress in dissociating economic growth from resource use and its impact within the EU and globally.[2]

In conclusion, the EU CE Action Plan has been designed to support a successful transition for the European economy to a circular model and to achieve climate neutrality based on the European Green Deal goals. It's important to acknowledge that this change will not happen overnight, and the implementation of these new practises might disrupt and challenge the current practices. Therefore, it is expected for each Member State to include these actions in their plans and strategies to foster dialogue among citizens and to achieve collaboration and support from all stakeholders at all levels, EU, national, regional, local, and international.

Moreover, it's essential to highlight the relevance of addressing harmful chemicals throughout this transition and how it is considered in almost all the actions outlined in the plan, with special emphasis on the need to map, decrease, and find alternatives for these harmful substances to ensure a safe change for the environment and for the people. In the following chapters of this thesis, some strategies, actions, and regulations will be explored in greater detail to achieve this goal during the transition to a CE model.

2.4 European Chemical Strategy for Sustainability

Life today is possible due to chemicals; they are fundamental in daily life and can be found anywhere from DNA synthesis to big-scale production of almost all products available worldwide in the market and in all sectors, such as health, energy, mobility, etc.[34] Although they can have hazardous properties, with improper use, they can be

harmful to the environment and to human health; therefore, a proper regulatory system is needed to guide the proper handling, development, and disposal of them.[34]

The EU chemical strategy was developed to address the issue, boost innovation for safer and more sustainable chemicals, and protect the environment and citizens. It was adopted in October 2020, and it is part of the EU's zero pollution ambition plan, which is a crucial promise of the European Green Deal.[35] Also, it supports and works together with the CE Action Plan to address the chemicals in products along with the waste legislation to encourage safer recyclability of waste streams.[2]

As mentioned, one of the main goals of this strategy is to address and identify the hazardous chemicals or substances of very high concern (SVHCs) that have been identified in several commercial products in the EU and global market that can affect the environment and are one of the main drivers putting the Earth at risk and amplifying the climate crises, degradation of ecosystems, and loss of biodiversity; moreover, these hazardous chemicals pose a risk for human health, affecting the immune, respiratory, endocrine, reproductive, and cardiovascular systems.[35]

Hence, this strategy addresses the need for transparency, availability, and accessibility of data and information on chemicals, especially through the supply chain, to impulse the data-based knowledge for the legal framework on chemicals, support evidence-based policy-making for sustainable chemical management, and propose the toxic-free hierarchy shown in Figure 4.[35]

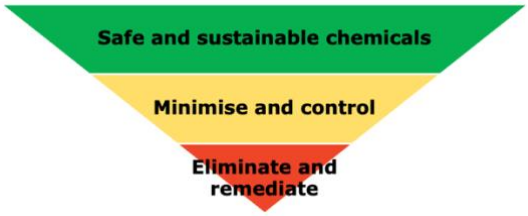


Figure 4. The toxic-free hierarchy presented in the EU Chemical Strategy[35]

The toxic hierarchy focuses on protection and innovation to achieve a toxic-free chemical approach. For protection, it prioritises the safety of people and the environment by encouraging and prioritising from the beginning the safe and sustainable design for over-minimizing the exposure to hazardous chemicals; this can be translated into pushing the initial phase of the value chain, and when this is not possible, the exposure should be minimised and tracked so it can later be eliminated from waste streams or from secondary raw materials when recycled to support the CE transition.[35,36]

It emphasises innovation; the EU chemical strategy proposes the development of safe and sustainable materials, novel risk assessments and testing for chemicals with

innovative tools, and the creation of clean technologies and processes. To minimise and control these toxic substances, the strategy proposes the promotion of smart production, business models, and IT solutions to track the chemicals, and lastly, use the innovative approach for safe elimination of the hazards through the implementation of waste management technologies or decontamination solutions.[35]

To achieve the previous objective of this strategic plan, some key actions have been defined and done until today according to ECHA[36,37]:

1. The revision of REACH assures the prohibition of the most harmful chemicals for products, only allowing the chemicals in their most essential uses. Also includes the review of the combination with other legislation on chemicals found in water, food, additives, toys, food, detergent, and cosmetics.[37]
2. Attention to the effects of the chemicals or substances in mixtures, especially when performing assessing chemical risks.
3. Regulation of per- and polyfluoroalkyl substances, or better known as PFAS, with a crucial revision and defining specific actions to address the use and contamination of PFAS and to prohibit use unless proven essential.
4. Increase the investment in research and innovation for the safe production and use of chemicals, from the design throughout their whole lifecycle of them, under the guidelines of the Green Deal goals.[37]
5. Develop and establish a simple assessment procedure, "one substance, one assessment", for assessing the risk of chemicals.

This strategic approach to chemical management is a long-term vision for EU chemical policy and aligns the societal value of chemicals with human well-being and planetary boundaries to support safe and sustainable chemical production. Furthermore, it aims for a toxic-free environment, avoiding the release of harmful substances where they can maximise their contribution to society and be used in a safe way for the green and digital transition.[35]

This strategic plan offers a roadmap for the transformation of the chemical industry with its 80 actions, with a special focus on the new chemicals and materials that are safe and sustainable from the moment they are produced and throughout their whole life cycle. Therefore, innovation plays a key role in the development of new technologies and processes that need to be implemented to achieve a climate-neutral transition.[35]

2.4.1 European Chemicals Agency

ECHA was designated to lead, put in place, and develop the appropriate regulations to achieve the milestones proposed by the European Commission in the EU Chemical

Strategy and in the EU CE Action Plan. ECHA is an independent regulatory agency, and it is constituted of representatives of EU Member States, the European Commission, the European Parliament, and stakeholder organisations. It oversees implementing European Chemicals' legislation with the main goal of protecting the well-being of the population and the environment and promoting the safe use of chemicals.[38,39]

ECHA was established in 2007 in Helsinki, Finland, and from day one has worked for the well-functioning of the internal market, innovation, and competitiveness of Europe's chemical industry. Also, ECHA encourages the knowledge and regulation of harmful chemicals, aiming to protect workers, consumers, and the environment by encouraging recycling practises and encouraging the industry to find new and safer alternatives.[38,39]

Furthermore, ECHA ensures that chemical companies comply with European laws by generating scientific and technical assessments and providing this knowledge for transparent decision-making. Also, it offers the European Commission information with a special emphasis on the potential impact of hazards and risks of chemicals on society and strategies to mitigate them.[38]

To accomplish its mission of safeguarding the well-being of the people and environment from hazardous substances, ECHA manages several regulations regarding chemicals, including REACH (explained in the chapter on other regulations), the Classification and Labelling of Chemicals (CLP), the Biocidal Products Regulation (BRP), Persistent Organic Pollutants (POPs), and chemical databases.[38] One of these databases is public and available free of charge and holds the largest amount of chemicals in the world, with more than 245,000 chemicals, allowing companies, researchers, industry, and consumers to take advantage of and benefit from it. Another is the candidate list with SVHCs or the SCIP database.[38]

ECHA plays a key role in the objective of the EU CE Action Plan of reducing hazardous substances in waste streams and contributing to more sustainable development by better regulating these substances, recognising all materials and products made out of chemicals, facilitating quality and knowledge available for recycling practices, and ensuring the protection of workers, consumers, and the environment by encouraging industrial innovation and product quality by inclining the substitution for safer substances.[2,34,38] Also, it manages to control and increase the transparency of the import and export of hazardous chemicals and limit their distribution worldwide.[38]

ECHA is also an active player in the EU Chemical Strategy of reducing toxic compounds from the environment, and under the WFD, ECHA constructed and is responsible for administering and managing the SCIP database (explained in detail in the chapter of

SCIP regulation) containing articles with SVHCs for the EU market. This database is crucial to increasing and facilitating the exchange of information throughout the supply chain, allowing the authorities of the SVHCs in the market to initiate proper regulatory actions, increasing knowledge, and giving the consumer the freedom to make more informed decisions about the articles they are buying. As well, it allows the information to be available to the waste management companies to design better recycling methods to dispose of them and avoid the possible release of these hazardous substances into the environment.[40,41]

2.5 Waste Framework Directive

The WFD has a strategic responsibility to succeed in the transition towards a CE in Europe, especially for the goals of turning "waste" into resources to close the loop and increase the resources' efficiency. This directive is the primary legislation for regulating hazardous waste in the EU. It sets a legal framework for waste management with the aim of protecting the well-being of people and the environment through the promotion of sustainable waste management practices and reducing waste generation, especially hazardous substances from the waste stream.[42]

Furthermore, the WFD dictates procedures to protect the environment and human health by preventing or reducing waste generation in Europe, addressing the importance of the efficient use of resources, which is crucial for the transition towards a CE.[3,42,43] This directive established the five-step "waste hierarchy" for managing and disposing of waste, shown in Figure 5 , this shows that preventing waste is preferred versus sending it into landfills, which should be the last option.[42,43]

The WFD was adopted for the first time in 1975 as EC Council Directive 75/442/EEC on Waste and provided a basic framework for waste management. Through the years, the directive has evolved, and in 2018, the European Parliament and Council adopted the European Parliament and Council Directive (EU) 2018/851 amending Directive 2008/98/EC, where the WFD was revised for the last time and aligned to achieve the EU CE Action Plan and EU Chemical Strategy goals to introduce new measures to promote waste prevention to support the transition to CE.[43]

The WFD sets global goals to achieve for all EU members; however, it is up to each individual member estate to devise and implement their own laws and rules to be achieved, the next oncoming goals are increasing to 55% by weight the municipal waste recycling by 2025, 60% by 2030, and 65% by 2035.[42]

Figure 5. Waste hierarchy set by the WFD[42]

Another aim of the WFD is to decrease all waste containing any hazardous substance, chemical, or material; therefore, article 9 of this directive focuses on "prevention waste," setting the pillar for the formation of the SCIP database, which foresees that all Member States shall take measures to prevent waste generation containing hazardous chemicals. This database aims to enhance the traceability and proper management of the waste streams containing such hazardous substances.[44]

SCIP supports the WFD by promoting waste management practices, mapping, and identifying complex products in the market with SVHCs that might end up in waste streams when they reach their end-life cycle, enabling the identification and facilitation of appropriate handling, recycling, and disposal according to the waste hierarchy. Moreover, SCIP incentives the substitution of these SVHCs, therefore preventing them from appearing in waste streams in the future making SCIP a complementary tool to the WFD in achieving a CE and promoting the efficient use of resources.

2.6 SCIP Regulation

As previously stated, the EU CE Action Plan and the EU Chemical Strategy for Sustainability, share the goal is to reduce the harmful substances in waste streams and in articles for a toxic-free environment. Thus, Article 9(1)(i) of the WFD appointed ECHA to create the SCIP database. The SCIP database is a tool to increase transparency and ensure the information on articles containing SVHCs in the EU market is available throughout the lifecycle of products, including at the disposal stage.[3,45]

SCIP has three main goals[45]:

1. To reduce the amount of waste generated containing SVHCs and encourage the substitution of those substances for safer alternatives in the production process.

2. Improve waste treatments and management by increasing the information available and contributing to a better CE by helping waste operators ensure those substances are not present in recycled materials.
3. Enables authorities to monitor the use of SVHCs in articles, thus creating actions over the articles' lifecycle when needed.

This regulation applies to all companies supplying articles to the EU. If any of those articles contain SVHCs reported in the candidate list created by REACH above the threshold of 0.1% (w/w), they should be reported to the SCIP database.[4] This regulation entered into force on July 4th, 2018, while the submission of information started on January 5th, 2021, and since that day, companies must report those articles to ECHA and provide the information to the supply chain.[43]

To better understand the obligations, the definition of articles and complex products needs to be clarified, according to the regulation:

- An article – is an object that, during production, is given a special shape, surface, or design that determines its function to a greater degree than its chemical composition.[45]
- Complex product - is defined as an object that is made up of more than one article if they are only assembled and remain the same shape, surface, and design.[45]

The parties involved are required to notify such cases, which are applicable to producers, distributors, and assemblers. When done properly, it is expected to increase the transparency of hazardous chemicals in products, allowing consumers to make better and more informed decisions about the products they are buying and what the best use and way to dispose of them are.[45] Additionally, the SCIP database makes available additional information to waste operators for the improvement of waste treatment technologies and management practices, such as supporting the segregation of waste containing SVHCs in the collection, disassembling, and sorting of waste operations, and encouraging the use of waste as a resource and incentive for the CE.[45] Moreover, it pushes the reduction of hazardous substances in materials and products, especially recycled materials, increases visibility within companies, and encourages the substitution of SVHC with safer alternatives.

2.6.1 SCIP notification

Figure 6 shows the process that needs to be followed to notify an article or complex product of the SCIP database by manufacturers, importers, and assemblers. First, a dossier needs to be created, which should contain all the relevant information regarding

the article, the SVHCs, their concentration, location in the product, and the proper way to handle the product when it becomes waste.

This process can be complex; access and installation of the software need to be done, and then proceed to create the dossier manually when using the software offline or online. Each company can develop their own system to connect to the ECHA system and develop a more automatic process. After the submission, a report with a personalised SCIP number is received, and the article will appear in the database.[46]

Also, distributors and assemblers can use two extra tools to notify the SCIP database. Distributors that do not modify the articles can use Simplified SCIP Notification (SSN), which will use the already reported information in the database and will not need to create a dossier from scratch. This only applies when the upstream supply chain has provided the information needed. On the other hand, assemblers that create or assemble a new complex product using several unmodified articles containing SVHCs can use the referencing tool, which will take the already available information of the articles and link them to the new complex product, creating an SSN by including all the SCIP numbers of the articles of the new complex product.[47] Therefore, it's important to emphasise the need for transparency throughout the supply chain and provide information regarding the SVHC in articles.

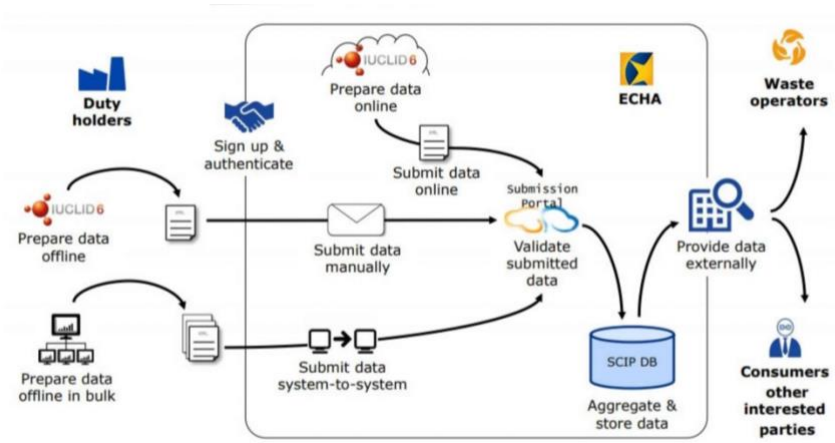


Figure 6. SCIP Notification Process[46]

2.6.2 SCIP database

After the submission, the articles can be found in the SCIP database, which is continuously updated; the last update of the database was in May 2023, and it already has more than 22 million notifications. Figure 7 shows the database and how the overview of each reported article is shown, and it has several options to look for the articles. It can be filtered by the identity of the article, categories (function of the

article), type of material, the type of SVHCs found in the article, the reason for the inclusion of the substance of concern, and lastly, the SCIP number.[41]

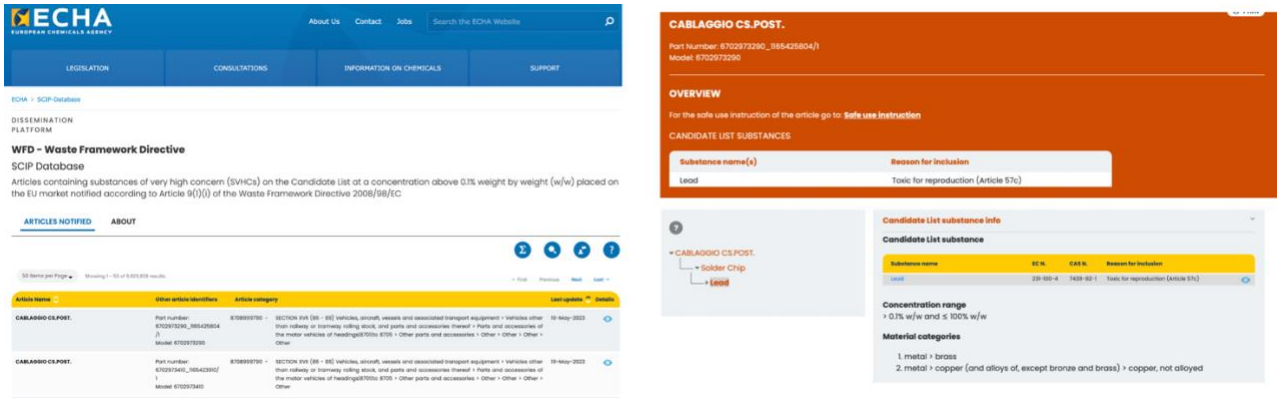


Figure 7. SCIP database[41]

Overall, complying with SCIP and reporting to the SCIP database can be challenging, but it is a valuable tool to create awareness of the harmful substances in products among producers and consumers, thereby pushing the necessity of creating new strategies for having safer designs in products. This will help to fulfil the goals of the transition towards a CE and decrease any harmful substances in products on the market and consequently in waste streams in the future. Additionally, it will push the necessity of developing new technologies to have a better recycling process for the removal of these hazardous substances to assure the protection of human health and the environment while increasing innovation and creating more jobs.

2.7 Other Regulations: REACH vs RoSH

It's important to recall other regulations that share similarities and differences with the SCIP regulation, especially to understand if they are applicable to the same users and what obligations each of them entails. The sister regulations considered in this thesis are REACH and RoSH, as both aim to identify SVHCs as well.

2.7.1 REACH Regulation

To ensure the safe management of chemicals, ECHA implemented REACH to control all chemicals produced or imported into the EU in a quantity of one tonne per year with the goal of protecting human health and the environment against the effects of harmful substances, increasing the novelty and competitiveness of the EU chemical industry, assessing the safety of chemical use in the EU, and hazardous substances by promoting alternative methods (non-animal).[48]

REACH entered into force on June 1st, 2007, and it oversees all chemical substances used in daily life to manufacture processes, therefore, this regulation impacts many sectors across the EU and is applicable to:[49,50]

- Manufacturers – as any company producing chemicals, including substances as intermediates or as part of a finished product, to supply themselves or other companies.
- Importers – who buy or import chemicals from companies outside the EU and EAA.
- Downstream users – companies or individuals that use chemicals for industrial activities, including formulators and manufacturers.
- Companies outside the EU – do not have any responsibility to comply with REACH, the one who must fulfil the requirements would be the importer.

Overall, to protect human health and the environment, REACH ensures the safe management of the chemicals through their whole life cycle, including production, importation, and disposal, and it does this through four main actions:[49]

- Registration – manufacturers and importers can register produced or imported substances above one tonne per year, including the properties, uses, safety datasheet, and the assessments proving their safe use.
- Evaluation – REACH evaluates all the submitted dossiers and assesses each substance's risk; this information is added to the ECHA databases.
- Authorisation – the substances with the most severe hazardous properties are put on the authorisation list and companies must apply for permission to use them by demonstrating how the risk is minimised and there is no other alternative.
- Restriction – REACH shares information for the EU to ban the manufacturing, use, or placing of hazardous substances on the EU market.

It’s important to highlight that ECHA forms the candidate list based on the results obtained in the evaluation done by REACH. This candidate list groups the SVHCs that have been identified scientifically to have damaging properties towards the environment and can cause serious human health issues. These SVHCs tend to be carcinogenic, mutagenic, toxic to reproduction, persistently bioaccumulative and toxic (PBT), endocrine disruptive, etc.[49] This list is updated twice a year, and currently, it has listed 233 substances, with January 2023 being the last actualization.[51]

It's mandatory for manufacturers and importers to share information about REACH and the presence of SVHCs in articles above the threshold of 0.1% (w/w) through the supply chain, providing safe use and handling instructions according to Article 33 of the regulation, although end-users are excluded to notify to REACH, but not to notify the

SCIP database. Therefore, REACH is closely linked with SCIP because the latter requires reporting to the SCIP database the presence of these SVHCs in complex products made by articles above the same permitted threshold for traceability. SCIP also contributes to fulfilling the goal of REACH of protecting human well-being and the environment from hazardous chemicals and promoting the use of safer alternatives.[49]

2.7.2 RoSH Regulation

While REACH focuses on the control of hazardous chemicals in the market and in the manufacturing process, RoSH focuses on the restriction of certain hazardous substances in electrical and electronic equipment (EEE) and aims to restrict the use of certain hazardous substances in electronic equipment to protect the well-being of the population and the environment.[52]

The rapid evolution of technology and its nonstop production results in the obsolescence of electronic products, making e-waste one of the biggest waste streams in Europe,[53] and during the e-waste process of collection, treatment, and disposal, harmful chemicals can be released, leading to major damage to the environment and human health. To tackle this challenge, the EU works through the RoSH Directive to restrict the use of hazardous substances in EEE, while the WEEE Directive promotes the recycling of those products. RoSH was adopted by the European Parliament and Council Directive 2011/65/EU, and the last modification entered into force on July 21, 2011.[52]

This directive supports the European Green Deal and EU CE Action Plan by encouraging reuse, recycling, and adequate management of electric components and equipment. It also supports the goal of reducing environmental harm caused by hazardous chemicals. It also restricts these harmful substances by encouraging the production of easier-to-recycle electric and electronic components and promotes the use of safe materials in a CE framework. Last, the Chemical Strategy aids in the goal of achieving a toxic-free environment and a sustainable chemical industry, including reducing the presence of SVHCs in products and promoting safer alternatives.[2,34,52]

The ten substances listed under RoSH (Table 1) are under REACH SVHCs and are categorised as heavy metals, flame retardants, and plasticizers commonly found in EEE. The directive states that all EEE products should comply with this restriction, although there are some specific exceptions for some industries and products (i.e., healthcare with medical devices, military and aerospace equipment and spare parts for repair for products on the market before the directive entered place). Also, these exceptions are linked due to the availability of safer alternatives, technical limitations, and the inadequacy of the impact on the functionality of the alternatives.[54]

Table 1. Restricted substances under RoHS Directive[54]

Substance	Max. concentration (%) (w/w)
Lead (Pb)	0.10
Mercury (Hg)	0.10
Cadmium (Cd)	0.01
Hexavalent chromium (Cr^{6+})	0.10
Polybrominated biphenyls (PBB)	0.10
Polybrominated diphenyl ethers (PBDE)	0.10
Bis(2-Ethylhexyl) phthalate (DEHP)	0.10
Benzyl butyl phthalate (BBP)	0.10
Dibutyl phthalate (DBP)	0.10
Diisobutyl phthalate (DIBP)	0.10

Therefore, the obligations to comply with this directive apply to[54]:

- Manufacturers – who must design and manufacture to ensure the compliance of EEE, prepare technical documentation, have proper inter-production control, and maintain conformity during production.
- Authorized representatives – are appointed by the manufacturers and must keep up with the EU declaration of conformity, and all technical documentation for national surveillance and demonstrate it to the competent authorities.
- Importers – should only place compliant EEE products on the market, guaranteeing the conformity of technical documentation by the manufacturer and demonstrating it to the competent authorities; if non-conforming EEE products are found, they need to notify the manufacturer and distributors.
- Distributors – must verify the compliance of the products and not make available non-compliant products in the market, for the latter must inform the authorities and cooperate on compliance actions.

All the mentioned obligations for each mandatory participant in this directive have an impact on all the electrical and electronic industries and all the products covered in the regulation, therefore forcing a transition in the market towards more sustainable product development and innovation by using more safe alternatives in the manufacturing process of EEE products to be compliant with RoSH.

RoSH and SCIP share the same goal of promoting the safe and sustainable management of such hazardous substances in products, although RoSH only focuses on the manufacturing of EEE in the EU market, while SCIP addresses the reporting and traceability through the entire supply chain of all articles placed in the EU containing a more extensive list of SVHCs.

2.8 Vanderlande Industries

In terms of material handling and logistic automation, Vanderlande is the company to go to. As they describe themselves, Vanderlande is a market-leading, global partner for future-proof and innovative logistics process automation and distribution in warehousing, baggage and handling systems at airports, and parcel stores, and their products can be found worldwide.[55] Vanderlande offers personalised solutions, innovative systems, intelligent software, and life-cycle services that result in the realisation of fast, reliable, and efficient automation technology. Vanderlande works with its customers to optimise their processes and competitive position to improve their operational activities and expand their logistical achievements.

2.8.1 About the Company

Globalisation has played a key role in the massive growth of Vanderlande since it was established in 1949 by Eddie van der Lande and known as Machinefabriek Van der Lande. The company started refurbishing and later producing machines for the textile industry, until they moved to the manufacturing sector by fabricating conveyor belts and cranes for bulky materials and barrels of oils.[56]

In 1963, a joint venture was formed with the American company Rapistan Incorporated, consequently including in the portfolio the personalised transport system and renaming the company Rapistan Land, which was the turning point for the beginning of the global success of the company.[56] In 1988, the company returned to Dutch management due to a buyout followed by NPM Capital renaming the company known today as Vanderlande Industries and allowing it to achieve its goal of expanding on an international scale;[56] and in 2017, Vanderlande was acquired by Toyota Industries Corporation (TICO), one of the global leaders in material handling, creating a synergy between both companies and allowing a partnership with a cross-selling of their products and solutions, reinforcing Vanderlande's position in the market with the new access to resources and expertise from TICO.[56,57]

Nowadays, Vanderlande keeps working with a strong focus on research and development for technological advances in material handling and automation to continue being a reliable partner to its customers, providing innovative and cutting-edge solutions to the market worldwide.

2.8.2 Vanderlande's Solutions

Vanderlande offers a wide range of solutions (products) and services, which, as mentioned before, are divided into three sectors: airports, warehousing, and parcels.

Vanderlande has an extensive portfolio of integrated solutions, from innovative systems to intelligent software, and life cycle services, with the outcome of fast, reliable, and efficient automation technology with the final goal of optimising the flow of goods, increasing operational efficiency, and therefore enhancing the customer experience.[55,58]

As mentioned, Vanderlande is a global partner for future-proof airport solutions, and it leads the market in baggage handling systems, moving over 4 billion pieces of luggage around the world per year. Vanderlande Solutions is active in more than 600 airports, having services in 12 of the world's top 20 airports due to its smooth and efficient service from the luggage drop, innovative passenger security checks, and the ahead journey of baggage processing (storage, sortation, flight-makeup, and baggage claim) shown in Figure 8.[58,59]

Figure 8. Vanderlande's solutions for airports: 1) Self-check-in and luggage drop-off, 2) Security System Service 3) Baggage Sortation Handling System, 4) baggage claim[59]

This logistic process automation for airports makes Vanderlande the largest Original Equipment Manufacturer (OEM) in the market with its wide range of solutions. Moreover, Vanderlande has created strategic partnerships to continue fulfilling and exceeding its customers' expectations, optimising the passengers' experience.[59]

Vanderlande has expanded beyond the airport market; now it is the first choice of many of the largest global e-commerce players and retailers in the food, fashion, and general merchandise around the globe (i.e., Lidl, Zalando, Walmart, Albert Heijn) as a warehousing and distribution solution (Figure 9). Due to its efficient and reliable solutions, Vanderlande helps them fulfil their promise of same-day delivery for billions of orders.[58]

Nowadays, with the possibility of buying almost anything with a click online, Vanderlande plays a role in the parcel market by leading the suppliers' process automation solutions. According to their reports, 52 million parcels are sorted by their installed systems every day for the world's leading companies, including UPS, DHL, FedEx, and DPD. Although this market faces new challenges every day with shorter order lead times, later cut-off times, small orders, and greater product diversity, it is demanding the highest reliability performance and expects the most cost-effective systems with zero faults. Vanderlande works to provide the best total personalised solution for their customers, as shown in Figure 9.[58,60]

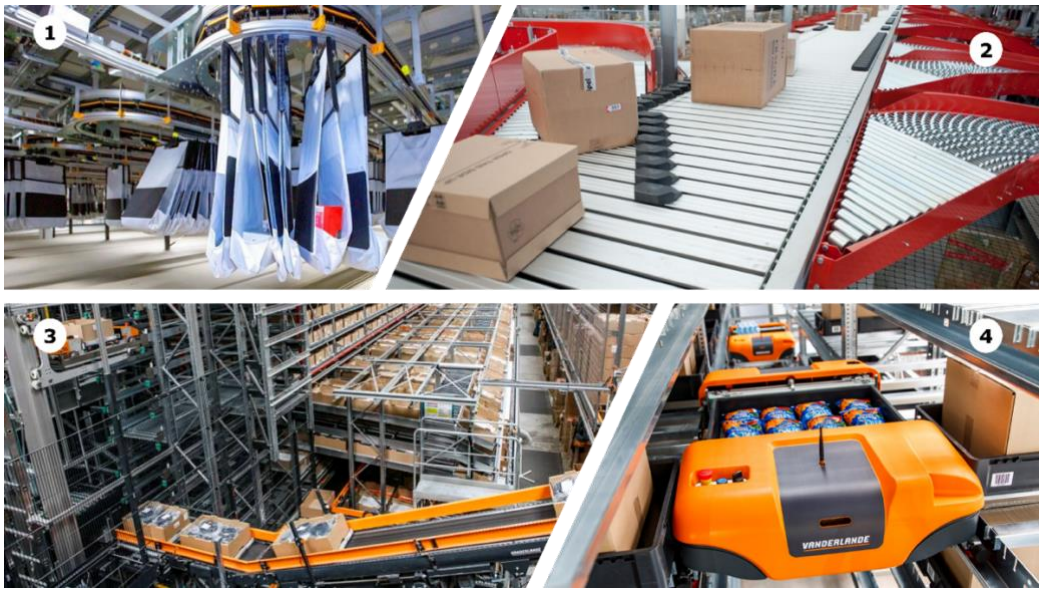


Figure 9. Vanderlande's solutions for parcels (1 & 2) and warehousing (3 & 4) automation systems

2.8.3 Sustainability Strategy

Vanderlande is committed to being a sustainable company, therefore, sustainability is one of the three top strategic priorities for the company, along with high-performance culture and being a powerful platform. To achieve it, Vanderlande has developed a global sustainability strategy, which takes the form of the framework shown in Figure 10.

This framework (Figure 10) focuses its approach on three main pillars: the planet, prosperity, and people, guided by the UN SDGs. Vanderlande classified their actions into four missions and set specific targets in the short, mid, and long term for the company, suppliers, customers, the world, and society. These targets are transformed into projects and actions within the company.

The four missions have their own approach according to the group that will be impacted, as explained below[61]:

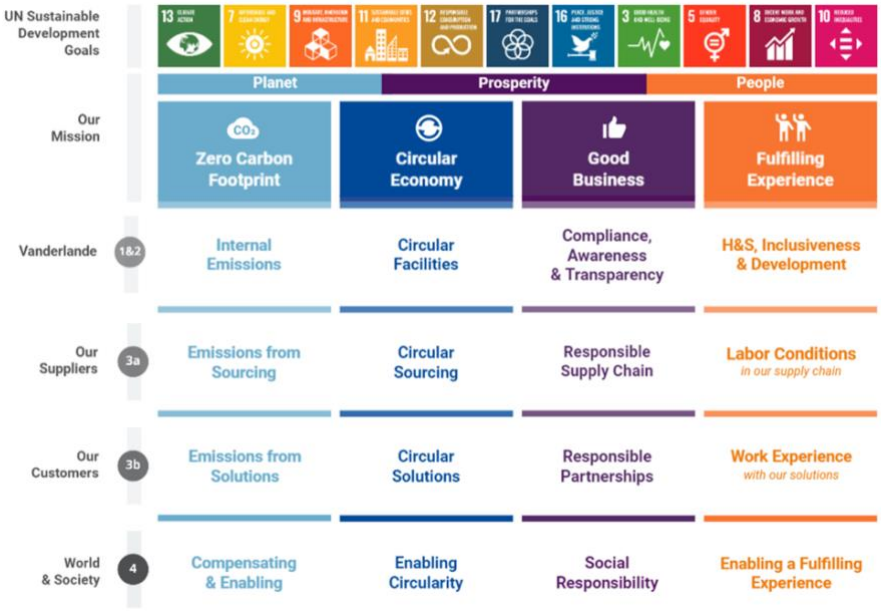


Figure 10. Vanderlande's Sustainability Framework[61]

1. be net zero carbon by 2040, 10 years ahead of the Paris Agreement and Vanderlande expects to do it by controlling and improving the internal emissions (buildings), tracking the suppliers' emissions, and making products more energy efficient.
2. Vanderlande aims to become a company a regenerative company by 2040 by modernising its facilities and manufacturing solutions, having solid contact with suppliers to source the best products, thus making the solutions as circular as possible.
3. Vanderlande strives to do Good Business by having strong business ethics, compliance, awareness, transparency, a responsible supply chain and partnership with customers, and a social responsibility.
4. By putting the people first, Vanderlande's goal is to provide a fulfilling experience by fostering the environment, promoting education, diversity, inclusion, and personal growth, and providing proper support to assure a full and excellent customer experience, such as training to use efficiently and safely the solutions and products provided.

For the aim of this thesis, the focus is on the circularity mission; hence, it is important to highlight Vanderlande's commitment to transitioning into a regenerative company; this can be observed through its statements, web page, and sustainability report.

Additionally, to follow the highest standards of sustainable production, Vanderlande is aware of the importance of complying with all the applicable regulations toward the products; therefore, an initiative pushed by TICO in all the sister companies (i.e.,

Bastian, Vanderlande, and Toyota Material Handling Europe) is the formation of the Product Environment Regulation – Working Group, or PER-WG, in 2021.[62] This group monitors and assess all new regulations that might affect the company and their products. Therefore, they could prepare and set an action plan to comply with them as soon as possible after the regulation is in place and share collaboration between the companies to discuss how to approach these new challenges.

As reported in the Sustainability Report of 2022, they highlighted teaming up with its customers and suppliers to design circular solutions, reduce their dependency on raw materials, and cut the amount of waste produced in the company, which are initiatives already mentioned and proposed by the EU CE Action Plan.[61] Moreover, Vanderlande wants to close the material loop in its production process by focusing on a sustainable and safe product design policy. They have stated the need to switch to non-virgin and recyclable materials and look for life-cycle extensions by optimising repair, reuse, and remanufacturing processes. In consequence, to keep track of these changes and their impact, proper documentation of each solution will be done to increase the transparency of the environmental impact.[61]

On the other hand, Vanderlande aims to contribute to a toxic-free environment by addressing substances of concern regulated by different directives and regulations under the EU Green Deal. Vanderlande is working to ensure compliance with the EU REACH regulation, which states that it is mandatory to inform all their customers of the presence of these SVHCs published in the candidate list contained in their solutions or products. Meanwhile, under the EU WFD, the SCIP regulation requires Vanderlande, as an assembler company, to report to the SCIP database if any of their solutions or products contain SVHCs above the threshold of 0.1% (w/w) and communicate the information to their downstream supply chain.[61]

The value chain (suppliers and customers) is the most affected community in Vanderlande's journey to achieve circularity when complying with these regulations. Thus, Vanderlande must have strong communication with the upstream supply chain to assure all the acquired materials comply with all the regulations, and therefore providing safe and sustainable products into the EU and global markets to fulfil its customers' requirements and needs.

Working under the PER-WG, this thesis focuses on the development of the process to strengthen the transparency and relationship with the upstream supply chain to gather the necessary information from their SCIP status to integrate it into Vanderlande's solutions and to keep working forward to ensure compliance with SCIP by 2025.

3 METHODOLOGY

3.1 Action Plan Development

3.1.1 Consultation with Royal HaskoningDHV

The implementation of SCIP is applicable to articles and complex products made by producers, manufacturers, and assemblers, thus, it is applicable for Vanderlande. Two consultations were done to define the action plan to ensure SCIP compliance.

The first consultation involved a consulting company, Royal HaskoningDHV, with the goal of defining an action plan for the implementation of SCIP in Vanderlande. The session consisted of the documentation of the regulations, understanding their requirements and obligations, the difference between an article and a complex object, and knowledge of the SVHC. The aim of the consultation was to gather information and insights on the SCIP frameworks and all their implications for Vanderlande. The consultant provided an overview and guidance on the SCIP requirements and suggested potential approaches to ensure compliance.

3.2 SCIP Project Implementation

The SCIP project for Vanderlande was divided into three phases: Pilot Phase, Phase II, and Phase III, the latter is out of the scope of this work.

3.2.1 Pilot Phase

The Pilot Phase was performed in 2021, and this thesis centres on the learnings from the Pilot Phase to develop the action plan for Phase II, therefore documentation of all the steps Pilot Phase were done to have a better understanding and to identify the opportunities, and challenges to minimise those in the next phase.

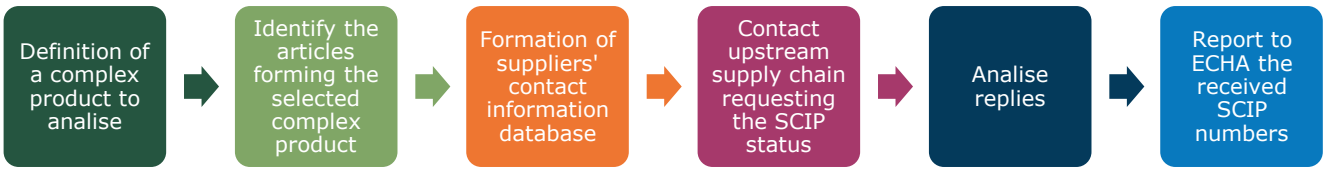


Figure 11. Process flow diagram for the SCIP Project Pilot Phase

The general process followed in the Pilot Phase is shown in Figure 11, in which a complex product was selected to be analysed as "Conveyor A", and then each article belonging

to this Conveyor A was identified according to its category and if it was produced in-house or bought from an external supplier. A database was formed by requesting the suppliers' contact information from the sourcing department.

To establish contact with the upstream supply chain, a personalised letter was developed for each supplier, requesting their status regarding the SCIP regulation. In the letter, a small explanation about SCIP regulations was included, focusing on explaining SCIP, SVHCs, and where they could read more information about the legislation, and the importance of transparency through the value chain for Vanderlande was highlighted. The main request was to provide an official statement to clarify their status. The received information was summarised in Excel.

3.2.2 Phase II

Phase II, which is the focus of this thesis, was defined to take the next step and escalate the project to cover and identify more SCIP-listed articles. Hence, after analysing and understanding what was done in the previous phase, some upgrades were made to the action plan. Therefore, the process flow and milestones for the SCIP project were modified, as shown in Figure 12. This time, instead of identifying the components of Vanderlande's solution or a complex product like in the previous phase, a category of articles was decided to pursue and analyse. These categories were labelled and classified as high-risk (HRC) and low-risk (LRC). The suppliers of these categories were contacted and requested to share all the SCIP-listed articles they have provided to Vanderlande.

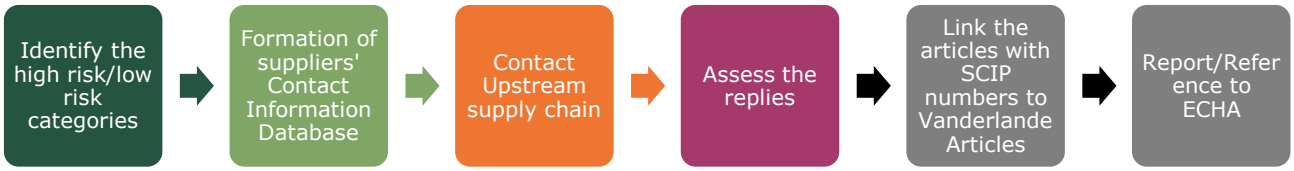


Figure 12. Process flow diagram followed for the SCIP Project Phase II

To define the HRC and LRC categories, the results obtained in the Pilot Phase identified three articles were identified from the category of electrical components. Additionally, it was contrasted to Table 2, of the LRC and HRC components' classification provided in the first consultation with the company Royal HaskoningDHV. In the end, 9 categories out of the 28 were classified as HRC categories, and the rest as LRC categories (19/28), although due to the time limit for the present thesis, only eleven were contacted (11/19) from the LRC categories.

The next step was to identify the suppliers belonging to each category and to do so, an internal sales report was used to guarantee the SCIP status request was done only with

suppliers with whom the company had established business relationships in the last year and are supplying within Europe.

Table 2. HRC and LRC components classification for materials

LRC	HRC
Steel objects	Recycled materials (non-metal)
Virgin polymers	Rubber
	Electronics
	Fire / heat resistant components
	Alloy objects

Then, the database of suppliers was constructed to gather the contact information for each supplier. To complete the database, the support of the department of sourcing was requested, in which they provided an internal document with all the information. A cross-reference was done to subtract the contact person's name and email address. In some cases, when the data was not found, it was obtained from the supplier's official webpage or by contacting different sourcing managers directly and requesting the information a second time. Also, some suppliers were discarded due to having several offices, but only the headquarters were contacted.

For the present work, 100 suppliers were contacted, of which 48 belonged to the HRC categories and 52 to the LRC categories, as shown in Table 3.

Table 3. Classification of contacted suppliers for HRC and LRC categories

Type of category	Contacted in Pilot Phase	Contacted in in Phase II	Totals
HRC	6	48	54
LRC	13	52	65
Totals	19	100	119

To establish contact with the upstream supply chain, a personalised letter was prepared for each supplier, as done previously in the Pilot Phase. This time, the letter contained a small explanation about the SCIP regulation and about the candidate list of SVHCs and where they could read more information about it. The importance of transparency and communication through the value chain for Vanderlande was highlighted, and the main request was to provide an official statement letter to clarify their status with the SCIP regulation, and in case they had provided any articles with SVHCs in the past, to share the SCIP number. This letter was sent to the contact information of each company, and they were given two weeks to provide the requested information.

3.2.3 Suppliers Status Assessment

After these two weeks passed, a first reminder was sent specifying the previous request and giving them another two weeks. If the supplier had not given any reply after three weeks of the second reminder, a third reminder was sent, including in the email another contact information found on the supplier's web page.

To keep track of the replies and feedback of each supplier, a planner as a backlog/reservoir was designed in Microsoft Teams (Figure 13), and the types of replies and statements/documents received were also included in the database (Excel) formed previously with the suppliers' information. The first tracking system was more visually helpful to keep identifying the status of each supplier according to each category they belong to and increased transparency within Vanderlande and with all the groups that wanted to know more about the SCIP in the company.

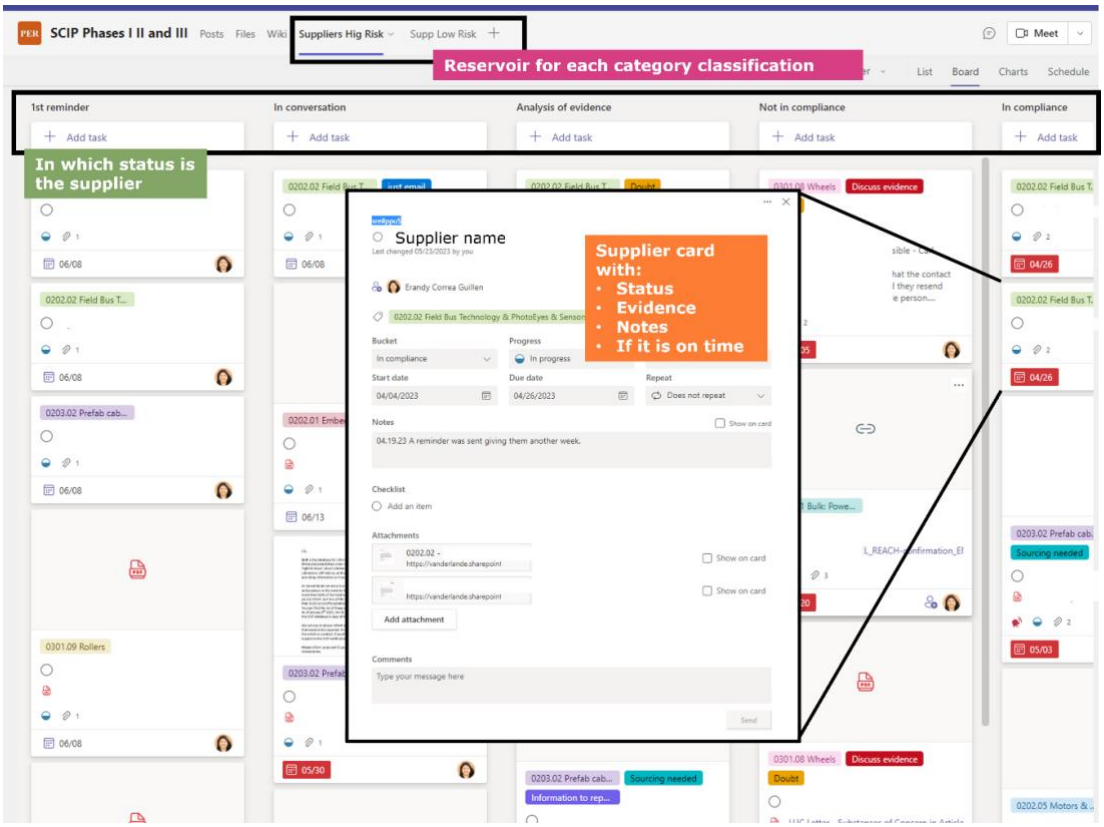


Figure 13. The tracking system of the suppliers' replies and compliance status to SCIP

Also, in the Excel document, more fields were added when exhaustive research was done for each supplier, analysing each webpage to identify how they share the compliance status and knowledge regarding SCIP, REACH, and RoSH. Additionally, in this search, the number of employees was identified to define the size of the company and the headquarters location.

The next steps of the process to link the SCIP numbers to Vanderlande's solution, which involves the integration of the SCIP information into the company's systems or products, are beyond the scope of this thesis.

3.3 Consultation Toyota Material Handling Europe

Toyota Material Handling Europe (TMHE) is a sister company to Vanderlande; both are under TICO; therefore, to improve and validate the implementation process to comply with SCIP in Vanderlande, a consultation with the person responsible for SCIP compliance at TMHE was done. This meeting was conducted as part of the research methodology and served as a helpful opportunity to engage in collaboration and exchange knowledge, best practices, and experiences about the SCIP implementation.

The main objective was to gain a deeper understanding, obtain first-hand insights about the SCIP process followed by another assembler company, and validate the decision taken for the new approach in Phase II. The session was carried out with an agenda of defined questions to discuss and ensure coverage of all the desired topics. During the session, both parties shared and discussed their experiences related to the SCIP implementation in each company, such as regulation documentation, supply chain communication, gathering SCIP information from the upstream supply chain, internal communication, training, reporting methods to ECHA, and future communication with customers.

Overall, the meeting with TMHE played a crucial role in supporting the plan of action taken into Phase II, enriching the process, serving as a baseline for future decisions on the project, and strengthening the relationship between the sister companies.

4 RESULTS AND DISCUSSION

4.1 Pilot Phase

4.1.1 Suppliers' Engagement

The implementation of SCIP by itself represents a huge challenge; manufacturing companies require to have a detailed and deep knowledge of their processes and raw materials and develop a meticulous process for the quantification and identification of the SVHCs in their articles. While for assemblers, importers and distributors companies must have an excellent relationship with their supply chain to get hits information.

The task was clear for Vanderlande, and to address the challenge the Pilot Phase was developed. In this phase, Conveyor A was analysed, and 19 suppliers were identified to be involved in providing the articles to Vanderlande to build it. Hence these 19 suppliers were contacted with a personalised letter asking for the specific articles needed to build Conveyor A. It took several three months of back-and-forth interaction (July-October 2022), but all of them showed willingness to engage and to provide the information, as can be seen in Figure 14, all of the suppliers responded to the inquiry, but it was found that only 5 of them reported articles to ECHA.

These 5 suppliers shared lists of all the articles they have in the SCIP database, and a crossmatch was done identifying three articles from the category Field Bus Technology belonging to Conveyor A that needed to be reported to ECHA for this phase. Also, this was important to determine the HRC categories for the next phase.

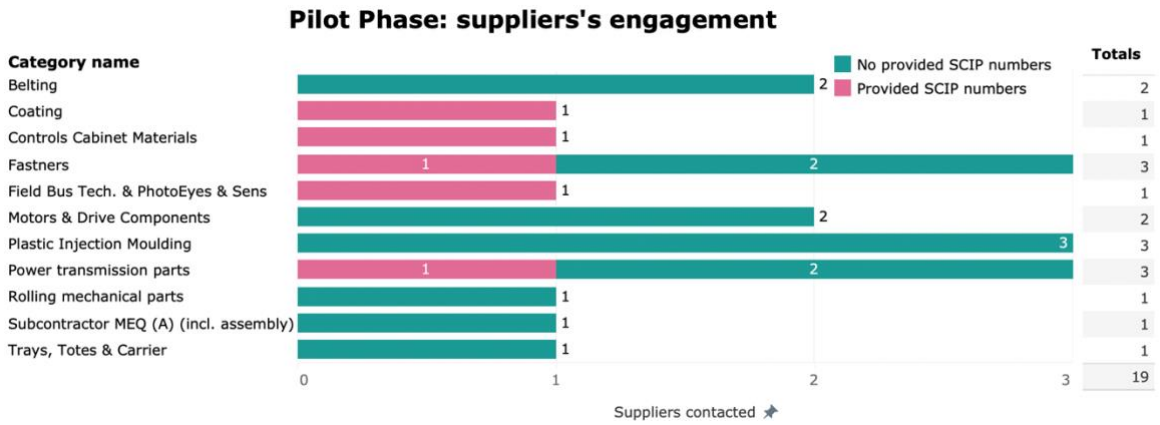


Figure 14. Replies from suppliers per article's category in the Pilot Phase

4.1.2 Types of Replies & Compliance

After analysing all the different replies provided by the suppliers, it was determined that all suppliers are following the regulation in their own way, assuming their stated status is 100% trustworthy. It's important to note that reporting into the SCIP database became mandatory as of January 5th, 2021; however, it is evident that several companies are still in the process of determining their own method to comply with SCIP.[63]

The replies were grouped to categorised according to how and what information they provided, and it is summarised in No legal sanctions have been stipulated against not complying or sharing SCIP information yet; this could be related to the regulation being new, although Vanderlande needs to consider measures to know what to do with this kind of behaviour in their supply chain.

Table 4. First, for the suppliers who had the best understanding of the regulation and even elaborated their own SCIP statement to provide to their customers, some of their letters were outdated[1], but when checking their status on their webpage, the latest version was available, and indeed they comply.

Although just one supplier stated in its letter that they won't provide the information in their supply chain, which goes against Article 33(1) of the REACH Regulation, which states that they must notify customers of the presence of any SVHCs in their products exceeding 0.1% (w/w) and the instructions on the safe use of the product.[49] No legal sanctions have been stipulated against not complying or sharing SCIP information yet; this could be related to the regulation being new, although Vanderlande needs to consider measures to know what to do with this kind of behaviour in their supply chain.

Table 4. Type of replies for the Pilot Phase

Grouped suppliers' replies	# replies	Provided another statement	Compliance status
1. Own SCIP statement	4	REACH (2)	Comply
2. SCIP Document	4	REACH (1)	Comply
3. REACH & SCIP	1	REACH (1)	Comply
4. Just REACH	4	-	Comply*
5. REACH & RoSH	3	-	Comply*
6. Own letter saying they don´t provide SVHCs	1	-	Comply

[1] The replies from pilot phase were received between July-October 2022.

7. Just an email stating they do not provide SVHCs	3	-	Comply*

*Recommended to check with them again, to see if they have a better understating of the regulation now.

The next type of reply was classified as a SCIP document, in which they used REACH as support for their understanding of the regulation, plus a document with all their SCIP numbers. In this category, most of the documents were personalised for Vanderlande, showing a strong interest in having a good supplier-customer relationship. The next group of replies were from the suppliers who only shared REACH, and their replies showed that they were not completely aware of SCIP. They were overlapping their duties and justifying the idea of not reporting because they considered themselves end users under REACH, which indeed means they don't have to report the use of SVHCs, although it does not exclude them from reporting to SCIP.[49] To Vanderlande, they are considered in compliance because, in their REACH letters, they stated they do not provide SVHCs in their articles, which is the goal of SCIP.

In the next group, the suppliers who sent REACH and RoSH are found, they highlighted that they have constant communication with their suppliers to avoid the presence of any SVHCs in their articles, and when they do, they try to find alternatives as soon as possible, therefore were considered in compliance but to be monitored in the future. The next type of reply was a statement saying that they do not provide any articles with SVHCs, this supplier considered itself a distributor, therefore it shared this statement of the company and the SCIP numbers provided by its suppliers.

The last group were suppliers that only stated in their email that they do not provide any SVHCs. As mentioned before, for this phase the replies were not questioned, but this gave the idea to ask for an official statement for the next phase. Also, it is suggested in this thesis to review the suppliers belonging to the groups that were given an asterisk in their compliance status to see if they have updated their status in the future, and if not, decide to look for alternatives to the articles bought from them.

4.1.3 Learnings Pilot Phase & THM consultation

The Pilot Phase clarified the requirements to ensure compliance with SCIP and determined the importance of a strong relationship with the upstream supply chain. Also, it was helpful to determine the next steps for Phase II, which are to assess the HRC categories first and then the LRC categories to speed up the process instead of choosing another complex product and requesting suppliers the information from specific articles instead of the whole list. This way, it would be easier to link the articles

with the SCIP number to the final solutions, build the dossier using the referencing tool provided by ECHA, and then provide Vanderlande's customer with the proper and needed information on how to handle the articles when they reach their end-life, as the WFD states as a goal of SCIP.[4]

Additionally, if the articles are identified and integrated into Vanderlande's system, it would help the engineers avoid their use and demand safer alternatives, which is the goal of the EU CE Action Plan of the product design policy.[2]

The last learning is regarding the suppliers' replies, which provided insights into their level of compliance and aided in improving the request letter to highlight the requirement of an official statement needed to assure their compliance status for the next phase and to start preparing possible answers that could help guide the suppliers who needed further clarification. Moreover, the replies provided a sneak preview of the potential replies that might be obtained in the following phase and how these answers could be categorised to develop a simpler and quicker process flow to determine the suppliers' compliance status.

When discussing these findings with the contact person in charge of SCIP compliance in TMHE, they agreed and supported the decided approach for the next phase, validating the process and confirming the similar approach that followed. Besides, they shared a similar task of engaging and communicating with the suppliers and the need to explain to them why it is important to follow the regulation and the benefits of decreasing the amount of SVHCs in their articles and therefore in waste streams in the future. Furthermore, the number of resources needed was a topic, highlighting the time consumed in the manual process of supplier engagement and the continued communication needed when the candidate list of SVHCs was updated, including reporting the articles.

Contrary to Vanderlande, to simplify one-on-one communication, they have designed a suppliers' platform, where they used to share messages and announcements for their suppliers when the candidate list is updated or to clarify doubts about SCIP compliance. They expect to use this platform along with their system to automate the reporting to ECHA's SCIP database. Another issue covered was how TMHE implemented, conducted training, and communicated SCIP within the organisation and with the customers. For the first option, they clarified they did not communicate much, only with the employees involved in constant communication with suppliers and working with the articles to add the information to their system, while for the customers, they created a QR code that directs them to the general list of articles showing their compliance, so no manual was modified.

These ideas showed the different approaches TMHE took and left the ideas in the air to discuss their inclusion into Vanderlande's action plan, particularly the communication with the customer, which is mandatory according to Article 33 of REACH,[49] where Vanderlande considered adding this information in the manuals, but that would require constantly updating those manuals in the future when safer alternatives are introduced to substitute the articles with SVHCs according to the goals of the implementation of SCIP.[4] Furthermore, communication with the entire company will be done to increase the engineers' awareness when developing new solutions, sourcing to request and prioritise articles free of hazardous chemicals from suppliers and sharing this step forward toward reaching Vanderlande's CE goals.

The consultation with TMHE was valuable in refining Vanderlande's SCIP implementation action plan and reaffirming the company's commitment to compliance and sustainability. Additionally, it helped to share the knowledge acquired through the implementation process and navigate the potential oncoming challenges. Along with the insights gained in the Pilot Phase, continuous improvement enables Vanderlande to modify and progress in ensuring compliance in the following phases, continuing its objective of becoming a circular and regenerative company by incorporating SCIP compliance into its overall sustainability strategy.

4.2 Phase II: Upstream Supply Chain Engagement

4.2.1 HRC and LRC engagement

For Phase II, the definition of the HRC categories was crucial, which was done by the input of the previous phase and the input given by the consultation Royal HaskoningDHV giving priority to electronics (motors, cables, sensors, and controllers), materials that would include alloys (wheels, rollers, power transmission, rollers) and rubber. After this, 9 categories out of the 26 were considered HRC. Also, the information reported in the SCIP database showed that the articles reported the most are machinery, measuring instruments, electronic equipment, vehicles, articles made of rubber, and furniture.[64]

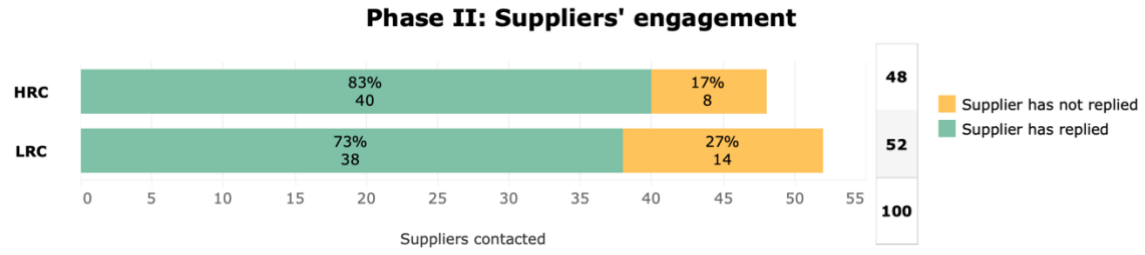


Figure 15. Suppliers' engagement for Phase II

The 48 suppliers from the HRC were contacted at the end of March, and because their input was not as expected (amount of SCIP numbers), the 52 suppliers left from the LRC with contact information available were emailed at the beginning of May, giving a total of 100 suppliers considered for this phase. At the end of May, 78% of all contacted suppliers had replied and shown any interaction regarding the inquiry, as shown in Figure 15. All replies varied but aided in identifying the involvement of each company in the regulation and the approach they are following to ensure their compliance.

4.2.2 SVHCs in articles

One of the objectives of requesting the SCIP-listed articles from suppliers is to identify the articles Vanderlande uses in their solutions containing SVHCs. Therefore, the suppliers who provided SCIP numbers were graphed by the type or articles' categories and into the HRC and LRC; the result is shown in Figure 16. This graph identifies that 16 of all contacted suppliers among the different risk levels and articles' categories have reported to the SCIP database, and as their duty, they have shared this information with their downstream supply chain, Vanderlande, when requested.

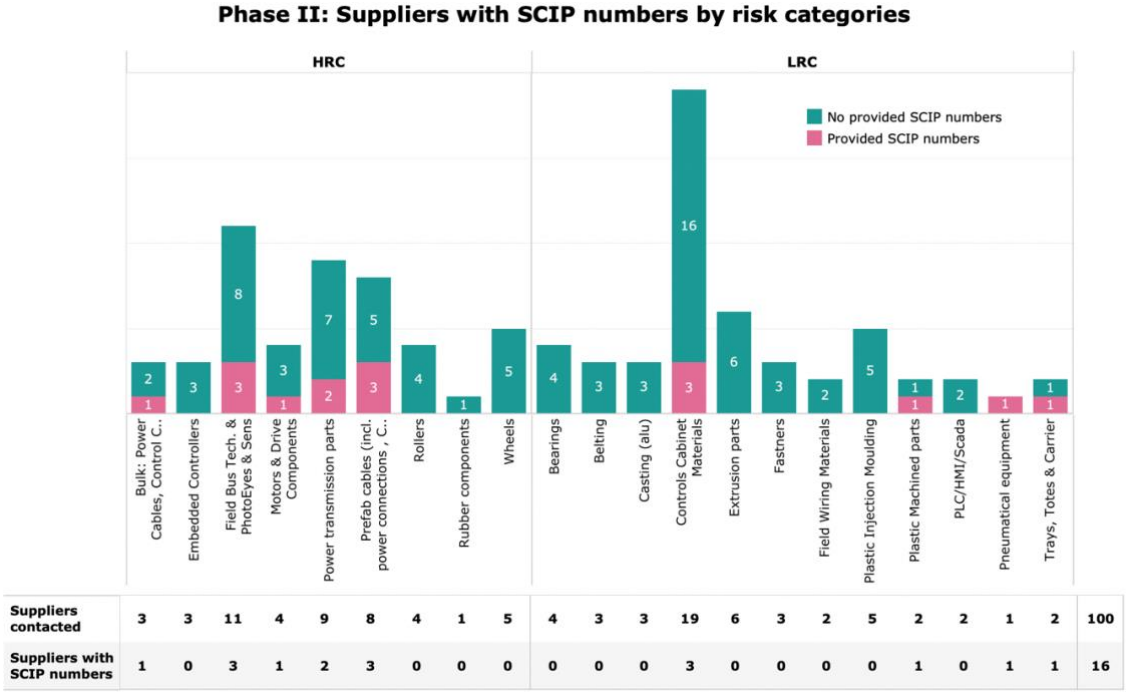


Figure 16. Suppliers who provided a list of SCIP-listed articles to Vanderlande

Additionally, the defined classification of HRC and LRC is supported when 5 out of 9 suppliers who reported having SCIP numbers are from the HRC, as was expected, though some adjustments should be made to include the categories that have SCIP numbers and exclude the ones that do not so in the future those categories could receive more attention to ensure all suppliers comply with the SCIP requirements. Furthermore,

the results are in accordance with what was foreseen to be the articles more likely to contain SVHCs, which were the ones within the classification of electronics equipment (i.e., sensors and cables) and machinery parts, aligning with what has been reported by ECHA to be the most commons notified products into the database.[64]

The reason electrical components tend to be one of the categories more reported to ECHA could be related to the fact that manufacturers of these kinds of articles have been required by the regulation of RoSH to notify the presence of hazardous substances, and because it has been in place since 2011, they have had more time to assess their products, and when SCIP entered into force, they were ready to report, compared to other types of articles in which companies needed to prepare and learn how to assess their own articles.[52]

Because the majority of the SCIP numbers are related to EEE, the SVHCs identified with a higher presence is lead titanium zirconium oxide, with 48% of the shared, while the second one is lead with 47% as can be seen in Figure 17. This contrasts with what has been reported by ECHA, where lead tends to be the most reported and common substance in the SCIP-listed articles.[64] It is important to clarify that these are not all articles; in some cases, the suppliers shared that they do have SCIP-listed articles, but they were in their catalogue, and it was the responsibility of Vanderlande to find each one of them. Due to a lack of information, the procurement department is preparing a list of all articles to identify them and have a clearer picture of what would be more likely to be found in Vanderlande's solutions. Figure 17, provides a glimpse of the articles that were provided by the suppliers for the moment.

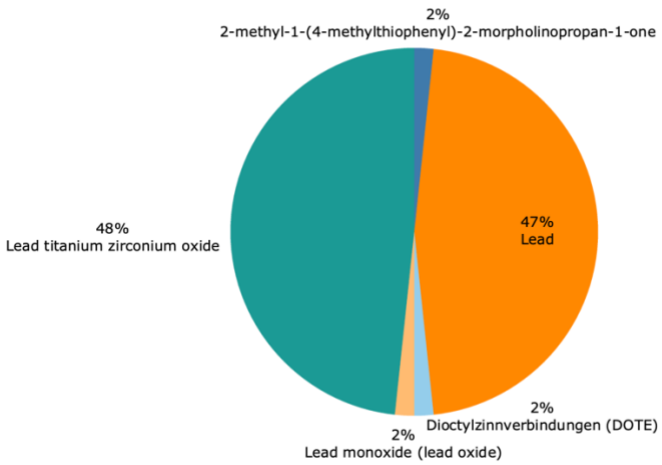


Figure 17. Share of SVHCs found in the articles provided with SCIP numbers

Also, it would be interesting to analyse in more detail why, within the same categories, some suppliers do not have SCIP numbers when they provide relatively the same articles

to Vanderlande. This could be explained with a deep analysis of all the articles bought by each supplier within the same categories to confirm the transparency of their statements for the ones who have reported no presence of SVHCs in their articles; nevertheless, this is not covered by the scope of this thesis.

4.2.3 Types of suppliers' replies to determine compliance status

To determine each supplier's compliance status a process flow was developed based on a thorough examination of all the information given by them. Each piece of evidence (statement, letter, email) was categorised into 13 categories which aided to provide a broad overview of the different approaches taken by each supplier to fulfil their SCIP obligations, considering their reporting status, the type o statements and wording, their understanding of the regulation, willingness to communicate the information through their supply change and their long-term goals to decrease the number of SVHCs in their products.

Furthermore, this approach helped identify their potential compliance status and how they engaged with the request, highlighting their genuine interest in cooperating, and providing Vanderlande with the information. This evidence is summarised in Table 5, including notes discussing the image they provided through the type of reply and evidence shared. Moreover, Table 5 also includes, according to the provided information, the most likely status to be received by Vanderlande, the order of appearance is from the most common answers received to the less common.

Table 5. Type of replies received in Phase II

Types of replies grouped	Notes	Most likely compliance status
1. REACH & RoSH	These suppliers showed their commitment to comply, although in some cases they use the exceptions in RoSH. It was explained to them that it does not exclude them from reporting to ECHA.	Compliance & not in compliance when they need to report articles
2. Own statement just saying not SVHC	The supplier in this section was most likely to have their own statement for two main reasons: 1) They comply and have checked all their products. 2) They prepared the statement just to provide it to Vanderlande as requested in the letter.	Compliance / Keep monitoring
3. Just REACH	Most distributors of suppliers consider themselves end-users. most likely not understating their obligations with the SCIP. Although most of them	Compliance / Keep monitoring

Types of replies grouped	Notes	Most likely compliance status
	specify not providing SVHCs, some distributors provided the information from their suppliers.	
4. Just email saying not having SVHC	The suppliers tend to reply fast, and in most cases, they don't share the request with their quality or sustainability department, although, after a more detailed conversation, they share that, as far as they are concerned, they do not provide SVHCs, and it is because they have a continuous interaction with their suppliers to assure it.	Compliance / Keep monitoring
5. Product declaration	The most complete statement, mostly focused on the impact of their product on the environment. Including information of their carbon footprint, composition and other applicable regulations and standards for the articles.	Compliance
6. They are still processing with their suppliers	These suppliers showed their status; for some, this petition was the first time to receive it, so they requested more time to provide the outcome of their investigations. Others shared that they are still doing the revision but have not finished yet, and so far, they have not provided articles with SVHCs.	Compliance / Keep monitoring
7. Own SCIP statement	These suppliers have a clear understating of the regulation, have developed their own statement for SCIP, including the SCIP numbers when applicable and shared their strategies to avoid and decrease the amount of SVHCs in their articles.	Compliance
8. REACH & SCIP	These suppliers understand the requirements of SCIP and how it builds REACH; therefore, they updated their REACH statement, adding the required information about their compliance status. Some cases include the SCIP numbers in the letter.	Compliance
9. We need to look the SCIP in their catalogue product by product	These suppliers have indeed done their SCIP assessment, although they do not provide a document with their SCIP numbers; instead, Vanderlande needs to access their customer portal and check article by article to check if they have an SCIP number. In some cases, the suppliers	Compliance

Types of replies grouped	Notes	Most likely compliance status
	narrow down which families of types of articles have SVHCs.	
10. Just email	These suppliers were the hardest category to define; they define themselves as end-users, distributers, or requested the list of suppliers to assess the status of those articles. It's evident that the knowledge of the regulation is not deep, but it's not clear if it's the person who received the email or the company.	To assess their status, their webpage is analysed to see the status of REACH, RoSH, and details shared/ advertised by their products.
11. Document with SCIP	This was when the supplier did not have their own SCIP letter, so it only shared their knowledge of the articles having the SCIP numbers, in some cases it included RoSH, REACH and other regulations.	Compliance
12. Sent wrong information	They confused the request for other regulations, such as conflict minerals, showing their lack of understanding. Therefore, an explanation of the regulation was provided.	In conversation, but if nothing changes, not in compliance
13. Will share from a tool	They do not have any statement because they are tracking all the components of their articles through external software, and they offered to share the information.	Compliance / Keep monitoring

4.3 Compliance status determination

After the analysis of all the replies, shared documents, and grouping of them, a process flow was developed to determine if the supplier fulfils its duty and is complying with the SCIP regulation in the eyes of Vanderlande as a supplier. This process flow is shown in Figure 18, where it all starts with analysing the reply from the supplier. The first way to comply or be "in compliance" is to show that the company understands the regulation, has done its duty, and has analysed all the articles they manufacture and provided to Vanderlande, ensuring no content of SVHCs is above the allowed threshold of 0.1 % (w/w). If this is the case and they have articles with SVHCs, a list of the SCIP numbers would be expected to be shared when the article is bought or when requested, as it was on this occasion.

The next filter is whether the supplier shares REACH or RoSH. Both of these regulations, as explained before, are related and aim to decrease the release of hazardous substances into the environment that can be harmful to it and to human health, according to the WFD and the EU Chemical Strategy.[3,36] Therefore, these regulations can be considered to comply with SCIP if they do not have articles with any substance listed in the candidate list and they include in their statements their true commitment to these regulations, assuring periodic discussions with their upstream supply chain to ensure they do not have articles with SVHCs.

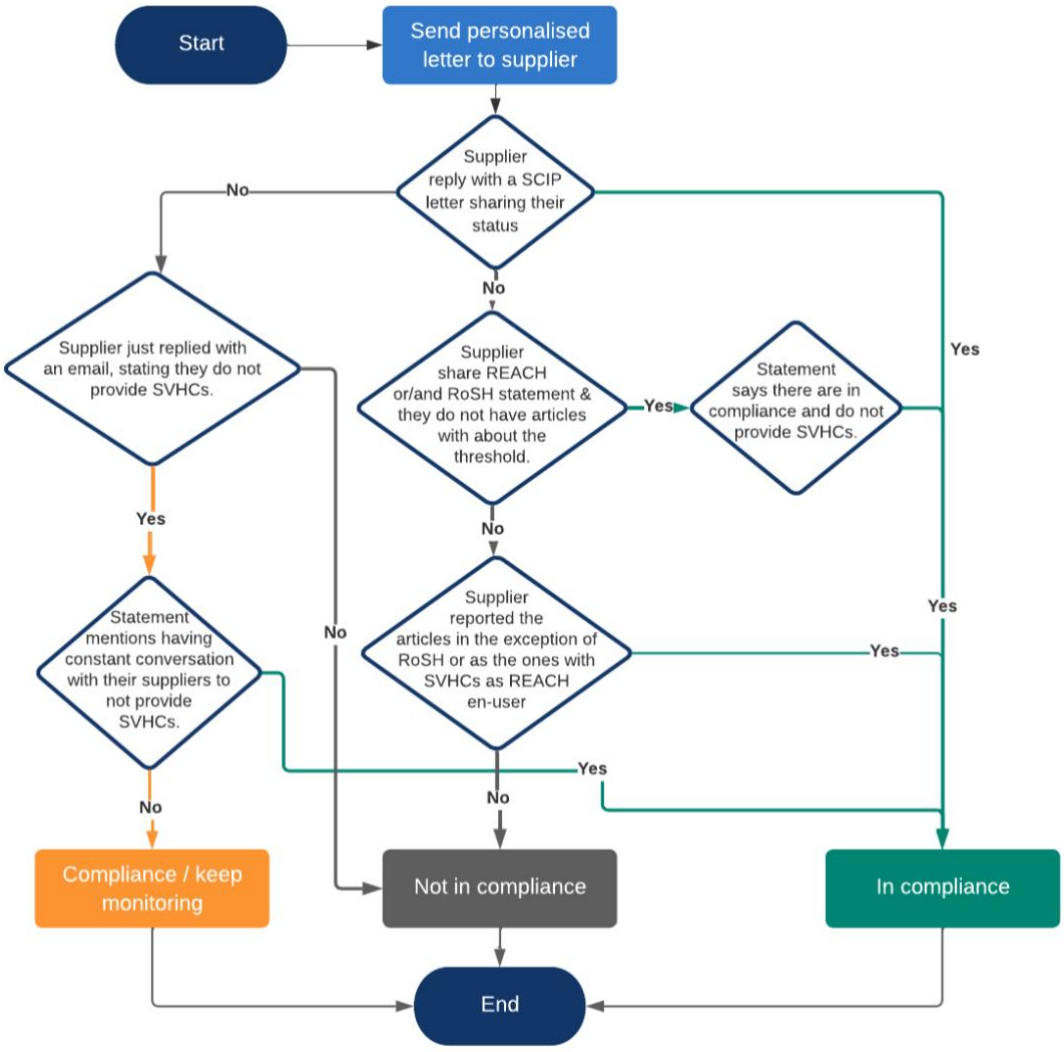


Figure 18. Process flow to determine the compliance status of the suppliers according to their replies

Although if they use any exception of RoSH allowing them to have articles with SVHCs, they must report those articles to the SCIP database.[52] Furthermore, if they identify themselves as end users under REACH, which gives them the option to abstain from informing ECHA about the use of chemicals but not from having products with SVHCs above the threshold, it automatically associates them with SCIP. They must report this

to ECHA and notify their customers in accordance with the regulation; otherwise, they will be deemed to be "not in compliance".[49]

The suppliers that are categorised as "compliance and keep monitoring" are the ones that should be observed in the following years to reassure that they are complying or if more strict requirements must be applied, such as finding another supplier. Also, this should be added as a requirement when sourcing new suppliers and defining from whom Vanderlande is buying, so it can be ensured that suppliers comply. Suppliers are also included in this category if they provide an official statement or email showing no clear knowledge of SCIP but guaranteeing they do not supply articles with SVHCs to their downstream supply chain and that they are monitoring their own suppliers. They are also included in this category if they send other statements, such as REACH or RoSH, assuring as well that they are not providing articles with SVHCs or that the articles, when handled correctly, will not be released, although they do not express the relationship of the request with SCIP.

And last, the suppliers who fall under the category of "not in compliance" are the ones who did not follow the requirements outlined above, meaning they just shared an email trying to fulfil the petition but not showing proper understanding of SCIP, neither the involvement of quality, compliance, or sustainability department to support their statement.

4.3.1 Suppliers' compliances status

After this categorisation and following through the designed process flow, Figure 19 shows the compliance status for all the suppliers contacted in Phase II, segmented by HRC and LRC. It shows that 58% of all the suppliers from HRC comply with SCIP, compared to 44% in the LRC; also in this graph, the total compliance status of all suppliers is shown, where 14% of the suppliers are considered complying, but it is recommended to be monitored in the future. Additionally, it displays that only 2% are not complying, and 12% are considered in conversation, meaning that the suppliers stated that they have not finished their audit and therefore have not shared any statements yet. Last, 22% of suppliers were classified as "Lack of evidence" because they have not answered the inquiry yet. It is advised to assess these suppliers and measure their impact on Vanderlande. This assessment will aid in defining appropriate actions, such as ensuring future cooperation or reconsidering business relationships in case they are unwilling to collaborate and comply with regulatory requirements, which is an important pillar for Vanderlande.

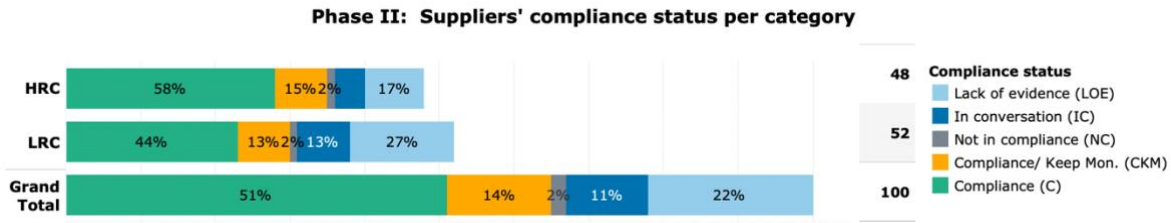


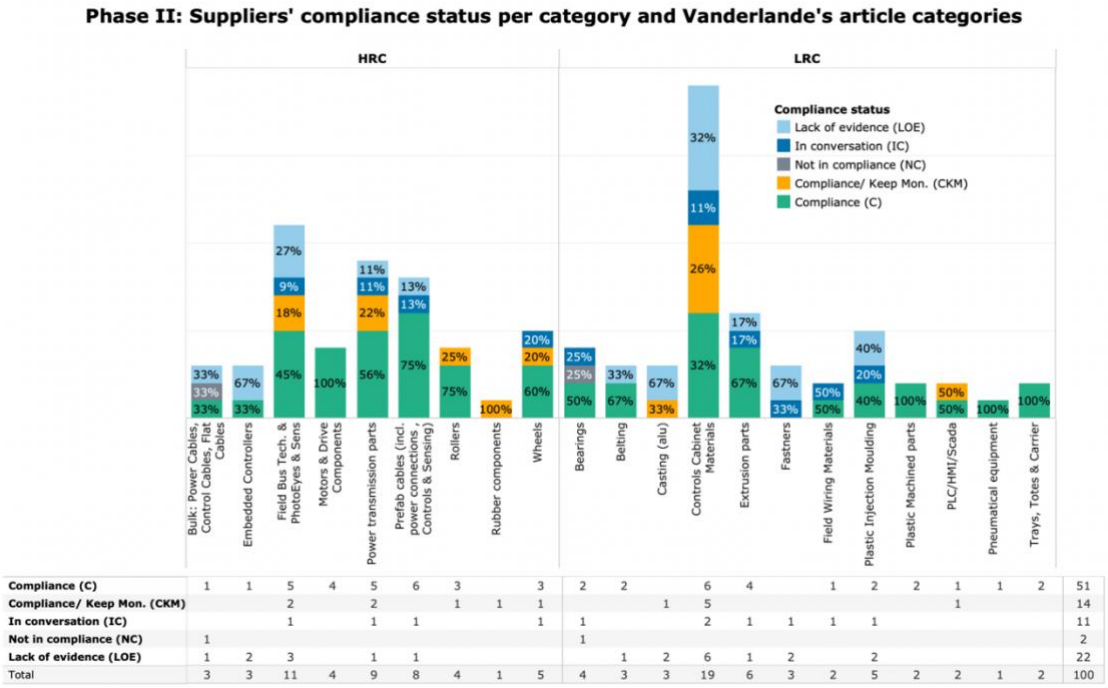
Figure 19. Suppliers' compliance status per category

To dig deeper, Figure 20 was segmented into Vanderlande's article categories, showing a more detailed analysis of the compliance status at the different assigned risk levels of each article's categories. In this way, it is possible to observe how the compliance status rates vary among them and allow which makes it easier to identify patterns, highlight the potential areas of improvement for each category, and prioritise which are more urgent.

Contrasting with the obtained results on the suppliers who provided SCIP numbers, it demonstrates which article's category should be prioritised to develop more focused actions to achieve a 100% compliance rate of all suppliers in those categories and ensure they provide all the required information. Such is the case for the categories of:

- Bulk power cables, which have one supplier with the status of not in compliance and the other has not replied.
- Field Bus Tech, with the highest rate of suppliers who has not replied from the HRC, and
- Power transmissions and Prefab cables, with still one supplier without a reply.
- Control Cabinet is the sole category from LRC, that should be prioritised to comprehend why so many suppliers have not replied, others are still in the process of providing the information and why it has the highest number of suppliers in compliance but need to be monitored in the future.

In other words, Figure 20, gives the upstream supply chain's overall compliance, where it can be improved, and it pinpoints areas to make tailor-made adjustments.

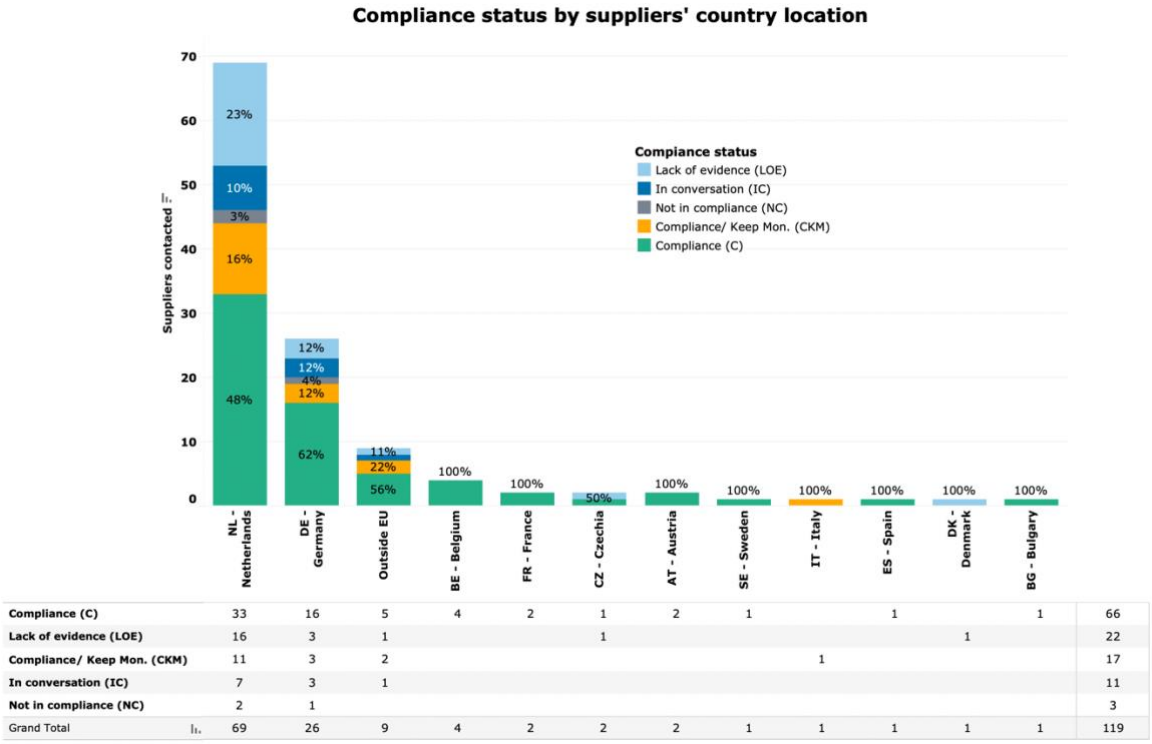


Compliance (C)	1	1	5	4	5	6	3		3	2	2		6	4		1	2	2	1	1	2	51
Compliance/ Keep Mon. (CKM)			2		2		1	1	1			1	5						1			14
In conversation (IC)			1		1	1			1	1			2	1	1	1	1					11
Not in compliance (NC)	1									1												2
Lack of evidence (LOE)	1	2	3		1	1					1	2	6	1	2		2					22
Total	3	3	11	4	9	8	4	1	5	4	3	3	19	6	3	2	5	2	2	1	2	100

Figure 20. Suppliers' compliance status per category & by Vanderlande's article categories

4.3.2 Suppliers' compliance status by location

Vanderlande is an international company with offices around the globe and the goal of providing the best quality products to their customers. The highest standard is required from the sourced suppliers. These suppliers are geographically located all around the world as well, with the majority in countries belonging to the EU, as shown in Figure 21. This graph included all 119 suppliers from both phases analysed in this thesis, with the Netherlands being the majority with 69 suppliers, which is logical due to the headquarters and biggest production being in Veghel, Netherlands, while the following is the neighbouring country, Germany, with 26 suppliers. Next are the grouped countries outside the EU, which are the USA, China, the UK, and Turkey, followed again by EU countries. Figure 21 also shows the percentage of compliance status per country, in this way could be easier to identify the tendency of suppliers in which country is more likely to comply with the SCIP regulation, therefore in the future could be a factor when assessing new suppliers.



	NL - Netherlands	DE - Germany	Outside EU	BE - Belgium	FR - France	CZ - Czechia	AT - Austria	SE - Sweden	IT - Italy	ES - Spain	DK - Denmark	BG - Bulgary	
Compliance (C)	33	16	5	4	2	1	2	1		1		1	66
Lack of evidence (LOE)	16	3	1			1					1		22
Compliance/ Keep Mon. (CKM)	11	3	2						1				17
In conversation (IC)	7	3	1										11
Not in compliance (NC)	2	1											3
Grand Total	69	26	9	4	2	2	2	1	1	1	1	1	119

Figure 21. The compliance status of all contacted suppliers by geographical location

Figure 21 shows German suppliers' have the highest rate of status compliance according to their replies when analysed per country, adding up to the fact that they are the country with the highest percentage of Vanderlande's suppliers reporting articles to ECHA, as demonstrated in **Error! Reference source not found.**. This may be related to the country's adoption of the Circular Economy Act amendment to Section 62a of the KrWG (*Kreislaufwirtschaftsgesetz*), which outlines the obligation of suppliers to report SVHCs as Article 3 No. 33 of REACH states must be submitted to the SCIP database. This adoption was done in September 2020.[65] Although, in the same year, the obligation was transposed into a new section, 16f, of the Chemical Act (ChemG), changing the obligation to "making the information available" to ECHA but not specifying the SCIP database.[66]

Table 6. Suppliers who provided SCIP numbers by country

Country	Number of suppliers (A)	Suppliers providing SCIP numbers (B)	% suppliers reporting to SCIP from each country (A/B)
Netherlands	69	11	16%
Germany	26	8	31%
Outside EU	9	1	11%
Belgium	4	1	25%
All suppliers	119	21	18%

For the rest of the countries, no legislation, strategy, or policy has been developed to encourage the registration of articles with SVHCs into the SCIP database. Only in the Netherlands, the Dutch Government, in their policy to transition to a CE, has expressed concern about SVHCs and believes that this offers the opportunity to handle these substances safely. As a result, it encourages using the SCIP database to monitor these substances and therefore invites the companies to keep the database updated, which will help them in their plan to be circular by 2050. However, the Netherlands has not implemented any strategy directly to command to report the SVHCs.[67]

ECHA released the first SCIP Evaluation report last year, which shows that German companies are the legal entities that submit the most notifications to SCIP, followed by Italians and French. Meanwhile, in this case study, the highest is indeed Germany, followed by the Netherlands and the third, Belgium, as shown in

Table 6.

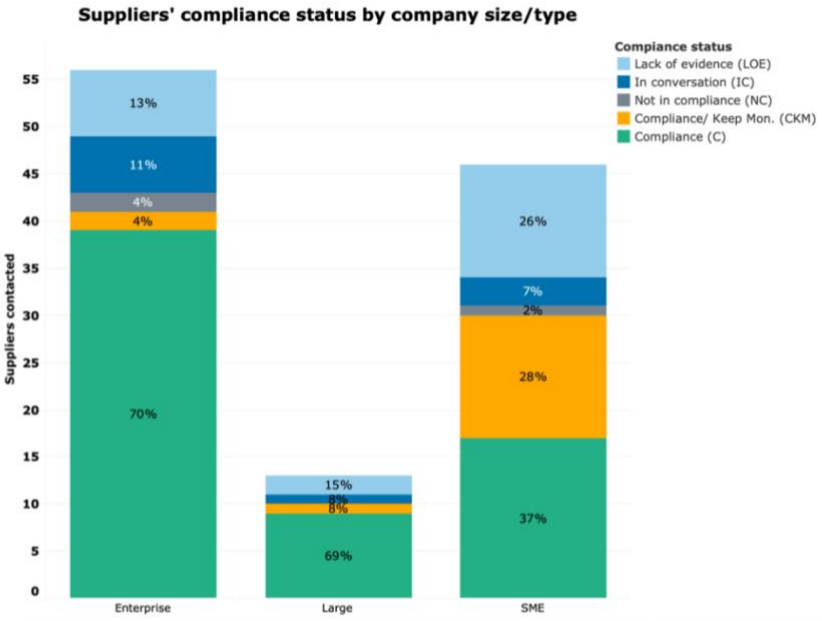
4.3.3 Suppliers' compliance status by company size

Another question to understand during this journey is whether the size of the company's suppliers influences the compliance status. Thus, the size of the company was compared to the compliance status of the suppliers. It was expected from the beginning that larger companies would be more likely to be complying compared to small and medium (SME) companies due to the availability of resources. For this comparison[1], the size of the suppliers' company was determined by the number of employees as follows:

- SME: 2 to 200 employees
- Large: 201 to 1,000 employees
- Enterprise: more than 1,001 employees

The obtained results can be seen in Figure 22, where the compliance status rate per category size decreases along with the size of the company, as was expected. Literature has reported that complex regulations inhibit firms from achieving "perfect" compliance, especially for small enterprises, which tend to have fewer resources to keep up with all the regulatory requirements.[68]

[1] The suppliers' samples for this comparison were reduced to 115 due to the inability of the other four firms' webpages or LinkedIn to locate and so identify their size.



Compliance (C)	39	9	17	**65**
Compliance/ Keep Mon. (CKM)	2	1	13	**16**
Not in compliance (NC)	2		1	**3**
In conversation (IC)	6	1	3	**10**
Lack of evidence (LOE)	7	2	12	**21**
Grand Total	**56**	**13**	**46**	**115**

Figure 22. Suppliers' compliance status by company size

According to the results presented in Figure 22, the SCIP regulation presents a bigger challenge for SMEs. The highest share of suppliers with a lack of evidence is found in this size category, meaning that they decided not to reply to the request. It could be inferred, corresponding to what was explained before, that they decided to focus their efforts on achieving a sale instead of replying to a regulation compliance that they might not have in place. Additionally, SMEs represent the highest share of suppliers that have been considered in compliance but are marked to be monitored in the future to keep reassuring their status.

An interesting similarity is that in both cases, the status "in conversation" means that those suppliers are still processing the information and don’t have an answer yet; the SMEs, they are figuring out how, while the enterprises request more time because they have a considerable number of articles to process. In both cases, at least one supplier sent the wrong information regarding conflict minerals.

Analysing compliance by country, size, and categories is crucial for Vanderlande's implementation of the SCIP database regulation. The regulation, which became available for reporting at the end of 2020, poses a significant challenge across the European Union. To overcome this challenge, Vanderlande has leveraged an action plan, as presented above, to ensure compliance.

Through the analysis, it becomes possible to understand the behaviour of suppliers, especially within each category. This understanding allows for the development of new

actions that can be implemented to ensure compliance with Vanderlande. By analysing compliance on a country level, Vanderlande can adapt its strategies to meet specific regulations in different regions. Additionally, considering the size of suppliers can help prioritize actions and allocate resources effectively.

Furthermore, categorising suppliers based on the type of products or services they provide enables Vanderlande to focus on HRC areas and develop targeted initiatives to address compliance issues. This approach ensures that resources are utilized efficiently and that the company can prioritize efforts to mitigate any potential risks associated with SVHCs.

In summary, analysing compliance by country, size, and categories is essential for Vanderlande to navigate the challenges posed by the SCIP database regulation. It allows the company to adapt to regional regulations, allocate resources effectively based on supplier size, and develop targeted actions to address compliance issues within different categories. By conducting this compliance analysis focused on the supply chain, Vanderlande can proceed to develop new measures to ensure that its solutions are free of SVHCs, safeguarding the environment and human well-being while maintaining regulatory compliance.

4.4 Impacts on the circular economy by SCIP

The implementation of SCIP within the EU is a step forward to close the material loop by decreasing the presence of SVHCs in articles or products and incentive safe recycling. In Vanderlande, implementing SCIP offers the opportunity to advance the CE within the company. To achieve compliance with this regulation, a detailed understating of the composition of the articles is needed, especially to determine whether they contain SVHCs or not, these prompted Vanderlande to assess its supply chain and engage with the suppliers. This created the opportunity to evaluate the sustainability of materials used and identify alternatives that align with the principles of the CE and Vanderlande's goals.

Ensuring the compliance of Vanderlande with SCIP through the management of the supply chain and getting to know more in detail about the composition of all the articles Vanderlande buys from different suppliers across Europe helped to increase material transparency. The results gathered about SCIP will build up into the material passport initiative that Vanderlande has in which the information about SVHCs will be shared to increase transparency and empower the engineers in Vanderlande to assess the recyclability, reusability, and potential resource recovery to take informed decisions in the development of new products, therefore facilitating the transition to a CE.

Furthermore, SCIP is enabling knowledge about the chemical composition of articles and products, facilitating the substitution of harmful substances for safer and more sustainable alternatives by seeking alternatives that align with the CE principles. The new materials or articles will aid in closing the loop by being safely introduced back into the production process and therefore decreasing the negative impact on the environment and human health caused by the traditional materials with SVHCs.

SCIP was created to foster circularity by increasing knowledge of waste streams and using the appropriate technologies and recycling methods. Although, after this research, the implementation of SCIP promotes collaboration and engagement in the supply chain when exchanging and gathering information related to SCIP, the companies can work together to detect potential risks and develop strategies for a gradual elimination or substitution of the SVHCs, therefore fostering circular supply change through the promotion of circular design, responsible sourcing, and resource efficiency. Through the supply chain engagement, it was able to identify Vanderlande's relationship with the suppliers through their willingness to provide the requested information; therefore, this process has strengthened the bond with them by creating a more durable and sustainable supply chain.

Last, the SCIP implementation incentives innovation by looking for new ways of substituting or eliminating the SVHCs by implementing eco-design principles from the beginning of the development of the products. It is expected for the new Vanderlande's products to procure the use of articles without SVHCs in them so that when they reach their end-of-life, they could be recycled as the CE model promotes and therefore contribute to a more sustainable and resource-efficient economy.

4.5 Challenges and opportunities

The implementation of SCIP in Vanderlande presented both challenges and opportunities regarding SCIP compliance and CE. The first challenge to present was the proper understanding at the begging of the implementation process, providing the opportunity for an in-depth documentation process and therefore the learning and development of the implementation by phases. This challenge is observed as well by the supply chain showing a lack of awareness and understating of the SCIP requirements, therefore, as shown, there was an inconsistency in the replies received, this gives the opportunity to increase the communication with suppliers to ensure effective collaboration and alignment of objectives to improve the supplier engagement.

During the data gathering, the supplier tends to share the SCIP-listed articles in pdf files with their own article number, this challenge presents the opportunity to include as a

mandatory field to request the presence of SVHCs since the procurement process, so the articles could be included in Vanderlande's system, especially considering that the descriptions of articles tend to change according to their function within the company, and when asking from the beginning this information could simplify the data collection and management.

Having the SCIP information increases material transparency, enabling the evaluation of sustainable materials, and identifying alternatives that align better with the CE principles. It also aids in including in Vanderlande's process more sustainable product design policies and supply chain management. Another challenge is the communication within the company to promote awareness of the importance of SCIP as an initiative and that complying is a challenge for the whole company, from sourcing to requesting the right information from suppliers to R&D to develop the best and safer product designs to the compliance team ensuring all the requirements are followed properly.

External communication is a challenge as well, to decide the most convenient option and the best moment to do it. Although this gives the opportunity to engage with customers and share the benefits of implementing SCIP, this will help in the sales speech and strengthen Vanderlande's image and reputation as a responsible and sustainable partner to do business with.

Seizing these challenges and opportunities, Vanderlande can ensure SCIP compliance and be closer to its circular goals. Also, this aids in the process of decreasing SVHCs in the EU market, promotes sustainability and conforms to international guidelines for proper substance management.

4.6 Recommendations and next steps

Ensuring SCIP compliance has proven to be a big challenge, but not impossible. Finding the SCIP-listed articles was one part of the equation, and now the next steps in the action plan should be implemented to ensure complete compliance in Vanderlande. These steps can be summarised by adding these articles to Vanderlande's system, linking the articles to the products, and reporting the relevant products. Although new changes should be made in the process map to include more departments (i.e., sourcing, R&D, quality assurance, etc.) to integrate these activities within the company as operational activities.

First, as mentioned, the identified articles with SCIP numbers should be integrated into Vanderlande's systems so they can be easily found by engineers when designing new developments, and they could assess and prioritise articles without these SVHCs to

prevent putting on the EU market products with SVHC. To fulfil the goals of SCIP regulation, and to support the CE continuous monitoring of the articles in the market with the current suppliers would be recommended to identify the best alternatives for replacing the articles containing SVHCs, therefore not adding them to the products.

After Vanderlande linked SCIP-listed articles to current products, those products should be reported to the SCIP database. This could be achieved by creating groups of articles alike, using the referencing tool from the SSN when creating the dossier, and simplifying the reporting. Considering Vanderlande's size, it would be recommended to develop or acquire a system to automate the process; otherwise, manually, it would require more resources to maintain the continuous notification and editions when articles with SVHCs are removed from the product and therefore adjusted in the SCIP database.

Additionally, if it must develop a notification system for its customers, it would be advised not to add the information in the manuals as was considered before because it will require continuous changes when adding or deleting any article from the product containing SVHCs. Additionally, it is recommended to include appropriate handling measures at the end of the articles' shelf life. It would be of high added value for customers to offer them a system of recovering products as they reach their end of life, especially if they contain SCIP-listed articles. This would add to the company's goals of circularity, encourage more strategic partnerships with waste treatment plants, and increase the use of recycled products within the company.

As shown, the suppliers play a key role in ensuring compliance; therefore, communication and collaboration with them should be strengthened, in this case with the SCIP regulation, but ensuring a strong bond with them will allow a smoother implementation of future regulations; this could be achieved by having meetings, webinars, or workshops, sharing guidelines on how to achieve compliance to educate them, and sharing and remind them constantly what requirements are necessary to be part of Vanderlande's supply chain. Furthermore, the supplier selection criteria should be updated to request compliance information from the start of the procurement process (applicable regulations), so transparency can be assured from the beginning in the future allowing saving time and resources could be saved when new regulations are required to be implemented.

Vanderlande needs to put in place a feedback loop and continuous improvement process to enhance its SCIP compliance efforts, including reviewing and evaluating the effectiveness of the implemented actions, identifying areas for improvement, and implementing corrective measures to ensure compliance with SCIP. Additionally, conducting follow-ups with suppliers to ensure compliance with their obligations,

focusing on the suppliers mentioned in this thesis as "compliance and keep monitoring" to ensure they are indeed working to fulfil the requirements and implementing sustainable supply chain practices, will help to identify potential risks and appropriate measures can be taken.

Lastly, staying up to date with any changes in the regulation. The PER-WG is doing an excellent job being informed and analysing the upcoming regulations, although they should include in the task to remain informed with the current regulations to see if any change happens and adapt the compliance strategy according to it. This can be done by monitoring announcements on the respective web pages, engaging with regulatory bodies or associations, and participating in industry forums.

By implementing these recommendations and taking the suggested next steps, Vanderlande may improve its SCIP compliance efforts, and future regulations advance into a more sustainable supply chain, and aid in the shift to a more CE.

SUMMARY

Resources depletion is linked to being the cause of unsustainable production, therefore a change towards a CE model is being urged to be implemented worldwide. The European Union has creatin and proper action plan, stating strategies for the economic, social, and environmental pillars of sustainable development to achieve circularity in all Member States.

Those strategies focus on developing safe and long-lasting products, reducing waste production, and increasing the availability of secondary raw materials by recycling, highlighting to ensure all those products should be safe and should not contain hazardous substances. Therefore, the WFD and ECHA created the SCIP database, which states that all articles containing more than 0.1 %(w/w) SVHCs should be reported.

The objectives set in this present work were achieved, and a clearer understanding of how Vanderlande is implementing SCIP to ensure compliance through the Pilot Phase and Phase II. These phases were designed through the documentation of the legislation and through external consultation with Royal HaskoningDHV. Both phases consisted of gathering the information on the articles they use for their products was requested from its supplier's chain. Finding in the Pilot phase, 6 suppliers out of the 19 providing articles of SVHCs, and the ones applicable to the product analysed in that phase were reported to ECHA into the SCIP database, although all suppliers were considered complying with SCIP.

Through this research, it was clear that companies across Europe commonly have a different understanding of the SCIP regulation, which was seen through the different replies from the suppliers. Most commonly confusing the SCIP regulation with REACH and RoSH, due to all shared the common goal of decreasing the number of SVHCs in the environment. After the pilot phase, along with consultation with the sister company THME, changes in the action plan were made to increase the range of articles to cover by analysing them by HRC and LRC.

For Phase II, 100 suppliers were contacted in this phase, but only 78% replied to the request and it was found that 16 have SCIP-listed articles and have provided them to Vanderlande, and when analysing the SCIP numbers, the most common SVHC found was lead titanium zirconium oxide, followed by lead. All the replies were analysed and grouped so a process flow could be determined to state the compliance status of the suppliers. In this phase, similarly to the previous, the suppliers provided their own SCIP letter, but REACH and RoSH were also shared frequently. This process flow helped to

determine if the supplier was in compliance, compliance but should be monitored or not in compliance.

The result of the compliance status showed that 51% of all suppliers contacted in Phase II of the SCIP implementation comply, while 14% are also in compliance but will be monitored in the future. Only 2% are not in compliance, and 11% of the suppliers are still in consultation because most of them are still processing their products and cannot give a statement yet. It's important to notice that 22% of suppliers have not replied at all, which is a red flag, and more measures need to be considered towards them to ensure their compliance because their status affects Vanderlande’s status.

Understanding the compliances status of its suppliers, allows Vanderlande to develop tailor-made measures toward its supply chain management, adding new protocols to ensure a sustainable procurement and the involvement of its suppliers in having all regulations in place, in other words, responsible sourcing. Also, it helps Vanderlande to develop more initiatives to implement more sustainable practices, fostering circular design with the aim of not including SVHCs in the new developments. This also allows the increase of materials traceability used in the company for future identification of SVHC's free materials and to contribute to the transition of Vanderlande into a more regenerative company.

It was found that German companies are the ones who tend to report more to the SCIP database and to be more in compliance compared to the companies of other member states of the EU. Additionally, the size of the company influences their compliance status as well, with big enterprises more likely to be complying.

Challenges such as not having a proper understanding of the legislation from suppliers and therefore not having standardised responses made it a little complicated to ensure Vanderlande’s SCIP implementation, although these show the opportunity to strengthen the bond with its supply chain to have a more transparent interaction and to develop more sustainable practices. As well, this regulation shows Vanderlande's commitment to being a sustainable company and sharing this information with their customers strengthens their image and contributes to a safer and toxic-free environment.

There are still more steps to follow to ensure compliance with SCIP, such as the case of linking and identifying which Vanderlande’s products have these articles with SVHCs and reporting them to ECHA and later sharing that information with their customers. Although, this work presents a huge step forward and will serve as an example for future regulations to comply for a CE transition.

LIST OF REFERENCES

(1) Khan, M. K.; Trinh, H. H.; Khan, I. U.; Ullah, S. Sustainable Economic Activities, Climate Change, and Carbon Risk: An International Evidence. *Environ Dev Sustain* **2022**, *24* (7), 9642–9664. https://doi.org/10.1007/S10668-021-01842-X/FIGURES/4.

(2) European Commission. *A New Circular Economy Action Plan For a Cleaner and More Competitive Europe*; Brussels, 2020. https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:52020DC0098 (accessed 2023-05-24).

(3) ECHA. *Understanding WFD - ECHA*. https://echa.europa.eu/understanding-wfd (accessed 2023-05-08).

(4) Europe Chemical Agency. *SCIP*. https://echa.europa.eu/scip (accessed 2023-05-07).

(5) Global Material Resources Outlook to 2060. *Global Material Resources Outlook to 2060* **2019**. https://doi.org/10.1787/9789264307452-EN.

(6) *Sustainable Economies | WWF*. https://www.wwf.eu/what_we_do/sustainable_economies/ (accessed 2023-05-04).

(7) United Nations. *Transforming our world: the 2030 Agenda for Sustainable Development*. https://sdgs.un.org/2030agenda (accessed 2023-05-04).

(8) General Assembly Resolution 70/1. Transforming Our World: The 2030 Agenda for Sustainable Development Transforming Our World: The 2030 Agenda for Sustainable Development.A/RES/70/1, 2015.

(9) United Nations Publications. *The Sustainable Development Goals Report 2022*; 2022.

(10) Ellen Macarthur Foundation. *What is the linear economy?* https://ellenmacarthurfoundation.org/what-is-the-linear-economy (accessed 2023-06-02).

(11) Hazen, B. T.; Russo, I.; Confente, I.; Pellathy, D. Supply Chain Management for Circular Economy: Conceptual Framework and Research Agenda. *International Journal of Logistics Management* **2020**, *32* (2), 510–537. https://doi.org/10.1108/IJLM-12-2019-0332/FULL/PDF.

(12) Lüdeke-Freund, F.; Gold, S.; Bocken, N. M. P. A Review and Typology of Circular Economy Business Model Patterns. *J Ind Ecol* **2019**, *23* (1), 36–61. https://doi.org/10.1111/JIEC.12763.

(13) United Nations. *Sustainable consumption and production* . https://sdgs.un.org/topics/sustainable-consumption-and-production (accessed 2023-06-06).

(14) Geisendorf, S.; Pietrulla, F. The Circular Economy and Circular Economic Concepts—a Literature Analysis and Redefinition. *Thunderbird International Business Review* **2018**, *60* (5), 771–782. https://doi.org/10.1002/TIE.21924.

(15) Suchek, N.; Fernandes, C. I.; Kraus, S.; Filser, M.; Sjögrén, H. Innovation and the Circular Economy: A Systematic Literature Review. *Bus Strategy Environ* **2021**, *30* (8), 3686–3702. https://doi.org/10.1002/BSE.2834.

(16) Geissdoerfer, M.; Savaget, P.; Bocken, N. M. P.; Hultink, E. J. The Circular Economy – A New Sustainability Paradigm? *J Clean Prod* **2017**, *143*, 757–768. https://doi.org/10.1016/J.JCLEPRO.2016.12.048.

(17) European Parliament. *Circular economy: definition, importance, and benefits*. https://www.europarl.europa.eu/news/en/headlines/economy/20151201STO05603/circular-economy-definition-importance-and-benefits (accessed 2023-06-02).

(18) Ellen MacArthur Foundation. *What is a circular economy?* . https://ellenmacarthurfoundation.org/topics/circular-economy-introduction/overview (accessed 2023-06-03).

(19) Ellen MacArthut Foundation. *The Butterfly Diagram: Visualising the Circular Economy*. https://ellenmacarthurfoundation.org/circular-economy-diagram (accessed 2023-06-02).

(20) Neves, S. A.; Marques, A. C. Drivers and Barriers in the Transition from a Linear Economy to a Circular Economy. *J Clean Prod* **2022**, *341*, 130865. https://doi.org/10.1016/J.JCLEPRO.2022.130865.

(21) Govindan, K.; Hasanagic, M. A Systematic Review on Drivers, Barriers, and Practices towards Circular Economy: A Supply Chain Perspective. *https://doi.org/10.1080/00207543.2017.1402141* **2018**, *56* (1–2), 278–311. https://doi.org/10.1080/00207543.2017.1402141.

(22) Korhonen, J.; Honkasalo, A.; Seppälä, J. Circular Economy: The Concept and Its Limitations. *Ecological Economics* **2018**, *143*, 37–46. https://doi.org/10.1016/J.ECOLECON.2017.06.041.

(23) Jones, P.; Comfort, D. Towards the Circular Economy: A Commentary on Corporate Approaches and Challenges. *J Public Aff* **2017**, *17* (4), e1680. https://doi.org/10.1002/PA.1680.

(24) Ghisellini, P.; Cialani, C.; Ulgiati, S. A Review on Circular Economy: The Expected Transition to a Balanced Interplay of Environmental and Economic Systems. *J Clean Prod* **2016**, *114*, 11–32. https://doi.org/10.1016/J.JCLEPRO.2015.09.007.

(25) Bourguignon, D. Closing the Loop: New Circular Economy Package; 2016.

(26) European Comission. The European Green Deal. December 11, 2019. https://eur-lex.europa.eu/legal-

content/EN/TXT/?qid=1576150542719&uri=COM%3A2019%3A640%3AFIN (accessed 2023-06-04).

(27) European Commission. *Circular economy action plan*. https://environment.ec.europa.eu/strategy/circular-economy-action-plan_en (accessed 2023-05-23).

(28) Commission, E.; Energy, D.-G. for; Industry, D.-G. for E. and. *Ecodesign Your Future: How Ecodesign Can Help the Environment by Making Products Smarter*; European Commission, 2014. https://doi.org/doi/10.2769/38512.

(29) European Commission. *RoHS Directive*. https://environment.ec.europa.eu/topics/waste-and-recycling/rohs-directive_en (accessed 2023-05-28).

(30) EU-OSHA. *Regulation (EC) No 1907/2006 - Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) | Safety and health at work EU-OSHA*. https://osha.europa.eu/es/legislation/directives/regulation-ec-no-1907-2006-of-the-european-parliament-and-of-the-council (accessed 2023-05-28).

(31) European Parliament and of the Council. *Directive on end-of life vehicles*. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02000L0053-20230330 (accessed 2023-05-23).

(32) Ellen MacArthur Foundation. *A New Textiles Economy: Redesigning Fashion's Future*; 2017.

(33) Commission, E.; Environment, D.-G. for. *Impacts of Circular Economy Policies on the Labour Market: Final Report and Annexes*; Publications Office, 2018. https://doi.org/doi/10.2779/574719.

(34) European Comission. *Chemicals strategy*. https://environment.ec.europa.eu/strategy/chemicals-strategy_en (accessed 2023-05-20).

(35) *SUSTAINABLE CHEMICALS FOR THE GREEN AND DIGITAL TRANSITION*; Brussels, 2020. https://ec.europa.eu/environment/pdf/chemicals/2020/10/Strategy.pdf (accessed 2023-05-21).

(36) European Chemical Agency. *Chemicals Strategy for Sustainability - ECHA*. https://echa.europa.eu/hot-topics/chemicals-strategy-for-sustainability (accessed 2023-05-26).

(37) European Comission. *Implementation of the Chemical Strategy*. https://environment.ec.europa.eu/strategy/chemicals-strategy/implementation_en (accessed 2023-05-25).

(38) European Chemical Agency. *ECHA*. https://echa.europa.eu/about-us (accessed 2023-06-04).

(39) Knight, by D. J. The European Chemicals Agency Experience. *Chemistry International -- Newsmagazine for IUPAC* **2012**, *34* (6), 6–8. https://doi.org/10.1515/CI.2012.34.6.6.

(40) PwC. *European Chemicals Agency First Ex-Post Evaluation of SCIP*; 2022.

(41) Europe Chemical Agency. *SCIP Database*. https://echa.europa.eu/scip-database (accessed 2023-03-07).

(42) European Commission. *Waste Framework Directive*. https://environment.ec.europa.eu/topics/waste-and-recycling/waste-framework-directive_en (accessed 2023-05-07).

(43) European Commission. *DIRECTIVE 2008/98/EC on Waste and Repealing Certain Directives*; 2018. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02008L0098-20180705 (accessed 2023-05-07).

(44) Becker, T. The SCIP Database under Directive (EU) 2018/851. *International Chemical Regulatory and Law Review* **2020**, *2* (4), 147–156. https://doi.org/10.21552/ICRL/2019/4/4.

(45) Europe Chemical Agency. *SCIP infographic*. https://echa.europa.eu/scip-infographic (accessed 2023-03-07).

(46) European Chemical Agency. Requirements for SCIP Notifications October 2020 2 Requirements for SCIP Notifications Requirements for SCIP Notifications. **2020**. https://doi.org/10.2823/686692.

(47) European Chemical Agency. *Tools to Refer to SCIP Data Already Submitted to ECHA*; Helsinki, 2021. https://doi.org/10.2823/119.

(48) European Commission. *REACH Regulation.* https://environment.ec.europa.eu/topics/chemicals/reach-regulation_en (accessed 2023-06-06).

(49) European Parliament and of the Council. *Regulation (EC) No 1907/2006 concerning REACH*. Official Journal of the European Union. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=OJ:L:2006:396:TOC (accessed 2023-06-06).

(50) European Chemical Agency. *Understanding REACH*. https://echa.europa.eu/regulations/reach/understanding-reach (accessed 2023-06-06).

(51) European Chemical Agency. *Candidate list update*. https://echa.europa.eu/-/echa-adds-nine-hazardous-chemicals-to-candidate-list (accessed 2023-06-06).

(52) European Commission. *RoHS Directive*. https://environment.ec.europa.eu/topics/waste-and-recycling/rohs-directive_en#timeline (accessed 2023-06-05).

(53) Thakur, P.; Kumar, S. Evaluation of E-Waste Status, Management Strategies, and Legislations. *International Journal of Environmental Science and Technology* **2022**, *19* (7), 6957–6966. https://doi.org/10.1007/S13762-021-03383-2/TABLES/2.

(54) European Parliament. DIRECTIVE 2011/65/ on on the Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment (RoSH). European Union Law June 11, 2011. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02011L0065-20230301 (accessed 2023-06-06).

(55) Vanderlande Industries. *About Vanderlande and acquisitions - Vanderlande industries*. https://www.vanderlande.com/about-vanderlande/ (accessed 2023-05-05).

(56) Vanderlande Industries. *History - About Vanderlande.* https://www.vanderlande.com/about-vanderlande/history/ (accessed 2023-05-20).

(57) Vanderlande Industries. *Toyota Industries Corporation (TICO) - Vanderlande*. https://www.vanderlande.com/about-vanderlande/toyota-industries-corporation-tico/ (accessed 2023-05-20).

(58) Vanderlande industries. *Company profile | About Vanderlande -*. https://www.vanderlande.com/about-vanderlande/company-profile/ (accessed 2023-05-20).

(59) Vanderlande industries. *Partner in Airport solutions*. https://www.vanderlande.com/airports/ (accessed 2023-05-20).

(60) Vanderlande Industries. *Vanderlande - Parcel*. https://www.vanderlande.com/parcel/ (accessed 2023-05-20).

(61) Vanderlande Industries. *Sustainability Report FY2022*; Veghel, 2022.

(62) Vanderlande Industries. *Toyota Industries Corporation to acquire Vanderlande - Vanderlande*. https://www.vanderlande.com/news/toyota-industries-corporation-to-acquire-vanderlande/ (accessed 2023-06-14).

(63) PWC. *European Chemicals Agency First Ex-Post Evaluation of SCIP*; 2022.

(64) European Chemical Agency. *Know more about hazardous chemicals in products – SCIP data published*. https://echa.europa.eu/-/know-more-about-hazardous-chemicals-in-products-scip-data-published (accessed 2023-06-13).

(65) GlobalNorm. *SCIP DATABASE IN ACCORDANCE WITH DIRECTIVE 2018/851/EU COMING SOON*. https://www.globalnorm.de/en/news-product-compliance/details/scip-database-in-accordance-with-directive-2018-851-eu-coming-soon/ (accessed 2023-06-13).

(66) Bundesministerium der Justiz. § 16f ChemG - Einzelnorm. October 2020. https://www.gesetze-im-internet.de/chemg/__16f.html (accessed 2023-06-13).

(67) National Institute for Public Health and the Environment. Coping with Substances of Concern in a Circular Economy. *National Institute for Public Health and the Environment* **2020**.

(68) Doyle, E. Compliance Obstacles to Competitiveness. *Corporate Governance* **2007**, *7* (5), 612–622. https://doi.org/10.1108/14720700710827194/FULL/PDF.

APPENDICES

Appendix 1. Table with the Key Actions in the EU CE Action Plan

Table 7. Key main actions in the Circular Economy Act[1,2]

The environmental strategies

Category	Key action
A sustainable product policy framework:	Legislative proposal for a sustainable product policy initiative Legislative proposal empowering consumers in the green transition Legislative and non-legislative measures establishing a new "right to repair" Legislative proposal on substantiating green claims Mandatory Green Public Procurement (GPP) criteria and targets in sectoral legislation and phasing-in mandatory reporting on GPP. Review of the Industrial Emissions Directive, including the integration of circular economy practices in upcoming Best Available Techniques reference documents Launch of an industry-led industrial symbiosis reporting and certification system
Key product value chain	Circular Electronics Initiative, common charger solution, and reward systems to return old devices Review of the Directive on the restriction of the use of certain hazardous substances in electrical and electronic equipment and guidance to clarify its links with REACH and Eco-design requirements Proposal for a new regulatory framework for batteries Review of the rules on end-of-life vehicles Review of the rules on proper treatment of waste oils Review to reinforce the essential requirements for packaging and reduce (over)packaging and packaging waste Mandatory requirements on recycled plastic content and plastic waste reduction measures for key products such as packaging, construction materials and vehicles Restriction of intentionally added microplastics and measures on unintentional release of microplastics Policy framework for bio-based plastics and biodegradable or compostable plastics EU Strategy for Textiles Strategy for a Sustainable Built Environment Initiative to substitute single-use packaging, tableware, and cutlery by reusable products in food services
Less waste, more value	Waste reduction targets for specific streams and other measures on waste prevention EU-wide harmonised model for separate collection of waste and labelling to facilitate separate collection Methodologies to track and minimise the presence of substances of concern in recycled materials and articles made thereof

	Harmonised information systems for the presence of substances of concern Scoping the development of further EU-wide end-of-waste and by-product criteria Revision of the rules on waste shipments
Making the circular economy work for people, regions, and cities	Supporting the circular economy transition through the skills Agenda, the forthcoming Action Plan for Social Economy, the Pact for Skills and the European Social Fund Plus Supporting the circular economy transition through Cohesion policy funds, the Just Transition Mechanism, and urban initiatives
Crosscutting actions	Improving measurement, modelling, and policy tools to capture synergies between the circular economy and climate change mitigation and adaptation at EU and national level Regulatory framework for the certification of carbon removals Reflecting circular economy objectives in the revision of the guidelines on state aid in the field of environment and energy Mainstreaming circular economy objectives in the context of the rules on non-financial reporting, and initiatives on sustainable corporate governance and on environmental accounting
Leading efforts at the global level	Leading efforts towards reaching a global agreement on plastics Proposing a Global Circular Economy Alliance and initiating discussions on an international agreement on the management of natural resources Mainstreaming circular economy objectives in free trade agreements, in other bilateral, regional, and multilateral processes and agreements, and in EU external policy funding instruments

Appendix 2. Table of articles classification in Vanderlande

Table 8. Categories for articles in Vanderlande and its risk level assigned.

Articles categories	Type of category
Bearings	LRC
Belting	LRC
Bulk: Power Cables, Control Cables, Flat Cables	HRC
Casting (alu)	LRC
Coating	LRC
Controls Cabinet Materials	LRC
Embedded Controllers	HRC
Extrusion parts	LRC
Fastners	LRC
Field Bus Technology & PhotoEyes & Sensors	HRC
Field Wiring Materials	LRC
Machining/Turning mechanical parts	LRC
Mechanical parts fabrication (incl. coating)	LRC
Motors & Drive Components	HRC
Plastic Injection Moulding	LRC
Plastic Machined parts	LRC
PLC/HMI/Scada	LRC
Pneumatical equipment	LRC
Power transmission parts	HRC
Prefab cables (incl. power connections, Controls & Sensing)	HRC
Raw materials (e.g., steel, wood)	LRC
Rollers	HRC
Rolling mechanical parts	LRC
Rubber components	HRC
Trays, Totes & Carrier	LRC
Various Mechanical Components	LRC
Wheels	HRC
Woodworking parts	LRC