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Doing Business in the Age of Transparency

A case study of Full Material Disclosure in the electronics sector

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Abstract

Electronic products consist of substances that can be harmful to human health and the environment if exposed or leaked during the product use and end-of-life phases. Full Material Disclosure (FMD), which usually requires suppliers to disclose on the concentrations or masses of all substances in a product, is one method of increasing supply chain transparency on chemicals in products. This case study developed a framework to systematically analyze the development and implementation of FMD at hard drive manufacturer Seagate Technology Ltd., with the purpose of improving the understanding of how a firm's external and internal environments can relate to and influence the outcomes of FMD as a chemicals-in-products (CiP) disclosure strategy. It assessed, for Seagate, why FMD was chosen, how it was developed, how challenges were overcome and what factors led to its success. The relevance and influence of Seagate's business environment (the political environment, external stakeholders, market environment and organizational context) were analyzed. Comparisons with four other electronics companies were made. This study found that client requirements were the biggest driver for Seagate's FMD, though regulatory requirements, NGO pressures and industry initiatives were more significant for downstream OEMs. A trickle-down effect was observed where downstream companies pass such requirements up the supply chain which can manifest into voluntary (i.e. non-regulatory) substance restrictions. This study demonstrated that the likelihood of success for a company to establish FMD is dependent on two elements. First, a set of preconditions related to the external and internal contexts of the company, such as high buyer power, long-term collaborative relationships with suppliers, high supplier capability, high vertical integration and complex and irregular changes to regulatory and client requirements, fewer product lines and relatively non-complex products, and a networked firm structure that values sustainability and meaningful corporate responsibility engagement. Second are a number of actions that a company can take to facilitate FMD implementation and overcome common challenges. Areas of further research were recommended on understanding FMD adoption trends in the electronics industry, perceptions on existing FMD data standards to improve FMD standardization and additional studies using the same units of analysis to verify the findings. NGOs should also take a company's size (product diversity and production quantity), position in the supply chain and overall supply chain structure into account when promoting FMD as a strategy to enhance supply chain transparency on CiP.

Keywords: Chemical management, green chemistry, electronics, Full Material Disclosure, case study, cleaner production, chemicals in products

Executive Summary

This case study developed a framework to systematically analyze the drivers, development and implementation of Seagate's Full Material Disclosure (FMD) system, with the purpose of improving the understanding of how a firm's external and internal environments can relate to and influence FMD as a chemicals-in-products (CiP) disclosure strategy.

Problem definition and research questions

The dramatic rise in the production, consumption and turnover of electronics have made electronic products highly prevalent in society. However, the presence of hazardous substances in electronic products pose threats to human health and the environment, especially those that are classified as substances of very high concern (SVHCs).

Electronic products are composed of numerous components which can consist of toxic heavy metals (e.g. mercury, cadmium and lead) and toxic chemicals that should be destroyed at the product's end-of-life (e.g. brominated flame retardants and phthalates added to polyvinyl chloride (PVC) in cables). These substances can be harmful to human health and the environment if exposed or leaked during the product use and end-of-life phases. If improperly treated, for example, PVC-containing electronic waste can release dioxins (a highly toxic persistent organic pollutant that can cause reproductive and developmental defects, cancer and damage to the immune system) into the environment.

NGOs and public interest groups have been working to raise awareness on hazardous substances in electronic products among consumers and the public. In response, government policies have emerged to control the presence and prevalence of hazardous substances in electronic products. Policymakers, international organizations and the private sector have also begun collaborating and sharing good practices on establishing information systems to understand the issues of hazardous chemicals in products.

In the face of mounting regulatory pressure coupled with rising consumer awareness, firms are turning towards increasing supplier transparency to understand what is in their products. Indeed, a Harvard Business Review article introduced the idea that firms are operating in the *Age of Transparency*, in which it is no longer feasible to ignore the negative externalities of business operation and production. Firms understand that the presence of toxic substances in their products presents not only risks to human health and the environment but also reputational and regulatory risks to the firm. However, many companies lack knowledge of the chemicals and substances in their products and must turn to suppliers to collect such information.

Full material disclosure (FMD) is one method of increasing supply chain transparency on chemicals in products. Since 2006, Seagate Technology Ltd. (the world's second largest hard drive manufacturer) has established a robust and stringent FMD system with over a decade of operation, driven by changing regulatory, industry and client requirements. Seagate's FMD requires suppliers to disclose, by Chemical Abstract Number and concentration (or mass), every constituent substance in every homogeneous material in the products supplied to Seagate. FMD data is checked against Seagate's substance restrictions to determine the level of compliance. In parallel, Seagate continuously pressures suppliers to avoid indiscriminate claims of proprietary information as a justification to not disclose.

FMD has proven for some companies to be a useful data collection and measurement approach. It is beneficial because it can help companies pre-empt new chemicals regulations (such as new substance restrictions and requirements to disclose CiP information), make regulatory compliance more efficient, achieve long-term compliance cost savings, allow for product design

changes and substitution of hazardous substances and improve supplier engagement and CiP management. Ultimately, the adoption of FMD can contribute to reducing human exposure and environmental pollution from hazardous chemicals and improve waste management practices for electronic products, benefiting society and the environment.

Despite the apparent benefits of FMD, it remains an uncommon practice among most industries. Even in the electronics industry, there is inconsistent adoption and the lack of a formal definition and standardization of FMD has resulted in a divergence of data formats, levels of stringency and data quality. The high upfront investment costs for establishing FMD infrastructure can also be a major deterrent. Furthermore, companies tend to face strong resistance or inability from suppliers to participate and comply when attempting to establish FMD. In the end, the decision boils down to whether FMD constitutes a suitable business strategy and whether investing in FMD infrastructure (including data collection systems, software and new supplier engagement procedures) is worth it.

What enables successful outcomes for companies that have adopted FMD? Some studies have analyzed cases of supplier companies that established FMD compliance systems as a response to specific client demands, and others that adopted FMD to seek out safer chemical substitutions in products. However, most studies on FMD have only had a narrow focus on the factors that drive companies towards adopting FMD as a compliance strategy, how challenges were overcome and other contextual factors that may have led to successful outcomes.

Considering its relative maturity, Seagate's FMD presents a unique opportunity for analysis and a fuller understanding of its drivers, implementation experience, challenges and success factors can help NGOs, regulators and other companies to improve standards, policies and practices in CiP disclosure and increase overall chemicals transparency in supply chains.

To create a better understanding of what drives firms towards FMD and what makes FMD systems successful, this case study of Seagate's FMD posed the following research questions:

1. "Why did Seagate decide to adopt FMD as a CiP disclosure strategy?",
2. "How did Seagate adopt FMD? What challenges were faced in the process and how were they overcome?",
3. "What factors enabled the success of Seagate's FMD?", and
4. "To what extent is the case of Seagate's FMD relevant to other companies?"

This study has a greater purpose to improve the understanding of the drivers of FMD for NGOs to improve the targeting of FMD promotion initiatives and strategies. It can also help regulators understand the context and experience of companies in responding to regulatory pressures on CiP management and provide lessons learned to other companies seeking to adopt FMD.

Methodology and research design

This case study project was developed in discussion with Beverley Thorpe (Clean Production Action) based on the rationale that understanding the details behind Seagate's FMD story can inform NGOs on how FMD can be more effectively promoted and adopted across various industries. What emerged was an explanatory single-case study that seeks to answer the "why" and "how" of Seagate's FMD adoption, with exploratory elements to identify areas of further research given the lack of similar case studies on Full Material Disclosure at the firm level.

The research design of this thesis is based on the proposition that Seagate's external and internal business environments influenced the company's decision to adopt FMD, as well as played a role in shaping FMD outcomes. The design of the study is split into two parts: **Part 1** answers

the main questions of "why" and "how" behind Seagate's FMD program – in terms of why FMD was chosen, how it was developed, and how challenges were overcome. In each stage of the story of Seagate's FMD, the relevance and influence of Seagate's business environment (the political environment, external stakeholders, market environment and organizational context) were analyzed. The case study also explained in further detail how Seagate's FMD system works, which is important given that a standard definition of FMD does not currently exist and the detailed design, characteristics and standards of FMD systems differ among companies.

Part 2 of this study consisted of conducting similar case analyses (albeit to a much smaller scale) on four other companies in the electronics industry, including those with FMD or list-based disclosure systems (the latter referring to declarations of the absence of specified substances above specific thresholds). The companies were Motorola Mobility, Sony Mobile Communications, HP Inc. and Electrolux. The units of analysis in this part were as follows: first, the *function and design* of the selected disclosure systems were studied. Next and where feasible, the cases were analyzed based on the *relevance and influence of the four units of analysis* (i.e. the political environment, external stakeholders, market environment and organizational context of the companies). Further, input was sought from individuals of other stakeholder groups with insight on CiP disclosure systems and the electronics industry, to complement the findings.

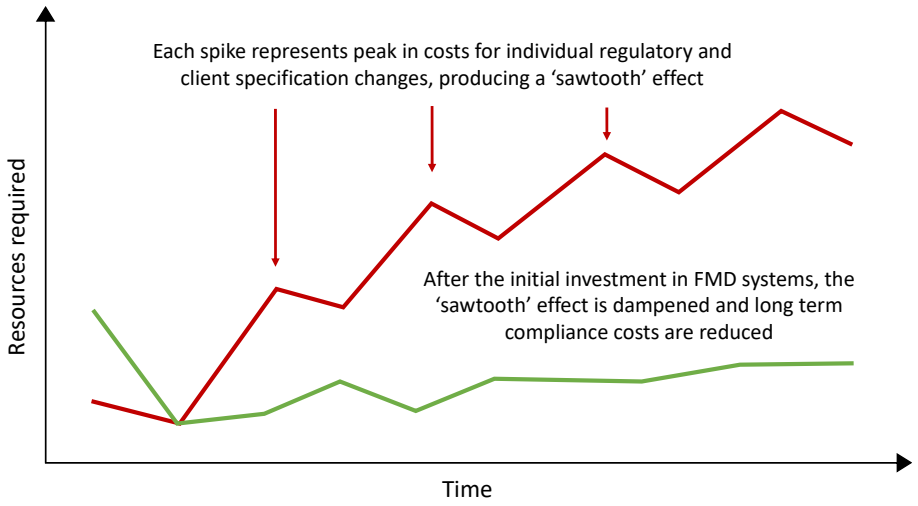
Besides desk research, a semi-structured interview approach was used in both parts of the study to collect data. A coding structure was used for the categorization and analysis of findings. The table below summarizes the sample scope and number of interviewees across samples.

Targeted data	**Sector**	**Organizations (number of individuals)**
Primary case study of FMD	Electronics company	Seagate (5)
Cases of FMD, industry issues and trends	Electronics companies	Motorola Mobility (1)
		Sony Mobile Communications (1)
Cases of list-based disclosure, industry issues and trends	Electronics companies	HP (1)
		Electrolux (1)
Industry issues and trends, perception of supply chain challenges	Chemicals compliance contractor	SciVera (1)
		Assent Compliance (1)
	Government	Swedish Chemicals Agency (3)

Findings

Part 1 – Seagate's FMD experience

Seagate decided to adopt FMD because it was deemed as the appropriate strategy to efficiently and cost effectively manage frequently changing regulatory and client requirements on chemicals in products. The expected cost of compliance pre-FMD was estimated to be significant, ranging between USD 1.9 to 5.2 million per year for all hard drive products in the days before FMD (in the early to mid-2000s). For Seagate, while the upfront costs of establishing FMD were high, it nonetheless provided net cost savings over time when compared with the compliance measures used before FMD, which were based on reacting to regulatory and client specification changes on a case-by-case basis. This is described as the so-called "sawtooth effect", illustrated below:



Seagate selected the IPC 1752 industry standard for material data reporting and developed their Compliance Assurance System to collect and manage FMD data. Lessons from a pilot project to collect FMD for one product were taken to make system adjustments, after which FMD was officially launched in 2006 with a 95% data completion requirement.

The main challenges in FMD development and implementation were supplier resistance (overcome by officializing FMD as a procurement standard, setting a fee structure for suppliers to pay and participate in FMD and leveraging on relevant internal and external relationships), low supplier capacity (overcome by continuous training with the help of third-party support and the strategic targeting of capacity building beneficiaries), and internal resistance (overcome by persistent engagement and consultation). Suppliers' concerns on product proprietary information are addressed by allowing them to not disclose up to 5% proprietary substances as long as they considered as "low risk" materials (i.e. those found in long-established parts numbers from suppliers with whom Seagate has had a mature and stable relationship). In parallel, Seagate continuously pressures suppliers to avoid indiscriminate claims of proprietary information to avoid disclosure.

Besides Seagate's active measures to address FMD implementation challenges, other factors that contributed to the success of FMD include Seagate's strong buyer power (as a result of a highly vertically integrated supply chain, purchasing power and other structural and relational matters), efforts of a champion of change that pushed FMD through with top-level support, and sustainability-driven organizational values, culture and staff.

Part 2 – Comparison with other FMD and list-based disclosure cases

On FMD trends: Based on the data collected, this study found that the ability for a company to establish FMD in the I.T. electronics sector is greatest for upstream basic parts suppliers and diminishes down the supply chain. While most original equipment manufacturer (OEM) brands request FMD data, a number of downstream companies still rely on list-based disclosure. Nonetheless, further study is needed to clearly map out trends of FMD adoption in the I.T. electronics industry.

On the political environment: Seagate and most of the other companies studied shared the same regulatory drivers for CiP management, namely global RoHS policies, EU REACH and California Proposition 65. Downstream brand OEMs tended to face greater regulatory pressure from waste-related regulations such as the EU Waste Framework Directive. Because Seagate was one of the earliest adopters of FMD, external stakeholders (industry groups, NGOs and

the waste management sector) had less of an influence on its decision to adopt FMD, while the opposite was found for most of the other companies studied.

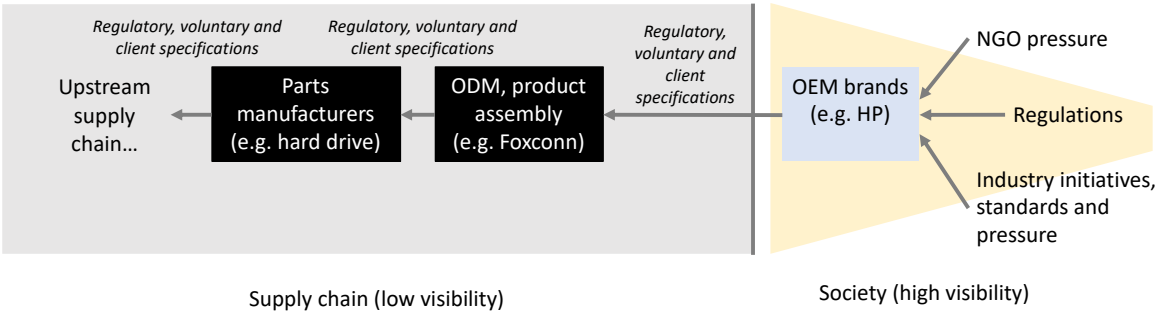
On drivers for corporate CiP disclosure strategies: While OEM brand companies have indicated that the pressures and standards to manage hazardous chemicals in products have shifted from industry groups to regulations, for Seagate such drivers were predominantly client-based. Furthermore, most companies indicated that NGOs have played a bigger role than industry groups in pushing for increased transparency in CiP disclosure systems. Nonetheless, industry-initiated ecolabels such as the Electronic Product Environmental Assessment Tool (EPEAT) can create a strong basis and market driver to collect CiP information from the supply chain. Household consumers were not deemed to be highly significant, though their interests are often reflected in NGO pressures. The waste management sector is also more involved with downstream brand OEMs where collaborations are emerging on circular economy development.

On suppliers: Suppliers play a fundamental role in providing CiP information to prove their compliance to client and regulatory specifications. The biggest barriers to engaging suppliers in FMD systems is addressing their concerns over proprietary product information and limited knowledge and technical capability to comply with FMD requirements. Nonetheless, suppliers are more likely to comply if the buyer has greater market power (e.g. procurement power), if existing systems are aligned with requested data formats and if standard FMD practices exist in the industry. Seagate's success in establishing strict FMD requirements and robust systems is closely linked to supply chain structure, relationships and management approaches, though the absence of industry-wide FMD standards pose challenges to adoption across the industry and supply chains.

On clients and competitors: All companies identified that their clients play a major role in influencing the CiP strategies adopted. For Seagate, clients and their evolving specifications were the biggest drivers that pushed Seagate to adopt FMD. Competitors are also relevant because companies are consistently seeking to stay in line or be ahead of competitors. While FMD may not necessarily provide direct competitive advantage, FMD systems can allow for the adoption of tools such as ecolabels, which can increase product value and boost revenue.

Discussion

This thesis found that while FMD exists among companies in the electronics industry, the specific approaches can vary. The types of pressure for CiP management and disclosure vary for different companies as well. While downstream brand OEMs face greater pressure from regulations, NGOs and industry, Seagate as a mid-stream supplier reported client pressure as their biggest source of pressure. This is likely because of their different positions in the supply chain and the greater reputational risk OEMs face due to their visibility and recognizability in society. In this regard, a trickle-down effect was observed where downstream companies pass on regulatory requirements, NGO pressures, industry initiatives and demands from the waste management sector up the supply chain, which manifest into voluntary company-based requirements (i.e. specific client requirements) from the perspective of suppliers, as illustrated below:



Based on the findings of all companies assessed, this study also demonstrated that the likelihood of success for a company to establish FMD is dependent on two general elements. The first is a set of preconditions related to the external and internal contexts of the company, such as high buyer power, long-term collaborative relationships with suppliers, high supplier capability, high vertical integration and complex and irregular changes to regulatory and client requirements that create a demand for increased efficiency in CiP management and compliance practices. FMD establishment is also easier if the company has fewer product lines and the products themselves are not overly complex. It also helps if the company has a networked organizational structure that values sustainability and meaningful corporate responsibility engagement.

The second are the actions that the company actively takes when implementing FMD. These include the strategic leveraging of internal and external relationships to increase FMD buy-in, maintaining close engagement with suppliers and providing ongoing support to suppliers to collect and submit FMD data. The role of change agents such as a champion of change with top-level support to create the shift to FMD is also significant in FMD success. The company should also pay close attention to understanding their suppliers and their capabilities and then set the standards and requirements according to what is feasible. Further efforts to develop the capacity of suppliers can be implemented over time. Smaller companies with fewer resources to develop in-house FMD systems may also consider contracting third-party companies to aid in the data collection and reporting processes. The involvement of third-party service providers can help to protect the confidentiality of suppliers' information should that be of major concern among the company's suppliers.

Recommendations

Based on the above, the author recommends that NGO efforts to promote FMD should take a company's size (product diversity and production quantity) into account, as well as its position in the supply chain and overall supply chain structure, to assess FMD feasibility. Appeals to regulators to develop sectoral CiP regulations (such as those similar to RoHS) or additions to EU REACH may also be effective depending on the current state of regulatory pressures in that particular sector. Value-adding industry initiatives such as ecolabels can also be useful to create drivers for FMD. However, FMD promotion in any sector should seek to develop a common industry standard to avoid the same issues related to the multitude of unique FMD formats faced in the electronics industry.

Other companies seeking to increase CiP transparency may also find the details of this report helpful. This includes lessons learned in setting up I.T. infrastructures, formatting data standards and approaches in supplier engagement (including how to address supplier concerns, what makes suppliers take FMD more seriously, how to build supplier capacity and the nuances of relationships management with suppliers). While such factors may be case specific to Seagate, a company interested in FMD may consider whether any of their contexts are similar to Seagate and as such whether the lessons learned are applicable.

For regulators, the CiP disclosure strategies described in this report may add to the understanding of how companies respond to regulations to improve existing regulations or develop new policies that promote greater CiP transparency in the supply chain and FMD adoption.

The author also recommends that further research can fill the gaps of this study by focusing on building understanding on FMD adoption trends in the electronics industry, perceptions on existing FMD data standards to improve on FMD standardization and additional studies using the same units of analysis from this thesis to verify the findings.

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Abbreviations

CiP – Chemicals in products

CAS – Chemical Abstract Service (typically referred to as a "CAS number" in this report) or Compliance Assurance System (typically referred to as a "CAS system" in this report)

ChemSec – International Chemicals Secretariat

ECHA – European Chemicals Agency

EHS&S – Environmental, Health and Safety & Sustainability (Seagate team)

EIT – Engineering and Information Technology

EPEAT - Electronic Product Environmental Assessment Tool

FMD – Full Material Disclosure

HDD – hard disk drive

IEC – International Electrotechnical Commission

IGO – international governmental organization

IPC – Institute of Printed Circuits

JIG – Joint Industry Guide

NGO – non-governmental organization

ODM – original design manufacturer

OEM – original equipment manufacturer

Prop 65 – Proposition 65 (Californian legislation)

RBA – Responsible Business Alliance

REACH – Registration, Evaluation, Authorization and Restriction of Chemicals (EU regulation)

RoHS – Restriction of Hazardous Substances

SAICM – Strategic Approach to International Chemicals Management

SVHC – substance of very high concern

WEEE – waste electrical and electronic equipment

List of Key Terms

Chemical – "distinct compound or substance, especially one which has been artificially prepared or purified" (Oxford Dictionary, 2018)

Compound – a substance formed by the chemical bonding of two or more chemical elements (Chemicool, 2017).

Substance – "a chemical element and its compounds in the natural state or the result of a manufacturing process", examples include metals, solvents and fuels (ECHA, n.d.). A material is composed of multiple substances (definition for the purpose of this report).

Homogeneous material – a material that "cannot be mechanically disjointed into different materials… The term "homogeneous" means "of uniform composition throughout". Examples of "homogeneous materials" are individual types of: plastics, ceramics, glass, metals, alloys, paper, board, resins and coatings. The term "mechanically disjointed" means that the materials can, in principle, be separated by mechanical actions such as: unscrewing, cutting, crushing, grinding and abrasive processes" (DG Enviornment, 2006).

Article – In EU regulations, an article is "an object which during production is given a special shape, surface or design that determines its function to a greater degree than its chemical composition" (Wehe, 2013). Both a part or component of a complex product and the complex product itself can be articles (e.g. a resistor is an article on a printed circuit board, which itself is also an article).

Components (electronics) – basic devices that are intended to be connected together to form electronic parts (Das, 2018). For the purpose of this report, the terms components and parts are used interchangeably, but both refer to the units and devices that make up final electronic products, such as a hard disk drive or a laptop computer.

1 Introduction

The dramatic rise in the production, consumption and turnover of electronics have made them highly prevalent in society, but the presence of hazardous substances in electronic products pose threats to human health and the environment (Zhu, et al., 2017).

Electronic products are composed of numerous components which consist of various substances. These substances can be classified into the following major groups: 1) Toxic heavy metals (e.g. mercury, cadmium and lead), 2) toxic artificial chemicals that should be destroyed at the product's end-of-life (e.g. brominated flame retardants and phthalates added to polyvinyl chloride (PVC) in cables), 3) relatively benign metals with recovery value (e.g. gold and copper), and 4) other chemicals and materials with recovery value (e.g. plastics)[1]. The first two groups include substances that can be harmful to human health and the environment if exposed or leaked during the product use and end-of-life phases. The focus of this paper is related to these two groups.

NGOs have been raising awareness on hazardous substances in electronic products among consumers and the public (Zhu, et al., 2017). In response, government policies have emerged to control the presence and prevalence of hazardous substances in electronic products. Many of these are policies that restrict or ban certain substances. Policymakers, international organizations and the private sector have also begun collaborating and sharing good practices on establishing information systems to understand the issue of chemicals in products (CiP) (Rossi, 2014).

In the face of mounting regulatory pressure coupled with rising consumer awareness, firms are turning towards supplier transparency to understand what is in their products. Indeed, in a Harvard Business Review article, Meyer and Kirby (2010) expressed that firms are now operating in the *Age of Transparency*, in which it is no longer feasible to ignore the negative externalities of doing business. Firms understand that the presence of toxic substances in their products presents not only risks to human health and the environment but also reputational and regulatory risks to the firm. However, many companies lack knowledge of the chemicals and substances in their products and must turn to suppliers to collect such information.

There are three main approaches for suppliers to disclose on substances: 1) *list-based reactive disclosure* (i.e. declaring the absence of certain substances based on existing regulatory restrictions), 2) *list-based proactive disclosure* (i.e. the same as the first type but based on existing and potential regulatory restrictions and other voluntary restrictions), and 3) *Full Material Disclosure* (FMD, i.e. usually the declaration of all materials and substances and their concentrations in a product regardless of whether the substance is restricted or not) (Assent Compliance, 2018a and SACIM, 2015a).

Since 2006, Seagate Technology Ltd. (the world's second largest hard drive manufacturer) has implemented Full Material Disclosure, which requires suppliers to disclose to Seagate on all substances and materials that are present in the components supplied (Schmidt, 2018). This is a requirement that suppliers must fulfil in order to secure Seagate's business.

For Seagate, FMD has proven to be a useful CiP data collection and measurement tool for devising change and compliance strategies. FMD is also beneficial because it can pre-empt new chemicals regulations (such as new substance restrictions and requirements to disclose CiP

[1] This categorization is based on the author's own elaboration.

information), make regulatory compliance more efficient, achieve long-term compliance cost savings, allow for product design changes, improve supplier engagement and CiP management and ultimately, contribute to reducing human exposure to hazardous chemicals and improve waste management practices for electronic products, both of which benefit society and the environment (Rossi, 2014; SAICM, 2015a and Martin, 2009).

1.1 Problem definition

Despite the apparent benefits of FMD described above, FMD remains an uncommon practice among most industries. Even in the electronics industry, there is inconsistent adoption and the lack of a formal definition and standardization of FMD has resulted in a divergence of FMD formats, levels of stringency and data quality. While standards for data formats and reporting exist, not all companies have found them to be user-friendly and have thus devised their own unique systems that further exacerbate the divergence issue.

In all industries, the most common challenge that a company must overcome to establish FMD is the strong resistance or inability from suppliers to participate and comply. And yet, some companies such as Seagate have managed to establish robust and stringent FMD systems with over a decade of operation, purportedly driven by changing regulatory, industry and client requirements. Studies on other cases of FMD have shown supplier companies that decided to fulfil FMD requirements due to client demand (who in turn was requesting FMD in the first place to meet regulatory demand) (Dills & Harris, 2008), brand companies that request CiP data to seek safer chemical substitutions in products (Strand & Mulvihill, 2016), and Seagate's case was also documented from the financial perspective in one case study (Rossi, 2014).

Evidently, these cases show that the decision to adopt CiP disclosure systems, be it list-based or FMD, is a business strategic decision, which in theory is driven by the external and internal conditions of a company's environment. However, most studies have had a narrow focus only on a small number of apparent drivers and their main outcomes.

A narrow study may not provide the full picture of all the factors that drive companies towards adopting FMD as a compliance strategy, how challenges are overcome and other contextual factors that lead to successful outcomes. A fuller understanding of Seagate's FMD can help NGOs, regulators and other companies understand the enabling factors that lead to successful outcomes when a company adopts FMD, and further devise strategies and policies to improve overall CiP transparency in supply chains.

1.2 Research questions

Based on the above, the following research questions were devised:

1. Why did Seagate decide to adopt Full Material Disclosure as a chemicals-in-products disclosure strategy?
2. How did Seagate adopt FMD? What challenges were faced in the process and how were they overcome?
3. What factors enabled the success of Seagate's FMD?
4. To what extent is the case of Seagate's FMD relevant to other companies?

It is important to note that the focus on answering the fourth research question is relatively minor compared to the first three research questions (discussed further in Section 1.3 Limitations and scope).

A case study approach is used to answer the research questions. This study has a greater purpose to improve the understanding of the drivers of FMD for NGOs to improve the targeting of FMD promotion initiatives and strategies. It can also help regulators understand the context and experience of companies in responding to regulatory pressures on CiP management and provide lessons learned to other companies seeking to adopt FMD.

1.3 Limitations and scope

The main focus of this study is on Seagate's FMD with minor focus on other companies in the electronics sector for basic comparison. It covers the state of affairs that led to the selection of FMD at Seagate, the development process, how Seagate's FMD system works and the outcomes and experiences during implementation. The rationale, challenges and enablers of success of each stage are analyzed through the perspectives of Seagate's external and internal contexts, namely the political environment, external stakeholders, market environment and the internal organization. Similar data is collected for four other companies (in the electronics sector) for comparative analyses but to a much lesser extent.

Given that this is mainly a single-case study, there are two major limitations. The first is the reliance on extensive interviews with a few individuals at Seagate, given that only these individuals can provide detailed accounts of their FMD story (particularly one individual who was directly involved with FMD establishment). This is helpful because they can provide detailed reflections but can also be limiting because of the difficulty of verification, given that many of these details are not provided in public records and written material.

Elaborating on the above, the second limitation is related to generalizability. A single-case study cannot guarantee that all findings are generalizable to other companies and cases. The scale of the project did not allow for a larger comparative case study to include other companies in detail, but the author attempted to address this limitation by including other cases for minor comparison, identifying similarities and differences and analyze for generalizability. Based on this, the potential contributions of this study are discussed at the end of the report.

This study does not discuss, at length, the role of FMD in the overall management of chemicals in products in society, however some discussion is made on the adoption trends of FMD, standard-setting, barriers to adoption and other views. The study also does not make detailed comparison between FMD and list-based disclosure systems.

1.4 Ethical considerations

In this study, one Seagate representative participated as the direct contact of this project (though this role was transferred successively among three individuals due to staff turnover) and one representative from NGO Clean Production Action who acted as the external supervisor. An agreement was signed between Seagate, the author and the IIIEE to proceed with the project. While the project contact and external supervisor provided contacts, suggestions and input to the research direction and data collection, they had no direct influence on the project methodology and analytical framework at any time.

Key aspects of ethical research responsibilities towards all of the interviewees of this project were ensured as follows: first, all the interview findings from this study were obtained with the consent of interviewees. Second, all interviewees were informed of the purpose and scope of the study in an introduction letter (see Appendix A: Introduction letter to interviewees). Next, the author always sought consent from interviewees before making any audio recordings of the interviews, and protected the interviewees' anonymity by default, only revealing other identifiers where permission was given (e.g. the interviewee's name, position and organization). Anonymity

on particular statements was maintained whenever it was requested. Finally, the data and content produced from this study are stored digitally with password protection.

1.5 Audience

This case study was conducted in close coordination with NGO Clean Production Action, which identified the value that understanding Seagate's FMD can provide by informing NGOs on how FMD can be more effectively promoted and adopted across various industries. Further, this report also targets Seagate personnel who expressed that a case study of Seagate's FMD can help document their 'legacy' and help newer employees understand the context of how their FMD system was established. Therefore, Clean Production Action and Seagate are the two main target audience groups for this report. In addition, this report also targets policymakers and regulators working in the area of CiP management, who may find this report helpful to better understand the perspective and experience of companies responding to regulations related to CiP disclosure. Other companies seeking to adopt more transparent CiP disclosure systems may also find this report helpful. Finally, this report identifies areas of research to improve the understanding of FMD as a CiP disclosure strategy and FMD standardization which researchers in this area may also find relevant and useful.

1.6 Disposition

Following this introduction (Section 1) which discussed the background issues and addressed the research focus of this study, the remainder of the report is structured as follows:

Section 2 summarizes the findings of the literature review that formed the basis of the scope and analytical framework of this study. *Section 3* describes the research design and the data collection and analysis methods.

Section 4 provides the findings and analysis results of the study, first by summarizing the findings related to case studying FMD at Seagate followed by the findings of the other companies studied. The analysis of basic findings is discussed.

Section 5 discusses select key findings that emerged upon the reflection of all findings in Section 4, drawing upon critical observations and posing 'so what' questions. Further explanations and reflections are offered for these key findings, followed by a discussion of critical reflections on the methodology of this study, potential contributions and a summary of recommendations. *Section 6* provides responses to the research questions and concludes the report.

2 Literature review

The literature review is split into the following subsections: 2.1 provides a summary of the background issues on hazardous chemicals in electronic products, the sources of demand for product chemical information and supply chain approaches to CiP disclosure. 2.2 reviews past studies on FMD and discusses research gaps and 2.3 provides an overview of major theories related to corporate strategic management to build the analytical framework of this study.

2.1 Background

2.1.1 Hazardous chemicals and electronic products

Chemicals and substances are at the core of production systems, as they make up the materials and components that enter into products sold on the market. It is estimated that over 80,000 chemicals are used and sold in the market for industries (Green Science Policy Institute , 2017).

Certain chemicals and substances are classified as substances of very high concern (SVHCs) given their particularly harmful effects to human health, wildlife and the environment. In general, the effects are referred to as follows (Thorpe, 2017 and EEB & ISTAS, n.d.):

1. Persistence – the tendency to remain in the environment without breaking down.
2. Bioaccumulative – the tendency to accumulate in the body of humans and organisms and increase in concentration up the food chain.
3. Endocrine disruption – refers to substances that disrupt hormonal systems, which can in turn result in impacts spanning multiple generations including reproduction, learning, diabetes, cancer, autism and obesity.
4. Toxic – a general term that refers to effects to reproductive, nervous and immune systems, including risks in causing cancer and endocrine disruption.
5. Carcinogenic, mutagenic and reprotoxic – terms that respectively refer to cancer-causing, gene-mutating and toxicity to reproductive systems.
6. Neurotoxicant – substances that damage the central and peripheral nervous system and sense organs.

SVHCs are problematic across all stages of the electronics product life cycle. During the manufacturing phase, workers can be exposed to production process chemicals such as solvents, heavy metals and epoxy resins (Nimpuno & Scruggs, 2011). For example, in 2016, electronics manufacturer Samsung was exposed to have withheld information to workers in semiconductor and LCD manufacturing plants on the chemicals they were exposed to at work. The reason for withholding this information was over concerns of exposing trade secrets. Over 76 deaths and 200 cases of serious illnesses such as leukemia, lupus and lymphoma were documented among the workers (Aljazeera, 2016).

During the use phase, hazardous substances in electronic products can also be released if they are not appropriately contained or handled, or from breaking down from wear and tear over time. The presence and leakage of such substances have been indicated in household dust studies. For example, a meta-analysis of household dust studies in the US in 2016 confirmed the prevalence of the same hazardous substances that are used in electronic products in household dust, including phthalates and flame retardants (Mitro, et al., 2016). Flame retardants such as polybrominated diphenyl ethers (PBDEs) are typically used in electronic products to provide fire protection throughout the use and disposal cycles of the product. They can be carcinogenic and endocrine disrupting when they enter the human body. PBDEs are also highly resistant to biodegradation and can persist in the environment for a long time (Swedish Chemicals Agency, 2016), the full impact of which is still not yet fully understood.

Likewise, workers in the waste management sector can be exposed to the same SVHCs in products during the break down, processing and recycling of waste electrical and electronic equipment (WEEE). If improperly treated, for example, PVC-containing WEEE can release dioxins (a highly toxic persistent organic pollutant that can cause reproductive and developmental defects, cancer and damage to the immune system (Thorpe, 2017). This is problematic because electronic products are now pervasive in modern global society. WEEE such as computers, mobile phones and appliances is the fastest growing waste stream in Europe (European Commission, 2015).

This thesis focuses on the issues of hazardous substances present in final products and is thus most relevant to the use and end-of-life phases of the electronic product life cycle. In particular, focus is placed on hard disk storage drives.

Hazardous substances in hard drives

Data storage drives are a staple component of computer products including desktop, tablet and laptop computers. Two common types of storage drives are hard disk drives (HDD) and solid-state drives (SSD). Given that HDDs are Seagate's principle product (Seagate, 2016a), they will be used to illustrate the components and substances being addressed.

Hard disk drives are composed of the following four main components within its casing (typically made of plastic) that are mounted on the drive's circuit boards (Nield, 2018 and Kay, 2001):

1. **Platters** – circular disks made of aluminum, glass or ceramic coated with a magnetic material, where data is stored. They can be stacked to increase storage capacity.
2. **Spindle** – located in the center of the platters, the spindle holds the platters in place and spins them when data is being read or written. The number of revolutions per minute is the main indicator for the speed of data writing and reading of a hard disk.
3. **Read/write arm** – consists of a magnetic head mounted at the end of an arm that can access any position of the platter. The magnetic head floats above the platter to read and write data without actually touching it.
4. **Actuator** – a small motor that receives instructions from the printed circuit board to control the read/write arm and oversee the transfer of data.

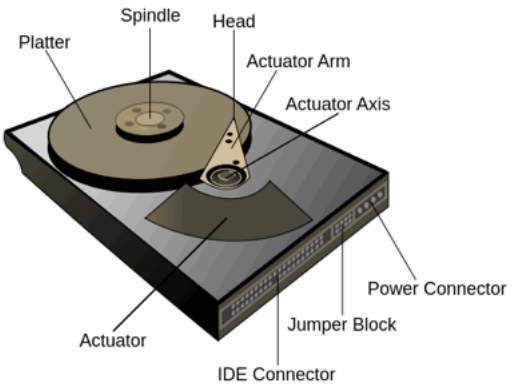

Figure 2-1 The main parts of a hard drive

Components are mounted on an internal circuit board and is usually encased in plastic.

Source: (Liu, 2013)

The main hazardous substances in HDDs are shown in the table below and will be the main substances of focus in this paper.

Table 2-1 Select hazardous substances in hard disk drives

Hazardous substance	**Application**	**Harmful effects to human health and environment**
Lead	Found in printed circuit boards and solder (though substitutes are emerging as lead-based soldering becomes increasingly restricted)	Carcinogenic, endocrine disruptor, neurotoxic, reprotoxic, persistent, bioaccumulative and toxic
Mercury	Printed circuit boards	Carcinogenic, endocrine disruptor, neurotoxic, sensitizer, reprotoxic, persistent, bioaccumulative and toxic
Cadmium	Printed circuit boards	Carcinogenic, mutagenic, endocrine disruptor, neurotoxic, reprotoxic
Chromium	Printed circuit boards	Carcinogenic
Beryllium	Commonly used in metal alloys, found in printed circuit boards	Carcinogenic, neurotoxic, sensitizer
Nickel	Printed circuit boards	Carcinogenic, neurotoxic, sensitizer
Brominated flame retardants	Printed circuit boards, semiconductors	Endocrine disruptor, persistent, bioaccumulative and toxic
Antimony trioxide	Printed circuit boards, plastic casings	Carcinogenic, neurotoxic
Halogenated flame retardants	Plastic casings	Carcinogenic, endocrine disruptor, neurotoxic, persistent, bioaccumulative and toxic

Note: The above lists substances that would likely have been present in HDDs produced in the past, as many of these substances have either been phased out or substituted by safer alternatives among major HDD producers over the last two to three decades (Larson, 2018).

Source: Adapted from Cui, J. and Forsberg E, 2003 as adapted from Nimpuno & Scruggs, 2011, TechRadar, 2010 and Eurometaux, 2018. Harmful effects to human health and environment are derived from the RISCTOX: Toxic and hazardous substances database (EEB and ISTAS, n.d.).

2.1.2 Demand for product chemical information

The issues with hazardous substances in electronics have led to a demand for knowing what is in products and their associated risks and impacts. This demand for product chemical information is driven by awareness building and promotion for safer chemical use by international governmental organizations (IGOs), non-governmental organizations (NGOs), regulations and industry initiatives.

IGOs and NGOs

While many organizations, programs and initiatives exist, below is a select few that are regularly mentioned in relation to the issue of chemicals in electronic products.

SAICM

The Strategic Approach to International Chemicals Management (SAICM) is a voluntary framework implemented by a secretariat with the participation of UN bodies, government representatives from various UN member countries, NGOs, industry groups and civil society (SAICM, 2018). SAICM programs are focused on five "emerging policy issues", three of which are relevant to electronic products (SAICM, 2015): 1) chemicals in products, 2) hazardous substances in the life cycle of electrical and electronic products and 3) endocrine disrupting chemicals.

The Chemicals-in-Products (CiP) Program focuses on products that may contain common hazardous substances such as lead, cadmium, mercury, brominated flame retardants, and that may pose exposure risks during product use, disposal and manufacturing. The CiP Program aims to facilitate the exchange of chemical information among various stakeholders of the product life cycle.

ChemSec

The International Chemicals Secretariat (ChemSec) is an EU-based NGO that was founded in 2002. It advocates for "a world free from hazardous chemicals… through independent research, cross-border collaboration and practical tools" (ChemSec, n.d.). One of the key tools is the Substitute It Now (SIN) List, a database of chemicals that may be subject to restriction in the EU REACH Directive or other EU regulations in the future. The SIN List provides guidance for companies seeking to substitute potentially restricted SVHCs with safer alternatives (ChemSec, n.d.(a)).

Clean Production Action

Clean Production Action is a US-based NGO that focuses on fostering global networks and partnerships between government, businesses and other NGOs to advocate and "advance green chemicals, sustainable materials and environmentally preferable products" (CPA, 2018a). One of its key programs is BizNGO, which conducts regular trainings and workshops for various stakeholder groups on the issues of safer chemicals, sustainable materials, policy initiatives and industry standards (CPA, 2018). Another major program is the Chemical Footprint Project, which conducts regular surveys of companies from various sectors on chemicals management. The surveys have found that companies continuously score the lowest in the area of transparency (Thorpe, 2018).

Greenpeace

In the area of CiP issues in electronics, Greenpeace is known for producing the Greener Electronics Guide – an annual assessment of global leading consumer electronics companies in terms of their efforts in addressing three environmental impact categories: energy use, resource consumption and chemical elimination (Greenpeace, 2016).

Regulations

EU RoHS Directive and other national RoHS policies

The EU Directive 2011/65/EU on the Restriction of Hazardous Substances (RoHS), commonly known as RoHS 2, is a recast of the original EU RoHS Directive (RoHS 1) created in 2002 (Horn, 2016). It covers a number of EEE categories including large and small household appliances, IT and telecommunications equipment and consumer equipment (Council Directive 2011/65/EU, 2011, Annex I).

EU RoHS 2 mainly works by restricting and setting upper limit concentrations for specific substances and categories at the homogenous material[2] level typically referring to the final product or individual major components. While the original restrictions list only covered six substances (numbers 1 to 6 in the list below), in 2015 the regulation was amended to add four

[2] According to the European Union, a homogenous material refers to a material that "cannot be mechanically disjointed into different materials… The term "homogeneous" means "of uniform composition throughout". Examples of "homogeneous materials" are individual types of: plastics, ceramics, glass, metals, alloys, paper, board, resins and coatings. The term "mechanically disjointed" means that the materials can, in principle, be separated by mechanical actions such as: unscrewing, cutting, crushing, grinding and abrasive processes" (DG Enviornment, 2006).

phthalates. Currently the following ten types of substances, shown in % weight by weight) are covered (Commission Delegated Directive 2015/863, 2015):

1. Lead (0.1%)
2. Mercury (0.1%)
3. Cadmium (0.01%)
4. Hexavalent chromium (0.1%)
5. Polybrominated biphenyls (PBB) (0.1%)
6. Polybrominated diphenyl ethers (PBDE) (0.1%)
7. Bis(2-ethylhexyl) phthalate (DEHP) (0.1%)
8. Butyl benzyl phthalate (BBP) (0.1%)
9. Dibutyl phthalate (DBP) (0.1%)
10. Diisobutyl phthalate (DIBP) (0.1%)

Since the establishment of EU RoHS, other countries such as China, Japan, Korea, Singapore and Turkey have also initiated their own RoHS-like policies covering a combination or all of the EU RoHS substances. The policies also differ in the details of compliance requirements such as labelling, categorization of products covered and the roles and responsibilities of producers (RoHS Guide, 2018).

EU REACH Regulation

The Regulation (EC) 1907/2006 concerning the Registration, Evaluation, Authorization and Restriction of Chemicals (REACH)[3] covers a wide variety of substances that are scoped based on the risks they may pose to society and the environment. The policy aims to control the prevalence of hazardous substances in society and encourage producers to seek safer alternatives (ECHA, n.d.(a)).

The European Chemicals Agency (ECHA) administers the REACH Regulation and risk evaluations of substances. If a substance is determined as an SVHC, it is placed on the REACH Candidate List, and companies will face two main obligations (Wehe, 2013):

1. Under Article 7(2): Notify ECHA of the listed SVHCs if they are present at the article[4] level above a concentration of 0.1% weight by weight, or if the SVHCs are present in articles and sold onto the market totaling over one ton per year. The notification must be submitted within six months of the SVHC's inclusion on the Candidate List.
2. Under Article 33: Suppliers of articles containing the SVHC over 0.1% weight by weight must provide information to buyers and distributors on the safe use of the article. Requests for information by consumers must also be answered within 45 days free of charge.

Depending on the risk level determined, a Candidate List substance may be restricted (for use only with authorization and/or below a specific concentration level) or phased out. If a substance is to be phased out, then there is a "sunset date"' after which the substance may no longer be placed on the market for use (Interview IF).

EU WEEE Directive

The EU Directive 2012/19/EU on waste electrical and electronic equipment (WEEE) is an extended producer responsibility scheme which requires EU producers (including manufacturers, importers and retailers) to coordinate the collection and recovery of WEEE. Collection and recovery targets are established for different types of products. In addition to

[3] The full name of the regulation is REGULATION (EC) No 1907/2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH), establishing a European Chemicals Agency, amending Directive 1999/45/EC and repealing Council Regulation (EEC) No 793/93 and Commission Regulation (EC) No 1488/94 as well as Council Directive 76/769/EEC and Commission Directives 91/155/EEC, 93/67/EEC, 93/105/EC and 2000/21/EC.

[4] An article is defined as "an object which during production is given a special shape, surface or design that determines its function to a greater degree than its chemical composition" (Wehe, 2013).

striving for the prevention of WEEE by encouraging recovery and reducing disposal, the WEEE Directive also strives to influence product design to facilitate the disassembly of electronic product components and recovery of valuable secondary raw materials. The RoHS and WEEE Directives are key components of the EU's legislation on chemicals in electronics (Council Directive 2012/19/EU, 2012).

EU Waste Management Directive

The EU Directive 2008/98/EC on waste (Waste Framework Directive) sets out the basic responsibilities of member states on waste management (including recycling, recovery and disposal). The Directive covers elements including extended producer responsibility on companies in member states to strengthen the re-use, prevention, recycling and recovery of waste and to ensure that when a product becomes waste, it is safe for recovery and environmentally sound disposal (DG Environment, 2016). Changes to Article 9 of the Directive will require ECHA to create a database on SVHCs in products, which will also be used by the waste management sector (Interview IF).

Prop 65

Proposition 65, formally known as the Safe Drinking Water and Toxic Enforcement Act of 1986, is a Californian law which aims to protect drinking water sources from contamination from carcinogenic and endocrine disrupting chemicals (OEHHA, 2018). Based on a list of known carcinogenic and reprotoxic chemicals, companies must include warning labels visible to consumers if their product consists of the listed chemicals. Prop 65 also prohibits companies from (knowingly) discharging such substances into drinking water sources in California (Calder & Nasr, n.d.).

Industry groups

Responsible Business Alliance

Responsible Business Alliance (RBA) is a non-profit industry group that was founded in 2004 and is "dedicated to electronics supply chain responsibility" (RBA, 2018). Its members include companies from the electronics, retail, automotive and toy industries who commit to a common code of conduct for supply chain management. RBA also provides tools and frameworks for conducting trainings and assessments on responsible supply chain management (RBA, 2018).

IPC

The Institute of Printed Circuits (IPC) is an industry group that created one of the first data exchange standards on electronics materials and substances called IPC 1752. The standard has since been updated from a pdf-based form to an Extensible Markup Language (XML) form referred to as IPC 1752A, which has affected its user-friendliness and uptake (discussed further in Sections 4) Findings and 5) Discussion). There are four classes within this standard: Class A is the most basic class which collects yes/no declarations on compliance with regulations and restrictions; Class B collects declarations on the amount of material groups in a product; Class C collects product-level declarations on whether substances are present in the product above or below specific thresholds (based on the industry standard IEC 62474 and REACH regulation lists); and Class D collects full material declarations at the homogenous level (Assent Compliance, n.d.).

IEC 62474 (previously known as the Joint Industry 101 Guide)

The International Electrotechnical Commission (IEC) is an international standards organization that develops standards for electrical and electronic technologies (IEC, 2018). *IEC 62474 – Material Declaration for Products of and for the Electrotechnical Industry* provides standards to electronics companies on the "substances, substance groups and material classes that need to be included in material declarations" and to software developers on the data format for exchanging material

declaration data (IEC, 2018a). The standard is based on agreement among the electronics industry on the materials in products information that should be declared by suppliers. The IEC 62474 was previously known as the Joint Industry 101 Guide (developed in 2005), which was an industry-initiated list of known substances of concern in electronics (ECD Compliance, 2014).

EPEAT

The Electronic Product Environmental Assessment Tool (EPEAT) is an electronics ecolabel, mainly covering final (individual and business) consumer products such as computers and displays, televisions, imaging equipment and mobile phones (EPEAT, n.d.(a) and EPEAT, 2017). Producers can apply for EPEAT certification and the right to include three categories of EPEAT labels (bronze, silver and gold) on their products if they fulfil a set of mandatory and optional criteria. These criteria include substance management, material use, energy efficiency, packaging, product longevity, lifecycle assessments, carbon footprinting and process chemicals (EPEAT, n.d.).

2.1.3 Approaches on chemicals-in-products disclosure

In response to increasing NGO, regulatory and industry pressure and initiatives on CiP information and demand for corporate responsibility, companies are turning to increasing transparency upstream in the supply chain by requesting CiP information from suppliers (Zhu, et al., 2017). The scope and breadth of the chemicals that are selected for information exchange can vary but are generally classified into three main types as show in the table below.

Table 2-2. Approaches to chemicals-in-products (CiP) disclosure systems

Type and description	Advantages	Disadvantages
1. Restricted-substance list based on regulated chemicals Mainly a reactive approach where suppliers are required to declare that their products do not contain the listed substances above a specified threshold (also known as an absence declaration).	• Straightforward scoping of chemicals • Product industry associations can provide a list for member companies, reducing individual research efforts • Clear target setting for legal compliance makes it easier to administer from a business management perspective	• The supply chain must adjust within a limited time period upon each change to regulations (e.g. a newly restricted chemical) – to include the new chemical in the information system, investigate for its presence in products, make substitutions and design changes, etc. • Must rely on government to regulate the use of hazardous substances in society
2. Restricted-substance list based on regulations, potential regulations and other chemicals of concern An elaboration of the first approach that covers voluntary restrictions beyond regulations.	• Can help companies to stay ahead of regulatory changes in terms of efficiently finding substitutions, making design changes and compliance reporting when regulations enter into force • Brands and manufacturers are kept abreast of regulatory developments • Product industry associations can provide a list for member companies, reducing individual research efforts	• Higher resource demand given the greater number of chemicals to monitor, track and report • Companies may also need to spend resources to track and/or participate in consultations on regulatory developments to monitor for potential future restrictions
3. Full material disclosure	• Provides the most comprehensive data and allows suppliers to create one complete dataset rather than	• Likely the most expensive approach for initial set-up of all three approaches

Type and description	Advantages	Disadvantages
A proactive approach that aims to collect as much CiP information from suppliers as possible.	multiple incomplete datasets which can be updated over time • Greater quality and reliability of information on CiP. Enhances supply chain transparency • Allows for instant verification of regulatory and voluntary compliance upon changes, which in turn also allows for efficient substitutions, product design changes and reporting • Minimizes incremental cost of compliance over time • Allows for shift to sustainable chemical management at product level	• Difficult to obtain supply chain buy-in due to high perceived resource demand and concerns over product proprietary information

Source: Adapted from SAICM (2015a) with input from Nimpuno & Scruggs (2011).

The first two 'list-based' approaches (also known as *negative lists* or *absence declaration*) typically cover only a small fraction of the total material composition of products (Martin, 2009). They are *reactive* towards the specific requirements and restrictions of chemicals regulations and customer requirements. Meanwhile, Full Material Disclosure *proactively* seeks to compile a list of all substances (whether restricted or not) as comprehensively as possible (Olson, 2018).

Full material disclosure

While there is no standard definition of Full Material Disclosure (FMD), this approach typically refers to the attempt of obtaining as much information as possible on the substances, chemicals and materials present in products purchased from suppliers. Chemical compliance consultancy Assent Compliance (n.d.) defined FMD as a way to "provide companies with a complete breakdown of the composition of their products, down to the homogeneous level". A homogenous material is one that "cannot be mechanically disjointed into different materials [and is] of uniform composition throughout" (DG Enviornment, 2006). Examples of homogenous materials are uniform plastics, ceramics, glass, coatings and alloys.

Different interpretations of FMD exist in terms of the degree of enforcement (i.e. whether a buyer requires FMD data as compulsory or voluntary for a supplier to be qualified), comprehensiveness of data collection (most FMD programs are below 100% data collection rate) and sources of data (i.e. whether data collection is limited to first-tier suppliers or includes upper tier suppliers) (Interviews SB, SC, IA and ID).

In addition to the advantages listed in Table 2-3, the biggest benefit of FMD is its strong business case for companies to positively impact the bottom line by (Assent Compliance, n.d.):

- Obtaining full knowledge of product composition and environmental and human health impacts, which helps to identify any chemical-related risks and opportunities in the supply chain and develop responsive measures (e.g. substitutions and product design changes);
- Serving as a basis for verifying compliance to regulatory and client specification changes, and allowing companies to respond efficiently to such changes including compliance reporting and responding to requests for CiP information; and

- Decreasing long-term compliance cost given that once the first round of FMD data is collected, it only needs to be updated regularly in the future.

However, adopting an FMD system can also be deeply challenging, mainly due to the high degree of protectionism amongst suppliers on trade secrets leading to their refusal to provide information (Thorpe, 2018). Suppliers participating in FMD systems may also claim that certain information is proprietary to avoid disclosure (Olson, 2018). Finally, many suppliers lack the ability, capacity and knowledge to collect FMD data to begin with. NGOs such as Clean Production Action cite these as the most significant barriers to engaging brands and manufacturers to adopt FMD as a proactive chemicals management approach (Thorpe, 2018).

2.2 Case study research in FMD

Using case studies to analyze the drivers and approaches behind companies' decisions to adopt FMD, how challenges were addressed, and the outcomes of their endeavor can help other companies determine whether their situation justifies the need for adopting FMD (and how to proceed). It can also inform NGOs to adjust and improve advocacy strategies to promote FMD as part of safer chemicals management and supply chain transparency campaigns, and help regulators to understand the experiences of companies related to chemical information exchange to improve on policy design.

As part of the literature review of this project, the author sought similar case studies on Full Material Disclosure in any sector. The method largely involved searches on the Lund University Libraries academic database (LUBsearch) and Google, targeting both academic and non-academic case studies using a combination of the keywords: "chemical", "substance", "product", "case study", "disclosure", "declaration", "Full Material Disclosure/declaration". However, the findings were very limited. While many studies and publications exist on analyzing the chemical content of products, the emissions and exposure pathways of chemicals from products and chemicals in life cycle assessment studies across various sectors (e.g. mining, buildings, food), studies specific to FMD and CiP disclosure systems were minimal. Results on the "electronics" sector were even fewer. Nonetheless, what follows is a summary of the few relevant studies that were found.

Textiles: Chemicals in Products Case Study of the Textiles Sector

This UNEP (2011) case study reviewed the state of existing information systems on chemicals-in-products in the textiles sector to identify gaps and make recommendations for improvement. It found that list-based disclosures were the dominant approach for manufacturers to extract chemicals information from their products. Further, the standards are mainly initiated by brand companies, which place restricted substance requirements on their suppliers. Such efforts often include supplier training, product testing and compliance certification of upstream suppliers. The study found that the main drivers for these requirements stemmed from the desire of manufacturers, consumers and government to know whether products sold on the market are safe for use. Waste managers also wish to know whether products are safe for waste processing and handling.

Textiles: Collecting chemical information from suppliers to develop alternative substance (positive) lists

The Haas School of Business at the University of California Berkeley conducted a case study of Levi Strauss & Co (LS&Co) on their Screened Chemistry program (Strand & Mulvihill, 2016), an initiative to create a positive list to substitute hazardous substances in products and processes. Fashion brands typically pass on the choice of chemical use to their manufacturers to avoid potential liabilities and costs in enforcing the use of greener chemicals. However, as vertical

integration becomes more common in the textiles supply chain, brands are gaining increasing access and control over supplier operations.

Based on sustainability-driven organizational values, recognition that the textile industry's conventional approach of using restricted substance lists was not adequate to drive innovation and signatory to the Detox Solution Commitment with Greenpeace, LS&Co implemented the Screened Chemistry Program in 2015. It involved working with third-party service provider ToxServices to develop an algorithm to evaluate substances used by suppliers based on two established methodologies: the U.S. EPA Safer Choice Program and NGO Clean Production Action GreenScreen® assessment framework. ToxServices acted as a trusted third party to collect substance information from suppliers and conduct hazard evaluation while protecting their proprietary and confidential formulations. The evaluations were used to rate the hazardous levels of substances and develop a positive substitution list for the most hazardous substances.

The program was successful in starting the shift towards hazardous chemical substitution at the chemical supplier level of the supply chain. In this case study, the most influential areas behind LS&Co's adoption of Screened Chemistry were NGOs, in driving industry initiatives such as the Greenpeace-led Detox Solution Commitment and providing technical tools such as the Clean Production Action's GreenScreen®; and its sustainability-driven organizational culture. LS&Co also cited success due to a relatively small supply chain (approximately 150 first-tier suppliers) compared to its competitors and assurance to suppliers in protecting proprietary formulations by contracting a third-party service provider.

While LS&Co also offered compensation to some chemical companies if their profits in the year following participation did not cover their initial investment in data collection and screening, LS&Co reported that no supplier claimed costs for this after all, indicating that "early adopters [of addressing hazardous substances in products] are actually gaining business" (Strand & Mulvihill, 2016, p. 10). Others (laggards) faced significant initial costs in certification and research and development. Nonetheless, a number of suppliers expressed that having to comply with a diversity of CiP disclosure requirements from different clients (i.e. inconsistent standards of reporting) was a major challenge.

Toys: Chemicals in Products Case Study for UNEP

This 2011 case study (Dannwolf, Ulmer, Cooper, & Hartlieb, 2011) found that the overall toys industry did not take any initiative on managing hazardous chemicals in products beyond basic regulatory compliance and even then, EU toys have been documented with the second most regulatory non-compliances for chemicals in products exceeding regulated thresholds. While most firms obtained their information from suppliers and lab analyses, the biggest challenge was related to efficiency and the lack of knowledge among suppliers on information requirements and formats.

The study identified two major challenges in developing effective chemicals-in-products disclosure systems along the supply chain. First, buyers in the toys sector tend to be very small firms with low buyer power, and thus have less influence on large suppliers to establish and provide good quality data beyond what is required by regulations. Second, the sector is dominated by short-term manufacturer and supplier relationships which limit the ability to develop successful CiP information exchange, given that suppliers require extensive and long-term support to understand the nature of information demand (e.g. data format and level of detail). In this sense, long-term collaborative relationships tend to provide greater opportunity for developing CiP information exchange systems.

Electronics: Establishing Full Material Disclosure for RoHS compliance

This case study was perhaps the most relevant to this present thesis project. In this 2006 case study (Dills & Harris, 2008), compliance service provider GoodBye Chain Group supported a "large Electronics Manufacturing Company" to respond to a customer's demand for Full Material Disclosure data to demonstrate true RoHS compliance. This demand emerged as a result of an audit conducted by the customer which found that over half of the yes/no RoHS compliance declarations it received from its suppliers were incorrect, and determined that collecting FMD data was the solution to ensure RoHS compliance. The GoodBye Chain Group was contracted to develop a program to fulfill this request.

The main challenges that the electronics manufacturer faced was a tight timeline (their customer requested the provision of FMD data within 90 days), abundant data that required collection (FMD demand was needed for eight printed circuit boards comprising 1200 parts), and the time intensiveness of data collection and limited availability of data among suppliers (the latter two challenges are described as industry-wide) (Dills & Harris, 2008).

Based on recommendations from the GoodBye Chain Group, the electronics manufacturer hired a data vendor to collect substance data. This helped to save substantial cost from in-house data collection. The company also integrated a data software and compliance management system provided by the GoodBye Chain Group, which served not only to store and maintain data but also to conduct compliance and exemption analysis, certification and reporting.

In the end, the electronics manufacturer achieved a 70% FMD data collection rate and 30% yes/no declaration on RoHS compliance at the part level, with efforts to increase FMD data coverage over time. The FMD data collection and software systems that were developed also formed a full compliance assurance system that future-proofed against other regulations such as global RoHS and EU REACH. The compliance assurance system allowed for more accurate exemption analysis, which was critical according to the authors given that incorrectly claimed exemptions comprised one of the greatest legal risks for companies. Based on these outcomes, the authors claimed that the electronics company "successfully turned compliance into competitive advantage" (Dills & Harris, 2008).

Multiple sectors: Business case for knowing chemicals in product and supply chains

This SAICM-published paper (Rossi, 2014) presents various case studies of passive and active strategies for CiP information management. One of the cases discussed in this paper is Seagate's FMD, which is described as a case of active chemicals management which benefited in reducing long-term compliance costs and increasing supplier reliability. The paper also includes a detailed description of how Seagate's FMD system works.

The paper also discussed cleaning product manufacturer Coastwide Laboratories (a division of Staples, Inc.), which was driven by the emerging industry trend of CiP transparency to substitute harmful substances in their products, but wanted to avoid lost resources from "regrettable substitution[s]" (Rossi, 2014, p. 23), or those that in itself turn out to be chemicals of concern. The collection of product substance data and determination of safe substitutes resulted in the formation of a new safer chemicals-based product line which was highly profitable.

Finally, the paper discussed the world's leading carpet manufacturer Shaw Industries which also saw increased sales after substituting hazardous chemicals in their products including PVC and phthalate plasticizers. This was made possible by their initiative in the 1990s to "fully know the chemicals and materials in their product" (Rossi, 2014, p. 23) and phase out hazardous materials.

The process of data collection and identifying substitutions was not discussed in the paper, however.

The above cases indicate that the drivers and challenges for developing CiP information systems and FMD vary across industries, based on the differences in supply chain relationships and structures, the relevant regulations of the sector and industry norms. While many companies recognize the environmental and social benefits of FMD data in producing safer products, in many cases the decision boils down to whether FMD constitutes a suitable business strategy and whether investing in FMD infrastructure (including data collection systems, software, time and human resources) is worth it.

While existing studies (including those reviewed above) shed some light on the most noticeable drivers and challenges, there is a general research gap that systematically studies these drivers and challenges at the various levels of a firm's business environment (i.e. the macro-environment, the industry/sectoral environment, the market environment and within the organization). Such a study can help elucidate the influences and context of the different levels and identify whether they are firm-specific or applicable industry-wide. The learnings can also be used to identify the suitability and feasibility of adopting FMD in the firms of various industries.

2.3 Theories behind corporate strategic management

There are myriad definitions of business strategy. One business management textbook defined corporate strategy as "an integrated concept with the object of ensuring long-term survival in active interaction with the competition and its inherent opportunities and threats" (Wiesbaden, 2000 as cited by Kotler, Berger & Bickhoff, 2010, p. 13). Another textbook defined it as a firm's top management plan to "develop and sustain competitive advantage" developed by "…a process that includes top management's analysis of the environment in which the organization operates prior to formulating a strategy…" (Parnell, 2013, p. 2).

The process of strategy development begins with an analysis of the external environment (i.e. the changes, opportunities, threats and constraints outside the firm) and the internal environment (i.e. the strengths and weaknesses of the organization) (Parnell, 2013; Porter, 2008 and Barney, 1991). This section outlines the major theories and frameworks behind the analyses of the external and internal environment of a firm.

2.3.1 Business Industry Environment Model

The Business Industry Environment Model provides a framework to explain how companies operate and strategize to obtain market and resource control. This involves responding to the situation and anticipated changes on the various layers of their business environment which are: externally in the macro-environment, the industry and the market (in competition with other firms), and internally within the organization (Johnson, Scholes, & Whittington, 2008).

Figure 2-2. Layers of the business environment

Source: Adapted from Johnson, Scholes & Whittington (2008)

2.3.2 The PESTEL framework (external)

Businesses use the PESTEL framework to assess the situation and possible changes in their external environment. These areas cover the *political, economic, social, technological, environmental* and *legal* aspects that may impact the organization

(Johnson, Scholes, & Whittington, 2008). With increasing societal demand for corporate social responsibility, PESTEL forms an important consideration for businesses to account for governmental influences, pressure groups and market forces as part of forming sustainability responses (Campbell & Craig, 2005).

Table 2-3. PESTEL framework

Political	This refers to the composition and stability of governmental institutions as well as the general policy direction of the government. It includes the direction of policy development, potential new legislations or legislative changes that may impact the organization.
Economic	This includes fiscal and monetary changes such as interest rates, taxes and inflation.
Social	Besides the demographic profile of a country, this area also focuses on the values, norms and culture of a society that may be affected by or impact the practices of an organization. Key stakeholders may include NGOs and household consumers.
Technological	This refers to the emergence of innovations and new technologies that can impact a company's competitiveness in communications and production. It can also refer to new materials and resources that may impact the resource availability and access for a company, which in turn would also impact its competitiveness.
Environmental	To remain competitive in the market and uphold a positive image, companies typically align their corporate sustainability and social strategies based on an understanding of how the company's business practices impact the natural environment, the relevant environmental regulations in place and the level of awareness and concern among society.
Legal	Contrasted with the political aspect, legal aspects include regulations and legislations that require compliance. The two may sometimes overlap.

Source: Created by the author based on Campbell & Craig (2005)

2.3.3 Industry, competitors and markets (external)

The two major schools of competition theory are Porter's Five Forces and Resource-based View of the firm, both of which share the same objective of sustaining competitive advantage (Asad, 2012). The theories argue that the fundamental objective of business strategy is to manage five external forces (discussed below) and available resources to improve a firm's market position, which is defined by its ranking in terms of sales volume compared to that of its competitors in the same industry (BusinessDictionary, 2018). It is an indicator of how well a firm performs in the market in comparison to its competitors.

While Porter's Five Forces is outward looking (in terms of how a firm can gain competitive advantage by responding to and managing external forces in the market) and Resource-Based View is inward looking (in terms of how a firm can gain competitive advantage by mobilizing key resources), in the end it has been argued that in the world of business strategic management both are "two sides of the same coin" (Werner, 1984 as cited by Asad, 2012, p. 9). They are complementary, and both schools are valuable in creating sustained competitive advantage in a firm.

Porter's Five Forces

Porter's Five Forces describes five fundamental competitive forces in the market and is a commonly-used framework for assessing the competitive position of a firm in relation to other market actors. This covers the bargaining power of buyers, bargaining power of suppliers, threat of existing competitors, new entrants and substitute products (Porter, 2008).

In the context of FMD, the influence of buyers (i.e. customers) may include requirements on chemicals compliance and substance restrictions, and the bargaining power of suppliers may

influence their level of cooperation and buy-in to participating in FMD systems. The CiP information approach taken by firms may also influence their competitiveness in the market.

Resource-based View of the firm

In Resource-based View, the firm is seen as equipped with resources and capabilities comprised of financial, human and intangible assets, which are non-homogeneous and at times immobile. A firm holds strategic advantage if it has resources that are valuable, rare and inimitable, and if the firm has the capabilities to exploit the resources (Barney, 1991). According to Jay Barney (1991), a firm's ability to sustain its competitive advantage is also associated with informal strategic planning because formal strategic planning approaches are more structured and thus more imitable by competitors. It is also associated with information processing systems – Barney argues that an information-processing system that is "deeply embedded in a firm's informal and formal management decision-making process" (Barney, 1991, p. 114) can be a source of sustained competitive advantage, if it provides benefits such as increased efficiency in information flow among managers and ability to rapidly process and share large amounts of information. FMD may constitute such a system.

Supply chain management

The performance and competitive advantage of a firm is also dependent on how firms manage their suppliers, which involves the management of business relationships and the availability and supply of suppliers' resources.

Related to the resource-based view, resource dependence theory attempts to explain how firms secure their resource supply. Firms reduce environmental uncertainties and dependence on suppliers by using control mechanisms such as supplier evaluation and selection (before making contractual agreements) and governance mechanisms such as monitoring and supplier engagement, training and development (after the contractual agreement enters into force) (Chu and Wang, 2012 and Reuter et al., 2010 as cited by Schnittfeld & Busch, 2016).

According to Andrew Cox (2004), the ability of a firm to exert control and governance mechanisms is dependent on the power dynamics between the buyer and its supplier, which is based on the supply chain's structural and relationship characteristics such as the number of buyers and suppliers in the market, percent market share of the buyer for the supplier, the supplier's dependence on the buyer for revenue, availability of alternatives and switching costs for both buyers and suppliers, attractiveness of the buyer's account to the supplier and the buyer's search costs. These dynamics are illustrated in Figure 2-3 below.

Sustainable supply chain management

Sustainable supply chain management is "the strategic, transparent integration and achievement of an organization's social, ecological and economic goals in the systemic coordination of key interorganizational business processes for improving the long-term economic performance of the individual company and its supply chains" (Carter and Rogers, 2008, p. 368 as cited by Schnittfeld & Busch, 2016, p. 338).

According to Ivory and Brooks (2018, p. 357), sustainable supply chain management allows firms to have an "intimate knowledge" of existing resources, continuous oversight of risks and act quickly and efficiently to deploy resources for responding to external changes or internal decision making, all with the aim to reduce delays and discontinuities in sourcing. It involves proactive and future-oriented approaches and advanced relationships with suppliers geared towards common aims.

FMD can be seen as a sustainable supply chain management strategy given that it can be used to fulfill a firm's corporate social and environmental sustainability objectives as well as improve resource management and sustain competitive advantage.

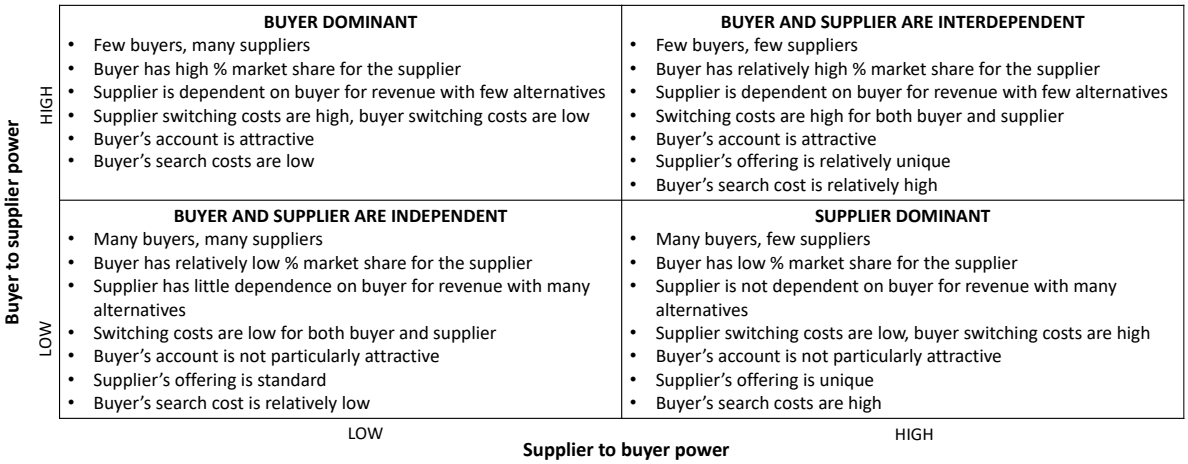

Figure 2-3. Determinants of power dynamics between a firm and its supplier

Source: Adapted from Cox (2004)

2.3.4 The organizational environment and change (internal)

According to Strategic Leadership Professor Costas Markides (2004), the internal organizational environment determines the outcome and success of implementing corporate strategies, based on the organizational culture and structure and its people. Campbell and Craig (2005a) also described the philosophy of the organization's founders, nature of business activities, nature of interpersonal relationships, degree of comradery, management style and influences from the external environment as determinants of organizational culture.

Campbell and Craig (2005a) further describe two types of organizational change: reactive change (in reaction to a change in organization's environment) and proactive change (planned in advance). The nature of a change in an organization's environment can be described in terms of the stability and complexity, in which stability is defined as "how often and by how much the external environment changes" and complexity is defined as the "number of potential external influences upon an organization". The need for organizations to change increases as its environment becomes more complex and unstable. For example, frequently changing regulatory requirements pose instability (i.e. uncertainties) on organizations, especially if the complexity of the demands vary (e.g. newly restricted substances that are complex because of limited knowledge on their impacts and suitable substitutions).

Organizations that are hierarchically and vertically structured (aka. 'mechanistic' organizations) are more effective in stable environments, while flexible and horizontally networked organizations (aka. 'organic' organizations) are more effective in dynamic conditions. Change tends to be difficult in mechanistic organizations, and easier in organic organizations, because the latter is more prone to encouraging risk-taking and entrepreneurial approaches to problem-solving (Campbell & Craig, 2005a).

Models of organizational change

Kurt Lewin's three step model

Kurt Lewin, considered as one of the foundational developers of change theory, proposed a three-step model for change in which human systems (such as an organization) undergo: *unfreezing*, *moving* and *freezing*. The unfreezing stage involves the abandonment of old practices

and beliefs, and the preparation of individual attitudes towards accepting the upcoming changes. After old attitudes are unfrozen, the moving stage then focuses on implementing the change. The freezing stage involves the establishment of new practices and prevention of a return to previous practices (Lewin, 1999).

Champion of change model

In this model, organizational change is largely driven by one or a group of *champions* (also known as *change agents*) that are involved in the whole process of change. The champion plays the role of leading the process, preventing the derailing of efforts, acting as a focal point and representing a symbol of leadership as well as a reminder that change is occurring. This process is illustrated in the Figure 2-4.

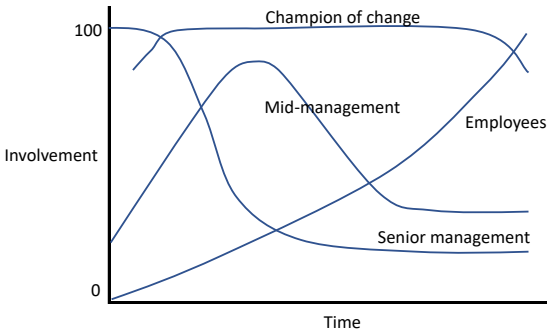

Figure 2-4. Champion of change model for organizational change

Source: Adapted from (Campbell & Craig, 2005a)

In this model, the need for change may be identified by senior management or an individual (or a group of individuals). After obtaining top level approval, senior management becomes less involved over time as the champion of change increasingly engages mid-management in changing their attitudes and implementing change actions among the staff in their teams. As the changes are carried out increasingly by all employees, the action of mid-management to drive change is no longer necessary. The change can be seen as fully implemented when all or the majority of employees behave within the new set of norms and practices. Throughout the process, the champion of change is actively engaged in driving the change and maintaining momentum (Campbell & Craig, 2005a).

2.3.5 Summary

The figure below forms the overall analytical framework of this case study. It illustrates the idea that firm strategy is developed in response to external changes in the macro-environment, industry and market and the internal changes and context of its organization. The theories and frameworks used for corporate strategy development are also listed in correspondence with the appropriate layer of the business environment.

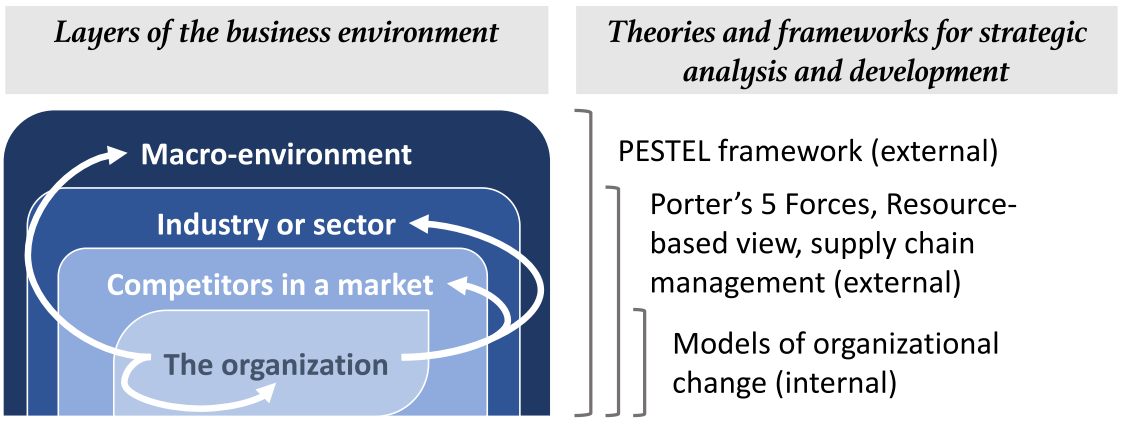

Figure 2-5. External and internal pathways of corporate strategic analysis within the business environment

Source: Author's elaboration based on Johnson, Scholes & Whittington (2008)

3 Methodology

3.1 Context

3.1.1 Introduction to the case organization – Seagate

Seagate Technology Public Limited Company (referred to as Seagate in this paper) is the world's second largest manufacturer of hard disk drives (Rogers, 2018). The company's main product is hard disk drives for internal and external storage which are shipped globally (Seagate, 2016). The main types of clients are original equipment manufacturers (OEMs), distributors and retail companies.

Seagate adopted FMD in 2006, which requires suppliers to "disclose by CAS [Chemical Abstracts Service][5] number and concentration (or mass) [for] every constituent substance in every homogeneous material" (Martin, 2009, p. 4). For Seagate, suppliers must comply with providing FMD data in order to be qualified in the procurement process. Mass balance is used to ensure that declared substances align with total material mass (Martin, 2009 and Olson, 2018). Seagate also states that they "[press their] suppliers to substantially reduce or eliminate their declarations of miscellaneous and proprietary substances" (Martin, 2009, p. 4). Seagate has achieved a 95% FMD data collection rate and is commonly referenced as a successful case of FMD adoption (Thorpe, 2017 and Rossi, 2014).

The sources referenced above are publicly available documents (in addition to Schmidt (2015)) that documented the FMD story and outlined the basic premise for adopting FMD. This includes the need to meet increasing regulations and fulfilling client requirements, outlining the basic functions and design characteristics of the FMD program. The outcome is typically described as long-term compliance cost savings, also as documented in the Rossi (2014) case study (described in Section 2: Literature review).

However, this common narrative may not provide the full picture of all the factors that drove the company towards adopting FMD as a compliance strategy (the "why"), details on its development and how challenges were overcome (the "how"), and other contextual factors that may have led to the program's success. Having a fuller picture of Seagate's FMD story can help other companies, NGOs and regulators understand the enabling factors that allow companies to be successful when attempting to make CiP information systems more transparent in the supply chain, and how barriers can be overcome.

3.1.2 Introduction to the external supervisor – Clean Production Action

This project initially emerged from the communication between the author and Beverley Thorpe, the Consulting Program Manager for Networks and Advocacy at Clean Production Action and guest lecturer on green chemistry at the host institute of this thesis (IIIEE). The idea for conducting a case study of Seagate's FMD was proposed by Thorpe based on the rationale described above, that understanding the details behind Seagate's FMD story can inform NGOs such as Clean Production Action on how FMD can be more effectively promoted and adopted across various industries. Thorpe has since supported this thesis project as the external supervisor.

[5] The CAS Registry is a global standard for labeling and identifying chemical substances. A CAS Registry Number is a "unique numeric identifier [that] designates only one substance" (CAS, 2018).

3.2 Research design

3.2.1 Introduction to case study research

Among the common social science research methods such as experiments and surveys, the case study is one method that is suitable when the questions of "why" and "how" are posed in relation to an event or decision that has taken place (Yin, 1994). "[T]he essence of a case study… is that it tries to illuminate a *decision* or set of decisions: why they were taken. how they were implemented, and with what result" (Schramm, 1971 as cited by Yin, 1994, p. 12).

According to Yin (1994), there are two main types of case study approaches: explanatory and exploratory. Explanatory case studies are the appropriate method for answering "why" and "how" research questions particularly when the researcher has little control over the events or behaviors being studied, and when the temporal focus of the study is situated in a contemporary context (i.e. reasonably recent) (Yin, 1994). Explanatory case studies should describe the facts of a case, consider alternative explanations and conclude with credible and fact-based explanations (Harder, 2010). Exploratory case studies, on the other hand, are suitable when the phenomenon has not been thoroughly studied. It can be useful for developing further questions and hypotheses for subsequent studies (Streb, 2010).

Case study design can be holistic (one unit of analysis) or embedded (multiple units of analysis). It can be classified into four types: 1) Holistic single case design, 2) embedded single case design, 3) holistic multiple-case design and 4) embedded multiple-case design. While multiple-case design allows for the comparison between similar cases, a single case can be useful if it is a unique case or if it is revelatory in allowing the researcher to observe and analyze "phenomenon previously inaccessible to scientific investigation" (Yin, 1994, p. 40).

3.2.2 Research design

This study is primarily an embedded, explanatory single-case study that seeks to answer the "why" and "how" of Seagate's FMD adoption, with exploratory elements to identify areas of further research given the lack of similar case study research on Full Material Disclosure at the firm level.

The rationale for conducting a single-case study is as follows: First, Seagate's FMD represents a unique case since it is recognized as an FMD pioneer in the IT electronics industry and it has also been outspoken in NGO and industry circles about it. The second reason is related to practicality, given that the author was able to obtain the contact of a Seagate employee (through the Clean Production Action external supervisor) to act as a key coordinator by providing information and access to other Seagate personnel. Such access is crucial to conducting a good-quality case study but difficult to obtain due to the protective nature of companies. In this case, it took approximately three months to form an agreement between Seagate and the author to proceed with the project. For these reasons, the unique nature of Seagate's FMD and accessibility of key personnel made for a good opportunity for single-case study research.

One limitation of single-case studies is its ability to ensure external validity, or the degree to which the findings of the case study can be generalized (Yin, 1994). In this Seagate case study, there is a need to identify elements and factors that are unique to Seagate and those that are generalizable to other companies. While this could perhaps be addressed by a comparative case study across several companies, it was deemed to be overly resource intensive for this three-month master's thesis project. Nonetheless, to address external validity and generalizability, the scope of data collection in this study was expanded to cover other companies albeit to a lesser degree and depth compared to the data collected on Seagate.

According to Yin (1994), case study research design consists of five parts: 1) research questions, 2) propositions, 3) units of analysis, 4) the logic linking the data to the propositions and 5) criteria for interpreting the findings.

Research questions

As outlined in Section 1 (Introduction), the research questions of this study are:

1. Why did Seagate decide to adopt FMD as a CiP disclosure strategy?
2. How did Seagate adopt FMD? What challenges were faced in the process and how were they overcome?
3. What factors enabled the success of Seagate's FMD?
4. To what extent is the case of Seagate's FMD relevant to other companies?

Propositions and units of analysis

The research design of this thesis is based on the proposition that Seagate's external and internal business environments influenced the company's decision to adopt FMD, as well as played a role in shaping FMD outcomes. The research design was further informed by the principles of case study research and theories and frameworks behind corporate strategic management (see above). The design of the study is split into two parts:

Part 1: Detailed case study of Seagate's FMD (main focus)

The figure below outlines the key areas of case study research and analysis in Part 1 that answer the main questions of "why" and "how" behind Seagate's FMD program – in terms of why FMD was chosen, how it was developed, and how challenges were overcome. In each stage of the story of Seagate's FMD, the relevance and influence of Seagate's business environment was analyzed. The units and sub-units of analysis are shown below. The case study also explains in further detail how Seagate's particular FMD system works – which is important given that a standard definition of FMD does not currently exist and the detailed design, characteristics and standards of FMD systems differ among companies.

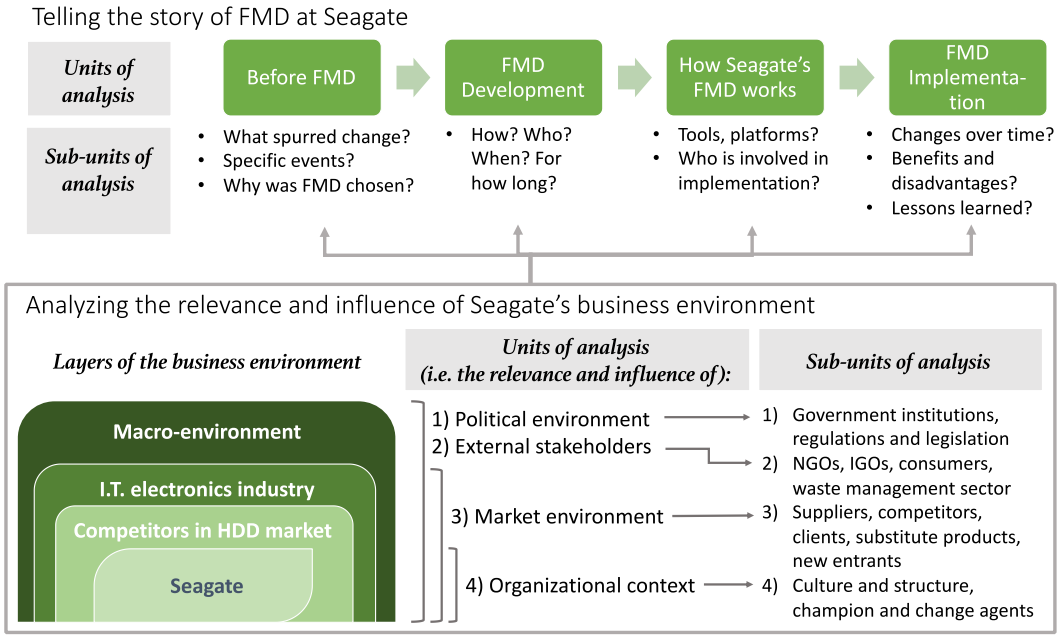

Figure 3-1. Overview of research design – Part 1

Source: Developed by the author based on own research, see above

Part 2: Brief studies of other cases and comparison with Seagate (lesser focus)
Part 2 consisted of conducting similar case analyses (albeit to a much smaller scale) on a number of companies in the electronics industry, including those with FMD or list-based disclosure systems. The units of analysis in this part are as follows: first, the function and design of the selected disclosure systems were studied. Next and where feasible, the cases were analyzed based on the relevance and influence of the four units of analysis (i.e. the political environment, external stakeholders, market environment and organizational context of the companies). Further, input was sought from individuals of other stakeholder groups with insight on CiP disclosure systems and the electronics industry, to complement the findings.

Logic linking the data to the propositions and criteria for interpreting the findings

Yin (1994) describes the steps of linking the data to propositions and the interpretation of findings to be the two key components of data analysis in case study research. In this study, the data collected on Seagate's FMD, CiP disclosure systems of other companies and the input from other individuals were analyzed based on their *relevance* and *influence* on the adoption and outcome of the respective CiP disclosure system studied. While there are no precise criteria for interpreting the findings, the author drew similarities and distinctions among findings as was deemed to be reasonable. For example, two interviewees from different companies that stated their CiP disclosure system was chosen because of requirements in the EU RoHS Regulation would be interpreted as a similarity between the two companies, and possibly an indicator for a start of a pattern. Further details on data analysis methods are discussed below in Section 3.4.

3.3 Data collection

3.3.1 Literature review

After defining the general scope of the study and outlining the areas that may be relevant and influential to the adoption and outcomes of a CiP disclosure strategy, a literature review was conducted on the theories and frameworks behind corporate strategic development. This included classic and contemporary works on corporate strategy, competition theory, supply chain management and organizational theory.

The literature review also included a review of similar case studies on FMD or list-based disclosure systems at the firm level. Further details on the method were given in Section 2: Literature review. Given the limited number of results, the scope for reviewing past case studies was expanded to those focusing on CiP information systems in general and the drivers and factors that influenced the outcomes of FMD or list-based disclosure systems in the supply chain. Other findings in the case studies that were deemed relevant for research were also collected. In both cases, additional sources of literature were reviewed as identified on an ongoing basis. Searches were conducted both on Google and LUBsearch databases.

3.3.2 Part 1: Seagate

Desk research

Desk research on Seagate's FMD focused on all sources of publicly available information, including the company website, publications, reports and presentations as well as publications by NGOs. The search for these sources were conducted in both Google and LUBsearch databases, and additional sources were included along the way. One major observation in this stage was that most of the sources discussed how Seagate's FMD system works, followed by the main drivers that led the company to adopt FMD (i.e. regulations and some industry restrictions) and general description of benefits (e.g. long-term savings in compliance costs). At

this stage the author noted that many of the nuances and details on the relevance and influence of other aspects must be derived directly from Seagate personnel. The author noted gaps in information to inform the development of the interview guide.

Sampling

Seagate interviewees were identified by the Seagate project contact, who recommended individuals based on their involvement in FMD (during its development and/or implementation). This consisted of personnel from the Environmental, Health and Safety & Sustainability team (one of which was directly responsible for the selection and development of FMD) and Engineering and IT (EIT) team. As the author's understanding of the personnel involved in FMD grew after the first few interviews, she requested interviews with additional people who are involved in FMD but was not initially recommended by the Seagate project contact. Separately, communication with a few individuals fell through and the interview did not take place. However, in the end five people were interviewed at Seagate. Further details on the interview list can be found in Appendix B: List of interviews.

Semi-structured interviews

As anticipated during the design of this thesis project, desk research was inadequate to obtain sufficient and comprehensive information on the units of analysis. Given the open nature of the information needed (e.g. recollections on the situation that led to FMD adoption, details on FMD development and other reflections), the semi-structured interview was chosen as the data collection method. Interviews were the appropriate method because it allows for probing to collect the targeted type of information, (which are not possible with other social research methods such as questionnaires and surveys) (Walliman, 2006).

The interviews were semi-structured to allow for a flexible format, based on a pre-developed interview guide, but the author allowed the interviewee to elaborate on other themes or topics of importance if they emerged during the interview. Furthermore, depending on the flow of the conversation and the rapport between the author and the interviewee, at times the questions were asked in a different order than the interview guide or even skipped, pending time limitations. Each interview with Seagate personnel lasted two hours, which allowed for thorough questioning and discussion of the topics, though the elaboration of some topics (that emerged as important to the interviewee) sometimes led to the exclusion of others. In all interviews, the author also attempted to avoid asking leading questions which can obtain desirable answers but would risk introducing bias to the findings (Patton, 2002).

An example of the interview guide can be found in Appendix C: Example interview guides.

3.3.3 Part 2: External to Seagate

Desk research and sampling

Similar to Seagate, many publicly available sources and websites of companies were often inadequate in explaining the drivers and processes that led to its CiP disclosure strategies. In this regard, semi-structured interviews were also identified as the data collection method for company representatives and other individuals outside of Seagate.

The sampling of non-Seagate interviewees can be categorized into two types: the first are representatives of electronics companies (that have either adopted FMD or list-based disclosure systems), and the second are individuals that would likely hold a "big picture" understanding of the I.T. electronics supply chain, and trends and challenges in CiP disclosure systems (including both FMD and list-based disclosure). The views of multiple stakeholder groups were sought,

including chemicals compliance service providers (that serve clients in the electronics industry) and government.[6]

With the above scope in mind and given the author's limited network of contacts in this field, the final identification of interviewees relied on the connections and contacts given (initially) by the individuals who were intimately involved in the project (i.e. the IIIEE supervisor, external supervisor and Seagate project contact). Then, a snowballing approach was used to seek other contact suggestions and make final connections with suitable interviewees. In the end, the following interviewees were identified:

Table 3-1. Sampling of cases and interviewees outside of Seagate

Targeted data	Sector	Organizations (number of individuals)
Cases of FMD, industry issues and trends	Electronics companies	Motorola Mobility (1)
		Sony Mobile Communications (1)
Cases of list-based disclosure, industry issues and trends	Electronics companies	HP (1)
		Electrolux[7] (1)
Industry issues and trends, perception of supply chain challenges	Chemicals compliance contractor	SciVera (1)
		Assent Compliance (1)
	Government	Swedish Chemicals Agency (3)

Source: Author's own data collection.

Before each interview, desk research was conducted on the case companies and industry trends following the same units of analysis as Seagate's FMD. The sources included academic and grey literature, website information, company reports and publications through searches on Google and LUBsearch.

Semi-structured interviews

Similar to the interview approach described for interviews with Seagate personnel, a semi-structured approach was used based on a pre-developed interview guide. While the interview guides for electronics companies were similar to Seagate (on the "why" and "how" of their respective CiP disclosure strategy and the relevance and influence of the four units of analysis), the questions for compliance service providers and government focused more on industry-wide issues and trends on CiP disclosure strategies in the electronics sector, perceptions of FMD, perceptions on the experiences of other companies and addressing private sector concerns and other issues at the broader level. The interview guides were adjusted slightly as appropriate to the interviewee and their probable areas of knowledge. Examples of the interview guides are given in Appendix C: Example interview guides.

3.4 Data analysis

Where permission was given, the interviews were recorded on an audio recording device. Wherever possible, after each interview the author reviewed her notes and the audio recording and summarized the key points and key messages of the interview, then coded and categorized them into the units of analysis. At times, raw data needed to be summarized or paraphrased

[6] Extensive input on issues and trends was also obtained from NGO Clean Production Action through extensive discussions with the external supervisor.

[7] The electronics sector is diverse. The reason for including an electronic appliance company was to explore whether differences exist between I.T. electronics and other electronics companies.

because interviewees often responded using examples and analogies. To ensure data accuracy, the extracts of the final draft text that were referenced from the interviews were sent to the respective interviewees to confirm whether their inputs were reflected correctly in the text. Further, fact-based claims or statements that came across as potentially biased or opinionated were verified with other sources where possible.

The above-described approach was used for both Seagate and non-Seagate interviewees. Other reflections on the interview, such as the quantity and quality of data, reliability of data, gaps and areas of follow-up were also noted. Carrying out such tasks as soon as possible after each interview avoided the loss of information and ideas that can occur over time. A coding structure was used for the categorization and analysis of findings (see Appendix D: Coding structure for analyzing interview data). The results are presented in the next section.

4 Findings and analysis

4.1 Part 1: Seagate's FMD

Unless otherwise specified, the information in this section is compiled and summarized based on interviews with Seagate personnel, including staff of the Environmental, Health and Safety & Sustainability (EHS&S) Team (of which the Sustainability group has been separated as its own team at the time of writing this report[8]). Significant input was taken from a Senior Director of the past EHS&S Team (denoted as SC) who was directly involved with the selection, promotion, development and establishment of Full Material Disclosure (FMD) systems at Seagate. For confidentiality reasons, this report does not make direct reference to Seagate interviewees by name. The full list of interviews can be found in Appendix B: List of interviews.

4.1.1 The state of affairs before FMD

Full material disclosure was 'virtually non-existent' in the early days before Seagate adopted FMD according to one interviewee from the Environmental, Health and Safety & Sustainability (EHS&S) Team, who recalled that Japanese companies – Sony in particular – were known to have relatively detailed material specifications, requirements and detailed restricted substances (SC). Sony had at the time developed a detailed set of environmental requirements that were far more demanding than RoHS requirements, and some viewed that their approach may have been closest to FMD at the time (SC).

This can be confirmed by the earliest version of the Greenpeace Green Electronics Guide published in August 2006 (around the time that FMD was being developed and launched at Seagate), in which Sony received its highest score under the "Chemicals Management" category (Greenpeace, 2006). One interviewee cited that it was partly due to Sony's leadership in this regard that many other companies also followed with unique and differentiating but albeit complex materials restrictions. Seagate and Motorola developed FMD shortly after Sony's standards were established (SC).

Before the FMD system was in place, Seagate managed customer specifications mainly on paper and excel spreadsheets, where RoHS certification was submitted as compliance reports to clients, and all compliance certification data was managed on supplier-specific spreadsheets (SB, SC and SE). RoHS certification was recorded in excel sheets following a format that was similar to the IPC format where suppliers filled in their compliance information. This was a highly time-consuming process that required the capacity of a large team. The data needed to be refreshed frequently to keep it updated, in order to keep up with customer requirements that changed every few months. Therefore, there was a substantial amount of paper-based documentation that was being created on a regular basis (SC and SE).

Another interviewee in the EHS&S Team (SB) described the past workflow for managing client queries on materials and substances as follows: First, queries for information from new clients were received by the Sales Team. Queries from existing clients were received by the Customer Technical Management Team. Based on the nature of the questions, the query would be partitioned into separate questions and sent to the 'touch points' at the appropriate teams in Seagate for follow-up. The EHS&S Team is responsible for answering questions related to environmental regulations (e.g. EU RoHS and REACH) and information on materials and chemicals in products. To gather specific information on chemicals and substances, the sustainability team must turn to their suppliers for answers. Typically, this would require

[8] According to the Seagate project contact, the strategic decision to separate out the Sustainability team from the past EHS&S team is a signal of the company's prioritization on contributing to sustainable development (Larson, 2018).

communicating and coordinating through the Materials/Commodities Team, which houses commodity managers responsible for holding the business relationships with individual suppliers and/or direct coordination with suppliers.

Drivers of change

According to the EHS&S interviewee who was directly involved in the development of FMD at Seagate (SC), the story of FMD began around 2005 when Seagate high level management (vice president level) identified the need to manage the upcoming EU RoHS regulation. High level management then sought to recruit support from this interviewee to address this problem. The interviewee recognized that the compliance data management systems at the time were rudimentary and ineffective, and identified the need to reform the existing data management system, both from a paper to digital format, as well as from a rudimentary spreadsheet platform to a more sophisticated data management system.

While a software solution had already been identified by the Engineering and IT (EIT) Team, the interviewee proceeded to conduct a deeper investigation to further define the problem, whereby the following two main issues were identified:

Problem 1) Seagate faced a substantial amount of data that required management
It was evident that client substance compliance requirements (namely specifications for substances in products) were far more complex than regulatory requirements such as RoHS. For example, the number of client restricted chemicals ranged between 500 to 600 CAS numbers, which is much greater than the six substance categories that were restricted by EU RoHS 1 at the time (SC).

Problem 2) The landscape of market requirements was frequently changing
Client compliance requirements were frequently changing (as indicated also by SB). For example, at certain times Seagate was receiving new materials restrictions specifications on the order of once per month among the top 20 major customers (of over 100 customers).

When new specifications (such as new substance restrictions) emerged from clients, Seagate must communicate this change to suppliers and request them to examine the materials in their products and report on the presence and concentration of the restricted substance. A new compliance data sheet would then be prepared for the newly restricted substance for all parts sold by the supplier as part of Seagate's supplier qualifier (procurement) process (SC).

Exchanges on inquiries for information between Seagate and existing suppliers also started to overlap, where new requests – based on new customer inquiries – would be sent to suppliers before the previous inquiry was answered (SB). An estimate was made on the number of restricted CAS numbers and restricted substance list changes per month, and it was roughly projected that such requirements would exceed 1,000 in a few years. It was also found that in order to keep up with these requirements while maintaining shipment of products to customers, the rate of data refresh and update was estimated to be once every three to four months (i.e. three to four rounds of update per year), at a cost of between USD 25 to 50 per part (SC).

Significant compliance costs
With approximately three suppliers for each Part Number (specifying individual Part or sub-assembly) of Seagate's products and given the material complexity of products (e.g. hard drives contain over 250 Part Numbers in the Bill of Materials) (SC), the above conditions posed a significant cost implication for Seagate. Based on the information given by interviewees and written sources, the author estimated the annual cost of compliance as follows:

Table 4-1. Estimation of compliance cost per year for individual hard disk products and all hard disk products

Base data:	3 to 4 instances of data updates per year, USD 25 to 50 per part, 250 parts per one hard drive product, average of 3 suppliers per part
Estimate of compliance cost per product:	• $Minimum\ compliance\ cost = \frac{3\ updates}{year} * \frac{USD\ 25}{update\ of\ 1\ part} * \frac{3\ suppliers}{part} * \frac{250\ parts}{product} =$ $\boldsymbol{USD\ 56{,}250\ per\ year\ (per\ HDD\ product)}$ • $Maximum\ compliance\ cost = \frac{4\ updates}{year} * \frac{USD\ 50}{update\ of\ 1\ part} * \frac{3\ suppliers}{part} * \frac{250\ parts}{product} =$ $\boldsymbol{USD\ 150{,}000\ per\ year\ (per\ HDD\ product)}$
Number of hard drive products:	50 distinctive hard drive products
Proportion of products with shared parts	70%
Estimated compliance cost for all hard disk products:	• $Minimum\ compliance\ cost = USD\ 56{,}250 * 50\ products * 70\% =$ $\boldsymbol{USD\ 1.9\ million\ per\ year}$ • $Maximum\ compliance\ cost = USD\ 150{,}000 * 50\ products * 70\% =$ $\boldsymbol{USD\ 5.2\ million\ per\ year}$

Source: Author's own elaboration. Base data is sourced from Interviewee SC, though it was not clear whether the estimated cost per part includes staff-related costs. The number of hard drive products and proportion of products with shared parts were sourced from Interviewee SE, though they represent 2018 figures since 2005 figures are unavailable (there may therefore be some discrepancies between the two time periods).

Therefore, compliance cost per product per year ranged between USD 56,250 to USD 150,000, while the compliance cost for all hard drive products per year ranged between USD 1.9 million to USD 5.2 million.

To understand the significance of the costs, the minimum and maximum estimated compliance cost for all hard disk products were calculated based on the revenue and income of Seagate in 2005 as follows:

Table 4-2. Estimation of compliance cost per year based on 2005 net income and adjusted for inflation for 2017

Estimated cost by net income:	Net income in 2005: USD 707 million • $Minimum\ cost\ by\ net\ income_{2005} = \frac{1.9\ million\ in\ cost}{707\ million\ in\ net\ income} * 100 = \mathbf{0.28\%}$ • $Maximum\ cost\ by\ net\ income_{2005} = \frac{5.2\ million\ in\ cost}{707\ million\ in\ net\ income} * 100 = \mathbf{0.74\%}$
Estimated cost by net income adjusted for inflation in 2017:	• $Minimum\ cost\ by\ net\ income_{2017\ values} = \frac{CPI_{2017}}{CPI_{2005}} * Min\ cost\ by\ net\ income_{2005} =$ $\frac{2.2}{2.6} * 1.9\ million = \boldsymbol{USD\ 1.6\ million\ in\ 2017}$ • $Maximum\ cost\ by\ net\ income_{2017\ values} = \frac{CPI_{2017}}{CPI_{2005}} * Max\ cost\ by\ net\ income_{2005} =$ $\frac{2.2}{2.6} * 5.2\ million = \boldsymbol{USD\ 4.4\ million\ in\ 2017}$ Net income in 2017: USD 772 million • $Minimum\ cost\ by\ net\ income_{2017\ values} = \frac{1.6\ million\ in\ cost}{772\ million\ in\ net\ income} * 100 = \mathbf{0.21\%}$ • $Maximum\ cost\ by\ net\ income_{2017\ values} = \frac{4.4\ million\ in\ cost}{772\ million\ in\ net\ income} * 100 = \mathbf{0.57\%}$

Source: Author's own elaboration. Financial figures for 2005 are from the 2005 Seagate Annual Report (Seagate Technology, 2005), figures for 2017 are from the 2017 Seagate Annual Report (Seagate, 2017). The latest consumer price index (CPI) data for inflation adjustment calculations was only available for 2017 from OECD (2018), which was an average figure for all OECD countries. OECD defines CPI as "the change in

the prices of a basket of goods and services that are typically purchased by specific groups of households" (OECD, 2018).

Therefore, the compliance cost of all hard drive products comprised between 0.28% and 0.74% of net income in the same year, posing a cost that is not insignificant to the company, solely for regulatory and client specification compliance on substances and materials. The figures adjusted for inflation are shown to give a sense of the costs in present value, which indicates that the costs also remain rather significant in between 0.21% to 0.57% of net income in 2017.

Sony non-compliance case

In December 2001 (a peak sales period for electronic products given the Christmas sales season), a shipment of over 1.3 million Sony Playstations worth over USD 162 million (CNN, 2001) were seized at the Dutch border, following an inspection that discovered cadmium levels exceeding twenty times the allowed concentration of 0.01% under EU regulations[9]. The non-compliance was found in the product's charging cables. As a result of this incident, Sony estimated loss in revenues to be in the order of USD 121 million (Kraeuter & Malone, 2006).

Two Seagate interviewees cited this case as a "wake up call" not only for Sony but many other electronics companies and was a "catalyst" for FMD establishment (SA and SB). Another interviewee speculated that the drivers of this may be due to the complexity of Sony's compliance specifications and the failure of suppliers to truly comply, coupled with the lack of employees and systems within Sony to manage suppliers and ensure compliance (SC).

With the emergence of the RoHS and WEEE Directives in the mid-2000s, private sector awareness on the risks of non-compliance began to grow, learning from Sony's experience that losing access to a market from non-compliance can lead to significant revenue losses. This created a greater shift for companies to address the hazardous substances in their products and comply with regulations (Davis, 2005). Building on this, OEMs also began to develop their own material standards and restrictions to comply with regulations, compete in the market for innovative environmental attributes and respond to growing NGO pressures for the sound management of chemicals in products.

In this sense, the main drivers for Seagate to adopt FMD stemmed much less from regulatory changes (as initially speculated) and much more from frequently changing OEM client specifications, as stated by an EHS&S interviewee (SC). Another interviewee also described increasing consumer demand, regulatory pressure and supply chain health risks to be among the biggest drivers for establishing FMD, citing the collection of comprehensive data as the only way to address such risks (SA).

How FMD was chosen as the solution

Against this backdrop, the EHS&S interviewee who was directly involved with FMD development (SC) described the factors that led to the selection of FMD as follows:

First, the interviewee identified that Seagate faced the above-described challenges from a unique position in the value chain. While Seagate is not a large corporation with highly diverse parts in products (such as OEM giants Apple and Sony), it is also not a small company with simple products (e.g. resistors). This is significant because a resistor company does not require highly

[9] The author was unable to find the specific legislation under which this non-compliance case was enforced. While the EU RoHS 1 Directive restricts cadmium concentration levels to the same concentration of 0.01%, the Directive was only created in 2002. This included an extensive search on online search engines as well as review of European legal documents in the EUR-Lex database (European Union, n.d.)

sophisticated systems to manage compliance data, given that resistors are composed of relatively simple parts and processes with few supply chain actors. Even in a large resistor company, establishing a complex data system would not necessarily provide payback. Seagate, on the other hand, is positioned between a small company with simple products and a large manufacturer with diverse products – also with moderate company resource availability and relatively intricate product complexity.

Separately, interviewee SC realized that under the existing data collection and coordination approach of requesting data from suppliers upon each specification change and inquiry from clients, the company faced significant costs while still lagging behind changing client requirements.

Based on this, the interviewee recommended for Seagate to adopt Full Material Disclosure as a method of stabilizing the data collection processes and move towards a regular data refresh cycle (which eventually became an annual cycle).

The interviewee also discovered that the conventional cost of compliance resembled a 'sawtooth' effect, in which compliance costs would spike upon each change in regulatory requirements and client specifications. Having an FMD system in place meant that there would no longer be a need to expend similar resources to process individual regulatory and specification changes or spend as much time in processing requests for product composition information from suppliers (SC). Instead, Seagate can simply conduct a search in the FMD data management system to determine their level of compliance and proceed with follow-up actions in the case of non-compliance or produce reports to prove their compliance (SC).

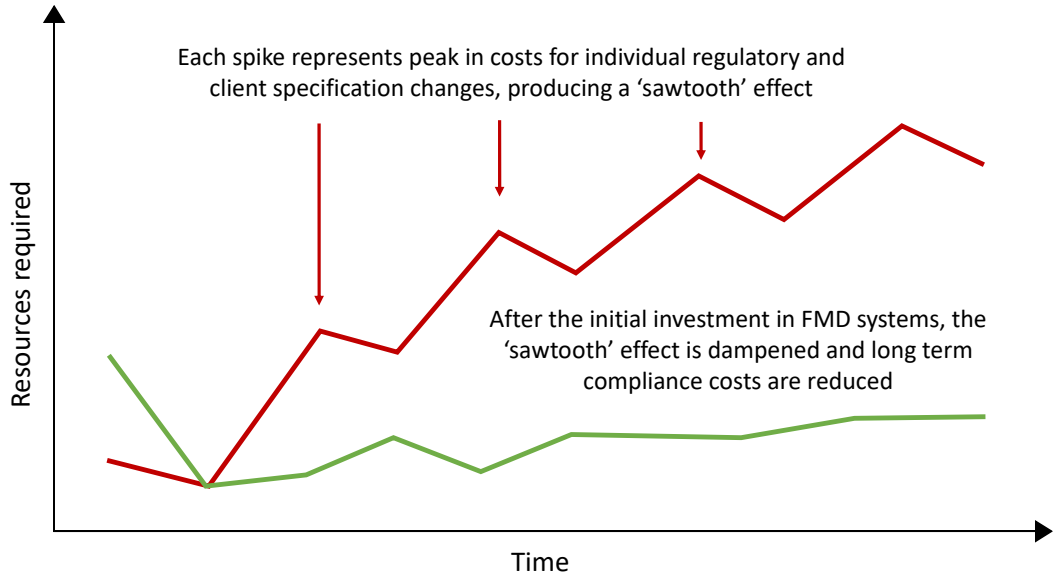

Figure 4-1. The 'sawtooth graph'

Cost comparison between conventional compliance approach (red) and with FMD systems in place (green)

Source: Elaborated from Martin (2011)

Establishing the FMD system also required the following:

1. **A data collection standard** – that was more sophisticated than spreadsheet templates. While spreadsheets were easy to use and readable, it was not sufficient to manage product material data (SC).
2. **Data management software** – that was also more sophisticated than spreadsheets in order to handle the multidimensional needs of compliance data (such as efficient grouping, filtering and labeling of data). Therefore, a new software solution was needed to manage, read and maintain the data efficiently (SC).
3. **Standard reporting system** – that allows for increased efficiency in exporting data and submitting standard reports to clients in a more systematic way (SE).

4.1.2 The FMD development process

Unless otherwise stated, the information given in this section was by interviewee SC.

Pilot project

Seagate adopted the IPC 1752 data reporting standard and purchased data management software which took one year to configure and customize. The overall system was called the Compliance Assurance System (CAS), comprising of a data management software solution that followed the IPC 1752 data collection protocol (for Full Material Disclosure data). The CAS system was piloted for one product where the suppliers of the product were requested to provide FMD data, with the reasoning that Seagate was also requested to provide FMD data from one of its clients. The communication process involved some travel from Seagate personnel to communicate with the executives of suppliers' companies.

After three months, the data for one part was collected but the results were poor and deemed a failure, partly due to data entry errors such as:

- Part Numbers – suppliers were requested to input the Part Numbers that both Seagate and the supplier use, which turned out to be too complex and resulted in mistakes.
- Supplier names – the field for supplier names also created messy results because suppliers may spell their names in different ways when entering their name.
- General complacency, lack of motivation and carelessness among suppliers in complying with the new FMD data entry requirements, resulting in spotty and poor-quality data.

In response, Seagate adopted the following adjustments and solutions:

- **Simplification of data entry requirements** – such as the Part Numbers and suppliers' names.
- **Supplier training** – extensive online training was conducted three times per week with supplier personnel who were directly responsible for data submission. Suppliers were separated into small groups to clarify questions and receive live support while they filled out their forms during the training sessions.
- **Help desk** – A help desk was established to provide continuous support.
- **Formalizing the requirement** – the Seagate Procurement Team (under the Materials/Commodities Team) integrated FMD into the supplier procurement specifications, and suppliers began to take the program much more seriously.
- **Payment system –** Seagate introduced a payment system where suppliers were required to pay approximately USD 1,000 per year to receive training and support in the FMD program. This counterintuitive approach was first developed due to a budget cut at Seagate that discontinued FMD funding, and a new source of funding was needed to continue to finance the FMD program. It was also believed that requiring suppliers to

contribute to the program would capture their attention and persuade suppliers to take FMD participation seriously.

> *"Interestingly enough, doing the thing everybody hated got their attention and got the data flowing. It's extremely counterintuitive. But it worked."*
>
> – Interviewee SC

Another EHS&S interviewee explained that one of the requirements of the program was also that if suppliers continuously underperform in FMD, then the fee would increase. At the same time, suppliers were given unlimited access to support, but the responsibility of ensuring that the data submitted was complete, accurate and of good quality rested with the suppliers themselves. The payment system was cited by multiple EHS&S interviewees as a contributor to success in Seagate's FMD program.

After another three to four months, most of the data was submitted for the pilot product. At that point, data collection was well over 80% for the product. The pilot project had a target of obtaining 85-90% of data on the product's Bill of Materials where the data had to have "acceptable FMD data" – defined by approval from the IPC 1752 class 6 FMD form, fulfilment of validation criteria (e.g. units, data formats and mass balance between reported substances and total product mass) and sufficient material level lab reports (i.e. testing of materials as specified by Seagate requirements) to support the data. On average, the data of one part was accompanied by seven lab reports.

When this target was reached, Seagate rolled out FMD across all products in the company with the goal that by the end of the following year, all products would be compliant. A new target of 95% was established at launch, where 95% of every part used in the product must have FMD data and approved lab reports. The other 5% must be considered as "low risk" materials. "Low risk" materials can be defined as those that contain long-established and old Part Numbers from suppliers who have had a mature and stable relationship with Seagate (Larson, 2018).

Challenges and lessons learned

Commitment from top-management

Obtaining top-management support in adopting FMD was crucial for the development process. This was done by communicating the business case for having FMD – to help maintain sales by meeting customer specifications and regulatory requirements more efficiently. Meeting customer requirements is important because it is the determinant for being qualified as a supplier (i.e. securing and sustaining sales) (SB).

Supplier resistance

Supplier resistance was one of the biggest hurdles in establishing the FMD system. According to multiple EHS&S interviewees (SA and SB), the following challenges were mentioned:

- Suppliers had doubts on whether the program would work.
- Many suppliers did not like the FMD program, citing grievances with added work, increased cost and complexity.
- Suppliers would escalate communications up the hierarchy (in some cases to the Seagate CEO), raise prices, send bills and complaints.
- Convincing suppliers to pay was a challenge.
- Convincing management to make the investment in the EIT system required for FMD was also a challenge.

One other lesson learned was that while the communication component of rolling out the FMD program involved traveling to in-person meetings, workshops and conferences with executives helped to capture the attention of top-level management, this form of communication turned out to be a smaller contribution to success than intimately engaging with supplier operational staff in trainings and consultations.

After the first year, a survey was circulated among suppliers to collect feedback on the FMD program. The results were largely negative. In response, FMD managers at Seagate travelled to where suppliers were located and held a consultation meeting to address their concerns. This was a major turning point, as suppliers realized that they were only required to make one large report in the first round of submission, and subsequent submissions would simply require revisions or improvements to existing data without major changes. Therefore, unlike many of the other clients in the industry, Seagate would not change their data reporting and product specifications every year. Following this realization, the level of buy-in and acceptance among suppliers increased significantly.

Finally, the success of the FMD system rests on the ability of suppliers to submit accurate and good quality data. Inputting bad data produces bad results, a problem referred to as "garbage in, garbage out". To avoid this problem, a Compliance Partner was recruited to work closely with suppliers on data entry, data quality review and training (SB).

Internal resistance

Among the most accepting of internal teams at Seagate were the Vice President of EHS&S (who signed off on the FMD program) and EIT Team (because they understood the multiple-dimension demand of FMD data which required more sophisticated data software). However, the EHS&S interviewee who was directly involved with FMD establishment (SC) recalled that there were many others in Seagate who were unconvinced of FMD. Many expressed concerns on cost and doubts on whether the program would work. One such team was the compliance staff in EHS&S itself, which was resistant given a lack of understanding on the multi-dimensional nature of the data as well as comfort in working with existing spreadsheet systems.

Another team that was resistant was the Materials/Commodities Team (who manages the relationships with suppliers) given that the fee required for FMD would be against suppliers' interests. Obtaining their buy-in on the FMD system including the financial model behind it was essential in its establishment.

4.1.3 In detail: How Seagate's FMD system works

Roles and responsibilities

Sign off at top-management to develop FMD was made by:

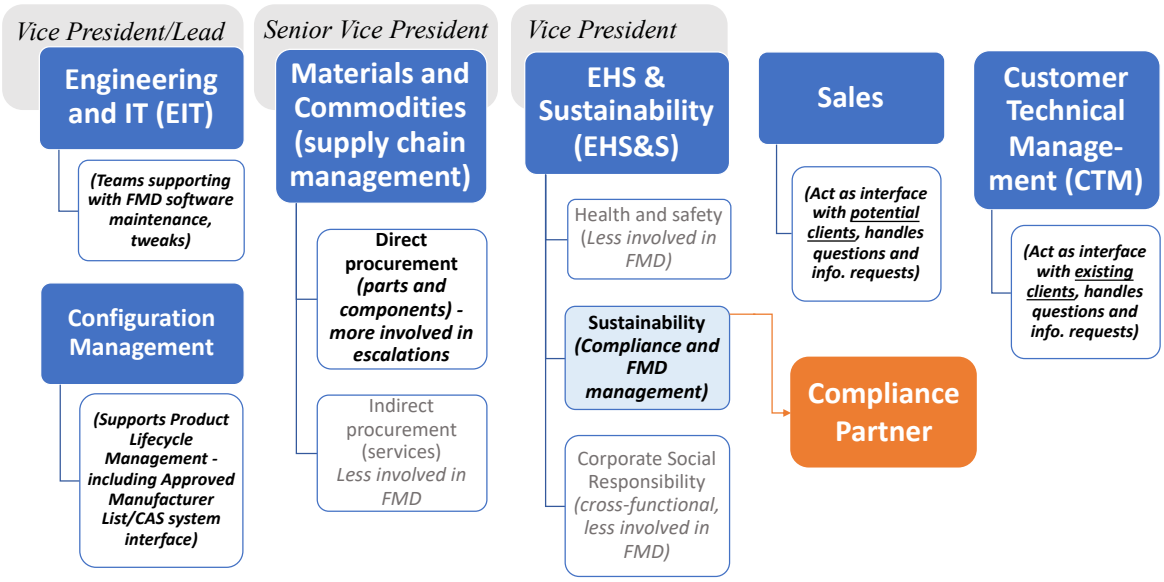

Figure 4-2. Seagate units involved in FMD development and implementation

The other units under the same teams but are less involved in FMD (in bold) are included for reference only. The EHS & Sustainability Team has since been reorganized to separate the Sustainability function as its own team.

Source: Author's own work based on interviews and confirmation from Seagate personnel (SA, SB and SE).

The key teams at Seagate that are related to FMD are the EIT Team, Configuration Management Team, Materials and Commodities (Supply Chain Management) Team, Environmental, Health and Safety & Sustainability (EHS&S) Team, Sales Team and the Customer Technology Engineers Team. A Compliance Partner is also extensively involved with FMD management. Other teams that are involved but not listed in the figure include the Corporate Counsel and Internal Audit teams. The roles and function of these teams are elaborated in Appendix E: Descriptions of Seagate teams involved in FMD and ordered based on their relative involvement in FMD.

The Compliance Assurance System

The Compliance Assurance System (CAS)[10] refers to the overall compliance system at Seagate which consists of a dedicated software platform for collecting FMD data following the IPC 1752 data reporting standard.

While initially established to collect FMD data, since 2017 the CAS system has been expanded to also collect data on conflict minerals and process chemistry. The two versions are referred to as CAS 1 and CAS 2, respectively.

[10] Not to be confused with Chemical Abstract Service (CAS) number, which is a unique chemical identifier number based on a global standard.

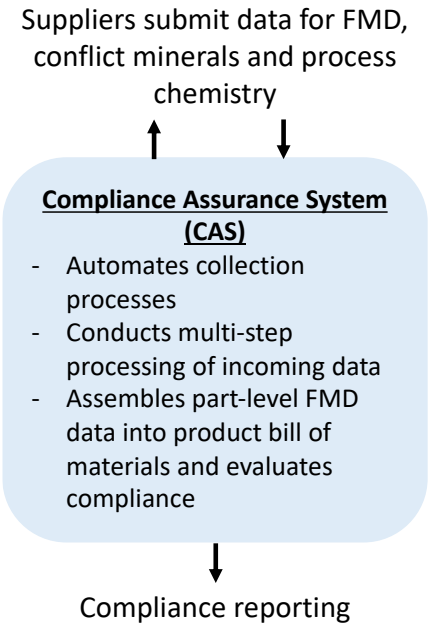

Figure 4-3. Basic overview of CAS workflow

Source: Adaptation from interview SE.

First, suppliers submit FMD data at the part level. Interviewee SC estimated that a supplier can complete their first round of data entry into CAS in approximately four hours (based on data from lab reports), which includes some failures and helpdesk support. Subsequent rounds of data entry in future years required far less time. However, this is also dependent on the complexity of parts and the extent of the suppliers' knowledge of their products.

Once the data is received, the CAS system assembles the part-level data into the Seagate product level to produce a product Bill of Materials. It evaluates the product's level of compliance based on the Bill of Materials and follow-up actions may be taken if certain parts are deemed to be non-compliant (SD). The CAS system also prepares compliance reports, which can be used for submission to clients and regulators.

According to an interviewee from the EIT Team (SD), Seagate maintains approximately three suppliers per part to ensure a secure supply of resources. A part is deemed as fully compliant only if all the suppliers of that part meet compliance standards. For example, if one of the three suppliers for a part is deemed to be non-compliant while the other two suppliers are, then the CAS system would flag the non-compliant part and the appropriate Seagate teams would act to correct the non-compliance with the supplier and alter the part. If the supplier does not alter the part, then the supplier becomes excluded. Some parts can also be compliant "with exemptions", however according to the interviewee, Seagate strives to minimize these occurrences.

An EHS&S interviewee (SA) also explained that each individual substance is labeled with a unique Chemical Abstract Service (CAS) identifier number. Searching the database by such numbers allows for the identification of substances at the individual component level. The system is set up so that employees are not permitted to change this information which is provided by suppliers. This ensures data security and reliability.

Further details of the CAS system workflow including determinants of compliance can be found in Appendix F: Detailed workflow of the Seagate Compliance Assurance System.

Data verification

Suppliers are required to refresh their data annually, which usually involves making updates such as adding overlooked CAS numbers, additional data upon the request of Seagate and the removal of irrelevant substances. The annual data refresh must be accompanied by new lab reports (SA and SC).

According to one EHS&S interviewee (SA), the following steps are taken to ensure data accuracy. First, the files are reviewed to ensure that the substances are within 5% of the claimed weight. Any new substances are reviewed and processed by Seagate staff. Hundreds of checks are run against compliance for RoHS, REACH, Prop 65 and Seagate's specifications. Substances that exceed limits are reviewed and approved by the compliance officer.

In addition to suppliers' lab tests, the Seagate program manager who is responsible for developing new products is also responsible for product analysis and testing. The lab testing of products involves screening with X-rays to identify substances of concern. Any flagged substances then undergo more detailed tests to identify their concentrations.

While the data is accompanied by lab tests, according to interviewees the lab tests can only assess a small number of substances, and there are no other means to verify data for materials that are not covered by suppliers' lab reports (verification is based on trust) (SA and SD). This remains a continuous challenge (SD).

Nonetheless, an interviewee from the Configuration Management Team (SE) indicated that Seagate's product lab tests (for compliance with client requirements that require FMD data) is one way to verify the data submitted by Seagate's suppliers.

Supplier training

According to one EHS&S interviewee (SA), Seagate provides suppliers with training through the Compliance Partner using a two-pronged approach. The first is comprehensive training on the basics of FMD requirements and how to comply and use the CAS system. The second is through one-on-one mentorship with Compliance Partner staff to help correct errors and avoid future mistakes. All suppliers and employees are required to take FMD training.

A note on costs

According to the EHS&S interview who was directly involved with FMD establishment (SC), the main costs for suppliers to comply with an FMD system is not with data entry (which involves copying and pasting data with some refinements), but with lab reports. Nonetheless, most first tier suppliers for Seagate actually transfer the cost of lab reports to their suppliers upstream in the value chain. This is possible because Seagate does not require lab reports under their first-tier suppliers' names as some other companies allegedly do.

Financial model of FMD

The annual USD 1,000 fee that is paid by suppliers is intended to cover the cost of the Compliance Partner for training and help desk support. One EHS&S interviewee explained that the reason for this is to ensure that suppliers have a stake in the system so that they take it seriously. They are less incentivized to provide quality data if Seagate does not set a high data quality standard that they must meet (SB).

The interviewee identifies this payment system to be a balanced method where the amount is not too burdensome. Furthermore, since the fee amount has not changed since the system's initial launch in 2006, in the interviewee's view this is another indicator of how Seagate tries to accommodate their suppliers (SB).

New product development

This section describes the relevance and involvement of the CAS system in new product development. Unless otherwise stated, the information is based on an interview with Seagate personnel from the Configuration Management Team (SE).

The Product Lifecycle Management (PLM) system manages all information related to the lifecycle of a product – from early design, materials procurement to mass production and other

milestones. It collects documents, information and data from the respective teams involved in new product development. The system holds data on Part Numbers which collectively make up components, and the components are then put together in bills of materials. The Bill of Materials represents the product.

During the supplier qualification phase of designing new products, one or more suppliers may be considered per component. The "qualification status" of suppliers is recorded in the Approved Manufacturers List, which is part of the Product Lifecycle Management system.

The criteria that determine the qualification status of suppliers and their parts is based on design and engineering specifications as well as regulatory and materials compliance. This is where the Approved Manufacturers List and CAS systems interact – the Approved Manufacturers List is regularly updated (manually) to document compliant parts based on data in the CAS system.

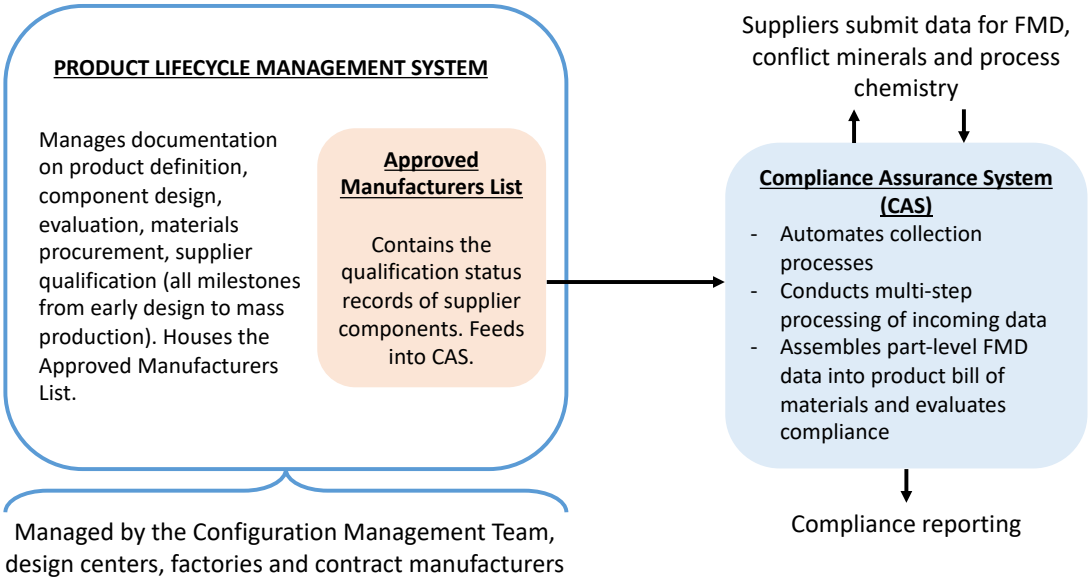

Figure 4-4. Relationship and workflow between the Product Lifecycle Management System and CAS System

Source: Adaptation based on information given by interviewee from the Configuration Management Team (SE)

To track material compliance, the Product Lifecycle Management feeds data into the CAS system. The CAS system then automatically triggers requests to the respective supplier of the part in order to collect data. This applies to all parts – both new entries that do have data yet, and also existing entries with data that needs to be refreshed annually.

If a data package sent from the supplier is non-compliant or erroneous, the CAS system will continue to send automated communications until the error is resolved. Throughout the data collection process, the Compliance Partner provides direct assistance to the supplier as much as possible and may escalate situations to Seagate when needed (e.g. if no response is obtained from the supplier).

4.1.4 FMD implementation experience

Benefits of FMD

Many Seagate interviewees pointed out that the main benefits of FMD are in making the compliance process more efficient, less laborious and less time consuming, both for Seagate's suppliers (to Seagate) and for Seagate to its clients (SA, SB, SC and SE). One EHS&S

interviewee (SC) added that with FMD, Seagate is no longer required to request individual instances of restricted substance disclosure from suppliers to determine whether they fulfill a new or revised client specification. It is also no longer necessary for suppliers to engage material experts, since Seagate personnel can determine whether a supplier qualifies based on existing FMD data from that supplier.

FMD has also significantly improved the efficiency of responding to regulatory inquiries. For example, upon the launch of EU REACH, Seagate was able to produce a response to the REACH SVHC list within 15 minutes using a search on the FMD database. The data was then validated by polling suppliers over an additional 48 hours. This means that the time needed to collect reliable chemical and substance data was reduced from the scale of weeks to a couple of days (Seagate Technology, 2009).

Contributors of success

According to EHS&S interviewees (SA, SB and SC), the following were the biggest contributions to FMD success at Seagate:

"Relentless training"
In addition to conducting trainings "relentlessly", it was also much more resource efficient to conduct the trainings online instead of in person. Trainee selection was also important: training suppliers' operational staff who were directly involved with managing their products and data submission is more efficient than training their managers who may be less likely to transfer the knowledge to their staff.

Formalizing FMD
By writing the FMD requirement into the supplier qualification process as well as establishing a payment system, these initiatives helped to encourage suppliers to take FMD more seriously.

Leveraging on external and internal relationships
One interviewee (SB) remarked that the success of FMD relies on the effective leveraging of relationships between the various internal teams with suppliers and customers. In Seagate, the Materials/Commodities Team tends to hold the business relationships with suppliers, while the Sales and CTM teams hold the relationships with clients. Individual managers also have their own relationships developed with suppliers, so it is important to understand the dynamics and nature of these relationships and leverage on them to build trust and communication.

For example, under a formal channel of communication between Seagate and its client, the product environmental sustainability engineer on the client side should communicate their queries to the corresponding commodity manager in charge of the client at Seagate, who then passes on the respective material-related questions to the sustainability team. However, if the sustainability team and the client contact already have a history of communication, then they may prefer to communicate directly. Understanding these relationships and leveraging on them accordingly were valuable to operate efficiently.

This is confirmed by another interviewee (SE), who indicated that communication tends to be direct between clients and EHS&S team once they are put in touch. Furthermore, the interviewee described the extensive automation of communication between the CAS system, suppliers, Compliance Partner and Seagate personnel as an indicator of the success of FMD, given that it created closer working relationships between Seagate and its suppliers.

Supplier engagement

Multiple interviewees remarked on Seagate's approach in managing and engaging suppliers as contributors to FMD's success (SB, SC and SE). One interviewee explained that given Seagate's position in the supply chain as both a buyer and a supplier, they are able to relate and empathize with their own suppliers (SB). Other interviewees also remarked that Seagate works to develop close relationships with their suppliers as well as with clients and accommodate suppliers as much as possible by ensuring that the Product Lifecycle Management systems are up-to-date and well maintained to avoid triggering wrong requests, and by providing suppliers sufficient time to submit information (SB and SE).

It was also helpful to gain supplier buy-in when suppliers realized that the FMD data generated for Seagate may be useful for compliance reporting for another client who also uses the IPC 1752 data reporting standard (SA, SB and SC).

Timing in the industry
Finally, one Seagate interviewee remarked on the emergence of data transparency as an industry trend, so the timing of FMD development at Seagate may have been opportune (SE).

Challenges and lessons learned

The following is a summary of ongoing challenges and other lessons learned based on multiple interviews with Seagate personnel:

Changing client specifications
Client specifications continue to change every six months from major OEM's including data reporting formats. Seagate continues to track over 40 different reporting formats and specifications for major customers and over 100 smaller customers (SC).

A "lucky guess"

According to the EHS&S interviewee who was directly involved with FMD establishment (SC), the 95% target of FMD data collection was a "lucky guess", as it turned out to be achievable in the long run.

Supplier engagement
Despite the establishment of FMD, Seagate also faces resistance from suppliers on an ongoing basis. Indeed, there have also been suppliers who refused to provide Full Material Disclosure, sometimes due to the belief that they are already compliant with most industry and regulatory requirements (SB and SC).

Organizational changes
The process of integrating new acquisitions also involves Seagate's FMD – in terms of engaging with and obtaining the buy-in from the commodity managers in the newly acquired personnel, explaining the rationale for FMD, how it works, and how to engage with the supply chain of the acquisition leveraging on the relationships that are also being integrated. This is particularly important as the new supply chain will face increased costs in meeting FMD requirements in Seagate (SB).

EIT challenges
Occasional limitations in EIT resources is an ongoing challenge to ensure that FMD systems operate smoothly (SB). Further details in EIT challenges were given by an interviewee from the Configuration Management Team (SE, see Appendix G: List of EIT challenges faced in establishing and implementing Seagate's FMD systems).

For each of the units of analysis below, the paper discusses its relevance followed by the context, challenges and solutions (where applicable).

4.1.5 Political environment

Government regulations

Not surprisingly, government regulations are highly relevant to product FMD at Seagate because it drives many of the substance restrictions in products that are tracked by FMD systems. This applies both to the products of Seagate's clients (mainly OEM's) as well as Seagate's own business-to-consumer products. Based on interviews with Seagate personnel and publicly available information, the most relevant regulations are as follows:

EU RoHS Directive and other national RoHS policies[11] - Seagate's products are RoHS compliant, and most (if not all) of Seagate's clients also require RoHS compliance.

EU REACH Regulation[12] - FMD allows Seagate to know whether any Substances of Very High Concern (SVHCs) are present above restricted concentrations, and to respond efficiently to changes in regulations and requests for information.

Prop 65[13] - According to an EHS&S interviewee, one of the standard compliance checks in Seagate's CAS systems is against Prop 65 requirements.

EU WEEE Directive[14] - While the WEEE Directive is theoretically relevant because Seagate should respond to product design requirements that may relate to improving e-waste recycling, in practice one EHS&S interviewee (SB) indicated that Seagate does not actually face direct pressure from the waste management sector since their products are sold through brand products. Instead, such pressures tend to be placed on big brands that place the products on market. Nonetheless, Seagate provides product disassembly information to clients to facilitate recycling, refurbish or recycle 100% of hard drives under warranty, and is also exploring the expansion of their take-back program for a wider range of products (Seagate, 2018).

Governmental organizations

The European Chemicals Agency (ECHA) was identified by one EHS&S interviewee (SA) as a relevant organization to FMD. ECHA is responsible for the implementation of key chemicals management policies, one of which is the EU REACH Regulation. It also works to support industries with regulatory compliance (ECHA, 2018).

While there was acknowledgement on the efforts of international government organizations such as UNGC and SAICM during interviews with Seagate EHS&S interviewees, it was also identified that such initiatives have not played a significant role in influencing or shaping FMD at Seagate (SA and SB). Rather, Seagate has participated in initiatives such as providing input to programs and research for SAICM (SC). Further, while Seagate has committed to UNGC, one EHS&S interviewee explained that UNGC influences more on the way Seagate operates (such

[11] Sources: Interviews SA, SB, SC and SD; (Martin, 2009), (Schmidt, 2015), 2017 Sustainabilty Report (Seagate, 2018), (Martin, 2011)

[12] Sources: Interviews SA, SB, SC and SD; (Martin, 2009), (Schmidt, 2015)

[13] Sources: Interview SA

[14] (Martin, 2011)

as in supply chain human rights) and less on the management of hazardous substance in products (SB).

4.1.6 External stakeholders

Industry organizations

The organizations that were most relevant in influencing the establishment and development of FMD at Seagate were identified as follows:

IPC

Seagate interviewees noted the deep relevance of IPC to Seagate's FMD because the organization shaped the standardization of FMD data formats. Indeed, the IPC 1752 standard (updated to IPC 1752A in 2014 (IPC, 2018)) was the chosen format for the exchange of material and substance data between Seagate and its suppliers. However, there was also acknowledgement that the lack of widespread adoption of IPC 1752A as a challenge to FMD implementation. One of the reasons is that the standard was updated from a pdf-based form to an Extensible Markup Language (XML) form, which helped to streamline data reporting and management but made it difficult for many users without XML coding skills.

Responsible Business Alliance

Seagate has adopted the Responsible Business Alliance Code of Conduct since 2007, which covers the operational standards on labor, health and safety, environmental matters, ethics and management systems (RBA, 2018a and Seagate, 2018a).

Two clauses under the environmental section were found to be relevant to FMD. First, a clause on *hazardous substances* requires companies to identify, label and manage hazardous chemicals and materials, in order to ensure safe handling, movement, storage, use, recycling, reuse and disposal. Secondly, a clause on *materials restrictions* requires companies to comply with the respective regulations and customer requirements on the restriction of substances in products (RBA, 2018a).

However, one EHS&S interviewee noted that RBA focuses more on supply chain operations but is not widely seen as a framework for *enforcing* product-related chemicals issues (SB). For example, RBA audits are not used to verify RoHS and REACH compliance. Nonetheless, RBA continues to drive progress in issues such as process chemistry, which is related to Seagate's FMD system (specifically CAS 2) (SA).

International Electrotechnical Commission

The standard is one of the compliance requirements for Seagate's suppliers (SA).

Software developers

One interviewee (SA) identified the following as important stakeholders to FMD at Seagate:

- **Oracle –** Oracle Corporation is a global company that specializes in enterprise software, cloud storage and technology services (Oracle, 2017). Oracle Agile PG&C is the Agile Product Governance and Compliance software that supports manufacturers to manage product compliance and audit substances in products. It is a platform that collects data on product materials, reviews compliance for suppliers at the part and product levels, generates reports and manages supporting documentation (Oracle, 2010).
- **Siemens Teamcenter PLM software –** The Siemens Teamcenter Product Lifecycle Management (PLM) software is a platform for managing the product lifecycle including

product design, documentation, data and processes and Bill of Materials (Siemens, 2018).

NGOs

According to EHS&S interviewees (SA, SB and SC), NGO pressure was not a significant direct driver of FMD development at Seagate. However, NGO actions that raise awareness on the presence of hazardous substances in electronic products have pressured publicly-recognized OEM brands to reduce the presence of hazardous substances and improve product design. In this sense, there has been a trickle-down effect of these demands from downstream OEMs to their suppliers including Seagate. For example, the no or low-halogen movement initiated by Apple was driven by NGO pressure, which resulted in voluntary restrictions and new specifications on electronics suppliers (Nimpuno, McPherson, & Sadique, 2009). While Seagate's FMD was launched at around the same time, the system nonetheless helps to track and comply with Apple's restrictions as well as other voluntary restrictions.

Industry Groups

EPEAT

Seagate's 2017 sustainability report also mentions the Electronic Product Environmental Assessment Tool (EPEAT) where companies can apply for various levels of the EPEAT electronics ecolabel depending on the level of criteria fulfilled. Seagate has indicated that while EPEAT does not apply directly to hard drives, Seagate's provision of information to OEM clients facilitates their declarations in EPEAT if they choose to participate (Seagate, 2018a).

Consumers and waste management

According to EHS&S interviewees, regular individual consumers did not play a role in the decision for Seagate to adopt and develop FMD. This is partly because most regular consumers do not recognize Seagate's brand and products, given that they are assembled into big-brand products (SC). Similarly, the waste management sector was also seen as too distant in the lifecycle of electronic products to be relevant to FMD (SB).

4.1.7 Market environment

Suppliers

Suppliers are highly relevant in any FMD system given that they play an important role in providing material and substance information of the products that are sold to clients. The quantity and quality of their data and level of engagement in FMD have impacts on the decisions that are made downstream including product design, research and development.

Context

In the hard drive industry, manufacturers like Seagate share many of the same suppliers. One EHS&S interviewee estimates that Seagate has over 650 first-tier suppliers (SA).

From the perspective of another EHS&S interviewee (SB), Seagate faces two main types of suppliers: First, suppliers who choose to comply with Seagate's FMD system because they foresee a long-term working relationship with Seagate, and/or because they see that aligning with Seagate's FMD system will drive efficiency in their own company. The second type are suppliers who are not dependent on Seagate for their business and thus may be more difficult to engage with in obtaining their participation in complying with Seagate's FMD requirements.

While many suppliers are large companies that also serve many other clients, multiple EHS&S interviewees believe that suppliers comply with Seagate's FMD requirement in order not to lose

their business (SA, SB and SC). At the same time, it is not always easy to switch suppliers, especially for those who supply very specific parts (SA). Seagate also tries to minimize the number of suppliers to a reasonable degree but recognizes that it is always strategic to have alternatives (SD).

Hard drive manufacturers are also highly vertically integrated. For example, according to an industry update conducted by financial research service provider Morgan Stanley MUFG, Seagate produces 97% of its own HDD heads and 92% of its own HDD media parts (Sato & Takahashi, 2018). According to one EHS&S interviewee, Seagate's in-house manufacturing goes back four tiers up the production chain. While Seagate owns much of the core technologies in disk drives, the company also purchases many of components externally, such as the outershell of hard disks (SB).

Challenges

The supplier context described above poses a number of challenges. One of the most commonly cited reasons for suppliers' resistance to disclose product substance information is due to concerns over the confidentiality of proprietary formulations (IC and IH), followed by concerns over perceived high costs and efforts in submitting FMD data (SC). Small business suppliers may also not be able to afford the annual FMD training fee without heavily impacting their bottom line (SB).

Solutions and facilitators of success

To address the above challenges, Seagate has adopted a number of strategies. First, suppliers are provided with mechanisms to protect the confidentiality of proprietary substances. For example, suppliers are allowed not to disclose on non-restricted substances. For this, secret CAS numbers are used to label substances in the database. At present, there are about 50 "proprietary substances" in the database (SA).

Seagate also makes effort to empathize and accommodate suppliers as much as possible, given their shared experience with the need to align with numerous unique reporting formats and standards developed by clients, and understanding that it can be frustrating and difficult (SB and SC). Understanding this shared difficulty as a supplier, Seagate designed their FMD system based on an existing standard to facilitate their own suppliers to comply (SC). Suppliers are also incentivized to participate in FMD because they can find other uses for the comprehensive data gathered, in meeting the disclosure requirements of other clients and in making product design changes (SB and SC).

Supplier development, capacity building and training are also conducted on an ongoing basis. Indeed, capacity building is one of four major programs in Seagate's supply chain environmental, social and governance strategy (Seagate, 2018a). This is especially relevant for newly acquired companies where FMD is a new concept and Seagate's FMD systems must be transferred.

These soft approaches are supported by the hard rule that suppliers must provide FMD data to enter the procurement process.

Competitors

Context

As of 2018, the global hard drive market is dominated by Western Digital (40%), Seagate (37%) and Toshiba (23%) (Sato & Takahasi, 2018 and Rogers, 2018). The global hard drive storage industry has also been consolidating. For example, Seagate acquired Samsung's HDD business

group in 2011, and has also purchased SDD companies to grow in that business area, given benefits in higher profit margins for SDD products (Rogers, 2015).

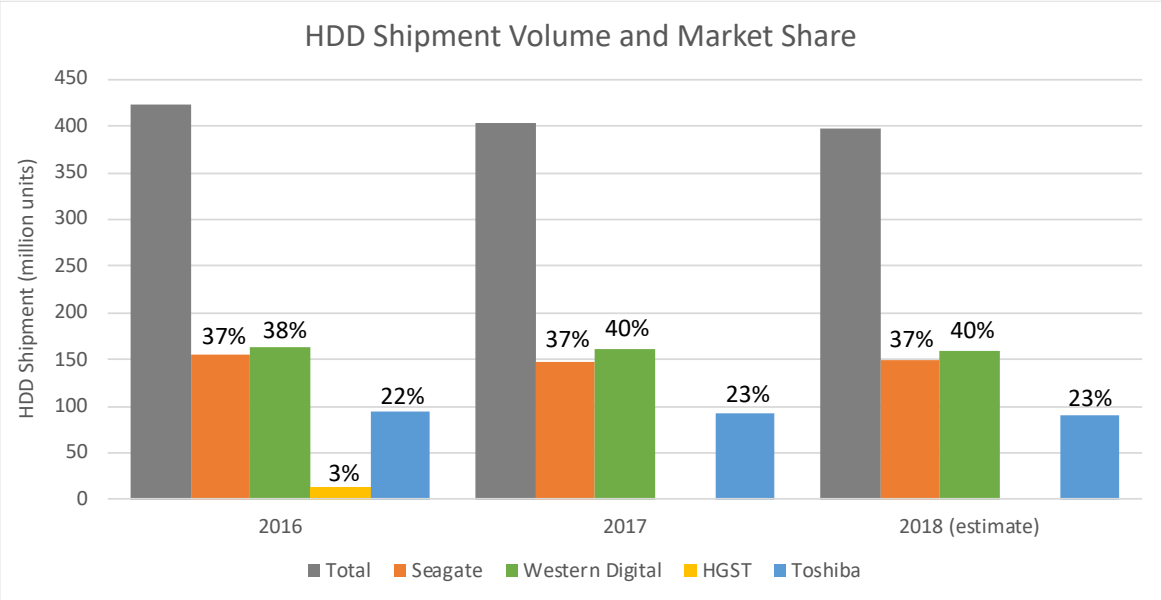

Figure 4-5. HDD shipment volume and market share

Note: HGST was acquired by Western Digital in 2012 (Hitachi, 2012).

Source: Adapted from TSR, Morgan Stanley Research as cited by Sato & Takahashi, 2018.

Competitors' approach to product material and substance compliance

Western Digital – The company website provides limited information on its material and substance disclosure policy. However, a Google search discovered a "WD environmental specification for materials, components and products" document that was last updated in 2015 (Western Digital, n.d.). It indicates that suppliers are required to provide FMD data for products including HDD products. A Western Digital guidance document on FMD data collection (also found via Google search) indicates that the data is collected using an excel-based form following the IPC 1752A standard. The data collection forms are in XML format, indicating that the company may use internal data management platforms to input and process FMD data (Western Digital, n.d.(a)).

Toshiba – While the company's website communicates its chemicals management policy, further review of the website and internet searches yielded limited information on the specific approach taken to collect and manage material and substance data.

Relevance of competitors to FMD

According to all EHS&S interviewees (SA, SB and SC), the approach taken by competitors on material and substance disclosure requirements has not affected Seagate's FMD development. While it is unclear when Western Digital adopted FMD, the general impression seems to be that Seagate established FMD well in advance of its competitors. Seagate also shared its FMD approach to another hard drive company that was eventually purchased by Western Digital, so perhaps FMD systems in Western Digital was integrated after this event.

FMD and competitive advantage

While authors of external publications have made the argument that FMD as a sustainability strategy can lead to competitive advantage (Larson, Olmsted, Teisberg & Johnson, 2000 as cited by Rossi, 2014), multiple Seagate interviewees have indicated that having an FMD system has not created a competitive advantage in terms of increased revenues and product sales (SA, SB and SC).

> *"[FMD] is technically a competitive advantage, but not enough to really set us apart from our competitor in a way that drives a significant amount of business"*
>
> – EHS&S interviewee

According to EHS&S interviewees, FMD boils down to being a regulatory and client compliance approach. It is not a source of competitive business advantage. For this reason, Seagate views that they can openly share its FMD approach to encourage greater adoption among the industry, adding that this can be beneficial because the overall disclosure standards can be pushed forward at the sector level.

Nonetheless, FMD has enhanced the image of Seagate among its clients as a reliable, compliant supplier and leader in this area, leading also to the achievement of sustainability awards (SB).

Clients

Clients were the original driver that led Seagate to adopt FMD, given the frequently-changing procurement specification and requirements which continue today. Therefore, clients are highly relevant to Seagate's FMD.

OEM clients present Seagate's largest revenue stream, at 67% as of 2017 (Seagate, 2017). Notable brands include Dell, HP, IBM and Apple. In 2014, Dell and HP accounted for 13% each of Seagate's revenues (Rogers, 2015). OEM products includes those for enterprise applications (e.g. servers, workstations, mainframes), computing (e.g. desktop and laptop manufacturers) and non-computing applications (e.g. gaming consoles and video recorders) (Rogers, 2015).

Apple and the birth of low/no-halogen specification (a voluntary restriction)

In 2006, Greenpeace published electronics ratings that highlighted high levels of brominated (Br) and chlorinated (Cl) flame retardants in Apple products (Lombardi, 2011). In response, Apple decided to remove all materials that contain Br and Cl entirely (Nimpuno, McPherson, & Sadique, 2009). The main reason for this elimination was to simplify the verification of Br- and Cl-containing hazardous substances during chemical analyses, given that the testing of chlorinated and brominated substances of very high concern (e.g. phthalates in PVC) can be very difficult at low concentrations, but detecting elemental chlorine and bromine was relatively easy and inexpensive (Nimpuno, McPherson & Sadique, 2009 and SC).

For Seagate, the elimination requirement included the removal of harmless compounds such as sodium chloride. But because of this effort, Apple products were able to produce clean test results for Br and Cl that were the indicators of BFRs and CFRs (SC).

Low halogen is now a standard for parts procurement in the electronics industry. According to an EHS&S interviewee (SC), following the halogen-free movement started by Apple, HP also decided to phase out phthalates in their products as a point of environmental differentiation. This is an example of how chemical management initiatives downstream of the supply chain have formed drivers for suppliers upstream, leading to adaptive measures such as FMD.

OEM clients have strict customer requirements and specifications. Seagate's FMD databases have catalogued over 2,000 restricted substances that were compiled based on client and regulatory requirements (Seagate, 2018a). An EHS&S interviewee explained that client specifications tend to be strict because they have a myriad of components from numerous major component manufacturers that are assembled into one single product (SB).

Substitute products

One of the biggest trends affecting hard drive storage products (especially those in computing devices such as laptops, computers and tablets) is the replacement with cloud storage. Cloud storage has become a standard data storage solution both for enterprises and individual consumers. The market is expected to grow from USD 25 billion in 2017 to over USD 92 billion by 2022 (Reuters, 2018). Nonetheless, data must still be stored on some form of physical infrastructure. In this case, the difference is that instead of being located on devices, the storage drives are now placed in large scale database storage and servers (Arokia Paul Rajan & Shanmugapriyaa, 2012 and SB).

While Seagate's strategy has been to move into cloud storage (acquiring companies along the way to expand into this area), EHS&S interviewees (SA and SB) indicated that the emergence of cloud storage technology does not actually affect the way Seagate carries out FMD. Cloud storage is composed of hard drives that are sold to clients (e.g. IBM) that produce and sell network servers to their clients (e.g. Facebook, Apple for iCloud, Google for Google Drive, OneCloud for Microsoft), which then sell the cloud storage to consumers. Regardless, Seagate does not differentiate its approach to track product material and substance composition (SA and SB).

However, there is a difference in the demand for chemical management standards among these clients. Whereas consumer electronics manufacturers such as HP would pass on the demand for safe chemical use from NGO and consumer groups to their suppliers like Seagate, cloud storage buyers such as Google face less pressure on these issues. In this sense, the same environmental regulations apply, but the "vigor is not as mature" as the traditional OEM companies (SB).

New entrants

The data storage industry has been on a consolidation trend, one reason being that smaller companies did not have the sufficient capacity to consistently improve manufacturing efficiency and research and development resources to keep up with emerging trends such as SSD (Rogers, 2015a).

One Seagate interviewee has remarked that new entrants have not been an issue as the data storage market has become quite mature and consolidated, as well as having even been commoditized (SE).

4.1.8 Organizational context

Culture and structure

Seagate interviewees (SB and SC) identified the following aspects on the organization's culture as contributors to the establishment and success of FMD:

- Top and executive-level commitment, which was possible given the strong business case for product FMD
- Engagement and passion among mid-level managers to drive the program forward

- Recognition of operational staff who carry out core FMD work. Buy-in from internal teams across the board with the shared understanding that FMD supports the shared goal of boosting business for the company.
- Recruitment of personnel who are deeply motivated about addressing sustainability issues. "We hire people who are absolutely committed", as stated by the EHS&S interviewee who was directly involved with establishing FMD (SC).
- Ability to confront and openly discuss with upper management. Representative quotes from the same interviewee (SC) include: "Seagate is open to tough discussions".

In addition, Seagate also communicates openly about its sustainability position. According to a materiality assessment in 2017, the most material aspects related to CiP issues (in terms of high importance to both stakeholders and business success) included: transparency and reporting, chemicals management, responsible sourcing and supply chain management (Seagate, 2018a).

The drive for environmental leadership also played a role. According to one interviewee, top level management also signed off on FMD because "Seagate wants to be a leader, not a follower" (SB).

The same interviewee described Seagate's organization as flat but with specified functional groups that drive different areas of work. While the teams and systems are decentralized and networked, FMD-related systems are built on the same foundation that are the CAS software platform and standard IPC 1752 data exchange process, which facilitate coordination among the different teams. Strategic decisions can also be made at the operational level (bottom-up approach) as opportunities are identified (SB).

Champion/change agents

The success of establishing FMD at Seagate was largely due to one EHS&S interviewee that was directly involved from the beginning (SC), in conducting detailed problem analysis and cost-benefit assessments, as well as advocating FMD as the solution. This interviewee played a significant role in driving forward FMD internally as well as in improving supplier engagement, buy-in and participation.

4.1.9 Summary of findings on the units of analysis related to the business environment

Table 4-3. Summary of findings for units of analysis related to the business environment - Seagate's FMD

Unit of analysis	Seagate
Political	The most relevant government regulations are EU RoHS and EU REACH, in terms of driving FMD establishment and shaping substance restrictions that are continually tracked by FMD systems. The European Chemicals Agency was also identified as a relevant governmental organization. Other regulations include Prop 65 and WEEE.
External stakeholders	The most relevant industry organizations were IPC (in setting the data format for FMD data exchange), RBA (in setting industry operational standards related to CiP issues) and IEC (in setting industry standards for identifying and working to remove/replace SVHCs in products). NGOs played a role in putting pressure on OEM brands, who responded by adopting stricter substance specifications and voluntary restrictions, creating a trickle-down effect and greater demand for CiP information up the supply chain. Such pressures created changes in client specifications that pushed Seagate to adopt FMD. General consumers and the waste management sector were found to of less relevance in driving FMD at Seagate.

Market	Clients and their evolving specifications were the biggest drivers that pushed Seagate to adopt FMD. Suppliers play a fundamental role in providing FMD information that is used by Seagate to prove their compliance to client and regulatory specifications. Competitors, new entrants and substitute products did not shape Seagate's FMD establishment or development. In Seagate's view, FMD does not have an effect on its competitive advantage, either positively or negatively.
Organizational	The most important aspects about Seagate's organizational culture and structure that facilitated FMD establishment were: top-level management support, internal buy-in across various teams, selective recruitment, and a working culture that welcomes the challenging of authority. One particular individual from the EHS&S team played a crucial role in selecting, promoting and driving forward FMD establishment at Seagate.

Source: Author's own elaboration based on findings

4.2 Part 2: External to Seagate

4.2.1 General trends

It was difficult to collect accurate and definite information on the prevalence of FMD adoption (either as a requirement by buyers or compliance approach by suppliers) in the electronics industry. There have been no known prior studies on this, and some companies that do adopt FMD may not communicate it externally. Therefore, the author attempts to draw general conclusions of common FMD trends and practices based on the perceptions of interviewees, while acknowledging that there may be gaps and inaccuracies. Further study is required to obtain a fuller and more accurate picture of FMD adoption.

An interviewee from chemical management software and services firm SciVera (which specializes in supporting consumer products brands and their suppliers in chemical data collection, chemical screening, advanced toxicology, and alternatives assessment) indicated that FMD requirements are more common among OEMs (downstream in the supply chain) (IC). Similarly, an Environmental Chemist at HP perceived FMD adoption in the IT electronics industry to be rare. The interviewee estimated that approximately only 10% of companies have adopted FMD, and while certain downstream companies have been leading in this regard (e.g. Seagate and Western Digital), FMD compliance is indeed more common among manufacturers of simpler electronics parts (IA).

An EHS&S interviewee from Seagate (SC) also indicated that Seagate was one of the first to adopt FMD, but many other companies have found FMD to be an efficient approach to manage changing regulatory requirements such as REACH. Original design manufacturers and contract manufacturers (e.g. Flextronics and Foxconn) also request FMD data in order to comply with brand clients (SC). The shift towards FMD as a trend in the electronics industry was reiterated by Johan Holmqvist, former Director of Corporate Sustainability at Sony Mobile (IE).

General Counsel of Assent Compliance (a Software as a Service supply chain software company that provides compliance automation and human support services to various sectors concerning regulatory compliance matters (ID)) provided a larger estimate, indicating that the majority of buyers along the IT electronics supply chain request full material declaration but to varying degrees. Some companies, like Seagate, request high-quality FMD data as a prerequisite for a supplier to be qualified, while others may require lower data collection rates or allow FMD data submission on a voluntary basis. The latter point was also mentioned by a Seagate interviewee (ID, SC).

The ability to comply with FMD data requirements varies along the supply chain and is most commonly achieved by component manufacturers upstream, because there are fewer upstream

actors and small components are relatively simple to collect data for. For example, it is estimated that there are approximately only ten to twelve materials in resistors that are declarable (over specified concentrations) while the other materials and their concentrations are common knowledge. On the other hand, a mobile phone can have thousands of components and parts with declarable materials (ID).

The coverage and accuracy of FMD data then declines further down the supply chain. Buyers in the middle of the supply chain request FMD data, but the ability to acquire it is not consistent. The motivation for mid-range manufacturers to provide FMD also decreases because of the perceived risks (ID).

Nonetheless, General Counsel of Assent Compliance explained that regardless of whether a buyer requests list-based disclosure or FMD data, suppliers are by standard required to submit a declaration of conformity. In general, in the electronics industry there are five to six common documents that are almost always exchanged (ID):

1. FMD declaration
2. Lab test report
3. Declaration of conformity for RoHS
4. Declaration of conformity for REACH
5. Declaration of conformity for low-halogen or halogen-free certification
6. (Sometimes) Prop 65 statement or other statements

4.2.2 Cases of FMD and list-based substance disclosure

In this section, a description of the material and substance disclosure system of select companies is presented based on publicly available information and interviews with representatives. The author would like to note that the summaries may only present a partial picture given limitations in interview time and dependent on the actual availability of published information.

Motorola Mobility (FMD)

Motorola Mobility is a subsidiary of Lenovo that produces telecommunication devices including smartphones, modems and Bluetooth devices (Motorola Mobility, 2018). Its predecessor, Motorola, was commonly referred to by Seagate interviewees as one of the first companies to adopt FMD (then followed by Seagate) (SA, SC), which is still in place today. According to an interview with a Senior Material Expert at the Global Regulatory Compliance Department of Motorola Mobility, FMD data is collected from suppliers when they are first qualified in the supplier qualification process and during new product development. Suppliers are required to update the data if there are changes to the design of parts, rather than annually as is the standard procedure at Seagate. Since the FMD data management system consists of built-in regulatory, voluntary and industry compliance requirements, the system conducts automatic checks on compliance at the part level whenever there are any changes to chemicals requirements (IB).

According to the most recent version of the company's specification on materials disclosure that is publicly available (Motorola Mobility, 2017), suppliers must:

- Report controlled and reportable substances using IPC 1752A format at the homogeneous material level. The IPC Creator spreadsheet-based tool is provided by Motorola for suppliers which allows for the conversion and submission of FMD data in XML format.
- Pass on Motorola's requirements to their own suppliers upstream in the supply chain to gather full material data.

- Disclose 100% of materials in products including inks, adhesives, tapes, platings and paints.

Sony Mobile Communications (FMD)

Sony Mobile Communications (referred to as Sony Mobile in this report) is a subsidiary of Sony Corporation which produces smartphones and tablets worldwide (Sony Mobile Communications, 2018). The company requires suppliers to provide FMD data (i.e. "full disclosure of all substances in a component" (Sony Mobile Communications, 2018)) in IPC 1752 format, which is entered into their declaration database for automated evaluation of substances in the component level. The components are aggregated into a Bill of Materials for compliance evaluation. This approach is complemented by chemical analyses. Sony's substance compliance requirements include regulatory, industry and voluntary restrictions (Sony Mobile Communications, 2018). FMD data collection has also reached 95% (IE).

HP Inc. (list-based disclosure)

HP Inc. (referred to as HP in this report) is a global producer of personal and enterprise computing products, ranging from laptop and desktop computers, tablets, printers, ink and toners, displays as well as business solutions including security, data storage and software (HP, 2018). According to an HP Environmental Chemist, suppliers are required to provide list-based disclosures to declare the absence of substances based on regulatory, industry and voluntary restrictions (IA).

HP uses its own proprietary format for material and substance data collection, however its systems also accept IPC 1752A format data. Data is collected and managed on Excel spreadsheets where suppliers fill in spreadsheet templates including those for REACH and RoHS (IA). Data is collected from suppliers at various points along the supply chain, from first-tier original design manufacturers to parts and components manufacturers farther upstream (such as resistor and capacitor producers) (IA). The format and approach for data collection were developed based on suppliers' capabilities, which in many cases are limited in terms of collecting material and substance data in products. As such, HP has so far opted not to adopt company-wide standards such as FMD and data reporting standards (such as IPC 1752) to "reach as many suppliers as possible" (IA).

The HP interviewee indicated that suppliers are not required to conduct regular lab tests given that REACH does not have this explicit requirement. Nonetheless, its systems are automated to conduct basic data validations including the data format, verification of the reported substances against SVHC lists, substance values and weights (which must add up to 100% of the total weight of the component or part) and other details (IA).

Electrolux (list-based disclosure)

Electrolux is a global household and business appliance manufacturer, providing products including refrigerators, dishwashers, washing machines, cookers, vacuum cleaners, air conditioners and other appliances (Electrolux, n.d.). It is a highly vertically integrated company with production sites scattered around the globe (IG).

According to an interviewee from Electrolux (IG), Electrolux requires their suppliers to provide absence declarations based on a restricted materials list. This is based on an in-house web-based system to which suppliers submit their information. There is no FMD requirement or particular data standard that is followed. Submissions are accompanied by lab tests, which are carried out both by suppliers and Electrolux itself. The selection of parts and materials for testing is based on risk assessments (i.e. the materials that may contain the most SVHCs).

The following sections summarize the relevance and context of the four units of analysis (political environment, market environment, organizational context and external stakeholders) in relation to the non-Seagate companies studied. The author would like to note that similar to the descriptions of the substance disclosure systems of the companies, the findings in this section may not be complete mainly due to the briefer duration of interviews with company representatives and the limited availability of public information.

4.2.3 Political environment

For Motorola, one big rationale for having FMD in place is to keep up with the regular changes of different regulations and ensure that all products are compliant. Given that Motorola has over 1,000 suppliers which can supply hundreds of components each, FMD allows Motorola to efficiently flag any supplier parts that fail to comply with regulations like REACH and ensure that non-compliant parts do not end up in Motorola products (IB).

For Electrolux, some of the most relevant regulations for materials management are also EU RoHS, REACH, Prop 65 and equivalent national regulations in China, Vietnam, US and other countries (IG). Other relevant regulations for the appliance manufacturer were the EU Directive 2008/98/EC on Waste (i.e. the Waste Framework Directive) and EU Regulation No 1935/2004 on Food Contact Materials, which sets out rules to ensure that materials do not "release their constituents into food at levels harmful to human health [or] [c]hange food composition, taste and odor in an unacceptable way" (European Union, n.d.).

RoHS policies were deemed as relevant for all companies studied. Further input was given on REACH AND Prop 65.

REACH

From all interviews, more comments were given for REACH. The REACH Regulation is among the biggest drivers of HP's material and substance disclosure strategy (in addition to Prop 65 and industry standards, namely EPEAT) (IA). Many of HP's substance restrictions are based on substances listed in the REACH SVHC list, and the frequency of sending requests for declarations to suppliers also aligned with the frequency of REACH SVHC updates, which is usually once every six months (once around January and once around June of each year) (IA). The frequency of REACH Candidate List updates was validated during an interview with the Swedish Chemicals Agency. However, the frequency of updates is not a written rule of procedure but rather due to the frequency of decision-making meetings related to the REACH Candidate List, which are conducted once every six months (IF).

REACH Article 33 obligates companies to communicate information if their articles contain substances newly added to the Candidate List above 0.1% (w/w). To anticipate newly restricted substances, HP works to collect information from their suppliers ahead of time. To streamline the communications, HP attempts to consolidate requests related to other requirements and standards (e.g. EPEAT) to minimize the total number of requests sent to suppliers (IA). Indeed, Johan Holmqvist (former employee of Sony Mobile) described REACH is a driver for companies to adopt FMD because the Candidate List is expanded every six months with new substances. He added that ideally, companies should be asking their suppliers to confirm whether their products contain the newly restricted substances, but this is not a widespread practice. FMD allows for easier compliance with REACH.

The HP interviewee cites REACH as having "laid the groundwork" for substance disclosure at the company, where new substances are continuously added to candidate and SVHC lists.

Today, the EU is a leader on regulating chemicals in products, such that a company's compliance with REACH will usually mean compliance with the regulations of many other countries (IA).

Prop 65

While a number of interviewees touched on the relevance of Prop 65 to the adoption of CiP information collection systems in the electronics industry (ID, IE, IG), one other interviewee further described Prop 65 as an older regulation that covers less substances than REACH and is overall less specific to the electronics industry, but it is nonetheless a relevant piece of well-established legislation that guides their company's material and substance standards (IA). For ease of production, HP has made all its products compliant with Prop 65 with the relevant labels regardless of where the product is shipped globally.

Other findings

According to the HP interviewee (IA), there has been a shift from industry drivers (such as industry-agreed SVHCs as listed in the JIG 101 Guide – now the IEC 62474) to regulatory drivers (with the emergence and leadership of REACH, in which many SVHCs overlap with industry SVHC lists).

The interviewee from Electrolux highlighted the lack of global regulatory harmonization as a major challenge. Given its large and highly complex global supply chain, with suppliers located in various regions governed by various levels of regulatory stringency, one of the biggest challenges in materials and substances management is in setting the bar of global chemicals requirements in line with the most stringent regulations – mainly those in the EU. Significant effort must also be spent to conduct regular compliance checks on the differing laws of different countries. In this sense, the interviewee expressed that extensive effort must be spent on verifying compliance to a diverse set of regulations across the globe.

4.2.4 External stakeholders

Industry organizations

Overall, multiple interviewees have expressed that industry groups have made only minor push for FMD and better chemicals management because of low interest (IE, SC). The trend has been much more on NGOs putting pressure on companies to make effort such as voluntary restrictions (IE). Nonetheless, in discussing the relevance and influence of industry organizations to product CiP disclosure systems, the three main initiatives that were mentioned are EPEAT, IPC and IEC.

EPEAT

According to the HP interviewee, EPEAT has been playing a significant role in "pushing along" the electronics industry to increase acceptance among suppliers on material and substance disclosure as well as to build disclosure and data management capabilities. One of the biggest aspects driving HP's materials management strategy is to achieve EPEAT standards, by achieving points under the substance inventory category where they must collect materials and substances data for 90% of the product weight. In this regard, HP has been coordinating with suppliers to collect data as well as working with them to build data collection and disclosure capability. The interviewee indicated that such industry initiatives have helped to create a market driver and strengthen justification for downstream buyers to request information from upstream suppliers (IA).

IPC 1752

Adoption of IPC data reporting standards varied among the non-Seagate companies reviewed

– while both Motorola and Sony require IPC 1752 standards, HP follows its own format (with capability to accept IPC 1752) and Electrolux uses its own data reporting format entirely (IA, IB, IE, IG).

IPC 1752 was the original standard for material declaration in the electronics industry. It was developed by Adobe in excel format and it was well-liked by some because of its simple PDF format (ID) but also frustrated others due to a number of limitations in handling large volume and more complex full material data (Dills & Harris, 2008). A study by Kogg and Thidell (2010) also found that not many companies have adopted IPC-1752 since the system emerged after many have already developed their own approaches to comply with EU RoHS in 2006, that the pace of development of the standard was not keeping up with rapidly changing regulations, and that it was overall complicated to use and not user friendly for data entry.

Over time Adobe stopped supporting the standard because the company licensing revenues were lower than expected (ID). Without sufficient EIT capabilities, the IPC failed to adequately maintain, update and adapt the standard for the industry, and therefore the standard eventually fell into disuse and companies began to develop their own reporting formats (ID).

IEC 62474

Previously known as the JIG 101 Guide, the IEC has been working before the establishment of the REACH Regulation to develop and maintain an industry standard for SVHC lists (the IEC 62474), forming the basis for SVHC disclosure along the supply chain. Many of the substances now overlap with REACH SVHCs (IA). According to the HP interviewee, there has been a shift from industry to government as drivers and leaders of maintaining SVHC standards (IA). The IEC also has data reporting standards that are more commonly used globally, whereas IPC 1752 is dominant in North America (ID).

NGOs

Many interviewees remarked on the significant role that NGOs have played in improving chemicals management efforts that may have led some companies to adopt FMD. For example, the Greenpeace Green Electronics Guide has helped sustainability managers of companies to get attention from top management to address these issues. This is especially influential when NGOs benchmark a company against its competitors. In this sense, NGOs have created a voice for household consumers (whether or not consumers have demonstrated significant knowledge or interest in these issues) that pushed companies to change (IE).

One interviewee indicated that in the past, the awareness raising campaigns of NGOs were targeted directly at companies, such as the case in 2009 when Greenpeace activists vandalized HP's headquarters to protest against the company for backtracking from commitments to eliminate toxic chemicals from products by the end of the year (Ganapati, 2009)(IA). While such activism has sparked regulations to shift the industry away from using these substances (e.g. EU RoHS), today regulations are also providing greater channels for NGOs to escalate concerns on chemicals. For example, NGOs can pressure EU Member States to push for substances to the added to the REACH Candidate List for regulation (IA).

Lastly, interviewees also remarked on the usefulness of NGO-derived tools. For example, Electrolux uses the ChemSec SIN List as a reference for substances of concern as well as a reference for chemistry-related information. The Electrolux interviewee further expressed that the support from NGOs is needed not only to develop negative lists (i.e. substances that should be substituted) but also to develop positive lists that identify the alternatives themselves.

Waste management and consumer demand

According to the HP interviewee, consumer demand is tied to EPEAT in that the industry-driven ecolabeling initiatives are meant to provide a decision-making tool for consumers (IA).

While waste management was not discussed extensively during interviews, much of the relevance of product CiP disclosure systems was related to emerging discussions on the circular economy. For example, the European Commission is exploring tools and legislation on information sharing to facilitate material recycling in the waste management sector, to support shifts to circular production (IG). The Electrolux interviewee also indicated that the market for recycled raw material is growing, and it is therefore important that these materials do not contain hazardous substances, which should be managed by a reasonable level of requirements that take into account of materials that are not fully traceable (IG). The significance of product CiP information for regulators was also emphasized during interviews (IF).

4.2.5 Market environment

Suppliers

Similar to Seagate, suppliers are intrinsic to material and substance disclosure systems given their crucial role in providing CiP information. General Counsel of Assent Compliance described three major considerations a supplier must make when being requested to provide FMD data (ID):

1. **Size of the procurement opportunity** – the greater the contract value and purchase volume, the more incentivized the supplier would be to comply.
2. **Alignment of supplier's existing systems** – If the supplier's existing data collection and management systems are already well aligned to FMD requirements, then the supplier is more likely to comply. Otherwise the supplier would need to expend greater resources and effort.
3. **Level of standardization and practices in the industry** – Industry standardization can present an expectation (norm) as well as provide practical support in the form of data reporting formats, templates and tools. The greater the level of standardization, the more likely a supplier will comply with FMD requirements.

Further, interviews outside of Seagate identified the following four challenges in terms of supplier engagement in FMD:

1. Concerns over confidential information

One of the biggest challenges that companies face in engaging their suppliers to submit FMD data is the suppliers' concern over the potential compromise or loss of proprietary product information. Magnified across multiple tiers in the supply chain, such concerns pose significant barriers to obtaining the full picture of materials in products when FMD is a requirement (IC).

From the perspective of the public sector (IF), it was recognized that companies are concerned over protecting confidential business information. However, it was also noted that arrangements such as non-disclosure agreements are available to address this. The interviewees from SciVera and Assent Compliance added that compliance consultancies, software platforms and service providers can act as a reliable third party to protect suppliers' confidential information, by sharing the results of a chemicals screening and assessment, while redacting proprietary ingredient identities. The SciVera interviewee added that significantly greater participation from suppliers occurs when assessment results flow downstream to decision makers while trade secrets are protected (IC and ID).

Separately, interviewees at the Swedish Chemicals Agency (IF) added that the issue of product confidentiality becomes much more complex in relation to information exchange outside of the supply chain – i.e. between producers and waste management sector. The other consideration is the appropriate level of detail when sharing information with household consumers, who do not need full material information but only information on substances that could have an impact on the health or the environment. Nonetheless, waste managers, product designers and raw material manufacturers indeed require product chemical information especially in the emergence of circular economy development.

2. Buyer and supplier power dynamics

Achieving compliance with suppliers on FMD depends on the leverage that buyers have on their suppliers, and requires strong supply chain management power (IC, IE). For example, a buyer that has the ability to purchase in large volumes would represent purchasing power over the supplier and incentivize FMD compliance if it is a procurement requirement (ID). Nonetheless, the SciVera interviewee added that smaller or less influential OEMs and suppliers have also achieved equivalent understanding of chemical characteristics when using assessment results and protecting supplier trade secrets (IC).

In the electronics industry, however, the upstream suppliers of parts and components can be very large corporations. Resistor manufacturers, for example, have generally consolidated into a number of corporations (IA). Big upstream supplier corporations can hold high supplier power to resist participation in material and substance declaration, if sales opportunities exist elsewhere without similar requirements.

3. Limited supplier capability

Many of HP's suppliers continue to use old versions of data management and office software that can pose technical barriers in compliance capability. Even among original design manufacturers, for example, it was estimated that only one or two manufacturers (among six to seven that sell to HP) have the capability to collect and disclose product material data despite their large production and operational size. It was speculated that this may be due to the exceedingly complex nature and variety of the subassemblies (e.g. motherboards, display panels) produced for OEMs. Suppliers of basic parts (e.g. resistors), on the other hand, are more capable of producing FMD data regardless of their company size, likely due to the relative simplicity of their products (IA).

Related to the above, HP has been facing difficulty in collecting material declaration data for EPEAT, given that many of their suppliers lack the capability to know the material and substance composition of their products, systems to organize data at the part and product levels and general data management infrastructure. HP has been working with suppliers to build these capabilities (IA). Similarly, the interviewee from Electrolux also indicated the challenge that suppliers lack the understanding and knowledge of material compliance requirements. The company is currently developing e-learning material to address this (IG).

4. Supply chain structure

According to the interviewee from Electrolux, large home appliance OEMs typically have an enormous supply chain with a diversity of suppliers ranging from large corporations to SMEs serving a variety of industries. This makes it immensely difficult to manage. It is for this reason that the interviewee argued that FMD is not yet common in the home appliance electronics industry. However, the company has been considering applying FMD systems for non-complex articles to test feasibility (IG).

Customers

Both interviewees from HP and Electrolux described their business customers as one of the major drivers of their substance disclosure approaches. For HP, frequent inquiries from customers on ingredients in products, particularly European healthcare electronic manufacturers such as Philips, influence the approach and scope of CiP information collected from suppliers (IA).

Competitors

In general, the companies interviewed take the substance disclosure approaches of their competitors into consideration when devising their own systems. One interviewee[15] described competitors as highly relevant because companies are fundamentally business driven. Most companies do not wish to expend more effort than what is required to maintain competition, especially when they are being benchmarked against their competitors. The significance of benchmarking was also noted by another interviewee (IG).

On the other hand, while companies try to keep abreast of the substance declarations of their competitors, there may also be hesitant to proactively communicate on certain substances that are not restricted by policies, given that they may actually raise further concerns and create a perceived health risk among consumers who are not knowledgeable of hazardous substances in products in the first place (IA).

FMD and competitive advantage

Since FMD can be seen as a strategy to improve the efficiency of business operations, the author speculated that perhaps it can also provide competitive advantage by improving compliance efficiency (which may translate into time savings), saving compliance costs in the long-term, making for easier substitution of hazardous substances and facilitating sustainable product design. While the HP interviewee indicated that having FMD does not provide business differentiation or competitive advantage, it can provide competitive advantage if it is packaged as part of the criteria for ecolabels such as EPEAT. In their case, the contribution of points scored in the substance inventory category leading to obtaining the EPEAT standard allows the company to attach the corresponding ecolabels on their products, which in turn can boost sales. In this sense, packaging FMD as criteria for informative instruments can help to generate a market push and provide business advantage (IA). The interviewee from Assent Compliance added that having an FMD requirement can provide a company with business advantage, but this ultimately depends on whether its clients find value in it (ID).

4.2.6 Organizational context

While the duration of most interviews was too short to cover the organizational context, interviewees who were asked about factors that drove the development of their product CiP disclosure strategy rarely pointed to organizational factors such as culture or structure. One interviewee remarked that while such factors are relevant, companies that have adopted FMD are not associated with particular or notable organizational characteristics. Nonetheless, when convinced and motivated (such as from NGO pressure), top management can play a significant role in changing practices (IE). Indeed, according to the HP interviewee top-level leadership coupled with a supportive working culture within the company have played a role in driving hazardous chemicals management and communication forward in the company (IA).

[15] The interviewee did not wish to be referenced for this particular statement.

4.2.7 Perceptions of FMD

This section summarizes other discussions on FMD that emerged from all interviews including those with Seagate personnel.

The importance of FMD

Most interviewees recognized the value of FMD in making compliance more efficient, facilitating the substitution of hazardous substances and providing safer recycling practices. According to one interviewee (IE), FMD is also important because the chemical manufacturing industry is producing new chemical products much faster than legislations are released to regulate their use. When new chemicals are produced, there is also no knowledge of their impact to the environment and human health. In the interviewee's view, the paradigm should be such that society has the right to know the substances in their products and what consumers are in contact with. The interviewee described this as the "bottom line" for rationalizing FMD: because when information on the risks and dangers of a chemical emerges after it is introduced to the market, regulators and companies can act to find alternatives or phase them out (IE). FMD at least allows for the knowledge of substances present in products when new knowledge of substance risks arises.

Lack of definition for FMD

The lack of a standard definition for FMD meant that different interviewees had different views on what actually constitutes as FMD. One Seagate interviewee explained that the principle of FMD is to report on all the materials and substances in a product or component. However, the way the information is collected and communicated can vary (SB). Another Seagate interviewee defined FMD as "the best we can do" in terms of sharing information on product materials, even though many materials and substances may be unreported or misreported (SC).

While the Seagate-like approach of formalizing data collection requirement from suppliers on FMD is generally regarded as FMD for most respondents, others viewed that FMD should involve a more rigorous approach (IE). The reasoning is as follows: Many manufacturers in the electronics industry that have FMD requirements is similar to Seagate in that data is collected mainly from supplier declarations not far up the supply chain. The problem with this is that the method only relies on the information provided by suppliers including lab test data, and it is not feasible to conduct comprehensive chemical analysis to obtain the full chemical composition of materials since this is extremely expensive and not manageable. In many cases, it is also difficult to know what to look for to begin with.

In that interviewee's view, a "truer" form of FMD would be to request information directly from material manufacturers. However, this requires significant resources, time and supply chain power. In some cases, chemical substances may be altered during the production of the material itself, and the manufacturer may not be able to provide information on the final composition (IE).

FMD standardization

One interviewee (SC) argued that an FMD standard similar to ISO standards is needed, which should involve verification and auditing in order to ensure that all companies that claim to have FMD actually have FMD according to an agreed definition and standard. It is the same logic to financial reporting standards that emerged from the Dodd Frank act and the ISO 14001 standard for environmental management. A common standard for data format and reporting, data refresh frequency and alignment among large downstream actors would greatly support suppliers because the supply chain is only required to conduct data refresh at the same frequency (SC).

Another interviewee (SB) views that the standardization of FMD has not reached the level or extent of ISO standardization because of the lack of collaboration and buy-in by industry actors and a tendency to compete among these actors on FMD approaches. In this sense, IPC 1752 can be seen as a form of standardization, but it is on a smaller scale than ISO standards.

Furthermore, the fragmentation in unique data reporting standards and formats was recognized as a challenge to standardization. One interviewee indicated that many companies in the electronics industry have chosen to adopt unique data reporting standards and formats as a differentiation measure (SC).

4.2.8 Summary of findings on the units of analysis related to the business environment

Table 4-4. Summary of all findings for units of analysis related to the business environment

Unit of analysis	Seagate	External to Seagate
Description of CiP disclosure systems	Stringent FMD system in which suppliers must provide FMD data in IPC 1752A format in order to be qualified. FMD data collection has reached 95%. Suppliers must also conduct lab analysis reports for select substances of concern.	Motorola Mobility and Sony (FMD): Similar to Seagate in that suppliers must provide FMD in IPC 1752A format to be qualified. Sony's FMD collection rate has reached 95% (similar figure for Motorola Mobility is unknown). HP (list-based): Suppliers must submit absence declarations for specified substances to HP's unique data format and system, though IPC 1752A format is also accepted. Lab reports are not compulsory. Electrolux (list-based): Suppliers must submit absence declarations for specified substances to a unique data format and system. Lab reports are necessary for certain substances.
Political	The most relevant government regulations are EU RoHS and EU REACH, in terms of driving FMD establishment and shaping substance restrictions that are continually tracked by FMD systems. The European Chemicals Agency was also identified as a relevant governmental organization. Other regulations include Prop 65 and WEEE.	Most companies shared the same relevant regulations of global RoHS policies, EU REACH and Prop 65. OEMs (brands) of I.T. electronics tended to face greater regulatory pressure from waste-related regulations such as the EU Waste Framework Directive. One difference stood out for the Electrolux on which the EU Food Contact Materials Regulation was also relevant for CiP.
External stakeholders	The most relevant industry organizations were IPC (in setting the data format for FMD data exchange), RBA (in setting industry operational standards related to CiP issues) and IEC (in setting industry standards for identifying and working to remove/replace SVHCs in products). NGOs played a role in putting pressure on OEM brands, who responded by adopting stricter substance specifications and voluntary restrictions, creating a trickle-down effect and greater demand for CiP information up the supply chain. Such pressures created changes in client specifications that pushed Seagate to adopt FMD. General consumers and the waste management sector were found to of less relevance in driving FMD at Seagate.	Industry initiated ecolabels such as EPEAT can create stronger basis and market driver to collect CiP information from the supply chain. IPC 1752 and IEC 62474 are industry standards for SVHC listing and data reporting although adoption is inconsistent. There is not quite significant overlap between the substances listed in IEC 62474 and EU REACH SVHCs. Most companies indicated that NGOs have played a bigger role than industry in pushing for increased transparency in CiP disclosure systems. Benchmarking efforts such as the Greenpeace Green Electronics Guide can push companies to take reactive measures, while tools such as the ChemSec SIN List can pull companies to improve (proactive measures). Household consumers were not deemed to be

		highly significant, though their interests are often reflected in NGO pressures. The waste management sector is more involved with downstream brand OEMs and there are increasing discussions on cooperation to aid circular economy development.
Market	Clients and their evolving specifications were the biggest drivers that pushed Seagate to adopt FMD. Suppliers play a fundamental role in providing FMD information that is used by Seagate to prove their compliance to client and regulatory specifications. Competitors, new entrants and substitute products did not shape Seagate's FMD establishment or development. In Seagate's view, FMD does not have an effect on its competitive advantage, either positively or negatively.	The biggest barriers to engaging suppliers in FMD systems is addressing concerns over proprietary product information and limited knowledge and technical capability for suppliers to comply. Nonetheless, suppliers are more likely to comply if the buyer has greater market power (e.g. procurement power), if existing systems are aligned with requested data formats and if FMD standards and practices exist in the industry. All companies identified that their clients play a major role in influencing the CiP strategies adopted. Competitors are also relevant because companies are consistently seeking to stay in line or be ahead of competitors. While FMD may not necessarily provide direct competitive advantage, FMD systems can allow for the adoption of tools such as ecolabels, which can increase product value and boost revenue.
Organizational	The most important aspects about Seagate's organizational culture and structure that facilitated FMD establishment were: top-level management support, internal buy-in across various teams, selective recruitment, and a working culture that welcomes the challenging of authority. One particular individual from the EHS&S team played a crucial role in selecting, promoting and driving forward FMD establishment at Seagate.	Organizational factors (such as top-level leadership and supporting working culture) can positively affect the outcome of FMD development but was not identified as highly influential.

Source: Author's own elaboration based on findings.

5 Discussion and recommendations

5.1 Discussion of key findings

The explanations of many findings have already been discussed in the last section (4. Findings and analysis). In this section, select key findings on the units of analysis of the thesis are discussed in further detail, drawing connections and patterns as well as posing questions. Each finding is stated followed by a discussion including explanations.

Finding: OEM brand companies (such as Motorola Mobility and HP) indicated that the pressures and standards to manage hazardous chemicals in products have shifted from industry drivers to regulatory drivers, although Seagate interviewees indicated that such drivers (for them) are predominantly client-based. For Seagate, this translated to pressures on time, human and financial resources.

The difference in the source of pressure is likely due to the different positions of Seagate compared to OEM brands in the supply chain. OEM brands are downstream in the supply chain, tend to coordinate directly with retailers and distributors and is therefore much more visible to society. As such, efforts from regulators and NGOs (reflecting societal concerns) to hold the industry accountable for managing hazardous substances in products tend to be directed at OEM brand companies. Being located further up the supply chain (above ODMs), Seagate would therefore not face the same pressures as directly. In this regard, a trickle-down effect (illustrated below) was observed where downstream companies pass on regulatory requirements, NGO pressures, industry initiatives and demands from the waste management sector up the supply chain, which manifest into voluntary company-based requirements (i.e. specific client requirements from the perspective of suppliers).

For Seagate, in the days before FMD, this demanded not only exhaustive effort but also significant financial resources to ensure continual compliance. In the absence of available data showing Seagate's actual cost calculations at the time of considering FMD as an alternative compliance solution, this thesis roughly calculated an estimate of the costs based on other indicative data (Table 4-1 and Table 4-2). The result indicated that the expected cost of compliance at the time without FMD was likely to be significant. It is unclear whether the data used for estimating compliance costs includes staff working time, however if it does not, then the total compliance cost may have been higher. For Seagate, while the upfront cost of establishing FMD was undeniably high, it nonetheless provided net cost savings over time when compared with past ad hoc compliance measures (Figure 4-1). A company considering a transition to FMD or relevant measures could use a similar calculation to compare the costs between current compliance practices and the cost of establishing the FMD approach being considered. However, such calculations should integrate considerations for costs related to staff and working hours. This should include the number of dedicated staff, amount of working time, salary and benefits, both for the scenario of current practices and the alternative scenario involving FMD measures.

Seagate's claim that the driver of their FMD was mainly client based is evident from the frequent requests for information they receive from clients. This can be supported by inputs from HP (a client of Seagate) that they regularly request data from suppliers based on both regulatory factors (e.g. REACH Candidate List changes which occur once every six months) and non-regulatory factors (e.g. efforts to achieve EPEAT ecolabel standards). Even after Seagate established FMD, NGO campaigns such as the Greenpeace report that highlighted the presence of brominated and chlorinated flame retardants in Apple products influenced Apple to adopt a voluntary restriction of BFRs and CFRs, which eventually became an industry-wide standard. Such restrictions have been passed upstream to suppliers like Seagate.

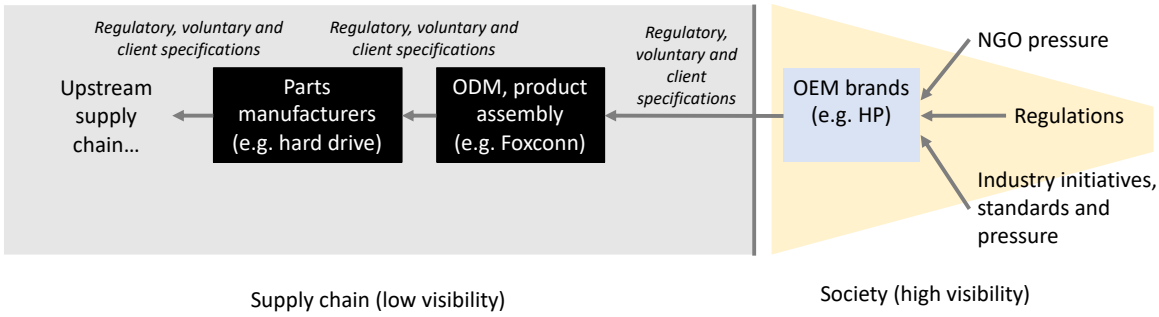

Figure 5-1. Pathway of influence and pressure on chemicals in products management.

Source: Author's work based on own research.

Finding: Seagate's success in establishing strict FMD requirements and robust systems is closely linked to supply chain structure, relationships and management approaches.

Cox (2004) indicated that a buyer-supplier relationship in which the buyer is dominant contributes to the buyer's ability to influence their suppliers' practices. Indeed, Seagate's thorough vertical integration was a strong contributor to the success of the FMD program, because this means that Seagate can exert greater influence in the practices, standards and operating systems in their acquired companies. In fact, part of the integration involves transferring FMD systems. Furthermore, given the consolidation and subsequent domination of the HDD market by Seagate and its two key competitors, it is speculated that there is a high supplier to buyer ratio. Seagate's position as a global producer of HDDs likely also add to its purchasing power and attractiveness of its accounts, adding to their power and influence on suppliers.

Related literature also discussed the benefits of long-term collaboration as a buyer strategy to achieve win-win situations and supply chain management goals (Cox, 2004 and Dannwolf, Ulmer, Cooper & Hartlieb, 2011). In this sense, Seagate's emphasis on maintaining supplier relationships, accommodating suppliers and providing capacity building and training support contributed to the long-term success of FMD.

Finding: Most companies care about what their competitors are doing in the area of CiP management.

While Seagate indicated that their competitors were irrelevant to their decision to adopt FMD, indeed their actions led to their competitors in adopting FMD as well. As described by Porter (2008), companies continuously monitor the actions and strategies of their competitors to keep up or get ahead.

Finding: Most companies indicated that FMD does not provide direct competitive advantage. But one indicated that it can provide competitive advantage if it was packaged as part of a product feature such as an ecolabel.

Companies may not feel that FMD provide direct competitive advantage, even though the findings have shown that Seagate's main competitor Western Digital apparently adopted FMD after Seagate has done so, perhaps to 'keep up' with the competition even if it may not necessarily boost sales, given that FMD may be too complex to be translated to a common language that can be understood by everyday consumers. The findings of this thesis showed a common perception that consumers lack the technical knowledge of the chemicals in products and their impacts. Indeed, a survey by Hartmann and Klaschka (2017) of 1,030 consumers on their perception of harmful substances in everyday products showed that most participants were

ill-informed despite being above average on educational level and knowledge and motivation in chemistry, and that most respondents sought out ecolabels as indicators of safer products. In that sense, an ecolabel that includes criteria related to FMD or robust CiP information systems may indeed provide competitive advantage for companies.

Finding: Despite the existence of industry data reporting standards and formats, some companies have developed their own unique systems and formats.

The findings indicated different explanations for this. First is the perception that establishing unique data systems can create a point of market differentiation. Indeed, Barney's Resource-based View (1991) argues that having information processing systems that support business decision-making and improved efficiency in information flow can be a source of sustained competitive advantage. One interviewee also argued that a company can claim their unique data system and data as intellectual property, whether the data itself contains trade secrets or not. It is therefore a protectionist strategy to avoid the sharing of potentially sensitive information to competitors.

On the other hand, OEM interviewees have indicated that the reason for establishing unique data systems was to accommodate and support supplier. Perhaps because they perceive that their systems are easier to use and pick up while using industry formats such as IPC 1752 requires a learning curve. Other interviewees pointed to the poor design and development of IPC 1752 as reasons for low adoption. In a vacuum of popular standards, companies may have perceived their system to be better than other existing systems and have therefore chosen to stick with their own systems. Nevertheless, a common challenge remains in which suppliers are faced with a variety of data reporting formats to report similar data. Further research should seek input from a larger sample of companies on the perceptions and reality of standard compared with self-developed data reporting standards and systems.

Finding: Organizational factors played a role in the success and outcome of Seagate's FMD but besides top-level commitment, it is overall not seen to be a significant factor by all interviewees.

The case of Seagate demonstrated a clear alignment with the champion of change model and alignment with the Kurt Lewin model of change (Campbell & Craig, 2005), in which one specific individual with the initial involvement of top-level management to issue the mandate to address external changes, was a major driving force in selecting and promoting FMD within the organization (to top management, mid-management and employees) as well as externally to suppliers. Seagate's experience shows that the combination of a champion of change and top-level support can create significant change in an organization. Seagate interviewees have also mentioned that the organizational structure is networked and that the working culture is informal, which supports Campbell and Craig's (2005a) argument that such organizations are more effective in the face of complex and unstable conditions, as evidenced by the frequent changes in regulatory and client requirements that Seagate faced.

On the other hand, discussions with interviewees outside of Seagate provided minimal input on the relevance and influence of organizational factors. This may be due to the limited time available to discuss and ask for elaboration, or, the author speculates a tendency to omit such factors or assumptions that such organizational cultures and behaviors are taken for granted, as described also by Alvesson (2017). Further research is needed to explore the linkage of organizational culture and structure to the establishment of FMD or other CiP disclosure systems.

Finding: The ability to establish FMD is greatest for upstream basic parts suppliers and diminishes along the supply chain. While most OEM brands request FMD, a number of downstream companies still rely on list-based disclosure.

The discussions above already mentioned that supply chain dynamics (including degree of vertical integration, buyer dominance, purchasing power, supplier capability and long-term rather than short-term relationships) and the existence of FMD standards and tools contribute to the feasibility for a company to establish FMD. Here, the author would add an additional factor on the company's products, including the types of products, number of product lines and product complexity. In this light it is obvious that upstream suppliers of basic parts can readily provide FMD because these products contain much fewer materials. On the other extreme, brand OEMs such as Electrolux which produces thousands of products in the EU alone must engage with a colossal supply chain, and therefore can only feasibly work with list-based disclosures. In this sense, the difference between the OEMs that adopted FMD (Sony Mobile and Motorola Mobility) and OEMs that use list-based disclosure (HP and Electrolux) is related more to product diversity and production quantity rather than supply chain position.

In this regard, Seagate can be seen as positioned in the middle of the two extremes. As a supplier of more complex components in final products but with a much more targeted focus on the types of products (i.e. data storage drives), it is likely still much more feasible for Seagate to establish FMD when the aforementioned conditions on supply chain dynamics and other factors are met.

Nonetheless, the above explanations for supply chain management cannot be given with certainty for the other companies that adopted FMD (i.e. Sony Mobile and Motorola Mobility) because the supply chain dynamics of those companies could not be studied in as much detail. It would have been useful to obtain the views of Seagate's suppliers, however it was difficult to gain access to contacts given that this was seen as a sensitive topic.

Other remarks

The above may add to the explanation to why FMD adoption is not more prevalent in the industry despite the common perception that it is an important part of a sustainable chemicals management approach. FMD adoption is also hindered by lack of a standard definition of FMD and FMD implementation approaches. In this thesis, the definition of FMD was generally considered as efforts to obtain as much information as possible on the substances, chemicals and materials present in a company's products and parts. In the samples studied, Seagate's FMD system appeared to be one of the most comprehensive and stringent, in requiring FMD data as a basic requirement for suppliers to enter Seagate's procurement process. However, the detailed approaches, scope of chemical data collection and requirements can vary among companies as indicated by interviewees and the sample companies studied.

Nonetheless, efforts are moving towards greater FMD adoption. In June 2018 a group comprised of industry representatives called Proactive Alliance agreed to develop a solution for collecting and sharing material data across sectors without causing I.T. problems (Stringer, 2018). This is based on existing standards such as IPC 1752A. Perhaps such initiatives will help to push the industry towards FMD standardization. However, the tendency for companies to adopt unique systems as a point of differentiation may continue to pose challenges for standardization.

Despite the recognition of the positive role that FMD can play in safer CiP management, it is not without its shortcomings. The FMD systems reviewed in this report focus mainly on collecting data from first-tier suppliers in the form of self-declarations. Few companies carry

out extensive verification of the data collected besides lab analyses, which itself is a method that can only feasibly cover a select number of substances. This means that the level of verification of the data communicated in the supply chain is low, leading to the cases of misreporting and underreporting as mentioned by interviewees and the Goodbye Chain Group case study[16] (in which the misreporting of RoHS compliance declarations sparked the demand for FMD in the first place). It also points to the significance and dependence on trust in current FMD practices, and the question of whether this is adequate to achieve the goals set out by FMD, including true compliance to regulatory and client specifications and safer chemical management in products.

It is also important to note that not all industry actors view FMD to be inherent to safer chemical substitution in products in the first place. One interviewee indicated that OEMs and their suppliers can achieve similar results in preferred chemicals selection without FMD, because it is only the most influential OEMs that have managed to achieve FMD effectively. In this regard, trusted third parties can also deliver similar results if safer substitution is the end goal. Further research should assess costs and benefits of FMD and compare its ability against other approaches to achieve effective and efficient hazardous substance management in products.

5.2 Critical reflections

5.2.1 Reflections on the analytical framework

The analytical framework used in this study combines elements from PESTEL, Porter's Five Forces, Resource-based view, supply chain management and organizational change theories but excluded certain elements from these theories and frameworks, namely the economic and technological aspects of PESTEL. While certain technologies related to FMD were discussed such as the I.T. solutions and data reporting standards on FMD, detailed exploration on the relevance and impact of such technologies on FMD adoption could not be included into the scope of this study due to time limitations.

The author attempted to cover the external and internal aspects of a firm's business environment as comprehensively as possible, but this may have covered too many topics for the scale of this project despite attempts to prioritize key areas as they were identified during literature review and data collection. For example, while each of the interviews with Seagate personnel lasted two hours, it was still insufficient time to explore all of the analysis areas in their relation to FMD. In some cases, more time was taken to understand the intricacies of Seagate's technical functioning, the details of how Seagate functioned before FMD and during the development of FMD, as well as exploring other topics that appeared to be important to the interviewee such as FMD standardization and issues with collaboration among industry actors on CiP transparency. With the latter, the author also adopted a more flexible and exploratory approach to observe and allow important issues to emerge during discussions.

[16] See Section 2 on

Electronics: Establishing Full Material Disclosure for RoHS compliance.

5.2.2 Reflections on methods

The author took an informal interview approach that was partly deductive and partly inductive/exploratory, following the analytical framework while allowing new themes to emerge as they were identified and explored with the interviewees.

Sampling

The sampling of companies may have been too diverse. The differences among companies (number and types of products, customers and suppliers) played a significant role in the challenges and experiences of their respective CiP disclosure strategies and could have shed light on how these specific contexts influenced the CiP disclosure strategy of companies at different positions of the supply chain. With this in mind, perhaps the author should have tried to collect quantitative data on the numbers of products, customers and suppliers from each of the companies for more tangible comparison. However, the author also sensed that such information was highly sensitive and confidential, and refrained from asking for such information especially when trying to maintain rapport with the interviewees.

Limited interview time in Part 2 of the study

While it was recognized that the scope of Part 2 would be much smaller, in the end the time that the author had to speak with company representatives outside of Seagate was too limited, and as a result it was not possible to extract the details and nuances of FMD/list-based disclosure drivers and other details adequately. The author has noted that understanding these aspects indeed requires sufficient time and a larger number of interviewees for each company, because input is needed from those working with the systems as well as ideally those who were directly involved with setting up the systems in the first place.

The interviews ranged between 30 minutes to 1.75 hours. Which means that some interviews were too short to elucidate full explanations on topics, or to cover all analysis areas with equal attention. To address this, the author posed questions openly and allowed topics of importance to emerge from the interviewees' responses. While an interviewee's focus on one topic was seen as an indicator of the importance of that topic, of course a limitation to this assumption/approach is that there may be other topics of equal or greater importance that the interviewee did not happen to think of or there was insufficient time to discuss. To address this, the author also probed for input on specific topics.

Limitations in interviews as a social research method

The author recognizes that certain parts of Seagate's FMD story could only be told by one individual given the interviewee's direct experience with developing FMD. The author tried to verify some of these details with other interviewees and while it was possible to obtain some viewpoints on the same topic from others, it was also not possible to verify many of the details given that the other interviewees were not involved or aware. Many times, interviewees responded saying they did not know or were not sure, and suggested that it was more appropriate to discuss these details with the individual who was directly involved with developing FMD.

The author also tried to verify some of these details by supplementing with written sources such as publications and reports by the company, interviews with individuals outside of Seagate and external written sources such as publications, reports and articles. For example, verification of the Sony Playstation non-compliance case was made with external research.

In this sense, the ability to access the individual who was extensively involved with the early days before and during FMD development was valuable in obtaining extensive details of that

time, however, given that there were not apparently more individuals who were as directly involved, it is important to note that many of the details could not be verified.

Finally, like other social research methods, there is a potential that the interview data collected contains bias despite attempts from the researcher to prevent it. The findings of this project are also based on the views of less than fifteen people, which can carry individual biases or anecdotal views. The findings can therefore be confirmed in a larger study covering a greater number of respondents with similar backgrounds.

Inability to obtain certain views

It was difficult to secure the availability of certain interviewees given the vacation season of July and August, especially those in Sweden where most people are out of the office. The author attempted to collect data from written sources or indirectly from industry experts in these cases (e.g. with regards to specific company cases where it was not possible to schedule an interview with company representatives).

There were cases where interviews did not work out. For example, one scheduled interviewee did not show up during the scheduled interview time, and contact was lost with a few individuals where they stopped responding to communications.

Even though interviews with Seagate personnel were scheduled for two hours, it was difficult to cover all analysis aspects (i.e. to ask direct questions about them) in the allotted time. To address this during the interviews the author tried to obtain views on the analysis areas by asking overarching questions. – e.g. "What were the greatest challenges?" "What contributed to success?" and allowed themes to emerge. In other cases, the author tried to focus on the themes that were observed to be more prominent throughout data collection (i.e. political environment and market drivers).

5.2.3 Reflections on the research questions and generalizability

Upon reflection, the author believes that the first three research questions (on why and how Seagate adopted FMD, how challenges were overcome and enablers of success) were answered adequately, while as anticipated, some gaps remain in answering the fourth research question on the relevance of Seagate's FMD to other companies. The latter reflection is related to the generalizability of the results. Nonetheless, certain aspects of Seagate's FMD case study could be generalized to other companies, such as the influence of supply chain dynamics, the combination of top-level support and a champion of change as well as the relevance of the product types and product lines in a company on the feasibility of establishing FMD. Further study is needed to confirm whether these aspects are indeed relevant, such as in a detailed comparative case study of other companies with FMD.

5.3 Relevance and contributions of the thesis

This study has compiled and summarized common perceptions on Full Material Disclosure trends, challenges and other views in the electronics industry, mostly focusing on I.T. electronics. An analysis and discussion of certain enablers of success was also given. Details on the lessons learned in FMD development from Seagate's experience may be helpful for other companies seeking to establish FMD. This includes lessons learned in setting up I.T. infrastructures and formatting IPC 1752 forms, approaches in supplier engagement (including how to address supplier concerns, what makes suppliers take FMD more seriously, how to build supplier capacity and the nuances of relationships management with suppliers). While such factors may be case specific to Seagate, a company interested in FMD may consider whether

any of their contexts are similar to Seagate and as such whether the lessons learned are applicable.

In addition to the above contributions, perhaps the more important contribution of this study is in mapping the pathway of the drivers and pressures on hazardous substance management in products in the supply chain which may lead to the adoption of FMD (or other CiP disclosure strategies, see Figure 5-1). This helps to fulfil the purpose of this study to improve the understanding of the drivers of FMD for NGOs like Clean Production Action, in order to improve the targeting of FMD promotion initiatives and strategies. While such pathways of influence may be intuitive, the evidence collected in this study helps to add verification and confirmation.

5.4 Recommendations for further research

Based on the above, the following summarizes recommendations for areas of further research:

Since companies do not readily share their CiP data management approaches openly, the knowledge and documentation on FMD adoption trends is low and this study was unable to fully elucidate the state of FMD adoption in the electronics supply chain. Further study on the state of FMD adoption can help to better understand the specific challenges at different points on the supply chain. This study also identified a need to conduct further collection of viewpoints on established standards such as IPC 1752 in comparison with unique standards, which would be helpful to understand what the specific limitations are and how to develop improved solutions. As mentioned above, it appears that existing initiatives are undergoing such as that of Proactive Alliance (Stringer, 2018).

Next, further study on the same units of analysis explored in this study on the selection and outcome of FMD adoption is needed to verify the relevance and influence of such factors, and generalizability of Seagate's case. One example that was assessed in less detail in this study is the linkage of organizational culture and structure to the establishment of FMD or other CiP disclosure systems. Detailed comparative studies on the same units of analysis will help to elucidate whether the Seagate-relevant aspects are applicable to other companies.

Finally, based on the findings of this study, further exploration on the barriers and approaches to FMD standardization, interest and feasibility in the electronics sector would be an interesting and meaningful area of research which may also improve FMD adoption in the industry.

6 Conclusion

This case study developed a framework to systematically analyze the development and implementation of Seagate's FMD, with the purpose of improving the understanding of how a firm's external and internal environments can relate to and influence FMD as a CiP disclosure strategy. Based on the four research questions of this study, the following conclusions are drawn:

Research questions: (1) "Why did Seagate decide to adopt FMD as a CiP disclosure strategy?", (2) "How did Seagate adopt FMD? What challenges were faced in the process and how were they overcome?" and (3) "What factors enabled the success of Seagate's FMD?"

Seagate decided to adopt FMD because it was deemed as the appropriate strategy to efficiently and cost effectively manage frequently changing regulatory and client requirements on chemicals in products. Seagate selected the IPC 1752 industry standard for material data reporting and developed their Compliance Assurance System to collect and manage FMD data. Lessons from a pilot project to collect FMD for one product were taken to make system adjustments, after which FMD was officially launched in 2006 with a 95% data completion requirement.

The main challenges in FMD development and implementation were supplier resistance (overcome by officializing FMD as a procurement standard, setting a fee structure for suppliers, leveraging on the relevant internal and external relationships), low supplier capacity (overcome by continuous training with the help of third-party support and the strategic targeting of capacity building beneficiaries), and internal resistance (overcome by persistent engagement and consultation). Suppliers' concerns on product proprietary information are addressed by allowing them to not disclose up to 5% proprietary substances as long as they are not designated SVHCs. In parallel, Seagate continuously pressures suppliers to avoid indiscriminate claims of proprietary information to avoid disclosure.

Besides Seagate's active measures to address FMD implementation challenges, other factors that contributed to the success of FMD include Seagate's strong buyer power (as a result of a highly vertically integrated supply chain, purchasing power and other structural and relational matters), efforts of a champion of change that pushed FMD through with top-level support, and sustainability-driven organizational values, culture and staff.

Research question: (4) "To what extent is the case of Seagate's FMD relevant to other companies?"

This thesis found that Seagate and the other companies studied share similar regulatory drivers for CiP management and disclosure. The importance of top-level management in driving CiP disclosure systems (whether FMD or list-based disclosure) was also common among companies. Furthermore, companies faced similar challenges with suppliers including their suppliers' concerns over proprietary and other confidential information, low supplier capability to collect and report on CiP data and complaints for having to fulfill a diversity of data reporting standards and formats of clients (something that Seagate itself experiences as a supplier).

Many of the differences between Seagate's case compared to the other companies are due to the differences in their positions on the supply chain, where downstream OEMs are more visible to the public. In this regard, the sources of pressure for CiP management and disclosure vary. While downstream brand OEMs face greater pressure from regulations, NGOs and industry, Seagate as a mid-stream supplier reported client demand as the biggest source of pressure that drove their adoption of FMD.

Furthermore, while FMD exists among other companies in the electronics industry, the specific approaches can vary. Lower product diversity and production quantity is associated with higher feasibility for a company to adopt FMD.

General implications of the findings

This study demonstrated that the likelihood of success for a company to establish FMD is dependent on two general elements. The first is a set of preconditions related to the external and internal contexts of the company, such as high buyer power, long-term collaborative relationships with suppliers, high supplier capability, high vertical integration and complex and irregular changes to regulatory and client requirements that create a demand for increased efficiency in CiP management and compliance practices. FMD establishment is also easier if the company has fewer product lines and the products themselves are not overly complex. It also helps if the company has a networked organizational structure that values sustainability and meaningful corporate responsibility engagement.

The second are the actions that the company actively takes when implementing FMD. These include the strategic leveraging of internal and external relationships to increase FMD buy-in, maintaining close engagement with suppliers and providing ongoing support to suppliers to collect and submit FMD data. The role of change agents such as a champion of change with top-level support to create the shift to FMD is also significant in FMD success. The company should also pay close attention to understanding their suppliers and their capabilities and then set the standards and requirements according to what is feasible. Further efforts to develop the capacity of suppliers can be implemented over time. Smaller companies with fewer resources to develop in-house FMD systems may also consider contracting third-party companies to aid in the data collection and reporting processes. The involvement of third-party service providers can also help to protect the confidentiality of suppliers' information should that be of major concern among the company's suppliers.

Suggestions for further research

Based on the above, the author recommended that further research to fill the gaps of this study can focus on building understanding on FMD adoption trends in the electronics industry, perceptions on existing FMD data standards to improve FMD standardization and additional studies using the same units of analysis from this thesis to verify the findings.

Contributions of the thesis and recommendations to target audience

The main contribution of this thesis is in identifying the drivers and enablers of success for implementing FMD in the I.T. electronics industry.

For Clean Production Action and other similar NGOs – The author recommends that efforts to promote FMD should take a company's size (product diversity and production quantity) into account, as well as its position in the supply chain and overall supply chain structure, to assess FMD feasibility. Appeals to regulators to develop sectoral CiP regulations (such as RoHS) or additions to EU REACH may also be effective depending on the state of regulatory pressures in that particular sector. Value-adding industry initiatives such as ecolabels can also be useful to create drivers for FMD. However, FMD promotion in any sector should seek to develop a common industry standard to avoid the same issues related to unique FMD formats faced in the electronics industry.

For Seagate – Should Seagate wish to continue sharing its FMD approach to other companies, perhaps some of the lessons learned and external factors (e.g. supply chain structure) may be applicable. Otherwise, the author hopes that the accounts reflected in this report can also be useful to inform existing and future staff on how FMD was developed and played a role in the company's overall CiP management strategies.

For regulators – This thesis demonstrated the significance of regulations in influencing CiP disclosure strategies at different points of the supply chain. Perhaps the CiP disclosure strategies described in this report can add to the understanding of regulators on how companies respond to regulations, and help regulators to improve on existing regulations or develop new policies that promote greater CiP transparency in the supply chain and FMD adoption.

For other companies seeking to increase CiP transparency – The same recommendations discussed for NGOs apply. In addition, the general implications of the findings (discussed above), the approaches Seagate used to develop FMD and the lessons learned from managing supplier-related issues and supplier concerns may also be useful.

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Appendix A: Introduction letter to interviewees

Letter to Seagate contacts

Master Student of Environmental Management and Policy
at the IIIEE, Lund University

Alexandra Wu

21 June 2018

Subject: Invitation to participate in a master's thesis project on a case study of Seagate's full material disclosure program

To whom it may concern:

My name is Alexandra Wu and I am a master's student of the Environmental Management and Policy Programme at the International Institute of Industrial Environmental Economics (IIIEE) at Lund University, Sweden. The purpose of this letter is to request your participation in a thesis project that analyzes the full material disclosure (FMD) program at Seagate.

As you are probably already aware, FMD can be an efficient data collection approach to support regulatory compliance, increase supplier transparency and move towards cleaner production. Seagate has demonstrated leadership in FMD establishment and implementation, and sharing the story of its experience may influence other companies to join in the adoption of FMD to improve chemical use practices.

My thesis project will conduct a case study of Seagate's FMD in terms of the tools and approaches used, barriers faced, success factors and lessons learned. It aims to develop a framework that can be useful to other companies that are seeking to address chemicals issues through FMD.

In consultation with Dr. Bill Olson (Seagate contact for the thesis project), you were identified as a key stakeholder in Seagate's FMD. Your input would be valuable in enriching the understanding of FMD in Seagate and findings could lead to greater understanding among the industry of how FMD can be successfully adopted. As such, I kindly invite you to participate in an interview, which is expected to take no more than two hours.

The interview period is scheduled to take place from **25th June to 13th July 2018**, which can be conducted over web conference. If you are willing to participate, please suggest possible days and times in that period between **8am to 12pm PST/10am to 2pm CST/11am to 3pm EST** (which takes into consideration the time difference between the US and Sweden).

If you have any questions, please do not hesitate to be in touch. Thank you very much and I look forward to an opportunity speak with you.

Yours sincerely,
Alexandra Wu

Alexandra Wu, MSc Student

Mobile: +46 76 204 46 04
Email: alexandra.wu.4410@student.lu.se
Skype: alexandrakwu

If you would like to reach the IIIEE, please contact:

Birgitta Olofsson, Student coordinator
Email: birgitta.olofsson@iiiee.lu.se
Phone: +46 46 222 02 06

Letter to contacts outside of Seagate

Master Student of Environmental Management and Policy at the IIIEE, Lund University

Alexandra Wu

9 August 2018

Subject: Invitation to participate in a master's thesis project on a case study of Seagate's full material disclosure program

To whom it may concern:

My name is Alexandra Wu and I am a master's student of the Environmental Management and Policy Programme at the International Institute of Industrial Environmental Economics (IIIEE) at Lund University, Sweden. The purpose of this letter is to request your participation in a thesis project that analyses full material disclosure (FMD).

As you may already be aware, the dramatic increase in the production and turnover of electronics has increased electronic wastes in society, posing threats to human health and the environment from the presence of hazardous substances. In response, regulators have been introducing and tightening policies on chemicals management.

FMD is an approach for companies to obtain a complete breakdown of product composition from their suppliers (down to the homogenous level). It can be an efficient approach to support proactive compliance with client and regulatory policies, increase supplier transparency and move towards cleaner production. Hard drive manufacturer Seagate is an example of a company that has benefited from FMD.

My thesis project will conduct a case study of Seagate's FMD in terms of the tools and approaches used, barriers faced, success factors and lessons learned. The project has a wider purpose to scale up the adoption of FMD across industries to address chemicals-in-product issues, increase supply chain transparency and improve compliance to client requirements and regulations.

Your input would be valuable in identifying the relevance of Seagate's FMD experience to other companies in the industry, to enrich the understanding of factors that affect FMD development and implementation. As such, I kindly invite you to participate in an interview, which is expected to take no more than two hours.

The interview period is scheduled to take place from **1 to 31 August 2018**. I am based in Stockholm and would appreciate an in-person interview if you are in the area, otherwise we can also discuss over web conference. If you are willing to participate, please suggest possible days and times in that period.

If you have any questions, please do not hesitate to be in touch. Thank you very much and I look forward to an opportunity speak with you.

Yours sincerely,
Alexandra Wu

Alexandra Wu, MSc Student

Mobile: +46 76 204 46 04
Email: alexandra.wu.4410@student.lu.se
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If you would like to reach the IIIEE, please contact:

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Appendix B: List of interviews

Interviewee	Interview date	Interview length	Type of organization	Name of organization	Position and department (if available)
SA	12 June 2018	2 hours	Component manufacturer	Seagate	Product Sustainability, Environmental, Health and Safety & Sustainability (EHS&S) *Note: Follow-up questions were answered by email after the interview*
SB	18 June 2018	2 hours	Component manufacturer	Seagate	Senior Director, EHS&S
SC	26 June 2018	2 hours	Component manufacturer	Seagate	Senior Director, EHS&S
SD	2 July 2018	2 hours	Component manufacturer	Seagate	Senior Software Architect, EIT
SE	12 July 2018	2 hours	Component manufacturer	Seagate	Product Lifecycle Management and Approved Manufacturers List Administrator, Configuration Management
IA	7 August 2018	1.5 hours	OEM	HP Inc.	Environmental Chemist
IB	9 August 2018	1 hour	Component manufacturer/OEM	Motorola Mobility	ENV Senior Material Expert, Global Regulatory Compliance Department
IC	9 August 2018	30 minutes	Contractor	SciVera	---
ID	13 August 2018	35 minutes	Contractor	Assent Compliance	General Counsel
IE	21 August 2018	1 hour	Academia/OEM	IVL Swedish Environmental Research Institute	Johan Holmqvist, Business Developer (former Director of Corporate Sustainability at Sony Mobile Communications)
IF	23 August 2018	1.75 hours	Government	Swedish Chemicals Agency	Anne-Marie Johansson, Senior Technical Officer, Development of Legislation and Other Instruments Anna Fransson, Senior Advisor, International Unit Hélène Kanellopoulos, Senior Technical Officer
IG	24 August 2018	1 hour	OEM (electronic appliances)	Electrolux	---

Source: Author's own data collection.

Appendix C: Example interview guides

Examples of the interview guides prepared for the interviews are given below. Note however that in reality, many of the questions were not asked in the same order as the guides but served more as a guidance of the types of questions and topics the author wished to cover. The wording used to pose the questions also varied. These examples therefore are meant only to illustrate the topics covered during the interviews.

Interview guide for Seagate interviewees

Introduction

The author expresses her thanks for the interviewee's participation in the interview and seeks permission for recording the interview with the explanation that any direct quotes will only be included with the interviewee's prior permission. The author explains the background and purpose of the study and provides an outline of questions, then asks if the interviewee has any questions before proceeding.

About the interviewee

Here the author asks about the interviewee's role and position at Seagate and their involvement with FMD.

Story of Seagate's FMD

1. Overview
    - Can you tell me briefly the story of FMD at Seagate? How did it begin, how was it developed? Where is it at now?
2. Before FMD
    - What was the main compliance method before FMD? How did things work?
    - What initiated the change?
        - What are the biggest regulatory drivers of FMD?
        - Specific events?
    - Why was FMD chosen?
    - Who was involved?
    - Role of the (champion of change)? Any other change agents?
    - When did this happen?
3. FMD development and design
    - How was FMD developed? What was the process and approach?
    - What were the main factors of consideration in designing FMD at Seagate?
    - How to integrate supplier interests, needs and challenges in FMD?
    - Who was involved?
    - When did this start? How long did it take?
4. Seagate FMD – How it works
    - Please give me a brief description of how Seagate's FMD works.
        - What is the overall process of FMD implementation? Including the communication and coordination process with existing and new suppliers?
    - What technical platform (database software) is used?
    - Who is involved? – Seagate staff (who?), WSP, suppliers

        - How important is the role of the contractor?
        - How important are the roles of Seagate staff?
    - How does FMD fit into the overall supplier management approach?
5. FMD establishment and implementation
    - Has the FMD program changed over time? If so, how?
    - Benefits and disadvantages? (e.g. demonstrated cost savings?)
    - Overall lessons learned?

Relevance and influence of the units of analysis

1. Organizational context
    - Description
        - Can you please briefly outline the organizational structure of Seagate? Where are the teams located? Would you describe it as hierarchical or flat?
        - How would you describe the organizational culture of Seagate? General mindset of employees towards sustainability?
        - How is Seagate's sustainability strategy formed? Who is involved? (formal vs informal, response to learning and new information)
    - What were drivers and enablers of success? Why did they facilitate success?
    - What were the barriers and challenges in the process? How were they overcome?
2. Market context
    - Supply chain context and management approach
        - How many suppliers? Estimate figure?
        - What is Seagate's supplier management approach?
        - Dependence – How specific are suppliers' products to Seagate? How dependent is Seagate on suppliers? Easy to switch?
        - Trust – How would you describe the level of trust between Seagate and suppliers? How did this feed into FMD system development? (e.g. increase level of stringency?)
        - Was there anything about your suppliers, supplier management approach that made FMD development easier or successful? Anything that made things difficult? How were challenges overcome?
    - Competitors
        - Who are your biggest competitors? Do they face the same demands on substance disclosure?
        - How do your competitors comply?
        - How did Seagate's FMD affect your competitors? How does their compliance approach affect Seagate? Does it affect Seagate's competition in the data storage market?
        - Was there anything about your competitors that made FMD development easier or successful? Anything that made things difficult? How were challenges overcome?
    - Substitute products
        - What are the trends in data storage products and services?
        - How do these trends impact FMD at Seagate? (Drivers/enablers of FMD or barriers to FMD)
3. External stakeholders

- Who are the biggest stakeholders outside Seagate that we have not talked about? (e.g. consumers, NGOs, waste managers)
- How did they affect FMD development at Seagate?
- Do they influence Seagate's FMD now?
- What is the status of FMD conceptualization across the industry or other industry? Is it being standardized?

4. Final remarks
    - Any final remarks, reflections? Or questions?
    - Opportunity for shorter follow-up interview, in case it is needed?
    - Words of thanks and closing.

Interview guide for company representatives (outside of Seagate)

Introduction

The author expresses her thanks for the interviewee's participation in the interview and seeks permission for recording the interview with the explanation that any direct quotes will only be included with the interviewee's prior permission. The author explains the background and purpose of the study and provides an outline of questions, then asks if the interviewee has any questions before proceeding.

About the interviewee

Here the author asks about the interviewee's role and position at Seagate and their involvement with their respective CiP disclosure strategy.

About the company's CiP disclosure strategy

1. What are the main requirements and standards in your company's CiP disclosure strategy/system?
2. Is Full Material Disclosure part of the requirements?
3. How and when did you develop the requirements?
4. How was it decided that the particular approaches chosen are right for the company?
5. What were the biggest challenges? How were they overcome?
6. How did you get your suppliers to engage and comply?

On how material disclosure works:

1. How does the data collection system work? What is the role of suppliers? In what format is data collected?
2. How often do you request product material and substance information from suppliers?

How did the following aspects shape your company's substance disclosure requirements (or FMD, if it exists)?:

1. Government agencies and regulations
2. Industry groups
3. Market forces (including competitors, suppliers, new entrants and products)
4. Your company's organizational culture and structure
5. Consumer demand

6. NGOs

Final remarks

1. Any final remarks, reflections? Or questions?
2. Words of thanks and closing.

Appendix D: Coding structure for analyzing interview data

Code name (unit of analysis)	Definition	Example (may be paraphrased)
Part 1: Seagate's FMD		
State of affairs before FMD	Recollections and reflections on chemical compliance approaches and trends before FMD was selected.	"Before FMD, there was only a small group of adopters. But today there is a lot more. Because more substances of interest come up, for example REACH substances can change twice a year."
FMD development process	Recollections and reflections on the FMD development process.	"And so we launched [an FMD pilot] with one product, and after 3 months of asking suppliers for IPC 1752 FMD data, we had one part level data input in our system, and it was poorly done."
How Seagate's FMD works	Explanations on the function and design characteristics of Seagate's FMD systems, descriptions of roles and responsibilities.	"A contractor plays a valuable role in Seagate in supporting implementation and maintenance of the FMD program, and engaging with Seagate's many suppliers."
FMD implementation experience	Recollections and reflections on the implementation experience of Seagate's FMD, including changes, challenges, benefits, disadvantages and lessons learned.	"So in many ways today we are still using that system from when we first launched, with some subtle refinements."
Political environment	Perceptions of the relevance and influence of government institutions, regulations and legislations on FMD.	"One of the catalysts of FMD in the electronics industry was the case of RoHS 1 violation of Sony Playstations…"
External stakeholders	Perceptions of the relevance and influence of NGOs, IGOs, consumers and the waste management sector on FMD.	"…we do get NGO pressure, but not very aggressive."
Market environment	Perceptions of the relevance and influence of suppliers, competitors, clients, substitute products and new entrants on FMD.	"Outcomes of FMD implementation are also related to the types of relationships between Seagate's various teams with suppliers and customers."
Organizational context	Perceptions of the relevance and influence of organizational culture and structure and any champion/change agents on FMD.	"Pushing for FMD was basically fundamental to his role because it was really about finding a more efficient way to do business."
Part 2: External to Seagate		
Industry trends on FMD	Perceptions and understanding of FMD adoption trends and practices in various industries.	"The majority of companies ask for FMD and the majority of component suppliers can provide it"
Cases of companies with FMD	Recollections and reflections on the drivers of FMD adoption, how the FMD system functions in the company, challenges and enablers of success.	"The most important thing is that we must decide on one rule. If the supplier's FMD data is approved then we can use and buy the parts. If their FMD data fails, then we cannot buy their parts."

Cases of companies with list-based disclosure	Recollections and reflections on the drivers of adopting list-based disclosure, how the FMD system functions in the company, challenges and enablers of success.	"Data is collected and managed on Excel spreadsheets where suppliers fill in spreadsheet templates including those for REACH and RoHS."
Political environment	Perceptions of the relevance and influence of government institutions, regulations and legislations on the CiP disclosure strategy of the case company and in general.	"FMD was chosen to have one system in place to submit material safety data sheets data to EU RoHS"
External stakeholders	Perceptions of the relevance and influence of NGOs, IGOs, consumers and the waste management sector on the CiP disclosure strategy of the case company and in general.	"[Industry groups have made] very little push for FMD and better chemicals management… much more like NGO pressure creating voluntary restrictions"
Market environment	Perceptions of the relevance and influence of suppliers, competitors, clients, substitute products and new entrants on the CiP disclosure strategy of the case company and in general.	"Most suppliers don't want to disclosure substance information because of proprietary reasons, complexity in supply chain in multiple tiers"
Organizational context	Perceptions of the relevance and influence of organizational culture and structure and any champion/change agents on the CiP disclosure strategy of the case company and in general.	"[company name] has a track record of looking at environmental issues"
Other perceptions of FMD	Opinions and perceptions on topics that emerged throughout the interviews including: definition of FMD, challenges to FMD adoption, role of FMD in chemicals management in products and FMD standardization.	"The industry is moving towards FMD standardization… working through issues with format and capability"

Source: Author's own elaboration.

Appendix E: Descriptions of Seagate teams involved in FMD

Environmental, Health and Safety & Sustainability (EHS&S)

The EHS&S Team houses over 70 people, most of which are in health and safety department due to the large number of manufacturing workers (over 42,000 people) worldwide. Four people work in the sustainability team.

The EHS&S Team is in charge of the health and safety side of production (e.g. workers' health and safety, hygiene), environmental management (e.g. regulatory environmental compliance such as RoHS and REACH, conflict minerals, and operational environmental compliance such as water emissions, GHG emissions and water waste). CSR management in Seagate is cross-functional, which involves personnel from the sustainability team, HR, legal, materials and operations managing areas including supply chain management and human rights.

The Sustainability Team is the main lead unit for managing FMD. They are responsible for managing annual updates and lab tests of FMD reporting from existing suppliers, monitoring and ensuring the company is in compliance with regulatory and client requirements and integrating new acquisitions to Seagate's FMD systems.

Compliance Partner

While not technically within the Seagate organization, the Compliance Partner (sometimes referred to as "contractor" or "external contractor" by interviewees) nonetheless plays a valuable role in supporting the implementation and maintenance of FMD systems as well as engaging with Seagate's many suppliers. For Seagate, this requires the resources of a fifteen-person team working full time according to an EHS&S interviewee. (SA)

Seagate sources the Compliance Partner following a competitive bidding process which renews every three years. The Compliance Partner communicates mostly with the Sustainability Team and is responsible for the following (SA and (Rossi, 2014)):

- Providing regular training to suppliers to prepare them for submitting data to the CAS system;
- Providing ongoing technical support to suppliers;
- Quality control for data submitted by suppliers, including auditing of IPC format data and supporting documentation;
- Managing high volume data; and
- Reviewing weekly reports generated by the CAS system for submission to Seagate.

According to an interviewee (SA), a Compliance Partner (rather than having an internal team) is useful because of two reasons: 1) training and knowledge development of FMD takes time, and company turnover of staff can result in lost resources and 2) a Compliance Partner can provide stable resources and services to fulfil Seagate's needs.

Not everything can be outsourced

While having a Compliance Partner can be helpful, one EHS&S interviewee (SA) emphasized that data ownership should not be fully outsourced because EU policies require producers to hold on to data for ten years (e.g. EU RoHS 2 Art. 3.6 and 7a (Council Directive 2011/65/EU, 2011)).

Seagate's ownership and record keeping of the data allows for easy compliance and response to inquiries by authorities. Data ownership can help assure data quality and integrity. One cannot "outsource safety and compliance", the interviewee added.

Materials/Commodities Team

The Materials/Commodities Team consists of two groups: the direct procurement group which houses commodity managers responsible for the procurement of parts, and the indirect procurement group which is responsible for purchasing services and logistics. Commodity managers hold detailed information on each component of Seagate's products, such as the number of suppliers per component. They also have more frequent communication with suppliers. Therefore, commodity managers are a channel for escalation, given that they hold ownership of the business relationships with suppliers.

The Materials/Commodities Team can be involved with connecting the Sustainability Team with contacts in supplier companies. Otherwise, they are usually not involved with FMD unless there is an escalation – for example, if the Sustainability Team escalates an issue to the Materials/Commodities Team due to a lack of response to queries or failure to meet specifications from a supplier.

EIT Team

The EIT Team provides support for the technical and software maintenance of the CAS system, including tweaks, updates and troubleshooting. The EIT Team is also involved in tweaking Seagate's specifications in the CAS system (e.g. minimum concentrations of substances, newly restricted REACH substances) upon changes in client and regulatory specifications.

Configuration Management Team

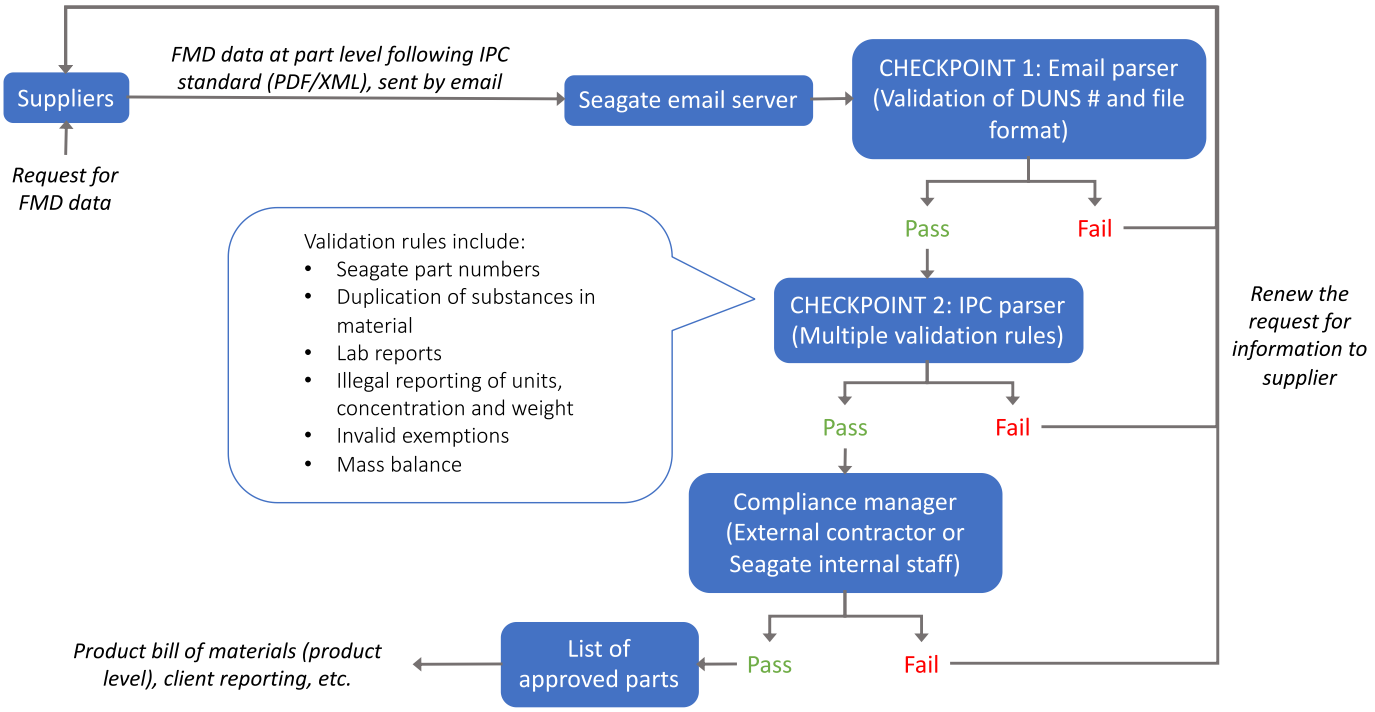
Located in all product design centers (which oversees new product development) and internal factory locations, the Configuration Management Team is responsible for managing documents related to the design center and Seagate's internal factories. It works closely with the teams responsible for product development, assembly procurement, materials planning and engineering to ensure that information related to product formulas are well documented for mass production.

The team also has high-level access and management of the Product Lifecycle Management database system, which manages the full lifecycle of a product from design, procurement, testing to mass production. This is relevant to FMD systems at Seagate, because the CAS system (which holds FMD data) is used in new product development. It interacts with the Product Lifecycle Management system to track the compliance level of parts selected in the design of new products.

Sales Team and Customer Technical Management (CTM) Team

The Sales Team acts as the point of contact for new clients and processes requests for information during the qualification process (for Seagate as a supplier to the client). Meanwhile, the CTM Team maintains clients after the point of sale, and act as the respective point of contact to process questions and requests for information on an ongoing basis. According to one EHS&S interviewee, the two teams generally have low interest in being involved with FMD (SB).

Appendix F: Detailed workflow of the Seagate Compliance Assurance System



Source: Adaptation based on interview with Seagate EIT personnel (SD).

The process of FMD data submission and compliance evaluation is as follows: First, the supplier submits their data on a PDF form that is formatted to the IPC 1752A data collection standard.

A new standard in XML has been released by IPC 1752A which allows for greater flexibility in reading, analyzing and presenting the data. However, a user-interface has not yet been developed. This means that the personnel responsible for data entry on the supplier's side must be knowledgeable in XML coding or have EIT resources in place to convert FMD data into XML code. One interviewee said that Seagate tries to encourage suppliers to use the new XML format, but the lack of EIT resources among smaller suppliers remains a challenge (SD).

The data (in PDF or XML format) is sent to Seagate by email, which enters Seagate's systems through their email servers. This is the first data validation checkpoint in the system, in which an email parser validates the data based on two main rules: 1) the validity of the DUNS number (i.e. the unique identifier of the supplier company/entity); and 2) the validity of the PDF or XML file that contains the IPC-standardized FMD data following a specific naming convention (this is to ensure that the correct file is extracted from the email) (SD).

For the purpose of data security, Seagate decided to use an email system to accept data submissions. The email parser is designed to automatically extract data from emails (SD).

Next, the extracted IPC file is validated with the second validation checkpoint, which is an IPC parser that conducts validation based on a set of rules. These rules include the validity of the Seagate Part Number, the existence of duplicated substances on the same material unit; and the validity of lab reports, mass and concentration units, exemptions and mass balance of the part.

If the file passes all validations, then it is sent to the Compliance Manager (either on the Compliance Partner side or internal to Seagate), which reviews and decides to accept or reject the data. Once it is accepted, the data is entered into the whole Seagate product. If the data is rejected, the further coordination and follow-up is carried out with the supplier to correct any mistakes (SD).

Appendix G: List of EIT challenges faced in establishing and implementing Seagate's FMD systems

According to an interviewee from the Seagate Configuration Management Team (SE), the following EIT challenges were faced in establishing and operating Seagate's FMD systems:

- Designing the various Product Lifecycle Management and CAS databases to interact and align with each other was a challenge. This required the IT Team to redesign the CAS system to meet product lifecycle management needs.
- Maintenance and upkeep of system functionality is also a challenge. This is something that the IT team is responsible for.
- Because automation of the interaction between the Approved Manufacturers List and CAS system was designed to be one-way only, the manual upkeep and updating of the Approved Manufacturers List can also be laborious. It may be possible to automate this, but at Seagate this currently remains as a manual process.
- There can also be lag time between updates and new information sent from the Approved Manufacturers list to the CAS system, which can create delays in workflows and communication with suppliers.
- Managing suppliers that have multiple manufacturing sites can complicate how data is handled in the Approved Manufacturers List and CAS systems. Seagate has resolved this to characterize suppliers based on the manufacturing site using the site's DUNS number rather than the supplier company's name itself.